Pollinator communities on public lands: creating new opportunities for management

A Senior Honors Thesis

Submitted in Partial Fulfillment of the Requirements
for Graduation in the Honors College

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April 1, 2020

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April 2020

EXECUTIVE SUMMARY

- This report contains the results of my analysis of butterfly abundance, butterfly use, and nectar source abundance at Montezuma National Wildlife Refuge (MNWR) in New York State; I collected these data from 8 July 2019 to 5 October 2019.
- Sites surveyed included Main Pool (MP), a marsh impoundment in total drawdown phase; Seneca Flats (SF), a marsh impoundment in partial drawdown phase; and Hidden Marsh (HM), an upland field mowed and cleared for planting native nectar sources in October 2017.
- To measure butterfly abundance and use at HM and MP I used visual line-transect distance surveying to record species, behavior, distance from transect, angle from transect, and use of nectar source along ten 45-m-long transects. To measure nectar source abundance I counted the number of flowers or inflorescences of each nectar source in five 1x1 m plots along each transect.
- The monarch was the most common species (0.94 of all nectaring observations) nectaring at Main Pool, and the only species nectaring at Seneca Flats. The red admiral was the most common species (0.58 of all nectaring observations) nectaring at Hidden Marsh.
- There was no significant difference in the number of butterflies per transect between Main Pool and Hidden Marsh. Each week the number of butterflies per transect at each site remained relatively constant, except for 8 July 2019 at Hidden Marsh and 15 September 2019 at Main Pool. Based on an analysis using the program Distance, I observed a relatively low proportion of the actual butterfly populations present at Hidden Marsh and Main Pool.

- At Main Pool, smartweed and beggarticks were the only nectar sources present. Smartweed was more abundant than beggarticks, but only beggarticks was nectared on. Three butterfly species nectared on beggarticks with monarchs showing a strong preference for it.
- At Seneca Flats, nectar sources present were the native beggarticks, smartweed, and pickerelweed, along with the non-native purple loosestrife and common marshmallow. Purple loosestrife was the only nectar source used, by a single monarch.
- At Hidden Marsh, nine of the 30 planted native nectar sources were present. Black-eyed Susan, fleabane, field hawkweed, and brown-eyed Susan were the most common native species present, while red clover and Queen Anne's lace were the most common non-native species present. There was never a significantly different ratio of non-native nectar sources to native nectar sources. Brown-eyed Susan, black-eyed Susan, New England aster, fleabane, field hawkweed, Queen Anne's lace, Canada thistle, and common teasel were nectared on by butterfly species, with brown-eyed Susan, Queen Anne's lace, Canada thistle, and fleabane most commonly used and red admirals showing a preference for brown-eyed Susan.
- Monarchs nectared on a variety of nectar sources including beggarticks, purple loosestrife, brown-eyed Susan, black-eyed Susan, field hawkweed, fleabane, and Canada thistle.
- At Hidden Marsh, non-native nectar sources were never more abundant than native nectar sources, but many of the non-native nectar sources were nectared on by a variety of butterfly species, suggesting managing for the conservation of pollinator populations may mean not managing for the removal of non-native plant species.

- Major management suggestions for promoting monarch and other butterfly populations in "non-traditional" habitats:
    - Managers should provide suitable habitat for beggarticks, one of the most used plants by monarchs. Beggarticks are abundant in late-season drawdowns, when monarchs are migrating.
    - Combined management of adjacent "non-traditional" sites like dikes and marsh impoundments can provide suitable resources for monarchs during much of the summer and fall portion of their life cycle.
    - Managers should mow dikes to enhance fall milkweed growth, along with managing marsh impoundments for increased beggarticks so that both plants can provide resources concurrently. Recently hatched larvae can utilize milkweed for food and, once those larvae transform into adults, they can utilize beggarticks in the impoundment to fuel their migration.

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ABSTRACT

Because butterfly species such as monarchs (*Danaus plexippus*) are declining, they have received renewed public and scientific interest. Butterflies provide important ecological services, such as pollination. Understanding their ecology is vital for proper conservation and management, with targeted management on public lands increasing in the last few decades. To determine useful management strategies for butterfly populations on public lands, I investigated butterfly use in two "non-traditional" sites utilized by butterflies at Montezuma National Wildlife Refuge (MNWR): a marsh in full drawdown phase (MP) and a marsh in partial drawdown phase (SF). I also investigated butterfly use at an upland field site planted with native nectar sources (HM). By doing so I hoped to provide MNWR with data on which nectar sources were present and utilized by butterflies, and suggest useful strategies for managing butterfly populations, particularly monarchs. Butterfly populations were present at all my sites and used a variety of nectar sources. At HM, many of the native nectar sources planted by MNWR were present, and a variety of butterfly species used them, with red admiral showing a preference for brown-eyed Susan. Several unplanted native nectar sources and non-native nectar sources were also present at HM, and were used by several butterfly species. Both "non-traditional" habitats supported butterfly populations, including foraging and migrating monarchs, which showed a preference for beggarticks at MP. Combined management of my "non-traditional" sites with other "non-traditional" sites, like dikes, can provide valuable resources for monarch populations throughout much of their life cycle.

INTRODUCTION

In the last few decades, butterflies have received renewed scientific and public interest, especially due to their rapidly declining populations (Flockhart *et al*. 2014) and ecological importance. Whether photographing, collecting, or just watching them, the public has a fascination with butterflies, with butterfly exhibits becoming extremely popular in zoos, museums, and fairgrounds around the world (Boppré and Vane-Wright 2012). More than public interest and citizen science initiatives are needed, though, in order to properly manage and conserve butterfly populations. Good knowledge of their ecology is required, especially in regards to their habitat requirements, pollination biology, and foraging.

Butterflies use a proboscis to obtain nectar, so their bodies do not touch the flower surface as much as do bees, generally making them less efficient pollinators (Kunte 2007), but butterflies still help to sustain plant populations in a variety of habitats (Cruden and Hermann-Parker 1979; Yahner 2001; Borges *et al.* 2003). Like most pollinators, butterflies can transfer pollen from plant to plant as it sticks to their legs (USDA 2019), and certain flowers have even specialized for butterfly pollination (Cruden and Hermann-Parker 1979; Borges *et al.* 2003). For example, Barrios *et al.* (2016) found that while butterflies are not the best pollinators, as defined by their efficiency in collecting and spreading pollen, they visit flowers more than bees and are responsible for spreading pollen longer distances, resulting in important genetic consequences, like cross pollination and genetic diversity for the plants (Winfree *et al.* 2011).

Four main factors affect the foraging behavior of pollinators: their evolutionary history; individual experience; intrinsic factors, such as genetics; and extrinsic factors, such as weather and temperature (Waddington and Heinrich 1981). Like other insects, birds, and bats, butterflies consume nectar, which provides critical energy for metabolic purposes (Real 1981). Unlike bees, some butterflies will obtain nectar from plants without ever performing the ecological duty of pollination (Real 1981; Kunte 2007; Stefanescu and Traveset 2009), reinforcing the idea that while butterflies are still important pollinators, they are not necessarily the most efficient ones.

Historically, the foraging ecology of butterflies in contexts other than pollination was studied relatively infrequently (Douwes 1975; Alm *et al.* 1990; Stefanescu and Traveset 2009), partly due to some researchers finding it particularly difficult to study small, mobile species (Gilbert and Singer 1975). Few researchers have attempted to identify foraging preferences of butterflies when they are searching for nectar, and studies on this aspect of butterfly ecology have just begun to increase (Winfree *et al.* 2011). The relatively small number of studies on butterfly foraging ecology have resulted in differences in opinion as to whether butterflies are generalists, not preferring certain nectar sources, or specialists, having a preference for one or a few nectar sources (Alm *et al.* 1990; Shreeve 1992; Olesen *et al.* 2007; Stefanescu and Traveset 2009). Shreeve (1992) and Kunte (2007) identified butterflies as generalists, while Olesen *et al.* (2007) and Stefanescu and Traveset (2009) identified them as specialists. Several factors influence selection of nectar sources by butterflies, including proboscis length, handling time for obtaining nectar (Kunte 2007), body size (Corbet 2000), and nectar source distribution, with distribution of nectar sources suggested as the biggest determinant (Douwes 1975; Gilbert and Singer 1975; Real 1981; Yamamoto *et al.* 2007). Certain plants have greater nectar rewards than others, as is the case for a true specialist: the monarch butterfly (*Danaus plexippus*).

The monarch butterfly is one of the best recognized butterflies in the world, and is a true conservation icon. A specialist as larvae and adults, monarch caterpillars feed solely on the leaves of milkweed species (*Asclepias* spp.), while adults preferentially utilize milkweed as a nectar source, because milkweed nectar is especially sweet and rich in nutrients (Southwick

1983). Monarchs can specialize on milkweed species because they are one of the few herbivores undeterred by the toxic alkaloid compounds produced by the plant (Southwick 1983). Monarchs convert the sugars in nectar into lipids to use for energy, which is especially important for their famously long and complex migration (Gustafsson *et al.* 2015; Nail *et al.* 2015). In western New York, four species of milkweed are used by monarchs for nectar and as host plants: common milkweed (*Asclepias syriaca*), swamp milkweed (*Asclepias incarnata*), whorled milkweed (*Asclepias verticillata*) and butterflyweed (*Asclepias tuberosa*), with common milkweed and whorled milkweed nectared on the most (Xerces Society 2018).

