# Larval Host plant Selection and Daily Behavior of Poweshiek Skipperling (*Oarisma poweshiek*) in Michigan

Henry Pointon

Advisors:

David Cuthrell
Lead Zoologist
Michigan Natural Features Inventory
Lansing, MI

Michael Monfils
Avian Ecologist
Michigan Natural Features Inventory
Lansing, MI

Ann M. Fraser
Associate Professor of Biology
Kalamazoo College
Kalamazoo, MI

A paper submitted in partial fulfillment of the requirements for the degree of Bachelor of Arts at Kalamazoo College

Fall 2015

# Acknowledgements

Special thanks to my advisors, Dave Cuthrell and Mike Monfils, for their guidance and assistance throughout the SIP process. Their help was greatly appreciated in all aspects of seeing this project through to the end. The contributions of the research team from MNFI helped make this particular project possible in the middle of a very busy field season. Their assistance helped make this project possible. This thesis would also not have been possible without the peer review group and faculty advisor: Ann Fraser, Shadi Larson, Olivia Nalugya, Charles Edick, and Sarah Woods.

# Table of Contents

**Figures**

Abstract:

Conservation efforts depend greatly on a working knowledge of the species of concern. Little is known about the basic biology of many endangered species regarding their life history information. This is true for the Poweshiek skipperling butterfly (*Oarisma poweshiek*), whose larval host plant is not yet known for Michigan populations. This is concerning as Michigan is where the least is known about the life history of the Poweshiek skipperling and where the greatest number of populations are currently. In this study we investigated the larval host plant by following the butterflies in the field to observe egg laying events. All of the observed events in this study we observed on mat muhley grass (*Muhlenbergia richardsonis*). This critical information will be helpful in the future conservation action taken to save the Poweshiek skipperling from extirpation from Michigan sites.

We also conducted a daily activity budget survey for the Poweshiek skipperling. No individuals were observed before 0923 h and none were seen after 1830 h. The results from these surveys will be used to provide suggested alterations to the current population surveys that the Michigan Natural Features Inventory is conducting. These changes to survey technique could provide more efficient use of time for the surveyors and allow the organization to conduct more in depth surveys and more surveys in each given flight season.

Introduction:

One of the leading causes for the decline of species diversity is the loss of suitable habitat (Swanson 1995). Humans are the most prevalent cause of destruction and modification of habitats that are critical for the survival of many species (Kleijn et al. 2009). This trend has persisted as population continues to grow. Habitat destruction and damage can manifest in several ways including, but not limited to, deforestation, simplification, fragmentation, and altered landscape (Fahrig 2003). Many of these anthropogenic habitat destructions are due to the consistent human development of natural areas and their surroundings into non-natural habitat. Habitat disturbances, such as altered hydrology, can have wide reaching impacts on sensitive habitats such as wetlands (Richter et al. 1996). The most common way conservationists attempt to combat these impacts are to set up protected natural areas for the purpose of preservation. There are several flaws to this method of protection including the previously mentioned fragmentation of habitat. Another unintended effect of protection is adjacent development or ecologically harmful land use practices such as the heavy use of pesticides and herbicides in crop fields that can enter the water of natural systems causing disruption. Some efforts to minimize these effects have been implemented in larger parks with a buffer zone of lesser protection surrounding the park itself (Shafer 1999).

Conservation efforts also rely heavily on an in-depth knowledge of the way that species interact within an ecosystem. These interactions can be the key-deciding factor in the planning of protected areas for species conservation areas. In order to effectively conserve an herbivore it is imperative to conserve the food source of that animal. It is important to fully understand the needs of the species of concern in order to appropriately

set aside a protected area. This critical information about the species that is necessary for effective conservation efforts to be put in place include the life history of the species and any additional important information such as migratory patterns. The basic life history for butterflies is an adult female must mate then find a suitable host plant for their larva to feed on to lay the eggs near or on that plant. The larva hatch and feed on the host plant until they reach the appropriate size then pupate and metamorphose into the adult. Each life event requires specific plants and conditions, without such information conservation efforts would fail. An example of this information assisting in the conservation efforts is the Monarch Butterfly. Many efforts have been implemented in order to facilitate the regrowth of this species. Home gardeners as well as several community projects that focus on the life history of the Monarch, specifically in regards to larval host plant and nectar sources, have greatly improved the species health by facilitating both the growth of the population and providing food sources along migratory paths (Landis 2014). These efforts were successful because they aimed to restore a resource, the milkweed host plant, which is essential for the Monarch to complete its lifecycle. Knowing the entire life history of an organism is imperative as conserving only portions is not enough. Recently another aspect of the Monarch Butterfly's life history has been disturbed; the overwintering site in Mexico has been heavily deforested leaving many butterflies without suitable conditions to survive the winter (Vidal et al. 2014).

