

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



5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service, Midwest Region
East Lansing Field Office
East Lansing, Michigan

5-YEAR REVIEW

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

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5-YEAR REVIEW
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1. GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office

Region 3 Midwest Regional Office

Contact: Jessica Hogrefe, Regional Recovery Coordinator, 612-713-5346

Lead Field Office

East Lansing Ecological Services Field Office,

Contact: Tameka N. Dandridge, Biologist, 517-351-8315

Cooperating Field Offices

Alabama Ecological Services Field Office

Contact: Dan Everson, Deputy Field Supervisor, 251-441-5181

Bloomington, Indiana Ecological Services Field Office

Contact: Lori Pruitt, Biologist, 812-334-4261

Mississippi Ecological Services Field Office

Contact: Paul Hartfield, Biologist, 601-321-1125

Virginia Ecological Services Field Office

Contact: William Hester, Biologist, 804-693-6694

Cooperating Regional Office

Region 4 Southeast Regional Office

Contact: Kelly Bibb, Regional Recovery Coordinator, 404-679-7132

Region 5 Northeast Regional Office

Contact: Mary Parkin, Regional Recovery Coordinator, 617-417-3331

1.2 Methodology used to complete the review

The U.S. Fish and Wildlife Service (Service) conducts status reviews of species on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12) as required by section 4(c)(2)(A) of the Endangered Species Act of 1973, as amended (ESA) (16 U.S.C. 1531 *et seq.*). The Service provided notice of this status review via the *Federal Register* (74 FR 11600) requesting new scientific or commercial data and information that may have a bearing on the Mitchell's satyr butterfly (*Neonympha mitchellii mitchellii*) classification of endangered status.

The East Lansing Field Office (ELFO), in coordination with Midwest Regional Office Ecological Services staff, conducted this review. New material considered in this review contains relevant information generated since the May 20, 1992 Final Rule (57 FR 21564) and the 1998 approved Mitchell's Satyr Recovery Plan. 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 by graduate students), data received from various federal and state personnel through personal communication involving electronic mail and letters and annual Mitchell's satyr recovery working group meetings. The ELFO did not carry out a formal peer review for this review because much of the information contained therein is derived from peer reviewed literature and reports. However, one of the sources of our genetics information was reviewed by Service's geneticist and the species' status in Michigan was reviewed by the Michigan Natural Features Inventory. All literature and documents used for this review are on file at the ELFO.

1.3 Background

1.3.1 *Federal Register* notice announcing initiation of this review: 74 FR 11600, Wednesday, March 18, 2009

1.3.2 Listing history

Original Listing

Federal Register notice: 56 FR 28825
Date listed: June 25, 1991
Entity listed: Species
Classification: Endangered, Emergency Listing

Revised Listing

Federal Register notice: 57 FR 21564
Date listed: May 20, 1992
Entity listed: Species
Classification: Endangered, Final Rule

1.3.3 Associated rulemakings: N/A

1.3.4 Review history

- January 20, 1984: A Service status review found (49 FR 2485) that insufficient data was available to support listing at that time.
- May 1984: The Service's Invertebrate Wildlife Notice of Review (49 FR 21664-75) listed the species as a category 3C species, indicating that at the time the species was believed to be too abundant for consideration for addition to the endangered and threatened species lists.

- January 6, 1989: Animal Notice of Review (54 FR 554–79) upgraded the species to a category 2 candidate for listing, indicating renewed concern for the species’ welfare, and encouraged further studies in the status of the species.
- June 25, 1991: Surveys indicated that Mitchell’s satyr had experienced significant range reduction and was listed as endangered under an emergency listing (56 FR 28825–28) to protect the species from over-collection. The emergency listing provided protection until February 20, 1992.
- May 20, 1992: The Service issued a Final Rule (57 FR 21564) that determined Mitchell’s satyr to be an endangered species under the ESA.

1.3.5 Species’ Recovery Priority Number at start of 5-year review: 3

Indicating a subspecies with a high degree of threat and a high recovery potential [48 FR 43098].

1.3.6 Recovery Plan:

Name of plan: Mitchell’s Satyr Butterfly (*Neonympha mitchellii mitchellii*)
Recovery Plan

Date issued: April 2, 1998

2. REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1. Is the species under review a vertebrate? No

The Endangered Species Act defines species as including any subspecies of fish or wildlife or plants, and any distinct population of a species of vertebrate wildlife. This definition limits listing DPS to only vertebrate species of fish and wildlife. Because the species under review is an invertebrate, and the DPS policy is not applicable, the application of the DPS policy to the species’ listing is not addressed further in this review.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan¹ containing objective, measurable criteria? Yes

2.2.2 Adequacy of recovery criteria

¹ Although the guidance generally directs the reviewer to consider criteria from final approved recovery plans, criteria in published draft recovery plans may be considered at the reviewer’s discretion.

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

No. Mitchell's satyr populations in Virginia, Mississippi, and Alabama were unknown at the time the recovery criteria were developed. As such, these populations, including information on their biology, are not included in the 1998 recovery plan and should be considered in future revision.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information. For threats-related recovery criteria, please note which of the five listing factors are addressed by that criterion. If any of the five listing factors is not relevant to this species, please note that here.

The Mitchell's satyr recovery plan has one reclassification and one delisting criteria.

- 1) **Mitchell's satyr may be considered for reclassification from endangered to threatened when 16 geographically distinct, viable populations or metapopulations are established or discovered range wide.** These 16 populations, or metapopulations, will include, at a minimum; 12 in southern Michigan; two in Indiana; one in Ohio; and one in New Jersey. At least 50 percent of these sites will be protected and managed to maintain Mitchell's satyr habitat.

When we listed Mitchell's satyr in 1992 as an endangered species, the butterfly was documented from 30 historical locations in four states, ranging from southern Michigan, adjacent counties in Indiana, one county in Ohio, and several disjunct populations in New Jersey, and possibly Maryland (Figure 1). Upon issuance of the recovery plan in 1998, there were only 15 documented extant populations: 13 in Michigan and 2 in Indiana.

Currently, 16 populations exist in Michigan and one in Indiana (Figure 2). Only six sites in Michigan are considered viable by the Michigan Natural Features Inventory (MNFI) (Daria Hyde, MNFI, pers. comm. 2011), see Appendix B. For a few years (2009–2011), access to the Indiana site was not permitted and management or monitoring did not occur. In 2008, surveyors counted 121 Mitchell's satyrs at the Indiana site (Lee Casebere, Indiana Department of Natural Resources [Indiana DNR], pers. comm. 2011). A few years later in 2012, The Nature Conservancy (TNC)-Indiana Chapter re-established a relationship with the landowners and was able to access the site to reassess the status of the satyr and habitat. See discussion under Criterion 2, below, for a summary of protection and/or management status of these sites.

Since issuance of the recovery plan (USFWS 1998), new populations of Mitchell's satyr have been documented in the southeast U.S. (Figure 2). In 1998, Mitchell's satyrs were discovered in Floyd County, Virginia (Roble *et al.* 2001), in 2000, populations were later found in Alabama, and additional populations were later found in Mississippi in 2003 (Hart 2004). These populations conform morphologically to Mitchell's satyr and will be treated as such unless more conclusive evidence indicates otherwise.

