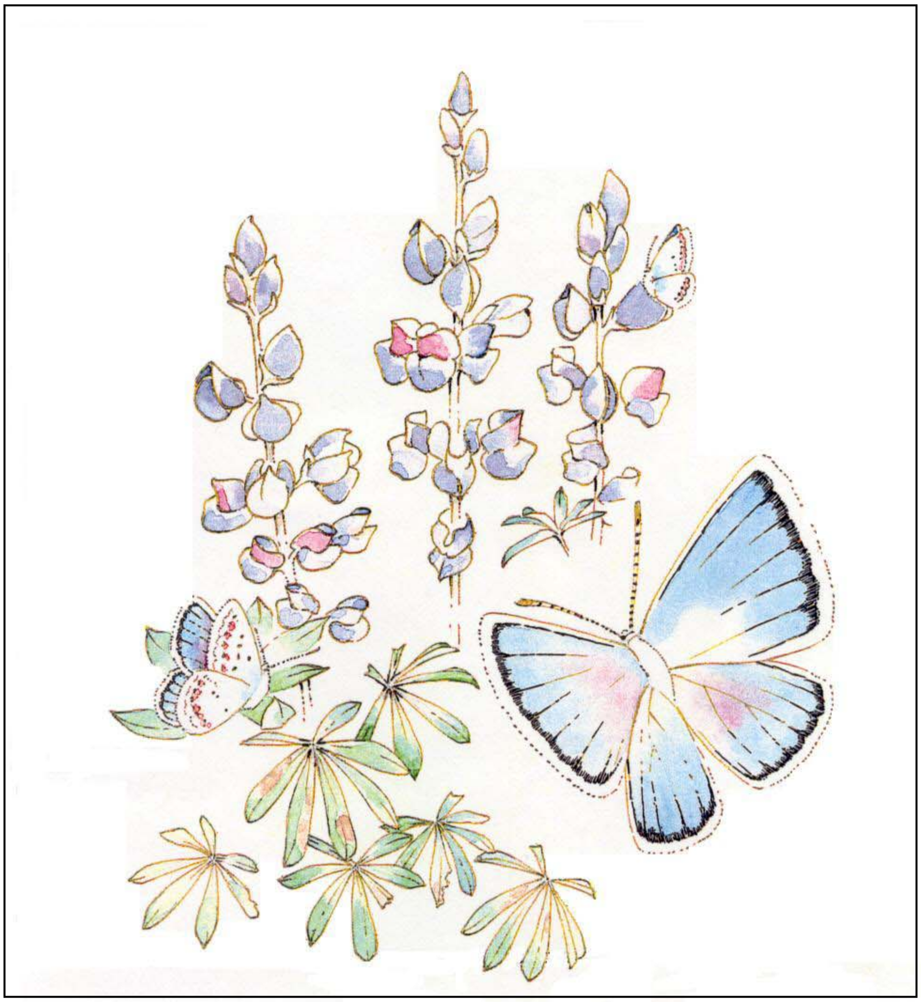
U.S. Fish & Wildlife Service

Karner Blue Butterfly Recovery Plan

(Lycaeides melissa samuelis)



September 2003

Department of the Interior
U.S. Fish & Wildlife Service
Great Lakes - Big Rivers Region (Region 3)
Fort Snelling, Minnesota

KARNER BLUE BUTTERFLY
(Lycaeides melissa samuelis)

RECOVERY PLAN

September 2003

Prepared by the
Karner Blue Butterfly Recovery Team

for

Region 3
U.S. Fish and Wildlife Service
Fort Snelling, Minnesota

Approved: ______________________

Acting Robyn Thorson, Regional Director, Region 3
U.S. Fish and Wildlife Service

Date: August 25, 2003

KARNER BLUE BUTTERFLY RECOVERY TEAM

David Andow, Team Leader	Department of Entomology University of Minnesota St. Paul, Minnesota
Miles Benson	Wisconsin Rapids, Wisconsin (former Director of Timberlands, Consolidated Papers, Inc.)
Catherine Carnes Recovery Coordinator	U.S. Fish and Wildlife Service Ecological Services Field Office (Green Bay) New Franken, Wisconsin
Mark Clough (Robyn Niver)	U.S. Fish and Wildlife Service New York Field Office Cortland, New York
Rex Ennis	Huron-Manistee National Forest Cadillac, Michigan
Stephanie Gifford (Neil Gifford) (formerly Bob Zaremba)	The Nature Conservancy Troy, New York
Bill Gilbert	Plum Creek Timber Wisconsin Rapids, Wisconsin
Thomas Givnish	Botany Department University of Wisconsin Madison, Wisconsin
Alan Haney	College of Natural Resources University of Wisconsin Stevens Point, Wisconsin
Steve Hatting	Huron-Manistee National Forest White Cloud, Michigan
Paul Kooiker (formerly Cathy Bleser)	Wisconsin Department of Natural Resources Grantsburg, Wisconsin
Cynthia Lane	Ecological Strategies, LLC Maiden Rock, Wisconsin

Kathy O'Brien	New York Department of Environmental Conservation Albany, New York
Pat Lederle (formerly Mary Rabe)	Michigan Department of Natural Resources Lansing, Michigan
Dale Schweitzer	The Nature Conservancy Port Norris, New Jersey
John Shuey	The Nature Conservancy Indianapolis, Indiana
Jennifer Szymanski	U.S. Fish and Wildlife Service Onalaska, Wisconsin
Larry Wargowsky	Necedah National Wildlife Refuge Necedah, Wisconsin

* * *

This recovery plan has been prepared by the Karner Blue Butterfly Recovery Team under the leadership of Dr. David Andow, University of Minnesota-St. Paul. Dr. John Shuey and Dr. Cynthia Lane assisted with the writing of the document. The purpose of the plan is to delineate reasonable actions needed to restore and protect the endangered Karner blue butterfly *(Lycaeides melissa samuelis)*. Recovery objectives will be attained and funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities.

The plan does not necessarily represent the views or official position of any individuals or agencies involved in plan formulation, other than the U.S. Fish and Wildlife Service. The plan represents the official position of the U.S. Fish and Wildlife Service only after it has been signed by the Regional Director. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

LITERATURE CITATION:

U.S. Fish and Wildlife Service. 2003. Final Recovery Plan for the Karner Blue Butterfly *(Lycaeides melissa samuelis)*. U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 273 pp.

ADDITIONAL COPIES MAY BE OBTAINED FROM:

The U.S. Fish and Wildlife Service
Ecological Services Field Office
2661 Scott Tower Drive
New Franken, Wisconsin 54229
920-866-1717

or

Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 100
Bethesda, Maryland 20814
301-492-6403 or 1-800-582-3421
Fax: 301-564-4059
Email: fw9_fa_reference_service@fws.gov
http://fa.r9.fws.gov/r9fwrs/

Fees for plans obtained from the Fish and Wildlife Reference Service vary depending on the number of pages in the plan. Recovery plans can be downloaded from the FWS website: http://endangered.fws.gov

ACKNOWLEDGEMENTS

The U.S. Fish and Wildlife Service recognizes that development of this draft recovery plan would not have been possible without the assistance of the many individuals who attended recovery team meetings, and contributed valuable information to the process. Special thanks goes to Mary Parkin, the Service's Region 5 Recovery Coordinator, who, while not seen but at one meeting, was ever-present as a guide and support in the evolution of this plan. Acknowledgement goes to Catherine Carnes, the Service's Karner Blue Butterfly Recovery Coordinator who oversaw and coordinated this project.

The Service also wishes to especially acknowledge the following individuals who served as technical consultants to the recovery team for their efforts on behalf of the species:

Mr. Richard King	Necedah National Wildlife Refuge, Wisconsin
Dr. Judi Maxwell	University of Wisconsin, Madison, Wisconsin
Mr. Robert Welch	Waupaca Field Station, Waupaca, Wisconsin

Thanks also to the following individuals who gave of their time and expertise to assist with this plan development:

Michael Amaral	Dave Lentz
Nancy Braker	Kim Mello
Hilda Diaz-Soltero	Amelia Orton-Palmer
Buddy Fazio	Noel Pavlovic
Anthony Frank	Chuck Pils
Ralph Grundel	Rebecca Power
Mark Heil	Gregory Smith
Bob Hess	Janet Smith
Ken Hujanen	John Staszcuk
Craig Johnson	Kathy Trudell
Randy Jurewicz	David VanLuven
Chuck Kjos	Tim Wilder
Randy Knutson	Jennifer Windus
Paul Kooiker	Mike Zeckmeister

Also, special thanks goes to David Kopitzke for the Karner blue butterfly artwork that appears on the cover and within the body of this document.

EXECUTIVE SUMMARY
Karner Blue Butterfly Recovery Plan

Current Species Status: The Karner blue butterfly, *Lycaeides melissa samuelis* Nabokov (Lepidoptera: Lycaenidae), formerly occurred in a band extending across 12 states from Minnesota to Maine and in the province of Ontario, Canada, and now only occurs in the seven states of Minnesota, Wisconsin, Indiana, Michigan, New York, New Hampshire, and Ohio. Wisconsin and Michigan support the greatest number of Karner blue butterflies and butterfly sites. The majority of the populations in the remaining states are small and several are at risk of extinction from habitat degradation or loss. Based on the decline of the Karner blue across its historic range, it was listed as endangered in 1992. Since listing, two populations have been extirpated and are being reintroduced to Concord, New Hampshire, and West Gary, Indiana. A third population is being reintroduced to Ohio.

Habitat Requirements and Limiting Factors: The Karner blue butterfly is dependent on wild lupine, *Lupinus perennis* L. (Fabaceae), its only known larval food plant, and on nectar plants. These plants historically occurred in savanna and barrens habitats typified by dry sandy soils, and now occur in remnants of these habitats, as well as other locations such as roadsides, military bases, and some forest lands. The primary limiting factors are loss of habitat through development, and canopy closure (succession) without a concomitant restoration of habitat. A shifting geographic mosaic that provides a balance between closed and open-canopy habitats is essential for the maintenance of large viable populations of Karner blue butterflies.

Recovery Objectives: The objective of this recovery plan is to restore viable metapopulations of Karner blues across the species extant range so that it can be reclassified from endangered to threatened. The long-range goal is to remove it from the Federal list of *Endangered and Threatened Wildlife and Plants*.