Michigan has several butterfly species that are endangered due to habitat loss. One such butterfly is the Karner Blue Butterfly (KBB). KBB habitat consists mainly of dry oak savannas, which, like many similar habitats, have been the target of both human development and deforestation. In recent years Michigan Natural Features Inventory

(MNFI) has conducted surveys to track the population patterns of several listed butterflies in threatened habitats throughout Michigan. Also among these endangered species is the Mitchell's Satyr Butterfly (MS). MS is a prairie fen obligate species that has been experiencing a reduction in population size in recent years (Hyde 2012; Szymanski et al. 2004). Prairie fen habitat is closely associated with several kinds of disturbance and destruction, from complete destruction to altered hydrology, each causing devastating effects on the biota contained within the fragile ecosystem (Spieles et al. 1999). It is likely that the decline in the populations of endangered animal species could be prevented if we had the sufficient information about what they need so that conservation would be more approachable.

Specific information about the basic biology of species is required for successful conservation efforts of butterflies (Schultz et al. 2008). Several skipper species ,of the family Hesperiidae, throughout the globe are at risk and are under investigation as crucial information about their basic life history is unknown (Beyer & Schultz 2010 ; Henry et al. 2013). In the case of the Poweshiek skipperling (*Oarisma poweshiek*), a prairie fen obligate species, there is very little known about the life history (Cuthrell & Slaughter 2012). There has been little recent research investigating the larval host plant of *O. Poweshiek* (Shepherd et al. 2005). Without this crucial information about the reproduction and development of this threatened butterfly conservation efforts are difficult.

The most common host plant citation for *O. poweshiek* is golden-seeded spike-rush (*Eleocharis elliptica*), which is based on a single oviposition event observation and observations of similar-looking eggs on *E. elliptica* (Holzman 1972). Unfortunately this citation is the one still used today for butterfly guidebooks in the Midwest and no further

research was done to attempt to confirm this host plant behavior. MNFI has conducted surveys for *O. poweshiek* in prairie fen habitats that contain *E. elliptica* and have not observed any individuals (Cuthrell & Slaughter 2012). The absence of *O. poweshiek* in sites that contain *E. elliptica* suggests that the citation of *E. elliptica* as a host plant is incorrect.

Borkin (1994) was able to determine prairie dropseed (*Sporobolus heterolepis*) as a larval host plant for *O. poweshiek* populations in Wisconsin by observing oviposition events (Cuthrell & Slaughter 2012 summarizing Borkin (1995)). MNFI has found a connection between *O. poweshiek* occurrence in prairie fen habitats that have *S. heterolepis* and *Muhlenbergia richardsonis* (mat muhly grass) and have hypothesized that these two species are larval host plants for *O. poweshiek* (Cuthrell & Slaughter 2012). Both *S. heterolepis* and *M. richardsonis* are listed at a state level as protected (state special concern and state threatened) (Penskar & Higman 1999). Thomas et al. (2011) found that the abundance, availability, and health of larval host plants of butterflies can contribute to fluctuations in populations up to two orders of magnitude (Thomas et al. 2011). Determining the importance of these two plants in the life history of *O. poweshiek* is crucial for future conservation plans.

*O. poweshiek* is listed as a state threatened and federally endangered species as of October 2014 (Higman 1999, Department of the Interior 2014). It is considered a native species to Michigan's prairie fens (Cuthrell 2012). The Poweshiek skipperling is a small butterfly belonging to the Hesperiidae family of butterflies including the skippers (Department of Natural Resources 2015). The wingspan is roughly 2.6-3.2 cm (0.9-1.25 in) (Cuthrell 2012). The coloration of males is not distinct from that of females with white

scales on the ventral torso and white venation on the ventral side of the forewing. The ventral hindwing and ventral side of the torso are orange. The margins of all wings are white (Fig. 1).

