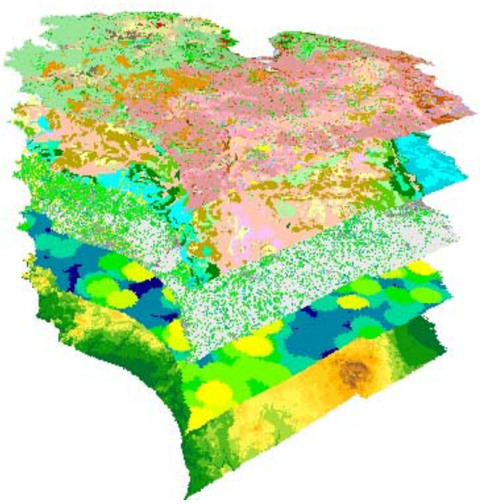
Use of a GIS-based Habitat Model to Identify Potential Release Sites for Mitchell's Satyr (*Neonympha m. mitchellii*) in Michigan



Prepared by:
Mary L. Rabe, Michael A. Kost, Helen D. Enander and Edward H. Schools

Michigan Natural Features Inventory
P.O. Box 30444
Lansing, MI 48909-7944

For:
U.S. Fish and Wildlife Service
Region 3 Endangered Species Office
Federal Building, Fort Snelling
Twin Cities, MN 55111

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Introduction

Mitchell's satyr, *Neonympha mitchellii mitchellii* French, is a federally-listed endangered species now known from only 17 sites in southern lower Michigan and two sites in northern Indiana. The U.S. Fish and Wildlife Service listed the satyr in 1992 (U.S. Fish and Wildlife Service 1997). Although it may always have been a relatively rare species, Mitchell's satyr has been more widespread in the past. The historical range of the species included northern New Jersey, northeastern Ohio, and perhaps Maryland (see U.S. Fish and Wildlife Service 1997 for discussion of this record's validity), as well as southern Michigan and adjacent northern Indiana where it is still extant.

Various factors have contributed to the decline of Mitchell's satyr; the most important may be the loss and disruption of suitable habitat. Much of the species known historical range coincides with prime agricultural areas, and farming and other development activities have impacted much of it. Wetland alteration or complete draining has resulted in the loss of the single known Ohio population of the butterfly, and several sites in Michigan (U.S. Fish and Wildlife Service 1997). Other alterations to hydrology include the removal of forest cover from adjacent uplands, drain tiling of adjacent fields, and ditch or drain maintenance. Road development has, in several cases, divided occupied sites and changed water flow to the extent that formerly suitable habitat now supports other plant communities. The disruption of landscape-scale processes that are crucial for the maintenance of suitable habitat and/or creation of new habitats complicates the loss of habitat for the species. Historical disturbance regimes such as wildfire, fluctuations in hydrologic regimes, and flooding caused by beaver have been eliminated or modified. Surviving populations now occupy isolated fen complexes in which the natural succession of vegetation is slowed, but not eliminated, by high water tables and the discharge of calcium carbonate laden groundwater. Eventually, in the absence of some process or management activity that arrests or resets succession to an earlier stage, the surviving open and edge components of these complexes will become increasingly unsuitable for the Mitchell's satyr. As habitats become more isolated, dispersal between populations and suitable unoccupied habitats becomes increasingly unlikely. This may account for the disappearance of several known populations from seemingly suitable wetland sites.

The main objective of the federal recovery plan for Mitchell's satyr (U. S. Fish and Wildlife Service 1997) is to perpetuate viable populations throughout its former range thereby allowing its reclassification, and ultimate removal, from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12). To reclassify to federal threatened status, 16 geographically distinct, viable populations or metapopulations must be established range-wide, including 12 in Michigan; to de-list, nine more populations must be established. These populations must remain viable for five consecutive years following reclassification and at least 15 of the 25 recovered populations must be protected and managed for the benefit of this species.

Currently, only nine of the 17 occupied sites in Michigan are considered to have any potential to contain viable populations. Satyrs at the remaining sites typically occur in much lower numbers or the amount of suitable habitat is limited in size or by threats to the site, making their long-term viability uncertain. Extensive survey work in Michigan since the butterfly was listed in 1992 has resulted in the discovery of only 3 new populations. Because survey for this species is difficult, there is always potential for new discoveries. Finding additional populations of Mitchell's satyr at this point, however, could be a time-intensive and costly endeavor. Releases of Mitchell's satyr into potentially suitable habitat may represent one tool that could help achieve both the Michigan recovery goal of at least 12 viable populations and the range-wide goal of 25 recovered populations.

Releases can be designed in several ways. One approach would be to return the butterfly to sites where it was known historically. In the case of this species, however, historical sites are often degraded or affected by an incompatible land use like pasturing or truck crop farming. An alternative would be to identify suitable habitat within the same watershed as other known sites, which assumes that larger scale variables affecting the species range, like weather, are within the limits tolerated by the species. Our existing knowledge of the species life history and habitat requirements must then be used to select a release site within the defined watershed that best meets the known landscape-level and microhabitat requirements of the butterfly.

Another approach would be to arrange for releases that test our ability to identify suitable habitat and establish viable populations. Under this scenario, one might choose to work within the general range of the species and select an array of sites that reflect the continuum of factors deemed to be important to the butterfly. Thus, multiple small, medium and large sites might be utilized to test the effects of size on satyr habitat stability and population viability.

Shreeve (1995) noted that much conservation effort has been placed on maintaining species *in situ* with considerable debate about the merits of reintroduction. Ehrlich and Murphy (1987) emphasized the need to define and identify suitable habitat. The presence of any given species likely depends on many factors. In addition to an abundance of plants suitable for egg-laying, the abundance and quality of food for adults and larvae, the abundance of predators and parasitoids and the prevalence of diseases could be equally important. Thomas (1991) emphasized that the presence, even in great abundance, of the larval food plant at a site within the range of a species is no guarantee that it can breed there. Most butterflies have very specific requirements. Consequently, the availability of adequate resources cannot be equated simply with the availability of the food plant. In spite of these complexities, Oates and Warren (1990) believe that releases can make effective contributions to the conservation of some species.

It has been difficult to neatly classify habitat for Mitchell's satyr. Most known habitats are peatlands but range along a continuum from bog to fen and from sedge meadow to swamp forest. Recent literature describes *N. m. mitchellii* habitat as open fen, wet prairie, prairie fen, sedge meadow, wet meadow, shrub-carr, tamarack savanna, and numerous variations and combinations of these community types (Shuey 1997). Certain attributes at each site, however, remain fairly constant. All historical and active habitats have a herbaceous community dominated by sedges, usually *Carex stricta*, with scattered deciduous and/or coniferous trees, most often tamarack (*Larix laricina*) or red cedar (*Juniperus virginiana*). It should be noted that a typical large fen complex is not a homogeneous system. For example, the Berrien County South site in Michigan supports seven identifiable wetland communities (Rogers et al. 1992). These different communities represent the end result of dynamic processes, such as the interplay between disturbance, groundwater discharge and plant succession, which act to produce a mosaic of habitat types within each wetland complex. Seeps and springs also are present at most sites (McKinnon and Albert 1996). Furthermore, most sites occur in valleys with distinct slopes (e.g., minimum rise of 6-10 m on both sides, and on at least one side, a rise of 9-15 m or more from the drainage channel) (McKinnon and Albert 1996).

The specific habitat requirements for Mitchell's satyr also seem to include structural components. Other researchers in the Midwest have noted the close relationship between Mitchell's satyr and young tamarack trees. Pallister (1927) noted that in the several hundred acre Portage County site, Ohio, Mitchell's satyr was limited to a small sedge meadow surrounded by tamarack. Likewise, Badger (1958) and McAlpine et al. (1960) noted that the butterfly was most often found flying among open stands of tamarack in the fens where they encountered it. At the LaGrange County West site, Indiana, Mitchell's satyr was found to fly at the edges of red cedar and shrubs along a floating fen mat. Similarly, at the Berrien County South site, Michigan, Mitchell's satyr was most often encountered at the interface between the open sedge meadow and bordering dense stands of deciduous shrubs such as gray dogwood (*Cornus stolonifera*) or among scattered trees in a tamarack savanna area (Rogers et al. 1992). In New Jersey, Mitchell's satyr habitat is characterized as narrow calcareous streamside sedge meadows bordered by red cedar and dense shrubs (U. S. Fish and Wildlife Service 1997).

The structural components of Mitchell's satyr habitat are similar to other wetland satyrines: the Appalachia eyed brown is found almost exclusively in shaded, scrubby wetland habitats while the closely related northern eyed brown is limited to open sedge meadow (Cardé et al. 1970; Shuey 1985). D. Schweitzer (pers. comm.) reports that in New Jersey, the Georgia satyr seldom occurs more than a few dozen meters from trees or tall shrubs even in extensive, very open sedge meadow. He has observed adults resting in these shrubs near the trees. Mitchell's satyr too seems to use the interface between open sedge meadow and the shrubby edges of later successional habitats.

Several efforts have been made to more clearly identify the critical habitat components of Mitchell satyr habitat in Michigan. Large and small sedge patches have potential to provide critical habitat for larvae that feed on the light-demanding sedges dominating these openings (Kost 2000, Legge and Rabe 1996, Szymanski 1998). Kost (2000) sampled vegetation at seven sites occupied by Mitchell's satyr in southern Michigan. He confirmed the findings of others describing the habitat of Mitchell's satyr as a mosaic of open prairie fen and sedge meadow mixed with tamarack savanna and shrub-carr (McAlpine et al. 1960, Shuey et al. 1994, Szymanski 1999). In this study, thin-leaved sedges (e.g. *C. stricta*, *C. sterilis*, *C. lasiocarpa*, *C. diandra*, *C. prairea*, *C. sartwellii* and *C. leptalea*), especially *C. stricta*, *C. sterilis* and *C. lasiocarpa*, dominated the ground layer of each of these habitats. Ground layer species found at all sites included *Aster firmus*, *Campanula aparinoides*, *Cirsium muticum*, *Eupatorium perfoliatum*, *Glyceria striata*, *Muhlenbergia glomerata*, *Oxypolis rigidior*, *Solidago patula*, *Thelypteris palustris*, and *Viola* spp. A small compact shrub, shrubby cinquefoil (*Potentilla fruticosa*), which also occurs as part of the ground layer, was a significant component of cover at more than half of the sites. Lastly, tamarack and poison sumac (*Toxicodendron vernix*) formed the upper stratum at most sites, creating a community structure often referred to as tamarack savanna.

Szymanski (1999) noted great variability in the structural and vegetation components of Mitchell's satyr habitat in Michigan, which suggests that habitat heterogeneity is important to the butterfly. Habitat diversity may help guard against environmental extremes (e.g., drought, late season frost, cool and wet springs) which influence butterfly activity and foodplant availability and quality. Others have found that habitat heterogeneity is an influential factor in the population dynamics of butterflies (Ehrlich and Murphy 1987, Thomas 1984, Dobkin et al. 1987). In fact, the long-term suitability of a site is judged by its ability to support a population through environmental extremes. It also is possible that the observed variability at the patch scale is due to non-habitat specificity. Further study is needed to determine if these habitat patch variables influence the presence of Mitchell's satyr. Specifically, comparisons with other occupied sites and vacant yet seemingly suitable sites may provide important insights.

