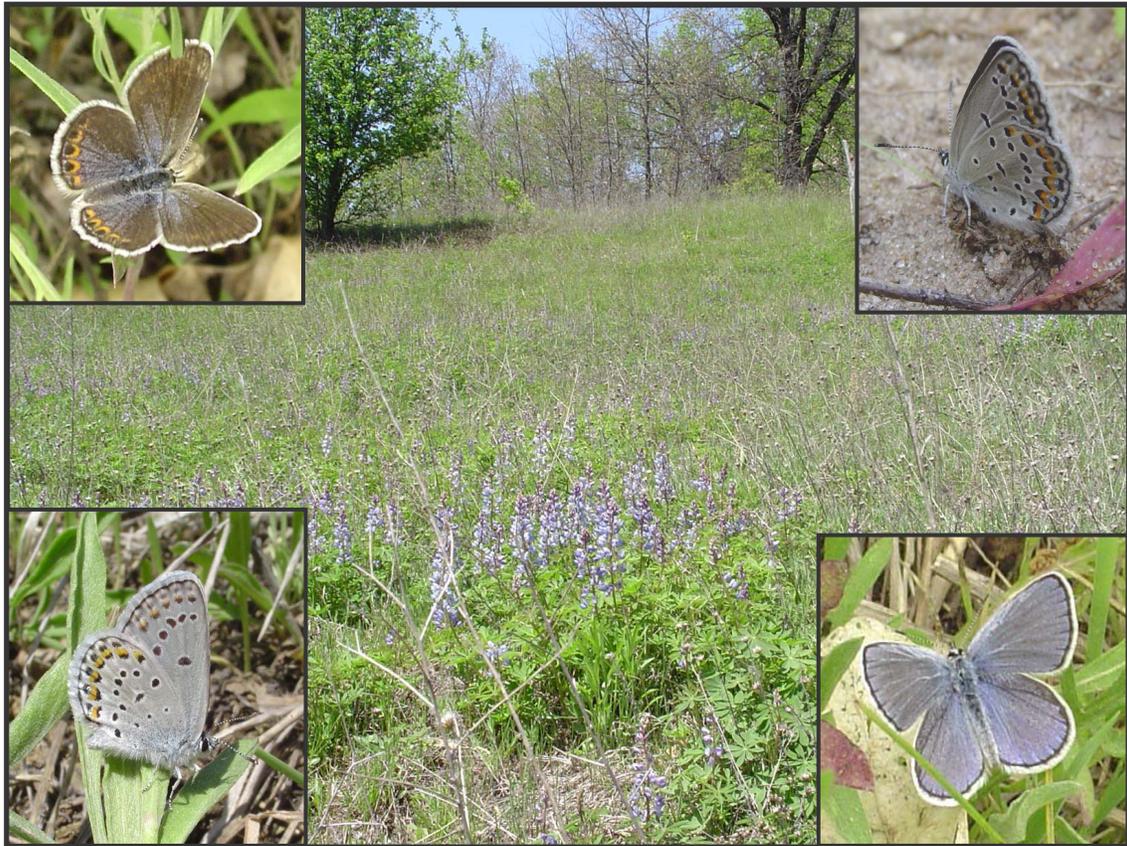

Comprehensive Population and Habitat Surveys for the Karner Blue (*Lycaeides melissa samuelis*) in Michigan: 2003 Progress Report



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Cover Photo Identification and Credits:

Clockwise from Upper left: Karner blue female, side view, male, side view

Center: *Lupinus perennis* on private property, Ionia County.

All photos in this report are by the author.

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INTRODUCTION

The Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov) was listed as endangered by the U.S. Fish and Wildlife Service (USFWS) in 1992. The butterfly was once known from 12 states and the Canadian province of Ontario, but currently occurs in just seven states - Indiana, Michigan, Minnesota, New Hampshire, New York, Ohio (reintroduced population), and Wisconsin (USFWS 2003). Michigan and Wisconsin contain the greatest numbers of butterflies and populated habitat patches (USFWS 2003). The species was once present in 11 Michigan counties and is now found in 10 western Lower Peninsula counties, half support just 1 to 5 small, isolated sites at risk for extinction from habitat degradation (Figure 1, Wilsman 1994, Rabe 2001).

The Karner blue butterfly is associated with barrens and savanna systems throughout its range. A variety of habitat characteristics unique to these systems influence Karner blue population viability. Wild or blue lupine (*Lupinus perennis* L.), a legume associated with prairies or savannas, is the only known food plant for the Karner blue caterpillar and must be present for Karner blue to persist in an area. Lupine density, abundance, and quality influence Karner blue population levels (Bernays and Chapman 1994, Savignano 1994, Herms 1996, Swengel and Swengel 1996, Grundel et al. 1998a, 1998b, Maxwell 1998, Lane 1999a.). Nectar of flowering plants serves as a food source for adult butterflies, and nectar plant diversity and availability also impact Karner blue populations (Fried 1987, Lawrence and Cook 1989, Bidwell, 1994, Grundel et al. 2000).

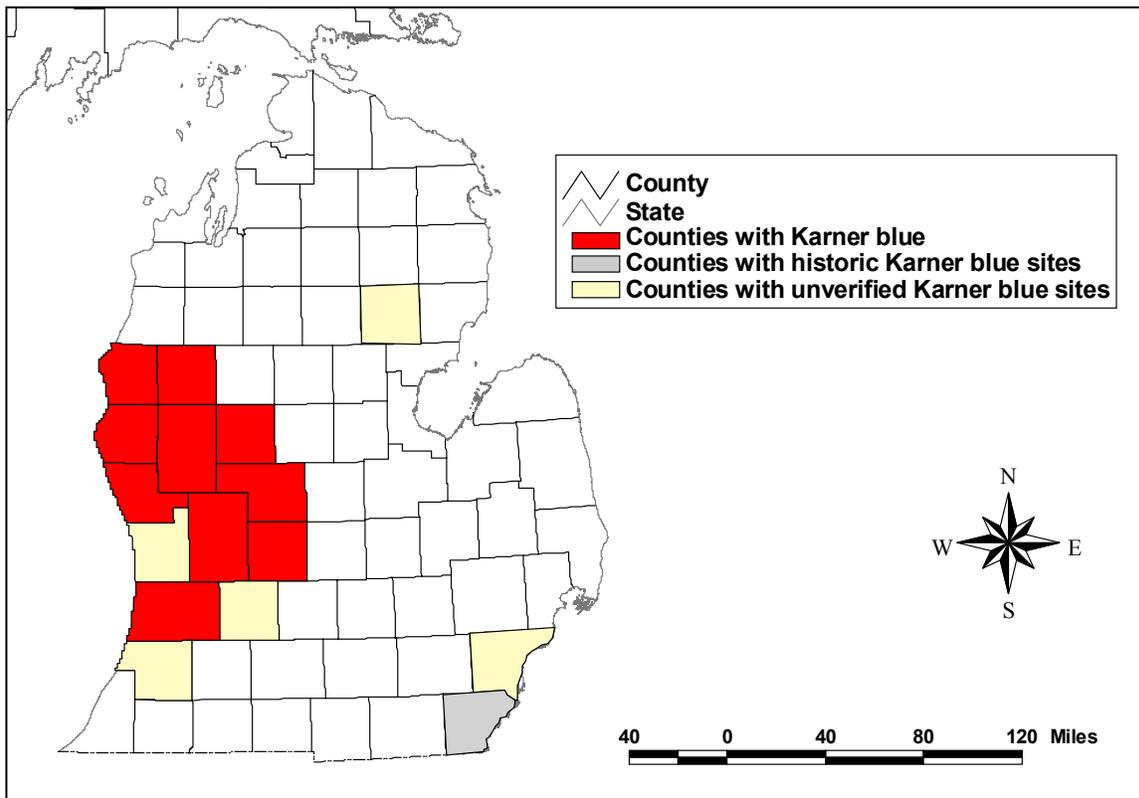


Figure 1. Karner blue butterfly distribution in Michigan.

Lupine and preferred nectar plant species are associated with semi-open to open areas, making the amount of canopy closure an important factor in determining habitat quality (Packer 1987, Lawrence and Cook 1989, Lane 1994, Maxwell and Givnish 1994, Smallidge et al. 1996, Maxwell 1998, Grundel et al. 1998b). In addition, a variety of microhabitats are used by Karner blue adults throughout the day, and butterflies are often more abundant in areas with diverse vegetation structure (Lane 1993, 1999b). The presence of mutualistic ant species appears to benefit Karner blue larvae, and areas with ant mounds have been found to contain more butterflies than comparable habitats without ants (Savignano 1990, 1994, Lane 1999b). Finally, the distribution of habitat patches across the landscape will determine long-term viability of Karner blue metapopulations. A single site likely cannot maintain a subpopulation indefinitely (Givnish et al. 1988, Packer 1994), and multiple habitat patches help spread the risk of extinction from a catastrophic event.

Declines in Karner blue populations are driven by the loss of barrens and savanna systems that meet Karner blue habitat requirements (USFWS 2003). Karner blue habitat patches were historically maintained by fires (Chapman 1984), which helped maintain the characteristic vegetative structure and species composition (Tester 1989). However, fire suppression efforts have led to succession of barrens and savanna to woodlots and forests in many areas. This, coupled with conversion of lands to agriculture, pine plantations, residential areas, and other uses have drastically reduced the quality and availability of habitats in Michigan (Wilsmann 1994). As a result, remaining Karner blue populations are now found only in remnant native oak savannas, barrens, and man-made habitats with conditions suitable for lupine growth. Man-made Karner blue habitat results from timber harvest, road and utility right-of-way maintenance, or direct management (e.g. mowing or prescribed burning) aimed at maintaining an open canopy (Evers 1994). A comprehensive understanding of the distribution and characteristics of Karner blue occupied, available, and potential habitats is needed to determine the current status and

guide future management efforts for the species in Michigan.

Currently, there are two primary sources of distributional information concerning this species in Michigan. These sources include the database maintained by the Michigan Lepidoptera Survey, with distributional information represented in Michigan Butterflies and Skippers (Nielsen 1999), and the Michigan Natural Features Inventory's (Inventory) Biological Conservation Database with ~200 confirmed records documented since the early 1930's (MNFI 2003). Records from the 1990's were obtained from surveys by the Inventory, the Michigan Department of Natural Resources (MDNR), the U.S. Forest Service (Forest Service), and The Nature Conservancy (TNC) that aimed to locate new extant sites, reconfirm historical occurrences, and monitor the butterfly's presence at known locations (Bess 1989, Sferra et al. 1993, Lawrence 1994, MDNR 1994, Wilsmann 1994, Schuetz 1996, Cuthrell and Rabe 1996, 1998).

Purpose of the Study

The USFWS and MDNR have initiated the development of a statewide Habitat Conservation Plan (HCP) for the Karner blue butterfly. Once the agreement is in place, the MDNR will have the ability to conduct management that might result in the incidental take of Karner blue, but will ultimately be to the benefit of the species. MDNR aspires to protect occupied sites, increase habitat availability, and increase butterfly populations to recovery levels, using the latitude of management options afforded by the HCP agreement (John Lerg personal communication). Important steps in the creation of a statewide HCP are to determine the current species distribution, define threats to population viability, and identify opportunities for enhancement of populations.

Although surveys have been conducted for Karner blue through much of the known range in Michigan, there are still large gaps in our knowledge of the current species distribution. First, not all recovery units (RUs) identified in the Karner blue Recovery Plan have received comprehensive surveys (USFWS 2003). Surveys over the last 10 years have focused on large, relatively contiguous tracts of state- and

federally-owned lands, namely Allegan State Game Area (SGA) in the Allegan Recovery Unit and the Huron-Manistee National Forest (HMNF) in the northern Muskegon RU (USFWS 2003). These surveys have undeniably added to the understanding of Karner blue distribution within those areas. However, the Ionia, southern Muskegon, and Newaygo RUs have much more fragmented ownership, making comprehensive surveys more difficult. As a result, fewer surveys have been conducted there, meaning much less is known about the Karner blue distribution in those RUs (USFWS 2003). In addition, re-survey of known sites is needed in much of the Ionia, Muskegon, and Newaygo RUs. Many Karner blue records may no longer represent occupied habitat because they have not been verified for several years. These “old” records should be re-surveyed to determine Karner blue presence or absence, and to identify threats to the persistence of extant subpopulations. Filling these gaps in our knowledge of current Karner blue distribution will lead to a better understanding of how the species is distributed across the landscape, facilitating informed management decisions and increasing the potential for species recovery.

In 2002, the Inventory began a three-year project with funding from the MDNR to determine the status and distribution of the Karner blue butterfly in Michigan. Inventory activities included presence-absence surveys on private and public land, habitat modeling, and

database support. The project goals are to identify the locations and extent of the most significant Karner blue metapopulations in Michigan, their current condition, threats to persistence, and opportunities for enhancement through habitat protection, expansion, reintroduction, or translocation. This report summarizes the first two years of activities conducted by the Inventory.

Project Objectives

The objectives of this project are to:

1. Complete comprehensive population and habitat surveys for the Karner blue in Michigan.
2. Transcribe and digitize new occurrence data.
3. Provide information on butterfly distribution and abundance.
4. Model potential habitat.
5. Document and survey other rare species that occur in association with Karner blue and are most likely to be affected by management activities.
6. Participate in meetings and conferences with HCP partners and the federal recovery team as needed.
7. Provide updates to regulatory agencies, ecoregion planning teams, landowner contact and private lands management programs and any other appropriate management, protection, and conservation efforts.

METHODS

Presence-Absence Surveys

Protocol

Karner blue presence-absence (detection-nondetection) surveys in 2002-2003 were conducted using a protocol adapted from the Wisconsin Habitat Conservation Plan (WI DNR 2000, Appendix 1). First flight (spring) surveys documented locations of lupine during actual site visits and roadside lupine surveys (conducted while driving to survey areas). Lupine, Karner blue, and targeted associated species locations were georeferenced using Garmin 12X GPS units. Second flight (summer) surveys were aimed at visiting targeted sites on public and private lands, and at lupine sites discovered during spring surveys. Habitat data

along with numbers and sex of butterflies observed were recorded on field forms. Forms included site location, general site characteristics, vegetation data, Karner blue observations, and sketched survey area maps (Appendix 2). Most surveys were conducted by two individuals, one watching for and counting butterflies and the other recording habitat data. Field packets containing field forms, maps (topographic, ownership, and aerial), and landowner information were created by Inventory seasonal staff for each site to be visited. Separate survey forms were completed in the field at sites separated by 100m of unsuitable habitat, 200m of suitable habitat, dispersal barrier, or a property boundary.

Priorities

Lupine and Karner blue Presence-absence surveys were conducted on private and public lands during the Karner blue flight periods, 2002-2003. Priority in 2002 was given to known element occurrences (EO, the spatial representation of a species and its required habitat at a specific location) where species presence had not been verified in two or more years, or where we obtained a site lead from Forest Service or MDNR personnel. Several MDNR lands were surveyed within the targeted RUs to determine lupine and Karner blue presence even if Karner blue had not been observed in the past. Other sites were surveyed in 2002 if they appeared suitable from 1992 or 1998 air photos, USGS topographical maps, IFMAP circa 2000 land use data for the Lower Peninsula, or circa 1800 vegetation maps (Comer et al. 1995).

The 2003 surveys were designed to provide a better understanding of connection among how sites on public lands, extension onto adjacent private lands, and locations of previously unknown populations. Therefore, private lands, utility rights-of-way, local government, and state and federal public lands were surveyed in 2003 if they appeared suitable and were within 200m of suitable or occupied habitat (NatureServe 2003). Several other private lands were surveyed upon obtaining permission if they appeared suitable from the road.

The USFWS established Recovery Units "...to preserve possible geographically associated genetic variation..." in the Recovery Plan (USFWS 2003). Metapopulations in southern Muskegon County are likely more similar genetically to those in the rest of the Muskegon RU than those in Allegan County, due to geographic separation. Therefore, the northern portion of the Allegan RU has been added to the Muskegon RU and labeled Southern Muskegon RU in this report (Figure 2). In addition, historic metapopulations in Monroe County were likely genetically similar to those in the Oak Openings RU in Ohio, which was expanded into southeast Michigan in this report to reflect this assumption.

In all, Portions of 57 townships were surveyed for Karner blue in 2002-2003 (Table 1). A majority of surveys were conducted within

the Ionia, Muskegon, and Newaygo RUs, although selected state lands outside those RUs were surveyed as well.

Public Lands Surveys

Surveys on state-owned lands included portions of State Game Areas (SGA), Recreation Areas (RA), Linear Parks (LP) and other managed areas within the targeted RUs (Table 2). Federal lands within the Huron-Manistee National Forest (HMNF) were surveyed if an EO was present, had not been verified extant for over 4 years, and the EO was near private or state lands.

Landowner Contact

Landowners with property targeted for survey in 2002 were contacted by phone using contact information obtained from previous correspondence. Ownership information for private parcels identified for survey in 2003 was obtained through county equalization offices. Township maps were printed from a GIS layout showing digitized and ranked properties overlain with plat maps. The maps were taken to the appropriate county equalization office and ownership information was recorded for high priority parcels. Ownership information for each record was then entered into the GIS table associated with the digitized parcel layer. Landowner contact information was generally not available through equalization and was therefore obtained for the highest ranked properties using internet white pages and information services, and subsequently entered into the GIS table.

Initial contact was aimed at gaining permission to survey and was conducted using a form letter and included a permission sheet (Appendix 3) which was to be filled out, signed, and returned using an enclosed postage-paid envelope. Second contact by phone or in person was attempted if no response resulted from the letter. Third contact in person was attempted when phone calls were not effective in reaching the landowners. Survey results were summarized and a letter stating whether Karner blue and/or lupine were present was sent to each landowner. Landowners with property containing lupine but where no Karner blue were found were asked to contact the Inventory if they were willing to allow a re-survey the following year.