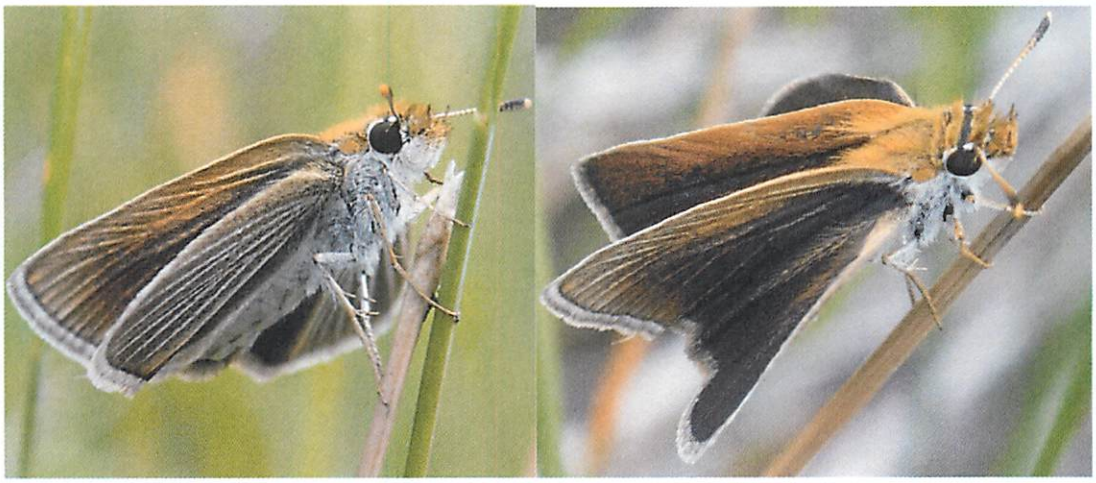

Fig. 1 **Left:** *O. poweshiek* ventral view. **Right:** *O. poweshiek* dorsal view. (Photo credit Rachael Patterson 2015).

The lifecycle of Michigan populations of this butterfly is not fully understood as it appears to differ from other populations in other regions in some key aspects of its life history as they are found in habitat that differs in composition. The eggs are laid on or close to the tip of a leaf on the host plant. Approximately eight days after the egg is laid, the caterpillar emerges from the egg. The caterpillar feeds on the host plant and overwinters as a third instar larva on the host plant itself. In the spring the caterpillar comes out of diapause and continues feeding throughout the summer. After a total of about eight instars the larvae pupate. The flight season varies considerably with the temperature and lasts roughly three weeks. Flights in Michigan typically begin mid June and can go as late as mid July (Cuthrell & Slaughter 2012; U.S. Fish and Wildlife Service. 2014). The range of the Poweshiek skipperling has been greatly reduced in recent

history (Hölzman 1972; Borkin 1994; Shepherd et al. 2005; Cuthrell 2012; Department of Natural Resources 2015).

The future of the species depends greatly on the conservation efforts in the near future. MNFI has been conducting surveys that aim to gather more information on the populations of *O. Poweshiek* in Michigan. These surveys are limited in the information that they are able to gather due to a limited staff size and time constraints. More information is needed in order to determine the efficacy of the surveys.


Fig.2 *O. poweshiek* larva with US Penny for scale. (Photo credit Minnesota Zoo).

*M. richardsonis* is a thin grass that is found in several counties in Michigan, typically growing in small groups or tufts with varying density (Fig. 3). The stems range in height from 20-60 cm and have a diameter of 1-2 mm. The state threatened listing is a result of the discovery of the association of the Huron River leafhopper (a state threatened

and critically imperiled species) as it only feeds on *M. richardsonis* in prairie fen habitat (Michigan Natural Features Inventory 2007). *M. richardsonis* has also been found to have an association with the occurrence of *O. poweshiek* in prairie fen habitat (Cuthrell 2012). This association suggests that *M. richardsonis* is important to the lifecycle of *O. poweshiek.*

Fig. 3 *M. richardsonis.* (Photo credit California.net).

