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

Prepared by:
Jennifer L. Fettinger

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

For:
Michigan Department of Natural Resources
Stevens T. Mason Building
Lansing, MI 48909

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EXECUTIVE SUMMARY

The Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov) is dependent on wild lupine (*Lupinus perennis* L.) as its sole larval food source. Lupine exists in dry, sandy soils associated with oak savannas and oak-pine barrens, some of the rarest natural communities in Michigan (Chapman 1984). Karner blue is listed as endangered (E) under the Federal Endangered Species Act (ESA) and is considered imperiled (G5T2) by NatureServe, mainly due to the rarity of its habitat. Loss of savannas and barrens is increasing across the butterfly's range, primarily from development and succession of the historically fire-maintained ecosystem. Efforts to maintain habitat suitable for Karner blue and lupine often include soil disturbance and removal of woody vegetation to encourage lupine growth. Because these efforts include the risk of harming Karner blue larvae, eggs, or adults when applied in occupied habitat, the Michigan Department of Natural Resources (MDNR) has set forth to obtain an incidental take permit through the Habitat Conservation Planning (HCP) process. The permit will allow the state and its partners to proceed with activities, otherwise legal, that may result in take of the species. Michigan Natural Features Inventory (MNFI) initiated presence-absence surveys in support of the HCP process in 2002. The surveys and work associated with this study have helped guide HCP development by filling gaps in the known distribution of Karner blue in Michigan, identifying opportunities for habitat enhancement or creation, locating opportunities for translocation or reintroduction, and outlining threats to Karner blue populations. This report summarizes the study methods and findings most relevant to HCP development and implementation, wildlife managers, and others that are involved in the conservation of Karner blue in Michigan. Detailed methods and results of the first three years of this study are presented in annual reports prepared for the Michigan Department of Natural Resources (MDNR) (Fettinger 2002, 2003, 2004).

I located potential gaps in the knowledge of Karner blue distribution in Michigan through analysis of Karner blue occurrences and reports from previous survey efforts. Five main deficiencies in our knowledge were identified through this analysis: 1) many known occurrences had not verified in four or more years (old data), 2) insufficient survey effort in the Ionia, Muskegon and Newaygo RUs due to fragmented ownership, 3) insufficient survey efforts in potential habitat outside the known distribution of the butterflies 4) unknown quality of habitat within occupied sites, and 5) unknown threats to Karner blue populations.

Lupine surveys, status surveys, and *de novo* searches were conducted during the summers of 2002, 2003, and 2004 to help fill these knowledge gaps. I identified sites where Karner blue had not been re-verified extant in recent years using Natural Heritage Database (Database) occurrences, created a deductive habitat model in GIS to identify areas where Karner blue habitat (lupine) may be present, and carried out *de novo* surveys to document Karner blue presence or absence. In all, surveyors searched for Karner blue and lupine within 3,966 ha (9,801 ac) in the Lower Peninsula, re-verified Karner blue presence at 79 previously known occurrences, discovered 43 new Karner blue occurrences, and documented six township records. In addition, surveyors located over 320 ha (791 ac) of previously unknown habitat (lupine and adjacent nectar sources).

Survey results were used to update occurrence data in the Database and define occupied and surveyed habitat patches in a Geographic Information System (GIS). New and updated occurrences were used to create maps of current Karner blue distribution in Michigan. Information on the total acreage of occupied and suitable areas (lupine present) within each Recovery Unit (RU) by ownership (public and non-public) was provided to the HCP Coordinator to assist with HCP development. Land managers were provided with the habitat model and maps of predicted suitable and known occupied habitats to aid in

management and conservation decision-making.

I evaluated habitat quality at sites occupied by Karner blue in Michigan by analyzing habitat data collected during 2002-2004 surveys. Habitat data were collected within 146 Karner blue occupied sites and compared with data from 112 sites where only lupine was observed. I collected data on several general site characteristics including current and potential threats, management occurring on the land, opening type, surrounding environment, and amount of canopy closure. Habitat parameters characterized included lupine density and abundance, percent of lupine blooming or in seed, presence of deer browse on lupine, presence of ant mounds, woody plant and exotic species and amount of encroachment, dominant ground cover, preferred nectar plant species and abundance, and other flowering plants. Data analysis included logistic regression, which I used to create a statistical model that predicts Karner blue presence based on habitat parameters within a site. The final model (logit(Pr(Y=1|x)) = -0.2528 + 0.8548(NEAROCC) - 1.4649(LDENS1) - 0.7728(LDENS2) + 1.1307(LDENS3) - 0.2017(RNKNECT) + 0.3933(NNECTSP) - 0.8863(CLOSCAN)) indicates that sites with <50% canopy closure that are within 1000m of occupied habitat and contain dense lupine in addition to diverse flowering plant species are of high quality for Karner blue. Managers can use this model with habitat data collected within sites they manage to determine current habitat quality and prioritize management activities.

To illustrate how the model can be applied, I used it to evaluate sites surveyed on state-owned lands in 2002-2004 based on the predicted probability of observing Karner blue (*p-hat*). I assumed that surveyors were more likely to observe Karner blue where they are more numerous, and that butterfly numbers are directly related to habitat quality. Given these assumptions, I was used the probability of observing Karner blue to evaluate habitat quality within sites. I then compared the predicted probabilities with actual survey data to determine habitat quality related to Karner blue observations and visually represented habitat quality related to Karner blue observations by mapping sites and their *p-hat* values. Habitat characteristics present within sites were analyzed to indicate what characteristics could be improved within individual sites to benefit Karner blue, where translocations may be possible, and where habitat could be expanded into the surrounding matrix.

Several threats to Karner blue populations exist in Michigan, including habitat loss due to internal and external forces, fragmentation of habitat, and incompatible land uses (USFWS 2003). I characterized the most common threats within 2002-2004 survey sites by Michigan Recovery Units (RU). The most common threats included management that, if unregulated, would result in take (present in 53% of sites surveyed), succession to forest (43%), exotic species encroachment (41%), off road vehicle use (39%), and development (33%).

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INTRODUCTION

The Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov) was listed as an endangered species by the U.S. Fish and Wildlife Service (USFWS) in 1992. Once known from 12 states and the Canadian province of Ontario, the butterflies currently occur 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, four of which support just 1 to five small, isolated sites at risk for extinction from habitat degradation and fragmentation (Wilsmann 1994, Rabe 2001).

Karner blue are associated with barrens and savanna communities throughout their 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 and 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; nectar plant diversity and availability also impact Karner blue populations (Fried 1987, Lawrence and Cook 1989, Bidwell 1994, Grundel et al. 2000). 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 often 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); 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.

Purpose of the Study

The USFWS and MDNR initiated the development of a statewide Habitat Conservation Plan (HCP) for the Karner blue butterfly. Once in place, the MDNR and its partners will be able to conduct management that might result in the incidental take of Karner blue. 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, MDNR, personal communication). Important steps in the creation of a statewide HCP are to determine current species distribution, define threats to population viability, and identify opportunities for enhancement of populations.

Surveys were conducted for Karner blue through much of the known range in Michigan prior to this study. However, there were still large gaps in our knowledge of the current species distribution. First, not all Recovery Units (RUs) identified in the Karner blue Recovery Plan received comprehensive surveys (USFWS 2003). Surveys over the last 10 years focused on large, relatively contiguous tracts of state- and federally-owned lands, namely Allegan State Game Area (SGA) in the Allegan RU and the Huron-Manistee National Forest (HMNF) in the Muskegon and Newaygo RUs (USFWS 2003). These surveys undeniably added to the understanding of Karner blue distribution within those areas. However, the Ionia, Muskegon, and Newaygo RUs have fragmented ownership, making comprehensive surveys difficult. As a result, fewer surveys were conducted there, meaning much less was known about the Karner blue distribution across ownership types in those RUs (USFWS 2003). Second, many records of Karner blue occurrence had not been verified for several years. These "old" records needed to be re-surveyed to determine whether Karner blue are still extant, and to identify threats to the persistence of those subpopulations. Third, an assessment of the potential for habitat to exist outside the known distribution of Karner blue had not been completed. Several areas in Michigan have the potential to support lupine and Karner blue, but had not been identified or surveyed for the species. Additionally, lupine density and abundance, nectar source availability, and canopy closure are identified as some of the most important factors determining habitat quality (Celebrezze 1996, Grundel et al. 1998b, Grundel et al. 2000), but had not been characterized within Karner blue occupied sites in Michigan. An analysis of habitat quality within Michigan sites would help guide decisions on where to focus habitat restoration or expansion efforts and identify areas with potential for translocation or introduction. Finally, an analysis of threats present within Karner blue sites had not been completed for Michigan, but would be useful in guiding conservation and management efforts. Filling these knowledge gaps would 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 Michigan Natural Features Inventory (MNFI) began a three-year project with funding from the MDNR to fill these knowledge gaps in Michigan. The project goals were to identify the locations and extent of the most significant Karner blue metapopulations in Michigan, describe their current condition, locate opportunities for enhancement through habitat protection, expansion, reintroduction, or translocation, and identify threats to persistence. MNFI activities related to these goals included presence-absence surveys on private and public land, habitat modeling, habitat quality evaluation, threats assessment, and database support. This report summarizes the study methods and findings most relevant to HCP development and implementation, wildlife managers, and educators involved in the conservation of Karner blue in Michigan. Detailed methods and results of the first three years of this study are presented in annual reports prepared for the Michigan Department of Natural Resources (MDNR) (Fettinger 2002, 2003, 2004).

METHODS

Karner Blue and Lupine Distribution

Knowledge Gaps

An analysis of the known distribution of Karner blue was conducted in 2002 to identify potential gaps in the knowledge of Karner blue distribution in Michigan. I completed a literature review to identify previous research efforts related to Karner blue in Michigan, reviewed the known Karner blue element occurrences in the Natural Heritage Database, and built a preliminary habitat model for Karner blue potential habitat using geology, minimum January temperatures, and ca. 1800 land cover. Five main deficiencies in our knowledge were identified through this analysis: 1) many known occurrences had not verified in four or more years (old data), 2) insufficient past survey efforts in the Ionia, Muskegon and Newaygo RUs due to fragmented ownership, 3) insufficient past survey efforts in potential habitat outside the known distribution of the butterflies 4) unknown quality of habitat within occupied sites, and 5) unknown threats to Karner blue populations.

Field Surveys

Lupine surveys, status surveys, and *de novo* searches were conducted during the summers of 2002, 2003, and 2004 to document locations of lupine and Karner blue in Michigan. Lupine surveys documented locations of the host plant in order to give a more complete understanding of the distribution of potential Karner blue habitat throughout the state and to locate areas for Karner blue surveys. Status surveys within old Karner blue occurrences were conducted to re-verify Karner blue presence and document new occurrences. *De novo* searches for Karner blue (presence-absence surveys) were conducted to locate previously unknown Karner blue occurrences and define the distribution of Karner blue in the state.

Lupine surveys consisted of both roadside surveys (conducted while driving to survey areas) and site visits. Surveys for lupine were conducted while lupine was blooming (May and June) for easy identification, but lupine locations were also recorded prior to and after the blooming period by individuals familiar with the plant. Roadside lupine surveys were carried out when lupine was blooming and detectible from a distance in the region of the state being surveyed. I visited known lupine sites and verified that lupine was visible from a distance of 10-15 m before proceeding with roadside surveys within the targeted area. Surveyors georeferenced lupine patches observed during roadside surveys using Garmin 12XL Global Positioning System (GPS) units and to record the latitude and longitude. Unique names or numbers were assigned to each point and notes about the number and location of plants were made (e.g. >20 plnts ~10m from road on N side at point #098). Site surveys for lupine consisted of walking through areas and visually scanning the ground for the plant. Surveyors delimited areas with lupine using a GPS to create points denoting concentrations of lupine (five or more plants present) or tracks around lupine patches. Unique identifiers were than assigned to each track or point to assist in conducting future Karner blue surveys. I selected spring lupine survey areas based on a predictive habitat model and using site leads previously gathered from the public and field biologists

Status surveys were conducted primarily during the 2002 and 2003 field seasons to document whether Karner blue and lupine remain extant within known sites. I analyzed last observation (Lastobs) and last survey (Lastsurv) dates for all Karner blue occurrences in the Natural Heritage Database to identify old occurrences. Occurrences with Karner blue not observed or not receiving surveys within the previous four years were selected for status surveys. Status survey sites were prioritized by time since last observation and using aerial photos of occurrence locations to determine whether habitat remained at the site.

The goal of *de novo* searches was to document previously unknown occupied habitat and to determine whether known

occurrences were linked or more expansive than previous survey efforts indicated. Survey sites were selected using aerial photo interpretation, a predictive habitat model, and site leads from knowledgeable individuals. Both private and public lands identified as having potential for lupine and/or Karner blue were surveyed and prioritized by their proximity to known occurrences. Sites that were within a kilometer of known occupied habitat were of high survey priority in 2002 and 2003, while potential habitats outside the known distribution of Karner blue were survey priorities in 2004.

Status surveys and *de novo* searches for Karner blue followed the same presence-absence survey protocols, which were adapted from the Wisconsin Habitat Conservation Plan (Appendix 1, Wisconsin DNR 2000). Surveyors visited sites during favorable weather (>65deg, <90deg, wind <15mph, partly sunny to sunny skies) from mid-May to early June and mid-July to early August. Surveys consisted of searching for Karner blue while meandering through areas with (Figure 1). Survey sites included lupine and the surrounding flowering plants and grasses. Areas were searched for approximately 25 minutes per hectare (10 minutes per acre) of habitat. Most surveys were conducted by two individuals, one watching for and counting butterflies and the other recording habitat data on KBB and Lupine Survey field forms (Appendix 2). If surveyors did not observe butterflies, surveys were repeated and data were entered on Follow-up KBB Survey forms (Appendix 3). Repeat surveys were aimed at reducing the probability of reporting false absences due to non-detection, and were generally conducted three to seven days after the initial survey. Surveyors took GPS points at Karner blue locations when one or more individuals were present. Points were given unique names, and the number and sex (if determined) of individuals observed at each point was recorded on field forms for later use in updating the Natural Heritage Database.