This specialization by monarchs, along with their habitat use and long, grueling migration, make them especially vulnerable to population decline. Over the last few decades monarch populations have fallen drastically (Fischer *et al.* 2015; Gustafson *et al.* 2015; Semmens *et al.* 2016), with monarchs currently under review for listing under the federal Endangered Species Act (USFWS 2019). In January 2014, the lowest number of monarchs were recorded at Mexico overwintering sites (Gustafson *et al*. 2015). Habitat destruction and increasing severe weather patterns due to climate change have also greatly affected monarch populations (Flockhart *et al.* 2014) and their breeding grounds. For example, normal migrating California populations decreased by 86% in one year due to habitat loss and severe droughts (Xerces Society 2018) and the most recent survey confirmed that populations are still critically low (Xerces Society 2020). Monarchs are not the only species declining, as a number of butterfly populations could become vulnerable as the effects of climate change increase (Gustafsson *et al.* 2015). As with monarchs, all butterfly populations are limited by predation, parasitism, weather, and larval and adult resources, as many species' larvae require certain host plants (Gilbert and Singer 1975). A continuously changing environment is affecting these limiting factors, putting populations at risk, and leading to increased management efforts for butterfly populations and their habitats.

Targeted management of pollinator habitat has begun to increase only in the last few decades. Since then several different management techniques have been implemented on public lands, such as wildlife refuges and national parks. Many strategies are involved with reducing the loss of nectar sources and host plants due to habitat loss (Mueller and Baum 2014). One management strategy that has become common in recent years is mowing areas with nectar sources, especially to conserve monarch populations (Smith and Cherry 2014; Fischer *et al.* 2015; Halbritter *et al.* 2015; Alcock *et al.* 2016; Kenyeres and Szentirmai 2017; Clay 2019). Mowing at the appropriate time can promote fresh, regenerated milkweed for ovipositing females, which can then feed both larvae and late adults (Alcock *et al.* 2016). However, as with many management issues, studies on mowing have produced conflicting results, with Smith and Cherry (2014) finding that mowing can lead to increased mortality of monarch larvae. However, as long as mowing is timed appropriately, it creates optimal habitat, and not just for monarchs. Smith and Cherry (2014) found that mowed fields had significantly higher butterfly species diversity and richness than grazed fields, as did Halbritter *et al.* (2015), but both studies stressed that minimal, appropriately timed mowing is better than frequent mowing. Other management strategies for native nectar sources include removing non-native species that do not allow native species to grow well (MNWR 2017).

Montezuma National Wildlife Refuge (MNWR), originally established in 1938 as a refuge and breeding area for waterfowl and other migratory birds, recently began planting native nectar sources for pollinators, and has made pollinator conservation a management priority (MNWR 2013). Given the lack of information on the foraging behavior of butterflies on public lands such as MNWR, and the growing need for managing and conserving butterfly species, I observed and recorded the behavior and abundance of butterflies at three managed sites at the refuge.

In my study, I investigated butterfly use in one upland site and two "non-traditional" pollinator habitats: one marsh in total drawdown phase (Main Pool) and one marsh in partial drawdown phase (Seneca Flats). These sites are "non-traditional," as the habitats they contain are generally not thought of as habitats with suitable resources for pollinators; additionally, there are no known detailed studies on the effects of impoundment drawdowns on pollinators. The major management objectives of drawdown, meaning lowering the water level of the marsh, is to allow for a mix of open water, emergent vegetation, and underwater vegetation, which in turn creates breeding and feeding habitat for migratory waterfowl (MNWR 2017). Drawdown is also used on the refuge as a way to remove invasive species such as cattail (*Typha* spp.) and purple loosestrife (*Lythrum salicaria*) (MNWR 1997; MNWR 2017).

Since butterfly use and management have not been studied in marshes in drawdown, my first objective was to determine the abundance of butterflies and which nectar sources were being used by butterflies at these sites. By doing so, I hoped to show that sites in drawdown can be useful to other taxa in addition to migratory waterfowl, and suggest management practices to enhance pollinator populations in these "non-traditional" habitats. My second objective was to determine the abundance of butterflies in an upland field previously planted with native nectar sources, and which nectar sources in the field were being used by the butterflies. I hoped that this part of my project would provide MNWR with information on which planted nectar sources were present and used by butterflies. At both sites, I also had a secondary objective of determining if abundant butterfly species preferred particular nectar sources.

METHODS

I conducted my study between 8 July 2019 and 5 October 2019 at Montezuma National Wildlife Refuge. For my first objective I used two sites: Main Pool (MP) and Seneca Flats (SF). MP, located at approximately 42.9755°N, -76.7379°W, is 640 acres (259 ha), and is one of the largest and most recognized marshes on the refuge. It is located just west of Wildlife Drive, 1.6 km north of the visitor center, and is the first marsh seen to the west once visitors enter Wildlife Drive (Figure 1). Between June and October of 2019, MP was in full-drawdown phase, having little to no standing water during much of my sampling period. Two nectar sources were present at MP: smartweed (*Polygonum* spp.) and beggarticks (*Bidens* spp.). Cattail (*Typha* spp.) dominated the outer edge of the impoundment, with some intermixed wetland shrubs. At the start of my sampling, vegetation was short and below my waist, but eventually it grew well above my head to approximately 2 m. Starting around mid-August, the water level in MP was slowly increased. In addition to butterflies, other species I commonly saw nectaring at MP were honeybees (*Apis mellifera*), bumblebees (*Bombus* spp.), and flies (Diptera).

SF, located at approximately 42.9751°N, -76.7372°W, is 7 acres (2.8 ha); as a new impoundment in drawdown, it was in “shallow water impoundment” phase, with water levels between 0.05 m and 0.6 m. SF is directly east of MP, on the east side of Wildlife Drive (Figure 1). SF was divided into several island-like areas where many nectar sources and other vegetation grew. Between the islands was standing water anywhere from less than 0.5 to about 0.6 m deep. In addition to the nectar sources, lots of tall wetland graminoids and occasional wetland shrubs were present in SF, and the site was surrounded by grasses and nectar sources commonly found in edge habitats like spotted joe-pye weed (*Eutrochium maculatum*) and false sunflower (*Heliopsis helianthoides*).

For my second objective I used Hidden Marsh (HM), located at approximately 43.0483°N, -76.7812°W, on a refuge access road located off of Hogback Road in Savannah, Wayne County, NY (Figure 2). HM is a 2-acre (0.8 ha) upland field site, which was mowed and cleared to plant native nectar sources in October 2017. The refuge's official objectives were to increase the acreage of native nectar sources for multiple pollinator species; provide an area that contributes to the increased health, diversity, and populations of pollinators; contribute to the U.S. Fish and Wildlife pollinator initiatives; provide an area for future native seed collection; and help increase education and awareness of healthy pollinator habitat, populations, and their services (MNWR 2017). The full and expanded list of the objectives can be found in the MNWR 2017 Pollinator Habitat Restoration Grant Proposal (MNWR 2017). Table 1 shows the native nectar sources that were planted at HM (and their corresponding symbols), with all seeds provided by Ernst Conservation Seeds, Meadville, PA. HM is bounded by thin strips of mid-successional forest habitat approximately 30 m deep, but at the landscape level is surrounded mostly by upland fields and fallowed farm fields. In addition to the planted nectar sources, non-native nectar sources, such as Canada thistle (*Cirsium arvense*) and Queen Anne's lace (*Dacus carota*), were also present, along with mixed grasses. Along with the nectaring butterflies, I commonly saw bumblebees, honeybees, dragonflies (*Anax* spp.), and hummingbird clearwings (*Hemaris thysbe*).

At the start of every sampling session I recorded weather, temperature, time, cloud cover percentage, wind direction, and wind speed, and again recorded temperature and time at the end of sampling. At MP and HM I set up ten 45-m-long transects, each 16 m apart from adjacent transects. Transects were oriented northeast to northwest at MP and west to east at HM. Along each transect I placed five 1x1 m^2 quadrats for measuring nectar source abundance, 9 m apart from each other, starting 5 m from the beginning of the transect. Measuring total length of each site from transect 1 to transect 10, with each transect 45 m in length and 16 m wide, the total observation area of each site was 7200 m^2. To measure butterfly abundance I slowly walked along the transect, observing butterflies as I went. In an effort to avoid recounting I only recorded butterflies I observed in front of me. When I observed a butterfly along the transect, I measured the distance to it using a range finder and estimated the angle using a protractor. I also recorded the behavior of the butterfly; if the behavior was nectaring, I recorded what nectar source the butterfly used. To estimate nectar source abundance, I recorded the number of flowers or inflorescences of each source within each quadrat. If there were more than 100 flowers or inflorescences in a quadrat I recorded the number as 100 for statistical purposes. I sampled HM once a week starting on 8 July 2019 and continuing to 5 October 2019. I sampled MP once a week starting on 20 August 2019, because no nectar sources were present prior to then, and continued sampling until 5 October 2019. I typically started sampling between 1000 and 1030, and finished between 1200 and 1245. Once I began sampling both HM and MP, I would alternate which site was sampled first to reduce any temporal bias.

At SF, due to the site's much smaller size and my inability to establish equally-long transects as at my other sites, I randomly placed seven plots using a 1x1 m^2 quadrat. My plots were about 9 m apart, in order to have some similarity with my methodology at the other two sites. To measure butterfly abundance I counted a butterfly seen anywhere at the site, recording whether it was inside or outside of a quadrat, what quadrat it was closest to, and its behavior, again recording the nectar source if the butterfly was nectaring. In each plot, as at HM and MP, I recorded the number of inflorescences. I sampled SF once a week starting on 20 August 2019 and continuing to 21 September 2019, due to the absence of any nectar sources after this date. I typically started sampling between 1030 and 1130, depending on when I sampled MP.

