

**Mitchell's Satyr Butterfly**  
*(Neonympha mitchellii mitchellii)*

**5-Year Review:**  
**Summary and Evaluation**  
**January 13, 2021**



*Photo courtesy of Doug Landis; Michigan State University*

**U.S. Fish and Wildlife Service, Great Lakes Region**  
**Michigan Field Office**  
**East Lansing, Michigan**

# 5-YEAR REVIEW

**Species reviewed:** Mitchell’s satyr butterfly (*Neonympha mitchellii mitchellii*)

## TABLE OF CONTENTS

<b>GENERAL INFORMATION .....</b>	<b>3</b>
Reviewers.....	3
Methodology used to complete the review .....	3
Background .....	4
<b>REVIEW ANALYSIS.....</b>	<b>4</b>
Application of the 1996 Distinct Population Segment (DPS) policy .....	4
Recovery Criteria .....	5
Updated Information and Current Species Status .....	12
Synthesis .....	24
<b>RESULTS .....</b>	<b>26</b>
Recommended Classification.....	26
New Recovery Priority Number .....	26
Listing and Reclassification Priority Number.....	26
<b>RECOMMENDATIONS FOR FUTURE ACTIONS.....</b>	<b>26</b>
<b>REFERENCES.....</b>	<b>27</b>

## TABLE OF FIGURES

Figure 1. The current county distribution of Mitchell's satyr in Michigan, Indiana, Virginia, Alabama, and Mississippi. The hatched symbol indicates counties recently extirpated (since 2014) in Michigan .....	13
--	----

## 5-YEAR REVIEW

### Mitchell's satyr butterfly (*Neonympha mitchellii mitchellii*)

#### GENERAL INFORMATION

##### Reviewers

**Lead Regional Office:** Region 3, Laura Ragan (612) 713-5157

**Lead Field Office:** Michigan Field Office, Kaitlyn Kelly and Carrie Tansy (517) 351-2555

**Cooperating Field Offices:** Alabama Field Office, Bill Pearson; Indiana Field Office, Lori Pruitt; Mississippi Field Office, Paul Hartfield; Virginia Field Office, Amarilys Irizarry

**Cooperating Regional Offices:** Region 4; Region 5

##### Methodology used to complete the review

In accordance with section 4(c)(2) of the Endangered Species Act of 1973, as amended (Act), the purpose of a status review is to assess each threatened species or endangered species to determine whether its status has changed and if it should be classified differently or removed from the Lists of Threatened and Endangered Wildlife and Plants. The U.S. Fish and Wildlife Service (Service) evaluated the biology and status of the Mitchell's satyr butterfly to inform this status review.

The Michigan Field Office (MIFO), in coordination with Midwest Regional Office Ecological Services staff, conducted this status review. Data for this current review were solicited from interested parties through a Federal Register notice announcing the review on August 31, 2020. We also contacted the Mitchell's Satyr Butterfly Recovery Working Group (MSBWG), including the Indiana Department of Natural Resources, Kalamazoo Nature Center, Michigan Department of Natural Resources, Michigan Natural Features Inventory, Mississippi State University, The Nature Conservancy, Toledo Zoo, and the Virginia Department of Conservation and Recreation Natural Heritage Program to request any data or information we should consider in our review.

Information contained herein is derived from published reports in peer-reviewed literature, gray literature (e.g., various state reports, Federal grant reports, theses and dissertations), data received from various federal and state personnel through personal communication involving electronic mail and letters, and notes from annual Mitchell's satyr recovery working group meetings. Additionally, we conducted a literature search and a review of

information in our files. We examined whether new information was available and whether that new information would alter or affect analyses and conclusions made in the previous status review. The MIFO did not carry out a formal peer review for this review because much of the information we relied upon is derived from peer reviewed literature and reports. All literature and documents for this review are on file at the MIFO.

The information below summarizes substantive new information since our previous 5-year review in 2014.

## **Background**

### **FR Notice citation announcing the species is under active review**

[85 FR 53842, Endangered and Threatened Wildlife and Plants; Initiation of 5-Year Status Reviews of 14 Listed Animal and Plant Species, August 31, 2020](#)

### **Listing History**

Emergency Listing: [June 25, 1991 \(56 FR 28825\)](#). Listed as Endangered under an emergency rule.

Final Listing: [May 20, 1992 \(57 FR 21564\)](#). Endangered, Final Rule. Critical habitat not prudent.

### **Associated rulemakings and conservation plans:**

[Mitchell's Satyr Programmatic Safe Harbor Agreement](#) 2016 (Draft 81 FR 33543)

[Habitat Conservation Plan for Mitchell's Satyr and Poweshiek Skipperling Butterflies; Categorical exclusion for Indiana and Michigan habitat restoration and management activities, Notice of Availability](#) (83 FR 45136)

### **Review History:**

A [previous 5-year review](#) was completed on August 28, 2014 (74 FR 11600)

**Species' Recovery Priority Number at start of 5-year review: 3**

**Recovery Plan:** [Mitchell's Satyr Butterfly Recovery Plan, April 1998](#) (61 FR 13513)

## **REVIEW ANALYSIS**

### **Application of the 1996 Distinct Population Segment (DPS) policy**

**Is the species under a review a vertebrate?**

No. The species is an invertebrate; therefore, the DPS policy is not applicable to this listing.

**Recovery Criteria**

**Does the species have a final, approved recovery plan containing objective, measurable criteria?**

Yes.

**Adequacy of recovery criteria**

**Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?**

No. The Recovery Plan has not been updated since 1998.

**Are all the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?**

All 5 listing factors were considered in the recovery criteria. However, new information (e.g., genetics, *Wolbachia*) has become available since the Recovery Plan was written.

**List the recovery criteria as they appear in the recovery plan and discuss how each criterion has or has not been met, citing information.**

The Mitchell's Satyr Butterfly (*Neonympha mitchellii mitchellii*) Recovery Plan was approved in 1998. As addressed in the previous 5-year review for Mitchell's satyr (in 2014), the recovery criteria do not reflect the most up-to-date information as populations in Alabama, Mississippi, and Virginia were discovered after completion of the Recovery Plan. The current status of the species is described below. For additional discussion on the recovery criteria, refer to the previous 5-year review.

**Recovery Actions since the last status review**

Great Lakes Recovery Initiative

The Great Lakes Restoration Initiative (GLRI) was launched in 2010 to accelerate efforts to protect and restore the largest system of fresh surface water in the world — to provide

additional resources to make progress toward the most critical long-term goals for this important ecosystem. One of GLRI's five focus areas is for federal agencies and their partners working together to maintain, restore, and enhance the habitats of native fish and wildlife species. GLRI has worked to protect and restore several federally listed species within the Great Lakes Basin, including the Mitchell's satyr. Since 2010 GLRI has provided approximately \$1.9 million to support habitat restoration, land acquisition, monitoring, research, and captive rearing efforts for Mitchell's satyr. Most of these funds have been spent in the past five years (i.e., 2015-2020, the time covered by this five-year review), with just over \$1 million spent on Mitchell's satyr recovery efforts during this time period.

#### Other Investments in Mitchell's satyr

In addition to the GLRI, other Federal, State, non-governmental, and private funding sources have significantly contributed to preventing the extinction and recovery efforts for the Mitchell's satyr. Other funding sources have included the Endangered Species Recovery Land Acquisition grants, the Service's Partners for Fish and Wildlife Program, State Wildlife Action Grants, land trusts, zoos, conservation organizations, and private donors. This support has allowed for habitat restoration, land acquisition, and captive rearing. Since 2010, this investment has been at least \$1.7 million (in addition to GLRI funding).

#### Safe Harbor Agreement

In 2016, the Service developed a Safe Harbor Agreement (SHA) for non-Federal landowners in Michigan and Indiana willing to voluntarily participate in conservation activities that benefit and advance the recovery of Mitchell's satyr (81 FR 33543). The purpose of the agreement is to reintroduce butterflies to historic sites and/or to suitable fens that occur within its historic range. It also provides assurance to adjacent, non-participating landowners if satyrs disperse onto their property (Recovery Plan Recovery Action 3.7, Promote protection of occurrences on privately owned land). Under the SHA, The Nature Conservancy (TNC), in partnership with the Toledo Zoo, started the reintroduction of Mitchell's satyr onto one of its properties in Noble County, Indiana in 2016.