Figure 1. Example of Karner blue presence-absence field surveys, which consisted of watching for Karner blue butterflies while meandering through open areas containing lupine.

Potential Habitat Distribution

A spatial model predicting Karner blue habitat potential was created in a geographic information system (GIS). The model predicts locations of open areas suitable for wild lupine. Model creation began with a literature review and expert consultations to identify potentially limiting factors for lupine growth and persistence. I selected spatial data layers available in GIS that best represent those factors. Final model layers included IFMAP 2000 Michigan Land Cover, Michigan Land Use Circa 1800 (Comer et al. 1995), and Geological features. I extracted relevant information from each data layer and weighted those variables according to their influence on lupine presence (Figure 2). All GIS work was conducted using ArcGIS Desktop (ArcMap, ArcCatalog and ArcToolbox) and the ArcGIS Spatial Analyst extension (ESRI 2001, 2002). Spatial data layers were re-projected to the UTM coordinate system and assigned weights using the reclassify command in Spatial Analyst. Layers were added together using the raster calculator in Spatial Analyst. I reclassified the resulting grid layer into two categories, potential Karner blue habitat and unsuitable for Karner blue, using the combined layer values as a guide. Cells with a value of 889 and higher (roughly one-third of all cells) were considered potential habitat while cells 888 and lower received an unsuitable characterization. Grid cells were further categorized into poor, fair, good, and very good potential for habitat based on cell value.

I validated models by comparing Karner blue occurrence locations (determined from surveys) with model-predicted presence and absence. This analysis was possible because Karner blue occurrences were not used in model creation. However, because the model was used to guide survey efforts, the evaluation shows a bias toward predicted habitat presence. Several steps were needed to conduct model validation using GIS. First, I converted polygons delimiting surveyed areas and current Karner blue occurrences to a grid layer in Spatial Analyst using the polygon identifier (PI) for the cell value. I used the Tabulate Areas command to create a table of model cell values present in each PI. The resulting table showed range of predicted habitat suitability in each polygon. I exported the table to an Excel spreadsheet and polygons were then queried to determine whether they contained cells predicting habitat presence (i.e. having a value of 889 or greater). If so, the polygon was characterized as having potential Karner blue habitat, unsuitable for Karner blue if not. I then assigned the observed value of potential habitat (lupine or lupine and Karner blue present) or unsuitable (no lupine observed) to each polygon. Using these data, I constructed a confusion matrix (table showing the predicted and actual classifications) that compared predicted versus observed results. I validated the predictive model through *de novo* searches for lupine and comparing lupine locations (determined from site visits and roadside lupine surveys) with model-predicted habitat presence (poor to very good potential for Karner blue habitat) and absence.

Natural Heritage Database Updates

Prior to this effort, all Karner blue occurrences existed in the Natural Heritage Database as tabular data associated with buffered point locations in BioTICS (the Natural Heritage Program's GIS software based on ArcView, MNFI 2004). Karner blue occurrences were re-digitized to represent the spatial boundaries of occupied habitat and the associated data were updated to reflect the most recent survey efforts. This made the data more useful for conservation planning than buffered points. Data and maps from 2002-2004 surveys and field forms with maps from previous surveys were used to create polygons representing Karner blue locations. Aerial photos from 1992 or 1998, topographical maps, and/or GPS points were used to create polygons in GIS. All polygons have a representational error that depends on the method used to delineate the occurrence boundaries. The amount of error associated with a particular polygon is included in the tabular data in the Database. Occurrence data including number and sex of butterflies observed, time and date of survey, and other survey information were updated in the Natural Heritage Database.

Geology	Attribute Value	Attribute Weight	Cell Weight
Coarse textured glacial till	1	0.333	0.000
End moraines of coarse textured till	1	0.333	0.000
Glacial outwash sand and gravel	3	1.000	0.000
Ice-contact outwash sand and gravel	2	0.667	0.000
Lacustrine sand and gravel	3	1.000	0.000
Post glacial alluvium	1	0.333	0.000

Landuse Circa 1800	Attribute Value	Attribute Weight	Cell Weight
black oak barren	4	1.000	0.000
mixed oak savanna	4	1.000	0.000
oak/pine barrens	4	1.000	0.000
pine barrens	1	0.250	0.000
white pine mixed hardwood	1	0.250	0.000
white pine, white oak forest	3	0.750	0.000

IFMAP 2000 Land Cover	Attribute Value	Attribute Weight	Cell Weight
Herbaceous Open land	5	1.000	0.000
Upland Shrub / Low Density Trees	5	1.000	0.000
Oak Association	3	0.600	0.000
Upland Mixed Forest	1	0.200	0.000

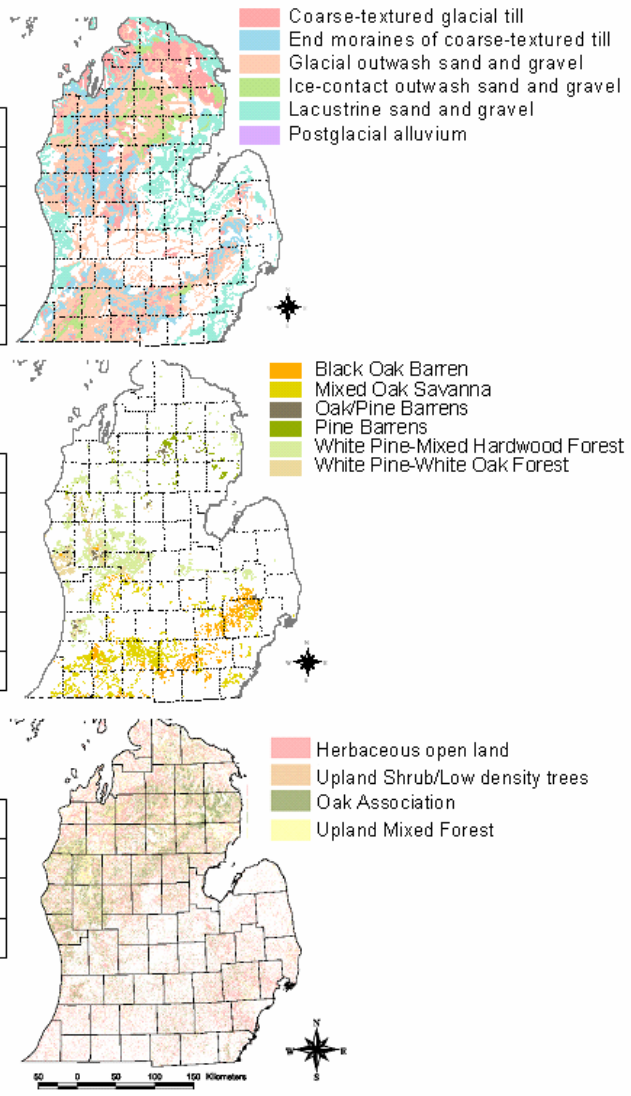

Figure 2. Spatial data layers and their weighted categories used in building a predictive Karner blue butterfly habitat model.

Current Karner Blue and Lupine Distribution

A map of Karner blue and lupine distribution in Michigan was created using survey results from the last seven years (1998-2004). I created a polygon GIS shapefile representing all areas surveyed by MNFI and others (MDNR, U.S. Forest Service, The Nature Conservancy, qualified researchers) while updating Karner blue occurrences in BioTICS. I digitized polygons using GPS locations of lupine and Karner blue, paper maps created during surveys, and aerial photographs. I then selected polygons that reflected data collected between 1998 and 2004 by MNFI and others to determine the current distribution of lupine and Karner blue. I intersected the polygon shapefile with a datalayer of Michigan PLSS sections in ArcView GIS. Separate intersections were conducted to select sections where Karner blue were observed during surveys, and where only lupine was observed. I then color-coded sections to represent Karner blue or lupine observation, added a layer showing RU boundaries, and created an ArcView Layout to represent the current presence of lupine and Karner blue at the section level.

The total lupine area and area currently occupied by Karner blue was determined from the polygon data described above. Acreages reported reflect areas with lupine and Karner blue verified between 1998 and 2004. It should be noted that additional occupied areas may exist that did not receive surveys or survey efforts during that time were not sufficient to detect Karner blue at low population levels.

Habitat Analysis

Habitat was characterized within all survey locations and compared between sites where Karner blue were observed versus those where only lupine was observed during the 2002-2004 field season. In order to ensure the analysis was evaluating habitat rather than survey conditions or effort, only survey data gathered during favorable weather and at a rate of between 10 – 15 minutes of survey per acre were included in the analysis. I assumed surveyors were more likely to observe Karner blue where butterfly densities are higher and could not eliminate the possibility that Karner blue occupy areas where they were not observed. I also assumed that Karner blue densities are higher within high quality habitat than lower quality and therefore Karner blue were more likely to be observed in high quality habitat. Using these assumptions, the results of this analysis can be used to predict Karner blue observation and give an index of habitat quality.

Site-level habitat data was collected for the entire site surveyed (lupine and adjacent flowering plants within an opening). Data were recorded on field forms (Appendix 2). Sites were separated by 100m of unsuitable habitat, 200m of suitable habitat, or a perceived Karner blue dispersal barrier (Nature Serve 2003, USFWS 2003). Survey location and weather conditions at the beginning and end of the survey were noted on the form, along with beginning and end time of the survey. Number, sex, and GPS location for all Karner blue butterflies observed were also noted. I then described current and potential threats, management of the land, opening type, surrounding environment, and canopy closure (Table 1). I described habitat characteristics using ocular estimation. Habitat parameters included lupine density and abundance, percent of lupine blooming or in seed, presence of Karner blue caterpillar feeding damage, deer browse on lupine, ant mounds, woody plant and exotic species and amount of encroachment, dominant ground cover, preferred nectar plant species and abundance, and other flowering plants (Table 2). In order to facilitate analysis, some habitat variables were classified or transformed into dummy variables while others were grouped together to get an overall quality ranking (Table 3). In all, data on 24 variables were used in habitat analysis: GRASS, SEDGE, FORB, FERN, BARE, LDENS, LDIST, LUP_BLM, NNECTSP, RNKNECT, NWOODYSP, RNKWOOD, NEXOTSP, RNKEXOT, SUMDIST, SUMTHR, NEAROCC, ACRES, EDGE, ANTS, BROWSE, OPEN, PARTIAL, CLOSCAN.

Table 1. General site characteristics, component variables, and indicators identified during Karner blue surveys, 2002-2004. Variables were given values of one if present within the site and zero if absent.

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	Evidence of building or road construction within or adjacent to the site
	Other	
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	Pine plantation or evidence of past planting
	Other	
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	Openings in woods created by natural disturbance or environmental factors
	Roadside	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	Area of mesic soils with wetland vegetation in one or more cardinal directions
	Other	
Canopy Closure	OPEN	0-24% canopy closure
	PARTIAL	25-49% canopy closure
	MOST	50-74% canopy closure
	CLOSED	75-100% canopy closure

Table 2. Habitat variables and their possible values collected at all Karner blue butterfly survey sites, 2002-2004.

Variable	Values	
Dominant Ground Cover	Grass Sedge (*Carex* spp.) Forb Fern	
Lupine Density and Distribution	0 – no lupine present 1 – Groups of 1-3 lupine plants scattered in <33% of the area 2 – Groups of 1-3 lupine plants scattered in 33-66% of the area 3 – Groups of 1-3 lupine plants scattered in >66% of the area 4 – Clumps of 4-20 lupine plants in <33% of the area 5 – Clumps of 4-20 lupine plants in 33-66% of the area 6 – Clumps of 4-20 lupine plants in >66% of the area 7 – Dense patches of >20 lupine plants in <33% of the area 8 – Dense patches of >20 lupine plants in 33-66% of the area 9 – Dense patches of >20 lupine plants in >66% of the area	
% Lupine in bloom or seed (LUP_BLM)	0 to 100%	
Deer Browse on lupine (BROWSE)	1 – Present 0 – Absent	
Ant Mounds (ANTS)	1 – Present 0 – Absent	
Woody Species*	Oak (*Quercus* spp.) Cherry (*Prunus* spp.) Sassafrass (*Sassafrass albidum*) Hazelnut (*Corylus americana*) Aspen (*Populus* spp.)	Maple (*Acer* spp.) White pine (*Pinus alba*) Other deciduous Other evergreen
Exotic Species*	Spotted knapweed (*Centaurea biebersteinii*) St. John's wort (*Hypericum perforatum*) Hoary alyssum (*Berteroa incana*) Sweetclover (*Melilotus* spp.) Queen Anne's lace (*Ammi majus*)	Hawkweed (*Hieracium* spp.) Autumn olive (*Elaeagnus umbellata*) Honeysuckle (*Lonicera japonica*) Other exotics
Nectar Species*	Aster (*Aster* sp.) Blackberry (*Rubus* sp.) Black-eyed susan (*Rudbeckia hirta*) Blazing star (*Liatris* spp.) Blueberry (*Vaccinium* spp.) Butterfly weed (*Asclepias tuberosa*) Dewberry (*Rubus flagellaris*) Dotted horsemint (*Monarda punctata*) Downy phlox (*Phlox pilosa*) Dwarf dandelion (*Krigia biflora*) Fleabane (*Erigeron* spp.)	Flowering spurge (*Euphorbia corollata*) Goldenrod (*Solidago* spp.) Lance-leaf coreopsis (*Coreopsis lanceolata*) New Jersey tea (*Ceanothus americanum*) Primrose (*Oenothera lamarckiana*) Puccoon (*Lithospermum* spp.) Sunflower (*Helianthus* spp.) Violet (*Viola* spp.) Wild bergamot (*Monarda fistulosa*) Yarrow (*Achillea millefolium*) Other

Species ranked on an abundance scale from 0 to 4:* 0=absent, 1=sparse, 2=scattered, 3=common, 4=abundant

Table 3. Habitat variables derived from data collected at all Karner blue butterfly survey sites, 2002-2004.