The Department of Natural Resources (DNR) states "Michigan is the stronghold for Poweshiek and found only in high-quality prairie fens (Department of Natural

Resources 2015)." Prairie fen habitat is characterized by the biota found within them, their substrate composition, and the location (Kost et al. 2007). These species include a mixture of prairie plants and wetland plants that can survive in neutral to slightly alkaline soils. Prairie fens develop in recently glaciated areas and are often associated with other wetland types and small lakes (Spieles et al. 1999). Prairie fens are home to many listed species of plants and animals as they are unique habitat (Landis et al. 2012). Prairie fen habitat is delicate and threatened by many human-caused shifts in regimes and disturbances (Landis et al. summarizing van Diggelen et al. 2006; Amon et al. 2002; Middleton et al. 2006; Bowles and Jones 2006; and Panno et al. 1999). These changes and disturbances threaten many species that rely on the historic tendencies and the environment of prairie fen and the specific composition of the biota and environmental factors.

MNFI has been conducting population studies for *O. poweshiek* to monitor populations in Michigan. These studies are being conducted in hopes to better understand the activity and population trends of the species. Efforts for reintroduction have not been possible as there have not been successful attempts at captive breeding nor is there enough information about its larval host plant to determine suitable reintroduction sites. Two field technicians usually conduct these surveys. The technicians must determine whether the conditions are suitable for surveying on any given day. The climactic constraints on the study are aimed to get the most consistent data across years. Surveys must take place between 10:00 and 18:00 Eastern daylight time. The temperature must be at or above 15° C, If the air temperature is between 15° C - 12° C then the sky must be at

least 50% clear. Surveys must be conducted without interruption of precipitation of any kind and wind speeds cannot exceed 25 km/h.

These surveys gather information such as population growth, population concentration and density, and environmental health. The presence and relative abundance of native versus invasive plants and the extent of human impact on the sites that *O. poweshiek* and associated species are found. Assessing the health of the populations and the systems they are in are the main goals of the studies that are being conducted which help gain crucial information about maintaining current populations. The critical information that is missing from these studies includes life history events that are necessary for the growth of conservation efforts of rearing and reintroducing species. Studying the population laid the groundwork for the study of larval host plant in that populations are now known to be breeding without previously determined host plants.

With only five sites remaining in what is considered the stronghold for the species, there is a pressing need for data on the life history of *O. poweshiek*.. It is important to understand the role that the butterflies have in interacting with their habitat (Henry 2013). In the same report the DNR also suggests that the protection status of *O. poweshiek* be changed from state threatened to state endangered (Department of Natural Resources 2015). With such a lack in information of the host plant in Michigan it is crucial to gain a deeper understanding of the importance of both *S. heterolepis* and *M. richardsonis*. This paper aims to determine the importance of *M. richardsonis* as a larval host plant for *O. poweshiek*.

Materials and Methods:

**Study habitat:**

The site selected for this study was a prairie fen located in Oakland County, Michigan (Fig. 4). This site was chosen for the anticipated ease of the host plant determination study and activity budget study. Since *O. poweshiek* is found only in high quality prairie fen habitat in Michigan (Department of Natural Resources 2015). The site selected is considered to be a relatively healthy prairie fen and had a long-standing, steady population of *O. poweshiek*. The specific portion of this fen was chosen due to the high observed population density of *O. poweshiek* as determined by the ongoing population studies by MNFI.

Fig. 4 Photo of the prairie fen this study was conducted in.

**Host Plant Selection Survey:**

All surveys were conducted starting June second and ending June 9 between 0900 h and 1900 h. Due to the high demands of other studies only a single researcher was able to conduct this study. The researcher entered the area of the fen with the highest relative density of *O. poweshiek* individuals based on previous population surveys conducted by MNFI (Fig. 5). Proceeding through the survey area the researcher visually scanned vegetation for butterflies. Once one was found it was identified to species (sex determination is only possible with a microscope). Only *O. poweshiek* individuals were followed. The researcher followed the individual and maintained visual contact and keeping enough distance as to not disturb the butterfly. Once an individual was lost the researcher proceeded to scan the survey area for another individual in the same way as before. Once an oviposition event was observed the researcher placed a pin flag and tied colored tape at the base of the plant. A GPS point was taken using a Samsung Galaxy Tab 4 7.0" (Wi-Fi) using the Backcountry Navigator application. Notes on behavior were recorded in a field notebook after the oviposition event. Due to both material and time constraints of the study, it was not possible to gather accurate climactic information during this study. The researcher then attempted to follow the same individual. At the end of the recording day the researcher returned to the oviposition site, the plant was identified to the species level and the egg was found. Unfortunately the resolution of the photographs that were taken of the eggs is too low to see clearly. Plant specimens were left in the field as to provide the maximum amount of host plant for the larva to eat. The eggs of this species are protected so they were also left in the field.