To test for significant differences between the number of butterflies per transect at HM and MP, I used a Wilcoxon signed-rank test, with samples paired by date. I also performed a chi-squared goodness-of-fit test to examine preferences for individual nectar sources. I defined preference as a species visiting a nectar source disproportionately to its frequency in the environment and the overexploitation of that nectar source when other nectar sources are present (Cock 1978; Aldridge and Campbell 2007). I analyzed preference data for monarchs at MP on 15 September 2019 and for red admirals (*Vanessa atalanta*) at HM on 8 July 2019, as each of these dates had the most observations for those species. I also used a chi-squared goodness-of-fit test to see if there was a significant difference in the proportion of native and non-native nectar inflorescences/flowers present for five dates at HM. To estimate detectability, the proportion of the population of butterflies present at HM and MP that I actually observed, I used the online program Distance (Thomas *et al*. 2010). I ran five different Distance projects: all butterflies at HM, all butterflies at MP, red admirals at HM, monarchs at HM, and monarchs at MP. Red admirals and monarchs were the only species with more than 20 observations.

RESULTS

Butterfly use - At MP I observed three butterfly species feeding on nectar sources: monarch, painted lady (*Vanessa cardui*), and yellow sulphur (*Phoebis sennae*). Monarchs were the most common, making up 94% of nectaring observations. Other non-nectaring butterfly species I observed at MP included eastern tailed-blue (*Cupido comyntas*), cabbage white (*Pieris rapae*), and giant swallowtail (*Papilio cresphontes*).

At SF I only observed a single monarch feeding on a nectar source throughout my entire study period. The only other butterfly species I observed at SF was eastern tailed-blue.

At HM I observed 11 butterfly species feeding on nectar sources: red admiral, painted lady, cabbage white, monarch, yellow sulphur, fritillary (*Boloria* spp.), eastern tiger swallowtail (*Papilio glaucus*), black swallowtail (*Papilio polyxenes*), viceroy (*Limenitis archippus*), eastern tailed-blue, and white admiral (*Limenitis arthemis*). I most commonly observed red admirals feeding, making up 81% of nectaring observations for the first four observation days and 58% of total nectaring observations. Another non-nectaring butterfly species I observed was giant swallowtail.

Butterfly abundance - There was no significant difference in the number of butterflies per transect between MP and HM ($Z = -0.762$, $p = 0.44$). At HM, butterfly abundance was high on my first observation day and then decreased and remained relatively constant for the rest of my study period (Figure 3). At MP, butterfly abundance was consistently low except for 15 September 2019, when I observed a large spike in abundance (Figure 3); this spike was due to monarch abundance, which remained relatively constant at HM and MP, except for the large increase on 15 September 2019 (Figure 4).

Detectability of common butterfly species - According to Distance, I observed a relatively low proportion of the entire butterfly population at HM (p = 0.15895), but a somewhat higher proportion at MP (p = 0.26150). I observed a lower proportion (p = 0.17384) of the red admiral population at HM than I did for the monarch populations at HM (p = 0.37904) and MP (p = 0.32046). Figures 5 and 6 show total butterfly abundance and monarch abundance at each site adjusted for detectability.

Nectar source use and abundance – At MP, smartweed (*Polygonum* spp.) and beggarticks (*Bidens* spp.) were the only potential nectar sources present; both of these species are native. Smartweed was present before beggarticks and remained present until the end of sampling. Beggarticks was present from the third week of sampling until the end of sampling. Smartweed inflorescences were more abundant than beggarticks inflorescences for my entire study period, but smartweed was not nectared on by any butterflies, while beggarticks was nectared on by monarchs, painted ladies, and yellow sulphurs. Monarch visits tracked the tracked the pattern of beggarticks frequency (Figure 7) and monarchs showed a strong preference for beggarticks (x^2-goodness-of-fit test, $X^2 = 171$, df = 1, p = <0.001, Figure 8).

At SF, nectar sources present included beggarticks, smartweed, purple loosestrife (*Lythrum salicaria*), pickerelweed (*Pontederia cordata*), and common marshmallow (*Althaea officinalis*). Purple loosestrife and common marshmallow are both non-native. The only nectar source that I observed being used was purple loosestrife, by a single monarch.

Several of the native species planted by MNWR at HM (Table 1) were present during my study period. I observed the following native nectar sources in my plots: purple coneflower (*Echinacea purpurea*), wild bergamot (*Monarda fistulosa*), tall white beardtongue (*Penstemon digitalis*), black-eyed Susan (*Rudbeckia hirta*), brown-eyed Susan (*Rudbeckia triloba*), New England aster (*Symphyotrichum-novae angliae*), and yellow false indigo (*Baptisia tinctoria*), while butterfly weed and wild senna (*Senna hebecarpa*) also were present, but not in any plots. Native nectar sources that were present, but not planted by the refuge, included fleabane (*Erigeron* spp.) and field hawkweed (*Hieracium caespitosum*).

Black-eyed Susan, brown-eyed Susan, fleabane, and field hawkweed were the most common native nectar sources at HM. Brown-eyed Susan and fleabane were the first native species to flower. By mid-August, Brown-eyed Susan was no longer producing nectar, but black-eyed Susan had begun to produce nectar (Figure 9). New England aster was present from mid-September through the end of my study (Figure 9). While fleabane was present for the entire study period, very few individuals were producing nectar from mid-August to mid-September, but they began to produce a lot of nectar again from mid-September until the end of my study period (Figure 9), as I began to observe butterflies nectaring on them once more. Field hawkweed was present from the beginning of August through the end of my study (Figure 9).

Potential non-native nectar sources present at HM included red clover (*Trifolium pratense*), Canada thistle, Queen Anne's lace, common teasel (*Dipsacus fullonum*), and yellow sweet clover (*Melilotus officinalis*). Red clover and Queen Anne's lace were the most common non-native nectar sources present. Both were present throughout my entire study period, but Queen Anne's lace became very abundant around mid-July and remained so throughout the rest of my study (Figure 9).

As my study period continued, non-native nectar inflorescences/flowers became more abundant, but were never more abundant than native nectar inflorescences/flowers. There was no significant difference in the proportion of native and non-native nectar inflorescences/flowers present on 8 July 2019 (x^2-goodness-of-fit test, $X^2 = 0.111111$, df = 1, $p = 0.739$), 23 July 2019 (x^2-goodness-of-fit test, $X^2 = 0.440104$, df = 1, $p = 0.507$), and 15 September 2019 (x^2-goodness-of-fit test, $X^2 = 0.033198$, df = 1, $p = 0.855$). There were significantly more native nectar inflorescences/flowers present than non-native nectar inflorescences/flowers on 29 July 2019 (x^2-goodness-of-fit test, $X^2 = 3.17582$, df = 1, $p = 0.075$) and 5 October 2019 (x^2-goodness-of-fit test, $X^2 = 10.3434$, df = 1, $p = 0.001$).

Of the planted native nectar sources present at HM, I observed butterflies using brown-eyed Susan, New England aster, and black-eyed Susan, while fleabane and field hawkweed were non-planted native nectar sources used. Of the non-native nectar sources present, I observed butterflies using Queen Anne's lace, Canada thistle, and common teasel. Brown-eyed Susan, fleabane and Queen Anne's lace were the most commonly used nectar sources, with red admirals showing a preference for brown-eyed Susan on 15 September 2019, relative to its presence in the environment (x^2-goodness-of-fit test, $X^2 = 793.440$, df = 3, $p = <0.001$, Figure 10).

Brown-eyed Susan, Queen Anne's lace, and Canada thistle were nectared on by the largest variety of butterfly species, with six each, followed by fleabane with four, black-eyed Susan with three, common teasel with two, and New England aster and field hawkweed with one. Table 2 shows the specific butterfly species that visited each nectar source.

DISCUSSION

Renewed interest in butterflies has led to better scientific understanding of their foraging behavior and ecological importance. However, studies on the foraging ecology of butterflies outside of pollination are still rare (Stefanescu and Traveset 2009). These relatively infrequent studies, combined with increasing conservation pressure (Xerces Society 2020), call for more studies on butterfly foraging behavior, particularly in "non-traditional" habitats, to increase knowledge about potentially valuable habitats. Although in my study these habitats did not host a larger variety of butterfly species compared to traditional habitats, such as meadows or montane environments, they still provided valuable resources for certain important butterfly species, like the monarch.

Butterfly richness and abundance - The higher butterfly species richness that I observed at HM could be attributed to higher nectar source richness and diversity, supporting generalist and specialist butterfly species (Menéndez *et al.* 2007). HM also had nectar sources present throughout the entire season, whereas MP only had nectar sources from August to October. Higher butterfly species richness is positively related to higher flower abundance and richness (Öckinger and Smith 2006). The difference in diversity could also be attributed to landscape differences, as MP was much more open than HM, which was surrounded by strips of forested habitat. Dover *et al.* (2000) found that areas surrounded by any type of forest cover supported higher butterfly species diversity and abundance compared to more open areas, while Illán *et al.* (2010) found butterfly species diversity was greatest in areas with forest cover. However, the lack of significant difference in the number of butterflies per transect between HM and MP suggests that both sites had sufficient resources to sustain butterfly populations of roughly the same size. My analysis of detectability suggested that HM and MP had more butterflies present than I observed, suggesting nectar sources are likely being utilized frequently, as well.