Derived From	New Variable	Possible Values
Dominant Ground Cover	GRASS	1 or 0 – Grass was or was not the dominant ground cover
	SEDGE	1 or 0 – Sedge was or was not the dominant ground cover
	FORB	1 or 0 – Forbs were or were not the dominant ground cover
	FERN	1 or 0 – Ferns were or were not the dominant ground cover
	BARE	1 or 0 – Bare soil was or was not the dominant ground cover
Lupine Density	LDENS	1– lupine was in groups of 1-3 plants 2 – lupine was in clumps of 4-20 plants 3 – lupine was in dense patches of >20 plants
Lupine Distribution	LDIST	1 – lupine plants were present in <33% of the area 2 – lupine present were present in 33-66% of the area 3 – lupine present were present in >66% of the area
Woody Species	NWOODYSP	Number of woody species present within the site
	RNKWOOD	Sum of woody species density rankings
Exotic Species	NEXOTSP	Number of exotic species present within the site
	RNKEXOT	Sum of exotic species density rankings
Nectar Species	NNECTSP	Number of nectar species present within the site
	RNKNECT	Sum of nectar species density rankings
Canopy Closure	OPEN	0-24% canopy closure
	PARTIAL	25-49% canopy closure
	CLOSCAN	50-100% canopy closure
Current Threats	SUMTHR	Number of threats present within the site
Management	SUMDIST	Number of management disturbance types within the site
GIS Derived Variables	ACRES	Area of surveyed site, in acres
	EDGE	Amount of edge, measured around the perimeter of surveyed site
	NEAROCC	1 or 0 – Site is within 1000m of occupied habitat, or not within 1000m

I created a model that predicts the probability of observing Karner blue using habitat data collected within sites. I used the default function for binary response data (Equation 1) to conduct logistic regression in PROC LOGISTIC (SAS 2000). Several models were created using different combinations of habitat variables and were compared using Akaike's Information Criterion (AIC), maximum re-scaled R-square value, Hosmer-Lemeshow's goodness of fit statistic, and percent correct classification rates (Hosmer and Lemeshow 1989). The model with the lowest AIC, highest R-square, best model fit, and highest correct classification rate was selected as best predicting Karner blue observation (habitat quality). I evaluated the model by creating bias-adjusted classification matrix showing false positive and negative error rates based on a 0.5 cutoff value, using the CTABLE option in PROC LOGISTIC.

Eq.uation 1:

$\text{logit}(p) = \alpha + \beta' x$ where $p = \Pr(Y = 1|x)$

Habitat Evaluation and Management Recommendations

Habitat within public lands was evaluated based on the habitat model and opportunities for management were identified. I assumed that surveyors were more likely to observe Karner blue where they are more numerous, and that butterfly numbers are directly related to habitat quality. Given these assumptions, the probability of observing Karner blue (*p-hat*, Equation 2) is linked to habitat quality, and I can make recommendations about how to improve habitat based on the *p-hat* value. I calculated predicted probabilities that can be used to determine whether a site is likely to

have Karner blue observed based on habitat characteristics. *P-hat* values were calculated for all sites using site characteristics and β estimates from the habitat model. Therefore, I evaluated habitat quality at each lupine site surveyed using the *p-hat* value for the site.

Equation 2:
$p\text{-}hat = 1/(1+ \exp(-\alpha - \beta' x))$

I created maps of state lands and surrounding areas that contain occupied Karner blue habitat. The maps show general locations of sites surveyed, whether Karner blue were observed at those sites, and the predicted probabilities of observing Karner blue (*p-hat*) based on the habitat model. I created summary tables for mapped areas and for public lands where Karner blue were not observed. Summary tables include *p-hat* values for each lupine site surveyed, and therefore give a prediction of habitat quality. Management recommendations and management priority suggestions were made based on the *p-hat* values and values of habitat variables within each site. Sites with Karner blue observed were considered high priority for management if *p-hat* <0.32 (High), and medium management priority if *p-hat* values were between 0.32 and 0.66 (Medium). A recommendation to expand the habitat was made at Karner blue sites with *p-hat*>0.66 (Expand). Additional surveys for Karner blue were suggested if Karner blue were not observed at a site but *p-hat* >0.66 (Survey). A suggestion of reintroduction and translocation following management was made for sites where Karner blue were not observed and *p-hat* was between 0.32 and 0.66 (Transloc). A low priority for management was suggested for sites where Karner blue were not observed and p-hat<0.32 (Low).

Threats

Threats to Karner blue sites were identified during surveys to help guide conservation. Eight types of threats were identified and were determined present or absent at a site based on indicator criteria (Table 4). A ninth threat type was added during analysis using the Browse variable from habitat data, indicating that deer browse was present on lupine. Multiple threats could be identified at a survey site. All threats present within sites were summarized by Recovery Unit and ownership type.

Table 4. Threats to Karner blue sites and indicators used to identify them during Karner blue surveys, 2002-2004. Threats were given values of one if present within the site and zero if absent.

Threat	Indicated by
ORV	Two-tracks or ruts through site
Vehicles	Site adjacent to busy road, roadkill Karner blue 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	Evidence of building or road construction within or adjacent to the site
Other	e.g. *Carex pennsylvanica* dominance threatening lupine viability

RESULTS AND DISCUSSION

Karner blue and lupine Distribution

Field Surveys

MNFI conducted three years of surveys for Karner blue across 3,966 ha (9,801 ac) in the Lower Peninsula (Figure 3). These surveys resulted in the discovery of 43 new Karner blue occurrences (277 ha), six township records, and verified Karner blue presence at 79 previously known occurrences (932 ha, Figure 4). In addition, surveyors located over 320 ha of previously unknown habitat (lupine and adjacent nectar sources).

Potential Habitat Distribution

The predictive habitat model identified several areas in the Lower Peninsula with potential for Karner blue habitat. The model, created with a 30m resolution, identified 13,755 ha (33,990 ac) with poor potential, 17,448 ha (43,115 ac) with fair potential, 23,739 ha (58,660 ac) with good potential, and 4,998 ha (12,350 ac) with very good potential for Karner blue habitat presence (Figure 5). Concentrated areas of suitable habitat were predicted in the Allegan, Muskegon, and Newaygo RUs, with more scattered areas in the Ionia RU and outside the known distribution of Karner blue (but within the known distribution of lupine). A majority of predicted habitat presence was located in the Newaygo RU (35%), though habitat was predicted within all RUs (Table 5).

The model correctly classified 63% of sites surveyed when sites classified as "poor" to "very good" were used to predict lupine presence. The model successfully predicted habitat (lupine) presence at 80% of all sites that were surveyed (true positives), but also predicted lupine presence at 69% of sites where lupine was not observed (false positives, Table 6). The model with all four levels of potential for habitat therefore predicts lupine presence more frequently than is actually on the landscape. If only areas predicted as having "good" and "very good" potential for habitat presence are used, the overall correct classification rate is reduced to 57%, true positive rate decreases to 62%, and false positive rate falls to 53%. Classification rates can be calculated for the various levels of predicted habitat potential using the number of sites classified (Table 7).

Current Karner Blue and Lupine Distribution

MNFI survey results combined with data provided to us from other sources (MDNR, U.S. Forest Service, and The Nature Conservancy) reveal that Karner blue currently occur within 1,541 ha (3,815 ac) of habitat in 10 counties located in the west-central portion of the Lower Peninsula, and are no longer present in one southeastern county (Figure 6). Nielsen (1999) reports Karner blue distribution as including an additional five counties, for which data are not available. Additionally, Bouseman and Sternburg (2001) report Karner blue from Ogemaw County. Searches for lupine in the area turned up neither lupine nor Karner blue and this record is assumed to be historic. A majority of current occupied habitat (lupine and nectar sources in the immediate vicinity of a Karner blue observation, verified between 1998 and 2004) was located on public lands (51%), but Karner blue were found on both public and non-public lands within all four RUs (Figure 7, Table 8). State Lands harbor the largest area occupied by Karner blue in the Allegan and Ionia RUs. Power company properties add significantly to the occupied area in the Allegan RU, especially in southern Muskegon County. Federal Land makes up a majority of occupied habitat in the Muskegon RU, primarily within southern Oceana County. The Newaygo RU, with much more fragmented ownership, has most of its occupied habitat within privately owned parcels and along roadsides managed for utilities. Concentrated areas of occupied habitat in the Allegan, Muskegon, and Newaygo RUs follow patterns predicted in our habitat model.

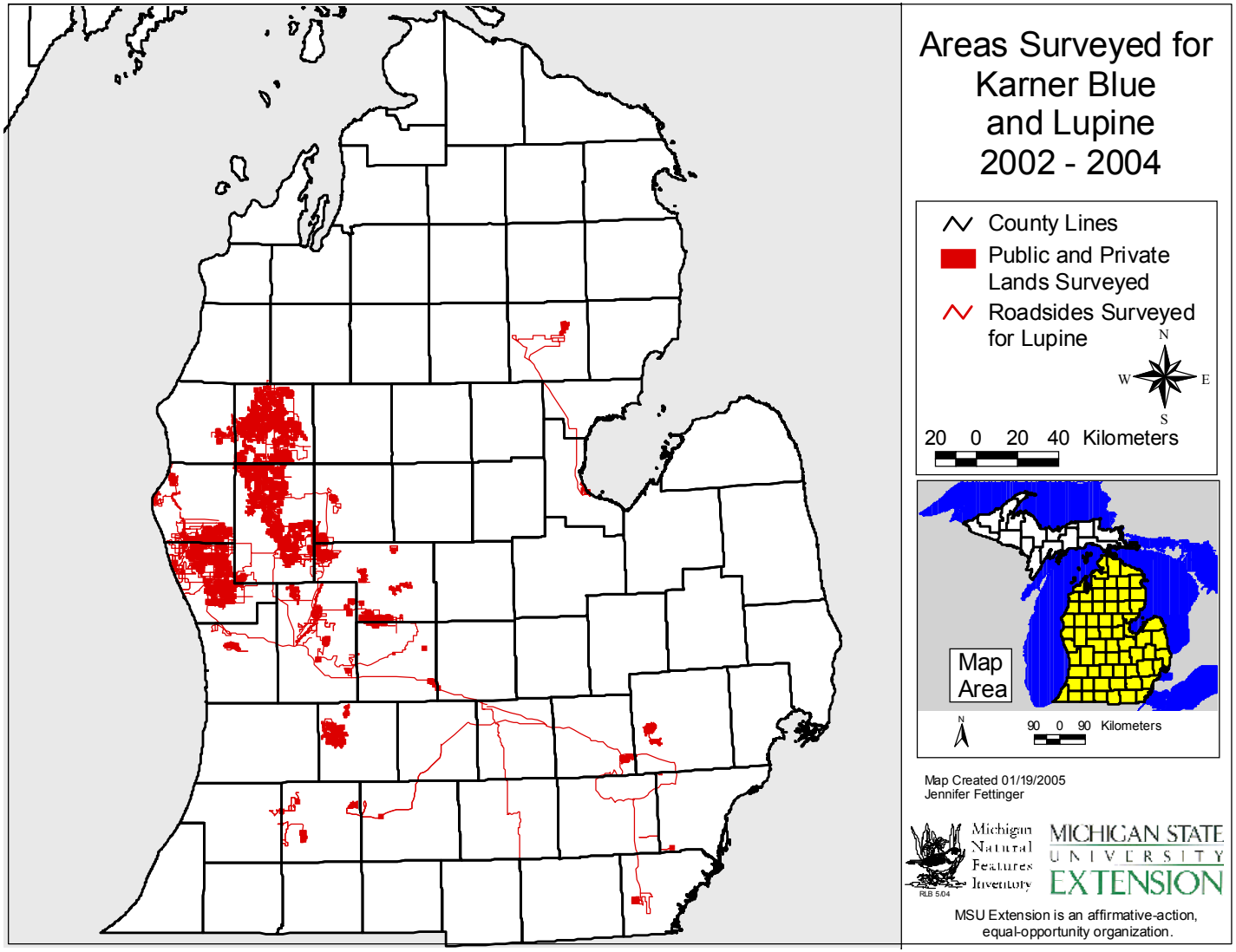

Figure 3. Michigan areas receiving roadside lupine surveys, status surveys, or de novo searches for Karner blue and lupine, 2002-2004.

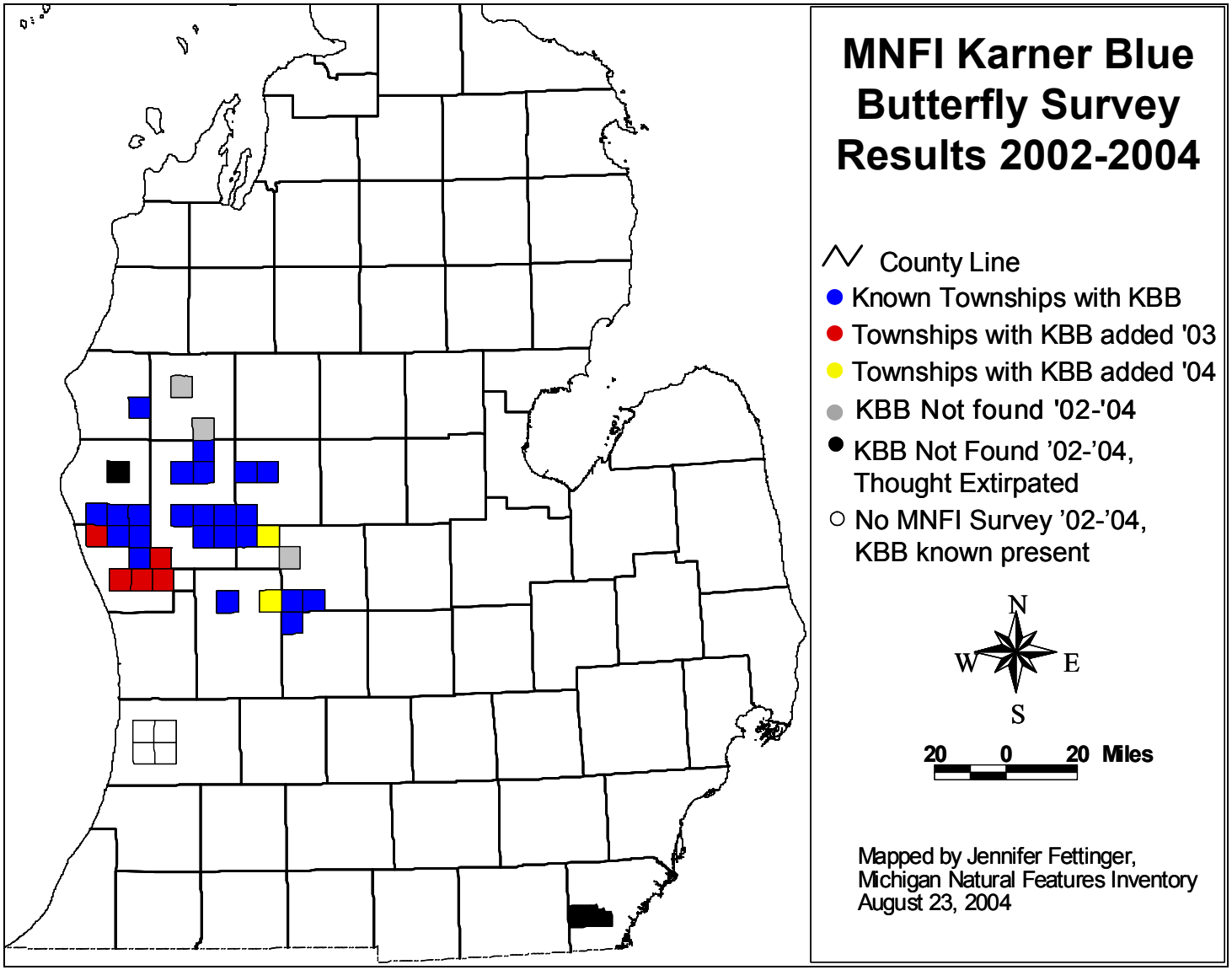

Figure 4. MNFI Karner blue butterfly survey results, 2002-2004, within Michigan townships.