#### Habitat Conservation Plan and Habitat Management Plans

In 2016, Michigan Natural Features Inventory, in collaboration with the MSBWG, completed management plans for six Mitchell's satyr sites within Berrien, Branch, Cass, Jackson, and Van Buren counties, Michigan. In addition, they developed plans for one planned introduction site within Noble County, Indiana, and two potential introduction sites within Kalamazoo and Washtenaw counties, Michigan (Hyde 2017).

The Michigan Department of Natural Resources (DNR) and Indiana Department of Natural Resources developed a Habitat Conservation Plan (HCP; Recovery Plan Recovery Action

3.7, Promote protection of occurrences on privately owned land) for Mitchell's satyr butterfly and Poweshiek skipperling (*Oarisma poweshiek*) (83 FR 45136) in 2018 to apply for an Incidental Take Permit with the Service under Section 10(a)(1)(B) of the Endangered Species Act of 1973, as amended. The Michigan DNR and Indiana DNR Incidental Take Permits were issued and signed in November 2020. The goals of the HCP are to (1) maintain and expand current populations through management, restoration, and protection of suitable habitat while minimizing take and (2) restore unoccupied habitat for reintroduction to increase the number of extant populations of Mitchell's satyr butterfly. All 192 acres in Michigan and 5 acres in Indiana of known occupied Mitchell's satyr habitat are covered under the HCP. This encompasses 11 occupied sites with 105 acres on protected state or non-government organization land and the remaining 92 acres on privately owned property (USFWS 2020).

Covered activities under the HCP include hydrology restoration, prescribed burning, mowing/hydro-axing, vegetation removal, biological control of invasive species, livestock grazing, seeding and planting, and butterfly surveys with the goal to maintain, manage, and restore prairie fen habitats occupied by these endangered butterflies in Michigan and Indiana. Activities associated with the maintenance and restoration of butterfly habitat may result in incidental take in the form of harm or mortality of individuals. Habitat management will only be applied to 1/3 or less of an occupied site per year to minimize take of the species (USFWS 2020). Management activities may directly impact individuals but the expected longer-term habitat improvement benefits for populations outweigh the short-term adverse impacts (Cayton et al. 2015, Haddad 2018). Management and monitoring of suitable Mitchell's satyr butterfly habitat will be conducted on state lands and via Certificates of Inclusion on private lands. Fen management has been increasing on state and private lands since the species was listed in 1992 with efforts accelerating under the Michigan Department of Natural Resources' Land Incentive Program (USFWS 2020).

### Conservation Strategy

In 2013, the MSBWG developed a Conservation Strategy to provide the framework for a coordinated and cooperative approach for the Working Group to implement recovery actions. The latest version, the *2019-2024 Mitchell's Satyr Conservation Strategy*, replaces the previous 5-year strategy and continues to provide an updated and stepped-down approach for the recovery partners to accomplish objectives identified in the Recovery Plan.

## Captive Rearing

Captive rearing efforts to support reintroductions began in 2015 (Cuthrell et al. 2015). The goal of the captive rearing program is to collect eggs from wild-caught females and raise them in a controlled environment to release back into the wild as adults in order to rapidly increase the population and help maintain genetic diversity (USFWS 2016). Currently, both the Toledo Zoo and Kalamazoo Nature Center serve as captive rearing facilities for Mitchell's satyr (Recovery Plan Recovery Action 5.1, Establish Mitchell's satyr breeding facilities).

Captive rearing efforts are guided by the *Mitchell's Satyr Butterfly Plan for Controlled Propagation, Augmentation, and Reintroduction* (USFWS 2016), which was developed collaboratively by multiple organizations and agencies interested in Mitchell's satyr conservation. The goal of the program is to augment existing populations or reintroduce butterflies into previously occupied areas to increase the number and distribution of viable populations. Augmentation and reintroduction would aid in recovery of the species (Recovery Plan Recovery Actions 2.2.5, Conduct captive rearing/reintroduction studies; and 5.0, Reintroduce into suitable but unoccupied habitats).

Both the Toledo Zoo and Kalamazoo Nature Center experimented with captive rearing surrogate species, eyed-brown (*Satyroides eurydice*) and Appalachian brown (*S. appalachia*) to develop controlled propagating and rearing methods for Mitchell's satyr (USFWS 2016). Collection of up to ten females Mitchell's satyr per facility were allowed, under a federal permit, from sites that had robust populations. Butterflies are collected from different areas of a fen at multiple times during the flight period to increase genetic variation as these methods should increase the likelihood of obtaining offspring from different individuals within a large population (USFWS 2016).

After identifying host plants of early-instar larvae, the Toledo Zoo shifted focus to Mitchell's satyr production for a reintroduction program. In 2014, they constructed a new greenhouse facility for Mitchell's satyr propagation (Tolson and Walsh 2015). Ten adult Mitchell's satyrs were collected from a fen in Branch County, Michigan in 2015 and brought back to the propagation facility. Overwinter survival in the greenhouse was 90% with 75 butterflies released back to the collection site (Toledo Zoo 2016). However, overwinter survival the following year was only 46%. The Toledo Zoo continues to improve rearing methodologies to produce the largest number of satyr offspring. In the winter of 2017/2018 adjustments to the greenhouse temperatures and snow pack were used to attempt to regulate winter temperatures and humidity (Toledo Zoo 2017).

Over the 2017 season, five female satyrs were captured during the brood period. The five females produced 142 eggs resulting in 62 larvae (Toledo Zoo 2017). The reduction in the number of females captured resulted in a subsequent reduction of the number of animals reared during the season. However with the new temperature control measures, only three adults pupated out of sync with the wild populations this year and were held at the Toledo zoo facility for captive breeding (Toledo Zoo 2017). In total, 120 eggs resulted from the captive breeding; however, none of the eggs were fertile. Thirty two adult satyrs were released at the Indiana site during the flight period of 2017 (Toledo Zoo 2017).

Wild collection during the 2018 season only resulted in 5 females due to the low populations at the fen in Branch County. Eighty eggs were laid and from that, 64 larvae hatches, and 44 of those overwintered (R. Walsh, The Toledo Zoo, pers. comm. 2021). The growth chamber where the larvae overwintered was set up to mimic the collection site's temperatures within the range of -10°C–10°C. Six of the overwintered larvae survived and were transferred to the new lab to be included in the breeding enclosures for the next year (R. Walsh, The Toledo Zoo, pers. comm. 2021).

In 2019, 30 adults collected from the fen in Branch County, Michigan were transported to the Toledo Zoo. Typically, adults lived an average of 4.2 weeks, but one adult exceeded previous life expectancy in captivity by living 6.1 weeks (Walsh 2019). Of 1,498 eggs laid only 458 developed into larvae with only 48 that transitioned to a second instar larvae (Walsh 2019). Six adults from the collection site and 4 reared larvae were tested for *Wolbachia*, a bacteria that infects arthropod species. See Section 2.2.2.3 for further information on threats associated with *Wolbachia*.

The Kalamazoo Nature Center (KNC) also contributed to captive rearing efforts. In 2018 KNC collected five Mitchell's satyrs for propagation from a site in Cass County, Michigan with the goal of repopulating adjacent unoccupied habitats (Meilinger 2018). From four females, 153 eggs were laid with many that fully developed. There was a second generation in September because of the heat in the greenhouse (Meilinger 2018). This resulted in 16 first generation larvae and 49 second generation larvae overwintering at the propagation facility. All of the second-generation larvae were descendants from only one original wild caught female (Hooper 2019). By June 2019, all larvae in captivity appeared desiccated and died. The relative humidity was much lower in captivity than in their natural fen habitat where it is close to 100% (Hooper 2019).