Of the butterfly populations at HM, red admirals were the most abundant, especially early in my study period. At HM, the high abundance of butterflies on the first observation day was due mostly to red admirals. Red admirals are most active in spring and fall, and can constantly be seen locally as they migrate within regions (Hutchins 2019). On my way to HM for the first few observation days, I saw many red admirals flying up from the brush at the side of the road. Their high abundance could possibly be due to patterned spikes in red admiral populations that occur around every ten years. In 1981, 1990, 2001, and 2011 populations in the northeastern United States greatly increased (Hutchins 2019). If the pattern continues to hold, 2019 should have been close to a big year for red admiral populations. The preference of red admirals for brown-eyed Susan suggests brown-eyed Susan produced more favorable nectar than other species present at

HM, like fleabane or red clover. The only other butterfly species that was relatively abundant and had substantial nectaring observations at HM was the monarch.

At MP, I attribute the large abundance of monarchs on 15 September 2019 to an early migrating population passing through the refuge. Monarchs usually begin their fall migration in October, but some populations begin as early as late August (Brower and Malcolm 1991; Reppert *et al.* 2010). Like all other observed monarchs during my study period, this population only nectared on beggarticks, which is one of the most common nectar sources used by monarchs (Xerces Society 2016). Their preference for the species on 15 September 2019 suggests that, although monarchs use a variety of nectar sources, they will nectar heavily on beggarticks when it is present and abundant.

Monarchs were the only butterfly species to use nectar sources at all three sites. Besides milkweed species (Southwick 1983; Jones and Agrawal 2016; Xerces Society 2018), monarchs have been observed using blazing stars (*Litris* spp.), beggarticks, thistles (*Cirsium* spp.), crownbeards (*Verbesina* spp.), goldenrods (*Solidago* spp.), and asters (*Symphyotrichum* spp.) (Xerces Society 2018). They are known to utilize a variety of habitats for a variety of different nectar sources, including native and non-native species.

Planted nectar sources at HM - At HM, nine of the 30 species planted by MNWR in 2017 were present, and many were fairly abundant. The lack of a significant difference between the native and non-native nectar inflorescences/flowers present on three days, and significantly more native nectar inflorescences/flowers present on two days show that natives were not being out-competed by non-natives, despite the most common non-native species being the only consistently present nectar sources. While this means that MNWR had some successful plantings, the native proportion was also increased by non-planted native nectar sources, like fleabane and field hawkweed.

The Xerces Society for Invertebrate Conservation lays out five basic steps for successfully managing pollinator plantings: site selection, site preparation, plant selection, planting techniques, and ongoing management (Xerces Society 2013). These steps were developed for bee species, but are successful for butterfly populations, too. MNWR employed many of these steps (MNWR 2017) at HM for successful planting. According to the Pollinator Habitat Restoration Grant Proposal for Hidden Marsh, MWNR broadcasted their seeds, with plans to regularly mow the area at specified intervals to remove plant debris. All species planted were native wildflowers, in addition to some native grasses. Xerces Society (2013) included all these techniques within their five basic steps. A plan to remove non-native species if necessary has been implemented (MNWR 2017), but as of now I do not believe non-native species have significantly impeded growth of native species.

Native vs non-native nectar sources - While not yet the case at HM, there have been many instances of non-native plant species invading habitats where native plant species thrive, resulting in their displacement (Hanna *et al.* 2013; Vanbergen *et al.* 2018). However, there are also several situations where non-native plant species become valuable, in that they provide nectar and pollen for declining pollinator populations (Stubbs *et al*. 2007; Stout and Tiedeken 2016; Vanbergen *et al.* 2018). Dilemmas are created when non-native plant species provide nectar for declining pollinator populations, and it is important to consider whether visiting pollinators prefer nectaring on non-native species. If non-native plant species overtake native plant species, it is important to know what the impact of removing the non-native plant species would have on the pollinator utilizing it as a nectar source, especially if that was their primary nectar source in that area. On public lands like MNWR, the cost of removing non-native plant species must also be considered. Whether non-native nectar sources are providing valuable resources for visiting pollinators or whether the visiting pollinators would visit these plant species in their natural habitat are two different questions.

The fact is that these non-native plant species are at HM and they are performing the same ecological duties that native plant species are. At HM, Queen Anne's lace, a non-native, was the tallest nectar source available, drowning out other native species like black-eyed Susan. It is important to consider, though, that Queen Anne's lace was the third most visited nectar source at HM. In a previous study focusing on the foraging ecology of butterflies along dikes at MNWR and Iroquois National Wildlife Refuge (INWR), I observed a variety of butterfly species utilizing non-native nectar sources, including Queen Anne's lace, bird's-foot trefoil (*Lotus corniculatus*), red clover, Canada thistle, purple loosestrife, common burdock (*Arctium minus*), crown vetch (*Securigera varia*), chicory (*Cichorium intybus*), and field sow thistle (*Sonchus arvensis*). Cabbage whites even showed a preference for red clover and Canada thistle. There is likely never going to be a clear resolution to the debate about the value of native and non-native nectar sources. The real question becomes whether to manage for the conservation of pollinator populations or for the removal of non-native plant species, especially when non-native nectar sources are utilized by true conservation icons: monarchs.

Use by monarchs - While many people associate monarchs with milkweed because monarch larvae require milkweed as their host plant (Yeargan and Allard 2005; Belsky and Joshi 2018), adult monarchs use a variety of native and non-native flowers as nectar sources. In my previous study I observed monarchs nectaring on common milkweed, swamp milkweed, spotted joe pye weed, and lance-leaf goldenrod (*Solidago lancifolia*), along with the non-native red clover, common burdock, Canada thistle, common teasel, purple loosestrife, and field sow thistle. I observed monarchs nectaring on several of the same non-native nectar sources in my current study, suggesting that non-native nectar sources can provide suitable nectar for a declining species. However, since monarchs also utilized several native nectar sources, this suggests if the non-native species at HM were removed monarchs would still have suitable resources. Perhaps attempting to target plantings so that they encourage particular nectar sources could help monarch populations. For example, while purple coneflower was not present in any of my plots at HM, I observed it being utilized by monarchs off site. Increasing suitable habitat for nectar source species that monarchs utilize could increase their populations, especially with the addition of managed habitats previously not considered for butterfly populations.

Pollinator management - For many decades, marsh impoundments have been drawn down to allow aquatic vegetation to reestablish itself, supplying food, cover, and nesting material for breeding, non-breeding, and migratory waterfowl (Merendino *et al.* 1990; Pickens and King 2014; MNWR 2017). These impoundments can provide important resources for waterfowl, while also being used to manage butterfly populations. Beggarticks is one of the most frequently used species by monarchs, comprising about 70% of nectaring observations along the fall migratory route in Texas (Williams 2019), and is one of the top monarch nectar sources (Xerces Society 2016; Xerces Society 2018). Beggarticks produces high-quality nutrient seeds during any drawdown season, which are readily fed upon by waterfowl using the impoundments (Nelms 2007). Nelms *et al.* (2007) found that late season drawdowns with fall flooding yield the highest beggarticks seed production and density, coinciding with monarch migrations (Brower and Malcolm 1991), suggesting these “non-traditional” sites can provide valuable resources for waterfowl and butterflies.

Pollinator management at “non-traditional” sites, such as marshes or dikes, is relatively new (Berg *et al.* 2013; Guédot and van Zoeren 2018). Dikes have recently been recognized as providing valuable diverse habitat for pollinators when properly managed (Berg *et al.* 2013; Guédot and van Zoeren 2018; Clay 2019), particularly when enhancing milkweed habitat for monarchs (Clay 2019). A recent study headed by SUNY Brockport graduate student Tiffany Clay examined how managing refuge dikes through mowing, particularly in mid-summer, can enhance suitable habitat for fall milkweed (Clay 2019). Managing dikes for fall milkweed growth while also managing drawdown impoundments for increased beggarticks could benefit monarch populations, as both plants can provide resources at the same time.

Milkweed can provide food for recently hatched larvae, and once those larvae transform into adults, they can utilize the nectar produced by beggarticks in the impoundment to fuel their long migration (Gustafsson *et al.* 2015; Nail *et al.* 2015). With the preference of monarchs for beggarticks and the timing of resource availability of milkweed and beggarticks in habitats typically adjacent to each other, I suggest that, if managed together properly, dikes and marshes in drawdown can provide valuable resources for monarch populations through much of the summer and fall portion of their life cycle, in addition to providing the necessary resources for waterfowl.

Limitations - Several limitations occurred during my study. I was unable to replicate my methodology for MP and HM at SF due to accessibility and limited impoundment size. I only found nectar sources in small patches, so line transects would have been inappropriate. SF also produced nectar sources on only two days of my observations, thus not attracting a large abundance or variety of butterfly species. The largest limitation came with detectability, both in the field and with analyses. Using Distance (Thomas *et al.* 2010) to obtain detectability of all butterflies can be thought of as a potentially faulty analysis because the detectability of each individual butterfly species is different, based on their size and behavior. In the field detectability most likely was decreased by tall vegetation, which was over my head for the majority of my study period.

Future research recommendations - For further research I recommend observing butterflies more than once a week to better understand the temporal patterns of use by various species, along with obtaining more accurate patterns of nectar source phenology. I would also examine an impoundment in drawdown that has dikes with milkweed present adjacent to it, to observe if both habitats are concurrently utilized by monarchs. I would also suggest examining wetlands on other public lands to determine if other nectar sources are utilized by butterfly populations. For example, it would be interesting to know if smartweed is used by butterflies in the absence of beggarticks. Iroquois National Wildlife Refuge also manages their impoundments with drawdowns, so it would be interesting to observe patterns of usage there.