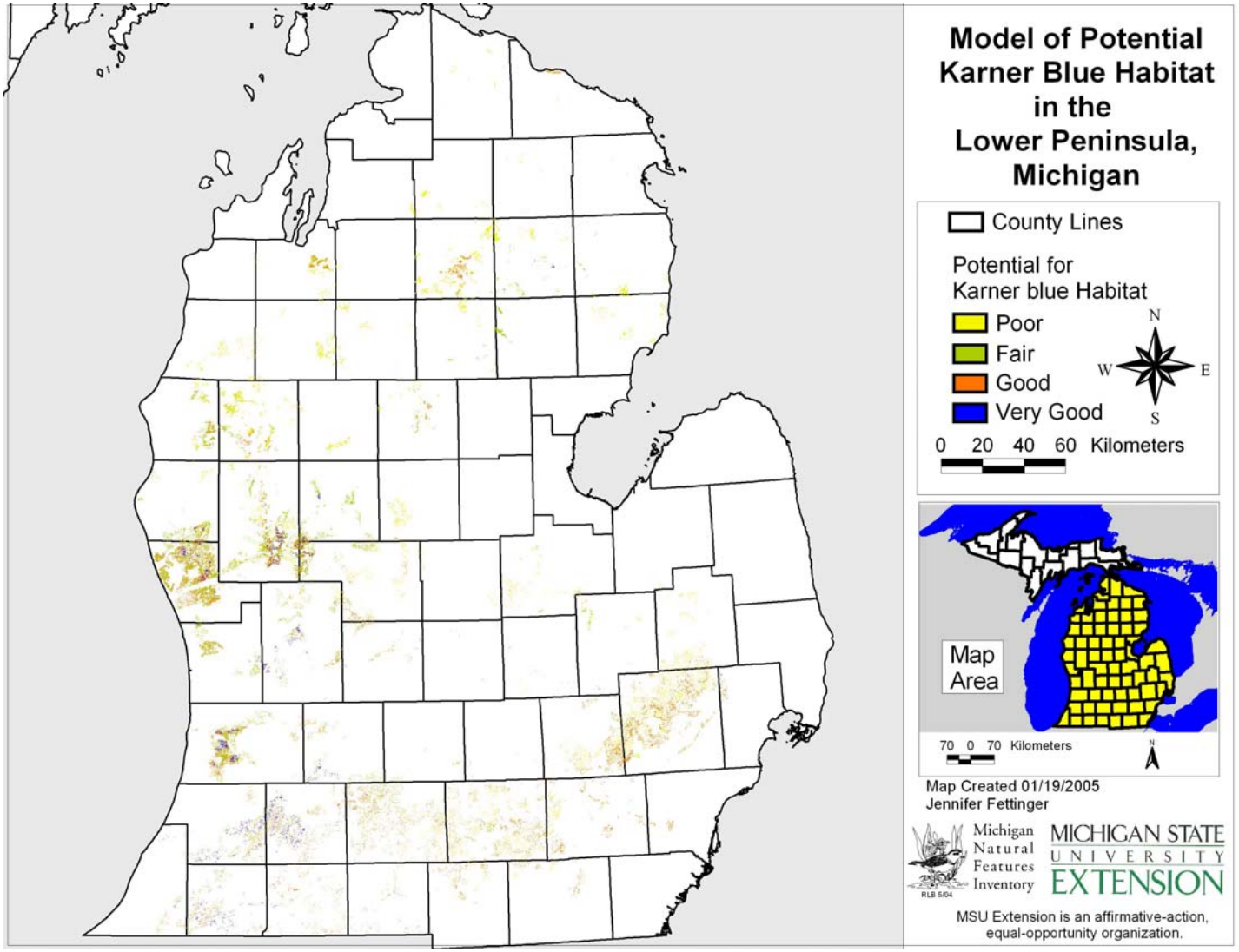

Figure 5. Model of potential for Karner blue butterfly habitat in the Lower Peninsula of Michigan.

Table 5. Amount of area (hectares), based on 30m^2 grid cells, with potential for Karner blue butterfly habitat within Michigan Recovery Units, as determined from the predictive habitat model.

Habitat potential	Ionia	Muskegon	Newaygo	Allegan	Total
Poor	2,485	1,008	10,048	210	13,755
Fair	4,184	10,878	12,201	15,856	43,115
Good	2,218	5,026	6,256	10,239	23,739
Very Good	441	1,064	1,801	1,696	4,998
Total Area	9,328	17,976	30,307	28,000	85,607

Table 6. Confusion matrix for the deductive habitat model showing the number of sites predicted to have poor to very good potential for Karner blue habitat presence.

	Predicted	
Observed	Lupine Absent (no habitat potential)	Lupine Present (poor to very good habitat potential)
Lupine Absent	101	220
Lupine Present	113	460

Table 7. Number of sites predicted by the deductive habitat model to have each level of potential for Karner blue habitat presence.

	Predicted				
Observed	None	Poor	Fair	Good	Very Good
Lupine Absent	101	15	35	82	88
Lupine Present	113	9	93	134	224

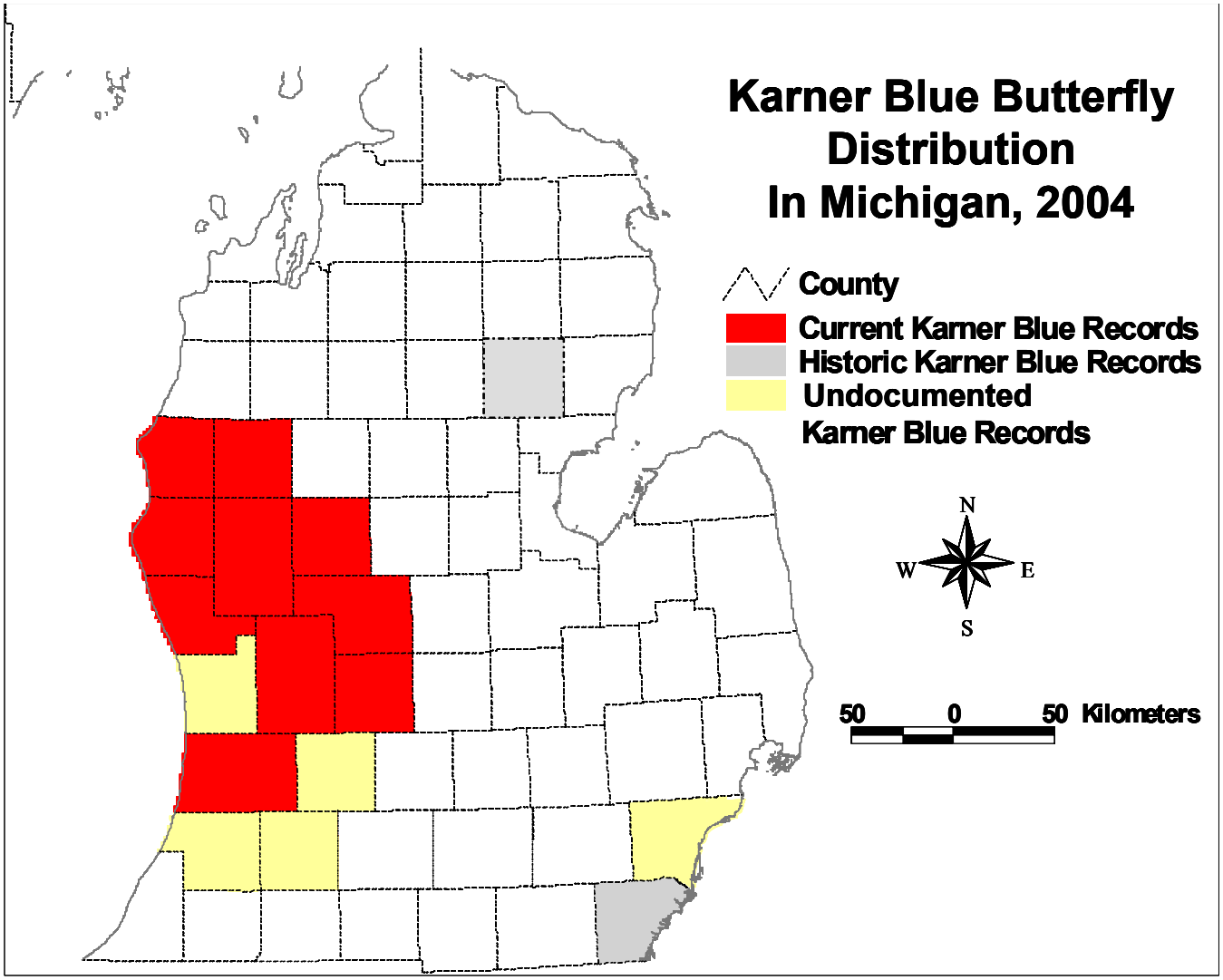

Figure 6. Known Karner blue butterfly distribution within Michigan counties, 2004, including counties with historic records but no known extant sites (historic Karner blue records) and counties with records for which no data exist in MNFI files, but reported by Nielsen (1999) as having the species present, (undocumented Karner blue records).

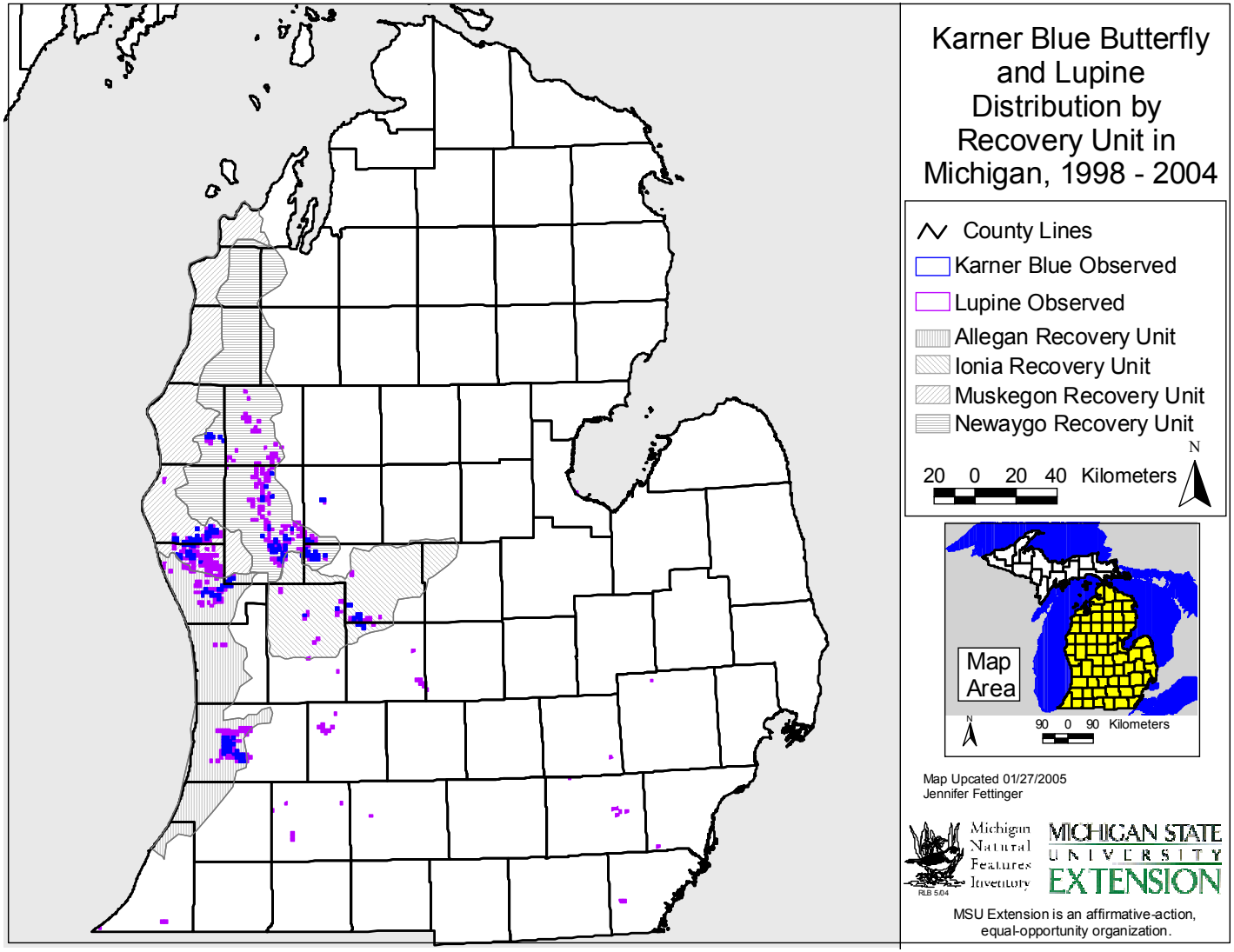

Figure 7. Karner blue and lupine distribution, 1998-2004, within PLSS sections by Michigan Recovery Unit.