Calcareous fens are very stable systems, generally due to large amounts of groundwater discharge (Hall 1993). The nutrient poor, highly alkaline conditions create an environment that is physiologically unsuitable for many species. Other vegetation zones associated with fen (e.g., sedge meadows, shrub carr communities) and occupied *by N. m. mitchellii* are relatively stable as well but require periodic disturbance (Curtis 1959, Moran 1981, Shuey 1997). Historically, fire may have been an important factor in maintaining wetland habitats associated with fire-prone uplands (Curtis 1959, Shuey 1997). Shuey (1997) contends that fire likely played a role in maintaining the graminoid-dominated systems occupied by *N. m. mitchellii* theorizing that as fire swept through the surrounding oak-savanna communities, it must also have swept through the wetlands.

Another possible disturbance source may have been beavers. Beavers had a significant historical influence on the Great Lakes landscape by damming streams and forested wetlands. Hall (1993) gives a detailed account of how beaver dynamics may have played a role in creating *N. m. francisci* habitat. Given that beaver dams occurred at 100 to 200 m intervals in the Great Lakes region, they could have created a shifting mosaic of suitable and unsuitable habitat patches over a very large area, and effectively maintained a dynamic network of sedge-dominated communities along stream margins. Somewhere in that mosaic, Mitchell's satyr is thought to have persisted. At the very least, the more open character of occupied watersheds would have facilitated dispersal, colonization and recolonization thus driving satyr population dynamics toward a more stable condition with greater viability.

An understanding of mobility, especially of the dispersal of individuals from existing locations, is fundamental to the establishment of new populations and to understanding the effects of habitat loss and fragmentation on the long-term viability of butterfly species. In particular, the mechanisms of dispersal and colonization, and the role of habitat features and population characteristics in maintaining or promoting mobility, must be understood. Dispersal and mobility are difficult to study especially when a species occurs in low numbers in fragmented, often isolated, habitats. For many species, we often do not understand the landscape context that provides the connectivity required for dispersal and genetic interaction critical for its survival.

Szymanski (1999) reported home range estimates for Mitchell's satyr that indicated the average individual butterfly uses only a small proportion of available habitat within a patch. Her movement results also indicated that the majority (83%) of range movements (i.e., the distance between the two most distant capture points) and most of the total distance estimates (73%) were less than 50 m. Intrinsic barriers to dispersal may provide an explanation for this sedentary behavior (Erhlich 1961). The short lifespan and the restricted environmental conditions suitable for activity (Szymanski 1999) limit the time available for butterflies to reproduce and disperse their eggs. Thus, *N. m. mitchellii* may confine activity to their natal microhabitats where suitable habitat is assured with minimal searching needed. The limited time to mate and disperse eggs has been implicated by other lepidopteran researchers (e.g., Dempster 1971, Bink 1982) as limiting factors for butterfly populations and seems plausible for *N. m. mitchellii* as well. Also, at low population densities, butterflies have been shown to restrict long-distance movements.

This project attempts to summarize what is known about Mitchell's satyr life history and habitat use by developing a model based on factors representing life history and habitat parameters known to be critical to the persistence of the butterfly. The model can then be used to evaluate and rank an array of sites for their potential to provide satyr habitat. These sites, in turn, can be evaluated for their potential to serve as recovery sites in Michigan. With careful thought and modification, it may be possible to apply the model in other portions of the species range in the Midwest.

The Mitchell's satyr habitat modeling work was undertaken as part of a larger three-year project funded by the U.S. Fish and Wildlife Service (Federal Aid in Endangered Species, Michigan Projects E-1-28, E-1-29, E-1-30). A summary of work completed in 1998 and 1999, the first two years of the project, can be found in Hyde et al. 1999, Hyde et al. 2000 and Kost 2000. Objectives for 2000, the final year of the project, are listed in Appendix 1. Activities related to Jobs 1.1, 1.2, 1.5, 2.1, 2.2, 3.1, 3.2, and 3.3 (in part) have been summarized in Hyde et al. 2001. Activities related to Job 1.3, 1.4 and 3.3 (in part) have been summarized in this report.

Methods

Model Development

A review of current and past literature helped to identify life history and habitat parameters that might be critical to the persistence of Mitchell's satyr. Six landscape-level criteria were thought to be important and should be considered when selecting potential release sites:

1) a wetland complex with a mosaic of habitat types or vegetation zones that include tamarack, poison sumac, shrubby cinquefoil, or other calciphiles (vegetation associated with carbonate and magnesium rich seeps and springs);
2) a buffer of natural vegetation around the complex;
3) seeps and springs, often associated with edges of lakes and streams, or the sides and bases of steep ravines and hillsides;
4) a minimal number of exotics throughout the complex;
5) proximity to an extant occupied) Mitchell's satyr complex; and
6) high quality and/or large size.

Important microhabitat criteria include the presence of a variety of forbs suitable for oviposition, and the presence of fine-leaved sedges like *Carex stricta*, to serve as larval host plants, either as a dominate zone within the complex or as pockets interspersed with open stands of tamarack or native shrubs.

Ownership criteria were considered since they have potential to impact our ability to manage a site, but ultimately were not included in the model. We believe the selection of release sites should rest on the overall quality of the site. Ownership can be tracked, with the final selection of release sites maintaining a reasonable balance between both public and private ownership types within a state.

Factors used in the model were selected to represent the landscape-level criteria identified as important to the survival and persistence of Mitchell's satyr. These are described in more detail below. They include: the site's Element Occurrence Rank, the percent of natural cover within a square mile around the site, the size of the wetland complex surrounding the site, the intactness of the upland area around the site, the potential for linkage to other sites, rare species richness, and residence within The Nature Conservancy (TNC) Portfolio Sites. All factors, except the Element Occurrence Rank, were represented with existing spatial (Geographic Information System or GIS) data sets. Since data on important microhabitat-level criteria are mostly lacking, we made the assumption that they were represented adequately by landscape-level criteria 1, 3, 4 and 6.

All of the factors represent a measure of site integrity. There is redundancy in the factors to insure that data gaps do not generate a bias against certain sites. For example, a site with no Element Occurrence Rank could still score high if it is has a large amount of surrounding natural area, if the upland buffer is intact, and if it is within a TNC Portfolio Site.

Each factor, with the exception of TNC Portfolio Site, is broken down into four levels (Table 1). Each level is assigned a numerical value of zero, five, ten or fifteen with the higher value indicating a better score. Each factor, except TNC Portfolio Site, is given equal weight in regard to the other factors. This insures that no one factor controls the results of the model.

The factor for TNC Portfolio Site is a presence or absence value. Sites contained within TNC Portfolio Sites are given a value of five and sites outside the portfolio site boundaries are assigned a value of zero. Consequently this factor is weighed less than the other factors. This deviation from an equal weighting scheme was used to recognize the added value of a site already identified for conservation efforts, without reducing the importance of overall quality to a site's total score.

Model Factors

Element Occurrence (EO) Rank

The Nature Conservancy's EO Rank is a measure of the ecological integrity of each site based on standardized assessments. Using standard natural heritage methodology, natural communities are assigned a rank that reflects their size, condition, and landscape context. Ranks of A, AB, B, BC, C, CD, or D are typically assigned by an experienced ecologist when natural communities are transcribed for entry into Michigan Natural Features Inventory (MNFI) Biological Conservation Database (BCD). Because ranking is performed by individual ecologists over time, it is the most subjective of the factors used. It is important to note that a natural community occurrence may be transcribed, and thus reside in BCD, without a rank. This occurs when information is provided by an outside source (e.g., consultant) and no MNFI ecologist is familiar enough with the site to assign a credible rank. Generally, larger sites are assigned higher ranks (e.g., A, AB). The condition of a natural community is based on its overall level of plant species richness and presence of rare plant species. The presence of factors that degrade a site's integrity, like invasive plant species or a lack of intact ecological processes, usually lowers the EO Rank. Natural community occurrences surrounded by other intact ecosystems are given higher ranks than occurrences adjacent to agricultural fields, subdivisions, or other urban land uses.

Sites with an A and AB rank were given 15 points; B and BC ranked sites were given 10 points; C and CD ranked sites were given 5 points. Sites that had no assigned rank (unranked or U) were given zero points.

This model factor addresses landscape-level criteria 1, 2, 3, 4, and 6.

Percent Natural Buffer

The amount of natural land cover surrounding a site provides a measure of buffer both for the site and for the Mitchell's satyr. The greater the percentage of natural vegetation, the greater likelihood of an intact ecosystem and the lower the potential for disturbance. A site with a high percentage of surrounding natural vegetation would be a better release site candidate than a site with a high percentage of incompatible land use.

The model uses the Michigan Resource Information System (MIRIS) data set to determine the percentage of natural buffer. The MIRIS land cover data were created in vector format from aerial photo interpretation. These data were converted to a raster format. The raster data set has a resolution of 30 meters with a minimum mapping unit of one hectare (2.5 acres). MIRIS data are a compilation of data from county and regional planning commissions or their subcontractors. It is available from the Michigan Department of Natural Resources.

Using Anderson level 1 classes (Anderson et al. 1976), urban and agriculture features were reclassified as incompatible or "hostile." The remaining features were reclassified as "natural." ArcInfo Grid (ESRI 2000) and Grid focal functions were used to calculate the percent natural area within one square mile of a grid cell. The resulting percentages were grouped into four classes: 0% – 25% natural, 26% - 50% natural, 51% - 75% natural, and 76% to 100% natural. The score for each class was 0, 5, 10, and 15, respectively.

This model factor addresses landscape-level criteria 2.

Wetland Size (NWI)
Each natural community site is examined for its relationship to a larger wetland complex. Sites within a larger wetland complex have a greater chance of having intact ecological processes. Also, a larger wetland complex may provide more appropriate satyr habitat and avenues for satyr dispersal. This increases the potential for establishing a viable satyr metapopulation.

The National Wetland Inventory (NWI) digital data set, which is distributed by the U.S. Fish and Wildlife Service, was used to determine the size of the contiguous wetland complex in which a site was located. The data set was generated from aerial photo interpretation. Because of limitations associated with photo scale, photo quality, interpretation techniques, and other factors, the NWI maps may not show all wetlands. Those wetlands that are identified are classified according the U.S. Fish and Wildlife Service wetland classification scheme (Cowardin et al. 1979).

In the model, adjoining wetland polygons were dissolved into one contiguous polygon. The contiguous polygons were then converted to raster format with a 30-meter cell size. The ArcInfo Grid command Regiongroup (ESRI 2000) was used to identify cells belonging to a contiguous region. To calculate the region's total area, the number of cells in a region was multiplied by cell area (900 m^2). Wetlands were then classified into three area classes: less than 100 acres, 101-500 acres, and greater than 500 acres. The scores for these classes were 5, 10, and 15 respectively. A score of zero was assigned to those fens not falling within a wetland area.

This model factor addresses landscape-level criteria 1, 2, 3, 4, and 6.

Upland Buffer
Fens, as one component of high quality satyr habitat, require groundwater discharge from the surrounding upland in order to remain viable. The type and amount of vegetation in the upland buffer helps determine the quality and quantity of groundwater discharge into the fen system. Areas with little or no vegetative cover will experience more surface runoff and less water percolation into the groundwater than areas with an intact vegetative cover. Fen systems with an intact upland buffer are more likely to have an intact hydrological system supporting them.