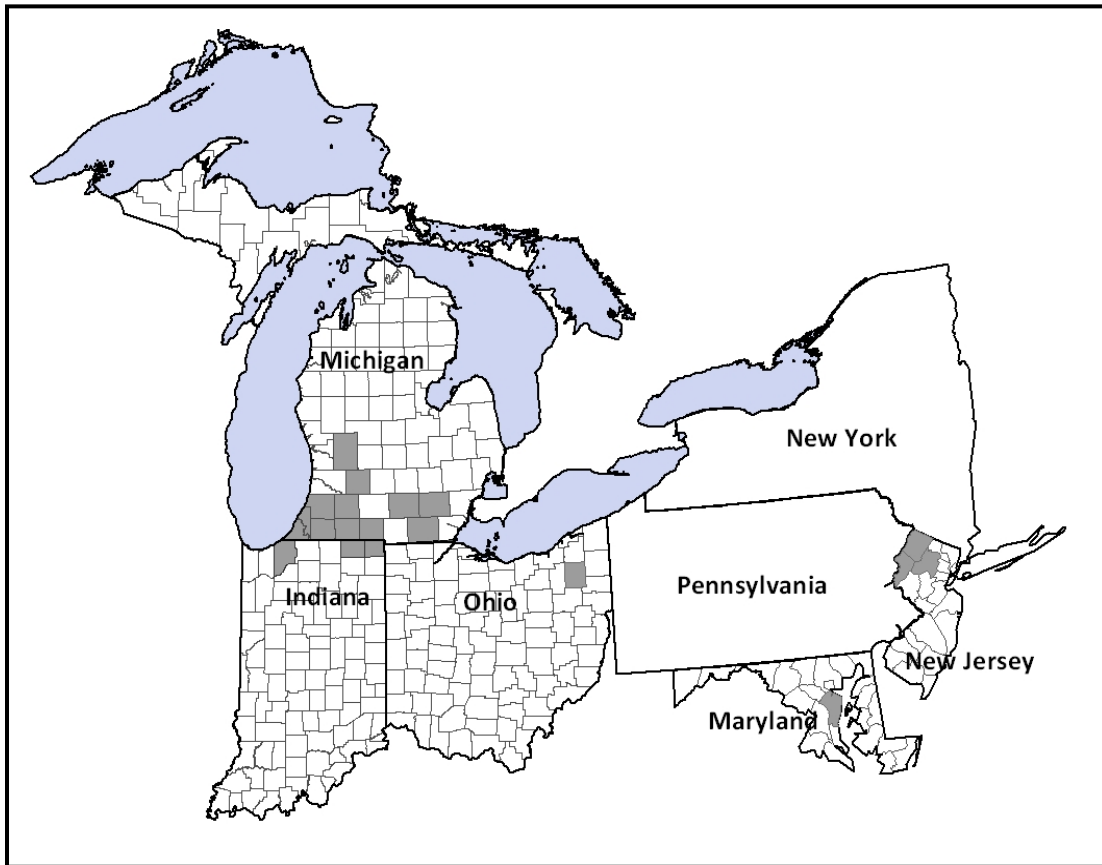


Figure 1. Historical distribution of Mitchell's satyr butterflies within the states of Michigan, Indiana, Ohio, New Jersey, and possibly Maryland. Shaded areas represent counties of documented or reported occurrences.

- 2) **Delisting the species will be considered when nine additional, for a total of 25, geographically distinct, viable populations or metapopulations are established or discovered range wide and remain viable for five consecutive years following reclassification.** A minimum of 15 of these sites will be protected and managed to maintain Mitchell's satyr habitat by state or federal agencies or by private conservation organizations before delisting will be considered.

Of the 17 sites in the northern portion (Michigan and Indiana) of the Mitchell's satyr range, two occur entirely on state land and one entirely on conservancy-owned property. Five sites are located partially on conservancy and other

private lands. Two sites are present on a mix of jurisdictions, including county, private, and land conservancy-owned land. The remaining sites are located entirely on private lands. (See Appendix C)

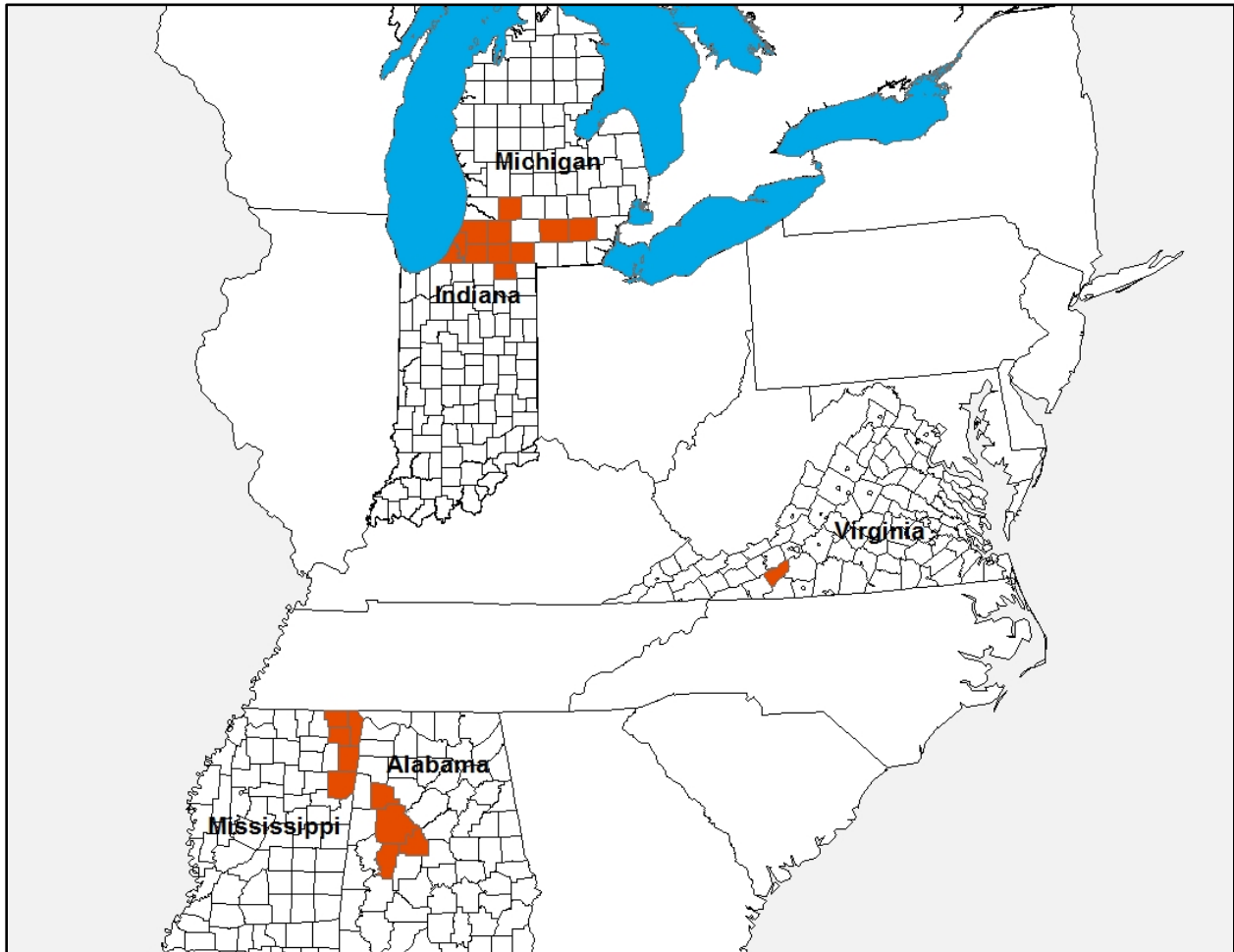


Figure 2. The current distribution of Mitchell's satyr in Michigan, Indiana, Virginia, Alabama, and Mississippi.

In the southern states, Mitchell's satyr occupied habitat occurs on a combination of federally and privately-owned lands. In Virginia, all occupied satyr sites, except one, are located on private lands (Steve Roble, Virginia Natural Heritage Program, pers. comm. 2012). One site is State of Virginia-owned and managed as a state natural area (Roble pers. comm. 2012). Most sites in Alabama are located on U.S. Forest Service (USFS) lands in the Oakmulgee Ranger District of the Talladega National Forest (Hart 2004). In Mississippi, seven Mitchell's satyr colonies are found on private land, one on National Park Service (NPS) land along the Natchez Trace Parkway, one on U.S. Army Corps of Engineers (USACE) property, and two on State property (Surette *et al.* 2010, Paul Hartfield, USFWS, pers. comm. 2013).

Both the reclassification and delisting criteria have not been met and at most northern sites, the Mitchell's satyr continues to decline in numbers, as well as in

habitat quality. Additionally, only a few sites are located on protected land; however, several private landowners work with conservation organizations and MNFI to protect the butterfly and its habitat on their properties. Population decline is caused by various factors including loss and disruption of suitable fen habitat, degradation of suitable habitat, hydrological disturbances, invasion by non-native species, isolation of suitable occupied sites, and possibly genetic factors.

Limited survey efforts in Mississippi continue to locate previously unknown colonies, however, the extent and status (i.e., stable, increasing, or declining) of the southern populations has not been determined. Additionally, if the results of the ongoing genetics study prove that these populations are *N. mitchellii mitchellii*, then the species' historical and known range will have to be reconsidered, and the recovery criteria would need to be reassessed.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history:

Life cycle

The recovery plan provides a description of the Mitchell's satyr life cycle. It mentions that the species is single-brooded range-wide and under caged conditions, McAlpine *et al.* (1960) noted that eggs hatch within 7 to 11 days, larvae feed through summer until reaching the fourth instar, then diapause to resume feeding the following spring. Mitchell's satyrs are mostly found in close association with dense stands of *Carex stricta*, a sedge that is the primary host plant. Adults fly in late-June through mid-July, with peak flight typically occurring during the first two weeks of July. Males generally emerge a few days before females.