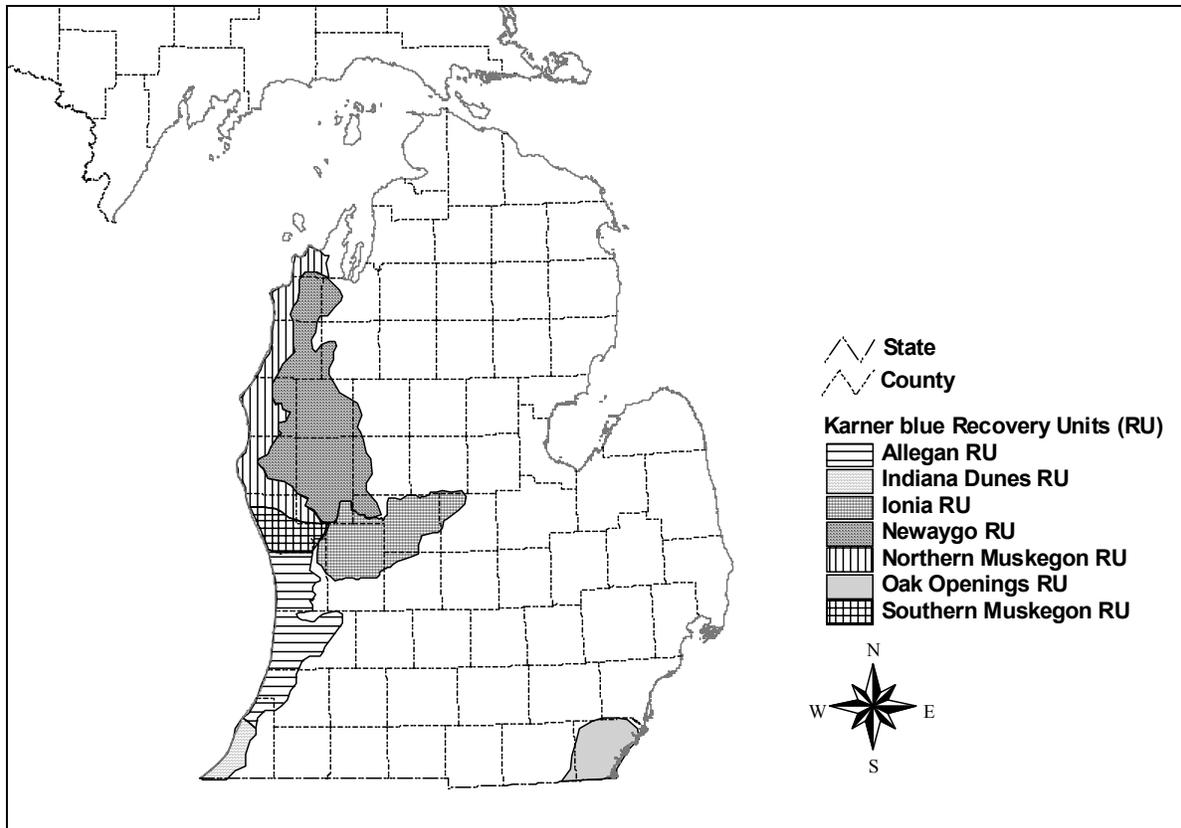


Figure 2. Karner blue Recovery Units (RU) in Michigan, adapted from the Recovery Plan (USFWS 2003). In this report, the northern portion of the Allegan RU has been added to the Muskegon RU and the Oak Openings RU has been extended to include historic Karner blue sites in southeast Michigan.

Table 1. Legal descriptions of townships surveyed in Karner blue Recovery Units (RU), 2002-2003.

Allegan RU	Ionia RU	Muskegon RU	Southern Muskegon RU	Newaygo RU	Oak Openings RU	No RU
T02N R14W	T07N R10W	T11N R14W	T10N R14W	T11N R12W	T07S R06E	T01N R06E
T03N R13W	T08N R07W	T11N R15W	T10N R15W	T12N R10W		T02S R12W
T03N R14W	T08N R08W	T11N R16W	T10N R16W	T12N R11W		T03N R09W
T03N R15W	T08N R10W	T12N R15W	T11N R14W	T12N R12W		T03N R10W
	T09N R07W	T12N R16W	T11N R15W	T13N R10W		T03S R11W
	T09N R08W	T12N R17W	T11N R16W	T13N R11W		T04N R09W
	T09N R10W	T13N R14W		T13N R12W		T06N R09W
	T09N R11W	T13N R15W		T14N R13W		T07N R05W
	T10N R06W	T13N R16W		T15N R09W		
	T10N R07W	T13N R17W		T15N R12W		
	T10N R12W			T15N R13W		
	T11N R06W			T16N R12W		
	T11N R08W			T16N R13W		
				T17N R12W		
				T17N R14W		
				T18N R13W		
				T18N R15W		
				T19N R13W		

Table 2. Public lands surveyed for Karner blue and lupine, 2002-2003.

Recovery Unit	Public Lands Surveyed	County
Allegan RU	Allegan SGA	Allegan
Ionia RU	Cannonsburg SGA	Kent
	Flat River SGA	Ionia/Montcalm
	Ionia County RA	Ionia
	Langston SGA	Montcalm
	Lowell SGA	Kent
	Rogue River SGA	Kent
	Stanton SGA	Montcalm
	Vestaburg SGA	Montcalm
Muskegon RU	Hart-Montague LP	Oceana
	HMNF	Muskegon/Oceana
	State Lands in HMNF	Oceana
	Muskegon SGA	Muskegon/Newaygo
Newaygo RU	HMNF	Newaygo/Montcalm
	White Pine Trail LP	Montcalm/Mecosta
	Newaygo SP	Newaygo
Oak Openings RU	Petersburg SGA	Monroe
No RU	Island Lake RA	Livingston
	Barry SGA	Barry
	Middleville SGA	Barry
	Gourdneck SGA	Kalamazoo
Total Counties Surveyed		13

Private Lands Surveys

We surveyed private lands, including lands owned by municipalities, organizations, businesses, power companies, and over 120 individuals. Private lands with existing EOs within the Ionia, Muskegon, and Newaygo RUs were surveyed in 2002 if the butterflies had not been observed in four or more years.

Private parcels were identified and prioritized for survey in 2003 using ArcView GIS. MDNR-owned digital image files including Rockford plat maps, USGS topographical maps (1981-1987), and USGS digital orthophoto quadrangles were used to identify private parcels with openings that potentially contained lupine. Data layers were then used to identify and prioritize sites with the most potential for Karner blue. Layers included Karner blue locations with a 200m buffer, circa 1800 vegetation cover (Comer et al. 1995), and public land boundaries. Property boundaries of private parcels were digitized from plat maps if the property contained openings, were historically barrens or savannas, and were within 200m of Karner blue

sites. Parcels were then ranked by distance to public land, distance to Karner blue occupied habitat, and size of the property. Larger properties and those that were closer to public land or occupied habitat were given higher priority. Additional properties were added where site leads were obtained from MDNR or Forest Service personnel.

Data Transcription and Digitizing

Element Occurrence Determination

Occupied habitat patches were considered separate if they were separated by 100m of unsuitable habitat, 200m of suitable habitat, or a significant barrier to dispersal (Nature Serve 2003, USFWS 2003). In order to determine whether a site was an extension of a pre-existing Karner blue EO or was a new record, the distance to a known EO was calculated in GIS for each site. In addition, sites were given a 100m buffer to determine whether multiple occupied sites were part of the same EO. Barriers to dispersal (e.g. large river basin or dense woods) were noted using aerial photos,

and separated EOs if they could be assumed to prevent dispersal between sites.

Sites were then classified as one of the following: (1) new Karner blue EOs – sites where Karner blues had not been previously documented, but were present in 2002 or 2003, (2) EO updates – sites where Karner blue had been previously documented and 2002-2003 Inventory surveys revealed that Karner blue was present (present update), lupine was present but Karner blue were not detected (lupine only update), or no lupine or Karner blue were found (absent update), or (3) EO extensions – sites near enough to an existing EO to be considered a part of that occurrence, but where Karner blues had not been previously documented. In addition, previously unsurveyed non-EO sites where Karner blue were not observed were classified as either (1) non-EO lupine only – Karner blue were not observed, but lupine was present or (2) non-EO absent – no Karner blue or lupine was found within the survey area. This distinction was made because several areas surveyed appeared suitable, were near known occupied habitat, but no Karner blue were observed.

Database Updates

Prior to 2002 Inventory surveys, most EOs were represented by buffered points or section records in the Database. In order to enhance the usefulness of the Database for land managers and conservation planners, all existing and new Karner blue EOs surveyed in 2002-2003 were digitized as polygons in BioTICs according to Natural Heritage Methodology. Aerial photos,

topographical maps, and GPS points taken in the field aided polygon creation. EO polygons represent the extent of suitable habitat (lupine and nectar species) potentially used by the butterflies observed during surveys and their progeny.

Data associated with EOs were transcribed into the Database from field survey forms. Information including survey dates, the number and sex of Karner blues observed, a general habitat description, and directions to the site is included and can be utilized by those with access to the Database.

Site Level Habitat Attributes

Habitat data was entered from field forms into a Microsoft Excel spreadsheet, saved as a database file, and linked to the digitized polygons in GIS using a common identifying field. Sites with certain characteristics could then easily be represented spatially across the landscape.

Habitat Features

The percentage of occupied, lupine only, and absent sites within the following variables was calculated to determine general site characteristics: Current threats, management, opening type, surrounding environment, and canopy cover (Table 3). Vegetation and other habitat characteristics were also recorded: dominant ground cover, woody species, exotic species, lupine density, lupine abundance, percent area covered by lupine, deer browse on lupine, nectar species, rare or indicator species, and ant mounds (Table 4).

Table 3. General site description variables, their categories, and how categories were identified during Karner blue surveys, 2002-2003.

Characteristic	Variable	Indicated by
Current Threat	ORV	Two-tracks or ruts through site
	Vehicles	Site adjacent to busy road, roadkill probable
	Exotic	Exotic species are dominant vegetation
	Succession	Woody species encroaching on site
	Management	Unregulated disturbance that may result in take, but otherwise may benefit Karner blue (mowing, burning, hand cutting woody vegetation)
	Dumping	Piles of trash or yard waste present
	Development Other	Evidence of building or road construction within or adjacent to the site
Management	Cut	Evidence of timber harvest
	Burned	Evidence of burn or presence of fire-obligate plant species
	Mowed	Evidence of mechanical brush removal or mowing
	Herbicide	Absence of vegetation susceptible to common herbicides, or where known herbiciding has taken place (e.g. right-of-way)
	Hand Cut	Area known to receive woody species removal via hand-cutting
	Planted Other	Pine plantation or evidence of past planting
Opening Type	Right-of-way	Power line transmission or distribution line, gas pipeline
	Field	Abandoned agricultural field
	Clearing	Open area that appears to have been cleared for purpose other than agriculture
	Barrens	Site supporting barrens, dry sand prairie, or savanna indicator species and vegetative structure
	Openings Roadside	Openings in woods created by natural disturbance or environmental factors Site along a road with two or more lanes
Surrounding Environment	Hardwoods	Deciduous woods in one or more cardinal directions
	Pines	Pine woods or plantation in one or more cardinal directions
	Agriculture	Row crops or pasture in one or more cardinal directions
	Residential	Assemblage of houses in one or more cardinal directions
	Potential habitat	Open or semi-open area with lupine or nectar species likely present in one or more cardinal directions, but not surveyed due to lack of permission
	Wetland Other	Area of mesic soils with wetland vegetation in one or more cardinal directions
Canopy Closure	Open	0-24% canopy closure
	Partial	25-49% canopy closure
	Most	50-74% canopy closure
	Closed	75-100% canopy closure

Table 4. Habitat variables and their components collected at all survey sites, 2002-2003. Presence or absence at a survey site was documented for species and other variables were recorded in categories as indicated.

Variable	Components	
Dominant Ground Cover	Grass Sedge (<i>Carex</i> spp.) Forb Fern	
Lupine Density and Distribution	0 – No lupine 1 – Scattered plants sparsely distributed 2 – Scattered plants common 3 – Scattered plants abundant 4 – Clumps sparsely distributed 5 – Clumps common 6 – Clumps abundant 7 – Dense patches sparsely distributed 8 – Dense patches common 9 – Dense patches abundant	
Lupine Density	Scattered Clumped Dense	
Lupine Distribution	Sparse Common Abundant	
% Lupine in bloom or seed	0-24% 25-49% 50-74% 75-100%	
Deer Browse	Present/Absent	
Ant Mounds	Present/Absent	
Woody Species	Oak (<i>Quercus</i> spp.) Cherry (<i>Prunus</i> spp.) Sassafras (<i>Sassafras albidum</i>) White Pine (<i>Pinus alba</i>) Other deciduous Other evergreen	
Exotic Species	Spotted knapweed (<i>Centaurea biebersteinii</i>) St. John's wort (<i>Hypericum perforatum</i>) Hoary alyssum (<i>Berteroa incana</i>) Sweetclover (<i>Melilotus</i> spp.) Queen Anne's lace (<i>Ammi majus</i>)	Hawkweed (<i>Hieracium</i> spp.) Autumn olive (<i>Elaeagnus umbellata</i>) Honeysuckle (<i>Lonicera japonica</i>) Other exotics
Preferred Nectar Species (Grundel and Pavlovic 2000)	Butterfly weed (<i>Asclepias tuberosa</i>) Dewberry (<i>Rubus flagellaris</i>) Dotted Horsemint (<i>Monarda punctata</i>) Flowering Spurge (<i>Euphorbia corollata</i>)	Goldenrod (<i>Solidago</i> spp.) Lance-leaf Coreopsis (<i>Coreopsis lanceolata</i>) New Jersey Tea (<i>Ceanothus americanum</i>)
Other Flowering Species	Aster (<i>Aster</i> sp.) Blackberry (<i>Rubus</i> sp.) Black-eyed susan (<i>Rudbeckia hirta</i>) Blazing star (<i>Liatris</i> spp.) Blueberry (<i>Vaccinium</i> sp.) Downy Phlox (<i>Phlox pilosa</i>) Dwarf Dandelion (<i>Krigia biflora</i>) Fleabane (<i>Erigeron</i> spp.)	Primrose (<i>Oenothera lamarckiana</i>) Puccoon (<i>Lithospermum</i> spp.) Sunflower (<i>Helianthus</i> spp.) Violet (<i>Viola</i> sp.) Wild bergamot (<i>Monarda fistulosa</i>) Yarrow (<i>Achillea millefolium</i>) Other

Habitat Analysis

The hypotheses tested in habitat data analyses were (1) Karner blue presence or absence is associated with general site characteristics, (2) Karner blue presence or absence is associated with site level habitat components, (3) detection or nondetection is associated with lupine density and distribution, and (4) detection or nondetection is associated with nectar species diversity and availability. Pearson Chi-square (χ^2) tests were used to determine whether variables were associated with Karner blue presence or detection. Associations were considered significant when the probability (P) of obtaining the observed table frequencies given the null hypothesis (no association) was less than 0.05.

In order to determine whether Karner blue presence is associated with general site characteristics, variables at present and absent sites were compared. Variable frequencies were placed in 2x2 tables (category presence/absence x Karner blue presence/absence) which were then analyzed using χ^2 tests.

Site level habitat variables were compared at present and absent sites using χ^2 analyses. Significant χ^2 values for variables were noted, but were difficult to interpret given the structure of the contingency tables analyzed. Significant variables were therefore separated into their components (Table 4). The components were then analyzed to determine whether an association exists with Karner blue presence.

Components of the lupine density and distribution variable and the number of nectar species available were compared between Karner blue presence versus lupine only sites. Components of the lupine variable used in the analyses, and the number or diversity level of preferred nectar plants and flowering species were compared with present and lupine only sites.

Landscape Level Model

A GIS model was created for Muskegon County as a test case to determine the practicality and usefulness of modeling Karner blue habitat management potential. The model was designed to reveal the locations of areas that, with some management activity, could develop into suitable habitat and potentially become occupied. In addition, the model was built to expose areas where occupied or suitable habitat exists, but may otherwise go unnoticed.

Spatial data layers representing factors that influence habitat suitability and management potential were selected using the literature and landscape level attribute data as a guide. Final model variables included IFMAP 2000 Michigan Land Cover, Michigan Land Use Circa 1800 (Comer et al. 1995), GAP Land Stewardship, Karner blue locations, and associate species and community EOs. Other layers exist that may have been useful in the model but were not used for various reasons (e.g. NRCS soils data not available for all counties, Geology resolution too coarse). Time constraints limited the creation and use of derived variables (e.g. habitat connectivity, patch size). Relevant information was extracted from each of the spatial layers, and those variables were weighted according to their influence on management potential for Karner blue habitat (Figure 3).

All of the GIS work was conducted using ArcGIS Desktop (ArcMap, ArcCatalog and ArcToolbox) and the ArcGIS Spatial Analyst extension (ESRI 2001, 2002). Spatial layers were clipped to the boundary of Muskegon County, re-projected to the UTM coordinate system, and assigned weights using the reclassify command in Spatial Analyst. Layers were then added together using the raster calculator in Spatial Analyst. The resulting layer was reclassified into seven categories using the Jenks natural breaks method. This located land that could be managed for the Karner Blue.

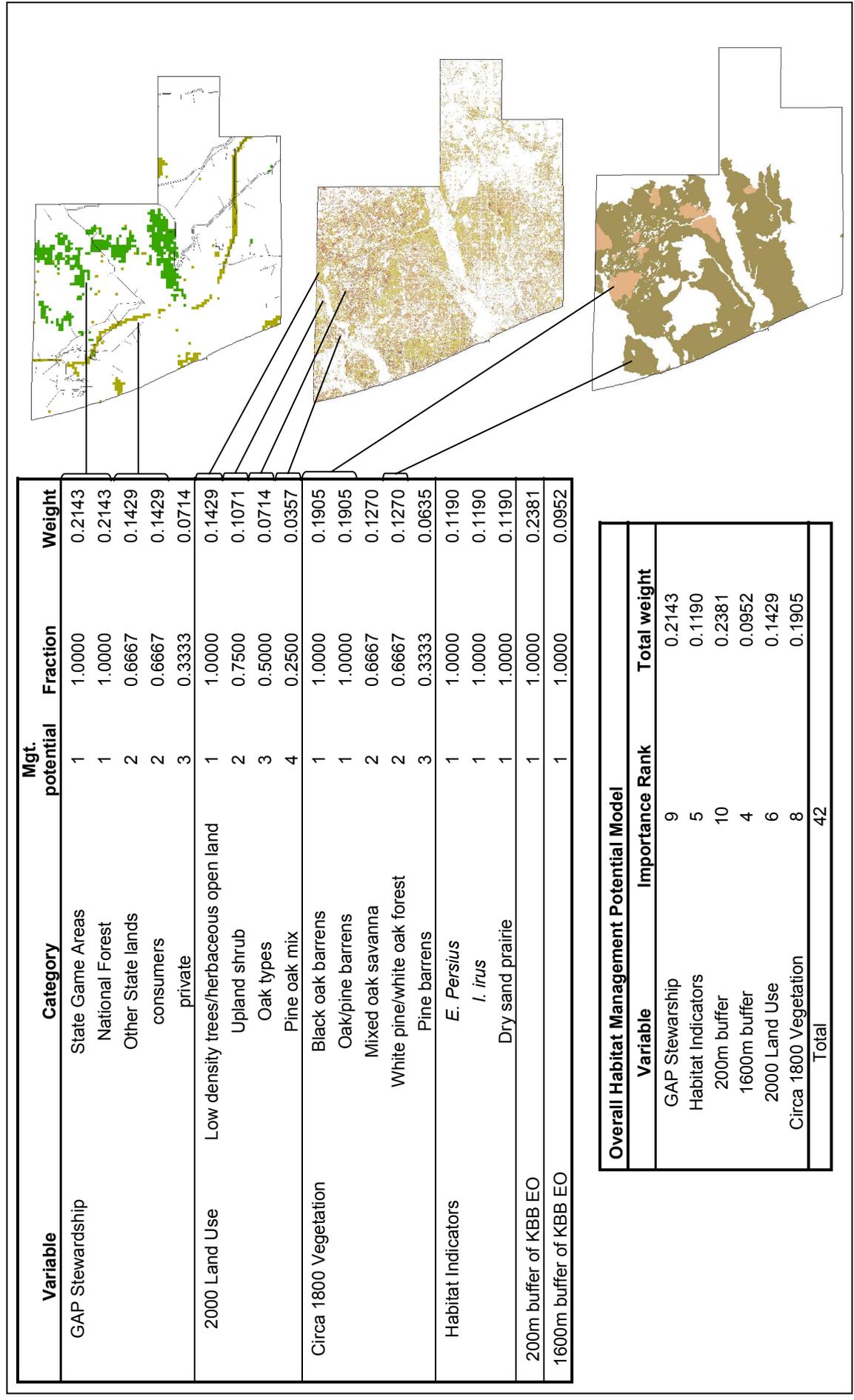


Figure 3. Illustrations of information extracted from spatial layers and their categories weighted according to their significance in determining the management potential for Karner blue butterfly habitat.