To assess the quality of upland buffer around a fen system, the area classified as “Upland” from the NWI data set was selected. The upland area was then intersected with the MIRIS land use data set. Using Anderson level 1 classes (Anderson, et al., 1976), urban and agriculture features were classified as “hostile” and the remaining features were reclassified as “natural.” The percent of hostile upland land cover within one square mile of each fen was calculated using ArcInfo Grid (ESRI 2000) and Grid focal functions. Four classes, 0% – 25% hostile, 26% - 50% hostile, 51% - 75% hostile, and 76% to 100% hostile were identified. The score for each class was 15, 10, 5, and 0, respectively.

This model factor addresses landscape-level criteria 1, 2, 3, 4, and 6.

Linkage Potential
Sites that can be linked to each other, with habitat suitable for Mitchell’s satyr dispersal, are more likely to support satyr metapopulations. Consequently, sites with potential to be linked are more desirable than isolated sites.

The National Wetlands Inventory (NWI) dataset was used to determine linkages between sites, or between sites and other occupied Mitchell’s satyr habitat. Palustrine wetlands (Cowardin et al. 1979), excluding the palustrine open water classes, were used as the potential linkage corridors. To allow for the butterfly to move a small distance out of the corridor, potential corridors were buffered by 50 meters. The buffered corridors were converted to an ArcInfo grid.

Sites in the analysis and known satyr habitats also were converted to an ArcInfo grid. Linkage potential was determined with the Grid Costdistance function (ESRI 2000), utilizing the site grid as the source grid and the corridor grid as the cost grid. Each cell in the corridor grid was given a value of one. When the Grid Costdistance function was run, the output was a grid with each cell's value the distance in meters from the nearest source. Sites that were not linked, or linked by a distance greater than five miles were assigned a score of zero. Sites that were linked by less than one mile were given a score of 15, sites linked by one to three miles were given a score of ten, and sites linked by three to five miles received a score of five.

This model factor addresses landscape-level criteria 5.

Rare Species Richness

Rare species are sometimes used as an indication of the overall health of an ecosystem (Crispin 1991). The model includes a factor to account for the presence of rare species at or near a site. The rare species chosen for the analysis include 16 species judged by MNFI biologists to have a high potential of occurring within a prairie fen (Table 2). By using data from the BCD, we were able to assign points to each site based on the number of different rare species occurring within 1 mile. Sites containing nine or more different rare species were given 15 points; sites containing between five and eight different rare species were given ten points; and sites containing between one and four different rare species were given five points. Sites lacking rare species were given a score of zero.

This model factor addresses landscape-level criteria 1, 2, and 6.

The Nature Conservancy Portfolio Sites

Overlap with The Nature Conservancy (TNC) portfolio sites is an indirect method of accessing ecosystem intactness. Portfolio sites are areas that TNC has identified as having conservation potential. These areas are more likely to contain intact or restorable ecosystems. Conservation efforts are more likely to be directed to these areas than areas not designated as Portfolio Sites. Sites located within a TNC Portfolio Sites were given five points. Sites outside TNC Portfolio Sites received a score of zero.

This model factor addresses landscape-level criteria 1, 2, 3, 4, and 6.

Model Analysis

The model was used to score and rank the 111 prairie fens in BCD based on biological and ecological factors that can be represented with available spatial data. Scores for the seven factors are summed resulting in a highest possible score of 95. Higher scores represent higher biological and ecological integrity and are indicative of more intact systems. Consequently, sites with higher scores should be better choices for Mitchell’s satyr releases.

Our initial analysis was limited to known prairie fens for several reasons. First, all sites currently occupied by Mitchell’s satyr contain ground water seepage zones characteristic of prairie fens. Secondly, 10 of the 17 occupied sites in Michigan have been identified as exemplary occurrences of prairie fen. Most of the remaining seven occupied sites still contain small patches of prairie fen. These patches still have potential to provide critical habitat for Mitchell’s satyr larvae. Finally, the database for this natural community type allowed our model to select from a large number of possible sites. Basing our model on known prairie fens will provide us with a range of release sites drawn from a large set of potentially high quality Mitchell's satyr habitat. We recognize that some potential release sites will not be identified with our current model. By working with the best data set available to us at this time, however, we should be able to identify an adequate array of potential release sites to meet the demands of recovery activities for the foreseeable future.

For the purposes of this study, fens associated with occupied satyr sites were left in the analysis. They were scored in the same manner as unoccupied sites. No attempt was made to change the model so that sites thought to better for the satyr, based on previous expert opinion, would score higher.

Additional analyses can be made with the model as data sets on other natural community types are developed. As more information becomes available, it will be possible to refine the habitat model to more accurately reflect a factor's contribution to satyr survival and long-term viability.

Results

Factors and total scores for each fen analyzed are shown in Table 3. Element Occurrence Ranks of the 111 prairie fens in BCD indicate that only 16 sites (14.4%) were of high enough quality to be ranked as A or AB with most fens ranking between B and CD (Figure 1). Only 8 fens (7.2%) were unranked and scored zero. Figure 2 indicates that the natural buffering for each fen, as expressed by the percentage of natural area within one square mile, was high with over half of the fens surrounded by 51-75% of natural land cover types. These sites generally are scattered across the southern Lower Peninsula with the least amount of natural land cover occurring in southeastern Michigan and the immediate area around the state capitol in Lansing, Ingham County (Figure 3). Surprisingly, most fens (70%) were associated with large wetland complexes (Figure 4) spread across southern Michigan (Figure 5). Given the high level of development and agricultural land use in the southern portion of the State, most fens had between 26 – 75% of their surrounding upland area in one of these two types (Figure 6). Only a few areas, mostly in southwestern Michigan, persisted in relatively intact, natural landscapes (Figure 7). This was further emphasized by the fact that nearly 90% of the fens were considerably isolated with 5 miles or more between them and the next nearest fen complex or occupied Mitchell's satyr site along a wetland corridor (Figures 8 and 9). In spite of this high degree of fragmentation, considerable contiguous palustrine wetland areas do exist in southern Michigan (Figure 10). Even though wetlands provide habitat for a variety of rare plant and animal species, very few fens contained them. Only 36 fens (32%) had 3 or more rare species documented (Figure 11). Nearly two-thirds of the fens in this study fall within the designated boundaries of a TNC Portfolio Site (Figure 12). Portfolio Sites are scattered throughout southern Michigan capturing a wide range of wetland types and associated rare species (Figure 13).

Overall, the scores of the 111 fens in our analysis ranged from 10 to 80 (Figure 14). The majority of sites scored between 35 to 55 points. The highest ranking sites (61 – 80 points) are scattered throughout southern Michigan in seven different counties (Figure 15).

Discussion

In general, the habitat model performed well. No fen community achieved the highest possible score of 95, although 24 fens had a total score of 60 to 70 points and three other fens scored between 75-80 points (Table 3). Element Occurrence Ranks did not correlate with a fen's total score since a number of fens with high EO Ranks ended up with less than half of the total possible points. It is interesting to note that few fens scored any points for linkage potential, but those that did tended to have higher overall scores also. While the model set a 50-m buffer around wetland corridors linking fens, it is a conservative figure based on satyr movements at small sites and low population levels. Specific studies to determine the dispersal ability of Mitchell's satyr may well prove that this can be relaxed, and a more generous buffer could result in higher linkage potential.

Future improvements to the data layers would benefit the model's performance. Greater consistency in scoring could be achieved if all the fens in BCD were visited or revisited by a single experienced ecologist. This would help standardize the Element Occurrence Ranks and eliminate all unranked sites. In addition, digitizing the location and extent of each fen community would reduce the potential for spatial error. In this analysis, fen occurrences were represented spatially as point data. This could potentially affect the information generated for the other spatial factors including percent natural buffer, wetland area size, upland buffer, linkage potential, rare species richness and overlap with TNC Portfolio Sites.

It also should be noted that a fen might score zero for wetland size in two ways. In some cases, a fen might actually be associated with a hillside or lakeside setting that is not immediately associated with a wetland complex. It also is possible, however, that the point data used for this analysis generated a spatial error that dissociates the fen from surrounding wetlands. That error could reduce the potential score for wetland area and/or linkage potential from 15 to zero thus reducing a site's overall score by as much as 30 points. This further emphasizes the value of using digitized occurrence data. Until that becomes available, only a site-by-site inspection would help control the potential for error associated with point data.

When high quality prairie fen communities are documented, the accompanying information on rare species can be lacking. Thus sites scoring low in rare species richness potentially represent gaps in survey effort, especially for the rare animals associated with fens since they often are only detected using specific methodologies at specific times of the day or year. It might be desirable to complete additional surveys for rare species before final selection of Mitchell's satyr release sites since their presence is a strong indication that a functional natural system still exists.

Most fens in Michigan, and nearly all high ranking satyr release sites, are associated with the Jackson Interlobate, Sub-subsection VI.1.3, and the Kalamazoo Interlobate, Subsection VI.2 (Albert 1995). These areas are typified by sandy, coarse-textured ground and end moraine, outwash and ice contact topography. Predominate natural communities include oak savanna and oak-hickory forest, swamp forest, prairie fens, wet prairie, tallgrass prairie, and bogs. The growing season across this broad area ranges from 140 to 160 days, generally decreasing to the north (Eichenlaub et al. 1990). The danger of late spring frosts is great given the numerous lowland depressions (outwash and kettle lakes). Snowfall averages 40 to 60 inches; greatest amounts are in the extreme north and in the southwest near Lake Michigan. Annual precipitation ranges from 30 to 38 inches with highest amounts in the south. Extreme minimum temperatures range from -22^{o}F to -30^{o}F, with coldest values in the north. Given the ice-contact topography and many ice-block depressions, it is no surprise that we find the calcareous seepages and springs that support fens in this region.

Historically, natural disturbance for the Interlobate included lightning fires. Early settlers reported fire as a widely used Native American management tool (Albert 1995). Without fire, all the oak openings have closed into become closed-canopy oak forest. Tallgrass prairie was originally quite extensive, but prairie lands were among the first farmed in Michigan. Tallgrass prairie persists as small fragments along railroad rights-of-way; small fragments of wet prairie also persist. Oak savannas have been either destroyed by agriculture or heavily degraded by fire suppression. Today, management with prescribed fire, herbicides, and manual cutting of encroaching natural vegetation is used to compensate for historical disturbance regimes.

Development pressures are high throughout the Interlobate (Albert 1995). Residential development threatens almost all lakes, wetlands and mature forests. Few preserves adequately represent both the wetlands and uplands of the Interlobate. These pressures and their resultant impacts on hydrology will make prairie fen conservation and protection for the Mitchell's satyr and other rare species a challenge.

Of the 27 highest scoring sites (60-80 points), many achieved the maximum points possible for four factors: percent natural buffer, wetland size, upland buffer and TNC portfolio site. This suggests that the model selected larger sites embedded in relatively intact landscapes with natural vegetation occurring in associated wetlands and uplands.

The State of Michigan owns almost half of the top-ranking sites. Local governments, The Nature Conservancy or single private individuals own a few other sites. Seven sites represent multiple private owners and probably would be the greatest challenge to mange for recovery and preservation of rare species.

Only two of the sites currently occupied by Mitchell's satyr scored more than 60 points. In fact, 10 sites currently occupied by the satyr scored less than half of the total possible points. This suggests that Mitchell's satyr persists today in small, fragmented patches of suitable habitat. One would expect these to be more vulnerable to threats and impacts from surrounding land uses. The extinction threat to the butterfly would likely be high and suggests that these populations may not be viable. If additional populations on small sites are lost, the importance of well-planned releases increases substantially.