Additional information has been gathered on the Mitchell's satyr life cycle since the recovery plan. Darlow (2000) noted that Mitchell's satyr larvae are difficult to locate in the field. However, the larvae have been studied in captivity. Tolson and Ellsworth (2010) observed captive-reared satyrs to overwinter in the fourth instar at the base of *C. stricta*. The larvae then resume eating the following spring. In late-spring to early-summer, usually around late-May to late-June, larvae form a chrysalis which persists for 10–15 days (McAlpine *et al.* 1960). The chrysalis transitions in color from light green to medium green about 48 hours prior to eclosion (Hamm *et al.* 2013). Adults emerge in mid-June to late-July. In recent years, the peak flight has occurred from the last week of June through the first week or two in July (Hyde, pers. comm. 2012).

The northern populations are univoltine. Peak flight is usually in the first week of mid-July (Szymanski 1999). During the Toledo Zoo's captive rearing experiments, Tolson *et al.* (2006) found that Mitchell's satyr is only facultatively constrained to a single flight in Michigan, and that more eggs could be produced from conservation breeding by artificially producing two flights in captivity. Populations in Virginia are also univoltine, with an approximately three-week flight period, ranging from late-June and ending in mid-July (Roble *et al.* 2001). Mitchell's satyrs in Alabama and Mississippi are bivoltine, with flight periods ranging from late-May to late-June and from early-August to early-September (Hart 2004). Protandry (the emergence of males prior to female emergence) is also exhibited in the southern populations (Hart 2004). For the northern and southern populations of Mitchell's satyr, it appears that voltinism is controlled by accumulated degree-days as second generations can be induced by rearing at higher temperatures and a single generation can be induced in Alabama populations through rearing at cooler temperatures (Hamm *et al.* 2013).

Oviposition Behavior, Host Plants, and Larvae

The recovery plan identified that the reproductive biology of Mitchell's satyr is poorly documented. Although it has not been observed ovipositing in nature, experiments with gravid females caged with *Carex stricta* indicated that its host plants are almost certainly sedges, and *C. stricta* is probably the primary host plant (McAlpine *et al.* 1960, Rogers *et al.* 1992).

Since issuance of the recovery plan, research has been conducted to better understand Mitchell's satyr oviposition, other behaviors, and food and host plants.

Female Mitchell's satyrs have been documented to exhibit certain behaviors prior to oviposition. During his study of a Michigan population, Darlow (2000) noted two general stages in the selection of oviposition sites: (1) selection of location, which is possibly chosen based on structural attributes such as shade, microclimate, humidity, or temperature; and (2) selection of suitable host plants. More specifically, Darlow (2000) found that after a resting period, females engaged in a dispersal flight, which later changed to an inspection flight, characterized by flying in a circle just below or at vegetation level. This was followed by another resting period, then a short, direct hop down low in the vegetation, below the sedge and grass canopy, either landing on a forb for oviposition or rejecting the plant (Darlow 2000, Hyde *et al.* 2000). In a mark-release-recapture study, Barton and Bach (2005) noticed females flying at greater frequencies during what was designated in the study as the mating period (when male and female ratios are equal) and throughout the flight season than were previously reported in Szymanski *et al.* (2004).

Upon selecting a suitable plant, females would land on the edge of a leaf, curl their abdomen below the leaf surface, lay an egg, uncurl the abdomen, and

repeat the process until a cluster of eggs was laid (Darlow 2000). Hyde *et al.* (2000) documented egg-laying events about 2 to 4 inches from the ground surface and on the underside of small forb leaves. After laying eggs, the female would make a direct hop higher up in the vegetation, near the oviposition site, to rest before pre-oviposition behavior recommenced (Darlow 2000). Several studies (Darlow 2000, Hyde *et al.* 2000, Szymanski 1999) have documented ovipositioning occurring only during the afternoon hours (between 1345 and 1745, with the majority occurring between 1517 and 1627).

In the wild, Darlow (2000) recorded oviposition on a variety of forbs: marsh shield fern (*Dryopteris thelypteris*), tall meadow rue (*Thalictrum polygamum*), Joe-pye weed (*Eupatorium maculatum*), goldenrod (*Solidago* spp.), and a few unidentified forbs. Captive-reared Mitchell's satyrs at the Toledo Zoo showed a preference for clearweed (*Pilea pumila*) (Tolson *et al.* 2006). Females caged by Legge and Rabe (1996) in a southwest Michigan fen preferred northern bog violet (*Viola neprophylla*). Females usually lay eggs on wildflowers and not food plants. Roble *et al.* (2001) and Hart (2004) observed the southern populations of Mitchell's satyr engaging in mate-locating patrolling by the males, and Hart (2004) further noted oviposition on *Carex bromoides* in Alabama.

Upon hatching, Mitchell's satyr larvae migrate to food plants (Tolson *et al.* 2006) and will select and feed upon a variety of plants, including those that do not support successful development (Ellsworth and Tolson 2012). The Toledo Zoo's food preference trials for captive larvae identified six species of *Carex* (*C. buxbaumii*, *lasiocarpa*, *leptalea*, *prairea*, *sterilis*, and *stricta*) and two grasses (*Panicum amplicatum* and *Poa palustris*) that support normal development until the 3rd instar diapause in August (Ellsworth and Tolson 2012). Through observations in Alabama, Hart (2004) noted oviposition on *C. bromoides*, and Roble *et al.* (2001) considered *Scirpus expansus* and other sedges as potential larval host plants in Virginia. These sedges and grasses are found in fens, sedge meadows, tamarack swamps, and other wetlands.

Adult Mitchell's satyrs are generally short-lived, with the average male living between two to five days and female two to four days (Szymanski *et al.* 2004). It is also rare to observe them feeding, especially in the northern portion of the species' range. Szymanski (1999) did not report Mitchell's satyrs nectaring; however, Darlow (2000) observed Mitchell's satyrs nectaring on mountain mint (*Pycnanthemum virginianum*), black-eyed Susan (*Rudbeckia hirta*), and swamp milkweed (*Asclepia incarnata*). Nectaring by Mitchell's satyrs has been observed on several occasions in the south (Hart 2004). In Virginia, Roble *et al.* (2001) recorded 14 nectaring events with adults visiting swamp milkweed, common milkweed (*Asclepias syriaca*), yarrow (*Achillea millefolium*), Queen Anne's lace (*Daucus carota*), and crown vetch (*Coronilla varia*). Mitchell's satyr has been observed nectaring only twice in Alabama (Hart 2004). Two

females butterflies were recorded nectaring on *Sagittaria latifolia* near the end of the second flight period in September 2002 and 2003 (Hart 2004).

Habitat

Mitchell's satyr habitat was originally described as bog fen (Schuey 1985, 1986). Since then, its habitat classification in the northern portion of its range has been more specifically described as prairie-fen (Spieles *et al.* 1999, Kost *et al.* 2007). Both bogs and prairie fens occur on peat soils. Prairie fens are sedge-, grass- and wildflower-dominated wetlands with alkaline soils and a continuous supply of cold groundwater that is rich in calcium and magnesium carbonates and persists throughout the year, whereas bogs have acidic soils and are fed by precipitation (Kost and Hyde 2009). Additionally, prairie fens occur in groundwater discharge zones, within a complex subsurface hydrology composed of hummocky topographies of glacial moraines and an extensive network of small streams, lakes, and other wetlands (Abbas 2011).

Abbas (2011) modeled the groundwater flow regimes of prairie fens in southern Michigan and identified source water for selected fens, including those containing Mitchell's satyr. He found that most fen sites occur around regional groundwater mounds and major rivers seem to have their headwaters emerging around these mounds. While identifying the source water areas, Abbas (2011) indicated that many fens have a "multi-scale" groundwater flow system, meaning that they are charged locally (surface water sources from a few 100 meters to a couple kilometers), sub-regionally (surface water sources or recharge areas a couple kilometers to approximately 10 kilometers away), and regionally (recharge areas tens of kilometers away). Additionally, Abbas (2011) reported that groundwater recharge may seep into the fen through shallow, relatively short, groundwater flow paths or through much farther, deeper paths. Prairie fens located far apart from each other, in different watersheds, or even in different counties or states, may share the same regional source water areas (Abbas 2011).