The results were tested in the spring 2003 field season by driving roads near areas that were given high potential values, and noting the apparent suitability of the habitat. Lupine observed along roads was georeferenced for later model validation. Some lupine patches discovered in this manner were surveyed during the summer season for Karner blue occupancy.

Distribution and Abundance

Digitized polygons were used to explore the present and past Karner blue distribution in Michigan. A final determination of Karner blue distribution will be completed using current and historic EOs in conjunction with a statewide habitat model, once completed.

Estimating abundance or density of individuals from presence-absence data requires the use of survey methods not utilized in this study (Pollard 1977, Pollard and Yates 1993, Thomas 1983, Brown and Boyce 1998). For that reason, Karner blue abundance analysis was limited to observation rate (KBB/minute) at specific survey sites during a particular point in time. This method is of limited value in ranking sites relative to one another, but is potentially useful in identifying sites with large populations. Therefore, sites with the highest observation rate were located.

Associated Species Surveys

Surveys, although focused on Karner blues, included several other rare barrens-associated species as targets (Table 5). Spring surveys included other lupine-obligate Lepidoptera species – the Frosted elfin (*Incisalia irus*, state threatened), and Persius duskywing (*Erynnis persius*, state threatened). Frosted elfin is dependant on lupine as the only larval food source, and occurs in oak savannas, open areas, and wooded edges where blueberry (*Vaccinium* spp.) is the only known adult nectar source (Nielsen 1999). Persius duskywings lay eggs on lupine in Michigan, and commonly feed on several barrens and prairie associated flowering species (Nielsen 1999). *E. persius* is similar to several other members of the *Erynnis* genus that fly in similar habitats at the same time. For this reason, voucher specimens are necessary for identification, which must be made by an expert. Dusted skipper (*Atrytonopsis hianna*, state

threatened) was targeted during spring surveys by visually scanning sites with its host plant, little bluestem (*Schizachyrium scoparium*, Nielsen 1999).

Great Plains spittlebug (*Lepyronia gibbosa*, state threatened), was targeted during spring surveys by searching for spittle masses at the base of prairie plants and grasses, and during summer surveys by sweep-netting big bluestem grasses (*Andropogon gerardii*). Summer surveys included the state threatened Ottoe skipper (*Hesperia ottoe*, state threatened), a large yellow skipper that depends on native prairie grasses such as big bluestem (*A. gerardii*), fall witchgrass (*Leptoloma cognatum*), and nectars on prickly pear cactus (*Opuntia humifusa*) and other flowering species characteristic of dry sand prairies and oak barrens communities (Cuthrell 2001). Eastern box turtles (*Terrapene carolina carolina*, state special concern) and Blanding's turtles (*Emys blandingii*, state special concern) were also observed during surveys, usually crossing roads near wet areas (*E. blandingii*) or in uplands with sandy soils (*T. carolina*), presumably searching for a suitable elevated area in which to lay eggs (Hyde 1999).

When possible, identification of rare species was made using voucher photos. However, voucher specimens of *A. hianna*, *E. persius*, *H. ottoe*, and *I. irus* were taken in the field when voucher photos for identification were not possible, or the observations were at new locations. Voucher specimens were collected under the authority of a Threatened/Endangered Species Permit granted by the MDNR Wildlife Division (Permit Number 1397). Specimens were collected using standard techniques, did not significantly reduce the size of the local population (one specimen taken/site/year), and were curated in the Michigan State University (MSU) insect collection after identification by Dr. Mogens Nielsen.

Barrens, savanna, and dry sand prairie indicator plant species and several species that serve as host plants for rare insects were noted when encountered (Table 6). Observations were documented for prairie smoke (*Geum triflorum*, state threatened), *S. scoparium*, *A. gerardii*, *L. cognatum*, *Veronicastrum virginicum*, various *Liatis* species, *Phlox pilosa*, and *O. humifusa*.

Table 5. Rare species associated with barrens and savannas targeted during Karner blue butterfly surveys, 2002-2003.

Species Common Name	Scientific Name	Occurrence Type	State Rank
Dusted skipper	<i>Atrytonopsis hianna</i>	Insect	Threatened
Eastern box turtle	<i>Terrapene carolina carolina</i>	Reptile	Special Concern
Frosted elfin *	<i>Incisalia irus</i>	Insect	Threatened
Great Plains Spittlebug	<i>Lepyronia gibbosa</i>	Insect	Threatened
Ottoo skipper	<i>Hesperia ottoe</i>	Insect	Threatened
Persius duskywing *	<i>Erynnis persius</i>	Insect	Threatened
Prairie smoke	<i>Geum triflorum</i>	Plant	Threatened
Red Shouldered Hawk	<i>Buteo lineatus</i>	Bird	Threatened

* Lupine obligate species

Table 6. Plant species on which barrens-and savanna-associated rare species depend.

Species Common Name	Scientific Name	Associated rare species
Big bluestem	<i>Andropogon gerardii</i>	<i>A. hianna</i> , <i>L. gibbosa</i> , <i>H. ottoe</i>
Blazing star	<i>Liatris</i> spp.	Blazing star borer moth, <i>Papaipema beeriana</i>
Culvers root	<i>Veronicastrum virginicum</i>	Culver's root borer moth, <i>Papaipema sciata</i>
Downy phlox	<i>Phlox pilosa</i>	Phlox moth, <i>Schinia indiana</i>
Fall witchgrass	<i>Leptoloma cognatum</i>	<i>H. ottoe</i>
Little bluestem	<i>Schizachyrium scoparium</i>	<i>A. hianna</i> , <i>L. gibbosa</i> , <i>H. ottoe</i>
Prickly Pear	<i>Opuntia</i> sp.	<i>H. ottoe</i>

RESULTS

Presence-Absence Surveys

Survey Areas

Karner blue surveys in 2002 and 2003 gave insight into butterfly presence at EOs, identified previously unknown occupied sites and potential habitat, and revealed the distribution of occupied sites on public and private lands (Figure 4). Surveys resulted in the discovery of 32 new Karner blue EOs (610 acres of previously unknown populated habitat), one new metapopulation, 69 present updates (1,802 acres), 26 EO extensions (808 acres), 35 lupine only updates (1,234 acres), and 57 non-EO lupine only sites (564 acres, Table 7).

Over half of the known Karner blue EOs were surveyed (n=102) in 2002 (Figure 5). Year one surveys were conducted by 11 Inventory employees between 15 July and 9 August, 2002 within portions of 38 townships in 12 counties: Allegan, Barry, Ionia, Kalamazoo, Kent, Lake, Mason, Mecosta, Montcalm, Muskegon, Newaygo, and Oceana (Figure 6). Survey teams completed 235 hours of surveys within 3441 acres at 113 potential Karner blue sites. Due to time constraints, most sites surveyed in 2002

were visited just once, making conclusions about lupine only sites inappropriate. More surveys at such locations were therefore warranted.

Year two surveys were conducted by nine Inventory employees between 1 May and 15 August, 2003. Public and private lands were surveyed in portions of 10 counties: Ionia, Kalamazoo, Kent, Livingston, Mecosta, Monroe, Montcalm, Muskegon, Newaygo, and Oceana. Surveyors completed 312 hours of surveys on 3,864 acres at 168 sites. Unlike 2002 surveys, a site was visited 1-5 times depending on whether lupine and Karner blue were present.

Public Lands Surveys

Surveys on Public lands included portions of 13 SGAs, one State Park, two LPs, two RAs, portions of state-owned lands within the HMNF and portions of the HMNF itself (Table 7). In all, over 1500 acres and 76 sites on public lands were surveyed for Karner blue during 2002-2003.

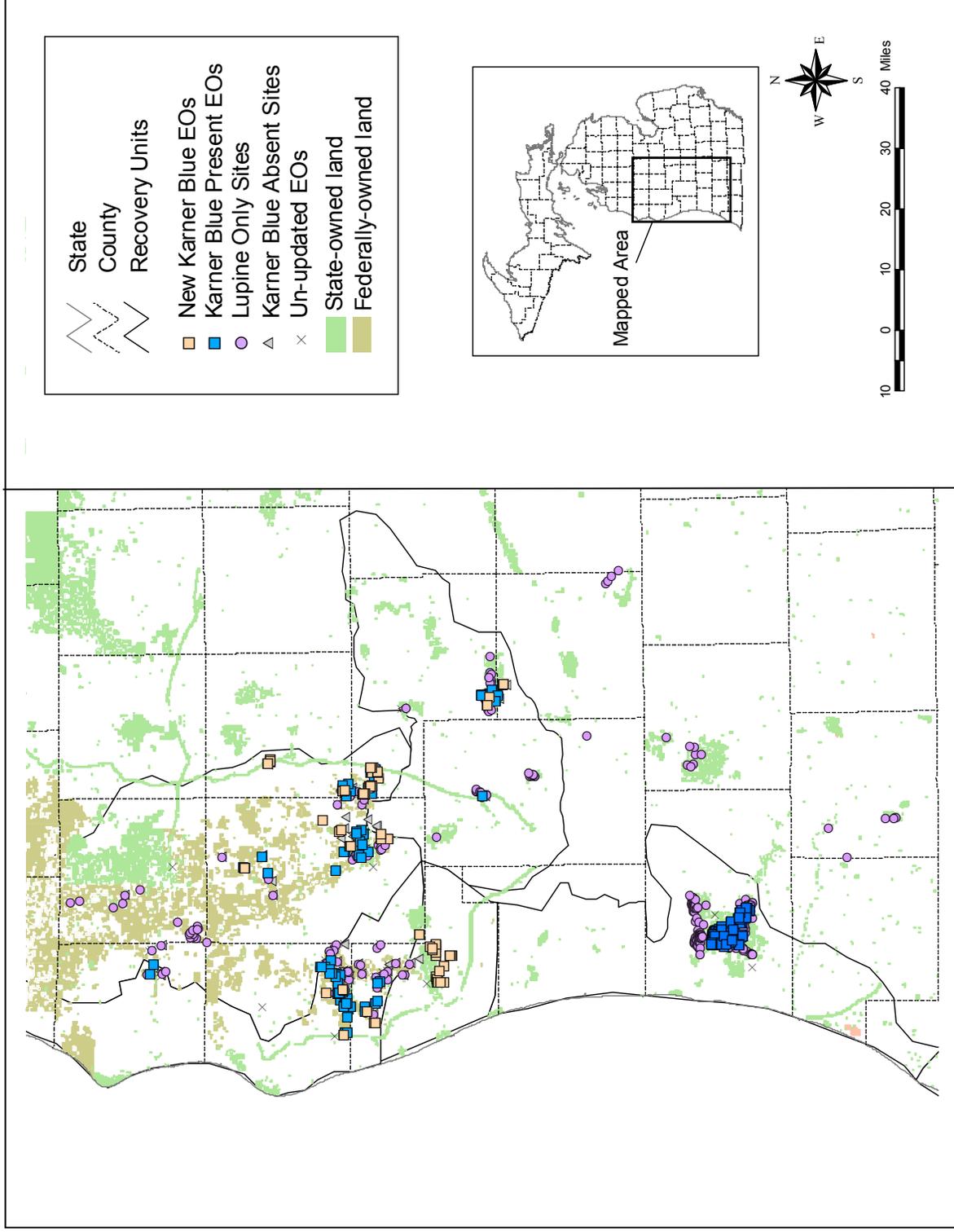


Figure 4. Results of Karner blue butterfly surveys in West Michigan, 2002-2003.

Table 7. Results of Karner blue butterfly surveys showing numbers and acres (Ac.) of Element Occurrence (EO), and non-EO sites surveyed 2002-2003.

Yr.	Owner	Lands Surveyed	New EOs		EO Updates				EO		Non-EO		Total Surveyed					
			EOs*	Ac.	Present		Lupine Only		EOs	Ac.	Sites**	Ac.		Sites	Ac.			
					EOs	Ac.	EOs	Ac.								EOs	Ac.	
2002	State	Allegan SGA	-	-	-	-	1	19	-	-	-	-	-	1	19			
		Barry SGA	-	-	-	-	-	-	-	-	6	30	-	-	6	30		
		Cannonsburg SGA	-	-	-	-	-	-	-	-	3	42	-	-	3	42		
		Flat River SGA	-	-	6	79	1	3	-	-	-	-	-	-	-	7	82	
		Hart-Montague LP	1	9	-	-	-	-	-	-	-	-	-	-	-	1	9	
		Ionia County RA	-	-	-	-	-	-	-	-	-	-	3	22	3	22		
		Langston SGA	-	-	-	-	1	267	-	-	-	-	-	-	1	267		
		Lowell SGA	-	-	-	-	-	-	-	-	-	-	3	63	3	63		
		Middleville SGA	-	-	-	-	-	-	-	-	1	11	-	-	1	11		
		Muskegon SGA	1	28	-	-	-	-	-	-	-	-	-	-	1	28		
		Newaygo SP	-	-	1	2	-	-	-	-	-	-	-	-	1	2		
		Rogue River SGA	-	-	-	-	-	-	-	-	1	23	-	-	1	23		
		Stanton SGA	-	-	-	-	-	-	-	-	-	-	16	380	16	380		
		Vestaburg SGA	-	-	-	-	-	-	-	-	-	-	6	85	6	85		
		White Pine Trail LP	-	-	1	8	-	-	-	1	5	-	1	10	3	23		
		State within HMNF	-	-	-	-	1	14	-	1	5	-	-	-	2	19		
		Private	Business	-	-	1	13	-	-	-	-	-	-	-	-	1	13	
Municipality	-		-	1	20	-	-	-	-	-	-	-	-	1	20			
Power Company	3		90	5	100	3	18	-	-	2	18	-	-	13	226			
Private Individuals	4		24	19	247	1	100	3	70	2	32	4	6	55	532			
Federal	HMNF	1	5	16	1029	17	453	6	58	-	-	-	-	40	1545			
2002 Totals			10	156	50	1498	25	874	9	128	4	42	17	128	35	615	150	3441

*EOs are Karner blue occupied habitat (lupine) patches separated by 100m of unsuitable habitat (e.g. closed canopy woods), 200m of suitable (open to partially wooded area with nectar plants available, lupine may or may not be present), or a barrier to dispersal (e.g. river surrounded by dense forest, planted pines).
 **Sites are defined as individual surveyed areas separated by 100m of unsuitable habitat, or 200m of suitable or potentially suitable habitat (open or partially wooded space, lupine and nectar species may or may not be present).

Table 7 (continued). Results of Karner blue butterfly surveys showing numbers and acres (Ac.) of Element Occurrence (EO), and non-EO sites surveyed 2002-2003.

Yr.	Owner	Lands Surveyed	New EOs			EO Updates			EO Extensions			Non-EO			Total Surveyed			
			EOs*	Ac.	EOs	Lupine		EOs	Ac.	EOs	Ac.	Sites	Ac.	EO/Sites		Ac.		
						EOs	Ac.										EOs	Ac.
2003	State	Gourdneck SGA	-	-	-	-	-	-	-	-	2	26	-	-	2	26		
		Flat River SGA	-	7	74	2	4	2	4	-	-	-	-	5	67	16	149	
		Cannonsburg SGA	-	-	-	-	-	-	-	-	-	1	27	-	-	1	27	
		Rogue River SGA	-	-	-	-	-	-	-	-	1	20	-	-	-	1	20	
		White Pine Trail LP	-	-	-	1	5	-	-	-	-	-	-	1	4	2	9	
		Langston SGA	-	-	-	1	37	-	-	-	-	-	-	-	-	1	37	
		Muskegon SGA	1	7	-	-	-	-	-	1	110	1	58	1	16	4	191	
		Petersburg SGA	-	-	-	2	37	-	-	-	-	-	-	-	-	2	37	
		Island Lake RA	-	-	-	-	-	-	-	-	-	1	15	3	61	4	76	
		State within HMNF	-	-	-	1	26	-	-	-	-	-	-	-	-	1	26	
		Business	2	11	2	57	-	-	-	-	-	-	-	1	65	5	133	
		Municipality	5	52	1	3	-	-	-	1	13	3	7	1	44	11	119	
		Power Company	4	200	3	41	1	198	3	25	1	255	3	69	2	63	17	851
		Private Individuals	10	184	5	36	1	38	4	39	16	345	25	201	31	1149	92	1992
HMNF	-	-	1	93	1	15	1	7	3	43	3	13	-	9	171			
2003 Totals			22	454	19	304	10	360	10	75	22	766	40	436	45	1469	168	3864
Total Surveyed 2002-2003			32	610	69	1802	35	1234	19	203	26	808	57	564	80	2084	318	7305

*EOs are Karner blue occupied habitat (lupine) patches separated by 100m of unsuitable habitat (e.g. closed canopy woods), 200m of suitable (open to partially wooded area with nectar plants available, lupine may or may not be present), or a barrier to dispersal (e.g. river surrounded by dense forest, planted pines).

**Sites are defined as individual surveyed areas separated by 100m of unsuitable habitat, or 200m of suitable or potentially suitable habitat (open or partially wooded space, lupine and nectar species may or may not be present).