Recovery Criteria: The reclassification criteria will be met when a minimum of 27 metapopulations [19 viable metapopulations (supporting 3,000 butterflies each), and 8 large viable metapopulations (supporting 6,000 butterflies each)] are established within at least 13 recovery units across the butterfly's range and are being managed consistent with the recovery objectives outlined in this plan. Delisting will be considered when a minimum of 29 metapopulations (13 viable and 16 large viable metapopulations) have been established within at least 13 recovery units and are being managed consistent with the plan.

Actions Needed:

1. Protect and manage Karner blue and its habitat to perpetuate viable metapopulations.
2. Evaluate and implement translocation where appropriate.
3. Develop rangewide and regional management guidelines.
4. Develop and implement information and education program.
5. Collect important ecological data on Karner blue and associated habitats.
6. Review and track recovery progress **(includes re-evaluation of recovery goals for Wisconsin).**

Total Estimated Cost of Recovery (in $1,000's):

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Need 6	* Total
2003	872.5	75	7	133	391	7	1,485.5
2004	964.5	55	26	63	423	27	1,558.5
2005	974	100	27	48	400	15	1,564
Total	2811	230	60	244	1,214	49	4,608

* Does not include land acquisition costs.

Date of Recovery: Full recovery of the species is anticipated to require at least 20 years, until about 2023.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PART I. INTRODUCTION

The Karner blue butterfly (*Lycaeides melissa samuelis*) was proposed for Federal listing on January 21, 1992 [U.S. Fish and Wildlife Service (USFWS) 1992a], and on December 14, 1992 it was listed as federally endangered rangewide (USFWS 1992b). Historically, the Karner blue butterfly occurred in 12 states and at several sites in the province of Ontario. It is currently extant in seven states (New Hampshire, New York, Ohio, Indiana, Michigan, Wisconsin and Minnesota) with the greatest number of occurrences in the western part of its range (Michigan and Wisconsin). The Karner blue is considered extirpated from five states and the Canadian province of Ontario. Reintroductions are underway at three sites, Concord, New Hampshire, West Gary, Indiana, and in Ohio. The historic habitat of the butterfly was the savanna/barrens ecosystems. Much of these ecosystems has been destroyed by development, fragmented, or degraded by succession, and has not been replaced by other suitable habitat, especially in the eastern part, and along the margins of the butterfly's range. The loss of suitable habitat resulted in a decline in Karner blue locations and numbers, with some large populations lost, especially in the eastern and central portions of its range. Presently, the Karner blue butterfly occupies remnant savanna/barrens habitat and other sites that have historically supported these habitats, such as silvicultural tracts (e.g. young pine stands), rights-of-ways, airports, military bases, and utility corridors.

The ecology of the Karner blue butterfly is closely tied to its habitat which provides food resources and key subhabitats for the butterfly. The larvae feed only on one plant, wild lupine (*Lupinus perennis*). Adults require nectar sources to survive and lay sufficient eggs. Because these habitat components can be lost to succession, Karner blue butterfly persistence is dependent on disturbance and/or management to renew existing habitat or to create new habitats. The distribution and dynamics of these habitats in the establishment of viable metapopulation of this species forms the ecological basis for recovery planning.

TAXONOMY AND DESCRIPTION

Taxonomy

The taxonomy of the Karner blue *(Lycaeides melissa samuelis)* follows Lane and Weller (1994) who have conducted the most recent review of its taxonomy. The Karner blue is a member of the genus *Lycaeides* (Lepidoptera: Lycaenidae: Polyommatinae) (Elliot 1973, Nabokov 1943, 1949). In North America there are two species of *Lycaeides*, *L. idas* (formerly *L. argyrognomon*) and *L. melissa* (Higgins 1985, Lane and Weller 1994). *Lycaeides melissa* is comprised of six subspecies, *L. m. melissa*, *L. m. annetta*, *L. m. inyoensis*, *L. m. mexicana*, *L. m. pseudosamuelis*, and *L. m. samuelis* (Lane and Weller 1994). Vladimir Nabokov conducted the taxonomy for this group in the 1940s. Sometime after this work was published, Nabokov commented in private letters that the Karner blue should be classified as a distinct species (Nabokov 1952, 1975, 1989). 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. The wing shape of *L. m. samuelis* is rounder and less pointed than that of *L. m. melissa*, especially the female hingwing. Moreover, *L. m. samuelis* uses only one host plant throughout its geographic range, while *L. m. melissa* uses many species of host plant. The taxonomic work to elevate *L. m. samuelis* to the species level was never completed, and the currently accepted status of the Karner blue butterfly is subspecific (Miller and Brown 1983, Nabokov 1943, 1949, Opler 1992, Opler and Krizek 1984, Lane and Weller 1994). While other work has been done on the taxonomy of the Karner blue, the data thus far does not support a change in the classification of the butterfly.

Packer et al. (1998) described protein variation detected by starch gel electrophoresis in a study of 34 loci in two samples of the Karner blue (Wisconsin and New York) and one sample of the Melissa blue (Minnesota). Based on their application of a phylogenetic species concept criterion for species-level distinctness requiring fixed allele differences between the two supposed species, they concluded that the Karner blue and the Melissa blue are not distinct enough to be considered different species. They also reported that the genetic identity values between samples from the different subspecies (0.967 and 0.976) were less than between the two samples of Karner blue (0.989). They observed that these identity values were within the ranges of values reported for subspecies and intraspecific populations of other insects. Genetic data alone, according to their interpretation, is consistent with both population-level and subspecies-level divergence. The utility of these data for making inferences about taxonomy and population structure is limited by the small number of populations sampled and the small number of individuals (ranging from 3 to 17 individuals, depending on the population and locus) sampled. In addition, genetics data alone should not be used in making taxonomic decisions; it must be considered together with morphological, life history, and ecological data.

Nice et al. (2000) investigated the taxonomy of the genus using male genital morphology and variation in nuclear (microsatellite) and mitochondrial (mt) DNA, sampled from over 60 *Lycaeides* populations. The microsatellite DNA data support the treatment of the Karner blue as a distinct evolutionary unit (coherent taxon). Genetic distances based on DNA among taxa in this genus were small relative to the differentiation in morphological and ecological traits. Microsatellite allele frequency data indicate that the Karner blue population is a well defined, closely related group, distinct from other *Lycaeides* taxa. Indeed, microsatellite data indicate that the Karner blue is the most clearly defined of the North American *Lycaeides* taxa**.**

The morphology of *Lycaeides* male genitalia indicated that while other forms of *L. melissa* are more variable (as Nabokov noted), there was no diagnostic distinction between them and the Karner blue. These data support the treatment of *L. melissa* as a distinct taxonomic unit. They do not refute the indications of the microsatellite data that Karner blue is a clearly defined taxon, but they cannot be used to support the concept either.

In contrast, mtDNA variation found by Nice et al. (2000) was inconclusive. These data did not support the concept of *L. melissa* or the Karner blue as a coherent taxonomic unit, and cannot be used for inferences about the genetic distinctions among populations of the Karner blue butterfly. The Wisconsin and Minnesota Karner blue populations share mtDNA haplotypes with populations of *L. melissa* and *L. idas* in the western U.S. Two unique haplotypes were found in Karner blue populations east of Lake Michigan (i.e., Indiana, Michigan, New York, New Hampshire), but haplotypes associated with European species were also related to these eastern populations. The mtDNA haplotype data suggest that there may have been movement of haplotypes among *Lycaeides* species and among *L. melissa* subspecies (Nice et al. 2000). [However, use of these mtDNA data for making any taxonomic inferences, including inferences about gene movement is limited by the small sample size from some of the sites (one sample each from Minnesota and Michigan) and limited number of base pairs analyzed (Robert Zink, University of MN, pers.comm. 2002).]

Taken as a whole, the genetic, morphological, ecological, and life history data support treating the Karner blue as a coherent taxon, with taxonomic affinities to both the *L. melissa* and *L. idas* groups. Karner blue butterfly populations are distinct from other nearby *Lycaeides.* They are bivoltine, dependent on *Lupinus perennis* (wild lupine), and possess distinct wing pattern elements. In addition, there is no evidence of morphological intermediacy in the Karner blue populations sampled (Chris Nice, pers. comm. 2002).

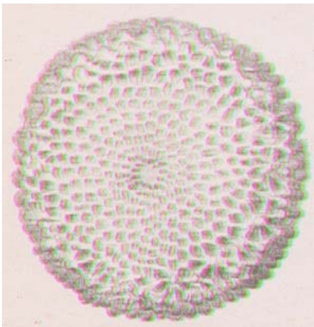
While additional genetics work, done with larger sample sizes, additional sample sites, and more analyses of nuclear and mtDNA may be helpful to further determine if *Lycaeides melissa samuelis* should be divided into two or more subspecies, such work is considered a low recovery priority for the reasons noted above.

Description

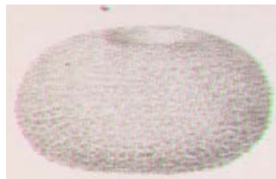
Figure 1 depicts the various life stages of the Karner blue. Karner blue butterflies are small with a wingspan of about 2.5 cm. (one inch). The forewing length of adult Karner blues is 1.2 to 1.4 cm for males and 1.4 to 1.6 cm for females (Opler and Krizek 1984). The wing shape is rounded and less pointed than *L. m. melissa*, especially in the female hind wing (Nabokov 1949). The upper (dorsal) side of the male wing is a violet blue with a black margin and white-fringed edge. The female upper side ranges from dull violet to bright purplish blue near the body and central portions of the wings, and the remainder of the wing is a light or dark gray-brown, with marginal orange crescents typically restricted to the hind wing. Both sexes are a grayish fawn color on the ventral side. Near the margins of the underside of both wings are orange crescents and metallic spots. The black terminal line along the margin of the hind wing is usually continuous (Klots 1979, Nabokov 1944). Nobokov (1944, 1949) believed that male genitalia were the most reliable character for distinguishing adult *L. m. samuelis* from other subspecies (and species). The work of Nice et al. (2000) however, did not find the morphology of the male genitalia to be a good diagnostic characteristic.