ACKNOWLEDGEMENTS

I would like to thank Dr. Christopher Norment for all his guidance, support, and advice throughout this entire process. I would also like to thank Linda Ziemba, Nick Vermeulen, and the rest of the staff at Montezuma National Wildlife Refuge for allowing me to conduct my study on the refuge; for providing information about the refuge; and for their support and enthusiasm. I additionally would like to thank Dr. Adam Rich and the Summer Undergraduate Research Program and the Rochester Butterfly Club for supporting and funding my study, with additional thanks to Dr. Kathryn Amatangelo, Dr. Ernest Williams, Tiffany Clay, and my family.

LITERATURE CITED

Alcock, J., L.P. Brower, and E.H. Williams Jr. 2016. Monarch butterflies use regenerating milkweeds for reproduction in mowed hayfields in northern Virginia. Journal of Lepidopterists' Society 70: 177-181.

Aldridge, G. and D.R. Campbell. 2007. Variation in pollinator preference between two *Ipomopsis* contact sites that differ in hybridization rate. Evolution 61: 99-110.

Alm, J., T.E. Ohnmeiss, J. Lanza, and L. Vriesenga. 1990. Preference of cabbage white butterflies and honey bees for nectar that contains amino acids. Oecologia 84: 53-57.

Barrios, B., S.R. Pena, A. Salas, and S. Koptur. 2016. Butterflies visit more frequently, but bees are better pollinators: the importance of mouthpart dimensions in effective pollen removal and deposition. AoB Plants 8: 1-10.

Berg, A., K. Ahrné, E. Öckinger, R. Svensson, and J. Wissman. 2013. Butterflies in semi-natural pastures and power-line corridors – effects of flower richness, management, and structural vegetation characteristics. Insect Conservation and Diversity 6: 639-657.

Belsky, J. and N.K. Joshi. 2018. Assessing role of major drivers in recent decline of monarch butterfly population in North America. Frontiers in Environmental Science 6: 86.

Boppré, M. and R.I. Vane-Wright. 2012. The butterfly house industry: conservation risks and education opportunities. Conservation & Society 10: 285-303.

Borges, R.M., V. Gowda, and M. Zacharias. 2003. Butterfly pollination and high-contrast visual signals in a low-density distylous plant. Oecologia 136: 571-573.

Brower, L.P. and S.B. Malcolm. 1991. Animal migrations: endangered phenomena. American Zoologist 31: 265-276.

Clay, T., C.J. Norment, and K. Amatangelo. Managing for Pollinators in Non-traditonal Habitats. Presentation at New York State Wetlands Forum, Saratoga Springs, NY, United States.

Cock, M.J.W. 1978. The assessment of preference. Journal of Animal Ecology 47: 805-816.

Corbet, S.A. 2000. Butterfly nectaring flowers: butterfly morphology and flower form. Entomologia Experimentalis et Applicata 96: 289-298.

Cruden, R.W. and S.M. Hermann-Parker. 1979. Butterfly pollination of *Caesalpinia pulcherrima*, with observations on a psychophilous syndrome. Journal of Ecology 67: 155-168.

Douwes, P. 1975. Distribution of a population of the butterfly *Heodes virguareae*. Oikos 26: 332-340.

Dover, J., T. Sparks, S. Clarke, K. Gobbett, and S. Glossop. 2000. Linear features and butterflies: the importance of green lanes. Agriculture, Ecosystems, and Environment 80: 227-242.

Fischer, S.J., E.H. Williams, L.P. Brower, and P.A. Palmiotto. 2015. Enhancing monarch butterfly reproduction by mowing fields of common milkweed. The American Midland Naturalist 173: 229-240.

Flockhart, D.T.T., J. Pichancourt, D.R. Norris, and T.G. Martin. 2014. Unravelling the annual cycle in a migratory animal: breeding-season habitat loss drives population declines of monarch butterflies. Journal of Animal Ecology 84: 155-165.

Gilbert, L.E. and M.C. Singer. 1975. Butterfly ecology. Annual Review of Ecology and Systematics 6: 365-397.

Guédot, C. and J. van Zoeren. 2018. Protecting pollinators and improving pollination on Wisconsin cranberry marshes. University of Wisconsin – Extension. Cooperative Extensions.

Gustafsson, K.M., A.A. Agrawal, B.V. Lewenstein, and S.A. Wolf. 2015. The monarch butterfly through time and space: the social construction of an icon. BioScience 65: 612-622.

Halbritter, D.A., J.C. Daniels, D.C. Whitaker, and L. Huang. 2015. Reducing mowing frequency increases floral resource and butterfly (Lepidoptera: Hesperioidea and Papilionoidea) abundance in managed roadside margins. The Florida Entomologist 98: 1018-1092.

Hanna, C., D. Foote, and C. Kremen. 2013. Invasive species management restores a plant-pollinator mutualism in Hawaii. Journal of Applied Ecology 50: 147-155.

Hutchins, R. 2019. The great butterfly migration: unnoticed by most, red admiral silently invades N.J. [Online.] Available at: https://www.nj.com/news/2012/05/the_great_butterfly_migration.html. Accessed February 2020.

Illán, J.G., D. Gutiérrez, and R.J. Wilson. 2010. Fine-scale determinants of butterfly species richness and composition in a mountain region. Journal of Biogeography 37: 1706-1720.

Jones, P.L. and A.A. Agrawal. 2016. Consequences of toxic secondary compounds in nectar for mutualist bees and antagonist butterflies. Ecology 97: 2570-2579.

Kenyeres, Z. and I. Szentirmai. 2017. Effects of different mowing regimes on orthopterans of Central-European mesic hay meadows. Journal of Orthoptera Research 26: 29-37.

Kunte, K. 2007. Allometry and functional constraints on proboscis lengths in butterflies. Functional Ecology 21: 982-987.

Menéndez, R., A. González-Megías, Y. Collingham, R. Fox, D.B. Roy, R. Ohlemüller, and C.D. Thomas. 2007. Direct and indirect effects of climate and habitat factors on butterfly diversity. Ecology 88: 605-611.

Merendino, M.T., L.M. Smith, H.R. Murkin, and R.L. Pederson. 1990. The response of prairie wetland vegetation to seasonality of drawdown. Wildlife Society Bulletin 18: 245-251.

MNWR. 1997. Montezuma National Wildlife Refuge Annual Water Management Plan. Seneca Falls, New York, USA.

MNWR. 2013. Montezuma National Wildlife Refuge Comprehensive Conservation Plan. February 2013, U.S. Fish and Wildlife Service, Seneca Falls, New York, USA.

MNWR. 2017. Resource Management. [Online.] Available at: https://www.fws.gov/refuge/Montezuma/what_we_do/resource_management.html. Accessed January 2020.

MNWR. 2017. Pollinator Habitat Restoration Grant Proposal. U.S. Fish and Wildlife Service, Seneca Falls, New York, USA.

Mueller, E.K. and K.A. Baum. 2014. Monarch-parasite interactions in managed and roadside prairies. Journal of Insect Conservation 18: 847-853.

Nail, K.R., C. Stenoien, and K.S. Oberhauser. 2015. Immature monarch survival: effects of site characteristics, density, and time. Annals of the Entomological Society of America 108: 680-690.

Nelms, K.D., B. Ballinger, and A. Boyles. 2007. Wetland Management for Waterfowl Handbook. [Online.] Available at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_016986.pdf. Accessed February 2020.

Öckinger, E. and H.G. Smith. 2006. Landscape composition and habitat are affects butterfly species richness in semi-natural grasslands. Oecologia 149: 526-534.

Olesen, J.M., Y.L. Dupont, B.K. Ehlers, and D.M. Hansen. 2007. The openness of a flower and its number of flower-visitor species. Taxon 56: 729-736.

Pickens, B.A. and S.L. King. 2014. Multiscale habitat selection of wetland birds in the Northern gulf coast. Estuaries and Coasts 37: 1301-1311.

Real, L.A. 1981. Uncertainty and pollinator foraging. BioScience 31: 58-59.

Reppert, S.M., R.J. Gegear, and C. Merlin. 2010. Navigational mechanisms of migrating monarch butterflies. Trends in Neurosciences 33: 399-406.

Semmens, B.X., D.J. Semmens, W.E. Thogmartin, R. Wiederholt, L. López-Hoffman, J.E. Diffendorfer, J.M. Pleasants, K.S. Oberhauser, and O.R. Taylor. 2016. Quasi-extinction risk and population targets for the eastern, migratory population of monarch butterflies (*Danaus plexippus*). Scientific Reports 6: 23625.

Shreeve, T. G. 1992. Adult behaviour. - In: Dennis, R. L. H. (ed), The ecology of butterflies in Britain. Oxford University Press, Oxford, pp. 22-45.

Smith, L.M., and R. Cherry. 2014. Effects of management techniques on grassland butterfly species composition and community structure. The American Midland Naturalist 172: 227-235.

Southwick, E.E. 1983. Nectar biology and nectar feeders of common milkweed, *Asclepias syriaca L.* Bulletin of Torrey Botanical Club 110: 324-334.

Stefanescu C. and A. Traveset. 2009. Factors influencing the degree of generalization in flower use by Mediterranean butterflies. Oikos 118: 1109-1117.

Stout, J.C. and E.J. Tiedeken. 2016. Direct interactions between invasive plants and native pollinators: evidence, impacts and approaches. Functional Ecology 31: 38-46.