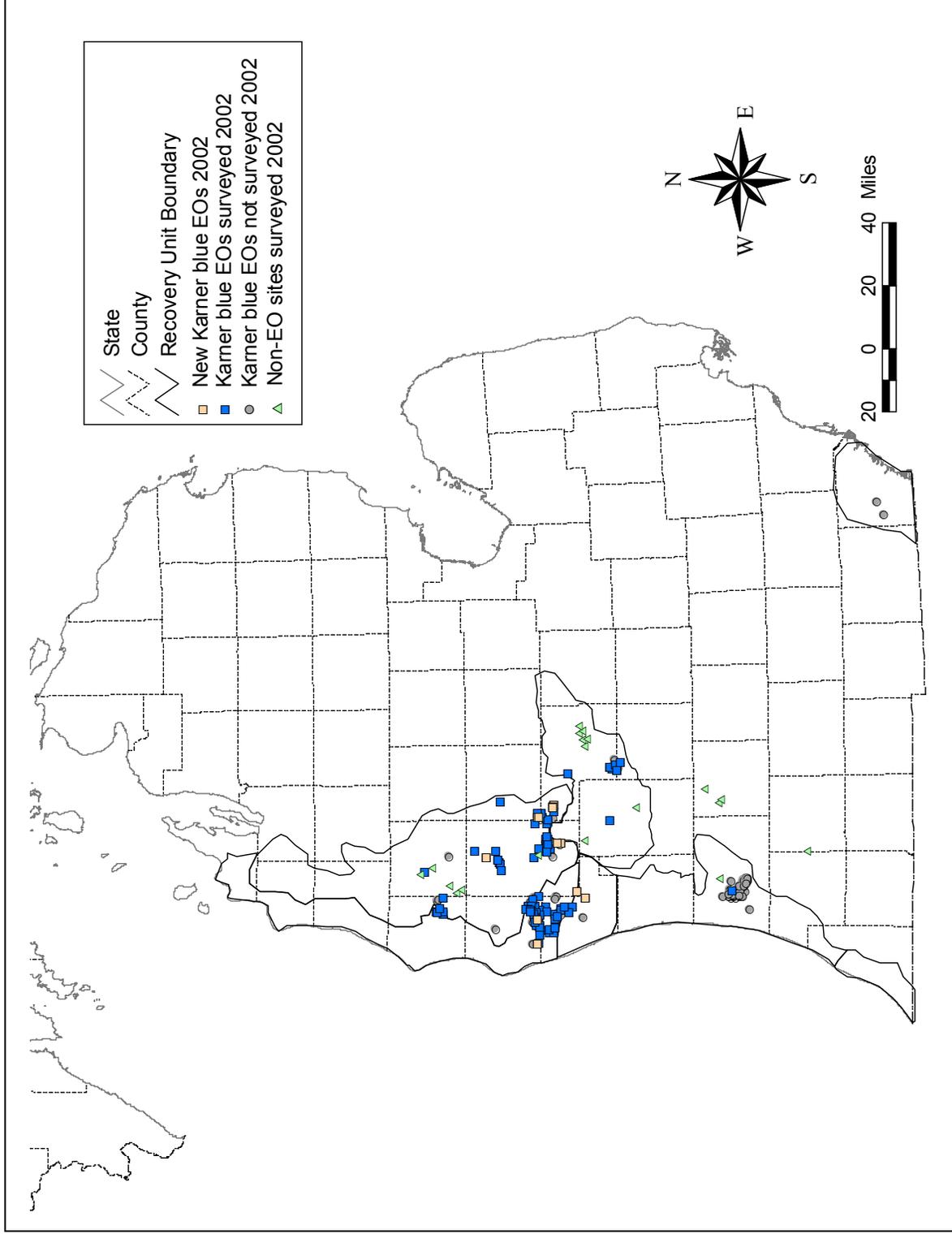


Figure 5. Element occurrences (EOs) surveyed for Karner blue during the 2002 field season by inventory personnel.

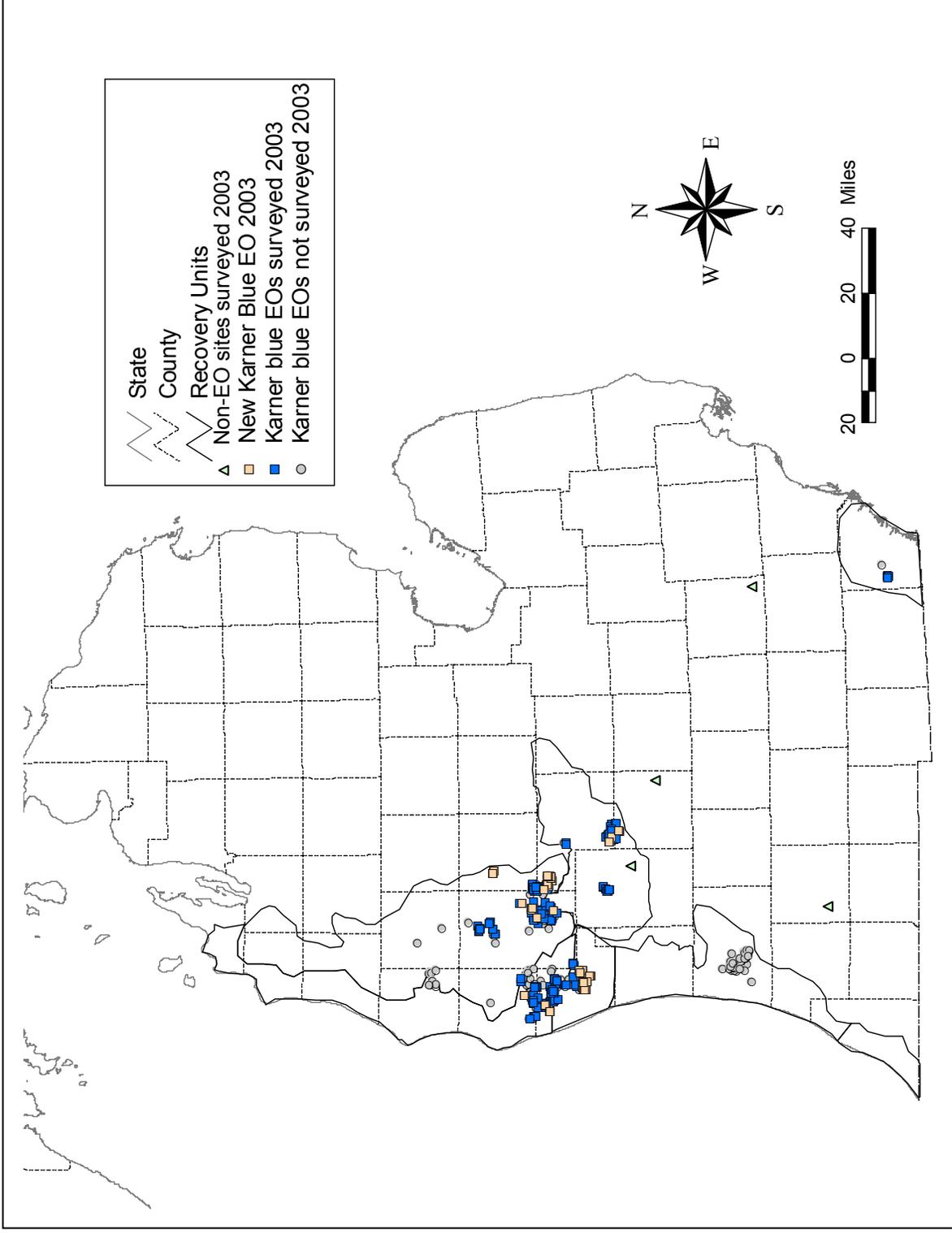


Figure 6. Element occurrences (EOs) surveyed for Karner blue during the 2003 field season by Inventory personnel.

Landowner Contact

In 2003, 696 private parcels owned by individuals were identified as having potential for Karner blue and lupine. Landowner information was determined for 584 of these properties using property ownership data obtained from equalization offices. Contact information was found for 290 of the highest priority properties, and 181 property owners were contacted via letter. Response was received from 68 (38%) of the landowners contacted initially (54 allowed survey, 14 denied survey). An additional 6 letters were returned as undeliverable due to address errors. Phone calls were made to 45 of the owners that did not respond to the initial contact (10 allowed survey, 6 denied, 29 not reached). A third contact attempt was made in person at 16 properties (15 allowed survey, 1 denied). Contact was made in person at an additional 21 properties as a result of roadside lupine surveys and site leads, all allowed survey.

In all, 100 separate property owners gave permission to survey and 21 denied permission. Most owners who denied permission did not specify a reason, but those that did often voiced concerns over decreased property value, loss of development opportunities, or feared being forced to sell the property if the butterflies were found. In most of these cases, attempts to address concerns were not successful, and often were not welcomed by the owners. However, four owners who were reached by phone were initially resistant to allowing surveys, but after learning more about the butterfly, conservation efforts, and programs for landowners with endangered species, allowed surveys on their properties. Two of the properties were occupied by Karner blue and the other two had lupine but no Karner blue were detected.

Private Lands Surveys

Private lands surveyed included those owned by businesses, municipalities, power companies, and private individuals. Overall, 44% of private lands surveyed in 2002-2003 had Karner blue present (n=85 properties, 1723 acres), and lupine was found on another 22% (n=43 properties, 653 acres). Private lands surveys verified the assumption that Karner blue are not confined to public lands, and are more prevalent in the Newaygo and Muskegon RUs than previously known.

Private lands surveys constituted the majority of survey efforts (n=218 sites, 4201 acres). Over 80% of those new EOs were found on private lands (n=28, 561 acres), reflecting the lack of prior survey efforts. A new Karner blue metapopulation (7 EOs, 324 acres) was discovered in Moorland, Egelston and Muskegon Townships in Muskegon County (Southern Muskegon RU), and extends into Bridgeton Township in Newaygo County (Newaygo RU). The metapopulation is apparently linked to the known Muskegon Wastewater EO by the network of Powerline rights-of-way running through private property and the Muskegon SGA (Figures 7 & 8). The rights-of-way (owned by Consumer's Energy) appear to contain most of the occupied habitat, although the extent to which adjacent private lands are populated is not known. An additional 129 acres along some sections of connected rights-of-way appear suitable but the butterflies were not detected within these areas in spite of multiple visits. Further surveys within these areas and in adjacent private lands are needed to determine the size and distribution of subpopulations in this area, which is rapidly being converted into residential land use.

Nearly 77% of the EOs extended (n=20) were expanded onto private lands (645 acres). Private lands surveys in Reynolds Township, Montcalm County added 152 acres of occupied habitat (19 private parcels) to four EOs, and revealed that lupine was present on four additional private properties (30 acres, Karner blue lupine only). Extensions onto private lands resulted in the combination of 11 EOs into four in 2003, a result of connecting occupied habitats across private lands.



Figure 7. Portions of powerline rights-of-way in Muskegon County, containing occupied Karner blue habitat, *Atrytonopsis hianna*, and *Lepyronia gibbosa*, newly discovered in 2003 Inventory surveys.



Figure 8. A worm Karner blue female (left) and Karner blue male nectaring on spotted knapweed found among the newly discovered Karner blue habitat along powerline rights-of way in Muskegon County.

Data Transcription and Digitizing

All new and updated occurrence information obtained during 2002-2003 Inventory surveys were entered into the Heritage Database and digitized in BioTICS. Karner blue sites not visited in 2002 were re-digitized in BioTICS using field forms from past surveys. As of December 2003, all but 7 Karner blue EOs have been digitized in BioTICS to represent the occupied habitat associated with each record. The un-digitized EOs do not have data specific enough to re-locate, survey, or digitize with any degree of certainty and will remain as they are in the database in perpetuity unless new information comes to light.

Site Level Habitat Analysis

Analysis of general site characteristics revealed several variables have significant associations with Karner blue present and absent sites (Table 8). Sites with Karner blue present were positively associated with ORV use ($\chi^2 = 4.97$, $df = 1$, $P = 0.026$), management using herbicide ($\chi^2 = 7.04$, $df = 1$, $P = 0.008$), and utility rights-of-way ($\chi^2 = 4.23$, $df = 1$, $P = 0.040$). Karner blue present sites were negatively associated with closed canopy areas ($\chi^2 = 8.33$, $df = 1$, $P = 0.004$).

Several site level habitat variables showed a statistically significant association with Karner blue present sites (Table 9). In order to determine where the associations lie, habitat components within significant variables were analyzed separately (Table 10). Analysis of these components revealed that sites with Karner blue present were positively associated with ant mound presence ($\chi^2 = 15.5$, $df = 1$, $P < 0.001$), St. John's wort ($\chi^2 = 17.38$, $df = 1$, $P < 0.001$), butterfly weed ($\chi^2 = 7.75$, $df = 1$, $P = 0.005$), dewberry ($\chi^2 = 3.80$, $df = 1$, $P = 0.051$), horsemint ($\chi^2 = 5.99$, $df = 1$, $P = 0.015$), flowering spurge ($\chi^2 = 27.57$, $df = 1$, $P < 0.001$), black-eyed susan ($\chi^2 = 11.32$, $df = 1$, $P = 0.001$), blazing star ($\chi^2 = 5.83$, $df = 1$, $P = 0.0016$), primrose ($\chi^2 = 6.69$, $df = 1$, $P = 0.010$), sunflower ($\chi^2 = 8.60$, $df = 1$, $P = 0.003$), and wild bergamot ($\chi^2 = 10.09$, $df = 1$, $P = 0.001$). Sites with Karner blue were negatively associated with bare ground ($\chi^2 = 4.18$, $df = 1$, $P = 0.041$), grass-dominated ground ($\chi^2 = 7.09$, $df = 1$, $P = 0.008$), Queen Anne's lace ($\chi^2 = 4.01$, $df = 1$, $P = 0.045$), and autumn olive ($\chi^2 = 7.85$, $df = 1$, $P = 0.005$).

In general, associated rare species and host plants did not show a significant overall association with Karner blue presence (Table 11). In fact, big bluestem ($\chi^2 = 7.2$, $df = 1$, $P = 0.007$) and blazing star ($\chi^2 = 5.8$, $df = 1$, $P = 0.016$) were the only species showing a significant positive association.

Table 8. General site characteristics associated with Karner blue (KBB) present (n=149) and absent (n=51) sites. Observed (Obs.) versus expected (Exp.) frequencies were compared using Pearson's χ^2 tests to identify significant associations. Sign inside parentheses indicates the direction of deviance from expected.

Characteristic	Variable	Sig. Assoc.	KBB Present		KBB Absent	
			Obs.	Exp.	Obs.	Exp.
Current Threats	ORV	*	57 (+)	51	11 (-)	17
	Vehicles		38	38	13	12
	Exotics		44	47	19	13
	Succession		50	51	19	18
	Management		61	62	22	21
	Dumping		20	20	7	7
	Development	**	31 (-)	41	19 (+)	14
	Other	**	19 (+)	16	2 (-)	5
Past Disturbance	Cut		77	78	28	27
	Burned		10	8	0	3
	Mowed		60	64	26	22
	Herbicide	*	20 (+)	16	1 (-)	5
	Hand Cut	**	5 (+)	4	0 (-)	1
	Planted		27	31	14	11
	Other	**	32 (-)	37	18 (+)	13
Opening Type	Utility Right-of-way	*	48 (+)	43	9 (-)	15
	Field		45	43	13	15
	Clearing		37	41	18	14
	Barrens		41	43	17	15
	Openings		36	36	12	12
	Roadside	**	37 (+)	33	7 (-)	11
Surrounding Env.	Hardwoods		136	134	44	46
	Pines		40	38	11	13
	Agriculture		6	7	3	2
	Residential		38	42	18	14
	Potential KBB habitat		68	64	18	22
	Wetland		12	15	8	5
	Other		10	8	1	3
Canopy Cover	Open		89	85	25	29
	Partial		53	55	21	19
	Most		7	7	2	2
	Closed	*	0 (-)	2	3 (+)	1

* Indicates significant χ^2 value - frequencies differ from expected at $P < 0.05$ level.

**Indicates a marginally significant χ^2 value - frequencies differ from expected at $P \leq 0.1$ level

Table 9. Pearson χ^2 values and significance for site level habitat variables showing associations with Karner blue present (n=149) and absent sites (n=51). Variables associated with lupine (shaded) are highly significant due to the definition of absent sites (No lupine), and could not be further analyzed.

Variable	χ^2	df	P
Lupine Density and Distribution	184.4	9	<0.001
Lupine Density	184.4	3	<0.001
Lupine Distribution	184.4	3	<0.001
% Lupine blooming or in seed	66.4	3	<0.001
Deer Browse on lupine	18.9	1	<0.001
Ant Mounds	15.5	1	<0.001
Dominant Ground Cover	14.8	3	0.064
Exotic Species	22.3	9	0.004
Other Nectar Species	23.8	10	0.008
Preferred Nectar Species	33.5	6	<0.001
Woody Species	8.4	5	0.113

Table 10. Site level habitat components associated with Karner blue (KBB) present (n=149) and absent (n=51) sites. Observed (Obs.) versus expected (Exp.) frequencies were compared using Pearson's χ^2 tests to identify significant associations. Sign inside parentheses indicates the direction of deviance from expected.

Variable	Categories	Sig. Assoc.	KBB Present		KBB Absent	
			Obs.	Exp.	Obs.	Exp.
Dominant Ground Cover	Bare	*	7 (-)	10	7 (+)	4
	Grass	*	3 (-)	7	6 (+)	2
	Sedge		73	69	19	23
	Forb		62	59	17	20
	Fern		4	4	2	2
Ant Mounds	Present/Absent	*	107 (+)	95	21 (-)	33
Exotic Species	Spotted knapweed	**	122 (+)	117	35 (-)	40
	St. John's wort	*	124 (+)	112	27 (-)	39
	Hoary alyssum		63	62	20	21
	Sweetclover		14	15	6	5
	Queen Anne's lace	*	13 (-)	17	10 (+)	6
	Hawkweed		27	27	9	9
	Autumn olive	*	10 (-)	16	11 (+)	5
	Honeysuckle	**	4 (-)	6	4 (+)	2
	Other exotics		66	65	21	22
Preferred Nectar Sp. (Grundel and Pavlovic 2000)	Butterfly weed	*	80 (+)	72	16 (-)	24
	Dewberry	**	99 (+)	93	26 (-)	32
	Dotted Horsemint	*	82 (+)	75	18 (-)	26
	Flowering Spurge	*	91 (+)	75	10 (-)	26
	Goldenrod		20	22	9	7
	Lance-leaf Coreopsis		22	19	4	7
	New Jersey Tea		6	4	0	2
	White Sweetclover		14	15	6	5
Other Flowering Species	Aster		17	16	4	5
	Blackberry		11	9	1	3
	Black-eyed susan	*	84 (+)	74	15 (-)	25
	Blazing star	*	41 (+)	35	6 (-)	12
	Downy Phlox	**	13 (+)	10	1 (-)	4
	Dwarf Dandelion		16	15	4	5
	Fleabane		22	19	4	7
	Primrose	*	11 (+)	8	0 (-)	3
	Puccoon		12	10	2	4
	Sunflower	*	14 (+)	10	0 (-)	4
	Violet		9	11	6	4
	Wild bergamot	*	54 (+)	45	7 (-)	16
	Yarrow		29	28	8	9
	Other		64	60	16	20

* Indicates significant χ^2 value - frequencies differ from expected at $P < 0.05$ level.

**Indicates a marginally significant χ^2 value - frequencies differ from expected at $P \leq 0.1$ level

Table 11. Rare barrens and savanna species associated with Karner blue (KBB) present (n=149) and absent (n=51) sites Observed (Obs.) versus expected (Exp.) frequencies were compared using Pearson's χ^2 tests to identify significant associations. Sign inside parentheses indicates the direction of deviance from expected.