The eggs of Karner blue are tiny and radially symmetric, about 0.7 mm in diameter, somewhat flattened, and pale greenish-white in color (Dirig 1994). The surface is deeply reticulated with a fine geometric pattern (Scudder 1889). Larvae are a pea-green color, pubescent and dorsally flattened, with a brown-black to black head capsule. The head is often not visible as it is tucked under the body. Older larvae have pale green (to white) lateral stripes, and a dark-green longitudinal stripe dorsally. In pre-pupal larvae, the lateral stripes become less distinct and the color becomes a duller green. Larvae have four instars (larval development stages) (Savignano 1990), and three glandular structures that are known to mediate interactions with ants in other species of Lycaenidae (Refer to PART I, LIFE HISTORY AND ECOLOGY, Associated Ants, and Savignano 1994a and references therein). Some of these glandular structures mediate interactions with ants in Karner blue, but it is not known what is secreted by any of the structures and if any of the structures are active throughout larval life.

Figure 1. Life stages of the Karner blue butterfly



Egg, top view
[-------------------------]
0.7mm



Egg, side view

Egg on lupine

Larva on lupine

Larva tended by ant
Larval feeding damage on lupine

Pupae on lupine

Adult Female

Adult Male

Photo credits. Drawings of eggs from Scudder (1889); Karner blue larvae tended by ant courtesy of the Wisconsin DNR, all other photos courtesy of Paul Labus, The Nature Conservancy, Whiting, Indiana (refer also to:
http://nature.org/wherewework/northamerica/states/indiana/preserves/art9126.html
for additional images).

Ants are known to tend larvae during their larval stage (Figure 1). Pupae are bright green and smooth, changing to a light tan with hints of purple shortly before emergence when the adult cuticle separates from the cuticle of the pupal case.

Distinguishing Karner blue from similar species

In the eastern United States, the Karner blue butterfly can be confused readily with the eastern-tailed blue (*Everes comyntas*) and less readily with the spring azure (*Celastrina argiolus*) complex (Opler 1992, Scott 1986). Eastern-tailed blues are on average smaller than Karner blue and they have black projections or "tails" on the outer angle of the hind wings (Opler 1992, Scott 1986). These tails may be broken off but usually leave some remnant indicating their former presence. On the underside of the wings, eastern-tailed blues lack orange crescents on the forewing, and four spots, two large and two small, are present on the hind wing (Opler 1992, Scott 1986). It may be difficult to distinguish a large male eastern-tailed blue from a small male Karner blue when they are in flight. Spring azures lack the orange crescents on the undersides of their wings (Opler 1992).

In the Midwest, Karner blue butterflies can be confused with Nabokov's blue (*L. idas nabokovi*), Melissa blue (*L. melissa melissa*), eastern- and western-tailed blues (*Everes comyntas* and *E. amyntula*), Reakirt's blue (*Hemiargus isola*), greenish blue (*Plebius saepiolus*), marine blue (*Leptotes marina*), acmon blue (*Icaricia acmon*), spring azure (*Celastrina argiolus*) complex, and silvery blue (*Glaucopsyche lygdamus*) (Opler 1992, Scott 1986). Species occurrence varies throughout the Midwest and to determine the species present locally, it is best to consult local guides and checklists. Eastern-tailed blue is the only species that is confused readily with Karner blue. Spring azure, silvery blue, Reakirt's blue, and marine blue lack the orange crescents on the under sides of their wings (Opler 1992, Opler and Krizek 1984, Scott 1986). Eastern- and western-tailed blues have tails (as described above), orange crescents are absent on the underside of the forewing, and there are, respectively, four or one orange spot(s) on the hind wing (fewer than Karner blue). The greenish blue has one or more orange marginal crescents, which are, however, much smaller in size than the spots on Karner blue. The marginal crescents on the dorsal side of the male acmon blue hind wing, tend to be more pink than orange (Opler 1992). Melissa blue can be distinguished from Karner blue by the orange banding on the upper (dorsal) side of the forewing (females only), genitalia differences and differential habitat use (Nabokov 1943, 1949, Scott 1986). Melissa blue larvae can feed on *Astragalus* sp., *Glycyrriza lepidota*, *Lupinus* sp., and several other species (Scott 1986). The occurrence of Melissa blue comes closest (30 miles) to Karner blue sites in southeastern Minnesota. The range of Nabokov's blue, *L. idas nabokovi*, overlaps with Karner blue in certain areas, but the Karner blue is typically found in oak and pine savanna/barrens, whereas Nabokov's blue is found primarily in forest clearings (Masters 1972). Also, the two species have different host plants. The Karner blue feeds exclusively on wild lupine (*Lupinus perennis*), and Nabokov's blue feeds on dwarf bilberry (*Vaccinium cespitosum*) (Nielsen and Ferge 1982). Although there are superficial differences in coloration between these two subspecies (Masters 1972), unequivocal identification would require dissection and examination of the male genitalia (Nabokov 1944). Interested readers should consult the cited references for more details.

DISTRIBUTION

Rangewide Distribution of Karner Blues

Historically, the Karner blue butterfly occurred in a geographic band between 41^{o} and 46^{o} North latitude extending from Minnesota to Maine (Dirig 1994) (refer to Figure B-1, APPENDIX B). The butterfly is commonly found on sandy soil types that have populations of *Lupinus perennis* (the only known larval food source), and often inhabits communities similar to oak and pine savanna/barrens communities. In this recovery plan, the term "lupine" will refer to *L. perennis* to the exclusion of all other species of *Lupinus*.

Dirig (1994) reviewed all of the locality records of the Karner blue he could find, whether or not they were confirmed with vouched specimens. His work is an exhaustive summary of the reports of Karner blue occurrence. To establish a definitive historic geographic range, this recovery plan only includes locality records with confirmed specimens. Additional information from Dr. Robert Dirig, requested by the Recovery Team, was especially critical for evaluating records from Pennsylvania, New Jersey, Maine, and Wisconsin. These findings are summarized here and presented in greater detail in APPENDIX B.

The historic northern, eastern, and western limits of the butterfly correspond roughly with the distributional limits of lupine. In all three regions, the present distribution of the butterfly has contracted away from these limits, with extirpations of populations occurring in all three geographic directions. The northernmost population of the Karner blue occurs in the Superior Outwash Recovery Unit (RU) in Wisconsin, the westernmost population in the Paleozoic Plateau RU in Minnesota, and the easternmost population in the Merrimac/Nashua River System RU in New Hampshire (refer to APPENDIX B, Figures B2 and B4).

The historic southern limit of the butterfly did not correspond to the distribution of lupine, which occurred historically much further south than the butterfly. But even here the distribution of Karner blue has contracted away from the historic distribution. The southernmost population of Karner blue is now in the Indiana Dunes RU (refer to APPENDIX B, Figure B3).

As of Fall 2002, extant populations of the Karner blue occur in Indiana, Michigan, Minnesota, New Hampshire, New York, Wisconsin, and Ohio. Reintroductions are currently ongoing in Ohio, at Concord, New Hampshire, and in West Gary, Indiana. Almost all known extant populations occur on sandy soils associated with glacial outwash plains and terraces, glacial moraines, the shores and bottoms of glacial lakes, the glacial shores of existing lakes, and dissected sandstone outwashes (Andow et al. 1994 and references therein, APPENDIX B). Wisconsin and Michigan have the largest number of local populations with the greatest numbers of individuals; New York has one large population (Baker 1994). Many local populations of the butterfly appear extirpated, and the States of Iowa, Illinois, Pennsylvania, Massachusetts, Maine, and the Canadian province of Ontario no longer support populations of the butterfly (Baker 1994).

State Distribution of Karner Blues

This section briefly reviews survey efforts and the distribution of the Karner blue in each state where recovery units (RUs) have been established via this recovery planning process. Survey efforts to identify additional Karner blue sites are continuing in Wisconsin, Michigan and New York, with additional Karner blue butterfly localities identified in all three states since Federal listing of the species. Several of the survey efforts are a result of formal section 7 consultations with Federal agencies including the Department of Defense (Fort McCoy) in Wisconsin and the U.S. Forest Service in Michigan (for forest management activities on the Huron-Manistee National Forest [NF] and for gypsy moth control). For a glossary of terms used in this recovery plan (Plan) refer to APPENDIX A. For information and locations on the 13 RUs and six potential RUs established by this Plan refer to APPENDIX B.

New Hampshire (Merrimack/Nashua River System RU)

No native Karner blue populations remain in New England. The last native population occurred in the Concord Pine Barrens in Concord, New Hampshire, and was extirpated in 2000. That last population, which existed in a powerline right-of-way and the grassy safeways of the Concord Airport had declined from 3,700 estimated butterflies in 1983 (Schweitzer 1983, 1994), to 219 butterflies in 1991, and to less than 50 in 1994, making this site at extreme risk for extinction (Peteroy 1998). A reintroduction program was started in 2001 at Concord, with the donor population coming from the Saratoga Airport in New York (refer to PART I, Translocation/Reintroduction, Captive rearing).

New York (Glacial Lake Albany RU)

The Karner blue butterfly was once common in New York (Cryan and Dirig 1978, Dirig 1994). In the Albany area alone, the Karner blue probably inhabited most of the 25,000 acres of the original Albany Pine Bush, the area from which Karner blues were first described. The Albany Pine Bush area once supported an estimated 17,500 butterflies in one 300 acre site during 1978 (Sommers and Nye 1994). By the mid-1980's, however, much of the Albany Pine Bush had been destroyed by development and degraded by introduction of non-Pine Bush species and natural succession. By 1988, only 2,500 acres of the original 25,000 acres remained (Givnish et al. 1988), and loss of habitat has continued. Current populations number only in the several hundreds (Schweitzer 1994a), and existing habitat continues to undergo succession and degradation.

Additional Karner blue butterfly sites occur in the Saratoga Sandplains and Saratoga West areas north of Albany. The majority of the sites in these areas support less than 100 butterflies. The largest population of the butterfly is at the Saratoga Airport, and is estimated to support 10,000 Karner blue butterflies.