Fig. 5 A satellite image of the prairie fen (outlined in blue) this study was conducted in. Individuals found in the 2015 field season are in purple; the circled area is the area that the study was conducted in.

**Activity budget survey:**

In tandem with the host plant selection survey a daily activity budget survey was also conducted to determine what the butterflies spent their day doing as well as what times they are active. These studies were conducted throughout the oviposition surveys. This study fit in very well with the host plant determination survey as the butterflies had to be followed for several days in order to gather enough information to propose a new host plant. For this portion of the survey a voice recorder was used to gather information on the activity of the butterflies. The audio files transcribed after the flight season of the butterflies had ended. This was done to maximize the amount of time spent in the field gathering data as well as increasing the efficiency of the note taking process in the field. The activities recorded include nectaring, flying, perching, and chasing. Nectaring is characterized by landing on the top of a flower near where the nectar source is and

inserting the proboscis into the flower. Flying is when the butterfly was actually in flight. Perching, like nectaring, is when the butterfly is stationary on a plant but is not feeding on nectar. Chasing is when two or more individuals are in flight and are following the flight path of the other individual(s).

Days were split up into three observation periods morning, afternoon, and evening each lasting for three hours. Morning started at 0900 h and lasted until 1159 h, afternoon starts at 1200 h and lasts until 1459 h, evening started at 1500 h and ends once the last individual found before 1759 h was lost. Each individual was put into these three categories based on the time period within which it was first observed. The researcher also gathered the time span of oviposition but this was not included in the activity budget data as it was insignificant as each event lasted for less than one second. These data were compared against each other as proportions to total time observed per individual. These proportions were then averaged over the five full days of observation (5 full morning observation periods, 5 full afternoon observation periods, and 5 full evening observation periods). The evening interval was the longest interval as individuals were followed until lost which was after the scheduled end of the observation period.

Results:

On each of the observation days *O. poweshiek* individuals were observed. In total seventy-three individuals were observed and six oviposition events observed. In all cases *O. poweshiek* females oviposited a single egg on *M. richardsonis* in the middle of the leaf near the middle of the plant. Each event occurred between the times of 1100 and 1600 h. The eggs were pale green and no larger than 1mm in size. The oviposition sites were spread throughout the survey site indicating no clustering behavior. Each event was preceded by an erratic flight in a meandering path. The butterfly landed each time and started flying immediately after laying the egg. Each event occurred in less than a second. Each oviposition event was immediately followed by a few seconds of flight followed by perching behavior, between two and five meters away from the oviposition site.

Two weeks after the oviposition surveys were complete the researcher returned to the site and spent two full days searching for the larva. No eggs were found on the plants that were tagged, indicating that they had hatched. Herbivory damage was clearly visible indicating that the larva had been feeding on the plants. No herbivory was visible on adjacent plants that consisted mainly of rushes and sedges indicating that the larvae were feeding on the *M. richardsonis* exclusively.

Each of the observation periods for the activity budget *O. poweshiek* individuals were observed flying, nectaring, perching, and chasing. In the morning, individuals were observed in the following proportions; nectar: 0.574, fly: 0.019, perch: 0.404, and chase: 0.003. In the afternoon individuals were observed in the following proportions nectar: 0.961, fly: 0.011, perch: 0.028, and chase: 0.002. In the evening individuals were observed in the following proportions nectar: 0.800, fly: 0.005, perch: 0.194, and chase:

0.001. No individuals were observed before 0923 h and activity was mostly done by 1830 h (Fig. 6).

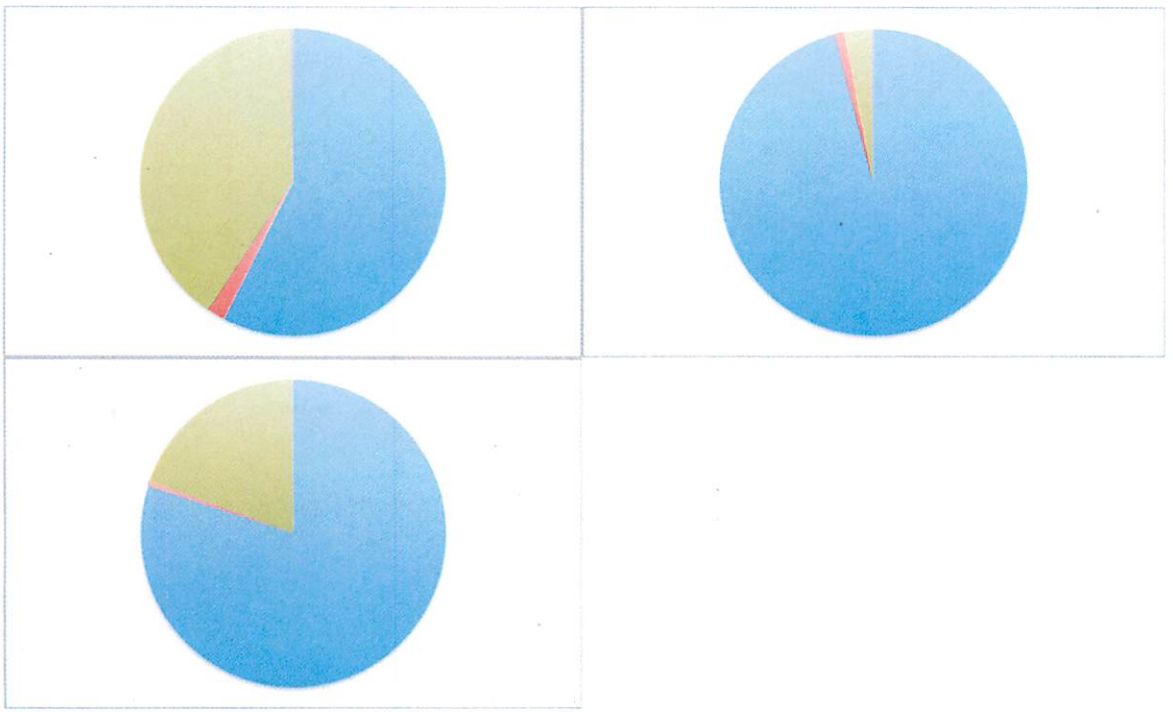

Fig. 6 **Top Left:** Morning proportions: nectar (blue): 0.574, fly(red): 0.019, perch(green): 0.404, and chase(purple): 0.003. **Top Right:** Afternoon proportions: nectar: 0.961, fly: 0.011, perch: 0.028, and chase: 0.002. **Bottom Left:** Evening proportions: nectar: 0.800, fly: 0.005, perch: 0.194, and chase: 0.001.

Discussion:

These are the first observations of oviposition on *M. richardsonis* by an *O. poweshiek* individual that have been reported from any field location. The implications that this has for the future conservation efforts of *O. poweshiek* can provide more guided protection and management. Now that more is known about the larval host plant future conservation plans of Michigan populations can include more on the preservation of high quality fens in which *O. poweshiek* are typically found (Department of Natural Resources 2015). Establishing a healthy community of host plants is the first step of a reintroduction process (Schultz et al. 2008).

Studies have been done investigating the reintroduction of butterflies in historical habitat where problems of habitat disturbance by humans has occured (Chan & Packer 2006; Dunwiddie & Bakker 2011; Schultz et al. 2011). Conservation efforts look into restoring habitat to historical, healthy conditions in order to provide the species of concern the best possible environment to reestablish a viable population (Schultz et al. 2008). With this new critical information about the life history concerning the *O. poweshiek* conservation efforts can now focus on reestablishing and improving the health of existing populations.