KNC upgraded their propagation facility in order to better control both temperature and humidity in order to facilitate more natural maturing conditions (Hooper 2019). In July 2019, 13 butterflies were caught at the Cass County, Michigan site and brought to the newly established propagation facility. Ninety-one eggs were laid and 39 developed into larvae in

captivity. Overall, KNC has had success of 42.86% egg hatchability and 38.46% larval survival (Hooper 2019).

Continued captive rearing efforts by Toledo Zoo and KNC have the potential to contribute greatly to the conservation and recovery of Mitchell's satyr.

### Reintroductions

In 2016, recovery partners collaborated to establish a new Mitchell's satyr population on land owned and managed by TNC in Noble County, Indiana as part of the SHA. Through this partnership, a National Fish and Wildlife Foundation Grant was awarded to obtain, rear, and release Mitchell's satyrs into the new location, as well as provide TNC resources to conduct habitat management prior to release (USFWS 2016). TNC developed a management plan for the site (Hyde 2017) with objectives to maintain fen hydrology, prevent agricultural runoff, reintroduce fire, acquire connectivity areas, and control non-native invasive plants so that the fen remains suitable habitat for Mitchell's satyr (USFWS 2016).

Habitat management at the Noble County, Indiana introduction site has consisted of controlling reed canarygrass (*Phalaris arundinacea*) and hybrid cattails (*Typha spp.*) from 2016-2018 (Herbert 2018). Ten Mitchell's satyr butterflies in September 2016 (Toledo Zoo 2016) and 32 butterflies in June 2017 (Toledo Zoo 2017) that were reared at the Toledo Zoo were released at this new location. No butterflies were observed during surveys conducted by TNC in 2018 and 2019 (Herbert 2018, Herbert 2019). TNC will continue to conduct monitoring and habitat management at this site.

The Service is investigating the availability of suitable habitat in the northern extent of the Mitchell's satyr historic range (i.e., northern lower Michigan and/or the Upper Peninsula) for possible reintroduction locations as a potential recovery strategy in the face of a changing climate.

### Fort Custer Reintroduction Planning

Despite multiple surveys and presence of high-quality suitable habitat, Mitchell's satyr has never been observed at Fort Custer Training Center (FCTC) -- a federally owned military installation operated by the Michigan National Guard in Kalamazoo and Calhoun counties. FCTC has effectively managed these areas in order to maintain suitable Mitchell's satyr habitat, and these fens are hydrologically intact and protected from many other stressors commonly seen at occupied Mitchell's satyr sites. Establishing even a temporary reserve population that is maintained *in situ* at FCTC could greatly benefit reintroductions and augmentations at other Mitchell's satyr sites. The FCTC has expressed interest in possibly

introducing Mitchell's satyr to pristine prairie fen on site in order to benefit conservation of the species, while also ensuring the military training objectives continue to be fully met. Planning for a potential introduction of Mitchell's satyr to FCTC is underway.

### Habitat Management

Natural disturbances including wildfire and beaver activity, historically maintained fens as open areas with a diversity of herbaceous vegetation. In the absence of these disturbances, wetlands and adjacent uplands become unsuitable for Mitchell's satyr. Active management is needed that mimics natural disturbance to restore habitats back to a more natural condition.

Butterflies within fire-adapted ecosystems, including Mitchell's satyr, may have adaptations to survive fire as observed with Regal fritillary (Hoving 2010, McCullough et al. 2017). Research is needed but Mitchell's satyr larvae may be able to survive a moderate to low intensity prescribed fire by escaping down the base of vegetation that remains inundated within fens. Mitchell's satyr butterflies were observed colonizing habitat that was burned 3 years ago at a second portion of the Berrien County, Michigan site (N. Fuller, Southwest Michigan Land Conservancy, pers. comm. 2019). This site had the greatest abundance of butterflies out of all the occupied sites in Michigan in 2018.

### Land Acquisition

The landowners of the only known Mitchell's satyr site in Indiana parceled their property for sale in 2018 and it included the occupied fens (T. Swinford, IDNR, pers. comm. 2018). The Service contacted the landowners about acquiring the site for conservation and collaborated with LaGrange County Parks to obtain the occupied fen in 2020 (S. Fetters, FWS, pers comm. 2020). A landowner agreement between the Parks Department and the Service is expected to be completed in the near future to obligate Great Lakes Restoration Initiative funds towards restoration. In addition, an adjacent six acres fen may become available for acquisition (S. Fetters, FWS, pers. comm. 2020; Recovery Plan Recovery Action 3.10, Encourage land acquisition).

In late 2016, 189 acres were purchased in Van Buren County to protect fen supporting Mitchell's satyr populations. The site is owned by Southwest Michigan Land Conservancy who manages the land for Mitchell's satyr.

In 2019, Southwest Michigan Land Conservancy acquired a 25 acre parcel adjacent to a likely viable Mitchell's satyr site in Branch County, Michigan; and TNC purchased 20 acres to the south of a site in Jackson County, Michigan (MSBWG 2019; Recovery Plan Recovery Action 3.10, Encourage land acquisition).

## Updated Information and Current Species Status

### Biology and Habitat

#### Habitat

Hydrologic input at a Michigan fen came from a variety of sources including a wetland, a lake, local recharge, and a regional groundwater mound (Sampath et al. 2016). The regional mound was found to be a part of a large, interconnected hydrological system that was also the source of water for other fens, streams, and lakes in the area. This is consistent with other research (Abbas 2011) that found that prairie fens that are far apart from one another may share the same regional water sources. Therefore, fens may be more sensitive to hydrological disturbances because of their requirement of a whole-system recharge from both local and regional sources (Abbas 2011, Sampath et al. 2016).

A habitat assessment at the LaGrange County site in Indiana observed rare plants and invertebrates in the fens that were indicators of a high-quality, rare wetland community with habitat conditions similar to observations in 1998 (T. Swinford, IDNR, pers. comm. 2018). The adjacent uplands were slightly degraded but fairly open oak woodlands (T. Swinford, IDNR, pers. comm. 2018).

Virginia habitat conditions were assessed during population surveys. Overall, butterflies occur in seepage wetlands and common vegetation includes sedges (*Carex spp.*), bulrushes (*Scirpus spp.*) and rushes (*Juncus spp.*) with an alder (*Alnus spp.*) shrub component that are commonly adjacent to grazed pastures (Roble et al. 2001, Chazal 2014).

Hill et al. (2015) assessed vegetation within occupied wetland sites and also unsuitable sites no longer occupied by Mitchell's satyr to evaluate habitat use in Alabama and Mississippi. The species did not occupy a site that had less than 30% ground cover, greater than 50% canopy cover, and less than 5% sedge cover. Overall, Mitchell's satyrs were present at sites with 70% ground cover, less than 55% canopy cover, and 60% maximum sedge cover (Hill et al. 2015). During larval and host plant surveys at a site in Prentiss County, Mississippi, caterpillars were observed on primarily three sedge species, which included *Carex atlantica*, *C. leptalea*, and *C. debilis*, with *C. atlantica* as the most used host plant (Peyton 2017).