Table 8. Area of habitat (hectares) known to be occupied by Karner blue 1998-2004, by ownership and owner type within Michigan Recovery Units.

Hectares of Occupied Habitat		Recovery Unit					
Ownership	**Owner**	**Allegan**	**Ionia**	**Muskegon**	**Newaygo**	**None**	**Total**
Public	County	10.44	0.00	0.04	-	-	10.48
	Federal	-	-	408.69	42.65	-	451.39
	Local	-	-	2.95	23.59	-	26.59
	State	222.66	65.28	3.32	14.81	-	306.02
Public Total		233.10	65.28	415.01	73.57	-	786.99
Non-Public	NGO	-	-	-	15.94	-	15.94
	Power Company	128.24	-	20.72	20.96	-	169.93
	Private	18.45	31.40	158.43	204.85	36.66	449.77
	Railroad	-	-	-	7.81	-	7.81
	Roadside	6.35	0.45	5.83	93.28	-	105.95
Non-Public Total		153.05	31.85	184.98	350.30	36.66	756.88
Total		**386.15**	**97.12**	**599.99**	**423.87**	**36.66**	**1543.88**

Karner Blue on Public Land

Karner blue are present on the Huron-Manistee National Forest, Allegan, Flat River, and Muskegon State Game Areas, Newaygo State Park, and near the White Pine Trail Linear State Park (Figure 8).

Allegan State Game Area (ASGA) contains 29 Karner blue element occurrences on approximately 220 ha (542 ac) of habitat. Additional lupine is present on 32 ha (78 ac) within the ASGA. Occurrences range in size from 0.08 to 51.84 ha (0.2 to 128 ac) and are separated by a minimum of 200 meters. Lupine north of the Kalamazoo River was once occupied by Karner blue but the butterflies have not been observed there since 1992.

Muskegon State Game Area (MSGA) contains one Karner blue occurrence in the Eastern Unit along approximately 18 ha (44 ac) of powerline right-of-way. Additional lupine is present on 17 ha (41 ac) within the MSGA, primarily along powerline openings surrounded by overgrown oak savanna.

Flat River State Game Area (FRSGA) in the Ionia RU contains seven Karner blue occurrences on 41 ha (102 ac). Much of the occupied habitat exists along powerline or railroad right-of-way. Additional lupine is present within 6 ha (15 ac) in the FRSGA. Lupine in openings along Snows Lake Road was once occupied, but Karner blue have not been observed there since 1997.

Newaygo State Park (NSP) has Karner blue in one area of occupied lupine along a Powerline right-of-way. The area of occupied habitat within the state park totals less than 0.1 ha.

White Pine Trail Linear State Park (WPT) may act as a corridor between two separate Karner blue occurrences. One occurrence in Kent County has sparse lupine along the right-of-way that connects two areas of lupine on adjacent private land. The WPT also connects occupied lupine on private lands in Mecosta County outside Big Rapids. Both sites are isolated from other Karner blue populations.

Huron-Manistee National Forest (HMNF) reports on Karner blue populations as a part of ongoing monitoring efforts. Presence-absence of Karner blue has been updated in the Natural Heritage Database using data provided by the HMNF biologists. According to the Database, there are 451 ha (1115 ac) of habitat that was known to be occupied between 1998 and 2004. There may be additional sites that are occupied but were not surveyed during those years or for which data was not received.

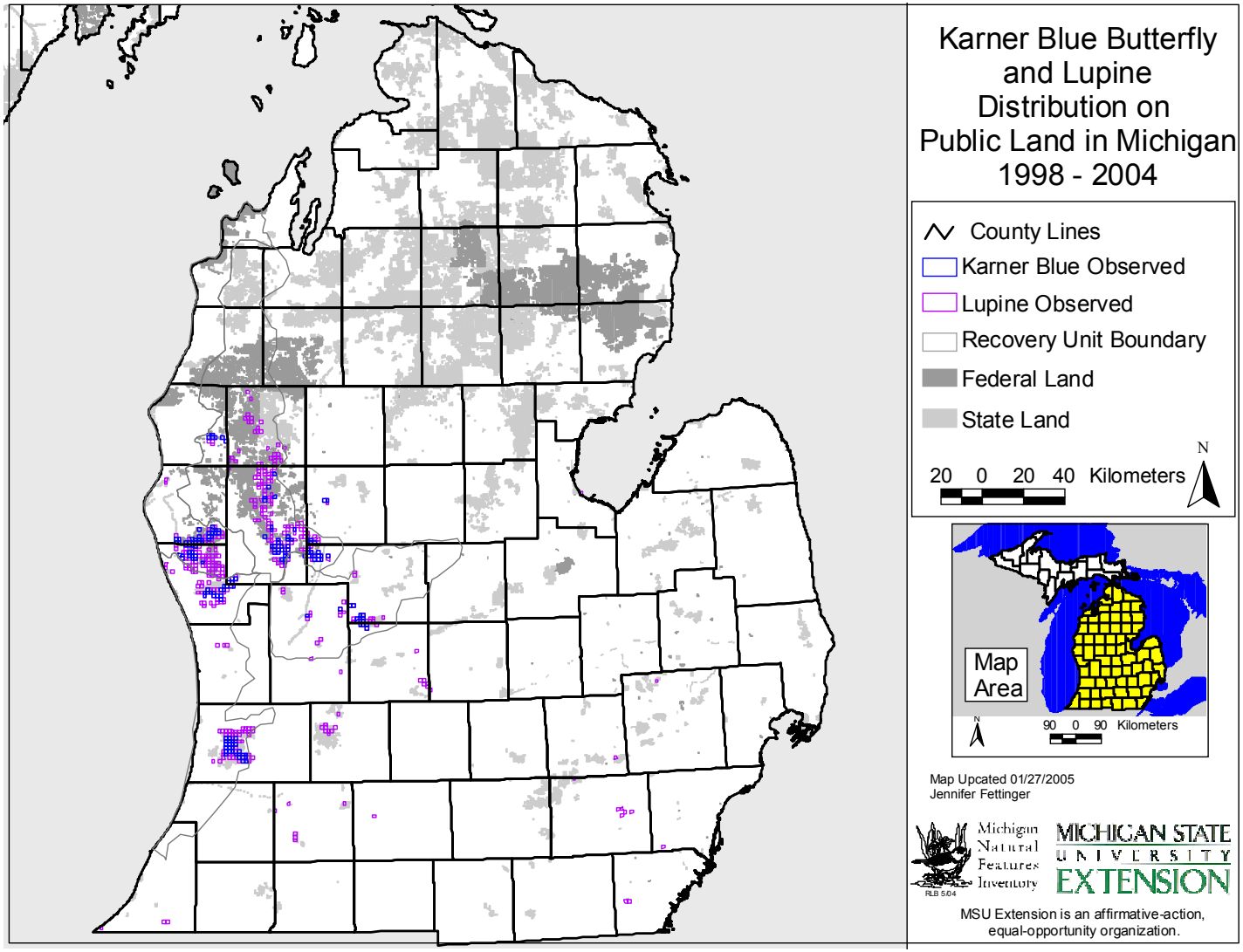

Figure 8. Karner blue and lupine distribution on public land, 1998-2004, within Michigan PLSS sections.

Karner Blue on Non-Public Land

Non-Public lands with Karner blue include property owned or managed by private individuals, power companies (electric and gas), county and state road commissions, railroad companies, and non-governmental organizations. Nearly half of all known occupied habitat in Michigan (49%) occurs on non-public lands. Habitat on private parcels owned by individuals makes up the majority of this area (Table 4).

Karner Blue Distribution Summary

Survey efforts over the last decade have revealed that Karner blue are distributed in the Lower Peninsula of Michigan in a pattern that approximates the historic range of prairie and savanna in the State. The butterflies once occurred in 11 Michigan counties: Allegan, Ionia, Kent, Lake, Mason, Mecosta, Monroe, Montcalm, Muskegon, Newaygo, and Oceana. MNFI surveys over the past three years and surveys conducted by others in the last six years have verified that Karner blue still occur in ten counties (Figure 3). Karner blue are thought extinct in Monroe County, southeastern Michigan where they once occurred on the Petersburg State Game Area (PSGA), and are thought to have had habitat connected to the Ohio populations (also now extinct, though reintroduction efforts are taking place). Approximately seven hectares (18 ac) of lupine and suitable habitat remains on PSGA, though Karner blue have not been recorded there since 1986. Restoration efforts are taking place and potential reintroductions are being considered in the Area (Laura Harris, Detroit Zoo , personal communication). Karner blue have experienced population declines in the northern portion of their range (Rex Ennis, U.S. Forest Service, personal communication) where they are most commonly known from the Manistee National Forest (HMNF) and adjacent private lands. Recent surveys suggest that the species may no longer be present in Lake County where it was known from just two sites – one last verified in 1953, the other in 1993. Lupine is found on both the MNF and Pere Marquette State Forest (PMSF) in Lake County, but present in limited amounts. Karner blue populations in Mason County are experiencing similar declines, as post 1998 surveys were successful in re-verifying the species at only two of the eight known occurrences.

Lupine Distribution

Additional lupine is present within nearly 750 ha (1850 ac) not currently known to be occupied by Karner blue (Table 9). This lupine is found both in and out of the established RU boundaries. The Muskegon RU has over 263 ha (650 ac) of lupine that is not currently occupied, much of it within the Manistee National Forest between the Muskegon and White Rivers and on private lands where the habitat is marginal. State-owned lands inside the RU boundaries include an additional 106 ha (263 ac) of lupine habitat in the Cannonsburg and Rogue River State Game Areas in Kent County, the Pere Marquette State Forest in Lake County, Langston State Game Area in Montcalm County (old Karner blue record, last observed in 1980), the Musketawa Trail in Muskegon County, Bass River State Recreation Area in Ottawa County, and portions of the Flat River and Allegan State Game Areas. Over 157 ha (390 ac) of lupine exists outside established RUs, and is mainly known from state and locally owned lands. State lands where lupine is present outside the established RUs include Howell, Island Lake, and Pinckney State Recreation Areas; Barry, Gourdneck, Middleville, and Petersburg State Game Areas; Fort Custer Military Training Center, and Bay City State Park. These areas are widely scattered, contain low densities of lupine, and are generally isolated from known Karner blue populations.

Habitat Analysis

Habitat data were collected within 350 separate sites. Habitat data were analyzed using data from 146 sites where Karner blue were observed and 112 sites with only lupine was observed. The final Karner blue habitat model retained five variables and an intercept: NearOCC, LDENS, RNKNECT, NNECTSP, and CLOSCAN (Table 10). This model had the lowest AIC score and highest R^2 value

when compared to other possible models (Table 11). Sites where Karner blue were observed more frequently at sites that were within 1000m of occupied habitat (P<0.0001), had an original lupine code of 3, 6, or 9 indicating dense patches of >20 stems (P=0.005), diverse nectar species (P<0.0001), moderate nectar plant availability (P<0.0001), and less than 50% canopy cover (P=0.0024). An interpretation of the variables retained in the model suggests that sites with <50% canopy closure that are within 1000m of occupied habitat, contain dense lupine, and have diverse flowering plant species have a high probability of having Karner blue observed. The model correctly classified 74% of sites surveyed ([71+120]/258) when 0.5 is used as the cutoff to predict whether Karner blue are observed (Table 12).

Lupine density and abundance, nectar source availability, and canopy closure have been identified as some of the most important site-level factors determining habitat quality (Celebrezze 1996, Grundel et al. 1998b, Grundel et al. 2000). A site that is within 1000m of occupied habitat is 5.5 times more likely to have Karner blue observed than a site not within that distance, given all the other variables are equal. This figure is obtained from the odds ratio estimates for the variables retained in the model (Table 13) and suggests that site isolation is an important factor for Karner blue populations. Additional research into the importance of the habitat matrix and distances smaller or larger than 1000m is recommended to better understand Karner blue metapopulation structure.

Habitat Evaluation and Management Recommendations

Habitat quality (*p-hat*) was evaluated at 258 lupine sites surveyed. Habitat quality ranged from very low (*p-hat* =0.0204) to very high (*p-hat* =0.9924) with a median value of 0.6072. The classification table created in PROC LOGISTIC revealed that the percent correct classification rate remains relatively level near 74% between *p-hat* values of 0.32 and 0.66. Therefore, a site was considered to have high quality habitat if *p-hat* >0.66, low quality habitat if *p-hat* < 0.32, and medium quality habitat if *p-hat* was between those values. Karner blue were observed at 85% of sites classified by the model as having high quality habitat, and were not observed at 79% of the sites with low quality habitat (Table 14). There was more uncertainty associated with sites classified as medium quality habitat (0.32<*p-hat*<0.66), as evidenced by approximately half of the sites having Karner blue observed and half having none observed.

Flat River and Muskegon State Game Area sites were mapped related to their *p-hat* values to show visually the habitat quality determination related to Karner blue observations (Figure 9, 10). Several opportunities to expand habitat on Flat River and Muskegon State Game Areas and other public lands were identified through this analysis (Table 15, 16, 17). Additionally, sites with potential for translocation were also identified (Table 15, 16, 17). These areas have potential to be managed as Karner blue habitat through disturbance that creates suitable conditions. For example, burns in open lands may encourage lupine growth if appropriate soils are present, oak forest may be thinned to open the canopy, and pines removed to encourage savanna species growth.

The most common management recommendation was to increase connectivity between occupied habitats and increase lupine density (Table 15, 16, 17). Low management priority areas may become suitable for translocation with significant management efforts. Some sites may have had Karner blue present in the past, and should not be dismissed. For example, Petersburg State Game Area may become suitable for reintroduction once habitat conditions are improved. Site management recommendations (e.g. burn 1/3 of the site) were not made because those decisions must take into account several variables not incorporated in this study (e.g. accessibility for management). In addition, Allegan State Game Area was not included in this analysis because habitat data were not collected by MNFI during this study. However, the model equation can be used with habitat data collected by others to calculate *p-hat* values and make management recommendations.