The importance of additional site assessments prior to any release of Mitchell's satyr must be emphasized. This would provide current information on site condition, new threats, and presence of other rare species. It also would be important to evaluate the landscape condition, changes in natural buffers and changes in surrounding land uses. As selections are finalized, the desire and ability of landowners to conduct compatible management activities will be essential to the ultimate success of any release effort.

Table 1. Factors and weighting used in model. (See text for a detailed explanation of each factor.)

Factor	Rank	Points
EO Rank	A, AB	15
	B, BC	10
	C, CD	5
	U	0
% Natural Buffer	0 - 25% Natural	15
	26 - 50% Natural	10
	51 - 75% Natural	5
	76 - 100% Natural	0
Wetland Size	> 500 Acres	15
	101 - 500 Acres	10
	< 100 Acres	5
	0 Acres	0
Upland Buffer	0 - 25% Hostile	15
	26 - 50% Hostile	10
	51 - 75% Hostile	5
	76 - 100% Hostile	0
Linkage Potential	< 1 mile	15
	1-3 miles	10
	3 - 5 miles	5
	> 5 miles	0
Rare Species Richness	> 9 species	15
	5 - 8 species	10
	1 - 4 species	5
	none	0
TNC Portfolio Site	Yes	5
	No	0

Table 2. Rare species associated with prairie fen in Michigan.

Scientific Name	Common Name	Federal Status	State Status	State/Global Rank
Plants				
Cacalia plantaginea	tuberous Indian plantain		Threatened	S2/G4G5
Cypripedium candidum	white lady's-slipper		Threatened	S2/G4
Filipendula rubra	queen-of-the-prairie		Threatened	S2/G4G5
Muhlenbergia richardsonis	mat muhly		Threatened	S2/G5
Sporobolus heterolepis	prairie dropseed		Special Concern	S2G5
Valeriana ciliata	common valerian		Threatened	S2/G4G5
Amphibians				
Acris crepitans blanchardi	Blanchard's cricket frog		Special Concern	S2S3/G5T5
Turtles				
Terrapene c. carolina	eastern box turtle		Special Concern	S2S3/G5T5
Emdoidea blandingii	Blanding's turtle		Special Concern	S3/G4
Clemmys guttata	spotted turtle		Special Concern	S2/G5
Snakes				
Sistrurus c. catenatus	Eastern massasauga	C1-Candidate Species	Special Concern	S3S4/ G3G4T3T4
Clonophis kirtlandii	Kirtland's snake		Special Concern	S1/G2
Insects				
Oarisma poweshiek	Poweshiek skipperling		Threatened	S1S2/G2
Calephelis mutica	swamp metalmark		Threatened	S1S2/G3G4
Papaipema berriana	blazing star borer		Special Concern	S1S2/G3

Table 3. Summary of factor scores and total score for each fen community modeled.

Surveysite	Total Fen Score	EO Rank	Linkage Potential	Rare Species Richness	Percent Natural Buffer	Wetland Size	Upland Buffer	TNC Portfolio Site	Current Satyr Site
MT. HOPE ROAD FEN	80	15	15	10	10	15	10	5	
MOTT ROAD FEN	75	15	0	15	15	10	15	5	
WHITMAN LAKE FEN	75	10	0	15	15	15	15	5	
BAKERTOWN FEN	70	15	10	15	5	15	5	5	
BAUER ROAD FEN	70	15	0	5	15	15	15	5	
GRAHAM LAKES	70	10	10	5	15	15	10	5	
HORSESHOE LAKE FEN	70	10	0	10	15	15	15	5	
INDIAN LAKE ROAD FEN	70	10	10	0	15	15	15	5	
LIBERTY BOWL FEN	70	15	15	10	5	15	5	5	
JACKSON COUNTY CENTRAL	70	15	5	15	10	15	5	5	*
PARK LYNDON FENS	70	10	0	15	15	15	10	5	
DAYTON WET PRAIRIE	65	15	10	10	5	15	5	5	
GLENN ROAD PRAIRIE FEN	65	5	15	5	10	15	10	5	
HALSTEAD LAKE	65	10	10	5	10	15	10	5	
PERRY FEN	65	10	15	5	10	15	10	0	
KALAMAZOO COUNTY NORTH	65	15	0	10	10	15	10	5	*
WHELAN LAKE FEN	65	10	0	10	15	15	10	5	
BURNS LAKE	60	5	10	5	10	15	10	5	
BUTTERFIELD LAKE FEN	60	10	0	5	15	15	10	5	
CHAMBERLAIN LAKES	60	5	10	5	10	15	10	5	
MONETTE STREET	60	15	0	10	10	15	5	5	
MUNGER FEN	60	5	15	5	10	15	10	0	
SEVEN LAKES FEN	60	5	10	10	10	15	10	0	
STEARNS LAKE	60	10	0	5	15	15	10	5	
SUTFIN ROAD FEN	60	0	15	10	10	15	5	5	
TIPLADY FEN	60	5	0	5	15	15	15	5	
TROUT LAKE	60	10	0	5	15	15	10	5	
42ND ROAD SEEP	55	10	0	5	15	5	15	5	
67TH AVENUE	55	10	5	10	5	15	5	5	
CAROGA LAKE PRAIRIE FEN	55	5	0	5	15	15	15	0	
CHILSON FEN	55	10	0	5	10	15	10	5	
CLINTON RIVER HEADWATERS	55	5	0	10	10	15	10	5	
HAMPTON CREEK FEN	55	10	0	10	10	15	10	0	
HURON RIVER WETLAND	55	5	0	0	15	15	15	5	
INDIAN BOWL	55	15	0	15	5	15	5	0	
LINCOLN LAKE FEN	55	15	0	0	10	15	10	5	
LITTLE APPLETON LAKE	55	10	0	5	15	5	15	5	
LOCKER LAKE FEN	55	10	5	0	10	15	10	5	
ST. JOSEPH COUNTY WEST	55	5	0	15	10	15	5	5	*
OAK GROVE PRAIRIE FEN	55	10	0	5	10	15	10	5	
KALAMAZOO COUNTY WEST	55	10	0	15	10	5	10	5	*
PORTAGE LAKE FEN	55	5	0	5	15	10	15	5	
BARRY COUNTY SOUTH	55	10	0	10	10	10	10	5	*
WESTMAN LAKE FEN	55	5	10	0	10	15	10	5	
ALGOE LAKE PRAIRIE FEN	50	10	0	0	15	5	15	5	
BRANDT ROAD FEN	50	10	0	5	10	10	10	5	
BRIDGE VALLEY	50	15	0	5	10	10	5	5	
CADY LAKE FEN	50	10	0	5	10	15	10	0	
JACKSON COUNTY WEST	50	10	0	5	10	15	5	5	*
CULVER RD. FEN	50	5	10	0	10	15	5	5	
HALL LAKE FEN	50	10	0	10	10	10	5	5	
INDEPENDENCE LAKE CO. PARK	50	5	0	5	15	10	10	5	
LAKEVILLE SWAMP	50	10	0	5	10	10	10	5	
LOST NATION FEN	50	10	0	5	10	15	5	5	

Surveysite	Total Fen Score	EO Rank	Linkage Potential	Rare Species Richness	Percent Natural Buffer	Wetland Size	Upland Buffer	TNC Portfolio Site	Current Satyr Site
RADRICK FEN	50	10	0	5	10	10	10	5	
RATTALEE LAKE FEN	50	10	0	10	10	15	5	0	
CASS COUNTY SOUTHWEST	50	10	0	15	5	15	0	5	*
JACKSON COUNTY EAST	50	10	10	0	5	15	5	5	*
BAYLEY'S FEN	45	10	0	5	5	15	5	5	
DAVISBURG FEN	45	5	0	5	10	15	5	5	
HARTWIG FEN	45	5	0	0	10	15	10	5	
HEADQUARTERS FEN	45	5	0	0	10	15	10	5	
HELMER BROOK FEN	45	10	0	5	10	10	5	5	
CASS COUNTY NORTHWEST	45	15	0	5	5	15	0	5	*
BERRIEN COUNTY NORTH	45	5	0	10	10	15	5	0	*
SPRING LAKE FEN	45	10	0	10	10	10	5	0	
ZIEGENFUSS LAKE	45	10	0	0	10	10	10	5	
COLD SPRINGS FEN	40	5	0	5	10	10	10	0	
DEW ROAD FEN	40	5	5	0	5	15	5	5	
FAY LAKE FEN	40	5	0	0	10	15	5	5	
HANKARD LAKE FEN	40	5	0	5	15	0	10	5	
IVES ROAD FEN	40	15	0	15	5	0	0	5	
JACKSON LAKE FEN	40	10	0	5	5	15	5	0	
LAMBERTON LAKE FEN	40	5	0	15	5	10	5	0	
LAWRENCE LAKE FEN	40	0	0	10	5	15	5	5	
LIME LAKE FEN (JACKSON)	40	5	0	10	5	15	0	5	
POKAGON CREEK FEN	40	10	0	5	5	15	5	0	
PRAIRIE RIVER COMPLEX	40	10	0	0	10	15	5	0	
RIKER LAKE PRAIRIE FEN	40	10	0	0	10	10	5	5	
TEEPLE LAKE	40	0	0	0	10	15	10	5	
ST. JOSEPH COUNTY EAST	40	15	0	0	5	15	5	0	*
BINDER PARK ZOO	35	10	0	0	5	10	5	5	
BRANDYWINE CREEK FEN	35	0	0	10	10	10	5	0	
CHASE LAKE	35	5	0	0	10	15	5	0	
COUNTY LINE LAKE	35	10	0	0	10	5	10	0	
EMERALD LAKE FEN	35	0	0	15	5	10	5	0	
JEFFERSON CENTER	35	5	0	10	5	15	0	0	
MANITO LAKE FEN	35	10	0	5	10	10	5	5	
MARL LAKE	35	5	0	5	10	5	5	5	
MCCORD'S CREEK	35	10	0	5	10	0	10	0	
MCKAY LAKE FEN	35	0	0	0	10	15	10	0	
PAGE CREEK FEN	35	10	0	0	10	5	10	0	
ROWE LAKE FEN	35	5	0	10	5	15	0	0	
SILVER LAKE NORTH	35	5	0	0	10	10	10	0	
TROUT LAKE	35	0	0	5	10	10	5	5	
VANDALIA PRAIRIE FEN	35	10	0	0	5	15	0	5	
BERRIEN COUNTY SOUTH	30	0	0	10	5	10	5	0	*
BUCKHORN LAKE	30	5	0	5	10	0	10	0	
EIGHT FOOT LAKE FEN	30	5	0	0	10	10	5	0	
HIGHLAND CEMETERY	30	10	0	0	5	5	5	5	
WASHTENAW COUNTY WEST	30	5	0	0	5	15	5	0	*
LITTLE FAWN RIVER	30	15	0	0	0	15	0	0	
BRANCH COUNTY	30	5	0	0	5	15	0	5	*
WILDWING FEN	30	5	0	5	10	0	10	0	
GOODRICH LAKE FEN	25	5	0	0	5	15	0	0	
LESLIE SCHOOL DISTRICT	25	5	0	0	5	10	5	0	
SOMERSET FEN	25	10	0	0	5	0	5	5	
VINCENT LAKE FEN	25	5	0	0	5	15	0	0	
ANDERSON LAKE FEN	15	5	0	0	0	10	0	0	
HONEY LAKE FEN	10	5	0	0	0	5	0	0	