Currently the New York Department of Environmental Conservation (NY DEC) has identified 70 Karner blue localities and 56 subpopulations (using the 200 meter separation criteria for subpopulations, refer to APPENDIX A) in the Glacial Lake Albany RU. Of those, 43 subpopulations are within the three recovery areas: 7 in the Albany Pine Bush, 27 in Saratoga Sandplains, and 9 in Saratoga West. Of these 43 subpopulations, only 15 are anticipated to have more than 10 butterflies in the annual index counts. Eight subpopulations are within the Queensbury Sandplains in Warren County, which is considered a location for recovery under the state's draft recovery plan. Five subpopulations are within Glacial Lake Albany RU, but are isolated from any expected interaction with the sites in the recovery areas. The NY DEC considers a site occupied until at least five years of adequate survey has failed to find the species. Some of the New York subpopulations are extremely small and vulnerable and will be considered extirpated if Karner blues are not found in the next year or two (Gerald Barnhart, NY DEC, in litt. 2002).

Michigan (Ionia, Allegan, Newago and Muskegon RUs)

The Karner blue butterfly is currently found in 10 of the 11 Michigan counties in which it historically occurred. Early surveys by Wilsmann (1994) noted that the Karner blue populations were reduced and highly fragmented. The majority of the Karner blue sites occur on state land (Flat River and Allegan State Game Areas [SGAs]) in the Ionia and Allegan RUs, and on Federal lands (Huron-Manistee National Forest) in the Newaygo and Muskegon RUs.

Survey efforts during 1994-1996 by the Michigan Natural Features Inventory (NFI) of 65 areas within the Ionia RU on public and private lands revealed nine extant Karner blue sites, eight within the Flat River SGA; with the exception of one site, all supported low numbers of butterflies (Cuthrell and Rabe 1996). Based on data through 1998, eight subpopulations (defined as separated by 200 meters of unsuitable habitat) have been identified at the Flat River SGA and 23 at the Allegan SGA. In addition, two other subpopulations occur on private property; one near each of these state properties (Daria Hyde, Michigan NFI, pers. comm. 1998). The Ionia RU is the least well surveyed of all the Michigan RUs with much of the area outside of the Flat River SGA developed for agriculture and other uses (Baker 1994, Wilsmann 1994). The most sizable populations in the state occur at Allegan and Flat River SGAs and most likely on the Huron-Manistee NF (Jennifer Fettinger, pers. comm. 2002).

Many locations in the Newaygo and Muskegon RUs that supported Karner blue butterfly populations 35-40 years ago have been lost to succession, agricultural conversion, forestry, and residential and commercial developments (Wilsmann 1994). The majority of Karner blue sites in these two RUs occur on the Huron-Manistee NF. As of the fall of 2002, a total of 13,792 acres of the Huron-Manistee NF were surveyed for the Karner blue, with butterflies found on 2,026 acres in 267 locations**.** As of 2002, 78 subpopulations (using the 200 meter criteria) were reported on the Huron-Manistee NF; these includes seven along powerline ROWs (Jennifer Fettinger, MI NFI, pers. comm. 2002). In 2002, the Michigan NFI surveyed 58 sites on the Huron-Manistee NF and found the Karner blue at 40 of these sites. Surveys on private lands within the Manistee National Forest boundary have documented an additional 56 localities on about 440 acres (Joe Kelly, pers. comm. 1998, Jennifer Fettinger, pers.comm. 2002). Some utility companies (e.g., Consumers Energy and Wolverine Power Company) in Michigan are surveying their transmission line corridors for Karner blues.

As of the fall of 2002, Michigan, excluding the Allegan SGA, supported 158 subpopulations of Karner blues (based on a 200 meter separation criteria) (Jennifer Fettinger, Michigan NFI, pers. comm. 2002). As noted above, in 1998, Allegan SGA supported 23 subpopulations of Karner blues; this number is currently under revision to reflect 2002 numbers.

Indiana (Indiana Dunes RU)

Historically, the Karner blue was reported from eight counties in Indiana. In 1990, Karner blue butterflies were identified at 10 sites out of 35 potential sites surveyed (Martin 1994). Two population clusters were identified within two counties (Lake and Porter), the majority of which was associated with medium to high quality Karner blue habitat (Martin 1994). The early surveys in Porter County (which includes the National Park Service's Indiana Dunes National Lakeshore [IDNL]) identified between 1,000 and 10,000 second brood Karner blue adults (Baker 1994). In Lake County, at the IDNL, several thousand second brood adults were estimated (Schweitzer 1992), and in other Lake County sites, the subpopulations likely number between 100-500 (John Shuey, The Nature Conservancy (TNC), pers. comm. 1998).

Currently it is estimated that 17 subpopulations of Karner blues (using the 200 meter separation criteria) occur at IDNL (Ralph Grundel and Noel Pavlovic, U.S. Geological Survey (USGS), pers. comm. 1998). In West Gary, about 21 tracts clustered into 11 individual preserves and management areas have been identified as potentially able to at least periodically support the Karner blue (Shuey, undated); these sites are associated with a remnant dune and swale complex. In 1998, four of these tracts supported Karner blues (John Shuey, pers. comm. 1998); however, by 2000, Karners were gone from all four sites. In 2001, a reintroduction project was started to restore Karner blues to West Gary (refer to PART I, Reintroduction/Translocation, Captive rearing)

Wisconsin (Morainal Sands, Glacial Lake Wisconsin, West Central Driftless, Wisconsin Escarpment and Sandstone Plateau and Superior Outwash RUs)

The Wisconsin Department of Natural Resources (WDNR) began systematic statewide surveys for the Karner blue in 1990 including surveys of 33 of the 36 known historic butterfly sites. Initial surveys by Bleser (1993) reported that only 11 of the 33 historical sites supported Karner blues, and also identified 23 previously unknown sites. Additional survey efforts were subsequently conducted by the Wisconsin DNR, the U.S. Fish and Wildlife Service (Service) [Trick 1993, Necedah National Wildlife Refuge (NWR)], Fort McCoy (Leach 1993), and other biologists (Swengel 1994, Bidwell 1996). By 1993, an estimated 150 to 170 discrete Karner blue sites were documented in Wisconsin (Baker 1994). In recent years, additional surveying has been done by partners to the Wisconsin Statewide Habitat Conservation Plan for the Karner Blue Butterfly (HCP) including eight county forest departments, several private forest and utility companies, The Nature Conservancy, and the Wisconsin Department of Transportation. Partners to the HCP routinely survey for the butterfly prior to conducting management activities in an effort to avoid adverse impacts to the Karner blue. In addition, partners monitor for Karner blues annually as part of the HCP effectiveness monitoring program coordinated by the Wisconsin DNR.

Two separate but related sources of data on the Karner blue and its habitat in Wisconsin currently demonstrate that Karner blue butterfly populations in Wisconsin are numerous and widely distributed across the state. As of April 2002, Wisconsin DNR's Natural Heritage Inventory (NHI) database noted 311 Karner blue butterfly occurrences (using a one-half mile separation criteria) across 20 counties in Wisconsin. This reflects an 815 percent increase in recorded NHI Karner blue occurrences since listing. Similarly, the HCP annual monitoring program has documented 256 Karner blue occupied sites as of December 2002 on HCP partner lands, reflecting a 241 percent increase in Karner blue occupied sites on partner lands between 1998 and 2002 (Darrell Bazzell, WDNR, in litt. 2002). Most of the 256 Karner blue occurrences on partner lands are a subset of the NHI data (i.e. included in the 311 NHI occurrences), although further analyses is necessary to determine if some of these sites are new NHI occurrences (greater than 1/2 mile from an existing occurrence).

The number of known lupine sites on HCP partner lands in Wisconsin has also increased. About 252,299 acres of land (WDNR 2002a) are covered by the HCP, and partners implement measures that contribute to the conservation, and in some cases, recovery of the butterfly on these lands (WDNR 2000) (not all this acerage supports Karner blues). In 1998, there were 90 identified lupine sites on shifting mosaic (i.e. forestry) habitat that contained at least 25 plants or clumps of lupine at a density of 50 lupine plants/acre, or 25 lupine plants/200 meters for linear sites (e.g., rights-of-way). Annual HCP monitoring since 1998 has identified an additional 220 sites containing lupine, bringing the total to 310, an increase of 244 percent from 1998 to 2002. In addition, approximately 1,600 identified long-term habitat (e.g. barrens, rights-of-ways) sites in Wisconsin contain lupine.

Taken as a whole, the data demonstrate that of all the states, Wisconsin has the most numerous and widespread Karner blue occurrences, and that the butterfly is likely to be more stable in Wisconsin than previously believed (additional detailed review of HCP monitoring data is needed to further assess this possibility). In addition, there are many thousands of acres of suitable or potentially suitable habitat for the Karner blue in Wisconsin especially on HCP partner lands. The data strongly suggests that future monitoring will continue to identify new occupied Karner blue occurrences as well as additional suitable habitat in Wisconsin. For these reasons it appears appropriate for the Recovery Team to thoroughly review the data on the distribution, status, and threats to the butterfly in Wisconsin and to re-evaluate the recovery goals and criteria for the state, and if appropriate, to revise the goals as warranted. A recovery task has been added to this plan to that effect (refer to PART II, RECOVERY TASKS, Task 6.3).

Most of the Wisconsin subpopulations can be lumped into about 15 large population areas, many of which are found on sizable contiguous acreages in central and northwest Wisconsin (WDNR 2000). At least one sizable population occurs in each of the five Wisconsin recovery units (refer to APPENDIX B). Some of the largest Karner blue populations are found at Necedah NWR, Fort McCoy, Glacial Lake Grantsburg Work Unit [which includes Fish Lake and Crex Meadows State WAs], Eau Claire County Forest, Jackson County Forest, and Black River State Forest. Some larger populations occur on HCP partner lands.

Minnesota (Paleozoic Plateau RU)

Karner blue butterflies currently only occur at the Whitewater Wildlife Management Area (WMA) in southeastern Minnesota. Two to possibly five small local populations are located in a 1770-acre expanse of poor to high quality oak savanna at the WMA. Translocation of butterflies into an unoccupied site was initiated in 1999 and was repeated in 2000 and 2002. Some success of this effort was evidenced by the discovery of butterflies during the first flight in 2001, thus indicating over-wintering survival (refer to PART I, CONSERVATION MEASURES, Reintroduction/Translocation).