Species Common Name	Significant Association	KBB Present		KBB Absent	
		Obs.	Exp.	Obs.	Exp.
Dusted skipper		3	2.2	0	0.8
Eastern box turtle		4	3	0	1
Frosted elfin		0	0	0	0
Great Plains Spittlebug		9	9	3	3
Ottoo skipper		1	0.7	0	0.3
Persius duskywing		0	0	0	0
Prairie smoke		7	7.5	3	2.6
Red Shouldered Hawk		3	4.5	3	4.5
Big bluestem	*	40 (+)	33.5	5 (-)	11.5
Blazing star	*	41 (+)	35	6 (-)	12
Culvers root		4	3	0	1
Downy phlox	**	13 (+)	10	1 (-)	4
Fall witchgrass		10	11	5	4
Little bluestem		36	35	11	12
Prickly Pear		29	29	10	10

* Indicates significant χ^2 value - frequencies differ from expected at $P < 0.05$ level.

** Indicates a marginally significant χ^2 value - frequencies differ from expected at $P \leq 0.1$ level

Although lupine was significantly associated with Karner blue present sites, this is a result of how present and absent sites were defined. However, analysis of present sites versus lupine only sites gave some insight into how lupine is related to Karner blue detection. Lupine density and distribution was positively associated with Karner blue detection when compared to lupine only sites ($\chi^2 = 34.0$, $df = 9$, $P < 0.001$, Figure 9). When lupine categories were analyzed individually, it was revealed that sites with Karner blue detection were positively associated with areas containing abundant clumps of lupine ($\chi^2 = 6.77$, $df = 1$, $P = 0.009$), and negatively associated with areas having sparse, scattered lupine plants ($\chi^2 = 21.18$, $df = 1$, $P < 0.001$, Figure 9). When the lupine density and distribution variable was reduced into a density

component and a distribution component, it became evident that lupine density and distribution are both associated with Karner blue detection (Figures 10 & 11).

Analyses of nectar plant data show that a wider variety of preferred nectar species was available at sites where Karner blue were present than at sites where they were there was lupine only ($\chi^2 = 15.3$, $df = 3$, $P < 0.002$, Figure 12). Likewise, sites with Karner blue present were associated with a wider diversity of all flowering species ($\chi^2 = 16.24$, $df = 3$, $P = 0.001$) compared to lupine only sites (Figure 13). Sites with Three or more preferred nectar species were present at over 58% of Karner blue occupied sites, but the same diversity was found at just 33% and 19% of lupine only and absent sites respectively.

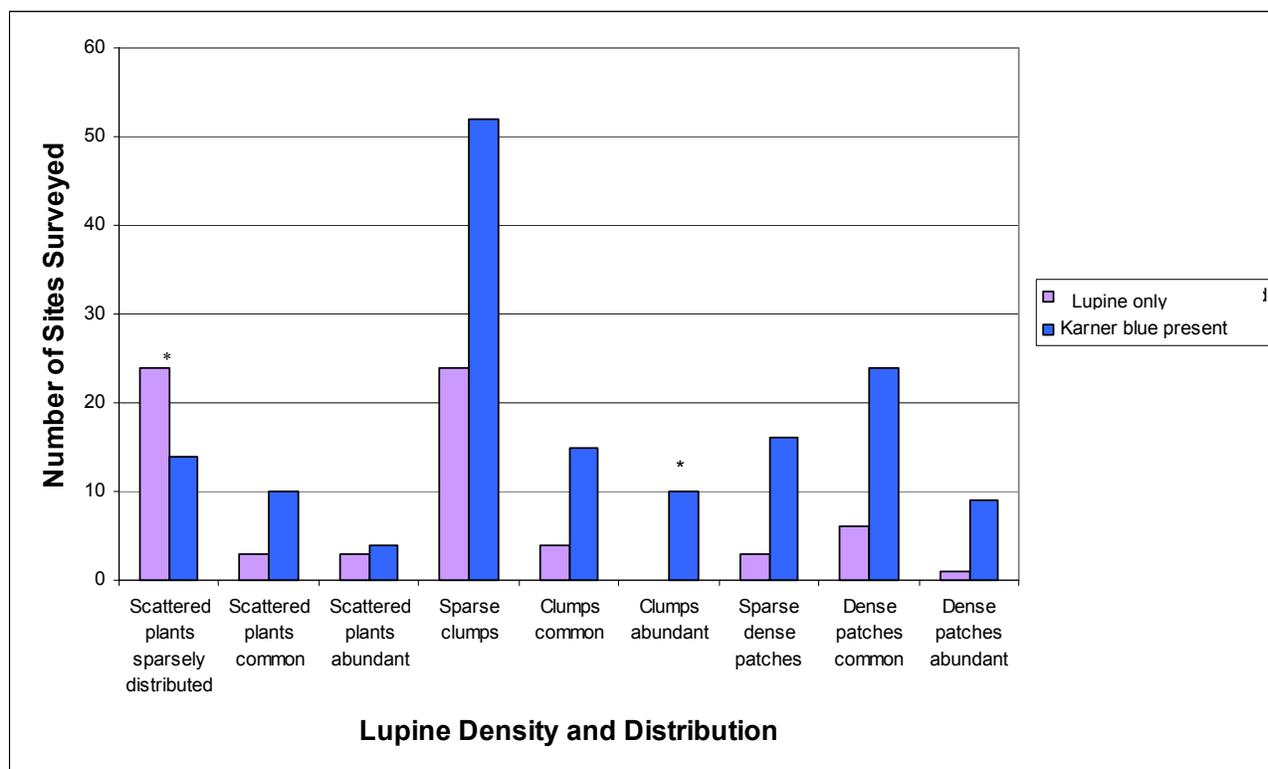


Figure 9. Lupine density and distribution at Karner blue present ($n = 149$) and lupine only sites ($n = 66$). * indicates a statistically significant association.

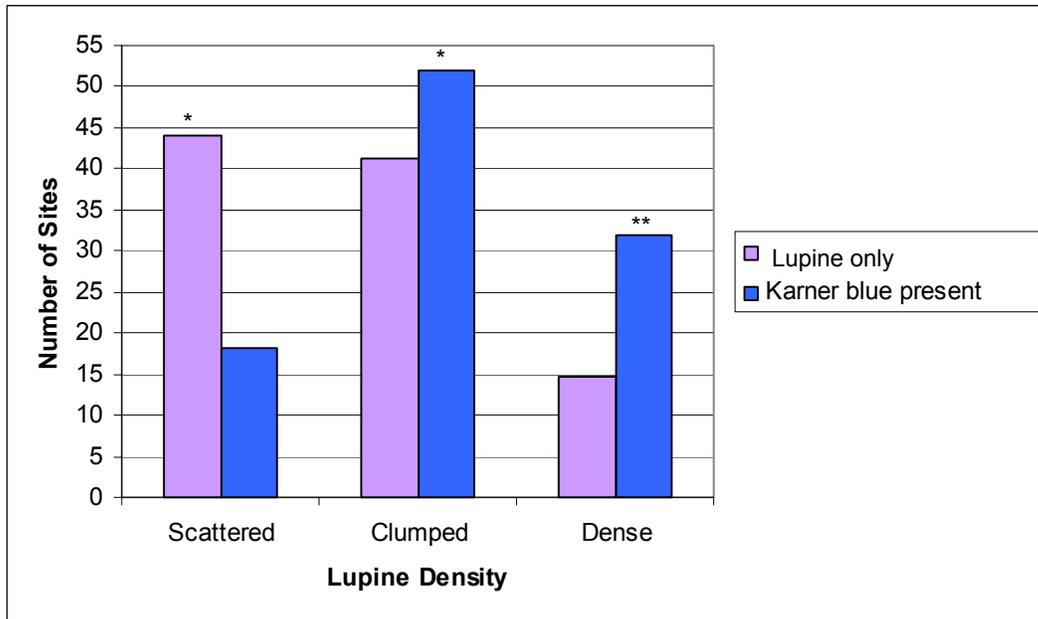


Figure 10. Lupine density at Karner blue present (n = 149) and lupine only sites (n = 66) related to Karner blue detection and non detection during Inventory surveys, 2002-2003. * indicates a statistically significant association.

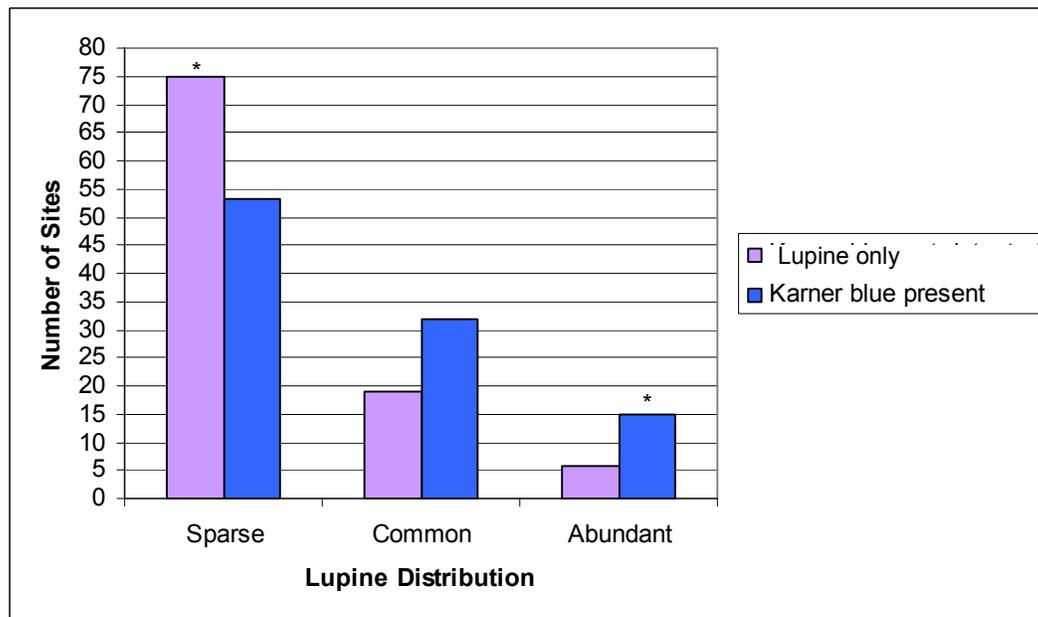


Figure 11. Lupine distribution at Karner blue present (n = 149) and lupine only sites (n = 66) related to Karner blue detection and non detection during Inventory surveys, 2002-2003. * indicates a statistically significant association.

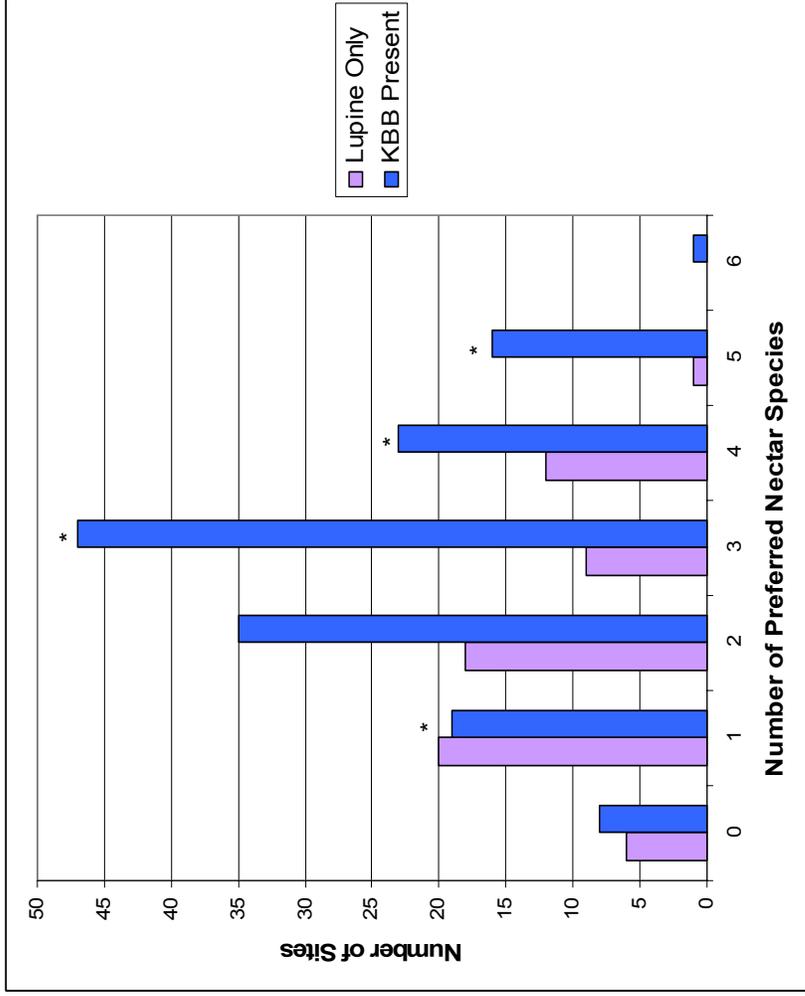


Figure 12. Preferred nectar species diversity at Karner blue present (n = 149) and lupine only sites (n = 66) related to, 2002-2003. * indicates a statistically significant association.

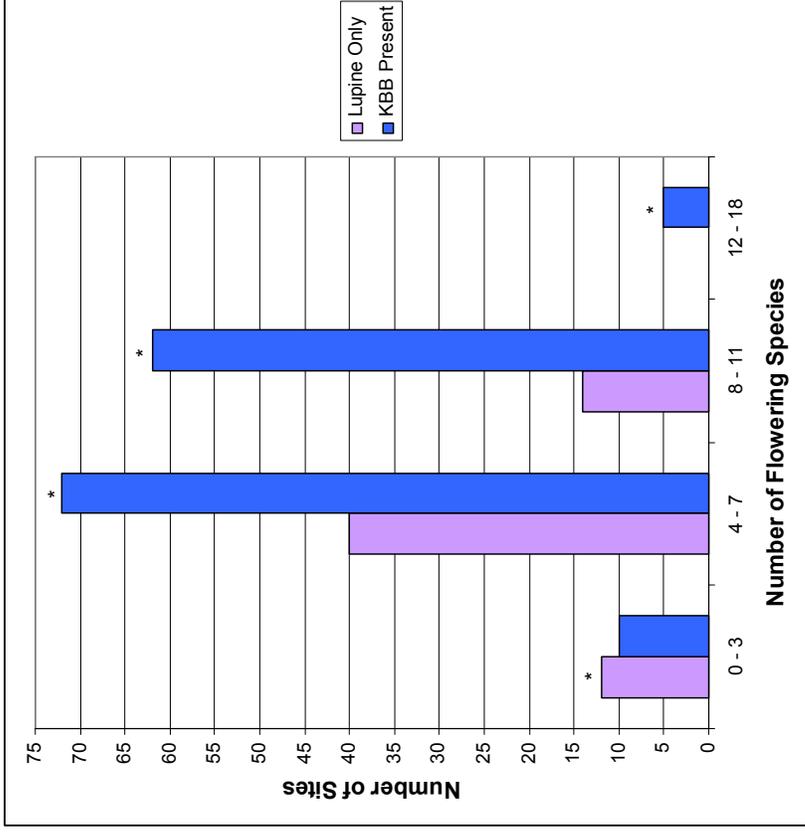


Figure 13. Flowering species diversity (includes spotted knapweed, St. John's wort, and sweetclover) at Karner blue present (n = 149) and lupine only sites (n = 66) related to, 2002-2003. * indicates a statistically significant association.

Landscape Level Model

The Muskegon County habitat management potential model uncovered several areas with high potential for management within the HMNF and other areas outside public lands (Figure 14). Roadside lupine surveys within areas designated by the model as having moderate to excellent management potential, revealed that many of these areas not only

have potential for management, but are in fact currently occupied by Karner blue or have lupine present (Figure 15). The results of this model test case indicate that the variables used in model creation are useful in predicting Karner blue habitat management potential and in locating previously unknown occupied or existing potential Karner blue habitat. The statewide model is currently being developed and refined and will provide a useful tool in Karner blue recovery efforts.

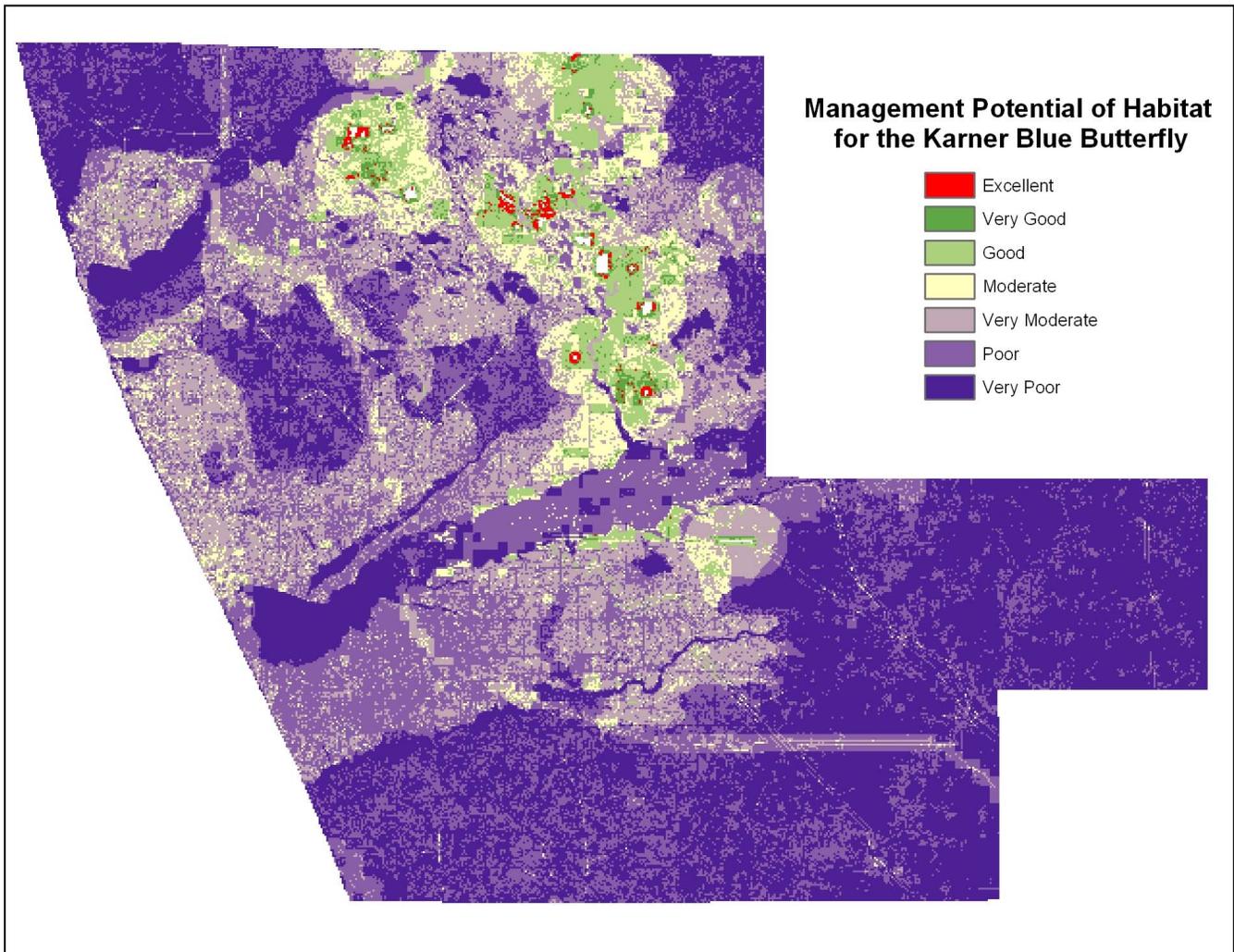


Figure 14. Map of Muskegon County showing areas with potential for Karner blue butterfly habitat management (expansion and restoration), resulting from the model landscape level variables.