Table 9. Area of lupine (hectares) where Karner blue were not observed during 1998-2004, by ownership and owner type within Michigan Recovery Units.

Hectares of Lupine		Recovery Unit					
Ownership	**Owner**	**Allegan**	**Ionia**	**Muskegon**	**Newaygo**	**None**	**Total**
Public	County	0.10	0.70	-	-	-	0.80
	Federal	0.20	-	315.40	151.00	-	466.60
	Local	-	-	0.20	-	148.80	149.10
	State	159.90	87.80	14.90	0.40	92.60	355.60
Public Total		160.20	88.50	330.50	151.40	241.40	972.10
Non-Public	NGO	-	-	61.50	0.10	-	61.60
	Power Company	81.40	-	-	35.30	8.20	124.90
	Private	108.70	23.10	250.40	125.40	123.30	630.90
	Railroad	-	-	-	-	20.30	20.30
	Roadside	9.50	0.50	10.20	18.00	0.50	38.80
Non-Public Total		199.60	23.60	322.10	178.80	152.30	876.40
Grand Total		**359.80**	**224.2**	**652.70**	**330.20**	**393.70**	**1848.50**

Table 10. Parameter estimates (β) and standard errors associated with variables retained in a model of Karner blue butterfly habitat.

Parameter		DF	β	StdError	Wald χ^2	Pr> χ^2
Intercept			-0.2528	0.504	0.2517	0.6159
NearOCC	1 vs 0	1	0.8548	0.1663	26.4332	<.0001
LDENS	3 vs 0	1	1.1307	0.4026	7.8867	0.005
LDENS	2 vs 0	1	-0.7728	0.3757	4.2322	0.0397
LDENS	1 vs 0	1	-1.4649	0.4207	12.1256	0.0005
RNKNECT			-0.2017	0.045	20.0449	<.0001
NNECTSP			0.3933	0.0975	16.2793	<.0001
ClosCan	1 vs 0	1	-0.8863	0.2915	9.2426	0.0024

Table 11. Akaike's Information Criterion (AIC) scores, -2log L values, and R^2 values for potential models predicting Karner blue observations.

Model variables	AIC	-2 log L	R^2
Intercept only	360	358	
Intercept, LDENS	334	326	0.15
Intercept, CLOSCAN	346	342	0.07
Intercept, NearOCC	356	332	0.13
Intercept, LDIST	357	349	0.04
Intercept, NearOCC, LDENS	301	291	0.30
Intercept, RNKWOOD, FORB	325	319	0.07
Intercept, LDENS, Acres	335	325	0.15
Intercept, NearOCC, Acres	337	331	0.13
Intercept, LDENS, LDIST	338	326	0.15
Intercept, NearOCC, LDENS, CLOSCAN	293	281	0.34
Intercept, NearOCC, LDENS, RNKNECT	296	284	0.32
Intercept, NearOCC, LDENS, NNECTSP	302	390	0.30
Intercept, NearOCC, LDENS, Acres	302	290	0.30
Intercept, RNKEXOT, CLOSCAN, NEXOTSP	339	331	0.12
Intercept, NearOCC, LDENS, NNECTSP, CLOSCAN	295	281	0.34
Intercept, LDENS, NNECTSP, CLOSCAN, RNKNECT	297	283	0.31
Intercept, NearOCC, LDENS, Ants, FORB,	300	286	0.31
Intercept, LDENS, LDIST, NNECTSP, RNKNECT	309	293	0.28
Intercept, RNKEXOT, CLOSCAN, FORB, NEXOTSP	334	324	0.16
**Intercept, NearOCC, LDENS, NNECTSP, CLOSCAN, RNKNECT	269	253	0.43
Intercept, NearOCC, LDENS, NNECTSP, SEDGE, RNKNECT	277	262	0.40
Intercept, NearOCC, LDENS, NNECTSP, OPEN, RNKNECT	278	262	0.39
Intercept, NearOCC, LDENS, NNECTSP, CLOSCAN, Acres	296	280	0.34
Intercept, RNKWOOD, RNKEXOT, OPEN, PARTIAL, NEXOTSP	324	312	0.15
Intercept, RNKEXOT, OPEN, PARTIAL, FORB, NEXOTSP	335	323	0.17
Intercept, RNKEXOT, OPEN, PARTIAL, Acres, NEXOTSP	341	329	0.14

**Selected model

Table 12. Classification matrix for the Karner blue habitat model based on a *p-hat* cutoff value of 0.5.

	Predicted	
Observed	No Observation	Observation
Not observed	71 (63%)	41 (26%)
Observed	26 (27%)	120 (82%)

Table 13. Odds ratio estimates and 95% confidence intervals for variables in the Karner blue model.

Point Effect		Point Estimate	95% Wald Confidence Limits	
NearOCC	1 vs 0	5.53	2.88	10.60
LDENS	3 vs 0	1.02	0.09	12.25
LDENS	2 vs 0	0.15	0.01	1.81
LDENS	1 vs 0	0.08	0.01	0.95
RNKNECT		0.82	0.75	0.89
NNECTSP		1.48	1.22	1.79
ClosCan	1 vs 0	0.17	0.05	0.53

Table 14 . Classification matrix for the Karner blue habitat model based on a *p-hat* cutoff values of 0.32 and 0.66.

Karner blue observation	*p-hat* value		
	<0.32	0.32-0.66	>0.66
Not observed	59 (79%)	34 (51%)	17 (15%)
Observed	16 (21%)	32 (49%)	100 (85%)

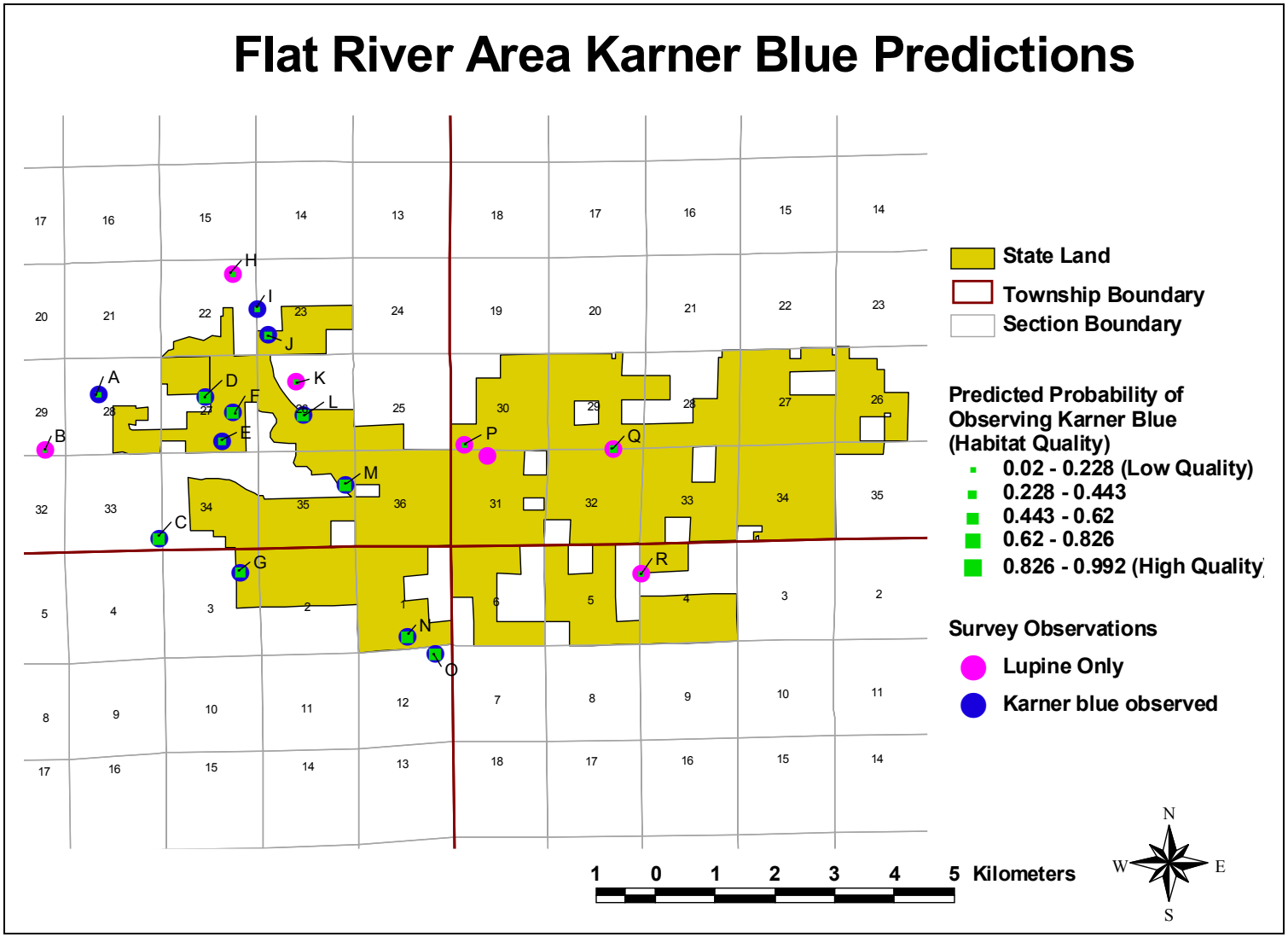

Figure 9. Flat River State Game Area Karner blue and lupine surveys sites, survey observations from 2002-2004, and predicted probabilities of observing Karner blue (habitat quality) as determined by *p-hat* values calculated from a site-level logistic regression habitat model.

Table 15. Management recommendations for the Flat River area Karner blue and lupine sites.

Label	Karner blue Observed	Increase Connectivity	Increase Lupine Density	Open Canopy	Increase Nectar Plant Diversity	Recommendation	*p-hat*
A	Y	X	X			High	0.2883
B	N	X	X		X	Low	0.1062
C	Y	X			X	Expand	0.8410
D	Y		X			Expand	0.8647
E	Y		X	X		Medium	0.5155
F	Y					Expand	0.9268
G	Y	X				Expand	0.7466
H	N	X	X		X	Transloc	0.3918
I	Y	X	X		X	High	0.3031
J	Y		X		X	Medium	0.5510
K	N		X	X		Low	0.2776
L	Y					Expand	0.9809
M	Y			X		Expand	0.8549
N	Y		X		X	Expand	0.9722
O	Y					Expand	0.9602
P	N	X	X			Transloc	0.4383
Q	N	X				Transloc	0.5030
R	N	X	X			Low	0.2564

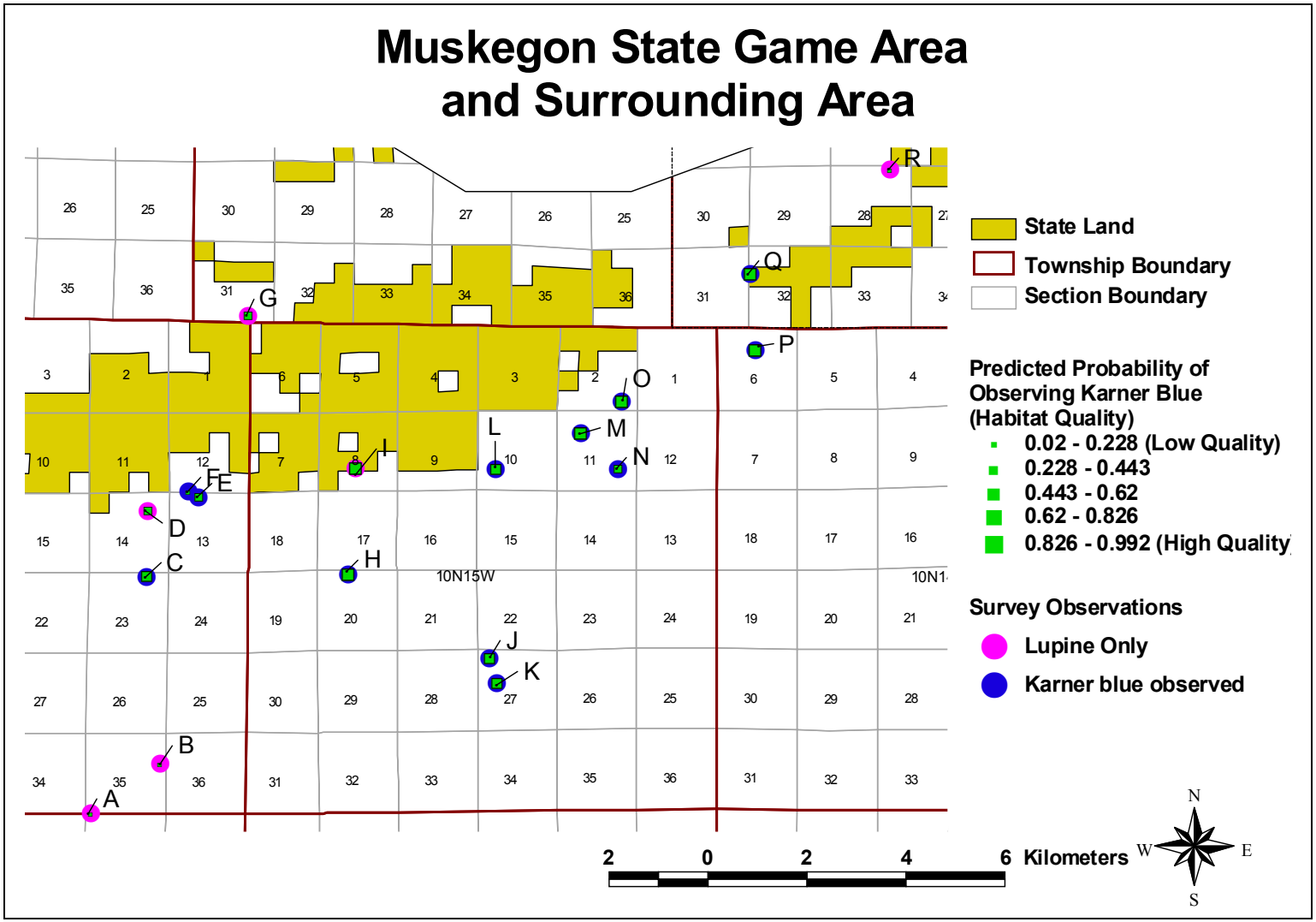

Figure 10. Muskegon State Game Area and surrounding Karner blue and lupine surveys sites, survey observations from 2002-2004, and predicted probabilities of observing Karner blue (habitat quality) as determined by *p-hat* values calculated from a site-level logistic regression habitat model.