Permanent transect counts conducted at two sites since 1992 (Cuthrell and Historic Sites) recorded peak second flight counts ranging from 0.63 to 4.00 butterflies per 1,000 square meters of transect (mean = 1.40) at the Cuthrell Site, and from 0 to 1.33 butterflies per 1,000 square meters of transect (mean = 0.60) at the Historic Site. These numbers represent relative abundance, and the relationship between numbers counted and total population size is unknown but is probably linear (Lane 1999a, Edwards 2002). Because other butterfly monitoring research has shown that only a portion of the butterflies in a sample area are counted and that in this case only a fraction of each site is surveyed, population numbers are considerably greater than the observed transect count numbers.

There are other locations in the southeastern and east-central part of the state that formerly supported lupine. The only other known location to have supported the Karner blue butterfly in Minnesota is the Cedar Creek Natural History Area (CCNHA). Surveys of 50 potentially suitable sites in Minnesota (oak savanna with sandy soil and lupine) revealed that many lupine sites were no longer present and that Karner blues had been extirpated from the CCNHA site (Lane and Dana 1994).

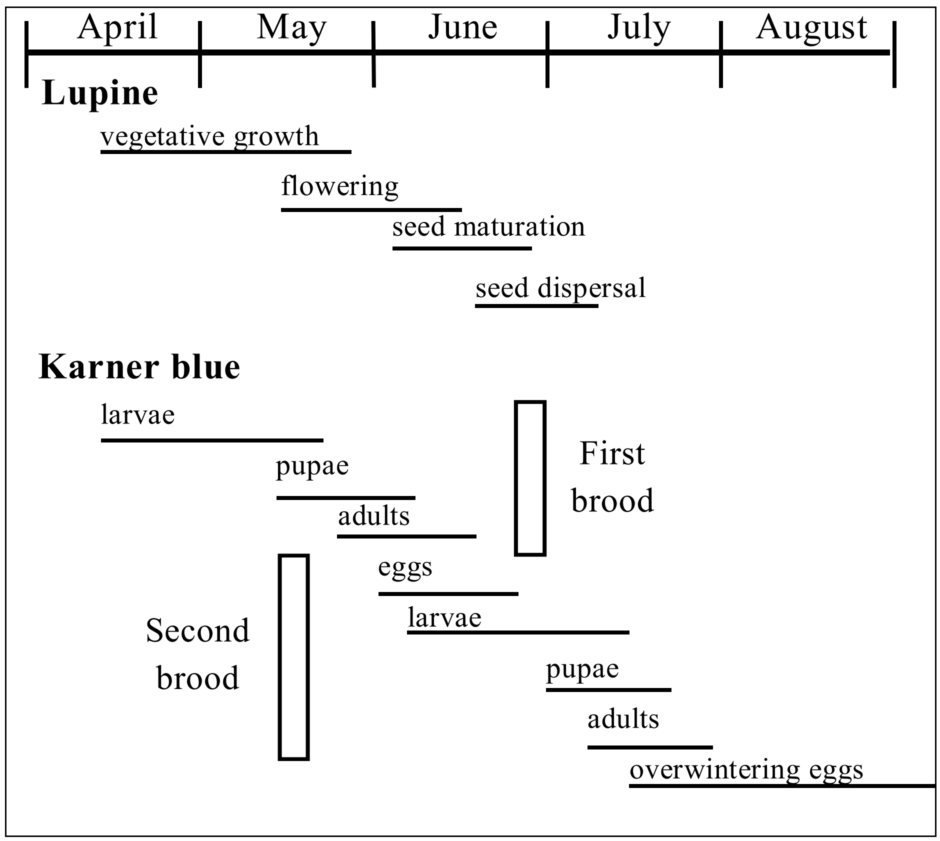
LIFE HISTORY AND ECOLOGY

Karner Blue Butterfly

The life history of the Karner blue butterfly has been studied by Scudder (1889), Dirig (1976, 1994), Cryan and Dirig (1978), Savignano (1990), Swengel (1995), Swengel and Swengel (1996, 1999, 2000), and Lane (1999b). The Karner blue butterfly is bivoltine, which means that it completes two generations per year (Figures 2 and 3). In typical years, first brood larvae (caterpillars) hatch from overwintered eggs in mid- to late April and begin feeding on wild lupine (*Lupinus perennis*), the only known larval food source (Figure 2). Larvae pass through four instars (developmental stages), between which the relatively soft larval exoskeleton is shed. Feeding by first and second instar larvae results in tiny circular holes in the lupine leaves while older larvae eat all but the upper or lower epidermis, creating a characteristic window-pane (Figure 1) appearance (e.g., Swengel 1995). Larvae feed for about three to four weeks and pupate (transform from larvae to adult) in late May to early June. Ants commonly tend larvae (refer to PART I, LIFE HISTORY AND ECOLOGY, Associated Ants). Mature larvae enter a wandering phase, after which the pre-pupal larvae attach themselves to various substrates with a silk thread. Karner blues are known to pupate in the leaf litter, on stems and twigs, and occasionally on lupine leaves (Dirig 1976, Cryan and Dirig 1978). Dirig (1976) reported that pupation generally lasted seven to eleven days in the field. Laboratory-reared pupae typically took seven to nine days, and sometimes up to eleven days before emerging as adults (Savignano 1990, Herms et al. 1996). First flight adults begin emerging in late May with the flight extending through late June (Swengel and Swengel 1996). At peak flight the sex ratio typically exceeds 50% males. The Swengels (1996) have reported 70 percent males at peak flight. The percent males decrease as the flight period progressess (Leach 1993, Swengel and Swengel 1996). Adults are believed to live an average of four to five days but can live as long as two to three weeks. First flight adult females lay their eggs primarily on lupine plants, often singly on leaves, petioles, or stems, or occasionally on other plants or leaf litter close to lupine plants.

Second brood eggs hatch in five to ten days, and larvae can be found feeding on wild lupine leaves and flowers from early June through late July. Typically, a larva can survive on one large lupine stem; however, the larva moves from leaf to leaf on the lupine stem, often returning to leaves fed on during earlier instars, and it may even move to other lupine stems (Lane 1999b). Larvae are found often on the lower parts of the stems and petioles. Ants also typically tend second brood larvae, but during midday on hot days tending may be reduced. Pupae are also frequently tended by ants (Cynthia Lane, pers. comm**.** 1997). Refer to Figure 1 which depicts the different life stages of the Karner blue.

Figure 2. Phenology of the Karner blue and lupine. In colder (warmer) areas and years phenologies will be delayed (advanced).



Second brood adults begin to appear in early to mid-July and fly until mid to late August, and in some years into early September (Swengel and Swengel 1996). Flight phenology may be delayed because of cool wet summers and result in an adult flight period lasting through late August (Cathy Bleser, pers. comm. 1995; Cynthia Lane, pers. comm. 1995). The peak flight period usually lasts one to two weeks. Generally, there are about three to four times as many adults in the second brood compared with the first brood (Schweitzer 1994b). Maxwell and Givnish (1994) surveyed Karner blue populations at 46 locations at Fort McCoy, Wisconsin, during 1993; they found that locations with high first flight butterfly counts also had high second flight counts ($r^2 = 0.674$) and that populations were three to four times as abundant during the second flight. However, the pattern is highly variable, and in some years, the second brood is not larger than the first brood (Swengel and Swengel 1996). The first brood is usually smaller most likely due to high overwintering mortality of eggs, the inability of larvae to find lupine in the spring, or greater oviposition success of first-flight females.

It is important to note that there is a significant amount of annual variation in adult abundance relative to peak flight date and in brood timing and length among years (Swengel and Swengel 1996, 1999). Based on extensive survey data, the Swengels (1999) suggest four kinds of variability to consider when assessing the butterfly's phenology: "1) inter-generational fluctuations in abundance, 2) phenological differences among years and 3) among sites, and 4) inter-annual variation in span between spring and summer generations."

Second flight females usually land on green non-senesced lupine, crawl down the stem, and lay eggs primarily on grasses and sedges, other plant species, leaf litter near lupine stems, and occasionally on lupine (Lane 1999b). In general, insects that overwinter in the egg stage often lay their eggs on various materials close to the ground because these sites afford better winter protection (Bernays and Chapman 1994). The eggs laid by second flight females are the overwintering stage (evidence summarized by Haack 1993), and studies by Spoor and Nickles (1994) and VanLuven (1993, 1994a) provide strong experimental evidence of this phenomena. Spoor and Nickles (1994) observed second brood eggs through November and determined hatching rates of these eggs the following spring. Researchers in New Hampshire and Wisconsin have successfully overwintered eggs for rearing experiments (VanLuven 1993, 1994a; Curt Meehl, University of Wisconsin-Stevens Point, pers. comm. 1997).