This study could have been improved with more researchers, equipment, and more time. More researchers would allow for more observations, which could provide for more data to eliminate sources of error in the data. More researchers would also be able to follow more individuals, which could result in more observed oviposition events. More equipment could have provided site specific data such as temperature and wind speed which likely effects the activity of the butterflies. The time constraints of the field season

did not allow for the researchers to take the time to survey for the entire flight season of the butterfly. More observation of the larva might have been possible with more time devoted to this project which would have given definitive that the oviposition selection plant is a viable host plant for *O. poweshiek.*

The daily time budget surveys were done to investigate the validity of the current population surveys conducted by MNFI. The data indicates that the survey periods should be effective but could be expanded to start at 0930 and end at 1830 h. This edit of the survey period would allow for more effective surveys and more data to be gathered about the populations. In the future climate data mixed with a daily activity budget could help improve survey techniques even further by adjusting the survey times to include the times that the butterflies are actually active.

This study provides some of the critical data for the future conservation efforts of *O. poweshiek.* There is still more research that needs to be done in regards to successful captive breeding programs. Some have been conducted but with very limited results (U.S. Fish and Wildlife Service. 2014). This study could provide more insight as to successful captive breeding programs in the future. This study also can help future researchers with reintroduction possibilities and protection management plans now that more is known about the basic life history of the species.

Literature cited

Amon JP, Thompson CA, Carpenter QJ, Miner J 2002. Temperate zone fens of the glaciated Midwestern USA. Wetlands 22:301–317.

Beyer, L. J., & Schultz, C. B. 2010. Oviposition selection by a rare grass skipper Polites mardon in montane habitats: Advancing ecological understanding to develop conservation strategies. *Biological conservation*,*143*(4), 862-872.

Borkin, S. S. 1994. Ecological studies of the Powesheik Skipper (Oarisma poweshiek) in Wisconsin." *Bureau of Endangered Resources, Wisconsin Department of Natural Resources. Madion, Wisconsin.*

Chan, P. K., & Packer, L. 2006. Assessment of potential Karner Blue butterfly (Lycaeides melissa samuelis)(family: Lycanidae) reintroduction sites in Ontario, Canada. *Restoration Ecology*, *14*(4), 645-652.

Cuthrell, D.L. and B.S. Slaughter. 2012. Special animal abstract for Oarisma poweshiek (Poweshiek skipperling). Michigan Natural Features Inventory, Lansing, MI. 4 pp.

Department of the Interior. 2014. Federal Register, Endangered and Threatened Wildlife and Plants; Threatened Species Status for Dakota Skipper and Endangered Species Status for Poweshiek Skipperling. 79 FR 63671 (24 October 2014), pp. 63671 -63748.

Department of Natural Resources (DNR) 2015. Michigan's Wildlife Action Plan-DRAFT. Fen

Dunwiddie, P. W., & Bakker, J. D. 2011. The future of restoration and management of prairie-oak ecosystems in the Pacific Northwest. *Northwest Science*, *85*(2), 83-92.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, 487-515.

Godwin KS, Shallenberger JP, Leopold DJ, Bedford BL 2002. Linking landscape properties to local hydrogeologic gradients and plant species occurrence in minerotrophic fens of New York State, USA: a hydrogeologic setting (HGS) framework. Wet-lands 22:722–737.

Henry, Erica H., and Cheryl B. Schultz. 2013. A first step towards successful conservation: understanding local oviposition site selection of an imperiled butterfly, mardon skipper. *Journal of insect conservation* 17.1 183-194.

Higman, P.J. and M.R. Penskar. 1999. Special plant abstract for Sporobolus heterolepis (prairie dropseed). Michigan Natural Features Inventory, Lansing, MI. 2 pp.

Holzman, R.W. 1972. Eastern range extension for *Oarisma powesheik* Parker (Lepidoptera: Hesperiidae). Great Lakes Entom. 5(4): 111-14.

Hyde, D. 2012. Update of Lee, Y. 2000. Special animal abstract for Mitchell's satyr butterfly (Neonympha mitchellii mitchellii). Michigan Natural Features Inventory, Lansing, MI. 7 pp

Kost, M.A., D.A. Albert, J.G. Cohen, B.S. Slaughter, R.K. Schillo, C.R. Weber, and K.A. Chapman. 2007. Natural Communities of Michigan: Classification and Description. Michigan Natural Features Inventory, Report No. 2007-21, Lansing, MI.