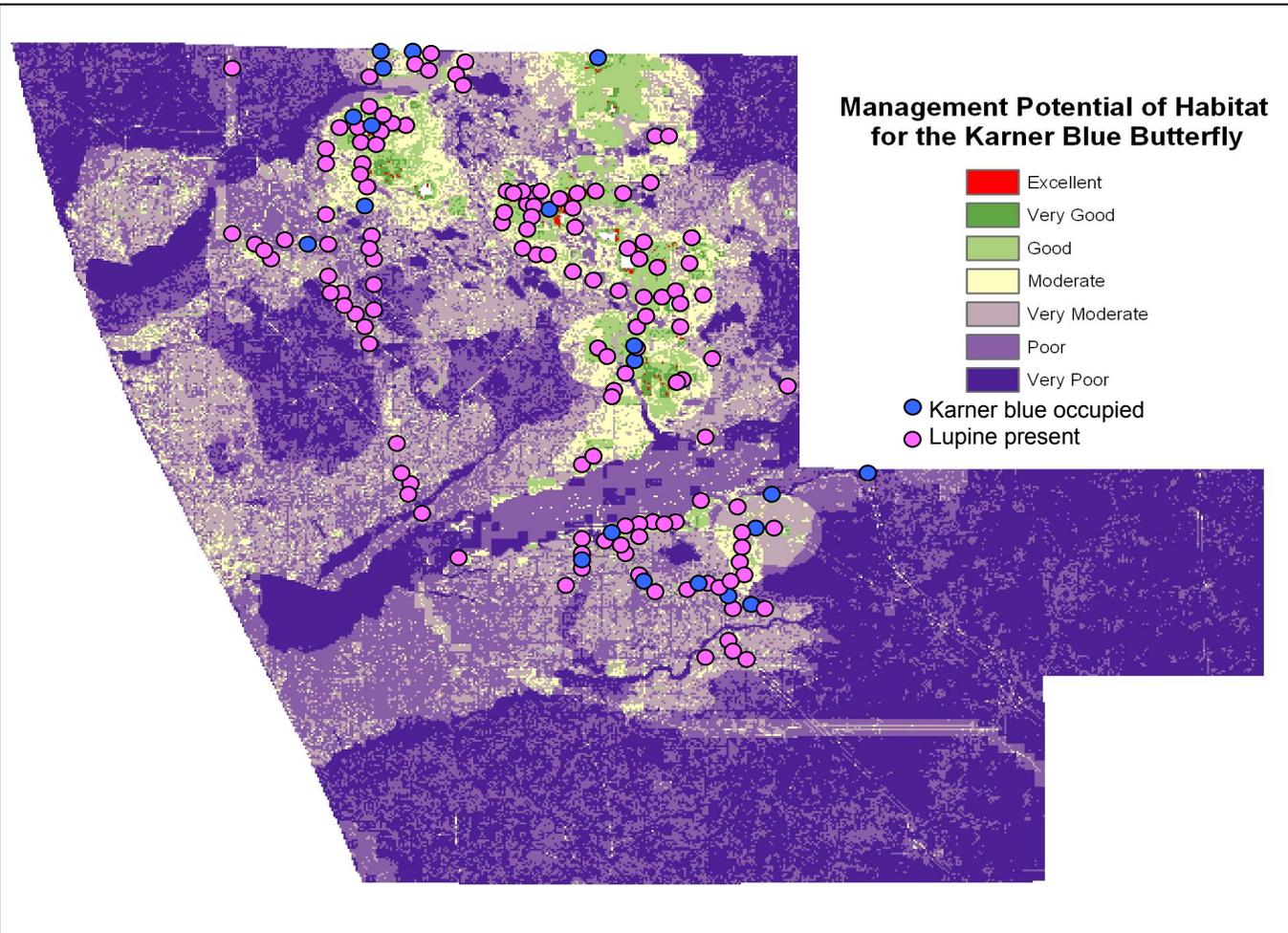


Figure 15. Lupine locations from roadside surveys and resulting Karner blue present locations in relation to the model of potential for Karner blue butterfly habitat management (expansion and restoration) in Muskegon County.

Distribution and Abundance

In general, the core distribution of Karner blue in Michigan is concentrated in the western Lower Peninsula of Michigan. From 2002-2003 surveys, it appears that some sites in Muskegon County and northern Newaygo Counties may no longer be occupied, in spite of lupine being present (Figures 16 & 17). Further surveys are needed in these areas, which are mainly within the HMNF. It's likely that many of these sites are extinct, as they often lacked nectar species and lupine was sparse or heavily browsed (Figure 18). However, given metapopulation structure and the fact that surrounding areas are still occupied, these sites may become occupied again if managed properly. The discovery of the Southern Muskegon RU metapopulation offsets the area presumed lost in Muskegon and Newaygo Counties, but observation rates (number of Karner blue observed per minute) were low in this area, even where lupine was abundant, dense, and expansive.

Although not statistically tested, overall butterfly numbers in 2003 seemed lower than in 2002 surveys, possibly as a result of an early warm spell in spring followed by a hard freeze. This is supported by the difficulty surveyors experienced in finding Karner blue at sites in 2003 that had relatively high observation rates in 2002 during the same time period. In addition,

the flight periods seemed quite long, as adults were observed in Muskegon County from 15 May through 28 June during spring surveys, and in two instances late instar caterpillars were observed with slightly worn adults in mid- and late-July (Figure 19).

In spite of generally low butterfly numbers, nine sites were identified as having high observation rates (one or more Karner blue butterflies observed every two minutes of survey, Figure 20). The sites with high observation rates were distributed evenly among state, private, and federal lands. Two sites within the Flat River SGA were previously known to harbor large numbers of Karner blue (Flat River "mega site" and Consumer's Energy right-of-way). Other sites with high observation rates on private lands were previously unknown, but were adjacent to or within one kilometer of other known occupied habitat. One new EO on private land south of Flat River SGA in Ionia County had an observation rate of over 3 butterflies per minute, for a total of over 100 individuals observed in one visit in 2003. One site in northern Newaygo County appears to be somewhat isolated from other occupied habitat, but had over 250 butterflies observed in one hour of survey in 2002.

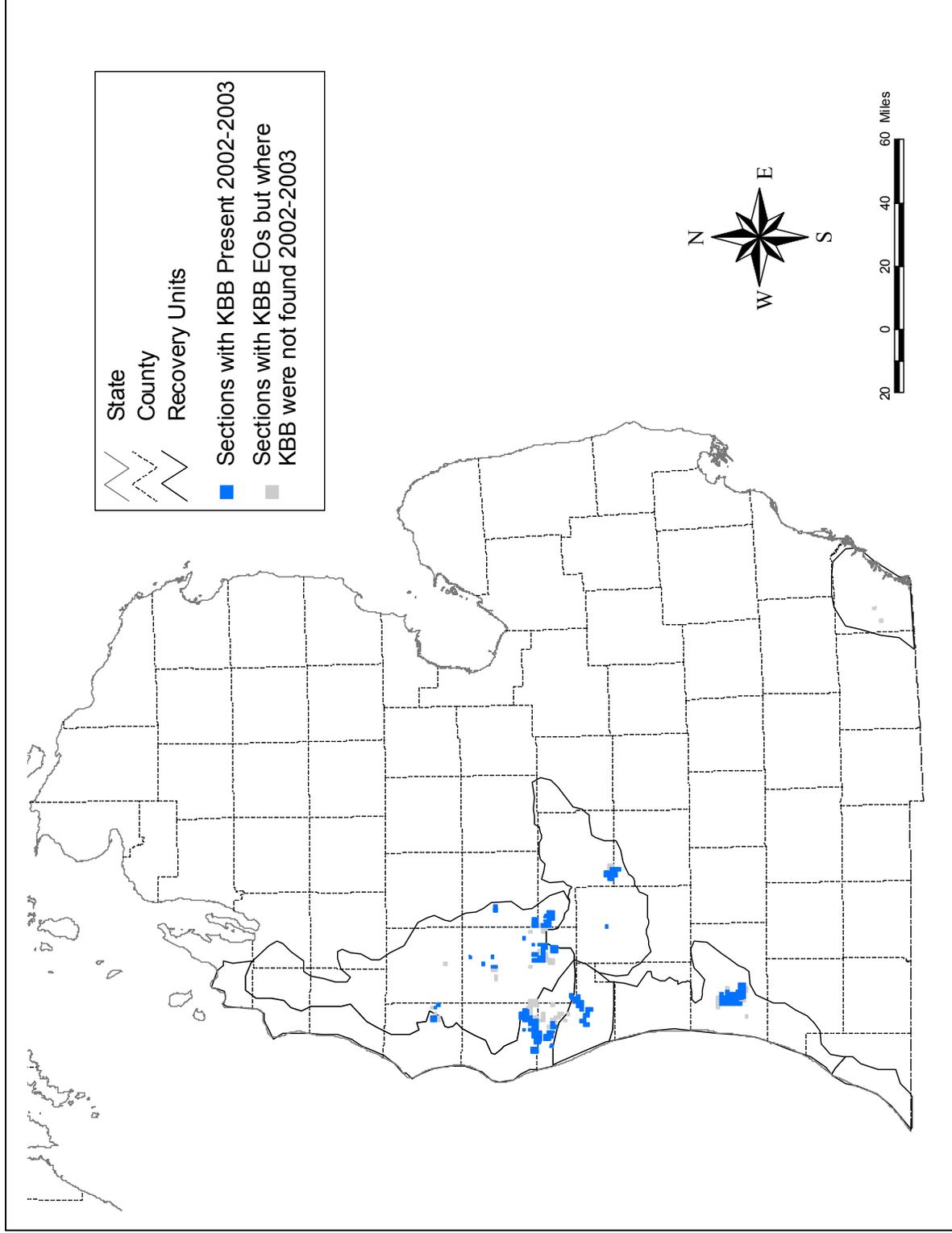


Figure 16. Current and past Karner blue butterfly (KBB) distribution in Michigan at the section level.

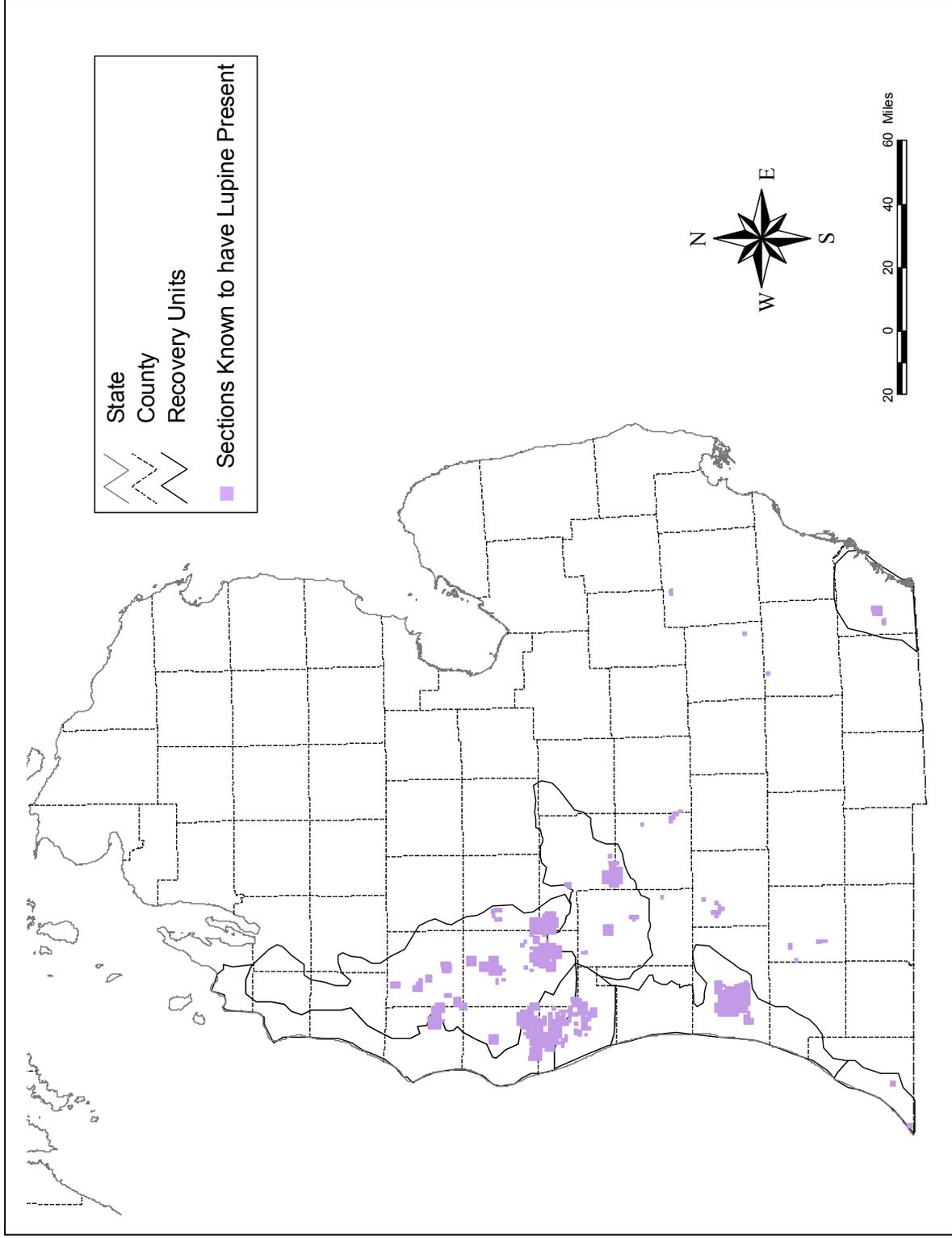


Figure 17. Current lupine (*Lupinus perennis*) distribution in Michigan determined from Inventory and MDNR Karner blue butterfly surveys 2002-2003.



Figure 18. Deer browse on lupine within the Huron Manistee National Forest, Muskegon County, Michigan.



Figure 19. Late instar Karner blue caterpillars being tended by ants (top) observed the same day and at the same location in southern Montcalm County as a slightly worn female, indicating an extended summer flight period in 2003.

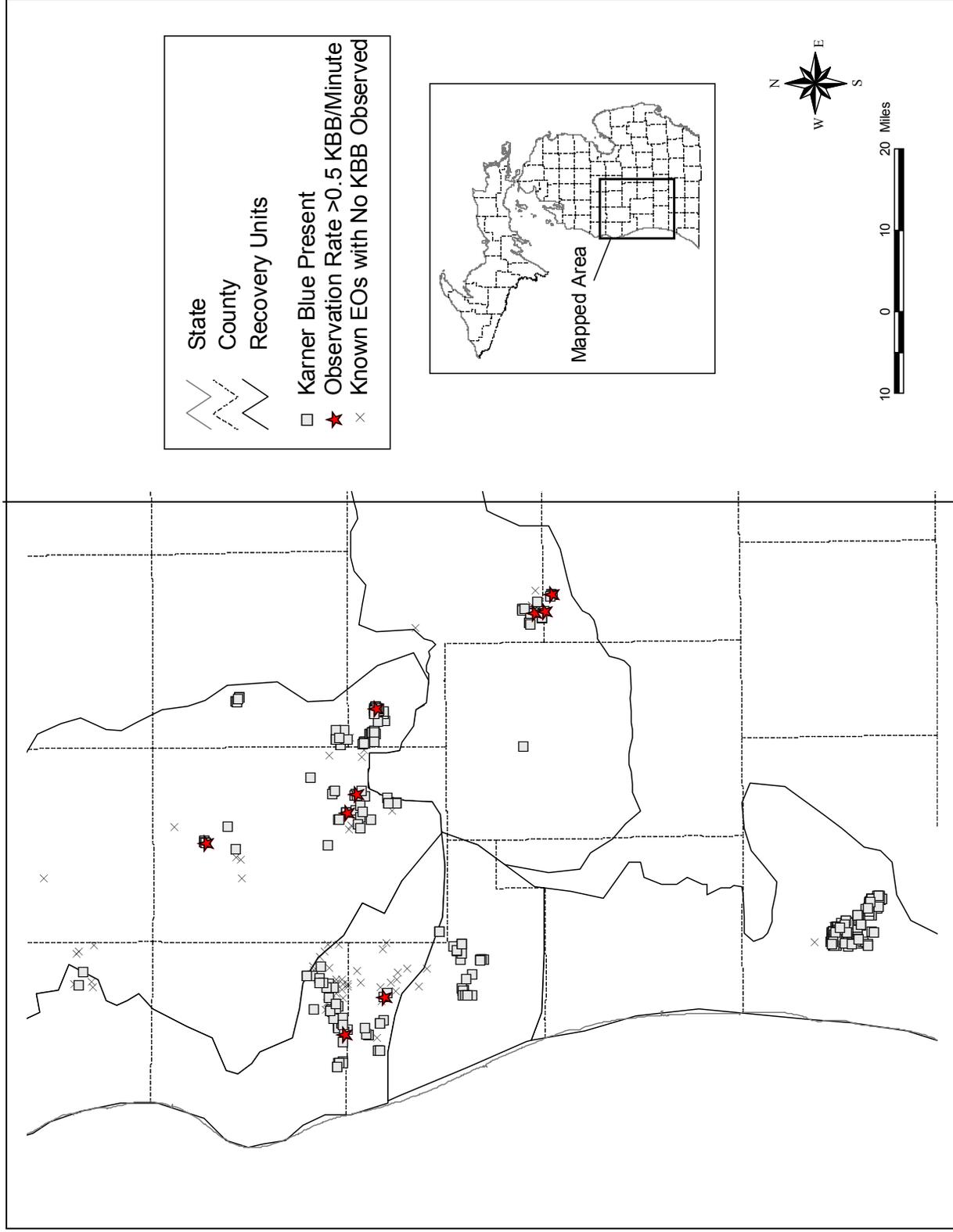


Figure 20. Karner blue present sites with high observation rates (Karner blue observed/minute > 0.5) related to all sites with Karner blue present and those where Karner blue were not observed during Inventory surveys, 2002-2003.