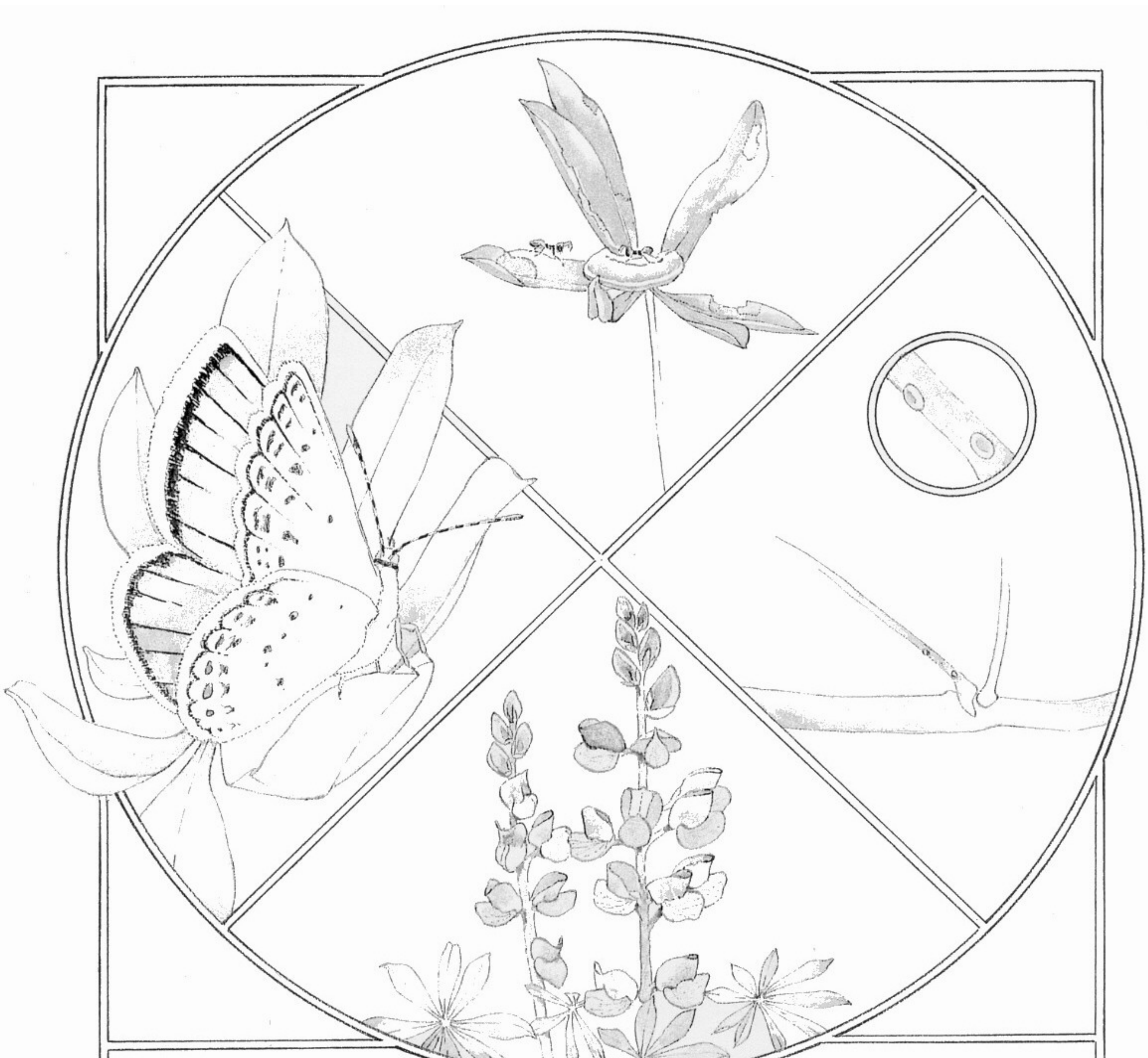
Karner blue adults are diurnal and initiate flight between 8:00-9:00 a.m. and continue until about 7:00 p.m. [although they have been observed flying as early as 6:51 a.m. by Swengel and Swengel (1996)], a longer flight period than most butterflies. Butterflies become more active with increasing temperature and/or sunshine (Swengel and Swengel 1998). Adult activity decreases at temperatures lower than 75^{o} F, and during heavy to moderate rains (Haack 1993).

Lupine Food Resource

Lupinus perennis is a member of the pea family (Fabaceae) and has the common names wild lupine and blue lupine. Lupine is the only known food plant of larval Karner blues and is an essential component of its habitat. Two varieties have been identified: *Lupinus perennis* var. *occidentalis* S. Wats. and *L. perennis* var. *perennis* L. (Ownby and Morley 1991). The varieties are morphologically similar except the former has spreading pilose hairs and the latter thinly pubescent hairs (Boyonoski 1992). The Karner blue may use both varieties, but the details of the interaction are not known. The inflorescence is a raceme of numerous small flowers which are two lipped, with the upper lip two-toothed and the lower lip unlobed. Flower color ranges from blue to violet and occasionally white or pink (Gleason and Cronquist 1991). Peak bloom typically occurs from mid-May to late June within the geographic range of the Karner blue, but varies depending upon weather, degree of shading, and geographic location in its range. Stem density and flowering is greatest in open- to partial-canopied areas (Boyonoski 1992), and in greenhouse studies lupine were larger in full light conditions (Greenfield 1997). However, areas receiving high solar radiation can have low lupine densities and may be less than ideal habitat (Boyonoski 1992). Plants in dense shade rarely flower.

Lupine distribution extends from Minnesota east to New England, then southward along the eastern Appalachian Mountains to southern Virginia and along the eastern coastal plain to Georgia wrapping around the Gulf coastal plain to Louisiana (Dirig 1994). Surveys of lupine throughout its northern range report populations to be declining and many sites have been extirpated (Cuthrell 1990, Boyonowski 1992, Grigore 1992). The primary cause of this decline appears to be loss of habitat from conversion to housing, retail, light industrial, and agricultural development, and degradation of habitat because of the deep shade that develops when disturbance is interrupted. *Lupinus perennis* is state-listed as threatened in New Hampshire.

Figure 3. Illustration of life history stages of the Karner blue.



Karner Blue Butterfly Life History: The Karner blue butterfly produces two broods of young each year, a spring brood and a summer brood. Larvae emerge in April from eggs that have overwintered and feed on wild lupine, Lupinus perennis, the only known larval food plant of the butterfly. The larvae are often attended by ants, which collect a sugary solution secreted by the larvae, and in turn may protect the larvae from predation and/or parasitism. Near the end of May, the larvae pupate and adults emerge in late May or early June. The butterfly then mates and lays eggs on the lupine plant. The second brood of butterflies emerge mid-July to early August. Their eggs overwinter to hatch again in April.

DAVID KOPITZKE 1992

Lupine abundance and Karner blue

Management for sufficient lupine is critically important for the Karner blue, because it is the only food plant for the larvae. Significant increases in the abundance of lupine will usually not be detrimental to the Karner blue, and may in many cases be beneficial. Lupine, however, is not the only factor limiting Karner blue butterfly subpopulations, and it is important to manage for additional factors important to the butterfly.

A positive association between lupine abundance and Karner blue abundance or persistence would indicate that lupine abundance could be a factor limiting Karner blue populations. Several researchers have found a positive correlation between lupine abundance and number of Karner blue butterfly adults in New York, Michigan, and Wisconsin (Savignano 1994b, Bidwell 1995, Herms 1996, Smallidge et al. 1996, Swengel and Swengel 1996, Lane 1999). In Wisconsin, lupine abundance and proximity to the middle of a large lupine population were correlated with adult Karner blue abundance (Swengel and Swengel 1996). Savignano (1994b) found a significant correlation between Karner blue numbers and the number of lupine rosettes in New York studies. At one site with abundant lupine but few butterflies, Savignano (1994b) suggested that a dearth of nectar plants limited the butterfly. Herms (1996) found a significant positive correlation between lupine density and Karner blue abundance at the Allegan SGA in Michigan.

The reproductive status of lupine was found to be a key in explaining butterfly numbers at Fort McCoy, Wisconsin, where Maxwell (1998) found significantly greater second brood larval densities in shady plots which had a higher proportion of non-reproductive lupine. Second brood adult abundance increased with the frequency of non-reproductive lupine plants, but declined with increasing cover of flowering plants. Maxwell (1998) also detected that lupine plants in open areas, which tended to be reproductive, senesced earlier than those in shaded areas and suggested that early senescence could result in larval starvation. However, the study year (1995) was particularly hot and studies by Lane (1999) suggest that in most years larvae are able to reach pupation before lupine senesces. In addition to the influence of lupine abundance on the Karner blue, it is important to consider lupine quality (refer to Lupine quality and the Karner blue below).

Lupine was not a good predictor of Karner blue abundance in Minnesota. Lane (1994a, 1999b) found that of her study sites, the site with the densest lupine did not support Karner blues; however, this site was over 2.5 kilometers (1.6 miles) from occupied habitat. Lawrence (1994) and Lane (1994a, 1999b) suggest that other factors, such as microhabitat might influence the butterfly's population dynamics.

Lupine abundance at a site may vary temporally within a year or between years. Late emergence or early senescence of lupine might result in larval starvation, although Swengel's (1995) field observations suggest that larval and lupine phenology are well synchronized even in years with delayed lupine appearance. The timing of lupine senescence varies with canopy cover and annual weather. Lane (1994b) observed that second brood larvae disappeared from lupine that senesced early. These individuals probably died because lupine density was low, and successful dispersal to another plant was improbable. Maxwell (1998) suggested that the shadiest lupine patches serve as “nurseries” for second brood larvae due the greater availability of non-reproductive lupine, which are not as susceptible to mildew and remain green throughout the larval stage.

It is unlikely that a single factor, such as the density of lupine, would account for variation in abundance of the Karner blue throughout its range. In places where it does, however, such as in the Glacial Lake Albany RU in New York, and at Fort McCoy, Wisconsin, it suggests that Karner blue populations might be enhanced by increasing the amount of lupine available. In localities where there is a poor correlation between lupine abundance and adult Karner blues, such as in the Paleozoic Plateau RU in Minnesota, and possibly, the Allegan SGA in Michigan, other factors may be important such as lupine quality, microhabitat, and distance from the nearest occupied site.

Lupine quality and the Karner blue

Variation in plant quality, as influenced by nutrient composition, secondary plant chemistry, morphology, and other factors can have significant effects on Lepidoptera (Bernays and Chapman 1994). *Lupinus* species have secondary plant compounds, typically alkaloids, that influence lupine’s suitability as insect food. Levels of alkaloids in *Lupinus* species vary with plant part and are highest in reproductive parts and the epidermis (Bernays and Chapman 1994). In addition, habitat differences in sun and shade may affect host plant quality by influencing host plant nutrients, secondary plant compounds, phenological state, and/or physical condition (Mattson 1980, Waterman and Mole 1989, Dudt and Shure 1994, Ravenscroft 1994).

Laboratory and field feeding studies have shown that the quality of lupine as larval food is affected by growing conditions (Grundel et al. 1998a, Maxwell 1998, Lane 1999). Grundel et al. (1998a) tested the effects of nine types of lupine on larval growth and survival. Lupine type was based on several factors including: age, reproductive/phenological status (non-flowering, flowering, seed, and senesced), percent canopy cover where lupine was growing, water status, presence of powdery mildew, and soil type. These laboratory feeding studies demonstrated that larvae fed leaves from shade grown plants that had gone to seed grew faster than larvae fed leaves from sun grown plants that had gone to seed (Grundel et al. 1998a). Lane (1999) also conducted laboratory feeding studies, using six lupine types, and found that larvae fed sun grown lupine in seed had the lowest survival rates of the lupine types tested (Lane 1999). Results from these studies are significant because during the second brood larvae feed extensively on leaves from plants that have gone to seed.