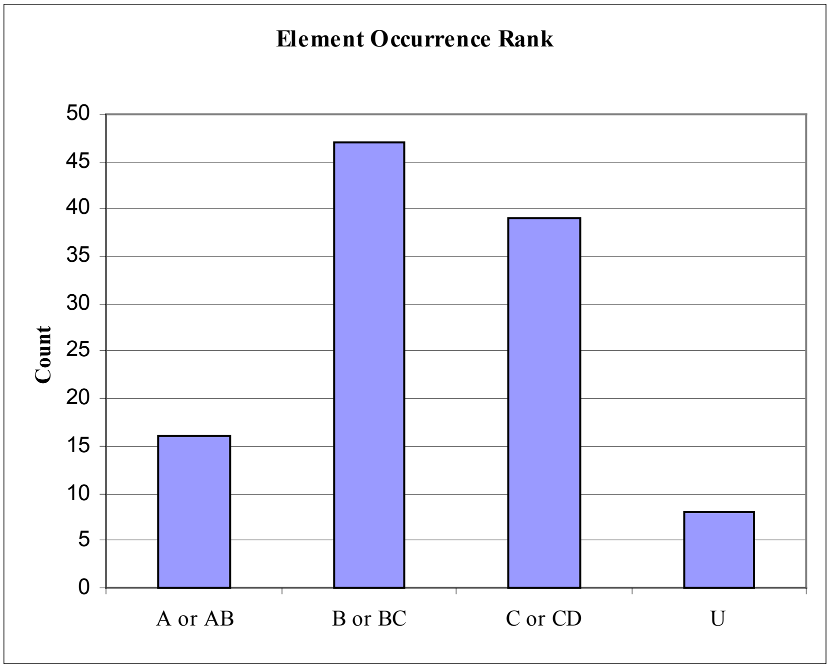

Figure 1. Element occurrence ranks of fen sites in southern Lower Michigan.

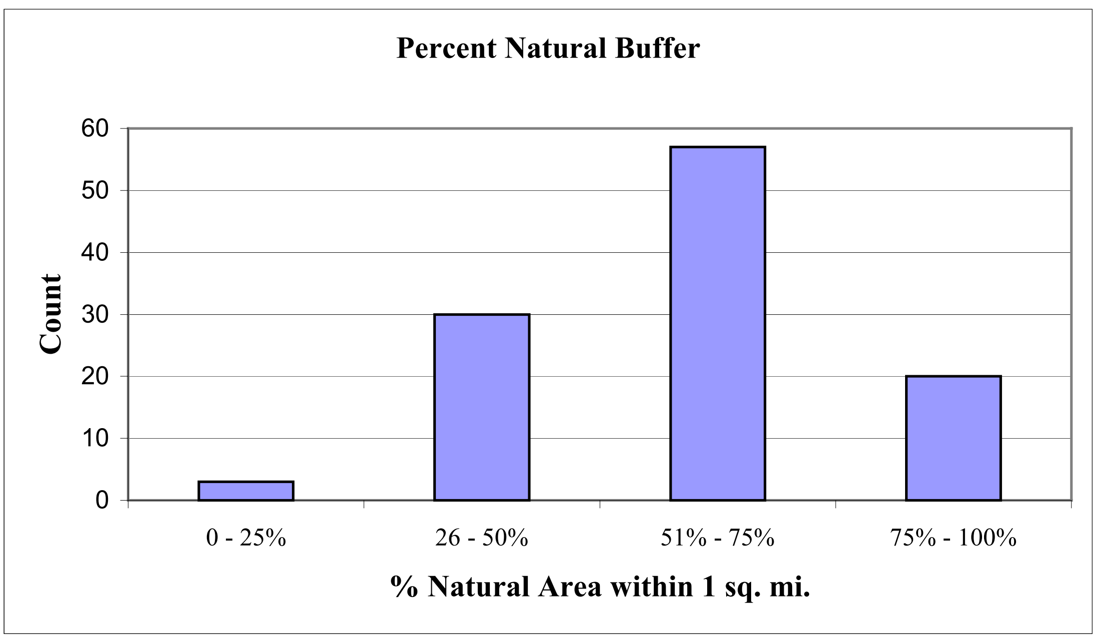

Figure 2. Percent natural area within one square mile of fen sites in southern Lower Michigan.

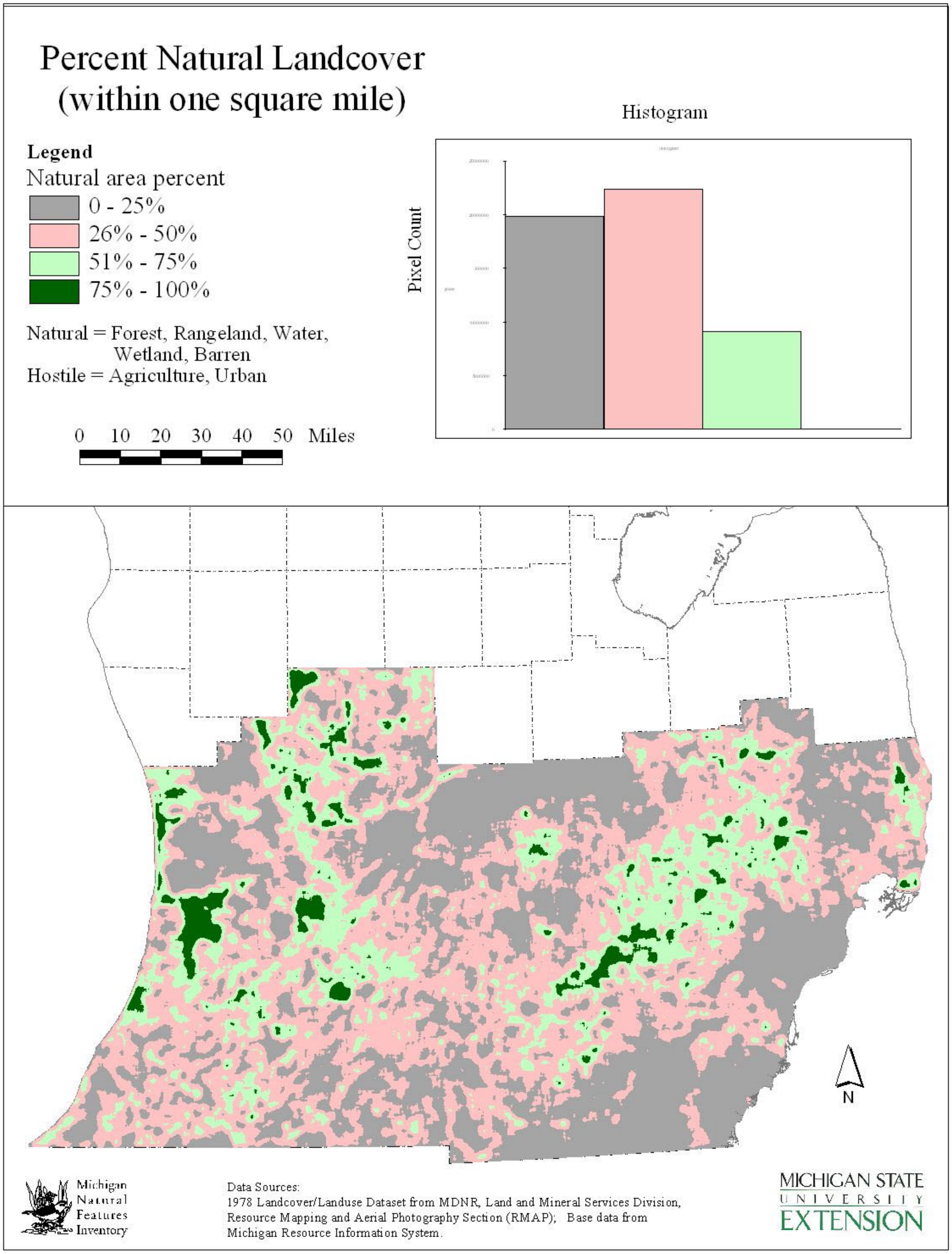

Figure 3. Percent natural area within one square mile of fen sites in southern Lower Michigan.

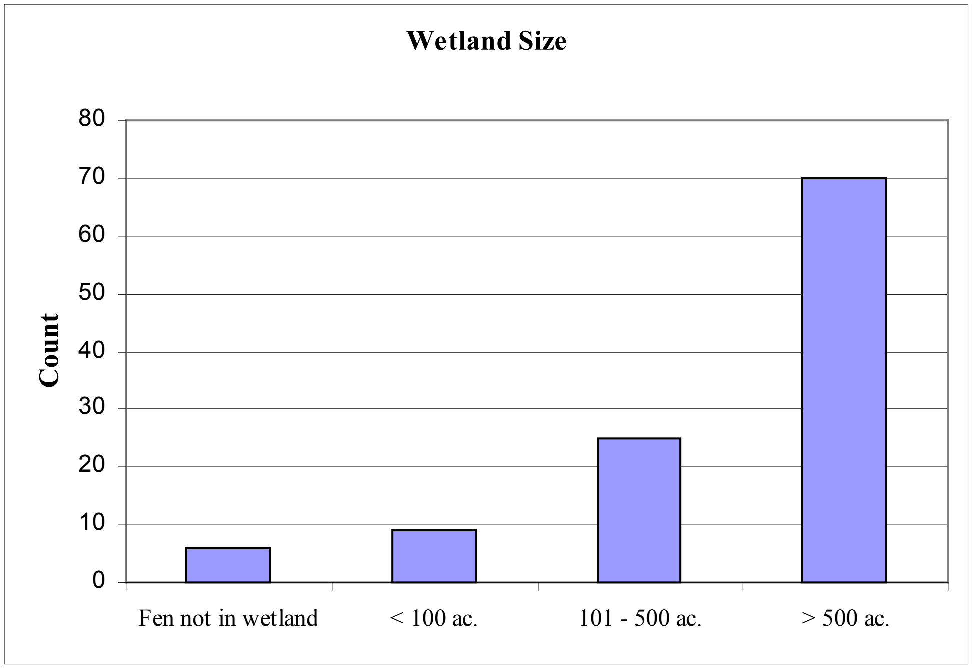

Figure 4. Size of the wetland complex associated with a fen.