Kleijn, D., Kohler, F., Báldi, A., Batáry, P., Concepción, E. D., Clough, Y., Diaz,M.& Verhulst, J. 2009. On the relationship between farmland biodiversity and land-use intensity in Europe. *Proceedings of the Royal Society of London B: Biological Sciences*, *276*(1658), 903-909.

Landis, D. A., A. K. Fiedler, C. A. Hamm, D. L. Cuthrell, E. H. Schools, D. R. Pearsall, M. E. Herbert, and P. J. Doran. 2012. Insect conservation in Michigan prairie fen: addressing the challenge of global change. *Journal of Insect Conservation* 16, no. 1: 131-142.

Landis, T. D. (2014). Monarch waystations. *Native Plants Journal (University of Wisconsin Press)*, *15*(1).

Michigan Natural Features Inventory. 2007. Rare Species Explorer (Web Application). Available online at http://mnfi.anr.msu.edu/explorer [Accessed Sep 12, 2015]

Penskar, M.R. and P.J. Higman. 1999. Special plant abstract for Muhlenbergia richardsonis (mat muhly). Michigan Natural Features Inventory, Lansing, MI. 2 pp.

Richter, B. D., Baumgartner, J. V., Powell, J., & Braun, D. P. 1996. A method for assessing hydrologic alteration within ecosystems. *Conservation biology*, 1163-1174.

Schultz, C. B., Russell, C., & Wynn, L. 2008. Restoration, reintroduction, and captive propagation for at-risk butterflies: a review of British and American conservation efforts. *Israel Journal of Ecology & Evolution*, *54*(1), 41-61.

Schultz, C. B., Henry, E., Carleton, A., Hicks, T., Thomas, R., Potter, A., ... & Reader, B. 2011. Conservation of prairie-oak butterflies in Oregon, Washington, and British Columbia. *Northwest Science*, *85*(2), 361-388.

Shafer, C. L. 1999. US national park buffer zones: historical, scientific, social, and legal aspects. *Environmental Management*, *23*(1), 49-73.

Shepherd, M. D., D. M. Vaughan, and S. H. Black. 2005. Red list of pollinator insects of North America. *CD-ROM Version* ).

Spieles, J.B., P.J. Comer, D.A. Albert, and M.A. Kost. 1999. Natural community abstract for prairie fen. Michigan Natural Features Inventory, Lansing, MI. 4 pp.

Swanson, T. M. 1995. Why does biodiversity decline? The analysis of forces for global change. *The economics and ecology of biodiversity decline: The Forces driving global change. Cambridge.*

Szymanski, J., Shuey, J. A., & Oberhauser, K. 2004. Population structure of the endangered Mitchell's Satyr, Neonympha mitchellii mitchellii (French): implications for conservation. *The American midland naturalist*, *152*(2), 304-322.

Thomas, J. A., D. J. Simcox, and T. Hovestadt. 2011. Evidence based conservation of butterflies. *Journal of Insect Conservation* 15.1-2 :241-258.

U.S. Fish and Wildlife Service. 2014. Endangered and Threatened Wildlife and Plants; Threatened Species Status for Dakota Skipper and Endangered Species Status for Poweshiek Skipperling. https://www.federalregister.gov/articles/2014/10/24/2014-25190/endangered-and-threatened-wildlife-and-plants-threatened-species-status-for-dakota-skipper-and#h-27

U.S. Fish and Wildlife Service. 2015. Poweshiek Skipperling fact sheet. Midwest region. http://www.fws.gov/midwest/endangered/insects/posk/PoweshiekSkipperlingFactSheet.html

van Diggelen R, Middleton B, Bakker J, Grootjans A, Wassen M.2006. Fens and floodplains of the temperate zone: present status, threats, conservation and restoration. Appl Veg Sci 9:157–162.

Vidal, O., López-García, J., & Rendón-Salinas, E. 2014. Trends in Deforestation and Forest Degradation after a Decade of Monitoring in the Monarch Butterfly Biosphere Reserve in Mexico. *Conservation Biology*, *28*(1), 177-186.

Wilcox DA, Shedlock RJ, Hendrickson WH. 1986. Hydrology, Water Chemistry and Ecological Relations in the Raised Mound of Cowles Bog. J Ecol 74:1103–1117.