Larvae fed wilted lupine took significantly more days to pupate than larvae fed all other lupine types (Lane 1999). Grundel et al. (1998a) found that water stressed lupine was one of four types of lupine that produced slow larval growth rates. Lane (1999) also observed a lower percent survival to pupation for larvae fed wilted leaves than for three of the six other lupine types tested.

Faster growth rates are often advantageous to immature stages as they are then vulnerable to parasitism and predation for a shorter period of time. For Karner blue larvae, faster growth rates for second brood larvae may offer the additional benefit of allowing larvae to complete their development before lupine plants senesce (Grundel et al. 1998a).

During field studies, Maxwell (1998) counted a greater number of larvae on non-flowering lupine than on reproductive lupine. In addition, summer brood adult abundance was positively associated with the frequency of non-flowering lupine and negatively with the frequency and density of reproductive lupine.

The quality of lupine as a larval food plant does not appear to be affected by whether the soil is predominately sand or one with an organic O and A horizon (Grundel et al. 1998a). However, because lupine abundance and reproduction on sandy soils can be low (N.B. Pavlovic and R. Grundel unpublished data), selecting sites where soils have greater organic content will be important if increasing lupine abundance is a primary management goal.

Studies have also examined the influence of powdery mildew, a common leaf disease, on lupine quality. Maxwell (1998) counted the number of lupines with larval feeding damage and found less larval feeding where the proportion of lupine infected with powdery mildew was the greatest. However, although feeding intensity may be lower in these areas, laboratory feeding studies by Grundel et al. (1998a) found that larvae grew faster when fed leaves with large scale infections of powdery mildew than similar plants without such an infection.

Fire may also influence lupine quality. Maxwell (1998) observed a fire-mediated improvement in lupine quality that was reflected in a significantly greater abundance of second brood larvae on burn plots.

In general, field and feeding studies suggest that lupine grown in partial to closed subhabitats provide a superior food source for Karner blue larvae, especially during the second annual brood of larvae. Female Karner blues have been observed ovipositing relatively more frequently in moderately shaded areas than in open areas where lupine is most abundant (Grundel et al. 1998b). The growth advantage of eating shade-grown lupine may explain this relative overuse of shaded areas by ovipositing females and larvae. Nonetheless, although lupine quality may be superior in areas with shade, the larger quantity of lupine in openings at some sites may result in a greater total number of butterflies produced from open subhabitats (Lane 1999). Therefore, a mixture of sun and shade across the landscape can increase the viability of Karner blue populations by providing for a tradeoff between lupine quality and quantity.

Lupine growth, reproduction, dispersal, and propagation

Lupine reproduces vegetatively and by seed. Seedpods have stiff hairs with an average of 4-9 seeds per pod (Boyonoski 1992). When seedpods are dry, they suddenly twist and pop open (dehisce), throwing seeds several feet. Dehsicing is the only known dispersal mechanism and Celebrezze (1996) suggests that lupine colonization would be very slow, about 0.5 to 2 meters (20 to 79 inches) per year. Alternatively, these results may imply that there is another unidentified dispersal agent. Seeds are known to remain viable for at least three years (Zaremba et. al. 1991), do not have a physiological dormancy, and will readily germinate if moisture and temperature conditions permit. The hard seed coat produces an effective dormancy, and germination is usually enhanced by scarification, stratification, and/or soaking in water (Boyonoski 1992, Zaremba and Pickering 1994) (Bob Welch, Waupaca Field Station, pers. comm. 1995).

Lupine also reproduces vegetatively by sending up new stems from rhizomatous buds. Usually, plants a few years old will form a clump of several stems and in areas with dense lupine, it is difficult to distinguish individual lupine plants. Established lupine plants do not grow every year. It is not known how long established plants can remain dormant.

Lupine can be propagated by planting seed or transplanting seedlings. Direct germination from seed appears to result in higher first-year survival than seedling transplants (VanLuven 1994b, Zaremba and Pickering 1994). Seedling establishment from seed in New Hampshire was between 3-43 percent in the first year, and survival of seedlings was about 50-60 percent per year (VanLuven 1994b). Large quantities of seed will be necessary to establish dense stands of lupine in this area. Welch (pers. comm. 1994) established lupine patches with over 5,000, 8,500, and 17,500 seedlings, two to four months old, and uncounted numbers of seeds near Waupaca, Wisconsin. The patches were established successfully, but no data are available on survival. Maxwell and Givnish (1994) established lupine by direct seeding in experimental plots in 1993. Although soil preparation was homogeneous, lupine establishment was better in the compacted subsided soils associated with an old trail. This area had less vegetative cover, and the lupine was growing in association with *Cycloloma atriplicifolium* (pigweed), which may have protected it from deer browsing. During the dry 1995 season, *C. atriplicifolium* was absent and lupine on this trail developed faster and senesced earlier than the surrounding lupine, and lupine cover was greater where the seeded perennial grasses had established the best (Maxwell and Givnish 1996). These observations suggest that nurse plants may be useful for establishing lupine.

<u>Renewal of lupine habitat</u>

Lupine is an early successional species adapted to survive on dry relatively infertile soils. Even the seedlings have long taproots that presumably allow the plant to reach soil moisture. It can grow on soils low in nitrogen because of its association with the nitrogen fixing bacterium *Rhizobium lupina*, and does not do well when grown without *R. lupina* (Zaremba and Pickering 1994). Similar to other legumes, it probably does best when growing on nitrogen-poor soils that have sufficient phosphorus. Lupine does not reproduce in dense shade. All available evidence suggests that lupine thrives on nitrogen-poor soils in partial- to open-canopied areas, and is suppressed by shade; it is possibly out-competed by other plants on nitrogen-rich and phosphorus-poor soils.

Based on Greenfield's (1997) work, lupine growing under trees may benefit from the lower pH levels caused by tree leaf litter. However, while lupine appears to benefit from association with trees (Boyonoski 1992, Greenfield 1997), without periodic disturbance to reduce tree cover, light levels under the canopy may become too low to support lupine growth.

Several species of pines, oaks, and shrubby vegetation are adapted to the same soils and habitat as lupine (Nuzzo 1986, Haney and Apfelbaum 1990), and without disturbance, these species will close the canopy, shading and suppressing lupine (Haney and Apfelbaum 1990, Apfelbaum and Haney 1991). The rate of closure will vary from locality to locality, based on edaphic and prevailing climatic conditions, and current and historic management practices. If the habitat supports high grass and sedge productivity, litter could build up and suppress lupine. 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. Several disturbances have been suggested to be beneficial for renewing lupine habitat, including prescribed fire, mowing, tree removal, and a variety of methods to kill trees and shrubs such as girdling and brush-hogging (Swengel 1995, Swengel and Swengel 1996, Smallidge et al. 1996, Maxwell 1998). Frequency of management treatment to reduce woody cover is an important consideration. Smallidge et al. (1996) found that infrequent removal of woody stems often resulted in an increase in woody plant density and suggested the use of frequent mechanical treatment or a seasonally timed application of an appropriate herbicide (refer to APPENDIX G)

<u>Other factors affecting lupine</u>

Mechanical disturbance of the soil can affect lupine. Research at Fort McCoy has demonstrated that military training activities appear to be beneficial to the Karner blue (refer to PART I, HABITAT/ECOSYSTEM, Renewal of Habitat for the Karner blue, <u>Other contemporary habitats</u>).

Lupine is browsed by deer, woodchucks, and insects. The relationship between grazer density, grazing intensity, and Karner blue populations is largely unknown. If deer populations are too abundant in the spring and browse is scarce, excessive browsing could occur on lupine, with potential detrimental effects on the Karner blue (Schweitzer 1994a). Heavy spring flower browse by deer reduces the number of seedpods for that season's lupine (Straub 1994). Transplanted lupine may be less able to recover from being browsed than field sown plants (Zaremba and Pickering 1994). Herbivory by the painted lady butterfly (*Vanessa cardui*) has caused severe defoliation of lupine foliage (Cynthia Lane, pers. comm. 1996), but the potential detrimental effects on the Karner blue are not documented. Lupine species typically contain alkaloid compounds, which are hypothesized to serve as chemical defense mechanisms against herbivory (Dolinger et al. 1973), but the significance of these compounds in the ecology of the Karner blue is not known. Several diseases of lupine are known, but their effects on Karner blue or lupine populations are unknown.

Recolonization or regeneration of lupine to areas that have had closed canopy or little disturbance for long periods may be reduced or even absent after disturbance. Sferra et al. (1993) used cutting and burning to restore savanna structure in Michigan but did not see increases in lupine abundance possibly because no plants or seeds were present on the site to regenerate, and because lupine was not able to recolonize. Celebrezze (1996) found less lupine on cultivated/homesteaded sites than would be expected. Also, no long distance dispersal mechanism is known for lupine. Celebrezze's (1993) work suggests that lupine might only move 0.5 to 2 meters per year. Without active disturbance/seeding regimes, lupine could undergo gradual elimination due to very slow reinvasion following local extirpation. There is concern that lupine habitat lost due to maturation of red pine stands may not be able to regenerate after harvest [refer to Recovery Task 5.25(d)].

Nectar Food Resources

Adult Karner blue butterflies feed at flowers, sipping nectar and presumably obtaining nourishment; adult feeding increases longevity and fecundity in many Lepidopteran species, especially butterflies (Chew and Robbins 1989). Although increased longevity and fecundity have not been specifically demonstrated for the Karner blue butterfly, it is generally agreed that nectar is an essential adult resource. Adult Karner blue butterflies spend considerable time nectaring on a wide variety of plant species (refer to APPENDIX C). Adults have been observed during the first brood to feed on flowers of 39 species of herbaceous plants and 9 species of woody plants, and during the second brood, on flowers of 70 species of herbaceous plants and 2 species of woody plants. Indeed, nectar plant availability may be a key factor in determining habitat suitability (Fried 1987). Lawrence and Cook (1989) suggested that the lack of nectar sources may limit populations at the Allegan SGA in Michigan, and Packer (1994) implicated the dearth of nectar sources as one of the causes of the extirpation of populations in Ontario. Bidwell (1994) found a positive correlation between nectar plant abundance, specifically abundance of *Monarda punctata* (horsemint), and the number of Karner blue butterflies. Other researchers, Herms (1996), and Richard King (USFWS, pers. comm. 1996), did not find a correlation between adult butterfly numbers and nectar plant abundance. Herms (1996) suggested that the lack of correlation between Karner blue and nectar sources could also mean that the minimal requirement for nectar was met and that nectar was not limiting during the years of study. It is generally accepted that nectar plant phenology, presence, distribution, and abundance can vary from year to year on any given site. In addition, absence of correlation might also mean that other factors, such as larval density, are more directly determining adult population numbers.