Table 16 .Management recommendations for the Muskegon State Game Area Karner blue and lupine sites.

Label	Karner blue Observed	Increase Connectivity	Increase Lupine Density	Open Canopy	Increase Nectar Plant Diversity	Recommendation	*p-hat*
A	N	X	X			Low	0.1254
B	N	X	X			Low	0.0842
C	Y	X				Expand	0.8090
D	N		X			Transloc	0.5074
E	Y	X				Medium	0.5557
F	N	X	X			Low	0.1571
G	N	X				Transloc	0.5080
H	Y					Expand	0.9574
I	N					Survey	0.9135
J	Y		X			Expand	0.6977
K	Y		X			Expand	0.6869
L	Y	X			X	Medium	0.6586
M	Y				X	Expand	0.8791
N	Y		X		X	Medium	0.6162
O	Y				X	Expand	0.8971
P	Y				X	Expand	0.8534
Q	Y					Expand	0.8470
R	N		X			Low	0.2179

Table 17. Management recommendations and *p-hat* values for Karner blue and lupine sites on public lands.

Public Land	Twp	Rng	Sec	Cty	RU	KBB Obs	Inc. Conn.	Increase Lupine Density	Open Canopy	Increase Nectar Plant Diversity	Recommendation	*p-hat*
Barry State Game Area	3N	9W	18	Barry	None	N	X			X	Transloc/Survey	0.6654
Barry State Game Area	3N	10W	11	Barry	None	N	X	X		X	Low	0.1773
Barry State Game Area	3N	10W	24	Barry	None	N	X	X		X	Low	0.1802
Barry State Game Area	3N	10W	2	Barry	None	N	X	X		X	Transloc	0.3518
Barry State Game Area	3N	10W	13	Barry	None	N	X			X	Survey	0.7087
Bay City State Park	15N	5E	29	Bay	None	N	X	X			Low	0.0761
Muir Prairie	7N	5W	16	Ionia	None	N	X				Survey	0.8106
Gourdneck State Game Area	3S	11W	19	Kalamazoo	None	N	X	X			Low	0.2925
Cannonsburg State Game Area	8N	10W	33	Kent	Ionia	N	X				Transloc	0.5999
Rogue River State Game Area	10N	12W	12	Kent	Ionia	N	X	X		X	Low	0.3009
White Pine Trail Private	9N	11W	24	Kent	Ionia	Y	X			X	Medium	0.5681
White Pine Trail State Park	9N	11W	25	Kent	Ionia	N		X			Survey	0.7423
Island Lake State Rec Area	1N	6E	4	Livingston	None	N	X	X			Low	0.2967
White Pine Trail Private	15N	9W	30	Mecosta	None	Y	X				Expand	0.8848
White Pine Trail Private	15N	10W	25	Mecosta	None	Y	X				Medium	0.6072
White Pine Trail Private	15N	10W	25	Mecosta	None	Y	X			X	Expand	0.7829
Petersburg State Game Area	7S	6E	15	Monroe	None	N	X	X			Low	0.0527
Petersburg State Game Area	7S	6E	15	Monroe	None	N	X	X			Low	0.2564
Langston State Game Area	11N	8W	16	Montcalm	Ionia	N	X	X	X	X	Low	0.0580
Dalton Township	11N	16W	8	Muskegon	None	N	X	X	X	X	Low	0.0367
Muskegon County Property	12N	17W	23	Muskegon	Muskegon	Y	X				Medium	0.5030
Musketawa Trail	10N	16W	34, 35	Muskegon	Allegan	N	X	X			Low	0.1254
Newaygo State Park	13N	11W	23	Newaygo	Newaygo	Y	X	X			Medium	0.5237
Pere Marquette	16N	18W	36	Oceana	Muskegon	N	X	X	X	X	Low	0.0204
Bass River State Recreation Area	7N	15W	2	Ottawa	Allegan	N	X	X			Low	0.2842

Threats

Several threats were identified within Karner blue sites during 2002-2004 presence-absence surveys. The most common threats included management that, if unregulated, would result in take (53%), succession (43%), exotic species encroachment (41%), orv use (39%), and development (33%). Threats present within sites varied by recovery unit ($P<0.005$, Table 18). Sites surveyed within the Allegan RU were most frequently threatened by management (91%), exotics (82%), and orv use (82%). Most sites surveyed in the Allegan RU were along powerline rights-of-way in southern Muskegon County, and the most common threats indicate that unregulated management of rights-of-way may threaten the butterfly populations. Additionally, many of the rights-of-way experience high levels of orv use, which in some cases have removed vegetation from large areas, creating conditions suitable for exotic species encroachment. Common threats within the Ionia RU include succession (62%) and exotic species (57%). The Ionia RU has richer soils than other RUs, and woody plant species tend to grow quickly and readily encroach on open areas. Woody species encroachment occurs quickly, and will decrease habitat quality within Karner blue sites if the canopy closes (see habitat evaluation and management recommendations section). Succession is also common in the Muskegon Recovery Unit (50%), where Karner blue sites are mainly within a forested matrix. Succession (61%), management (63%), and development pressures (50%) are common in Karner blue sites within the Newaygo RU. Many sites surveyed on the Newaygo RU were on privately owned land which managed for purposes other than Karner blue conservation. Unregulated management such as mowing coupled with development pressures around growing towns threatens many Karner blue sites in the Newaygo RU.

Karner blue sites on non-public lands, including private properties and powerline rights-of-way, are more commonly threatened by management (59%, $P<0.05$), deer browse (52%, $P<0.001$), exotic species (48%, $P<0.01$), and development (43%, $P<0.001$) than sites on public lands (Table 19). Most non-public lands are maintained for purposes other than wildlife conservation, the threats within Karner blue sites reflect this. Education of owners and managers of non-public lands as to how to reduce negative impacts on Karner blue habitat is needed. Impacts of development pressure on Karner blue sites around growing towns may be reduced if landowners know more about the species and its habitat needs. Similarly, management practices on non-public lands can be beneficial to Karner blue if implemented with the habitat needs of the butterfly in mind.

Table 18. All threats identified at Karner blue occupied sites during surveys, 2002-2004, by Michigan Recovery Unit. More than one threat could be identified at survey sites.

Recovery Unit	Deer Browse	Development	Dumping	Exotics	Management	ORV	Succession	Vehicle	Other
Allegan	1 (64%)	2 (18%)	4 (36%)	9 (82%)	10 (91%)	9 (82%)	5 (45%)	8 (73%)	1 (9%)
Ionia	1 (53%)	9 (43%)	3 (14%)	12 (57%)	10 (48%)	9 (43%)	13 (62%)	4 (19%)	1 (5%)
Muskegon	8 (42%)	1 (2%)	5 (11%)	8 (17%)	14 (30%)	20 (44%)	23 (50%)	11 (24%)	8 (17%)
Newaygo	7 (34%)	34 (50%)	9 (13%)	31 (46%)	43 (63%)	18 (27%)	21 (61%)	9 (13%)	7 (10%)
None	0 (0%)	3 (75%)	0 (0%)	2 (50%)	3 (75%)	3 (75%)	2 (50%)	0 (0%)	0 (0%)
Total	17 (12%)	49 (33%)	21 (14%)	62 (41%)	80 (53%)	59 (39%)	64 (43%)	32 (21%)	17 (11%)

Table 19. All threats identified at Karner blue occupied sites during surveys, 2002-2004, by ownership. More than one threat could be identified at sites.

Ownership	Deer Browse	Development	Dumping	Exotics	Management	ORV	Succession	Vehicle	Other
Non-public	52 (52%)	46 (43%)	17 (16%)	51 (48%)	63 (59%)	43 (40%)	42 (39%)	30 (19%)	11 (10%)
Public	8 (19%)	3 (7%)	4 (9%)	11 (26%)	17 (40%)	16 (37%)	22 (51%)	12 (28%)	6 (14%)
Total	17 (12%)	49 (33%)	21 (14%)	62 (41%)	80 (53%)	59 (39%)	64 (43%)	32 (21%)	17 (11%)

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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 60^0F
    - when temperatures are between 60^0F and 70^0F surveys should only be conducted under mostly sunny skies with calm to light wind
    - when temperatures are above 70^0F, 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 Fettinger at MNFI. An alternative to this is having Jennifer Fettinger 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.

Appendix 2. Survey form and instructions used in MNFI Karner blue butterfly surveys, 2004.

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

20 EXOTICS ENCROACHMENT Species	Density	Notes

KARNER BLUE BUTTERFLY OCCURRENCE

Mark occurrence on map using a * to indicate an occurrence

Total number of KBB adults: Male / Female / Unknown	% of opening occupied	Survey effort: Time spent in opening_____ % of area surveyed_____	Notes, observations, etc.:
21 _____ _____ _____	22 _____	23	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 _____

NECTAR SPECIES PRESENT

List nectar species observed at this site. Note the number of plants and blooms where possible.

Species 33	Blooming? Yes / No 34	Number Observed 35	Notes, observations, etc. 36

OTHER SPECIES PRESENT

List other species observed at this site. Note especially listed species and potential predators.

Species: 37	Number Observed 38	Notes, observations, etc. 39

Sketch the boundary of the area visited. Mark your survey route or area, KBB (*) and lupine (● × 0) occurrences and note other pertinent information.

40

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 you 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 (*Eleaganus 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 Fettinger 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 ●, ×, 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%, × = 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. Survey form and instructions used in MNFI Karner blue butterfly surveys, 2004.

FOLLOW-UP KBB SURVEY FORM

1 This is the 2nd 3rd (circle one) survey of this site this year

Fill out this section after the survey has been completed

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: 3 __ __ __ - __ __ - __ __	Time from: 4 __ to:_____	SITENAME:	Sourcecode: F __ __ __ __ __ __ __ M I U S

Surveyors (principal surveyor first, include first & last name): 5 _____

6 TOWNSHIP:	RANGE:	SECTION:	QUARTER SECTION:
OWNERSHIP: 7		QUAD CODE:	

Weather (see codes page): 8 Begin Temp:_____ Begin Wind code:_____ Begin Sky code:_____

End Temp: _____ End Wind code:_____ End Sky code:_____

KARNER BLUE BUTTERFLY OCCURRENCE

Mark occurrence on map using a * to indicate an occurrence

Total number of KBB adults:			% of opening occupied	Survey effort:	Notes, observations, etc.:
9 Male	Female	Unknown	10	11 Time spent in opening_____	12
_____	_____	_____	_____	% of area surveyed_____	_____

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

13 Type of unit: _____ Unit number:_____

Waypoint name/# (when using Garmin) _____ File name (when using Trimble)_____

OPTIONAL: Latitude _____ Longitude _____

14 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

NECTAR SPECIES PRESENT

List nectar species observed at this site. Note the number of plants and blooms where possible.

Species 15	Blooming? Yes 16	No	Number Observed 17	Notes, observations, etc. 18

OTHER SPECIES PRESENT

List other species observed at this site. Note especially listed species and potential predators.

Species: 19	Number Observed 20	Notes, observations, etc. 21

Sketch the boundary of the area visited on the back of this page. Mark your survey route or area, prominent vegetative characteristics, and KBB (*).

22

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

- 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.

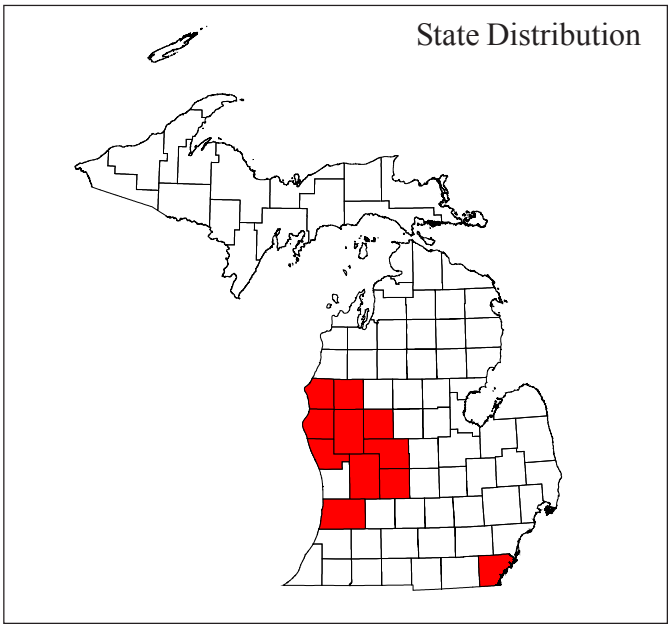
- It would be advantageous for the HCP Team to develop/coordinate a cooperative method of determining the flight period phenology each year that accounts for variation by geography an site ("fast" and "slow" sites).

- 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.

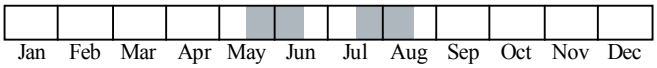
For information on identification of KBBs, contact:

Jennifer Fettinger
Michigan Natural Features Inventory Zoologist
4th Floor Stevens T. Mason Building
PO Box 30444
Lansing, MI 48909-7944
Office: (517) 241-5437
Fax: (517) 373-9566
email: fettingj@michigan.gov

Lycaeides melissa samuelis Nabokov — Karner blue



Best Survey Period



Status: State threatened, Federal endangered

Global and state rank: G5T2/S2

Family: Lycaenidae (the gossamer winged butterflies)

Taxonomy: Currently, seven species and 75 subspecies are recognized for *Lycaeides* (Bridges 1988). Two species, *idas* and *melissa*, occur in North America with 12 and 6 recognized subspecies, respectively. Main characters for distinguishing the two species involve wing markings and male genitalia.