Currently, extant populations of Mitchell's satyrs in Michigan and Indiana are found exclusively in fens and open tamarack stands with rich tamarack swamps. Within the fens, Mitchell's satyrs occur usually within three meters of woody vegetation (Barton and Bach 2005). They also prefer forest edges and shrub/tree areas and avoid open sedge meadows (Barton and Bach 2005). The Michigan DNR advised in the draft Habitat Conservation Plan for Mitchell's Satyr Butterfly in Michigan and Indiana that Mitchell's satyrs in more open fens occur along the shrubby edges, and satyrs in fens with more tamarack or woody vegetation are found in open, grassy lanes between trees and shrubs (Michigan DNR 2012). Barton and Bach (2005) recommended that habitat management activities in occupied Mitchell's satyr habitat should avoid creating large open sedge meadows when reducing shrub or small tree cover. Furthermore, a matrix of open fen, shrub-carr zones, and sufficient transitional edge habitat should

ensure the highest probability of increasing satyr populations (Barton and Bach 2005).

Fens also provide the microclimate and other attributes Mitchell's satyrs use when selecting oviposition sites or escaping the higher summer temperatures (Darlow 2000). Hamm (2012) and Hamm *et al.* (2013) cite evidence that suggests there are significant differences between ground level and air temperatures, with ground-level temperatures warmer than air temperatures in winter and cooler in summer. The sedge tussocks may provide insulating qualities and contribute to the warmer ground-level temperatures in winter (Hamm *et al.* 2013).

Southern populations of Mitchell's satyr are not found in prairie fens, as prairie fens are confined to glaciated portions of the north-central U.S. (Amon *et al.* 2002, Godwin *et al.* 2002, Spieles *et al.* 1999, Wilcox *et al.* 1986). Most of the southern sites supporting Mitchell's satyr in Alabama are small, localized herbaceous-shrub patches, dominated by a diverse assortment of sedges and other wetland graminoids (Hart 2004). Additionally, the majority of these sites are located in wetlands that are associated with or influenced or created by beaver activity (Hart 2004).

Hart (pers. comm. 2012) provided the following information to describe the relationship among beaver activity, creation of Mitchell's satyr habitat, and succession in the Oakmulgee Ranger District of the Talladega National Forest. "Many of the stream drainages that support beaver populations often have a number of dams and lodges interspersed throughout the drainage. Over time, incredibly complex mosaics of wetland habitats representing various seral stages are created. It is under this constant shifting of habitat succession that suitable Mitchell's satyr habitat patches are created. These patches are often small (<0.5 ha) and are present for brief periods before succession reclaims them. With persistent beaver activity, new habitat is created almost annually. These small patches are considered to be interconnected within the greater wetland complex of the respective drainage."

Because beaver activity, Mitchell's satyrs, and succession are linked, the long-term conservation of Mitchell's satyr in this region is dependent upon preserving the complex dynamics of 'intact watersheds' (Hart, pers. comm. 2012). The Oakmulgee Ranger District is possibly one of the best laboratories left to study the dynamics of this species (Hart, pers. comm. 2012).

A few of these southern occupied sites occur outside of beaver-influenced wetlands and are either associated with low, semi-open riparian areas and saturated depressions within floodplain forests, or supported by a spring and possibly groundwater intrusion (Hart 2004, Surrette *et al.* 2010). More specifically, the two occupied sites in Mississippi are both located on seepage slopes at the base of steep, moist, upland woods (Surrette *et al.* 2010). The

common component of both the northern and southern occupied Mitchell's satyr habitats is the species' occurrence in highly localized wetland habitats dominated by sedges in the genus *Carex* (Hart 2004, Landis *et al.* 2012).

Most of the Mitchell's satyr occupied sites in Virginia are small open-canopy areas, dominated by bulrushes (*Scirpus* spp.) and sedges (*Carex* spp.), within boggy seepage wetlands on lightly to moderately grazed pastures (Roble *et al.* 2001). Roble *et al.* (2001) found that these wetlands occupy only a small portion of the pastures. In Virginia, occupied habitat does not appear to be as fragmented as it is in the northern part of the range. Roble *et al.* (2001) noted that multiple sites occur in close proximity to each other (0.6–2.0 km) and are located along four different streams. Also, occupied sites in Virginia are not found in calcareous wetlands, bog fens or prairie fens, but contain a similar vegetative structure as occupied sites in Michigan and Indiana (Roble *et al.* 2001).

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

At the time of the emergency listing, as well as the final rule listing Mitchell's satyr as an endangered species, historical records documented Mitchell's satyr occurrence in approximately 30 locations, within 18 counties of four states, ranging from southern Michigan, adjacent counties of northern Indiana, and a single Ohio county, with disjunct populations in New Jersey. Now, only 16 extant butterfly populations are known in southern Michigan and one in northern Indiana (Hyde, MNFI, pers. comm. 2012). Despite the fact that seven new sites were discovered since 1986, the population overall is in decline. In 2009, there were 18 extant sites and 19 sites the previous year (Hyde, pers. comm. 2012). In the 25 years that MNFI has been conducting Mitchell's satyr surveys, the species has been lost from ten of 20 occupied sites, and 30 or fewer individuals are present in many sites where it still occurs (Landis *et al.* 2012; Hyde, pers. comm. 2012). Abundance of sites has declined, as well as abundance at some extant sites, leaving these populations more vulnerable and possibly unable to adapt to long-term environmental stochastic events (Lande and Shannon 1996, Hamm and Landis 2010).

The southern populations of Mitchell's satyr are known to occur in Alabama, Mississippi, and Virginia (Figure 2). Mitchell's satyrs have been recorded at 28 sites in the Fall-Line Hills region of central Alabama (Hart 2004). Surveys conducted in Mississippi in 2010 revealed two new colonies in Itawamba County and one in Tishomongo County, also in the Fall-line Hills region (Surette *et al.* 2010). These surveys did not locate the two previously discovered colonies from 2003. Limited surveys over the past two years have documented the occurrence of 11 extant colonies in five Mississippi counties. According to surveys conducted during 1999–2001 in Virginia, Mitchell's satyr

is known from 17 sites in Floyd County, located in Blue Ridge Mountains of southwest Virginia (Roble *et al.* 2001; Roble pers. comm. 2012; Virginia Natural Heritage Program – Virginia Dept. of Conservation and Recreation, vanhde.org, accessed May 30, 2013). Abundance and population trends are unknown for these sites. Metapopulation ecology is also unknown for the southern populations.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Genetics

In 1998, butterflies that appeared to be Mitchell’s satyrs were discovered in southwest Virginia (Roble *et al.* 2001). Two years later, Glassberg (2000) photographed a single Mitchell’s satyr in west-central Alabama. In 2003, an entomologist found the satyr in northeastern Mississippi (Hart 2004). Additional butterflies were found during subsequent searches between those time periods and after (Roble *et al.* 2001, Hart 2004).

Morphologically (based on wing maculations), these butterflies resembled the St. Francis satyr (*N. m. francisi*), more than Mitchell’s satyr, but molecular analysis suggested a closer relationship with Mitchell’s satyr (Goldstein *et al.* 2004). Results of this study also indicated that a more formal taxonomic revision be considered for the *N. mitchellii* complex (Goldstein *et al.* 2004). Based on these findings, the southern populations were designated protection as Mitchell’s satyr under the ESA until the taxonomic identity is resolved (cited in Hart 2004 as David Rabon, USFWS, pers. comm. to Steve Hall, North Carolina Heritage Program)².

Molecular studies have been conducted to better understand the relationship within the *N. mitchellii* complex (Goldstein *et al.* 2004, Hamm 2012). These preliminary genetic studies have been inconclusive on the taxonomic relationships of Mitchell’s satyr butterfly populations discovered in Alabama, Mississippi, and Virginia to each other, and with the listed Michigan and Indiana populations. Additional genetic and morphological research is ongoing to clarify these relationships.

2.3.1.4 Taxonomic classification or changes in nomenclature:

There have been no changes in nomenclature. Taxonomic investigations are currently under way to determine relationships between regional populations.

² ESA protection assigned to the southern populations as an endangered species (Mitchell’s satyr butterfly) is referenced in Goldstein *et al.* (2004) as a personal communication from David Rabon, USFWS, Raleigh Office (no year indicated) as follows: “The policy of USFWS is to assume that newly discovered populations belong to one or the other of only two described subspecies, and to extend protection to them until proven otherwise.”

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

Intensive searches were conducted for Mitchell's satyr from 1985 to 1990, at over 100 sites that had suitable habitat throughout its known range, including known historical sites or sites selected due to the presences of a fen (57 FR 21564). The results of these searches revealed that Mitchell's satyr had disappeared from approximately one-half of its defined historical range (57 FR 21564). The discovery of new populations in VA, AL, and MS suggest a much wider historical distribution of the species than was previously known.