## Distribution and Status

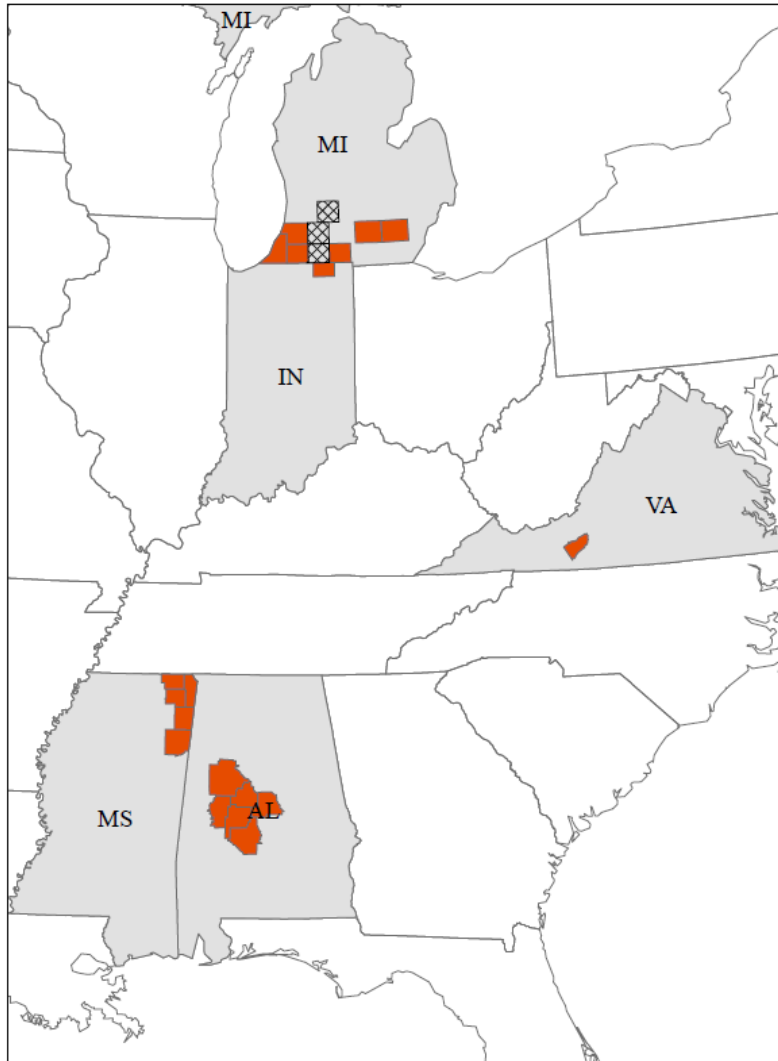


Figure 1. The current county distribution of Mitchell's satyr in Michigan, Indiana, Virginia, Alabama, and Mississippi. The hatched symbol indicates counties recently extirpated (since 2014) in Michigan.

### *Overview*

Since the previous 5-year review (2014), five previously extant Mitchell's satyr populations in Michigan are presumed extirpated, with the species no longer considered extant in Barry, Kalamazoo, or St. Joseph counties. There are currently six viable populations in Michigan within Berrien, Branch, Cass, Jackson, and Van Buren counties (MNFI unpubl. data, 2020). Viability ranks are assigned by MNFI using the NatureServe methodology (A. Cole-Wick, MNFI, pers. comm. 2020). One site is

currently ranked BC (Good or fair estimated viability/ecological integrity), two are ranked C (Fair estimated viability/ecological integrity), and three are ranked CD (Fair or poor estimated viability/ecological integrity; MNFI unpubl. data, 2020). An additional three populations in Cass and Washtenaw counties, Michigan, are extant but due to small numbers are not likely viable. Similarly, one additional extant population in LaGrange County, Indiana is not considered viable due to small population size.

Table 1. Summary of Mitchell's satyr butterfly range-wide populations.

State	Number of populations	Partial protection/conservation easement	Full protection/conservation easement	Number of populations from 2014 5 year review	Number of viable populations
Michigan	9	4	1	16	6
Indiana	1		1	1	0
Virginia	11	4		11	3
Mississippi	15	15		11	unknown
Alabama	28 sites	28 sites		28 sites	unknown

### *Michigan*

Mitchell's satyr were considered extirpated from two sites within Barry and St. Joseph Counties in 2015 because butterflies had not been observed during surveys for the previous three years (Hyde 2017). In 2018, Mitchell's satyr were not observed during surveys at a Berrien County site for the fourth consecutive year and are now considered extirpated from the site (Cuthrell and Hyde 2018).

Mitchell's satyr was newly discovered at a site in Washtenaw County, with 21 individuals observed in 2017. Only one satyr was seen during surveys in 2018, however, and no live butterflies were observed in 2019 or 2020. Due to beaver activity, habitat at this site was flooded during 2019 and 2020 which likely resulted in the loss of this population during these years (A. Cole-Wick, MNFI, pers. comm. 2020). Structurally, the habitat has not returned to pre-flooding condition after dewatering and trapping several beavers. An additional fen adjacent to the Washtenaw County site was also surveyed in 2018, but no Mitchell's satyrs were observed.

In summary, there are nine Mitchell's satyr populations in Michigan (MNFI unpubl. data, 2020), which is a decline from 16 since the previous 5-year review. In Michigan the species occurs in Berrien, Branch, Cass, Jackson, Van Buren, and Washtenaw Counties. Populations have been stable or declining in recent years. None of these sites occur on state or federal land and many Michigan populations occur on lands not formally committed to conservation into perpetuity. One of the viable population is considered fully protected and managed. Additionally, four of the potentially viable populations have partial protection and management (MSBWG 2019).

### *Indiana*

Mitchell's satyr continues to occur only at one site in LaGrange County, Indiana; however, the site is not considered viable because only six satyrs were found in 2018 (T. Swinford, IDNR, pers. comm. 2018) and just one in 2019 (S. Fetters, USFWS, pers. comm. 2019). In 2020 the fen was acquired from a private landowner by LaGrange County Parks and restoration efforts are planned for the future (S. Fetters, USFWS, pers. comm. 2020).

Reintroduction efforts of Mitchell's satyr have taken place on land owned and managed by TNC in Noble County, Indiana. While 42 individuals were released across 2016 and 2017, no butterflies were observed during surveys conducted by TNC in 2018 and 2019 (Herbert 2018, Herbert 2019)

### *Virginia*

The Virginia Department of Conservation and Recreation (VDNR) drafted a spatial distribution model for *Neonympha mitchellii* (Chazal 2015). Additionally, VDNR developed a Predicted Suitable Habitat layer for the species in the state of Virginia, which includes known Mitchell's satyr occurrence locations and is supplemented by environmental variables influencing the species' presence (Virginia Natural Heritage Program 2019).

Virginia has 11 known populations of Mitchell's satyr at ten distinct sites that are all within Floyd County in southwestern Virginia (Chazal 2014). Nine of the 11 populations are composed of multiple wetlands and populations are relatively close (0.6-2.0 km) to one another (Roble et al. 2001, Chazal 2014). Chazal (2014) reported Mitchell's satyr occurrences at nine of the 11 known populations, of which only three were ranked as having either good (B) or fair (BC) viability. The viability of the remaining eight populations was ranked as either fair to poor (CD) or poor (D) (Chazal 2014). Portions of four populations have some conservation protection, with three being under a conservation easement and one being a natural area preserve owned by the

state. The other six populations are on private ownership and potentially vulnerable to alteration or destruction (Chazal 2014).

In an effort to identify new populations outside of Floyd County, extensive surveys have been conducted within suitable habitat outside of the area of known occurrences, but searches have not found new populations (Chazal 2015, Orcutt 2016). Surveying potential wetlands had limited the effort for monitoring known populations (Chazal 2014). In 2014, surveys were conducted at 35 sites including three of the 11 known populations (Chazal 2015). Of the 35 sites surveyed, twelve were in western Floyd and eastern Carroll counties, within 8 km of known populations. The remaining 20 sites were within potential suitable habitat in Augusta, western Carroll, eastern Floyd, Franklin, Grayson, and Patrick counties. No new populations were discovered during 2014 surveys, but butterflies were observed at all three known sites (Chazal 2015). Virginia continued the effort to identify new populations by conducting surveys in 2015 at 49 sites across seven counties: Bland County (5 sites), Carroll County (26 sites), Grayson County (3 sites), Highland County (5 sites), Montgomery County (7 sites), Patrick County (1 site) and Roanoke County (2 sites; Orcutt 2016). However, Mitchell's satyr was not detected during the 2015 surveys (Orcutt 2016). The number of negative surveys conducted in Virginia since 1998 may indicate that the Mitchell's satyr is restricted to Floyd County. However, it is possible that landowner permissions may limit the effectiveness of surveys and some suitable patches of habitat may not have been detected.