Stubbs, C.S., F. Drummond, and H. Ginsberg. 2007. Effects of invasive plant species on pollinator service and reproduction in native plants at Acadia National Park. Technical Report NPS/NER/NRTR—2007/096. National Park Service. Boston, MA.

Thomas, L., S.T. Buckland, E.A. Rexstad, J.L. Laake, S. Strindberg, S.L. Hedley, J.R.B Bishop, T.A. Marques, and K.P. Burnham. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5-14.

USDA. 2019. Butterfly pollination. [Online.] Available at: https://www.fs.fed.us/wildflowers/pollinators/animals/butterflies.shtml. Accessed January 2020.

USFWS. 2019. Monarch butterfly (*Danaus plexippus plexippus*). [Online.] Available at: https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=I0WJ. Accessed January 2020.

Vanbergen, A.J., A. Espíndola, and M.A. Aizen. 2018. Risks to pollinators and pollination from invasive alien species. Nature Ecology & Evolution 2: 16-25.

Waddington, K.D. and B. Heinrich. 1981. Patterns of movement and floral choice by foraging bees. Pages 215-230 *in* A. Kamil and T. Sargent. Foraging Behavior. Garland Press, New York, New York, USA.

Williams, E. 2019. Monarch Butterflies Depend on Us. Presentation at Hart Theatre at Jewish Community Center, Rochester, NY, United States.

Winfree, R., I. Bartomeus, and D.P. Cariveau. 2011. Native pollinators in anthropogenic habitats. Annual Review of Ecology, Evolution, and Systematics 42: 1-22.

Xerces Society. 2013. Establishing pollinator meadows from seed. The Xerces Society for Invertebrate Conservation. [Online.] Available at: https://www.xerces.org/sites/default/files/2018-05/15-020_02_XercesSoc_Establishing-Pollinator-Meadows-from-Seed_web.pdf. Accessed January 2020.

Xerces Society. 2016. To save monarchs, we need more than just milkweed. The Xerces Society for Invertebrate Conservation. [Online.] Available at: https://xerces.org/blog/to-save-monarchs-we-need-more-than-just-milkweed. Accessed January 2020.

Xerces Society. 2018. Monarch butterfly nectar plant lists for conservation plantings. The Xerces Society for Invertebrate Conservation. [Online.] Available at: https://xerces.org/sites/default/files/publications/18-003_02_Monarch-Nectar-Plant-Lists-FS_web%20-%20Jessa%20Kay%20Cruz.pdf. Accessed January 2020.

Xerces Society. 2020. Western monarch population still at critical level. The Xerces Society for Invertebrate Conservation. [Online.] Available at: https://xerces.org/press/western-monarch-butterfly-population-still-at-critical-level. Accessed January 2020.

Yahner, R.H. 2001. Butterfly communities in residential landscapes of central Pennsylvania. Northeastern Naturalist 8: 113-118.

Yamamoto, N., J. Yokoyama, and M. Kawata. 2007. Relative resource abundance explains butterfly biodiversity in island communities. Proceedings of the National Academy of Sciences of the United States of America 104: 10524-10529.

Yeargan, K.V. and C.M. Allard. 2005. Comparison of common milkweed (Asclepiadaceae) as host plants for monarch larvae (Lepidoptera: Nymphalidae). Journal of the Kansas Entomological Society 78: 247-251.

TABLES

Table 1. Common names and binomials for species planted by MNWR at Hidden Marsh in 2017, and their corresponding plant symbols.

Common Name	Binomial	Plant Code
Anise hyssop	*Agastache foeniculum*	AGFO
Red columbine	*Aquilegia canadensis*	AQCA
Butterfly weed	*Asclepias tuberosa*	ASTU
Smooth blue aster	*Symphyotrichum laevis*	SYLA
Blue false indigo	*Baptisia australis*	BAAU
Partridge pea	*Chamaecrista fasciculata*	CHFA
Lanceleaf coreopsis	*Coreopsis lanceolata*	COLA
Purple coneflower	*Echinacea purpurea*	ECPU
Dense blazing star	*Liatris spicata*	LISP
Wild bergamot	*Monarda fistulosa*	MOFI
Tall white beardtongue	*Penstemon digitalis*	PEDI
Slender mountainmint	*Pycnanthemum tenuifolium*	PYTE
Black-eyed Susan	*Rudbeckia hirta*	RUHI
Brown-eyed Susan	*Rudbeckia triloba*	RUTR
Little bluestem	*Schizachyrium scoparium*	SCSC
Early goldenrod	*Solidago juncea*	SOJU
Showy goldenrod	*Solidago speciosa*	SOSP
Ohio spiderwort	*Tradescantia ohiensis*	TROH
Golden alexanders	*Zizia aurea*	ZIAU
New England aster	*Symphyotrichum novae-angliae*	SNAN
Zigzag aster	*Aster prenanthoides*	ASPR
Orange coneflower	*Rudbeckia fulgida*	RUFU
Wild senna	*Senna hebecarpa*	SEHE
Maryland senna	*Senna marilandica*	SEMA
Licorice scented goldenrod	*Solidago odora*	SOOD
Gray goldenrod	*Solidago nemoralis*	SONE
Hairy beardtongue	*Penstemon hirsutus*	PEHI
Yellow false indigo	*Baptisia tinctoria*	BATI
Sideoats grama	*Bouteloua curtipendula*	BOCU
Riverbank wildrye	*Elymus riparius*	ELRI
Marsh dense blazing star	*Liatris spicata*	LISP

Table 2. Nectar sources visited by each butterfly species I observed nectaring at Hidden Marsh, where **X** represents that the nectar source was nectared on by that butterfly species.

	Nectar source						
Butterfly species	brown-eyed Susan	fleabane	New England aster	black-eyed Susan	field hawkweed	Queen Anne's lace	Canada thistle
monarch	**X**	**X**	**X**	**X**	**X**		**X**
red admiral	**X**	**X**				**X**	**X**
yellow sulphur	**X**	**X**		**X**		**X**	
painted lady	**X**			**X**		**X**	
fritillary	**X**	**X**					
cabbage white	**X**						**X**
viceroy						**X**	**X**
eastern tiger swallowtail							**X**
eastern tailed-blue						**X**	
black swallowtail							**X**
white admiral						**X**	

FIGURES

Figure 1. The two drawdown sites: Main Pool (solid-lined circle) and Seneca Flats (dashed-line circle) located on each side of the Wildlife Drive by the MNWR visitor center in Seneca Falls, Wayne County, NY.

Figure 2. The upland field site, Hidden Marsh, located off of Hogback Road in Savannah, Wayne County, NY, where native nectar sources were planted in 2017.

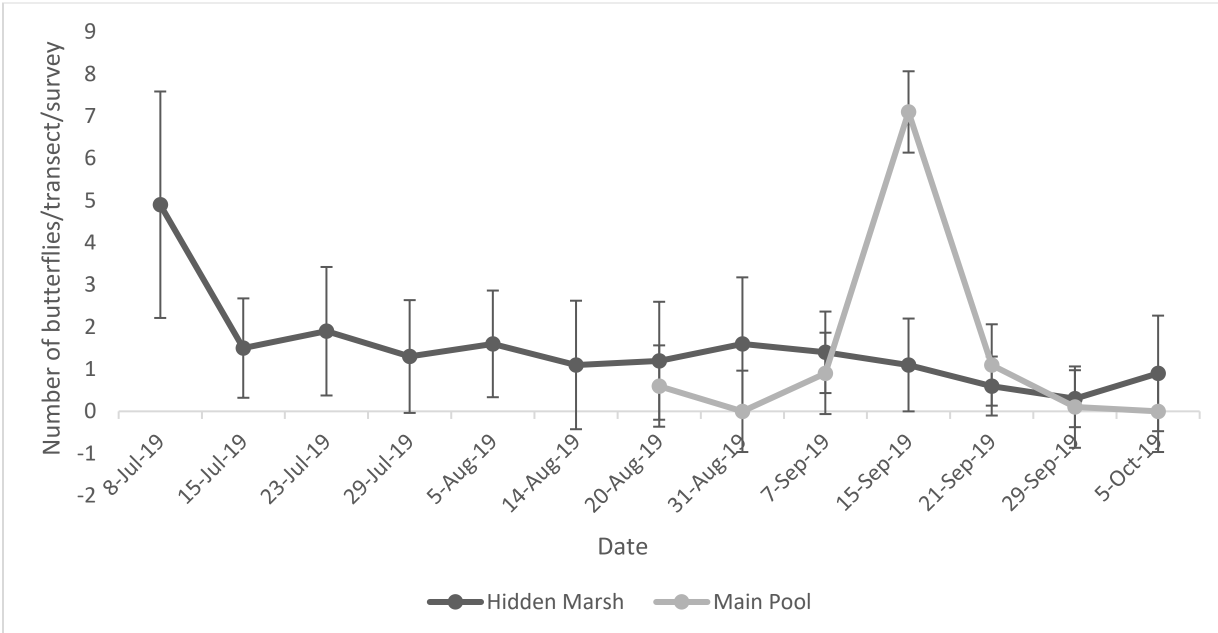

Figure 3. Number of butterflies observed per transect at Hidden Marsh and Main Pool at MNWR over time; error bars are ± 1 SE. Note that the I did not start observations at Main Pool until 20 August 2019.