Michigan

At the time of listing and according to the species searches conducted from 1985 to 1990, Mitchell's satyr was currently believed to exist in nine counties in Michigan and Indiana (57 FR 21564). The recovery plan (USFWS 1998) reports that Mitchell's satyr is historically known from 11 counties (22 sites) in Michigan, and extant populations are known from seven of those at 13 sites. Mitchell's satyr is currently found in nine counties: Barry, Berrien, Branch, Cass, Jackson, Kalamazoo, St. Joseph, Van Buren, and Washtenaw. It occurs in fens ranging in size from less than 0.5 hectare to 130 hectares (1.24–321.24 acres), with 46% percent of sites less than 5 ha (12.36 ac) and 21% less than 2 ha (4.94 ac) (Landis *et al.* 2012). Approximately 504 acres of fragmented occupied Mitchell's satyr habitat occurs in Michigan and Indiana combined (Michigan DNR 2012). Occupied sites in Michigan and Indiana are highly fragmented, and the majority is small in size.

Indiana

At the time of listing Mitchell's satyr was currently believed to exist in nine counties in Michigan and Indiana (57 FR 21564). The recovery plan (USFWS 1998) states a total of four or five sites in the counties of Lagrange, Laporte, and Steuben are known to have supported Mitchell's satyr. However, as of 2008, the butterfly occurs only in Lagrange County.

Ohio

Mitchell's satyr was known from a single Ohio county at the time of listing (57 FR 21564). According to the intensive Mitchell's satyr searches conducted from 1985 to 1990, no extant populations were found in Ohio. The recovery plan (USFWS 1998) lists Portage and possibly Seneca counties as supporting historical populations of Mitchell's satyr. As of 2013, the species is considered extirpated from the state.

New Jersey

At the time of listing, several disjunct populations of Mitchell's satyr were historically documented as occurring in New Jersey (57 FR 21564). In 1985,

only one population remained and in 1991, during the species searches in the state, no Mitchell's satyrs were found; possibly lost to over-collection (57 FR 21564).

Alabama

At the time of listing, Mitchell's satyr populations were not known to occur in Alabama.

Currently, twenty-eight sites are occupied by Mitchell's satyr in the central portion of the state within the Fall Line Hills physiographic province in the counties of Bibb, Hale, Fayette, and Tuscaloosa (Hart 2004). Most known sites occur within the Oakmulgee Ranger District of the Talledega National Forest (Hart 2004).

Mississippi

At the time of listing, Mitchell's satyr populations were not known to occur in Mississippi. Two populations of Mitchell's satyr were first documented along Natchez Trace Parkway in Prentiss and Tishomongo counties in 2003 located within the Fall Line Hills region (Hart 2004). Surveys in 2010 discovered two new colonies: one in Itawamba County and one in Tishomongo County (Surrette *et al.* 2010); however, butterflies were not found at the two original sites. Since 2010, limited survey efforts have discovered nine additional colonies in Mississippi, for a current total of 11 extant colonies in Tishomingo (3 colonies), Prentiss (1), Alcorn (1), Itawamba (1) and Monroe (5) counties.

Virginia

At the time of listing, Mitchell's satyr populations were not known to occur in Virginia.

Based on surveys conducted during 2000–2001, Mitchell's satyr is known from 17 sites in the southwest portion of the state (Roble *et al.* 2001). These populations lie within the Blue Ridge Mountains region in Floyd County (Roble *et al.* 2001; Roble, pers. comm. 2012).

The southern populations are highly disjunct, with Alabama and Mississippi populations occurring closer together, though they are separated by 115 miles (Goldstein 2004). Populations in Virginia are nearest to the northern range of Mitchell's satyr, but separated by approximately 300 miles from the nearest population, which is an extirpated site in Ohio (Goldstein 2004). Abundance and population trends are unknown for these sites.

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

Six of the 16 occupied sites in Michigan currently contain or have the potential to contain viable populations of Mitchell's satyr (Hyde, pers. comm. 2011,

2012) (Appendix A). Butterflies at the remaining ten sites occur in much lower numbers, or the amount of habitat is limited in size or by threats to the site, making their long-term viability uncertain (Hyde *et al.* 2001; Hyde, pers. comm. 2012). Site conservation plans aimed at reducing or eliminating threats at each site have been developed to promote long-term management at each Michigan location. In Indiana, decline in habitat at one site resulted in population extirpation. Habitat at the second site is also deteriorating and only a few butterflies were observed in 2012 (Shuey, TNC-Indiana Chapter, pers. comm 2012).

Mitchell's satyr habitat in the southern U.S. is also dominated by sedge species and much of the habitat is located on protected land. In Alabama and Mississippi, Mitchell's satyr occurs primarily on federal lands: Talladega National Forest (USFS – Alabama), Natchez Trace Parkway (NPS – Mississippi, and U.S. Army Corps of Engineers (USACE) property (Mississippi). The Talladega National Forest has designed their wetland and beaver management programs to ensure protection of Mitchell's satyr. The NPS protects all native species, regardless of federal status, and the USCOE is also aware of the presence of the satyr on their property and manages accordingly. Colonies located on State property (2) are also considered in management decisions. Populations located on private land in these states may not be adequately protected, however land owners are being contacted and notified of their presence.

Succession of graminoid-dominated seepage wetlands to forested habitats threatens Mitchell's satyrs in Michigan, Indiana, and Virginia. Conversely, Mitchell's satyr habitat in Alabama and Mississippi is dependent upon the constant shifting of habitat succession. However, succession of satyr habitat is likely to be altered with beaver control and eradication programs.

2.3.1.7 Other information on Mitchell's satyr:

Michigan and Indiana DNRs have applied for a section 10(a)(1)(B) Incidental Take Permit (ITP) to incidentally take Mitchell's satyr butterfly on non-federal lands in Michigan and Indiana. The ITP allows for incidental take associated with otherwise lawful activities. A Habitat Conservation Plan (HCP) includes measures to minimize and mitigate for take authorized by an ITP. Michigan and Indiana DNRs have prepared a draft HCP, which focuses on habitat restoration, management, monitoring, and other conservation actions to benefit Mitchell's satyr.

2.3.2 Five-Factor 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 mechanisms, and (5) limited ability to recolonize new habitat patches.

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

Human-induced destruction and natural succession are the leading causes of Mitchell's satyr habitat decline. Loss of habitat has occurred throughout the historic range of the species and continues in some locations as a result of succession, altered hydrology, agricultural conversion, weed plant invasion, and development. Most of the destructive activities are linked in some way to the hydrology that controls the groundwater flow and water quality in the fen.

The primary threat to the continued survival of Mitchell's satyr in the north is loss and disruption of suitable fen habitats. Urbanization, agricultural conversion, and highway construction have led to disruption of key ecological processes that are necessary to create and maintain habitat (Wilsman and Schweitzer 1991, Shuey 1997). Wetland alteration or complete draining has resulted in the loss of the single known Ohio population of the butterfly and in the loss of populations at several sites in Michigan (USFWS 1998). Wetland alteration and the influx of nutrients (e.g., fertilizers, leaking septic fields, salt spray) from adjacent farms and residential structures have also led to changes in nutrient inputs (Panno *et al.* 1999, Kost and Hyde 2009).

The addition of nitrogen, phosphorus, and salts provides a competitive advantage to aggressive nuisance plants, such as purple loosestrife, glossy buckthorn, narrow-leaved and hybrid cattails, non-native phragmites, and reed canary grass. These invasive plants form monocultures and reduce species diversity at Mitchell's satyr sites. The fine-leaved sedges that the larvae use as food plants are light-demanding and can be quickly crowded out by these invasive plants. Although which microhabitat variables are most critical to the satyr at various stages of its life cycle is unknown, it is clear that these invasive species drastically alter the community structure and microhabitat in the wetlands where they occur (Hyde *et al.* 2001).

Pesticide use (e.g., gypsy moth control), pollution, flooding, and cattle grazing are potential threats at some sites. In addition, a few sites adjacent to power line or railroad rights-of-way (ROW) need to be maintained by the utility

companies. If not performed properly, vegetation removal at these sites may damage habitat or harm Mitchell's satyrs.

Gravel mining projects are also occurring in the vicinity of a Mitchell's satyr occupied fen and nearby unoccupied fen that contains potential habitat for the species in Kalamazoo County, Michigan. Both projects have the potential to adversely affect the satyr through impacts on groundwater quantity, quality, and flow. The property owners have worked with the Service to develop groundwater monitoring plans that include installation of monitoring wells and data loggers to track groundwater levels and fluctuations in the area.