To complete a full status survey of Mitchell's satyr in Virginia, VDCR targeted the 11 known populations for survey in 2017. Eight of the known populations had individuals present on surveys (Orcutt 2018). It is noteworthy that several counts were above typical numbers compared to previous years, and subpopulations with no butterflies detected during 2017 were sites that usually produced low numbers in past surveys (Orcutt 2018). Low numbers may indicate that the subpopulations are small and difficult to detect. However, VDCR identified habitat degradation at several sites where the species was not detected in 2017, suggesting possible extirpation of the species at those locations (Orcutt 2018).

### *Mississippi*

Mitchell's satyr surveys were conducted to identify new populations and areas for habitat restoration efforts along the Natchez Trace Parkway from 2012-2015 (Hill et al. 2015). Sixty-nine sites were surveyed during flight periods, including 66 sites identified as potential habitat and three known populations were surveyed (Hill et al. 2015). During this research, only one of the known sites surveyed had Mitchell's satyr present,

a decrease from the three populations in 2003. This occupied location is small with 1-6 individuals observed during the survey. Mitchell's satyr was not found at any of the remaining 68 sites surveyed (Hill et al. 2015).

One of the largest populations of Mitchell's satyr in Mississippi was discovered in 2014 on private land in a separate survey effort. It is located downstream of the occupied site along the Natchez Tract Parkway in Prentiss County (Hill et al. 2015, Peyton 2016). During 2016, four sites at a state wildlife management area (WMA) in Prentiss County were surveyed based on the proximity to the population on private land. A total of 242 and 481 individuals were counted during summer and autumn surveys, respectively (Peyton 2017). From these surveys, plots were identified for long-term monitoring and potential habitat management at the WMA.

By the end of 2014, 15 Mitchell's satyr populations were documented in Alcorn, Itawamba, Monroe, Prentiss, and Tishomingo counties of Mississippi (Peyton 2017). This is an increase from the 11 populations reported in the 2014 5-year review. The viability of these populations is unknown. In Mississippi, Mitchell's satyr populations occur on federal and state lands: Natchez Trace Parkway (National Park Service) and a state WMA and are protected accordingly. However, the status of the monitoring or management are not known.

### *Alabama*

There has been no new information regarding surveys or population status for the Alabama Mitchell's satyr populations since the previous 5-year review. As stated in the previous 5-year review, in Alabama there are 28 sites occupied by Mitchell's satyr in the central portion of the state within the Fall Line Hills physiographic province in the counties of Bibb, Chilton, Dallas, Hale, Perry, and Tuscaloosa (Hart 2004). Currently, all known sites occur within the Oakmulgee Ranger District of the Talladega National Forest (Hart 2004). The viability and management status of these populations is unknown.

Active ecosystem management, including prescribed burning, is regularly conducted across the majority of the Oakmulgee Ranger District to restore natural conditions for native plant and animal species. However, the rush/sedge wetlands and beaver pond habitats occupied by Mitchell's satyr are typically outside the footprint of this active management, as they are usually too wet to be affected by fire. In drier seasons, the Oakmulgee Ranger District implements burns so that only a portion of these wetland habitats are burned (which improves their quality and sets back succession) in a single season. In this way adequate refugia for Mitchell's satyr are retained as unburned.

Besides maintaining the surrounding natural hydrologic conditions and protecting these habitats from destruction and/or invasive plant infestation, the Forest Service typically does not conduct forest management activities in these isolated wetland habitats.

### Genetics

A few genetic studies have been completed since the previous 5-year review. Conclusions vary between studies. A more robust dataset may be needed to clarify these relationships.

The taxonomic status of the previously recognized subspecies *Neonympha mitchellii mitchellii* (in Michigan/Indiana) and *Neonympha mitchellii francisci* (in North Carolina) was assessed by analyzing genetic variation among the known subspecies as well as within recently discovered populations in Alabama, Mississippi, and Virginia (Hamm et al. 2014). This study used six molecular markers (five nuclear and one mitochondrial) under a variety of analytical frameworks. Molecular data confirmed that *N. m. mitchellii* and *N. m. francisci* are evolutionarily distinct and suggested that they continue being managed as separate subspecies in Michigan/Indiana and North Carolina, respectively. Their analysis also confirmed that the recently discovered southern populations are members of the *Neonympha mitchellii* clade, but are genetically distinct from *N. m. mitchellii* and not completely distinguished from *N. m. francisci*. Based on their results, it was recommended that the Alabama, Mississippi, and Virginia populations not be managed as either of the listed subspecies and that a more powerful data set is needed to resolve the taxonomic status and relationships of the newly discovered populations (Hamm et al. 2014).

Other research compared genitalia to help resolve the taxonomic status of the southern populations (Seltzer and Hill 2013). Initial comparisons showed very minor differences between valves of *N. m. mitchellii* and populations in Mississippi. These differences may be due to variation within the species group or may be diagnostic features separating the southern population into a new species. More samples, as well as whole genome sequencing, are needed to clarify species delineation of the southern populations (Seltzer and Hill 2013).

Tissue samples from four *N. m. francisci*, three northern *N. m. mitchellii*, and 13 southern *N. m. mitchellii* were used to establish a genetic baseline for future monitoring of population health, dispersal events, and may guide reintroduction efforts (Hill et al. 2015). They utilized thirty samples for genomic sequencing which were quality checked and used to create a catalog assembly using the software program Stacks (Catchen et al. 2013). The catalog assembly identified on average 20,000 polymorphic

sites. A principal component analysis was conducted to examine the overall patterns of genetic differentiation. Using geographic distance between sample sites and the pattern of genetic divergence, they examined isolation by distance to indicate which *N. m. mitchellii* populations showed the greatest similarities. They determined there is little genetic differentiation among the Mississippi sites, but significant genetic differences between Mississippi and Alabama populations. This suggests strong population structure and little gene flow among populations (Hill et al. 2015). Several analyses of the preliminary dataset suggest that the southern *N. m. mitchellii* populations represent a geographically and genetically distinct lineage of *N. m. mitchellii* that are more similar to *N. m. francisci* than northern populations of *N. m. mitchellii*, while the northern populations grouped together independently from the southern and *N. m. francisci* populations (Hill et al. 2015). Additional samples from sites are being analyzed to further examine these results and population history of Mitchell's satyr and its closest relative.

More recently, preliminary results of genetic analysis for *Neonympha mitchellii* indicated that southern populations in Alabama and Mississippi are not genetically different than the northern populations in Michigan and Indiana. Genetic analyses from Mississippi State University indicate that there is no clear genetic variation between northern (Michigan and Indiana) and southern (Alabama and Mississippi) populations (B. Counterman, Mississippi State University, pers. comm., 2019). These findings suggested that the two populations can potentially mix to create more genetic diversity and that southern populations can help with Mitchell's satyr recovery efforts (MSBWG 2019). Genetic diversity was found to be higher in the southern (AL and MS) populations than the northern (MI and IN) populations of *Neonympha mitchellii*, but found the highest genetic diversity in the *N. m. francisci* in North Carolina (B. Counterman, Mississippi State University, pers. comm., 2019). Further, there was no evidence of genetic differentiation of the *N. mitchellii* sample collected from Virginia and *N. m. francisci* populations (in North Carolina). The satyrs in Virginia were more genetically similar to samples collected from *N. m. francisci* in North Carolina than to any *N. m. mitchellii* samples, which means the satyr collected from Virginia are likely a *N. m. francisci* (i.e., St. Francis satyr rather than Mitchell's satyr) (B. Counterman, Mississippi State University, pers. comm. 2019).

Additional research is needed to clarify the genetic relationships and taxonomic status.

### **Threats Analysis (threats, conservation measures, and regulatory mechanisms)**

The final rule listing Mitchell's satyr as endangered cited the following factors as threats to the continued existence of the species: (1) human-induced destruction of

Mitchell's satyr habitat by urban development, conversion to agriculture, or highway construction; (2) human activities adjacent to occupied habitat that can speed succession; (3) over-collection by butterfly collectors; (4) inadequacy of existing regulatory mechanism, and (5) limited ability to recolonize new habitat patches.