Associated Species Surveys

A total of 27 new EOs (element occurrence, the spatial representation of a species and its required habitat at a specific location) for seven species during 2002-2003 Karner blue butterfly surveys. In 2002, nine new EOs were discovered for five rare species associated with barrens and dry sand prairie systems. *I. irus* was located for the first time at Cannonsburg SGA in Kent County but a specimen could not be collected as a voucher. Cannonsburg has extensive and dense lupine patches, and may also support populations of *E. persius* and *L. melissa samuelis*, although the latter is somewhat unlikely due to isolation from other populations. *E. persius* was found at Barry SGA on what appeared to be an old utility right-of-way (1 new EO). A specimen was collected and verified to be *E. persius* by Dr. Mogens Nielsen at MSU. *H. ottoe* females were found at Flat River SGA (1 new EO) and a voucher specimen collected. *T. carolina carolina* were found in four counties (4 new EOs). The others were either crossing roads, or on roads after being killed by cars. Targeted surveys for *L. gibbosa* resulted in the species being located at Flat River SGA (1 EO) in Montcalm County and at Camp Owassipe Boy Scout Reservation (2 EOs) in Muskegon County.

Surveys in 2003 resulted in 18 new and four extensions of EOs for six species. An *I. irus* voucher specimen was collected at Cannonsburg SGA (1 EO) and several *Erynnis* were collected there as well, although none turned out to be *E. persius*. *A. hianna* was found at three locations in Muskegon County (2 EOs, 1 EO extension), on private parcels and along a Consumer's Energy power line. Two of the sites had voucher specimens collected, and one was photographed, presumably as it had recently emerged and was unable to fly away (Figure 21). The power line

also proved to contain *L. melissa samuelis*, and other associated rare species are likely present as well. Further surveys are needed to verify this suspicion. *H. ottoe* was found near Flat River SGA on private land (1 EO extension) by David Cuthrell. *T. carolina carolina* was found at five locations in four Counties (3 new EOs, 2 EO extensions). One very young (ca. 2 years) individual was found in the uplands in Cannonsburg SGA (Figure 22), the others were found along powerline rights-of-way or crossing roads. *E. blandingii* were observed at two locations along roads (2 new EOs). One turtle was found dead in the road, the second was crossing. *L. gibbosa* was found at 13 locations in 3 Counties (10 new EOs), adding to the suspicion that the species is more common than once thought (Dunn 2002). Most *L. gibbosa* were discovered by looking for spittle masses at the base of prairie grasses and identifying nymphs to species, but sweep netting for adults was also productive later in the summer when looking for adults (Figure 23). One nymph was discovered at the base of hoary puccoon (*L. canescens*), all others at the base of either *S. scoparium* or *A. gerardii*. Adults were found only among *A. gerardii*. *G. triflorum* was found at 8 locations, mostly on private lands. One property in Newaygo County was found to have hundreds of stems within approximately 1.5 acres (Figure 24). Data for *G. triflorum* were given to the Inventory's Botany program, and they will decide whether to create new EOs for the species. Red shouldered hawk was heard during the breeding season at three locations, two on private land (Montcalm and Mecosta Counties), and one in the Flat River SGA. The information was passed along to others in the Inventory's Zoology program for further investigation.



Figure 21. Dusted skipper (*Atrytonopsis hianna*), a state threatened species, on private land in Muskegon County, Michigan.



Figure 22. Young eastern box turtle (*Terrapene carolina carolina*), a state special concern species, at Cannonsburg SGA, Kent County, Michigan.



Figure 23. Great Plains spittlebug (*Lepyronia gibbosa*), a state threatened species, spittle mass at the base of little bluestem (*Schizachyrium scoparium*, top left), nymph (bottom left), adult sampling method (sweep netting big bluestem, *Andropogon gerardii*, top right), and adult (bottom right).



Figure 24. Prairie smoke (*Geum triflorum*), a state threatened species, in a dense mat of over 100 stems within 1.5 acre area on private land in Newaygo County, Michigan.

Meetings and Conferences

I attended several meetings during the first two years of the project. I attended quarterly Karner blue working group meetings at various locations in 2002-2003. Interested parties from the Inventory, MDNR, USFWS, Forest Service, TNC, Consumer's Energy, Howard Christensen Nature Center, Grand Valley State University, Michigan Nature Association and others were also in attendance. I presented summaries of Inventory surveys and project progress at each of the working group meetings. I also participated in an education and outreach meeting at John Ball Zoo in November 2002 in which working group members and other stakeholders met to discuss plans, goals, and actions needed to enhance knowledge of and participation in Karner blue recovery and the HCP process. Attendees included personnel from the Inventory, MDNR, USFWS, Forest Service, Grand Valley State University, Grand Rapids Community College, the West Michigan Land Conservancy, Consumers Energy, John Ball Zoo, Binder Park Zoo, and the Detroit Zoo. As a result of this meeting, I developed a Karner blue butterfly fact sheet which was distributed to MDNR biologists and placed on the <http://www.karnerblue.org> and <http://web4.msue.msu.edu/mnfi/> web sites. Other entities set out to produce several other products as a result of this meeting. A poster, audio and visual materials for presentations, and a lupine planting or habitat management program are being developed and will be completed between January 2003 and October 2004.

I participated in other activities including the southeast Michigan Prescribed Fire Council meeting in August 2002, The Nature Conservancy's BioBlitz at Camp Owassipe Boy Scout Reservation, The Wildlife Society's national conference in Bismarck North Dakota, and Core Natural Heritage Training in Arlington, Virginia. In 2003, the national conference of the Natural Areas Association was attended in Madison, Wisconsin, and a presentation outlining Karner blue Inventory

surveys was made at the Endangered Species Coordinators Conference.

Inter-Agency Cooperation

Results of Karner blue surveys were provided to a variety of interested parties. Maps of digitized locations were provided to MDNR wildlife biologists to provide a visual representation of the Karner blue distribution in the state and within managed areas. These maps can be used in presentations by MDNR staff and to provide information to stakeholders. I provided Doug Powless from the Land Conservancy of West Michigan with maps of the White River Area Karner blue sites in Muskegon County, in conjunction with their conservation efforts there. I also provided maps and summaries of township findings to the Forest Service, and in turn, the Forest Service shared site leads and updated information on known extents of sites and possible dispersal barriers. Inventory data will help the Forest Service determine where Karner blues occur near their lands, locate possible corridors, expose management opportunities, and learn locations of newly discovered sites. Tables outlining the numbers of sites within the Muskegon, Newaygo, and Ionia recovery units by ownership and county were provided to the USFWS, thereby equipping the Service with the most accurate and up-to-date information available regarding numbers of occurrences in those recovery units for Recovery Plan updates.

I continually provide comments on completed draft sections of the Karner blue Habitat Conservation Plan and the Michigan Recovery Implementation Plan as they become available. In addition, consultations with the HCP Coordinator on various aspects of surveys and planning are ongoing. My consultations with The Nature Conservancy, The Land Conservancy of West Michigan, John Ball Zoo staff, Consumer's Energy, and several private landowners have resulted in a better understanding of the collective efforts in Karner blue recovery, and have fostered a collaboration of those efforts where appropriate.

DISCUSSION

Presence-Absence Surveys

Presence-absence surveys are the preferred survey method when determining butterfly distribution across a large area when the amount of time for surveys is limited. The bivoltine nature of Karner blue flight periods limited our survey time to approximately three weeks in mid-May to early June and three or four weeks in mid-July to mid-August, 2002-2003. Additionally, the target survey area included over 10 counties, making presence-absence surveys ideal for this study. We were able to visit multiple sites across a vast landscape in a short period of time using this survey method. The tradeoff for being able to accomplish this level of survey lies in the usefulness of the data for future population monitoring. Our surveys resulted in expanding the knowledge of where Karner blue exist in Michigan, but were of limited usefulness in determining the status of individual subpopulations. I therefore suggest that subpopulations with habitat targeted for management under the HCP be re-visited to determine baseline butterfly numbers. This can be completed either concurrently with comprehensive surveys aimed at determining distribution or once those surveys are completed, but should be conducted prior to management under the HCP.

Public Lands Surveys

Because the HCP will allow management to take place on MDNR property and recovery goals are to be met on public lands, it is necessary to determine the exact locations of Karner blue occupied and potential habitat within these properties. Inventory surveys have covered much of the state-owned lands within the known range of Karner blue in Michigan, with emphasis in the Ionia, Muskegon, and Newaygo RUs. Within these RUs, it appears that state lands with Karner blue present include portions of the Flat River SGA, Hart-Montague LP, Muskegon SGA, Newaygo SP, and White Pine Trail LP. Exact locations of subpopulations on these properties are available to land managers through the Heritage Database.

The Flat River SGA appears to harbor the most subpopulations of the state lands within the

Ionia, Muskegon, and Newaygo RUs. Some sites within the Flat River SGA that were once occupied now appear to be locally extinct. Over six visits during the summer flight to two EOs along Snows Lake Road failed to yield Karner blue, although there was some scattered lupine present. Management within these areas will be necessary if they are to become re-established. In particular, exotic and woody species removal within these areas may promote lupine growth. However, even with such efforts, it is unlikely these sites will become re-established without significant efforts to link them with occupied areas. The remaining subpopulations on the Flat River SGA seem quite healthy, and in fact yielded some of the highest observation rates observed during Inventory surveys. There appear to be two or three small metapopulations on the SGA, separated by the Wabasis River and Flat River. It would be advisable to manage each metapopulation separately to spread the risk of local extinction. Each metapopulation appears to be linked to subpopulations on private lands around the SGA which may be useful as a buffer to the subpopulations on state-owned land.

Contrary to the case at the Flat River SGA, much of the metapopulation around the Muskegon SGA is off of state-owned land. The known subpopulations within the Muskegon SGA are currently confined to Consumer's Energy powerline rights-of-way and roadsides. This presents a unique opportunity to expand suitable habitat onto public land and add to opportunities for recovery. Some scattered lupine plants were found within wooded areas adjacent to the rights-of-way in section 12 of Muskegon Township and section 7 in Egelston Township, but do not appear to be occupied at this time. The butterflies were probably once present within these areas, which are now forested with small scattered openings. The subpopulations along the powerlines could potentially be expanded into the SGA with timber management aimed at reducing canopy cover.

The subpopulation within the Newaygo SP is also confined to a powerline right-of-way and is managed by Consumer's Energy. Five visits by Inventory staff during the second flight in

2002 did not turn up any Karner blue. However, it was later found at that site during a visit by Consumer's Energy employees, verifying that the site is still occupied.

Karner blues along the linear state parks present an entirely different opportunity. These sites are near or run through residential areas and are well known to the local people. Large tracts of lupine on private lands, once separated by forest and residential areas, are now connected with lupine along the White Pine Trail in Kent County thanks to planting efforts initiated by a local gardening club. It is unclear what affect these efforts are having on the subpopulations, but lupine planting has drawn the attention of the public to the needs of Karner blue butterflies, and to butterfly conservation in general. Similar efforts within other state-owned lands may benefit Karner blue and other rare species by raising public awareness and promoting responsible land stewardship.

Private Lands Surveys

Landowner contact response rates were similar to other efforts by Inventory staff. While several individuals refused permission for surveys, very few contacts were negative. In general, form letters were useful in reaching a large number of landowners with minimal effort. However, personal contact whether by phone or in person seemed to generate the most positive results and helped forge a relationship with the landowner. Owners were generally more likely to allow survey even when they had initial concerns if someone was available to speak to them one-on-one.

Private lands surveys were highly successful at finding new occupied sites and extending EOs. Properties near state or federal land with Karner blue present were targeted with the most success. Other properties surveyed as a result of identifying potential habitat while driving by were occupied as well, indicating that Karner blue are more prevalent on private land than previously thought. For instance, a property in section nine of Big Prairie Township, Newaygo County that was over three miles from the nearest known EO was surveyed in 2003 because it looked good from the road, and turned out to be occupied by Karner blue. There were at least 3 similar cases, suggesting that more

surveys on private lands will uncover additional subpopulations, especially in Newaygo, Muskegon, and to a lesser extent Oceana Counties.

Some areas on private land are currently not within the targeted areas covered by land conservancies nor are they near state-owned lands. The subpopulations in these areas are therefore vulnerable to development and will probably be lost in the next 15-20 years barring a significant education and outreach effort. One such area is located in Reynolds Township, Montcalm County. Fragments of the HMNF extend into this Township, but are commonly planted to red pine. Private lands surveys in this township uncovered approximately 150 acres of occupied habitat. Landowners may benefit from federal or state-run programs offering tax incentives for protection or management efforts.

Site-level Habitat Characteristics

The most influential habitat characteristics in Karner blue presence or absence (other than lupine) appears to be the presence and diversity of flowering plant species. Several flowering plants were positively associated with Karner blue presence. Butterfly weed, dewberry, horsemint, and flowering spurge have been listed in the literature as being preferred species (Bidwell, 1994, Herms 1996, Grundel and Pavlovic 2000) and were significantly associated with Karner blue in this study. Several other species identified as nectar sources in the literature were also associated with Karner blue presence. In particular, black-eyed susan, blazing star, evening primrose, sunflower, wild bergamot, and downy phlox all showed a statistically significant or marginally significant association in this and other studies (Packer 1987, Bleser 1992, Leach 1993, Papp 1993, Sferra et al. 1993, Bidwell 1994, Martin 1994, Maxwell and Givnish 1994, Grundel and Pavlovic 2000). Therefore, planting of native flowers for Karner blue should include some of these species along with lupine and other nectar plants listed in the Recovery Plan (USFWS 2003).

Grundel and Pavlovic (2000) suggest that Karner blue are generally opportunistic, feeding on nectar plant species in proportion to their availability. They also suggest that Karner blue

were more likely to feed on certain species with yellow or white flowers (Grundel and Pavlovic 2000). In this study, Karner blue were frequently observed feeding on spotted knapweed, which was commonly the dominant flowering species within the immediate area (personal observation). This supports the idea that nectar plants are selected in proportion to their availability. Therefore, the moderate association of Karner blue presence with this invasive species should not be interpreted as a reason to promote knapweed in Karner blue areas, but rather a sign that abundant flowering plants will probably be used by Karner blue as a food source.

The exotic species St. John's wort has a yellow flower, and was positively associated with Karner blue, and in some areas was the only flowering species available. Karner blue were rarely observed using it as a food source, however. Although not statistically tested, these areas seemed to have lower observation rates than nearby areas with even just one more flowering species available. This suggests that although Karner blue may select yellow or white flowers, not all such species are preferred, and, again, an association with St. John's wort does not imply that it is a beneficial species.

General characteristics at Karner blue sites suggest that many subpopulations are threatened by ORV use. Although ORV use creates disturbance and can initially encourage lupine growth, repeated use is detrimental to Karner blue and lupine. The sandy soils that characterize barrens and savannas are unstable and can be easily disrupted by ORVs, which uproot the vegetation. Repeated disturbance by ORVs prohibits vegetation renewal, and desertification results. The resulting environment is inhospitable for lupine and Karner blue. Habitat analyses support this by showing that Karner blue were less frequently associated with areas having bare sand as the dominant ground cover which is often created by repeated ORV use. ORV use on public lands is a complicated issue due to the multiple use goals of many managed areas. Regardless, Karner blue occupied habitat should be protected not only by physical means (e.g. barriers), but also by informing ORV users of the impacts of ORV use

on barrens and savanna systems and resulting impacts on Karner blue and lupine populations.

Areas surveyed in this study varied in quality and ability to support Karner blue butterflies. Several habitat patches were apparently suitable, but surveyors were unable to detect Karner blue. The probability of detecting Karner blue in an area was shown to increase as lupine density, distribution, preferred nectar species, and flowering plant diversity increase. This positive association indicates that these factors potentially limit Karner blue in Michigan. Alternatively, Karner blue are less likely to be present as the amount of canopy cover increases, and with the presence of certain exotic species, namely autumn olive and honeysuckle. These factors limit Karner blue by decreasing the ability of lupine and flowering species to exist in an area. Strategies for managing these factors have been examined in Michigan (Lawrence and Cook 1989, Sferra et al. 1993, Schuetz 1996) and recovery strategies are outlined in the federal Recovery Plan (USFWS 2003).

Future analyses will look at habitat patch size, connectivity, and distribution across the landscape in an attempt to gain a better understanding of how these factors influence Karner blue metapopulation viability. Further analyses may also investigate the associations between factors at absent and lupine only sites in order to investigate which lupine only areas are most likely occupied. Surveys in 2004 will target the highest ranked sites.

Landscape Level Model

The landscape level habitat model was run on Muskegon County as a test case, and will eventually be expanded to the entire state. The expanded model will potentially include other spatial layers as they become available, and will be flexible to accept modified weighting schemes for different objectives (e.g. reintroduction, habitat expansion). Areas identified as potentially suitable may be included in 2004 surveys to determine whether they are occupied by Karner blue, and to assess site-level habitat characteristics.

Distribution and Abundance

Interpreting nondetection of butterflies at previously occupied sites as extirpation may be premature at this time, but concern is certainly justified. Initial examination of the data reveals a number of potential local extinctions at known Karner blue sites. Of particular concern are the EOs appearing as an X in Figure 20. If Karner blue still exist in these areas, they are probably present in very low numbers and are highly vulnerable. This was the case in Ontario subpopulations which persisted at low numbers for years and gradually declined with the quality of habitat before disappearing from the landscape (Packer 1994). One lesson learned from the Ontario case is that "...recovery of very small local populations may be possible if potential limiting factors can be readily identified and their amelioration effected" (Packer 1994). Management of the potentially limiting factors identified in this report may increase the viability of those subpopulations that contain low Karner blue numbers.

Opportunities for

Translocation/Reintroduction

The MDNR has ambitiously taken on the task of increasing the Karner blue to recovery goals by, among other things, increasing the number of metapopulations on state-owned lands. Management to improve and expand existing habitat will help meet this goal, but several opportunities for translocation or reintroduction exist on state lands as well and are within the historic range of Karner blue in Michigan.

One candidate for reintroduction is the Petersburg SGA in Monroe County, which contains several lupine areas that currently support *Persius duskywing*. Management within the SGA has included prescribed burning and the removal of autumn olive. Although lupine is present and the butterflies once occupied the SGA, the isolation from other subpopulations is a concern. Metapopulations in nearby Ontario and Ohio have disappeared as well, although reintroduction efforts in Ohio appear to be quite successful. If the reintroduced metapopulation in Ohio cannot be linked to the Petersburg area, a viable metapopulation is unlikely to persist due to isolation.

Another potential opportunity for translocation lies within the Cannonsburg SGA in Kent County. Cannonsburg is approximately 10 miles southeast of the nearest known Karner blue site and is within five miles of Grand Rapids, making it a good candidate for study by students from Grand Valley State University or for use in educational programs by interested parties such as the nearby John Ball Zoo. Cannonsburg contains four one- to three-acre areas of extremely dense lupine which extends onto private land to the south. Karner blue have not been recorded from this Area, but Frosted elfin are present, and Karner blue may be able to survive there as well. An introduced population at Cannonsburg may also eventually succumb to the effects of isolation unless connected to other existing subpopulations.

Other possible sites for translocation include Barry SGA, Gourdneck SGA, and Island Lake RA. Barry SGA has multiple small lupine areas that could be connected and expanded with timber management or prescribed burns, and currently supports a *Persius duskywing* population. Gourdneck SGA in Kalamazoo County also has scattered lupine, but may require more significant management efforts to expand the available habitat. Finally, the Island Lake RA in Livingston County has an area populated with lupine that is managed with prescribed fire to reduce woody species. Island Lake would require the most management and is quite isolated from other known lupine areas. It should be noted that the latter two areas are outside of the known historic distribution of Karner blue in Michigan, which could be a factor when attempting to solicit support for translocation efforts.