Also in Michigan, historical practices at a copper tubing manufacturing facility in Cass County have contaminated the groundwater, soil, and surface water with trichloroethene (TCE) and other volatile organic compounds (VOCs) in the vicinity of the facility and surrounding areas. An occupied Mitchell's satyr site is located near the facility, and the groundwater is impacted with the contaminants. Mitchell's satyrs persist at the site, but their numbers are declining and the habitat is becoming more degraded through invasive species encroachment (Hyde, pers. comm. 2011). The U.S. Environmental Protection Agency (USEPA) is working with the facility's owner on a Resource Conservation and Recovery Act Corrective Action Administrative Order on Consent that requires the facility to address its release of hazardous waste and hazardous constituents into the environment. The company has completed a Corrective Measures Proposal to address and remove contaminants from the environment. The Service and USEPA provided comments on the facility's proposal.

Similarly in Virginia, wetlands in the Blue Ridge Mountains have recently been subjected to ditching and draining (Roble *et al.* 2001). Roble *et al.* (2001) further noted one site that contained Mitchell's satyr was altered and observed evidence of past ditching at five other sites. Livestock, primarily cows and horses, also grazed in some sites occupied by Mitchell's satyr, and although excessive trampling was not apparent, potential threats related to grazing exist (Roble *et al.* 2001).

Alabama and Mississippi have sites that are threatened by private landowner activities such as silviculture or beaver control (Hartfield, pers. comm. 2012). Hartfield (pers. comm. 2012) also advised that land management activities at other sites may consider the species presence and managers design activities to avoid direct impacts to the species and its habitat.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes

The recovery plan identified collection of Mitchell's satyr for the black market, which may have eliminated a few populations, as a threat (USFWS 1998).

Collection of Mitchell's satyr is allowed only with a permit issued by the Service. Currently, illegal collection of Mitchell's satyr does not appear to be a significant threat, as the Service is not aware of any such collection activities. Mitchell's satyr is a very rare butterfly, and illegal collecting can likely become a significant threat as long as the monetary reward exceeds the perceived risk of knowingly violating federal and state laws (USFWS 1998).

2.3.2.3 Disease or predation

Disease and predation of Mitchell's satyr are not identified in the recovery plan. However, various predators have been observed to prey upon the satyr. During captive rearing experiments, the Toledo Zoo documented predation on Mitchell's satyr eggs and larvae by *Theriid* spiders (Tolson *et al.* 2006). *Theriid* spiders are really small, about the size of a pin-head, and are possibly transported to the zoo in soil to be used as Mitchell's satyr rearing substrate. These and other spiders are also suspected to prey on the satyr in their habitat as well. It is also likely that Mitchell's satyr adults are preyed upon by birds and dragonflies (Hyde, pers. comm. 2012).

Aerial predation events were observed to occur when the satyrs exposed themselves by flying over sedges, instead of through them (Hamm 2012). Hart (2004) observed a female *Erythemis simplicicollis* dragonfly capture and consume an adult male Mitchell's satyr on two separate occasions at occupied sites in Alabama. The spider, *Argiope aurantia*, is also a very common predator in occupied habitat (Hart 2004). Hart (2004) has found remains of other species of dragonflies, butterflies, and moths in the large webs of this species, but none belonging to Mitchell's satyrs thus far (Hart 2004). Potential vertebrate predators in Alabama sites include the Carolina anole (*Anolis carolinensis*) and various bird species.

Wolbachia

Wolbachia is a genus of intracellular bacterial parasites that are commonly found in arthropods and nematodes (Werren *et al.* 2008). Hamm (2013) documented several *Wolbachia*-infected Mitchell's satyrs from sites in Michigan. *Wolbachia* are maternally inherited bacteria that are considered reproductive parasites because they increase the production of infected female hosts (Moran *et al.* 2008, Werren *et al.* 2008, Nice *et al.* 2009) while decreasing the fitness of uninfected individuals (Hamm and Landis, unpub. report 2010). Infected individuals have manipulated reproductive systems that exhibit the following phenotypes, as described by Werren *et al.* (2008): "(1) feminization of genetic males, (2) parthenogenic induction in the host, which results in development of unfertilized eggs, and (3) cytoplasmic incompatibility, in which the sperm and egg are incompatible, resulting in the killing of male progeny from infected females."

The above phenotypes also increase the spread of *Wolbachia* by creating more infected females in the population and eliminating or reducing the amount of males (Hamm 2012). Infected females that mate with uninfected males produce *Wolbachia*-infected offspring. Only pairings of males and females infected with the same *Wolbachia* strain result in fertile offspring (Nice *et al.* 2009, Hamm and Landis 2010).

Based on simulation models performed by Nice *et al.* (2009), documenting the demographic effects of the spread of *Wolbachia* infection to uninfected populations and metapopulations, an infection might further reduce already small population sizes and substantially increase the probability of population extirpation. Hamm (2012) also noted that such an infection or the introduction of a novel strain of *Wolbachia* into a small population can reduce the effective population size and induce a genetic bottleneck or result in population extinction. However, the population reduction is a temporary effect that lasts until the infection is fixed or extinct in the population (Nice *et al.* 2009).

At this point, the bacterial parasites may not be a threat as long as butterflies are not taken from an infected population for captive propagation or to augment existing populations (Nice *et al.* 2009). Therefore, Nice *et al.* (2009) and Hamm (2012) suggest screening a sample of individual butterflies for *Wolbachia* and identifying and understanding the strains in a population before those butterflies are reared and released into a recipient population.

2.3.2.4 Inadequacy of existing regulatory mechanisms

The 1992 Final Rule listing Mitchell's satyr as an endangered species (FR 21564–21569) advised that Mitchell's satyr is listed under state statutes as endangered in Michigan, Indiana, and New Jersey, and extirpated in Ohio.

Since the final listing rule, new populations of what morphologically appears to be *N. mitchellii* have been discovered in Alabama, Mississippi, and Virginia. In all locations, the butterfly is federally recognized as an endangered species. Listing under the ESA offers protection to this species, primarily through the recovery and consultation processes. Also, Mitchell's satyr is a wetland-dependent species and laws and regulations that protect wetlands and groundwater would provide additional protection.

In Michigan and Virginia, Mitchell's satyr receives full protection as endangered species under the respective states' endangered species protection laws. The Michigan Endangered Species Protection Law (Public Act 451 of 1994, Part 365) as well as the Virginia Endangered Plant and Insect Species Act (Chapter 10 §3.2–1003) prohibit taking, possessing, transporting, importing, exporting, buying, and selling of their state's endangered and threatened species. Additionally, the Michigan Endangered Species law allows Michigan DNR to establish programs for management of threatened and endangered

species and enter into cooperative programs with other states, federal agencies, and private persons for administration and management of the programs.

In Indiana, only vertebrates, mollusks and crustaceans classified as endangered are protected from taking, pursuant to the Nongame and Endangered Species Act of 1973 (IC 14-22-34). Insects are not included. Management authority for insects in Indiana comes from general authority by the state to manage wildlife resources.

Mitchell's satyr was listed in Mississippi as a state endangered species in 2011. The Mississippi endangered species law prohibits taking, possessing, transporting, exporting, processing, selling, offering to sell or offering to ship endangered species. Penalties for violations include fines and/or imprisonment. Alabama recognizes Mitchell's satyr as an imperiled species (S1/S2).

2.3.2.5 Other natural or manmade factors affecting its continued existence

The Final Listing Rule (57 FR 21567) identifies characteristics of Mitchell's satyr that may limit the species' ability to colonize new or historical habitat patches or provide significant gene flow among extant populations. As such, isolation of small populations makes the species more susceptible to local extinction if habitat degradation and/or collection pressure are also occurring (Wilsman and Schweitzer 1991 in 57 FR 21567).

Current natural or manmade factors affecting Mitchell's satyr include natural succession, stochastic events, such as severe thunderstorm events during butterfly emergence, genetics, beaver control, and climate change.

One of the most significant threats to Mitchell's satyr habitat in the northern portion of the range is natural succession from graminoid-dominated prairie fen to forested habitat. Non-native invasive plant species such as purple loosestrife, glossy buckthorn, reed canary grass, and cattails form monocultures and reduce species diversity at Mitchell's satyr sites. The fine-leaved sedges that the larvae use for food plants are light-demanding and can be quickly crowded out by these invasive plants. Although we do not know which microhabitat variables are most critical to the satyr at various stages of its life cycle, it is clear that these invasive species drastically alter the community structure and microhabitat in the wetlands where they occur (Hyde *et al.* 2001).