#### **2.2.2.1 Present or threatened destruction, modification or curtailment of its habitat or range**

As discussed more extensively in the Recovery Plan and previous 5-year review, human-induced habitat loss, degradation, and fragmentation are the primary threats affecting Mitchell's satyr. Succession is a long-term threat to the species and its habitat, resulting in loss of suitable habitat. The Recovery Plan identifies a goal of having at least 50% of populations on public or private lands where there is a commitment to manage for Mitchell's satyr habitat. Approximately 40% of the populations have state, federal, or land conservancy ownership across the range, although the level of active habitat management is not known for all sites.

Overgrazing by domesticated animals and frequent mowing creates conditions unsuitable for the species (Roble et al. 2001, Chazal 2014). Pesticides and neonicotinoid insecticides use may also be contributing to decline of Mitchell's satyr as has been suspected for other native butterfly populations (Main et al. 2014, Pisa et al. 2014, Warner et al. 2020).

Fens may be more sensitive to hydrological disturbances because of their requirement of a whole-system recharge from both local and regional sources (Abbas 2011, Sampath et al. 2016). Alteration of hydrology, leading to changes in fen vegetation, has been suspected as the cause of declines in Mitchell's satyr numbers at several sites and possibly even extirpation at some sites in Michigan (MNFI, unpubl. data). Some previously occupied wetlands in Virginia were dry during recent Mitchell's satyr surveys. Structures that alter hydrology, including ditches, drain tiles, culverts, and a water pump, were observed at most Virginia wetlands (Roble et al. 2001, Chazal 2014).

Natural alterations to hydrology may also impact populations. A beaver wetland had been drained at one site and beaver appeared to have abandoned another site creating unfavorable conditions for Mitchell's satyr at two previously occupied locations along the Natchez Trace Parkway in Mississippi (Hill et al. 2015). Mitchell's satyrs may have

declined at the newly discovered site in Washtenaw county, Michigan due to very high-water levels that decreased suitable fen habitats (Cuthrell and Hyde 2018).

Natural succession of encroachment by woody vegetation and non-native invasive species establishment form monocultures and closed canopy conditions that reduces herbaceous species diversity within fens occupied by Mitchell's satyr. Reed canarygrass and hybrid cattails (*Typha* spp.) are present within the introduction site in Noble County, Indiana and TNC is conducting treatments to control the spread of these non-native invasive species (Herbert 2018). An increase in woody vegetation, primarily alder and non-native multiflora rose, was observed and active management is needed to reduce encroachment, especially to maintain the largest population of Mitchell's satyr in Virginia (Chazal 2015).

Encroachment from alder is creating unsuitable dense canopy cover at the previously occupied site with a small abandoned beaver wetland, but the site's hydrology and sedge cover still appear within appropriate conditions (Hill et al. 2015). Similarly, an area between the occupied site along Natchez Trace Parkway and the newly discovered site on the private hunting club property is unsuitable for Mitchell's satyr because of a dense overstory and little groundcover (Hill et al. 2015). Habitat management is needed to restore these areas and enable dispersal between occupied sites.

Many Virginia populations occur near roads and there is concern that roadside mowing of potential nectar sources may threaten Mitchell's satyrs (Chazal 2014). Mowing outside of the flight period can minimize negative impacts on the species and communication of these efforts to local Virginia Department of Transportation is needed. Vehicle collisions may also directly kill individuals and research is needed to evaluate whether it is a major threat to Virginia populations (Chazal 2014).

#### **2.2.2.2 Overutilization for commercial, recreational, scientific, or educational purposes**

The recovery plan noted that over-collection by butterfly collectors was a threat to the continued existence of the species. For example, Mitchell's satyr is observed along major roads in Virginia, and it is suggested that law enforcement be notified of potential illegal collection (Chazal 2015).

However, illegal collection is not known to be a significant threat and the Service has not received any recent reports of collection activities.

### 2.2.2.3 Disease or predation

Disease and predation were not known threats to Mitchell's satyr at the time of the Recovery Plan. No new diseases or predators have been identified since the previous 5-year review. However, there is updated information on the presence of *Wolbachia*, which is a genus of maternally inherited bacteria that are considered reproductive parasites and are commonly found in arthropods. If an individual is infected by *Wolbachia*, only pairings of males and females infected with the same strain result in fertile offspring (Nice et al. 2009, Hamm and Landis 2010). Cytoplasmic incompatibility is the most widespread effect to hosts, where *Wolbachia* infection can lead to the death of embryos and immature offspring when infected males mate with uninfected females or females infected with a different strain (Hoffmann et al. 2015). Recovery partners are trying to better understand the implications of *Wolbachia* infection on Mitchell's satyr populations in the wild and in captivity. New information on *Wolbachia* is discussed below; see the previous Mitchell's satyr 5-year review for additional background on *Wolbachia*.

Presence of *Wolbachia* status has increased in recent years and has been documented in new populations. Satyrs collected by Toledo Zoo from a fen in Branch County in 2015 and 2016 all tested negative for *Wolbachia* (Toledo Zoo 2016, Hyde 2017, Toledo Zoo 2017). In 2019, there was unusually low survival of offspring in the captive rearing program at Toledo Zoo (Walsh 2019). Six adults and four reared larvae that had been collected at the same Branch County site were tested for *Wolbachia*. Two larvae tested positive for *Wolbachia* and the other two were unable to be processed (Walsh 2019). Further analysis of *Wolbachia* tests and mortality rates revealed a 99% mortality rate in larvae that tested positive or had a positive parent (Walsh 2019). The surviving larvae had at least one parent test negative for *Wolbachia*. Decreased fertility due to *Wolbachia* infection has been observed in species of Lepidoptera (Fenner et al. 2017, Hamm et al. 2014). Larval mortality of Mitchell's satyr has not been previously observed or noted in the literature, however, successful rearing may have provided a means for new observations.

*Wolbachia* has been documented in Mitchell's satyr populations in other Michigan counties (Cass and Jackson counties) and in Mississippi (Prentiss and Monroe counties) (Fenner et al. 2017). Individuals from Alabama or Virginia tested negative for *Wolbachia*, but little wood satyr (*Megisto cymela*) from these states tested positive. *Wolbachia* is present in all occupied Mitchell's satyr areas, however, there appears to be limited transmission between the satyr species within the study (Fenner et al. 2017). Therefore, caution must be used when conducting surveys and collecting individuals to minimize the spread of the bacteria.

The presence of *Wolbachia* in the Mitchell's satyr population at the fen in Branch County, Michigan, appears to correlate with recent declines in wild populations. It is likely *Wolbachia* is a major factor in MSB decline across Michigan (Walsh 2019). Due to recent low numbers of surviving *ex situ* larvae and prevalence of *Wolbachia*, the status and effects of *Wolbachia* infection must continue to be evaluated annually in order to inform captive rearing and other recovery efforts. In particular, the captive propagation program must continue to carefully avoid inadvertent introduction of *Wolbachia* into uninfected populations or introduction of a new strain into wild populations.

#### **2.2.2.4 Inadequacy of existing regulatory mechanisms**

The state listing for Mitchell's satyr remains unchanged since the most recent 5-year review in 2014.

#### **2.2.2.5 Other natural or manmade factors affecting its continued existence**

Climate change and extreme weather events may be straining rare butterflies (Patterson et al. 2019) and their habitats, including Mitchell's satyr. Approximately 4-5 inches of rain within 48 hours flooded the occupied site in LaGrange County, Indiana. Only one butterfly was observed during surveys and visible sediment deposits indicated high water marks that were at least a foot above normal levels (S. Fetters, USFWS, pers. comm. 2019). The temperature is projected to rise roughly 10 times as fast over the next 40 years as it has over the past 100 years in the state of Michigan (Hoving et al. 2013). Michigan has experienced relatively little year-to-year variation in precipitation which makes species more vulnerable to future change. The state is predicted to become drier,

which will disproportionately affect wetland species with the most vulnerable groups being amphibians, mollusks, fish, and insects. A climate change vulnerability assessment concluded that the Mitchell's satyr is extremely vulnerable to climate change in Michigan (Hoving et al. 2013). Climate change will impact Mitchell's satyr across its disjunct range, but the level of impact may vary from state-to-state.