Priorities for 2004 Surveys

Although 2002-2003 surveys were extensive and produced much information on Karner blue distribution, there are several areas for which surveys have never been conducted and habitat is available. One priority for surveys is found along railroad rights-of-way owned by Mid-Michigan Railroad and CSX Transportation in Muskegon, Newaygo, Montcalm, and Ionia Counties. Lupine has been observed along an extensive stretch of the CSX line running parallel to M37 in Newaygo County. If

occupied, this stretch of railroad could connect two metapopulations which are currently separated. An involved and costly application process is necessary to gain permission to survey CSX lines and may prohibit survey of these areas.

Another priority for 2004 surveys is found among private lands in southwest Michigan. Private property within five miles of Allegan SGA should be surveyed, as the metapopulations found there may not be confined within the SGA boundary. In addition, other private properties in southwest Michigan identified by our habitat models may receive surveys to find previously unknown subpopulations or metapopulations. Of particular interest are areas within Allegan, Barry, Berrien, Kalamazoo, Kent, southern Muskegon, Ottawa, Van Buren, and possibly Cass Counties.

Portions of the Pere Marquette State Forest should receive surveys where land managers have noted lupine or where our model indicates habitat may be present. This region has received little attention in the past and it is unknown what, if any, potential it holds for Karner blue. Several sites in outlying areas have been suggested for survey, and will be of low priority in 2004.

A portion of state-owned lands has gone unsurveyed thus far, has high potential to be occupied by Karner blue, and is currently unprotected. Highway rights-of-way managed by the Michigan Department of Transportation (MDOT) in Muskegon, Newaygo, Mecosta, and Montcalm Counties are populated by significant amounts of lupine and run through Karner blue occupied areas. A 10 mile stretch of I-31 has never (to our knowledge) been surveyed for the butterflies and contains long sections of dense lupine. Karner blue are known to occupy habitat within a mile of habitat that is found along that right-of-way, which is also probably occupied. I-131 is known to be occupied by Karner blue in northwest Montcalm County, but lupine has been observed to both the north and south of the known occupied area. State highways M37 and M82 in Newaygo County are lined with lupine and run through Karner blue areas, but are currently unprotected as well. It may be possible to conduct surveys along select portions of habitat in 2004, but a thorough investigation of all rights-of-way under MDOT jurisdiction should be a high priority for the State. Such surveys are possible, but will require more time and effort than current funding can support given the other survey priorities.

ACKNOWLEDGMENTS

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APPENDICES

Appendix 1. Karner blue butterfly survey protocol adapted from Wisconsin Habitat Conservation Plan.

KBB SURVEY PROTOCOL - PRESENCE/ABSENCE SURVEYS

(Adapted from Wisconsin HCP)

The following are *suggested minimum requirements* for conducting Karner blue butterfly (*Lycaeides melissa samuelis*) presence and/or absence surveys. For the purpose of this survey, *absence* means that KBBs were not detected at a particular site. It is not a 100% guarantee that KBBs do not exist at the site.

Purpose: First flight – To determine if lupine exists in a particular area and whether that area supports KBBs. Second Flight – Determine if KBBs occupy a particular habitat area (lupine and surrounding nectar species).

When To Survey:

- Surveys for the KBB can be conducted during both the first or second flight periods. The first flight normally begins in late May and ends in mid to late June while the second flight normally begins in mid-July and ends in mid to late August.
- Timing of flight periods can vary by as much as 2-3 weeks from year to year and from site to site, and the length of flight periods may vary from year to year (two weeks to five weeks in length).
- If resources do not allow you to conduct surveys during both flights, priority should be placed on conducting surveys during the main second flight (see "Determination of NO KBBs" listed below).
- Survey *three* times during the main second flight period. Only one survey is needed if KBBs are detected during the first survey. If you do not detect KBBs during the first survey, a second survey should be conducted. If KBBs are not detected during the second survey, a third survey should be conducted. Surveys should be spaced so that there is a 3-7 day interval between surveys.
- Conduct surveys during optimal time and weather conditions as listed below:
 - between 8:00 a.m. and 6:00 p.m.
 - when temperatures are above 60⁰F
 - when temperatures are between 60⁰F and 70⁰F surveys should only be conducted under mostly sunny skies with calm to light wind
 - when temperatures are above 70⁰F, no restrictions on cloud cover
 - when winds are less than 20 mph
 - do not survey under drizzly or rainy conditions

How To Survey: An individual who is knowledgeable in the identification of KBBs should conduct the surveys. It is recommended that individuals conducting surveys obtain training in identifying KBBs. Reference photos of KBBs may be obtained from Jennifer Fettingner at MNFI. An alternative to this is having Jennifer Fettingner or Dave Cuthrell positively identify a voucher photograph. Photo must capture underside of wing for positive identification.

- The KBB habitat area (lupine and associated nectar species) has been identified ahead of time and is indicated on a topographic map in each field folder.
- Each area separated by >100m of unsuitable habitat should be surveyed separately, each having its own field form.

- The surveyor(s) should walk the entire habitat area (being careful not to step on lupine plants) at a leisurely pace until all likely locations of KBB concentration areas are surveyed.
- The purpose of the survey is fulfilled when one KBB is observed (during either the first or second flight period). It would be advantageous to spend additional time at the site to record more observations.

Intensity Of Survey: Approximately 10 minutes of effort per survey are recommended for each acre of habitat (i.e. lupine patches and important nectar flowers within 100 meters of the lupine patch) to determine presence/absence and to map lupine. Surveying for a longer period of time is encouraged (but not mandatory) if KBBs are not found during the first 10 minutes of survey effort per acre of habitat.

Determination of No KBBs: The determination that no KBBs are present at a site can be made once the site has been surveyed (without documenting any KBBs) three times during the second flight period of one year. Surveys should be spaced so that there is a 3-7 day interval between surveys. The "KBB and LUPINE SURVEY FORM" should be filled out for the first visit to a site, and the "FOLLOW-UP KBB SURVEY FORM" should be completed on subsequent visits. Full instructions on filling out both field forms are located at P:/NFI/Zoology/Karner Blue/USFWS Grant Project/KBB Form Instructions.doc and /Follow-up Form Instructions.doc Note: Once one KBB is observed the purpose of the survey is fulfilled and additional surveys are not required *during that year*.

General Information:

- The "Determination of No KBBs" is based on surveys during the second flight since KBBs numbers are normally significantly greater during this flight period.
- KBB flight periods vary within year from site to site depending on the site's phenology (i.e. "fast" sites and "slow" sites). Flight periods normally occur first on sunny open sites and later on shady sites. Spacing of the surveys is necessary to ensure that at least one survey is conducted during the main flight. A 3-7 day range is used because the duration and amount of suitable survey weather varies among years.
- It would be advantageous for the HCP Team to develop/coordinate a cooperative method of determining the flight period phenology each year that accounts for variation by geography an site ("fast" and "slow" sites).
- Time Period and Effectiveness of Results: The presence/absence survey has both a spatial and temporal component (i.e. absent here now but present here later). The question - How long does the absent status apply? - will need to be addressed.

For information on identification of KBBs, contact:

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Appendix 2. Karner blue butterfly survey field form and field form instructions.

Page 1 of 2

KBB and LUPINE SURVEY FORM

Fill out this section after the survey has been completed

1 KBB Present?: NO ____ Why? (see codes and circle all that apply) L N W S
 YES ____ Certainty of location: >95% (location gps'd*) ____ 80 - 95% ____ 20 - 80% ____ 0 - 20% ____ UNKN ____

SURVEYOR AND LOCATION INFORMATION

Survey date: 2 ____ - ____ - ____ Time from: 3 ____ to: ____ SITENAME: ____ Sourcecode: F ____ M I U S

Surveyors (principal surveyor first, include first & last name): 4 ____

5 TOWNSHIP: ____ RANGE: ____ SECTION: ____ QUARTER SECTION: ____

OWNERSHIP: 6 ____ QUAD CODE: ____

Weather (see codes page): 7 Begin Temp: ____ Begin Wind code: ____ Begin Sky code: ____
 End Temp: ____ End Wind code: ____ End Sky code: ____

SITE CONDITION INFORMATION

Use space provided on back to sketch the area surveyed.

Type of opening (ROW, clearing, field, barrens, lawn): 8 ____ Size of opening: 9 ____

Vegetation surrounding opening (wooded, agriculture, etc.): 10 ____

Has the area been disturbed? (burn, cut, planted): 11 ____

Other threats to the area? (ORV, Mechanical, Horses, etc.): 12 ____

13 Light: open ____ partial ____ filtered ____ shade ____ 14 Moisture: moist (mesic) ____ dry-mesic ____ dry (xeric) ____

Ground cover description (Density, % bare soil, % grass/forb/fern): 15 ____

WOODY VEGETATION ENCROACHMENT: Tree/shrub/stump species and form	Height	Density	Notes
16 ____	17 ____	18 ____	19 ____
____	____	____	____
____	____	____	____

BOTANICAL ENCROACHMENT Species	Density	Notes
20 ____	____	____
____	____	____
____	____	____

KARNER BLUE BUTTERFLY OCCURRENCE

Mark occurrence on map using a * to indicate an occurrence

21 Total number of KBB adults: Male Female Unknown	% of opening occupied 22	Survey effort: Time spent in opening 23	Notes, observations, etc.: 24
____	____	____	____

*If the location(s) were gps'd, fill out this section, otherwise leave blank

25 Type of unit: ____ Unit number: ____
 Waypoint name/# (when using Garmin) ____ File name (when using Trimble) ____
 OPTIONAL: Latitude ____ Longitude ____

26 FEATURE INFORMATION (mandatory) Point : <12.5 m in both dimensions Line : >12.5 m in one dimension Polygon : >12.5m in both dimensions
 Source Feature (circle one): Single Source EO ____ Multi-Source EO ____ Conceptual Feature Type (circle one): Point ____ Line ____ Polygon ____

LUPINE OCCURRENCE

Map lupine distribution. Use a ● for scattered plants, an X for clumps, and circle (0) dense areas

Overall distribution pattern (see codes): 27 ____

28 Estimated % of area covered: ● ____ X ____ 0 ____

Estimated % of lupine blooming or in seed: 29 ____ Ants present: 30 ____ Evidence of Browse: 31 ____

Comments: 32 ____

KBB and LUPINE SURVEY FORM CODES

WIND CODES (Beaufort wind scale)

- 0 = Calm (< 1 mph) smoke rises vertically
- 1 = Light air (1-3 mph) smoke drifts, weather vane inactive
- 2 = Light breeze (4-7 mph) leaves rustle, can feel wind on face
- 3 = Gentle breeze (8-12 mph) leaves and twigs move, small flag extends
- 4 = Moderate breeze (13-18 mph) moves thin branches, twigs, and leaves, raises loose paper
- 5 = Strong breeze (19-24 mph) trees sway, branches move, dust blows
- 6 = Windy (> 24 mph)

SKY CODES

- 0 = Clear to few clouds
- 1 = Partly cloudy or variable sky
- 2 = Cloudy or overcast
- 3 = Fog or haze
- 4 = Drizzle or light rain
- 5 = Rain showers

KBB ABSENCE CODES

- L = No lupine
- N = No nectar sources
- W = Weather was poor, KBB may not be detectible
- S = Area >75% shaded

LUPINE DISTRIBUTION PATTERN CODES

- 0 = No lupine present
- 1 = Lupine scattered and sparsely distributed in the area
- 2 = Lupine scattered but common and distributed through much of the area
- 3 = Lupine scattered but abundant and distributed through most or all of the area
- 4 = Clumps of lupine sparsely distributed in the area
- 5 = Clumps of lupine common and distributed through much of the area
- 6 = Clumps of lupine abundant and distributed through most or all of the area
- 7 = Dense stands of lupine sparsely distributed in the area
- 8 = Dense stands of lupine common and distributed through much of the area
- 9 = Dense stands of lupine abundant and distributed through most or all of the area

“KBB and LUPINE SURVEY FORM” Instructions

1. Complete this box AFTER the survey has been completed. Check Yes or No if Karner blue butterflies were present or absent. If No, see the codes on page 3 and circle the appropriate letter. If none apply, write a reason next to the codes (eg. *Survey conducted outside KBB flight window*). If Yes, indicate the certainty with which the location(s) of KBB populations were placed on the accompanying topographic map.

SURVEYOR and LOCATION DATA

2. YYYY-MM-DD
3. Use military time or specify am or pm to indicate the duration of the survey
4. List surveyors by name rather than initials
5. List the appropriate Township/Range/Section and indicate the quarter section in which the survey was conducted
6. Describe the ownership (eg. State, Federal, or Private. If private, list landowners)
7. Describe the weather at the beginning and end of the survey by placing the appropriate codes in the blanks provided.

SITE CONDITION INFORMATION

Make a sketch of the area (as closely to scale as possible) on the bottom of page 2, noting major vegetative features

8. Describe the type of opening or area surveyed
9. Estimate, using the topographic map or visually, the size of the entire area
10. Describe the vegetation surrounding the survey area. This section should include potential barriers for butterfly dispersal or unsuitable habitat (eg. *planted pines to the north, dense hardwoods to the east and south, soybean field to west*)
11. List disturbances to the survey area, either evident or suspected (eg. *burned this growing season, evidence of past agriculture*)
12. List current or potential activities that would degrade the habitat and could potentially make the area unsuitable for KBB habitation now or in the future (eg. *Campfire in northwestern corner of opening in center of lupine stand, trash in southwestern ¼ also covering lupine*)
13. Check the category that best describes the majority of the survey area. Open = 75-100% sun, Partial = 50-75% sun, Filtered = 25-50% sun, Shade = 0-25% sun
14. Check the category that best describes the soil moisture at the site. (note: most sites with lupine will be dry/xeric)
15. Describe the ground cover in terms of % grass/forb/fern/bare for the site. (note: include lupine in your estimates of forb cover) If there is a section of the area that varies significantly from the rest, make a note, but include that type of cover in the overall area % (eg. If most of the area is covered in 100% forbs, but the northeast ¼ contains large areas covered with lichen with no other vegetation, indicate *75% forb and 25% lichen* and note *NE1/4 has large areas of lichen without other veg*. Likewise, if the area is a uniform mix of lichen and forbs with 3 times as much ground covered by forbs as lichen, indicate *75% forb and 25% lichen* and note *uniform mix throughout*).
16. List dominant species of woody vegetation within the area, including species entering the area from adjacent wooded areas and woody regeneration from past disturbances.
17. Indicate average height or range of heights at which the woody species are found inside the area
18. Describe the density of woody encroachment quantitatively in terms of the entire area and qualitatively in terms of the area covered by woody vegetation (eg. *10% scattered, 5% dense* would indicate that 10% of the area includes scattered stems of the species identified and another 5% is dominated by the species, for a total of 15% of the area including the species indicated. Qualitative descriptors from least dense to most may include sparse, scattered, patchy, abundant, and dense)
19. Make any notes to further describe the distribution and abundance of woody vegetation here
20. List species of exotic or invasive vegetation here. Common species encountered are Autumn olive (*Eleagnus umbellata*), spotted knapweed (*Centaurea biebersteinii*), and non-native hawkweeds (*Hieracium* spp.). Include woody and non-woody species. (note: some exotics are also used as nectar species, but do not include in that section if you include them here)

KARNER BLUE BUTTERFLY OCCURRENCE

Indicate KBBs on the drawing using a * for individuals or groups

21. Write the total number of male, female, and unknown KBBs under the appropriate category. If none were seen, draw a line through the spaces. See Jennifer Fettingler for identification tips and informational materials.
22. Indicate the % of the area surveyed that was occupied by KBBs. If the entire area (eg. Powerline ROW) was not surveyed, be sure to note this and indicate the area surveyed on the topo map and drawing.
23. Indicate the amount of time spent surveying the area and the amount of the area covered.
24. Note KBB behavior and important comments
25. If you have a GPS unit with you, take locations at the center of the KBB distribution(s) within the survey area
26. Fill out this section only if KBBs were present in the survey area, following procedures for the "Special Animal Form"

LUPINE OCCURRENCE (note: lupine may not be readily apparent during the second flight, and mapping may not be possible during that time)

Indicate where lupine is found in the area on the drawing using a ●, x, or 0 to indicate the density in a location

27. Describe how lupine is distributed in the area use the appropriate codes
28. Estimate the amount of the entire area covered by each lupine density type. (eg. if ½ of the area is covered by lupine, the sum of all three categories should not add up to >50%. Say that, of the area covered by lupine, half is scattered plants and half is in dense stands, ● = 25%, x = 0%, and 0 = 25%)
29. Indicate the % of all lupine in the survey area that is blooming and/or in seed
30. If active ant mounds are present in the survey area, write *yes*, otherwise write *no* or *none observed*.
31. If there is evidence of deer browse on the lupine (flower heads appear to have been cut off at the base), indicate the % of the lupine showing deer browse.
32. Write any notes on larval feeding evidence, lupine distribution here

NECTAR SPECIES PRESENT

33. List scientific or common names of dominant nectar species present on the site, either blooming or non-blooming (when possible)
34. Indicate whether the nectar species is blooming
35. Indicate the % of the area that contains the nectar species
36. Write notes on nectar species here. Include notes on barrens indicator species and rare species.

OTHER SPECIES PRESENT

37. List potential larvae or adult predators observed in the survey area (eg. dragonflies, robberflies, assassin bugs, praying mantids, parasitic wasps and flies, spiders, nesting songbirds, insectivorous songbirds, turkeys, rodents) along with other rare or notable species of plants and animals.
38. Indicate the number of each species or group of species. Where appropriate, use notation such as >25, >50, etc.
39. Write notes on predatory behavior and element occurrences here

40. Sketch the boundary of the area visited, prominent vegetative characteristics, mark your survey route, and indicate KBB and lupine within the area.

Appendix 3. Private landowner permission to survey permission sheet.

**MNFI Karner Blue Butterfly Project 2003
Access to Private Property Permission Form**

**Please make corrections or additions below if necessary:

Name:
Address:
City, State Zip:
Phone:
County/Site:

**Please check the following with an X:

- Yes, you may visit my property to conduct a survey.
- Yes, you may collect plant specimens for identification purposes.
- No, you may not have access to my property.

Signature _____ Date _____

Print Name _____

Michigan State University (MSU) agrees to indemnify the Landowner for losses from any personal injury or property damage claims made by others alleging negligence by MSU in its activities on the Landowner's property.

This authorization shall expire on September 30, 2003.

Signature _____ Date _____
Jennifer Fettinger, MNFI Zoologist

**Please indicate below if you have any concerns or wish to make additional comments.

Comments: _____

For office use only:	Source _____
CType _____ CD ___ / ___ / ___ CName _____ Init _____	
S _____ SDate ___ / ___ / ___ H _____ K _____ A _____ Re _____ Further _____	
CNotes: _____	
SNotes: _____	