To date, the Karner blue is still considered to be a subspecies of the species *melissa* (Nabokov 1943, 1949; Opler 1992). The Karner blue lacked a scientific name until Nabokov described it as a subspecies in 1944. Sometime after Nabokov's published work in the 1940s, he concluded that the butterfly should be classified as a distinct species. In a letter to Robert Dirig (Nabokov 1989), Nabokov gave three reasons for elevating the Karner blue to species status. He believed that there were sufficient "structural and larval differences" (probably structural differences in male genitalia) to warrant specific designation. Nabokov noted that the male genitalia of *L. m. melissa* were very variable geographically, but the male genitalia of *L. m. samuelis* were remarkably constant over the entire range of the subspecies. Moreover, *L. m. samuelis* larvae use only one host plant throughout their geographic range, while *L. m. melissa* larvae feed on many plants. Also, he noted the absence of interbreeding of *L. m. samuelis* and *L. m. melissa* where the specific ranges of each came into contact. Taxonomic work to elevate *L. m. samuelis* to species level was never published.

Total range: The Karner blue has a disjunct range. Historically, it occurred in eastern Minnesota, northeastern Iowa, northwestern and central Wisconsin, southwestern Michigan and northern Indiana, extreme southeastern Michigan and northeastern Ohio, central Ontario near the southern Lake Huron shoreline, in the pine barrens near Albany, New York and at a few localized sites elsewhere in New York, and in New Hampshire, Massachusetts, Pennsylvania, and Illinois (U.S. Fish and Wildlife Service 2000). The species is now extirpated in Iowa, Illinois, Pennsylvania, Massachusetts, Maine and Ontario. Today, wild populations of Karner blue exist only in Indiana, Michigan, Minnesota, New Hampshire, New York and Wisconsin. It is actively being reintroduced in northern Ohio after nearly a decade of absence.

State Distribution: Historically the Karner blue has been found in the southern Lower Peninsula in 11 counties. It has not been seen in Monroe County since

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P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552

1986, but still persists in Mason, Lake, Oceana, Newaygo, Mecosta, Muskegon, Montcalm, Ionia, Kent and Allegan counties.

Recognition: The Karner Blue is a small silvery butterfly with a 22 -32 mm (0.90 - 1.25 inch) wingspan (Pyle 1981). **The dorsal (top) surface is silvery blue in males with a narrow, dark border and white fringe. Females range from dull violet to bright purplish blue near the body and central portions of the wings; the remainder of the wing can range from light to dark gray-brown. The hindwing of the female also has a row of dark spots with orange crescents along the outer edge. The ventral (bottom) surface of both sexes is grayish fawn to pearly gray with several rows of small black spots on the inner portions of both wings and a row of metallic blue-green, orange, and black spots just inside the outer margin of both wings, becoming less pronounced in the forewing.** The black marginal line is not distinctly inflated into triangles at the ends of the veins. Several other blues resemble the Karner blue, but none have the combination of being tail-less with orange spots on the dorsal border of the hindwing. Neither the silvery blue (*Glaucopsyche lygdamus*) nor the spring azure (*Celastrina ladon*) has orange on any wing surface. The eastern tailed blue (*Everes comyntas*) has similar pattern and coloration, but both sexes have tails that look like small threads extending from the rear edge of the hind wing. The northern blue (*Lycaeides idas nabokov*) occurs only in the Upper Peninsula, and therefore does not overlap the range of the Karner at any point in Michigan. Larvae are green or whitish green, covered with white hairs, with a cream lateral stripe; the head is small and dark (Scott 1986). Larvae of the frosted elfin (*Incisalia irus*), another lupine-dependent species, often co-occur with Karner blue larvae, are similar in appearance, but have heads that are greenish white like the body.

Best Survey Time: Peak Karner blue flight dates in Michigan are mid-May through early June and mid-July through early August, with stragglers found between peak dates. Since the larvae are only 1 mm long at hatching, the best time to search for them feeding on lupine plants is 7-10 days before the adults begin to fly.

Habitat: The Karner blue usually is associated with landscapes composed of sandy soils, which supported oak or oak-pine savanna or barrens prior to European settlement. Since their historical habitat suffers from fire suppression efforts, the butterfly often occurs in openings, old fields, and right-of-ways surrounded by close-canopied oak forest. Karner blue larvae feed exclusively on wild lupine (*Lupinus perennis* Linneaus). Adults visit a wide variety of flowering plants for nectar.


MDNR Photo by Dave Kenyon

Biology: The Karner blue has two generations each year, with the later, or summer, generation typically having three to four times the number of adults as the earlier, or spring, brood. Males emerge earlier than females and some may disperse for a short time after emergence. Adults are active most of the day, decreasing activity during midday and during cool, rainy weather. Females can live up to two weeks in the field, but adults typically live an average of five days.

Spring females lay eggs on or near lupine and the summer brood larvae hatch in about a week. The larvae grow rapidly, feeding on the upper surfaces of the lupine leaves, as they pass through four instars where the relatively soft exoskeleton is shed each time. Pupation occurs in the litter near or on lupine. The summer adults emerge, mate and lay eggs that overwinter; the spring brood larvae hatch in April. Karner blue larvae are frequently tended by a variety of ant species (Packer 1987, Savignano 1987) that feed on the sweet secretions they produce. Although the results of recent experiments are inconclusive, the ants may help to protect larvae from predators or parasitoids. Tending levels for late instar larvae are close to 100 %, however, very few early instars are tended (Lane 1994, Savignano1990). Adults require adequate nectar resources and will utilize a wide variety of native and introduced flowering plants. In

Michigan they frequently nectar on lupine and dewberry (*Rubus* spp.) during the spring brood and horse mint (*Monarda punctata*), butterfly weed (*Asclepias tuberosa*), spotted knapweed (*Centaurea maculosa*), and blazing star (*Liatris aspera*) during the summer brood (Ewert and Ballard 1990). All life stages are fire sensitive.

Karner blue adults and larvae use a variety of subhabitats created by variations in tree canopy and shrub cover, topography and soil moisture. Adult butterflies use open-canopied areas for nectaring, roosting and mate location. Females have been observed ovipositing in open to closed-canopied areas and in a variety of slopes and aspects. Optimal subhabitat for larval stages contrasts with that used by adults. For second brood larvae, survival is highest in closed-canopied areas, intermediate in partial-canopied areas, and lowest in open-canopied and very xeric areas (Lane 1999). Maxwell (1998) found lupine shaded by shrubs and dense herbaceous cover contributed to larval survival and noted that removal of tree and shrub cover over a large area can be detrimental to the butterfly even when nectar and lupine resources are enhanced. It is important, then, that butterflies be able to move easily between these subhabitat types.

Nearly all researchers that have examined Karner blue dispersal have concluded that dispersal rates and distances for the butterfly are relatively low and short with nearly all movement less than 200 m (1/8 mile). Long distance movements up to 1600 m (one mile) and 1195 m (2/3 mile) for males and females, respectively, have been recorded (Bidwell 1994). The percent of marked individuals dispersing between suitable habitat sites have varied from 0 to 11 % (Bidwell 1994, Fried 1987, King 1998, Lawrence 1994, Schweitzer 1994a). Today's habitat patches are often small isolated remnants, which likely affects our ability to measure true dispersal capability. Definitive studies on insect dispersal frequently uncover unanticipated high frequencies of movement and distances far greater than expected. In studies of the Heath fritillary butterfly in England, Warren (1987) found an average of 1.5 % dispersal between habitat areas. He argued that if similar rates of dispersal were observed to other areas not sampled, that a fairly substantial proportion of adults might be emigrating from the populations studied and arriving at new habitat areas. It is unclear if observed rates of between-habitat dispersal will limit recolonization of suitable habitat by Karner blue, but the 11 % dispersal rate observed by King (1998) in Wisconsin indicates that recolonization can be extensive.

Barriers to dispersal might include many topographical features, vegetation types, and human structures like roads and parking lots. Currently, scientific evidence to identify actual barriers is absent. Welch (1993) found that dispersing butterflies almost always followed canopy openings along fence rows, woodland trails, or small gaps in the canopy, stopping frequently to bask in the sun. Thus dispersal corridors may be quite diaphanous in native habitat, formed by a network of partially connected canopy gaps and trails.

Karner blue populations have a metapopulation structure. The federal recovery team defines a metapopulation as a "population of populations" (U.S. Fish and Wildlife Service 2000). Such a metapopulation is distributed across a landscape at relatively discrete sites. Each of the relatively discrete sites that harbor Karner blue can be referred to as a subpopulation or local population. The number of subpopulations present at any given time is governed by the spatial structure of suitable and unsuitable habitat and the balance between local extirpation and local colonization. Factors that create a healthy metapopulation include sufficient suitable habitat to support the metapopulation, sufficient connectivity to promote recolonization, and management guidelines to aid decision-making. Because complete information is not available, adaptive management for improving or maintaining Karner blue metapopulations is essential. Monitoring can be adapted as the duration of successful management increases. As confidence is gained in the management practices, the need for monitoring declines.

Conservation/Management: In December of 1992, the Karner blue was listed as federally endangered rangewide (U.S. Fish and Wildlife Service 1992). The goal of the federal recovery plan is to perpetuate viable metapopulations of the Karner blue in the major ecological regions throughout its geographic range. This will be accomplished by maintaining extant populations throughout the range, and improving and stabilizing populations where the butterfly is imperiled. Wisconsin and Michigan now harbor the largest remaining metapopulations of Karner blue. Four recovery units

have been identified for Michigan: Ionia, Allegan, Newaygo, and Muskegon. Recovery goals for the state include having two viable populations in each recovery unit except Ionia, which has the option to contribute only one because of its small size and fragmented ownership.

Savignano (1994) showed that Karner blue subpopulations on sites with extensive lupine are more likely to persist than those on sites with less lupine. Lupine is an early successional species adapted to dry, relatively infertile soils. Lupine does not reproduce in dense shade. Shading from tree canopy and competition from sod-forming grasses and sedges have excluded lupine from many former barrens and prairies where it once was common (Bess et al. 1989). Consequently, disturbances that reduce tree and shrub canopy cover are necessary for lupine to persist, and under some conditions, occasional disturbances that remove the litter layer are needed for lupine regeneration. Disturbances that may be beneficial for renewing lupine habitat, include prescribed fire, tree removal, and a variety of methods to kill trees and shrubs.

Well-planned fire management is an important tool for rehabilitating and eventually maintaining Karner blue habitat. The frequency of fire management should be tailored to each management unit, taking into consideration the desired final community matrix, current community conditions, site characteristics, and the life histories of all fire sensitive species present. On a large scale, the final product should be a landscape complex of barrens, prairies and woodlands at different stages in succession. In this setting, semi-isolated Karner blue populations within the landscape complex would wax and wane as lupine populations changed, and would provide colonizers to sites recently opened by fire or to sites where butterflies have been lost to localized extinction events.

Inappropriate or incompatible management practices threaten some populations of Karner blues. These practices occur because land mangers have several management goals and they either are unaware of the detrimental effects on Karner blue or they judge them to be acceptable. Poorly timed or poorly located use of herbicides can have a negative effect on Karner blue butterflies by killing or suppressing lupine or important nectar plants. Their direct effect on Karner blue larvae is under investigation. In laboratory tests, even the relatively specific insecticide, *Bacillus thuringiensis kurstaku*, kills all larval instars of the Karner blue (Herms 1996). Mowing between late spring and mid-summer is anticipated to have detrimental effects on Karner blue populations. Mowing can damage lupine, eliminating food for larvae. Mowing during adult nectaring periods can greatly reduce flower and nectar availability. In addition, mowing can kill larvae that are present and may crush eggs laid on lupine plants. One of the most useful restoration and management tools, prescribed fire, may threaten Karner blue populations if the burning is conducted on the majority of the habitat, or if high intensity fires are used at frequent intervals. High deer densities can devastate Karner blue habitat and cause direct mortality by ingestion of larvae (Packer 1994, Schweitzer 1994b). Schweitzer recommends that deer be managed to density levels where no more than 15% of lupine flowers are consumed, but this recommendation has not been rigorously tested.

Many environmental effects that are potentially detrimental to Karner blue can extend over extensive areas, such as large-scale wildfire, extended periods of extraordinary weather (summer-long, hot droughts or extremely delayed and cool summers) or disease epidemics. In these cases, local extirpation is likely to increase throughout the metapopulation, perhaps to the point that the entire metapopulation has no chance of recovery. It is critical, therefore, for management decisions to be made in ways that bring greater stability to the Karner metapopulation.

Research Needs: Considerable research has been conducted on this species, and a thorough review is provided in the federal recovery plan. In Michigan, additional surveys are still needed to describe the extent of populations and habitat persisting in the northwest lower peninsula (Mason, Lake, Oceana, Newaygo, Mecosta, and Muskegon counties). Karners were discovered in Kent counties for the first time in 2000. While suitable habitat may have existed there at one time, no historical records for Karners were ever reported, and much of the former oak-pine barren habitat has been converted to agricultural uses. Further surveys in Kent county would be useful. Systematic surveys for two other state threatened lupine-feeders, the Persius duskywing (*Erynnis persius persius*) and frosted elfin (*Incisalia irus*), as well as the state threatened

Ottoe skipper (*Hesperia ottoe*) which inhabits the dry sand prairie habitats associated with barrens and savannas, are lacking.

Of particular importance is research to determine the relationship of fluctuation in the butterfly population to the size, phenology, and distribution of the lupine population. The dispersal capabilities of the butterfly must also be determined to ensure proper design and spacing of habitat patches within each landscape complex. Finally, the impact of ant species on the reproductive success of the butterflies and the effects of management activities on the ants must be determined. Experiments with a variety of burn regimes would be useful to managers. Some areas may need additional information on the establishment of lupine and site-appropriate nectar plants to improve long-term viability.

Related Abstracts: Oak-pine barrens, dry sand prairie, coastal plain marsh, frosted elfin, Persius duskywing, Ottoe skipper, dusted skipper, Culver's root borer, Great Plains spittlebug, phlox moth, leadplant flower moth, box turtle, eastern massasauga, prairie smoke, Hill's thistle, meadow beauty.

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Michigan Natural Features Inventory
P.O. Box 30444 - Lansing, MI 48909-7944
Phone: 517-373-1552