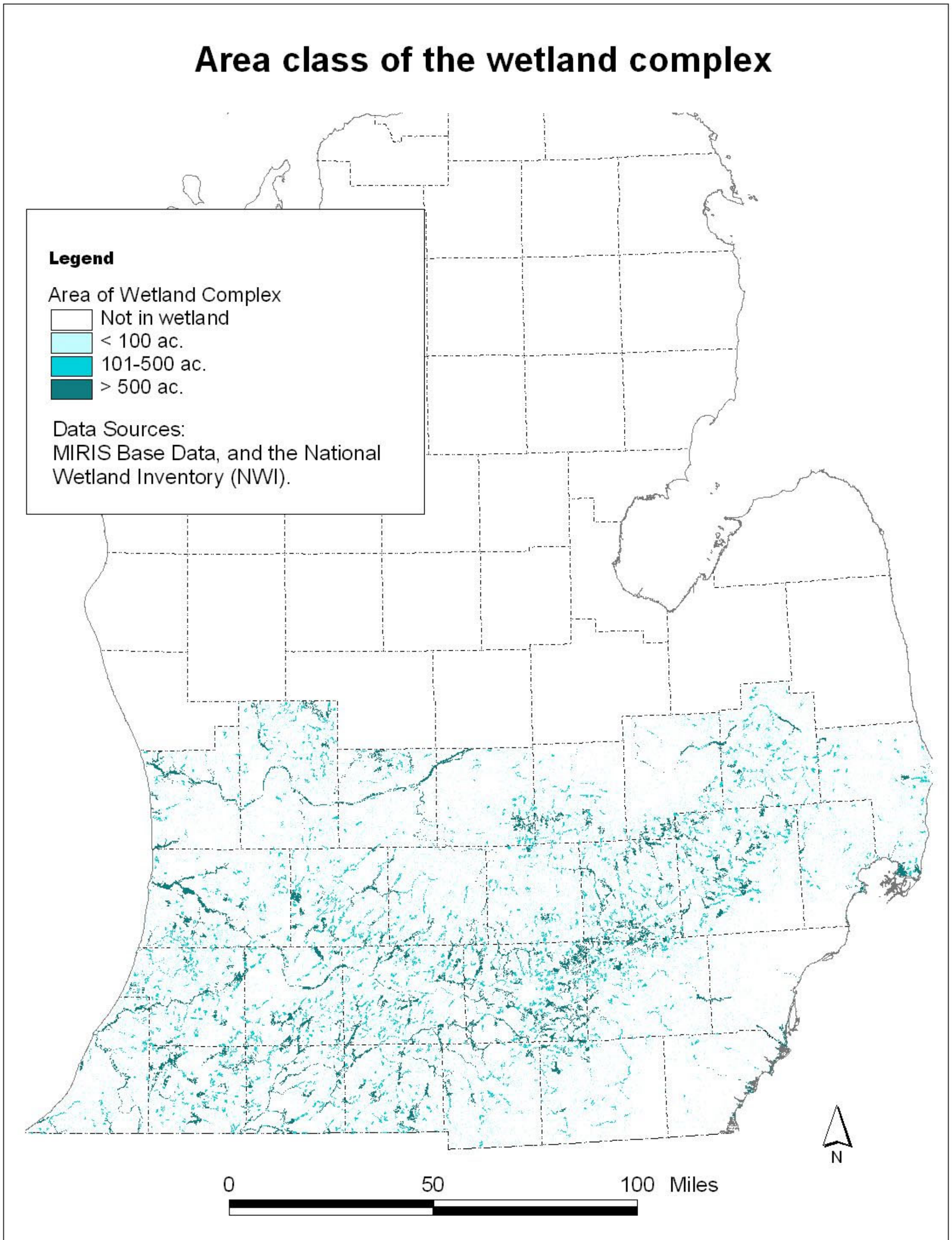

Figure 5. Size classification of wetland complexes in southern Lower Michigan.

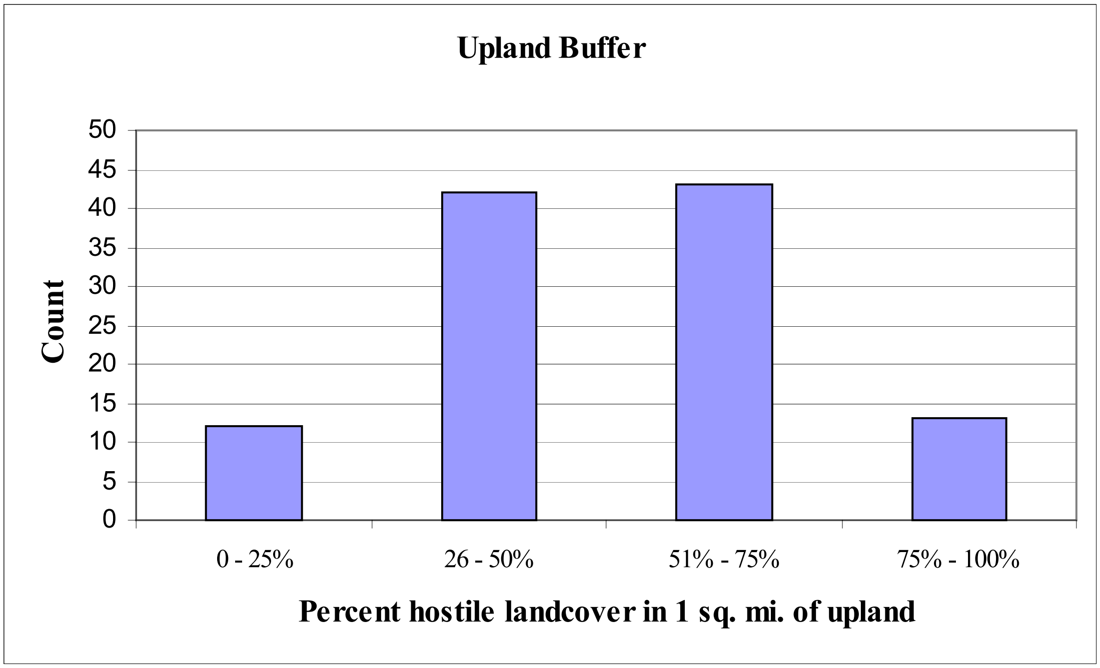

Figure 6. Percent hostile (urban and agriculture) upland land cover within 1 square mile of a fen.

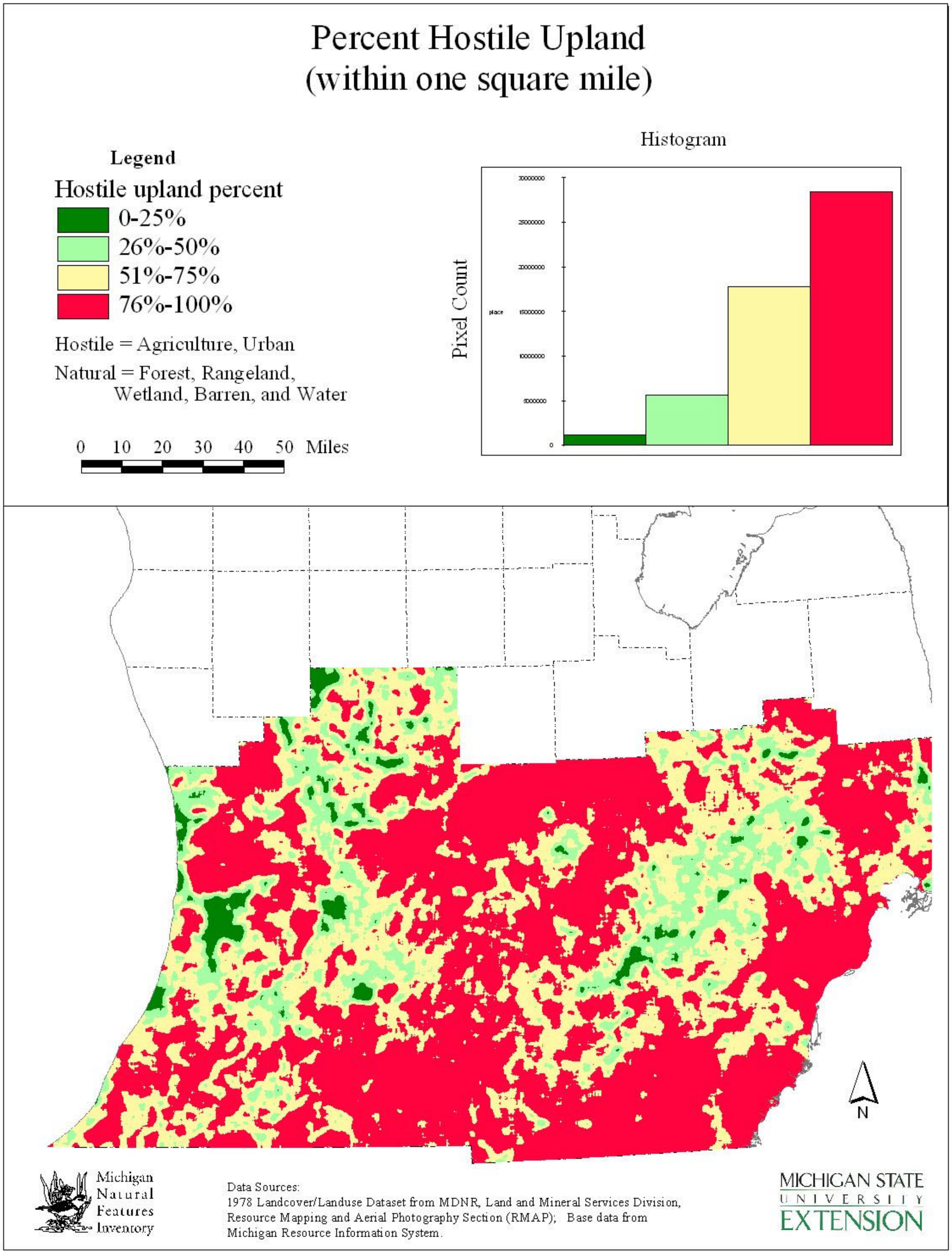

Figure 7. Percent hostile upland within one square mile of fen sites in southern Lower Michigan.

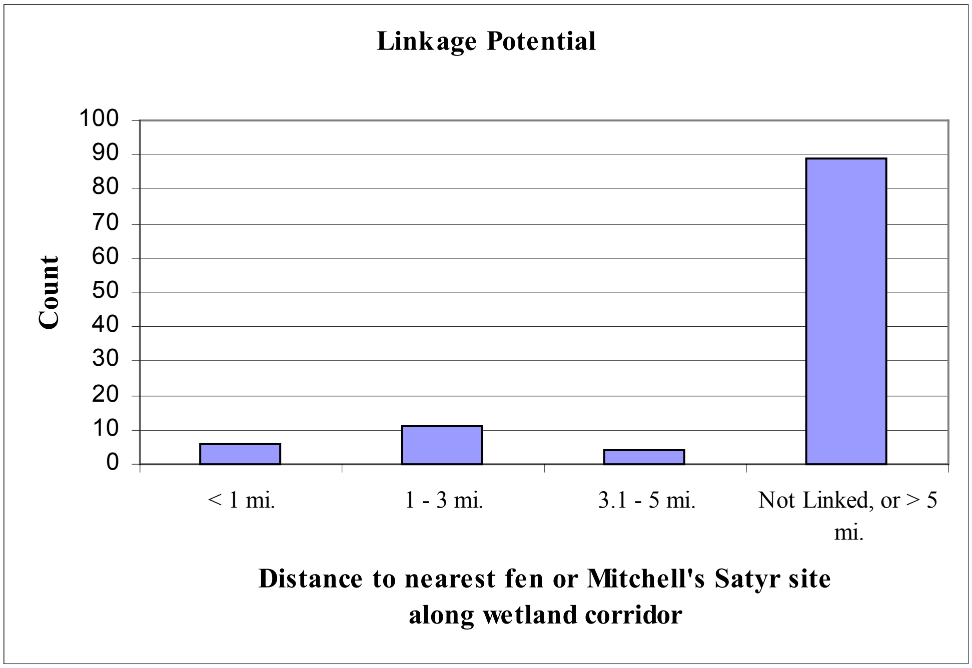

Figure 8. Distance of a fen to the nearest fen or Mitchell's satyr site connected by a wetland corridor.