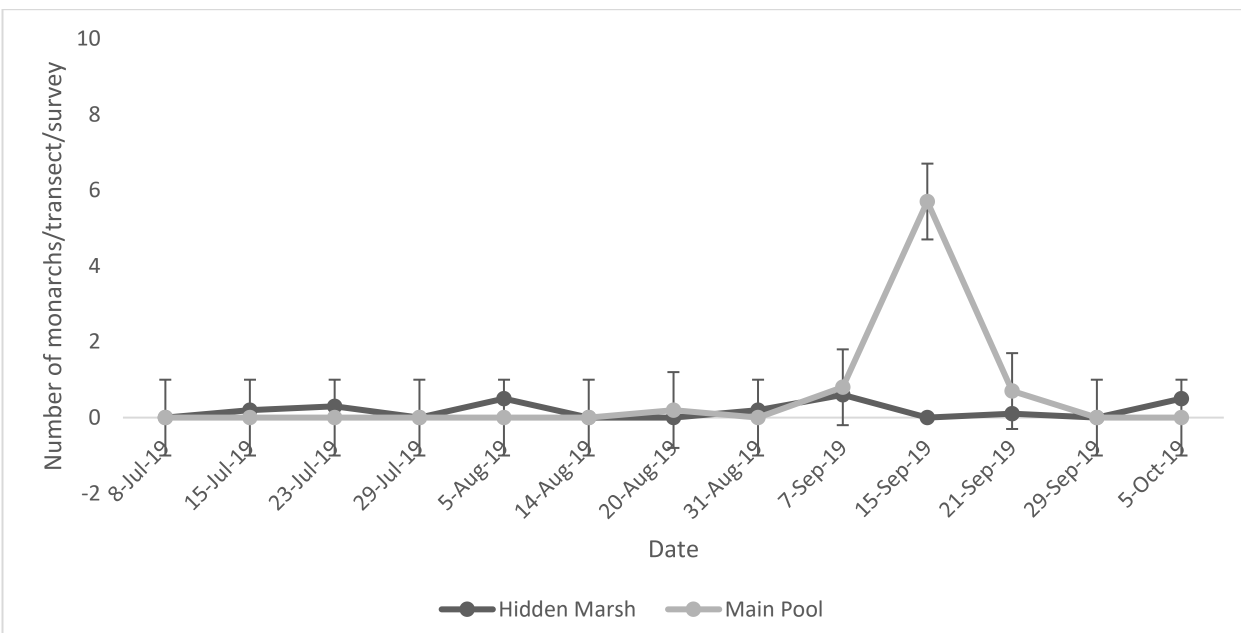

Figure 4. Number of monarchs observed per transect at Hidden Marsh and Main Pool at MNWR over time; error bars are ± 1 SE. Note that the I did not start observations at Main Pool until 20 August 2019.

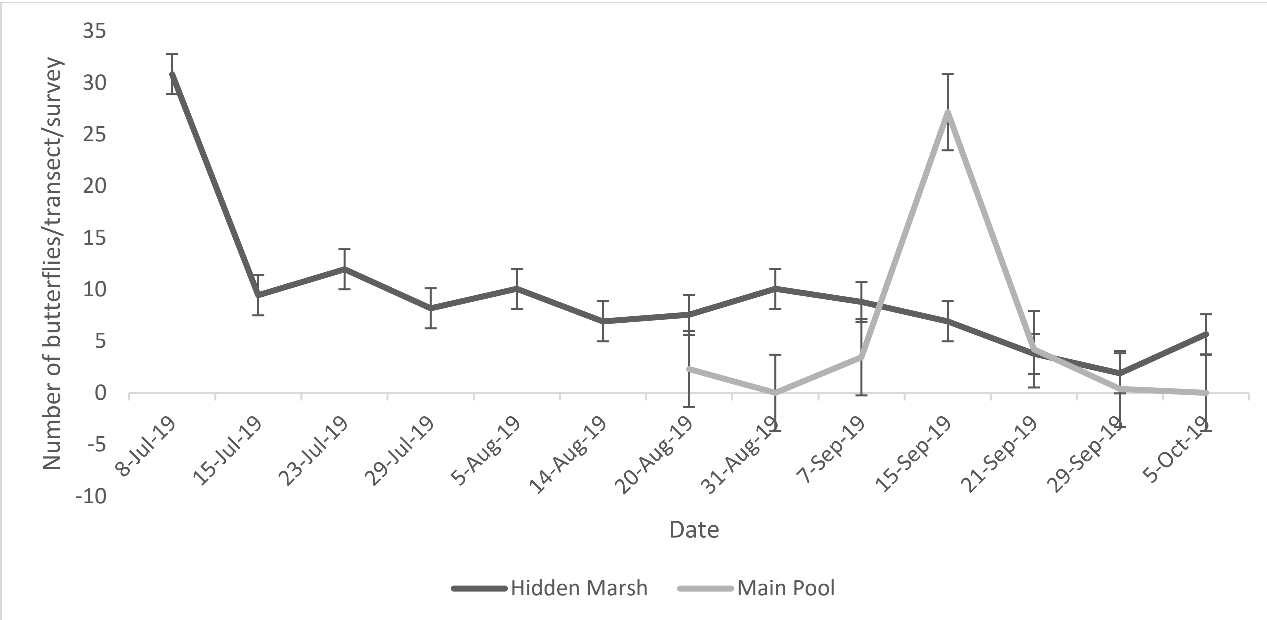

Figure 5. Number of butterflies observed per transect at Hidden Marsh and Main Pool at MNWR over time adjusted for detectability; error bars are ± 1 SE. Note that the I did not start observations at Main Pool until 20 August 2019.

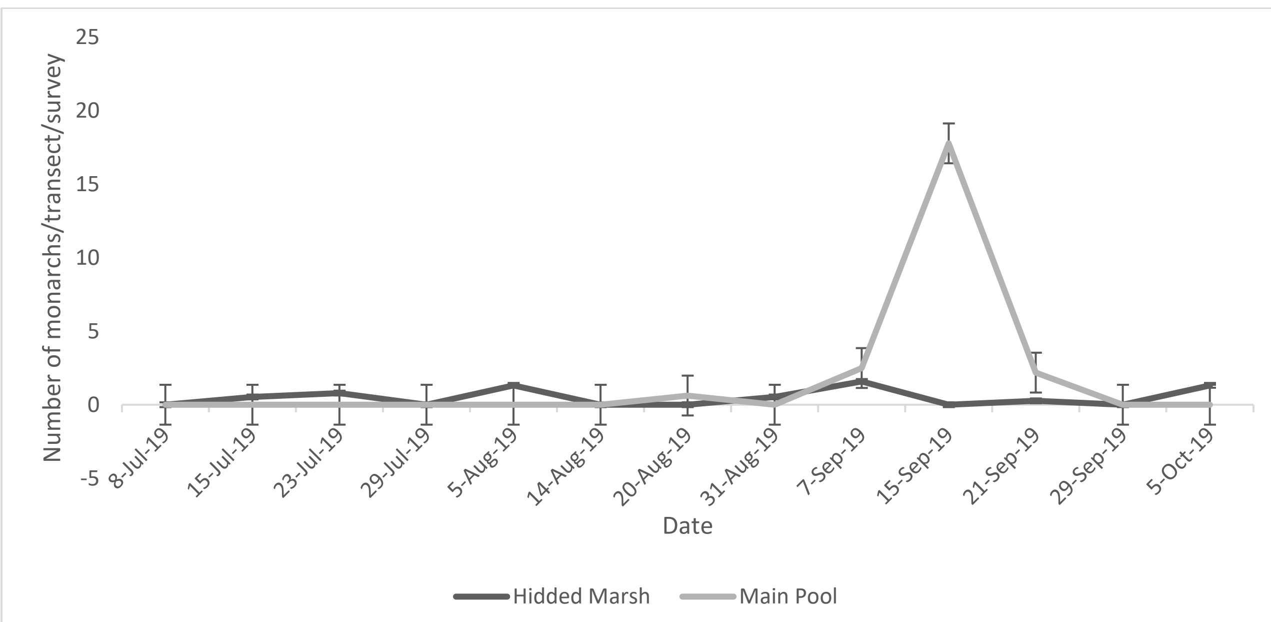

Figure 6. Number of monarchs observed per transect at Hidden Marsh and Main Pool at MNWR over time adjusted for detectability; error bars are ± 1 SE. Note that the I did not start observations at Main Pool until 20 August 2019.

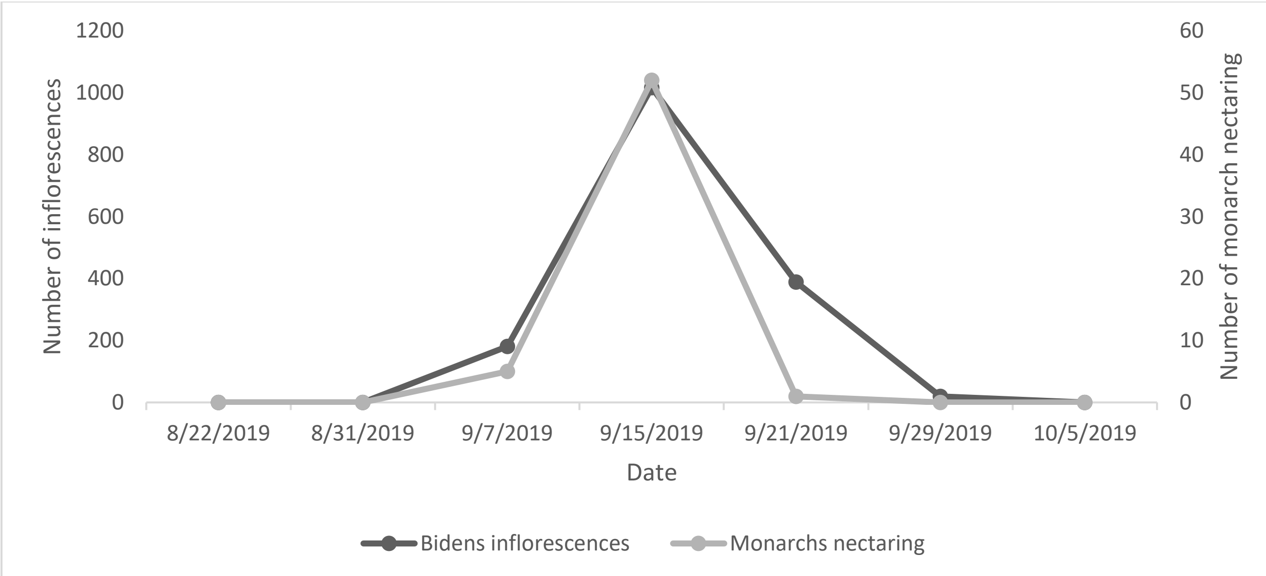

Figure 7. Nectaring monarchs plotted against the number of *Bidens* inflorescences at Main Pool by date.