The loss of fen habitat is complicated by the disruption of landscape-scale processes that may be crucial for the maintenance of habitat suitability and the creation of new habitats for Mitchell's satyr. Historical disturbance regimes, such as wildfire, fluctuations in hydrologic regimes, and the flooding caused by beaver, have been all but eliminated or modified throughout the northern range of the species. Surviving populations now occupy highly isolated fens in which succession processes are slowed, but not eliminated, by the discharge of calcium

carbonate-laden groundwater. Eventually, in the absence of some process that resets succession to an earlier stage, the surviving fen habitats will become increasingly unsuitable as habitat for Mitchell's satyr. As such, management of Mitchell's satyr habitat is necessary to maintain fairly open, sedge-dominated communities.

As habitats become more isolated in the north, dispersal between populations and suitable unoccupied habitats becomes increasingly unlikely, and the rate of extirpation out-paces the establishment of new populations. Habitat fragmentation and isolation of occupied sites leads to more individuals being inbred and lowers the viability and fecundity of the population due to inbreeding depression (Couvét 2002, Landis *et al.* 2012). This may account for the disappearance of several historically known populations at pristine wetland sites. Couvét (2002) points out that in isolated populations of moderate size, individual viability and fecundity are expected to decrease until population extinction.

The majority of sites used by Mitchell's satyr in the south are wetlands associated with beaver activity. The disturbance regime that beavers create in the flooding of lowland areas directly aids and contributes to the formation and creation of habitats used by the satyr and provides ideal conditions for supporting its host plants (Hart 2004). Thus, it appears that the butterfly is not entirely dependent upon beaver activity, but its host plants are (Hart 2004). Therefore, wide-spread beaver control, in addition to disruption of a natural fire regime, would severely modify and possibly destroy the habitat required by Mitchell's satyr and its host plants.

Climate Change

Our analyses under the Endangered Species Act include consideration of ongoing and projected changes in climate. The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC). The term "climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2007a). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2007a).

Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has been faster since the 1950s. Examples include warming of the global climate system, and substantial increases in precipitation in some regions of the world and decreases in other regions. (For these and other examples, see IPCC 2007a, p. 30 and Solomon *et*

al. 2007, pp. 35–54, 82–85). Results of scientific analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is “very likely” (defined by the IPCC as 90 percent or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (IPCC 2007a, Solomon *et al.* 2007). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011), who concluded that it is extremely likely that approximately 75 percent of global warming since 1950 has been caused by human activities.

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (e.g., Meehl *et al.* 2007; Ganguly *et al.* 2009; Prinn *et al.* 2011). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increased global warming through the end of this century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of GHG emissions (IPCC 2007a; Meehl *et al.* 2007; Ganguly *et al.* 2009; Prinn *et al.* 2011). (See IPCC 2007b for a summary of other global projections of climate-related changes, such as frequency of heat waves and changes in precipitation. Also see IPCC 2011 for a summary of observations and projections of extreme climate events.)

Various changes in climate may have direct or indirect effects on species. These effects may be positive, neutral, or negative, and they may change over time, depending on the species and other relevant considerations, such as interactions of climate with other variables (e.g., habitat fragmentation) (IPCC 2007a). Identifying likely effects often involves aspects of climate change vulnerability analysis. Vulnerability refers to the degree to which a species (or system) is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the type, magnitude, and rate of climate change and variation to which a species is exposed, its sensitivity, and its adaptive capacity (IPCC 2007a; see also Glick *et al.* 2011). There is no single method for conducting such analyses that applies to all situations (Glick *et al.* 2011). We use our expert judgment and appropriate analytical approaches to weigh relevant information, including uncertainty, in our consideration of various aspects of climate change.

Although many species already listed as endangered or threatened may be particularly vulnerable to negative effects related to changes in climate, we also recognize that, for some listed species, the likely effects may be positive or neutral. In any case, the identification of effective recovery strategies and actions for recovery plans, as well as assessment of their results in 5-year reviews, should include consideration of climate-related changes and interactions of climate and other variables. These analyses also may contribute to evaluating whether an endangered species can be reclassified as threatened, or whether a threatened species can be delisted.

The Great Lakes have tremendous capacity for water and heat storage, which influences air temperatures and precipitation in the region (Hayhoe *et al.* 2010). Earlier climate change models indicated that increased precipitation, higher air temperatures, and reduced ice cover would increase evaporation in the Great Lakes, resulting in lake level drops of 1.5 feet to as much as 8 feet (Sousounis and Glick 2000; AMEC 2006; Kling *et al.* 2003). However, more recent models show a more variable response in lake levels. A majority of the model simulations run by Angel and Kunkel (2010) resulted in consistently warming temperatures, a wide range of wetter and drier conditions, and reductions in lake levels, yet also showed a high degree of uncertainty in possible future lake levels, depending on future emissions.

In the northern part of its range, Mitchell's satyr is a groundwater-dependent species. Fens that the species rely on are also likely to be negatively impacted by heavy precipitation events and droughts. The warmer temperatures and fewer colder days, including increased frequency of extreme rainfall events and drought, and shifting seasons could mean increased reliance by human populations on groundwater sources, especially for agriculture (Karl *et al.* 2009). Aquifer recharge rates are expected to drop, especially for the shallow aquifers (Hall and Stuntz 2007). Furthermore, even with heavy precipitation, Hall and Stuntz (2007) expect more water will go to run-off instead of percolating into the aquifers.

The number of Mitchell's satyr generations produced each year appears to be controlled by temperature. Northern populations of Mitchell's satyr, which normally produce one generation per year, can be induced in captivity to produce two generations by rearing at higher temperatures (Tolson and Ellsworth 2010; Hamm *et al.* 2013). Consistently, warmer temperatures could possibly result in a second generation in the north and Virginia, or a third generation in Mississippi and Alabama. If this occurs, the host plants could have already senesced and the appropriate food resources may not be available to support subsequent generations, resulting in death to the offspring (Hamm, pers. comm. 2011).

Also in the northern part of the range, Mitchell's satyr larvae enter diapause and overwinter on the leaves of tussock sedge and have been observed in captivity

to overwinter at the base of the plants. The tussock is usually snow-covered in winter, and larvae are likely insulated by the snow avoiding exposure to freezing temperatures. As winters become shorter and warmer, and the protection of snow cover is likely to be reduced, intermittent or completely lost, the effects on the species are uncertain and difficult to predict (Bale and Hayward 2010). For example, Bale and Hayward (2010) mentioned that diapause could be disrupted, delayed, or may not occur at all; larvae may or may not be able to survive repeated freeze-thaw cycles, or the species could take advantage of a “longer” summer season. Overall, much uncertainty surrounds Mitchell’s satyr larval and habitat responses to climate change.

In the southern portion of the range, primarily in Alabama and Mississippi, beaver control and eradication is a concern. Through the creation of dams and lodges, Hood and Bayley (2008) have confirmed that beaver have an overwhelming influence on wetland creation and maintenance and can mitigate the effects of drought. Habitat modification by beaver also increases riparian plant diversity, creates wetland habitats that support plant species not found elsewhere in riparian zones, and increases plant species diversity across the landscape by creating a novel combination of patch types (Wright *et al.* 2002, Bartel *et al.* 2010). Beaver activity has also been shown to indirectly maintain populations of St. Francis satyr (Bartel *et al.* 2010) and Mitchell’s satyr in Alabama and Mississippi and historical occurrences of Mitchell’s satyr in Michigan and Indiana.

The southeast U.S. has experienced an increase in heavy downpours and moderate to severe drought (Karl *et al.* 2009). Models further predict that Gulf Coast states will have less rainfall in winter and spring (Karl *et al.* 2009). Additionally, temperature increase and drought is expected to lead to decreased water availability and declines in groundwater recharge, soil moisture, forest growth, and dissolved oxygen in streams, lakes and shallow aquatic habitats in this region (Karl *et al.* 2009). It appears that by removing beavers, the effects of climate change will be magnified, and the ecosystem services it provides, including providing habitat for endangered butterflies, will be lost.

2.4 Synthesis

The Mitchell’s satyr is a very rare butterfly and fen habitat specialist (in northern the portion of its range) that is threatened with, among other things, the loss and disruption of suitable fen habitats. Prairie fen is also a very rare wetland and vegetation community.

Satyr populations in the northern part of the range have decreased drastically; however, multiple new populations of what appears to be Mitchell’s satyr continue to be discovered in the southeastern U.S. (Alabama, Mississippi, and Virginia). Ongoing genetics research will confirm and compare the taxonomy of the southern butterflies. In

the interim, we recommend that the southern populations continue to remain protected as Mitchell's satyr under the ESA unless more conclusive evidence indicates otherwise.