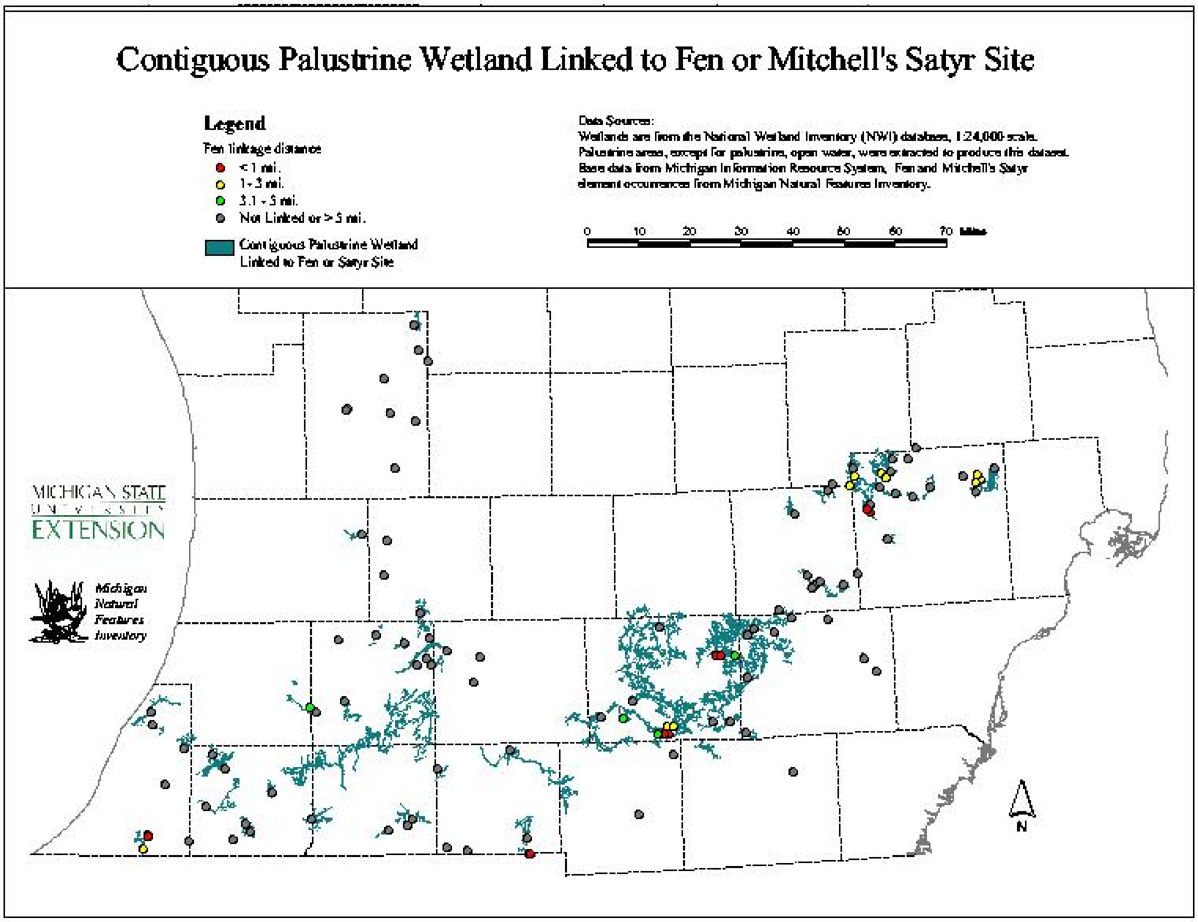

Figure 9. Contiguous palustrine wetland linked to fen or Mitchell's satyr site.

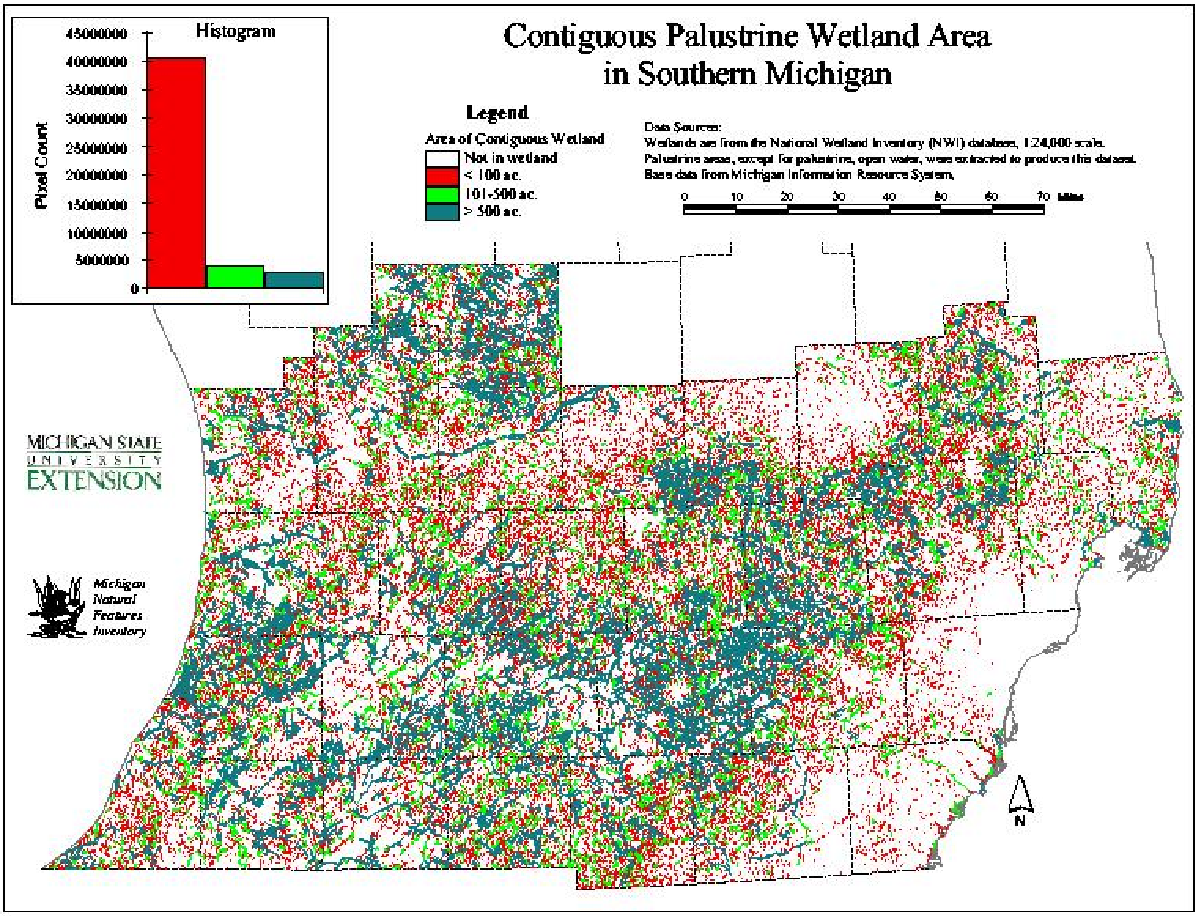

Figure 10. Contiguous palustrine wetland area around fens in southern Lower Michigan.

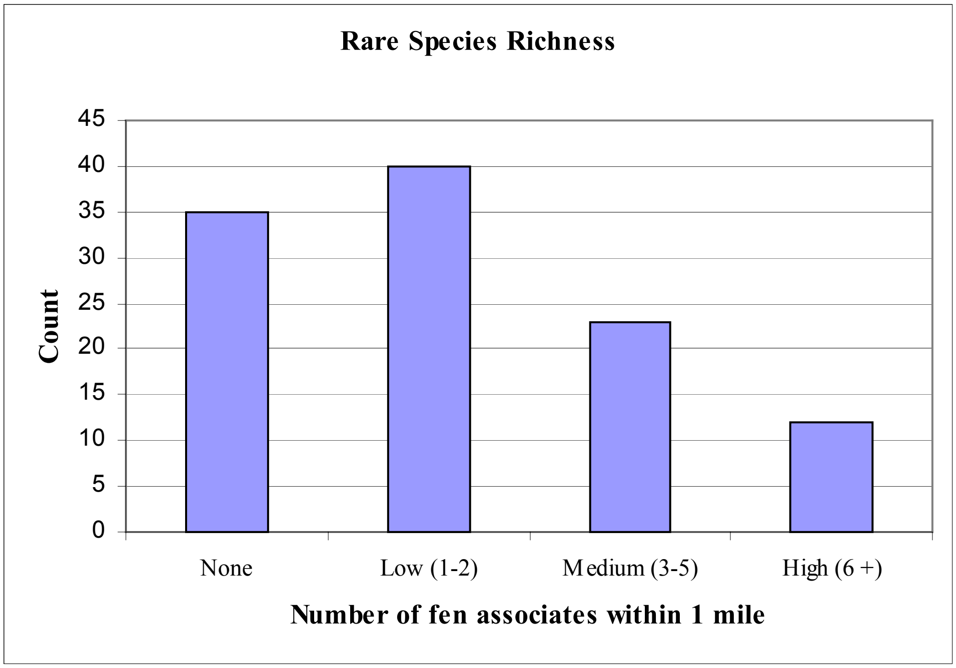

Figure 11. Number of fen-associated rare species within one mile.

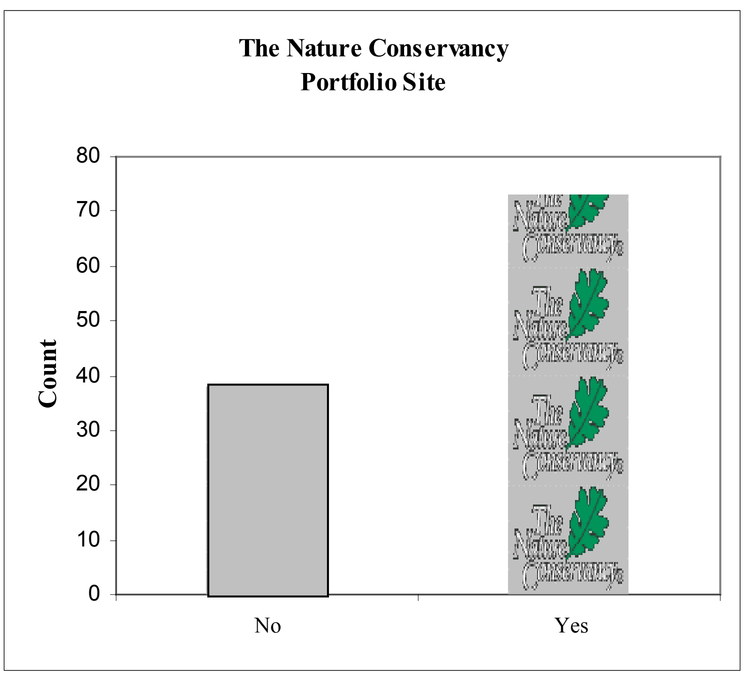

Figure 12. Number of fens falling within a Nature Conservancy Portfolio Site.