## Synthesis

Currently, there are nine Mitchell's satyr populations in Michigan (six viable), which is a decline from 16 since the previous 5-year review (2014). Population trends have been stable or declining in recent years. None of these sites occur on state or federal land and many Michigan populations occur on lands not formally committed to conservation into perpetuity. There is one population in Indiana that is not considered viable and recently acquired by local government. Populations in Virginia (11) are confined to 1 county, despite wide ranging surveys. Only three of these populations are considered to be good to fair viability, with one partially owned by the state and three under a conservation easement. Mississippi has 15 populations across five counties, an increase from the 11 populations noted in the 2014 review; however, viability is unknown. While some of these populations occur on state and federal lands, status of monitoring or management are not known. There is no new information regarding or surveys for the Alabama Mitchell's satyr populations since the 2014 5-year review. There are 28 sites in four counties of unknown viability that occur on federal land that is managed via prescribed burning but monitoring is unknown.

Captive propagation, reintroduction, and augmentation are concentrated in Michigan and Indiana because of long-term trends of population declines and ongoing threats in the northern part of the species range. In 2016, the Service developed a Safe Harbor Agreement with the purpose to reintroduce butterflies to historic sites and/or to suitable fens that occur within its historic range. Limited introductions began in 2016 at a TNC property in Indiana; however, the number of individuals available for release have been relatively small and no individuals were found during surveys in recent years. An HCP was developed for Michigan and Indiana in 2018 and signed in 2020 to maintain and expand current populations through management, restoration, and protection of suitable habitat while minimizing take and restore unoccupied habitat for reintroduction to increase the number of extant populations.

Conclusions from recent genetic studies since the previous 5-year review vary between studies. A more robust dataset may be needed to clarify these relationships. A couple studies concluded that the northern and southern Mitchell's satyr populations were significantly distinct (Hamm et al. 2014; Hill et al. 2015). However, genetic analyses from Mississippi State University indicate that there is no genetic variation between northern (MI and IN) and

southern (AL and MS) populations. These findings suggest that the two populations can potentially mix to increase genetic diversity of certain populations and that southern populations can help with Mitchell's satyr recovery efforts (MSBWG 2019). Further, the preliminary results indicate populations in Virginia were not Mitchell's satyr and are more closely related to St. Francis satyr (listed as endangered in North Carolina) (USFWS 2020; B. Counterman, Mississippi State University, pers. comm. 2019). Additional research is needed to clarify the genetic relationships and taxonomic status.

Human-induced habitat loss, degradation, and fragmentation are the primary threats affecting Mitchell's satyr. These result from nutrients entering groundwater from surrounding agricultural and other lands; continued groundwater withdrawal and other changes to hydrology due to roads, wells, ditches, etc.; use of pesticides and other chemicals that drift from surrounding areas; loss of habitat due to residential development; invasive species; and natural succession resulting in woody shrub encroachment. These habitat stressors are expected to continue into the future and likely increase as the human population increases and expands. *Wolbachia* is present across the range, though more often found in the northern populations. The captive propagation program must continue to carefully avoid inadvertent introduction of *Wolbachia* into uninfected populations or introduction of a new strain into wild populations.

Climate change will impact Mitchell's satyr across its disjunct range, but the level of impact may vary from state-to-state. Drier conditions in the northern part of its range could further limit populations that are already small and isolated. Lack of commitment to Mitchell's satyr habitat management and conservation is a long-term concern. Approximately 83% of the populations have state, federal, or land conservancy ownership across the range, although the level of active habitat management is not known for all sites (Table 1). The majority of these sites occur within Alabama and Mississippi where management practices and protections are unknown. State protections and listing as endangered or imperiled remains unchanged in Alabama, Indiana, Michigan, Mississippi, and Virginia since the previous 5-year review.

Despite considerable recovery efforts ranging from captive rearing to habitat management, Mitchell's satyr continues to decline. After reviewing the best available scientific information, we conclude that Mitchell's satyr (*Neonympha mitchellii mitchellii*) remains an endangered species.

## RESULTS

### Recommended Classification

Downlist to Threatened

Uplist to Endangered

Delist

No change is needed

### New Recovery Priority Number

No change from 3 indicating subspecies with a high degree of threat and high recovery potential [48 FR 43098]

### Listing and Reclassification Priority Number

N/A

## RECOMMENDATIONS FOR FUTURE ACTIONS

Recommendations for future actions includes collecting more information about the southern populations, confirming genetics across the range, increasing survey efforts, and assessing viability. Additional studies are necessary to learn if genetics from southern populations can be mixed with northern populations to avoid small population threats genetic depressions. Research and adaptive management should continue regarding the use of prescribed fire and the effects on populations and larvae. Additional future actions should include the continued effort to acquire occupied habitat.

## REFERENCES

- Abbas, H. 2011. Prairie fen hydrology. PhD Dissertation, Michigan State University, East Lansing. 212 pp.
- Cayton, H., N.M. Haddad, B. Ball, E. Henry, and E. Aschehoug. 2015. Habitat Restoration as a Recovery Tool for a Disturbance-Dependent Butterfly, The Endangered St. Francis' Satyr. *Butterfly Conservation in North America*, Springer, Netherlands, pp 147–159.
- Cayton, H.L. and N.M. Haddad. 2018. Water Availability Coincides with Population Declines for an Endangered Butterfly. *Diversity* 10: 94. DOI 10.3390/d10030094.
- Chazal, A. C. 2014. Results of surveys for Mitchell's satyr (*Neonympha mitchellii*) in Virginia, 2013. Natural Heritage Technical Report 14-1. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. 13 pp. plus appendix.
- Chazal, A. C. 2015. Results of surveys for Mitchell's satyr (*Neonympha mitchellii*) in Virginia, 2014. Natural Heritage Technical Report 15-6. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. 12 pp.
- Cuthrell, D.L., D.A. Hyde, J. Shuey, and P. Tolson. 2015. Draft Criteria and Protocol for Mitchell's Satyr Introduction. Unpublished report to U.S. Fish and Wildlife Services.
- Cuthrell, D.L. and D.A. Hyde. 2018. Globally Rare and Declining Prairie Fen Butterflies: Population Status and Ecological Risk Assessments. Michigan Natural Features Inventory, Report No. 2018-23, Lansing, MI.
- Fenner, J., J. Seltzer, S. Peyton, H. Sullivan, P. Tolson, R.P. Walsh, J. Hill, and B.A. Counterman. 2017. Demographic Variation of *Wolbachia* Infection in the Endangered Mitchell's Satyr Butterfly. *Insects* 8:50. DOI 10.3390/insects8020050.
- Haddad, N.M. 2018. Resurrection and resilience of the rarest butterflies. *PLoS Biology* 16(2): e2003488. DOI 10.1371/journal.pbio.2003488.
- Hamm, C.A., V. Rademacher, D.A. Landis, and B.L. Williams. 2014. Conservation Genetics and the Implications for Recovery of the Endangered Mitchell's Satyr Butterfly, *Neonympha mitchellii mitchellii*. *Journal of Heredity* 105(1): 19-27.
- Hart, B. 2004. A Survey for the Mitchell's Satyr (*Neonympha mitchellii* French) in the National Forests in Alabama. Final Report to the U.S. Fish and Wildlife Service, Daphne, AL. 93 pp.