The northern populations exist primarily on private land while in the south it occurs on a mixture of jurisdictions, mostly federal and private land. Since listing and issuance of the recovery plan, new information resulting from research and management has been gathered on the species and its habitat. Although armed with more information about the species, such as oviposition behavior, host plants used during oviposition, larval food plants, and habitat characteristics, habitat management has not halted the population declines in the north.

Groundwater modeling indicates that prairie fen management should not be concentrated just within the fen and surrounding uplands, but should occur within the groundwatershed, especially since a single prairie fen could be recharged from multiple sources. However, most groundwatersheds have not been delineated and management at such a large scale is probably very costly and not feasible for land managers.

Mitchell's satyrs in the south are mostly found in beaver-influenced wetlands or semi-open riparian areas, but like their northern counterparts, they use localized wetland habitats dominated by *Carex* sedges. The ecosystem maintenance provided by beavers in Alabama and Mississippi is essential to the satyrs' existence, as well as buffering some of the effects from climate change. Like its northern counterparts, active habitat management is needed at occupied satyr sites in Virginia to control invasive and woody species encroachment to maintain an open canopy and potential dispersal corridors.

Known threats have not diminished and new threats to habitat as well as the species have been documented. An intracellular bacterial parasite, *Wolbachia*, could possibly reduce the already decreasing Mitchell's satyr population by half. Populations are isolated from each other and habitat is extremely fragmented, which leads to increased inbreeding and decreased population viability. These threats, compounded with a warming climate, makes the species even more susceptible to stochastic events that could result in extinction. New information suggests the status of the species has worsened at some locations since listing or its last status review. While the range and number of known colonies of Mitchell's satyr has expanded significantly with the discovery of the southern populations, the size and status of these populations are not very well known. Therefore, the listing classification should remain as endangered under the Act (see Appendix A).

3. RESULTS

3.1 Recommended Classification

<u> </u>	Downlist to Threatened
<u> </u>	Uplist to Endangered
<u> </u>	Delist
<u> X </u>	No change is needed

3.2 Recovery Priority Number: 3

No change in priority number.

Brief Rationale: Despite management, Mitchell’s satyr northern populations continue to decline for multiple reasons. Populations are also isolated from each other and occupied habitat is highly fragmented. As such, dispersal between populations and suitable unoccupied habitats is difficult and unlikely. The discovery of populations in three southern states improves the status and potential of recovery; however, the size and local status of these populations are unknown.

4. RECOMMENDATIONS FOR FUTURE ACTIONS

1. Complete the Mitchell’s satyr propagation plan.
 - a. Identify methodology and facilities for captive rearing.
 - b. Identify sites for reintroduction, augmentation, or introduction.
 - c. Screen chosen sites and donor populations to determine Wolbachia status and strains.
2. Implement reintroduction program.
3. Implement the Mitchell’s satyr HCP, while incorporating adaptive management techniques.
 - a. For example, adaptive management will be used to assess Mitchell’s satyr’s response to aggressive habitat management (e.g., prescribed fire) at a larger scale than previously used (burning 1/3 of an occupied site as opposed to burning only 1/5 of a site).
4. Use the completed groundwater modeling tool to accurately delineate Mitchell’s satyr habitat to provide more suitable habitat management on a larger scale, if feasible.
5. Use completed groundwater modeling tool for project planning and to predict and evaluation impacts of potential threats to Mitchell’s satyr habitat.
6. Investigate metapopulation dynamics (i.e., dispersal) in the southern range.
7. Complete genetic and taxonomic studies of northern and southern populations.

8. Continue to define the southern range of Mitchell's satyr butterfly.
9. Conduct surveys for unknown populations within appropriate habitats between the northern and southern populations.
10. Revise Recovery Plan and criteria as necessary.
11. Prioritize sites for land acquisition and acquire suitable additional suitable habitat for Mitchell's satyr.
12. Protect sites through conservation easements and continue to work with private landowners to develop conservation plans.

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Appendix A. Rankings and viability of Mitchell's satyr occupied sites in Michigan.

<i>Site Name</i>	Current rank	2011 rank	2010 rank	2005 rank	2002 rank
<i>Likely viable sites</i>					
<i>Branch County</i>	B	B	B	B	C
<i>Cass County SE</i>	C	C	C	CD	Not known previously
<i>Cass County SW</i>	C	C	C	C	C
<i>Jackson County Central</i>	AB	AB	AB	AB	C
<i>Jackson County E</i>	C	C	C	CD	D
<i>Van Buren County NW</i>	BC	BC	BC	BC	CD
<i>Potentially viable sites</i>					
<i>Berrien County N</i>	CD	CD	C	C	C
<i>Washtenaw County W</i>	CD	CD	C	C	D
<i>Cass County E</i>	CD	CD	CD	CD	C
<i>Not currently viable sites</i>					
<i>Barry County S</i>	D	D	CD	C	CD
<i>Berrien County E</i>	D	D	CD	CD	Not known previously
<i>Barry County SW</i>	D	D	D	CD	D
<i>Berrien County S</i>	D	D	D	CD	C
<i>Jackson County W</i>	D	D	D	D	D
<i>Kalamazoo County W</i>	D	D	D	D	D
<i>St. Joseph County E</i>	D	D	D	D	CD
<i>St. Joseph County W</i>	H	F	F	C	CD

Adapted from Hyde, pers. comm. 8-9-2012.

F = failed to find; Includes historical (H) sites.

Appendix B. Historical and current Mitchell’s satyr sites in Michigan.

Site name	Status	First observed	Last observed	Core area (acres)	Potential habitat (acres)	Acres of wetland	EO rank	Land ownership*
Barry South	Fair/Poor	1974	2011	2.5	72	360	D	State
Barry Southwest	Poor	1965	2009	6.6	37.5	332	D	State
Berrien East	Fair/Poor	2004	2010	4	25–30	5	D	Land conservancy
Berrien North	Good/Fair	1986	2011	2.12	3	374	CD	Private (nature center)
Berrien South	Poor	1987	2007	8	232	25	D	Private, County, State & Land conservancy
Branch	Very good	1965	2011	30.1	126.5	126.5	B	Private & Land conservancy
Cass East	Good/Fair	1889	2011	25	Unk	~300	CD	Land conservancy & private
Cass Northwest	Extirpated	1979	1993				X	Private
Cass Southeast	Fair	2005	2011	7.1	Unk	Unk	C	Private
Cass Southwest	Good	1987	2011	5.28		280.44	C	Land conservancy & private
Jackson Central	Very good	1974	2011	50	68		AB	Land conservancy & private
Jackson East	Good	1996	2011	18	80+	Unk	C	Private
Jackson West	Very poor	1980	2009	1.7	19		F	Private

Site name	Status	First observed	Last observed	Core area (acres)	Potential habitat (acres)	Acres of wetland	EO rank	Land ownership*
Kalamazoo East	Extirpated	1978	1978	Unk			H	State
Kalamazoo North	Extirpated	1973	2002	5		347	H	Private
Kalamazoo West	Poor	1974	2009	16	40?	512	D	Private
Lenawee	Extirpated	1965	1980				H	State
St. Joseph East	Poor	1996	2008	19		435	D	Private
St. Joseph West	Poor	1952	2007	14.2	?	332	H	Private
Van Buren Northwest	Very good	1999	2011	1.3	16.5	180	BC	Private
Van Buren	Unk, likely extirpated	1974	1993	14	68	315	D	Private
Washtenaw West	Fair/Poor	1958	2011	3	50		CD	Land conservancy & private

Extirpated sites = 6

Extant sites = 16

*Landownership consists of the following:

State of Michigan properties on State Game Areas

Sarett Nature Center

The Nature Conservancy

Michigan Nature Association

Southwest Michigan Land Conservancy

Church camps

Legacy Land Conservancy

Single private landowners

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW
of
Neonympha mitchellii mitchellii

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change is needed

Appropriate Recovery Priority Number: 3

Review Conducted By: Tameka N. Dandridge

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve Scott Hicks Date 11-12-13

REGIONAL OFFICE APPROVAL:

Lead Assistant Regional Director, Region 3, Midwest Region, Fish and Wildlife Service

Approve [Signature] Date 8/28/2014

Cooperating Assistant Regional Director, Region 4, Southeast Region, Fish and Wildlife Service

Concur Do Not Concur

Signature [Signature] Date 1-20-14

Cooperating Assistant Regional Director, Region 5, Northeast Region, Fish and Wildlife Service

Concur Do Not Concur

Signature [Signature] Date 2-19-14
Martin Miller