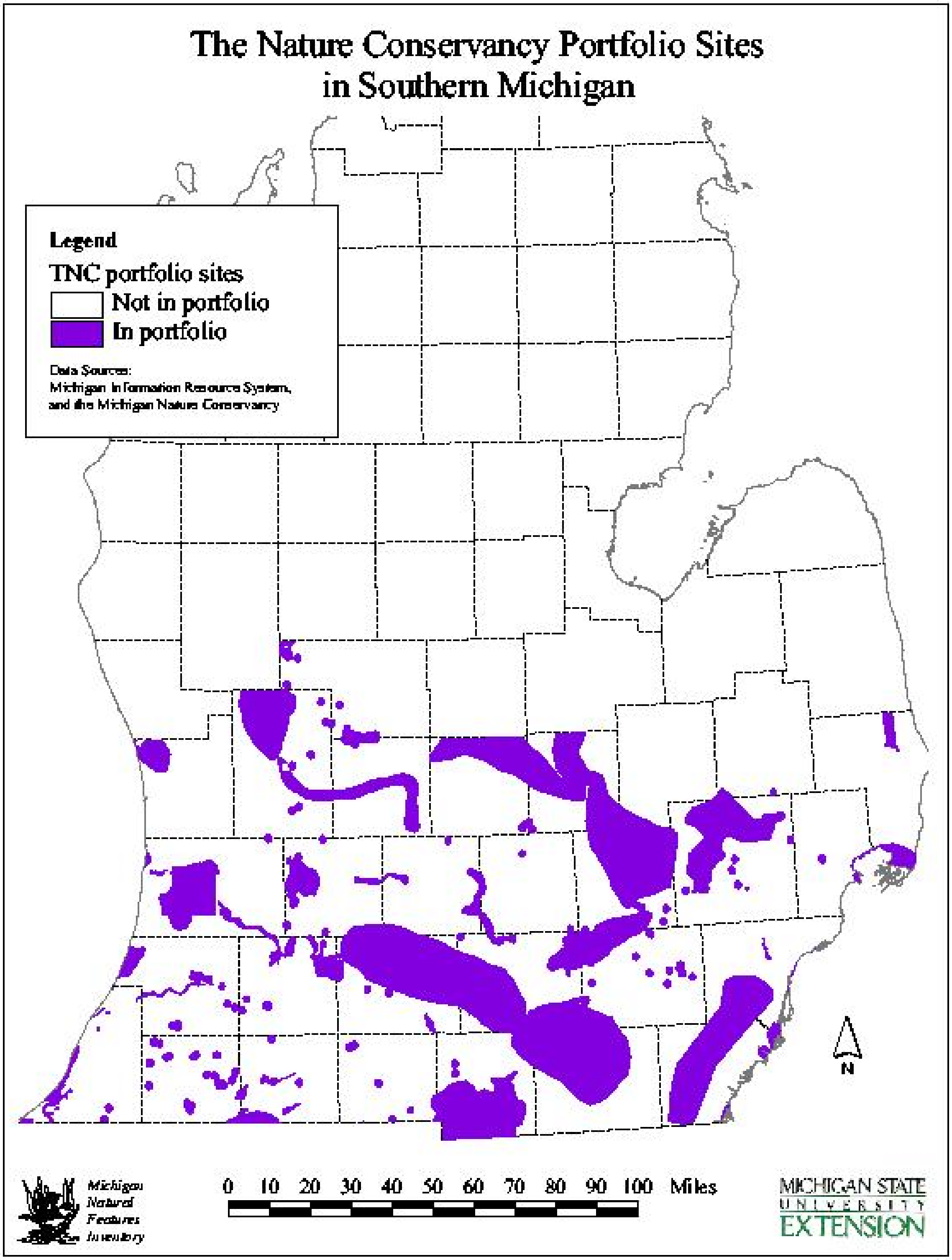

Figure 13. The Nature Conservancy Portfolio Sites in southern Lower Michigan.

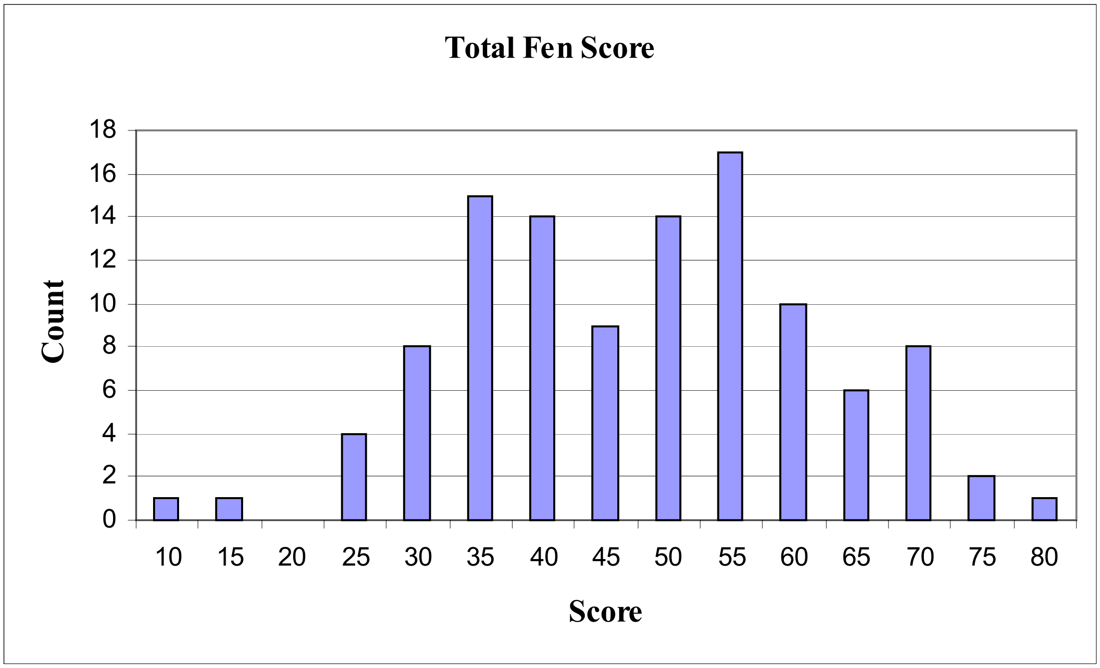

Figure 14. Histogram of total scores for 111 fen sites analyzed by habitat model.

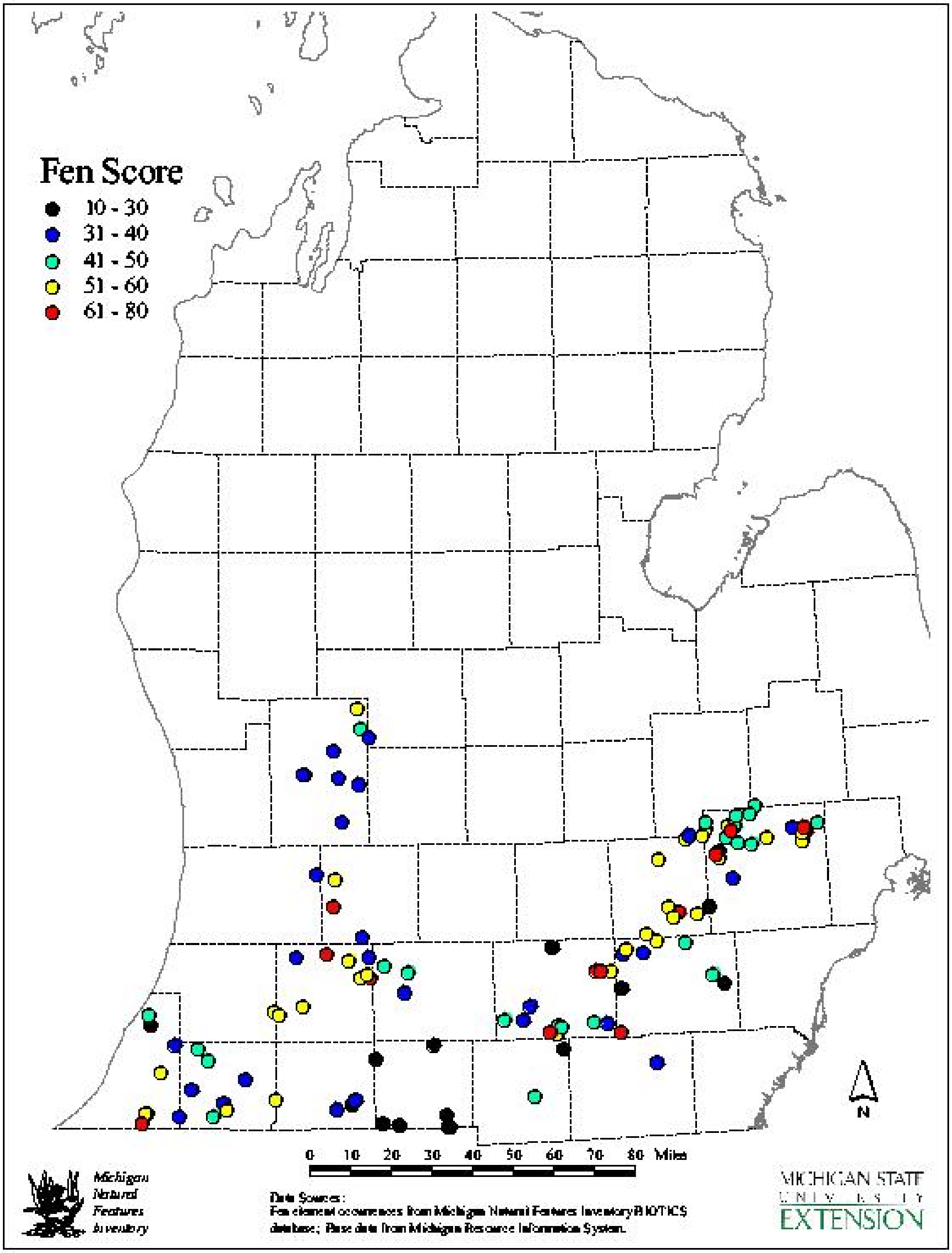

Figure 15. Distribution of fens, grouped by their total score, in southern Lower Michigan.

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APPENDIX 1

Objectives for 2000, Year Three
Federal Aid in Endangered Species, Michigan Project E-1-30

Job 1.1. Conduct field surveys to identify *N. m. mitchellii* occurrences within the species known historical range in Michigan and in new habitat with potential to support the species.

Job 1.2. Conduct surveys for eggs, larvae and pupae to improve our understanding of satyr life history.

Job 1.3. Characterize habitat at occupied sites to use in identifying potential reintroduction or translocation sites.

Job 1.4. Identify potential reintroduction or translocation sites to meet recovery goals in Michigan.

Job 1.5. Survey for rare species associated with satyr habitat as time permits.

Job 2.1. Assess threats to *N. m. mitchellii* at all occupied sites, including habitat destruction, the presence of invasive exotic species, altered hydrology, and lack of landowner interest in managing for the species.

Job 2.2. Work with Michigan Satyr Working Group to develop and initiate a monitoring protocol for *N. m. mitchellii* occurrences and associated relevant species and habitat characteristics.

Job 3.1. Provide updated occurrence information to regulatory agencies, Natural Heritage BCD, ecoregional planning teams, landowner contact and private lands management programs, and other appropriate management, protection, and conservation projects.

Job 3.2. Identify ecosystems as conservation units around viable sites, incorporating objectives for other state and federally listed species and species of concern, and provide to relevant conservation and protection efforts.

Job 3.3. Consult with researchers, other experts, and the Michigan Mitchell's Satyr Working Group to discuss results and to determine the next steps for inventory, site assessment, and reintroduction or translocation efforts.