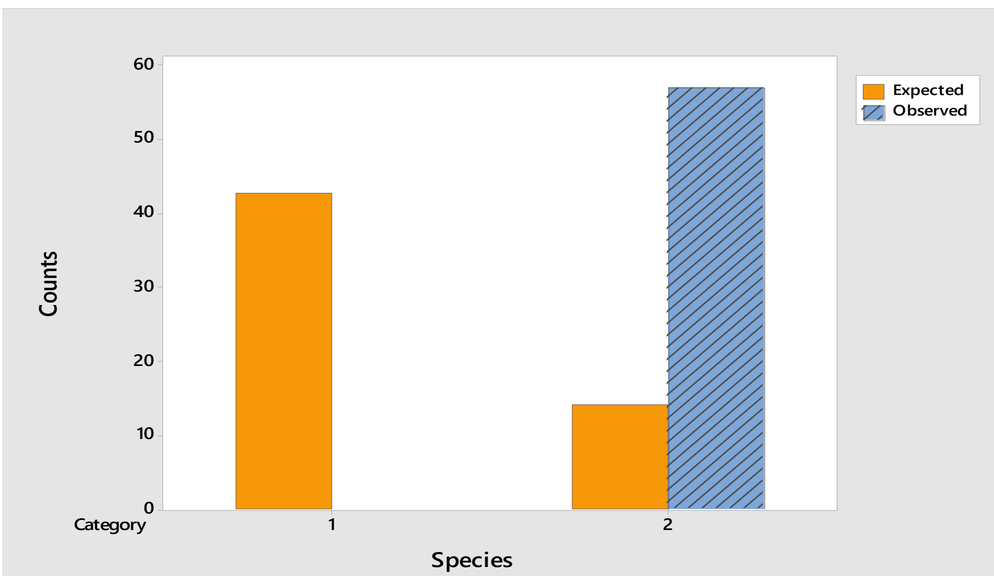

Figure 8. Observed and expected counts for nectaring monarchs at MP on 15 September, where 1 = smartweed and 2 = beggarticks.

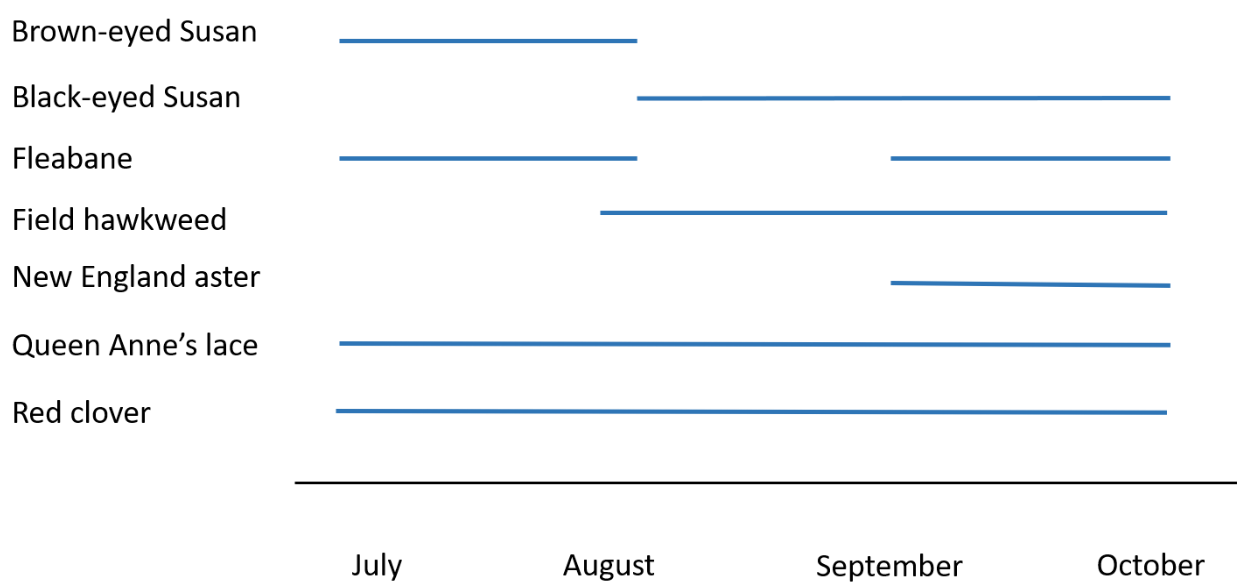

Figure 9. Flowering phenology of commonly used nectar sources at Hidden Marsh, July – October 2019.

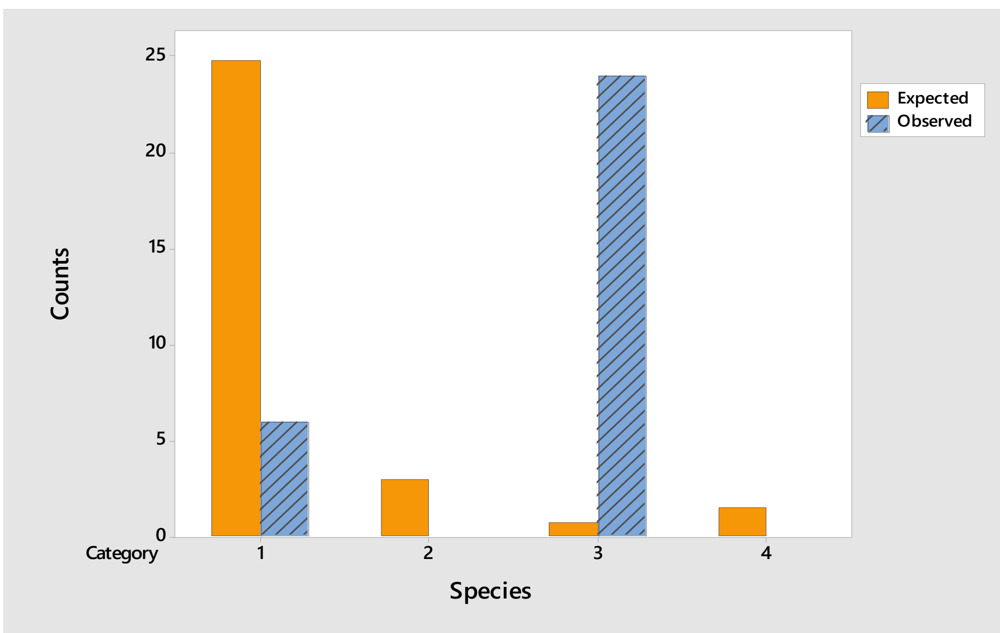

Figure 10. Observed and expected counts for nectaring red admirals at HM on 8 July, where 1 = fleabane, 2 = red clover, 3 = brown-eyed Susan, and 4 = all other species present that were not nectared on and contributed very little to the overall floral distribution.

APPENDICES

Appendix 1. Summary of butterfly species and their nectaring behavior observed at Main Pool.

Binomial	Common Name	Total Number of Observations	Did Species Nectar?	Percent of Nectar Observations
Danaus plexippus	monarch	80	Y	94
Vanessa cardui	painted lady	4	Y	5
Cupido comyntas	eastern-tailed blue	4	N	-
Phoebis sennae	yellow sulphur	2	Y	1
Pieris rapae	cabbage white	1	N	-
Papilio cresphontes	giant swallowtail	1	N	-

Appendix 2. Summary of butterfly species and their nectaring behavior observed at Seneca Flats.

Binomial	Common Name	Total Number of Observations	Did Species Nectar?	Percent of Nectar Observations
Cupido comyntas	eastern-tailed blue	4	N	-
Danaus plexippus	monarch	2	Y	100

Appendix 3. Summary of butterfly species and their nectaring behavior observed at Hidden Marsh.

Binomial	Common Name	Total Number of Observations	Did Species Nectar?	Percent of Nectar Observations
Vanessa atalanta	red admiral	79	Y	58
Phoebis sennae	yellow sulphur	36	Y	4
Danaus plexippus	monarch	24	Y	15
Pieris rapae	cabbage white	15	Y	2
Limenitis archippus	viceroy	12	Y	9
Vanessa cardui	painted lady	9	Y	4
Boloria spp.	fritillary	8	Y	2
Cupido comyntas	eastern-tailed blue	5	Y	2
Papilio glaucus	eastern tiger swallowtail	3	Y	2
Papilio polyxenes	black swallowtail	2	Y	1
Papilio cresphontes	giant swallowtail	1	N	-
Limenitis arthemis	white admiral	1	Y	1