- Herbert, N. 2018. 2018 Monitoring Report: Mitchell's Satyr Release and Monitoring Results at Swamp Angel Nature Preserve, Noble Co. Indiana. Unpublished report to the U.S. Fish and Wildlife Service.
- Herbert, N. 2019. TNC 2019 Annual Report. Unpublished report to the U.S. Fish and Wildlife Service.
- Hill, J.G., B. Counterman, J. Schawb, J.A. Barone, and J.L. Seltzer. 2015. Progress Report for: Development and Implementation of a Conservation Plan for the Mitchell's Satyr, *Neonympha mitchellii mitchellii*, (Lepidoptera: Nymphalidae: Satyrinae) on the Natchez Trace Parkway. 17 pp.
- Hoffmann, A.A., P.A. Ross, and G. Rasic. 2015. *Wolbachia* strains for disease control: ecological and evolutionary considerations. *Evolutionary Applications* 8: 751-768
- Hooper, H. 2019. Collection and Propagation of the Mitchell's Satyr at the Kalamazoo Nature Center 2019 Report. Permit Number: TE85231B-3. Unpublished report to the U.S. Fish and Wildlife Service.
- Hoving, C. 2010. Fen and the Art of Mitchells' Satyr Maintenance: A Draft of the Fen Community Conservation Plan with Special Reference to Michigan and Indiana. Michigan Department of Natural Resources, Lansing, MI. 59 pp plus appendices
- Hoving, C.L., Y. M. Lee, P.J. Badra, and B.J. Klatt. 2013. Changing Climate, Changing Wildlife: A Vulnerability Assessment of 400 Species of Greatest Conservation Need and Game Species in Michigan. Michigan Department of Natural Resources, Wildlife Division Report No. 3564. 82 pp.
- Hyde, D.A. 2017. Laying the Foundation for Establishment of New Mitchell's Satyr (*Neonympha mitchellii mitchellii*) Populations in Indiana and Michigan and Securing Populations through Updated Species Management Plans Final Performance Report, January 1, 2015 – January 31, 2017. Michigan Natural Features Inventory, Report No. 2017-06, Lansing, MI. Unpublished report to the U.S. Fish and Wildlife Service. 5 pp. plus appendix.
- Main, A.R., J.V. Headley, K.M. Peru, N.L. Michel, and A.J. Cessna. 2014. Widespread Use and Frequent Detection of Neonicotinoid Insecticides in Wetlands of Canada's Prairie Pothole Region. *PLoS ONE* 9:e92821-1-e92821. DOI 10.1371/journal.pone.0092821.

- McCullough, K., G. Albanese, and D.A. Haukos. 2017. Novel Observations of Larval Fire Survival, Feeding Behavior, and Host Plant Use in the Regal Fritillary, *Speyeria idalia* (Drury) (Nymphalidae). *The Journal of Lepidopterists' Society* 71(3): 146-152.
- Meilinger, J. 2018. Collection and Propagation of the Mitchell's Satyr at the Kalamazoo Nature Center 2018 Report. Permit Number: TE85231B-2. Unpublished report to the U.S. Fish and Wildlife Service.
- Mitchell's Satyr Butterfly Working Group. Draft report November 2019. Mitchell's Satyr Conservation Strategy 2019-2024. 7 pp.
- Orcutt, E.C. 2016. Results of Surveys for New Mitchell's Satyr (*Neonympha mitchellii*) Populations in Virginia, 2015. Final Report submitted to Virginia Department of Agriculture and Consumer Services, Richmond, VA. 16 pp.
- Orcutt, E. C. 2018. Results of Surveys for Mitchell's Satyr (*Neonympha mitchellii*) in Virginia, 2017. Natural Heritage Technical Report 18-07. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. 9 pp. plus appendix.
- Patterson, T.A., R. Grundel, J.D.K. Dzurisin, R.L. Knutson, and J.J. Hellman. 2019. Evidence of an extreme weather-induced phenological mismatch and a local extirpation of the endangered Karner blue butterfly. *Conservation Science and Practice* 2 (1): e147. DOI 10.1111/csp2.147.
- Peyton, S. 2017. Unpublished report to the U.S. Fish and Wildlife Service.
- Pisa, L.W., V. Amaral-Rogers, L.P. Belzunces, J.M. Bonmatin, C.A. Downs, D. Goulson, D. P. Kreuzweiser, C. Krupke, M. Liess, M. McField, C.A. Morrissey, D. A. Noome, J. Settele, N. Simon-Delso, J.D. Stark, J.P. Van der Sluijs, H. Van Dyck, and M. Wiemers. 2014. Effects of neonicotinoids and fipronil on non-target invertebrates. *Environmental Science and Pollution Research* 22: 68-102. DOI 10.1007/s11356-014-3471-x.
- Roble, S.M., C.T. Kessler, B. Grimes, C.S. Hobson, and A.C. Chazal. 2001. Biology and Conservation Status of *Neonympha mitchellii*, A Globally Rare Butterfly to the Virginia Fauna. *Banisteria*: 18. Virginia Natural History Society.
- Sampath, P.V., H. Liao, Z.K. Curtis, M.E. Herbert, P.J. Doran, C.A. May, D.A. Landis, and S. Li. 2016. Understanding fen hydrology across multiple scales. *Hydrological Processes* 30: 3390-3407.

- Seltzer J. and J.G. Hill. 2013. Comparison of the Genitalia from Northern and Southern Populations of *Neonympha mitchellii* (French), including *N. francisci* (Pearson and Kral). Mississippi Entomological Museum, Mississippi State University.
- Toledo Zoo. 2016. Mitchell's Satyr Butterfly (*Neonympha mitchellii mitchellii*) Conservation Activities-2016. Unpublished report to U.S. Fish and Wildlife Service.
- Toledo Zoo. 2017. 2017 Mitchell's Satyr Butterfly Conservation Activities. Permit TE106217. Unpublished report to U.S. Fish and Wildlife Service.
- Tolson, P.J. and R.P. Walsh. 2015. Final Report – Mitchell's Satyr Conservation Activities. Permit # TE-106217-2. Unpublished report to U.S. Fish and Wildlife Service.
- U.S. Fish and Wildlife Service (USFWS). 2014. Mitchell's satyr butterfly (*Neonympha mitchellii mitchellii*) 5-year review. Prepared by Michigan Ecological Services Field Office, East Lansing, MI. 40pp.
- U.S. Fish and Wildlife Service (USFWS). 2016. Mitchell's satyr butterfly (*Neonympha mitchellii mitchellii*) plan for controlled propagation, augmentation, and reintroduction in Michigan and Indiana. East Lansing, MI. 46 pp.
- U.S. Fish and Wildlife Service. 2020. Biological opinion Issuance of Section 10(a)(1)(B) Permits to the Michigan and Indiana Departments of Natural Resources for the Mitchell's Satyr Butterfly and Poweshiek Skipperling Multi-state Habitat Conservation Plan. Prepared by Michigan Ecological Services Field Office, East Lansing, MI. Log # 19-R3-ELFO-02
- Virginia Natural Heritage Program. 2019. *Neonympha mitchellii* Predicted Suitable Habitat, version neonmitc 10May2018 (model version neonmitc 20170918 155854). Virginia DCR-DNH, Richmond, VA.
- Walsh, R.P. 2019. Mitchell's Satyr (*Neonympha mitchellii mitchellii*) captive rearing at The Toledo Zoo 2019 Permit Report – Permit TE106217. Unpublished report to U.S. Fish and Wildlife Service.
- Warner, S., Golden, N., Warburton, D. and L. Williams. 2020. Supplemental materials for the monarch species status assessment report, Revised July 2020. U.S. Fish and Wildlife Service Report. 24pp.

**U.S. FISH AND WILDLIFE SERVICE**

**5-YEAR REVIEW**

**MITCHELL'S SATYR BUTTERFLY (*Neonympha mitchellii mitchellii*)**

**Current Classification:** Endangered

**Recommendation resulting from the 5-Year Review:**

Downlist to Threatened

Uplist to Endangered

Delist

No change needed

**Appropriate Listing/Reclassification Priority Number, if applicable:**

**FIELD OFFICE APPROVAL:**

**Lead Field Supervisor, Fish and Wildlife Service, Michigan Field Office**

Approve \_\_\_\_\_