Some plant species appear to be utilized more frequently than others (Fried 1987, Bleser 1993, Leach 1993, Bidwell 1994, Lane 1994a, Lawrence 1994, Herms 1996). The nectar plant used most frequently in the field may be the one that is spatially or temporally available or most abundant, and not the species that is preferred. Observations of nectaring frequency, however, can indicate the relative utility of the species as a nectar resource. For example, Herms (1996) found that *Asclepias tuberosa* was the most frequently used summer nectar sources two years in a row, but was consistently rare on all sites. Common nectar plant species used by first and second brood Karner blues in Minnesota, Michigan and Wisconsin are summarized in Table 1. A more comprehensive list of nectar plants used by the Karner blue can be found in APPENDIX C, Table C1.

Studies by Grundel et al. (2000) at IDNL suggest that the Karner blue is opportunistic in selecting nectar plants, choosing species with the greatest total number of flowers or flowering heads. However, the studies also showed that the Karner blue preferred certain select nectar species (Table 1) and nectar plants with yellow or white flowers.

In addition to nectaring, males and females sip at moist earth (mud-puddling) and human perspiration, and males sip at animal droppings (Swengel and Swengel 1993). Adults may be obtaining sodium or other substances from this behavior.

Subhabitats

Karner blue adults and larvae use a variety of subhabitats created by variation in tree canopy cover, topography, and soil moisture, and the population dynamics of the butterfly is probably influenced by these factors. Adult butterflies use open-canopied areas for nectaring, roosting, mate location, and oviposition (Packer 1987; Lawrence and Cook 1989; Lawrence

1994; Maxwell and Givnish 1994; Lane 1994a, 1994b, 1995, 1999b; Grundel et al. 1998b). The majority of Karner blue nectar plants require medium to high levels of sun to produce flowers and the adults nectar most frequently in open-canopied areas. The phenology of flower production also varies with subhabitats; therefore, subhabitat diversity may provide a more guaranteed source of nectar. For example, wetlands adjacent to suitable Karner blue habitat at IDNL or Necedah NWR may provide almost unlimited nectar resources. Extremely xeric sites, on the other hand, such as Allegan SGA, may have limited adult nectar resources, which could limit butterfly populations (Lawrence and Cook 1989).

Adults are commonly found in open-canopied areas. In Minnesota, Lane (1994a) classified habitats with lupine or adult butterflies, and showed that adults were found in areas with less than five percent canopy cover. In western Wisconsin, Maxwell and Givnish (1994) collected data on the physical structure of habitat and cover estimates of selected vegetation, and found a positive correlation between adult Karner blue butterfly abundance and grass cover. Because the grass was used as adult roosting sites, they suggested that this indicated the importance of roosting sites for healthy populations of Karner blue. Grass cover may also indicate open canopy on less xeric, slightly more fertile areas of savanna, which could be beneficial in other ways to Karner blue.

Specific adult behaviors are commonly seen in open-canopied areas. Adults have been observed roosting in open- to closed-canopied areas during the day on several woody and herbaceous plant species, but at night adults have been seen roosting in the open on grasses such as big bluestem (*Andropogon gerardii*) (Schweitzer 1989). Male Karner blue butterflies used open habitat areas for nearly 90 percent of their activities - primarily mating and nectaring activities (Grundel et al. 1998b). Males are commonly observed in open areas, and in studies on butterfly movement, Bidwell (1994) frequently observed males flying back and forth through open areas.

Female activity is more spread across subhabitat than male activity. Females have been observed ovipositing (laying eggs) in open- to closed-canopy areas and in a variety of slopes and aspects (Lane 1993, 1994c, 1999b; Grundel et al. 1998b; Maxwell 1998). Females may be ovipositing in open- and partial-canopied areas in response to the greater lupine, nectar plant, and male abundance in these subhabitats. In addition, during periods of cool weather, open and sunlit areas appear to enable butterflies to achieve threshold temperatures needed for flight activity (Lane 1994c, 1999b). Based on experiments that tested the minimum temperatures needed for Karner blue flight and measurements of temperatures in open- and closed-canopy areas, the average number of hours available for first flight females is 10.5 hours in the open versus one to two hours in partial to closed-canopy areas (Lane 1999b). In addition, observations of adult butterflies determined that a greater proportion of females occur in partial- and closed- canopied areas at higher temperatures. Studies also suggest that females were not moving into shaded areas to escape high temperatures (Lane 1999b).

In general, females tend to oviposit in partial to closed subhabitats (Lane 1999). Grundel et al. (1998b) measured an average canopy cover at oviposition sites of 54.8 percent. For spring flight females, a larger number of eggs were laid per lupine stem in partial and closed subhabitats than in open subhabitats (Lane 1999b). However, based on informal adult counts in New York, Karner blue adults did not appear to utilize lupine in heavily shaded areas (Dolores Savignano, pers. comm. 2002). Lupine quality in shaded subhabitats, direct benefits from shade, and avoiding male harassment are all factors thought to contribute to the observed oviposition patterns (Grundel et al. 1998b, Lane 1999). Lupine quality influences on larval growth and survival are reviewed above in the "Lupine quality and Karner blue" section.

The direct effects of shade have been shown to contribute to higher larval survival rates in field studies (Lane 1999b). In closed-canopied areas, larvae may be more protected from temperature extremes, wind and rain, and/or natural enemies. It may be that natural enemies do not inhabit these areas or are less efficient at searching these areas. Although the proportion of older larvae tended by ants has been found to be similar in open- and closed-canopy areas, early instar larvae have been found to be tended more in partial-canopy areas (Lane 1994b). Moreover, Lane (1999b) found tending ant species were different in different subhabitats.

At Fort McCoy during 1995, the summer drought conditions resulted in early senescence of lupine (Maxwell 1998). In open-canopied areas, late-maturing second brood larvae were often seen on completely senesced plants, while in shady areas senescence was delayed. Karner blue populations declined during this generation and were more abundant in the shade suggesting that early lupine senescence may have been the cause. Lupine quality has also been shown to be affected by shade (refer to Lupine quality and the Karner blue).

Another factor influencing oviposition site may be male harassment. Studies by Lane (1999b) indicated that a greater number of females were harassed by males in open- versus closed-canopy areas. The interruption of activity caused by harassment may encourage females to shift to partial- and closed-canopied areas during oviposition.

Egg deposition in a variety of subhabitats may also serve to mitigate physical or biological risks to immature stages (Bidwell 1994, Lane 1994c, 1999b). For example, several researchers have suggested that lupine senescence is earlier in xeric, open-canopied areas and may result in larval starvation, particularly during drought years.

Optimal subhabitat for larval stages contrasts with that used by adults (Savignano 1990; Lane 1994b, 1999b; Grundel et al. 1998a, 1998b; Maxwell 1998). Studies on larvae in Minnesota and Wisconsin found significant differences in larval survivorship between open-, partial-, and closed-canopy areas (Lane 1994b, 1999b). For second brood larvae, survival was highest in closed-canopied areas, intermediate in partial-canopied areas, and lowest in open-canopied and very xeric areas (Lane 1999b). The cause of higher mortality for larvae placed in the very xeric areas is uncertain. However, the lupine often were heavily infested with powdery mildew and the introduced predator, the seven spotted lady beetle (*Coccinella septempunctata*) (Schellhorn et al. unpublished), both of which may have contributed to observed mortality (Lane 1999b). Maxwell (1998) found lupine shaded by shrubs and dense herbaceous cover contributed to the 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.

In summary, mating and adult feeding take place primarily in open-canopied areas. Oviposition occurs in many types of subhabitats, but larval growth and survival may be best in partial- to closed-canopy areas. Small-scale variation in topography and soil moisture could be

Table 1. Nectar plant species used commonly by first and second brood Karner blue butterflies. Percent of all nectaring observations at a locality for all plant species used by more than 10 percent of the observed butterflies.

Plant species — Percent of butterflies nectaring at plant species

First Brood	Locality: MI[1]	WI[2]	WI[3]	WI[4]	WI[5 #]
* + *Arabis lyrata*			50		11
Hedyotis longifolia			14		
Hieracium aurantiacum				56	
Lupinus perennis				29	13
Melilotis offincionalis		16			
* *Potentilla simplex*					35
+ *Rubus flagellaris*	89	19			
Rubus sp.					20

Second Brood	MN[6]	MI[1]	MI[7]	MI[8]	MI[9]	WI[2]	WI[3]	WI[4]	WI[5]
Amorpha canescens						15	39	16	
* *Asclepias tuberosa*		66	40	22					
Asclepias verticillata							11		
Berteroa incana								23	
Centaurea biebersteinii				33	40				
* *Euphorbia corollata*				33					11
Euphorbia podperae						12			
Helianthus occidentalis									13
Liatris cylindracea				11					
*+ *Melilotus alba*						38			
* *Monarda punctata*	91	20	20		60	13	25	13	
Rudbeckia hirta								28	
* *Solidago speciosa*									17

References: 1 = Lawrence 1994, 2 = Leach 1993, 3 = Maxwell and Givnish 1994, 4 = Lane pers. comm. 1994, 5 = Swengel and Swengel 1993, 6 = Lane 1994a, 7 = Papp 1993, 8 = Sferra et al. 1993, Site 1, 9 = Sferra et al. 1993.

Notes: * Species most frequently chosen by Karner blues; also *Coreopsis lanceolata, Rubus spp. and Helianthus divaricatus.* (Grundel et al. 2000).

+ Nectar species preferred by Karner blues at IDNL; also *Coreopsis lanceolata.* (Grundel et al. 2000).

averages based on 4 years of data.

beneficial to Karner blue. A highly variable microtopography creates a highly variable thermal environment and a highly variable plant community and canopy structure. Variation in soil moisture will also contribute to variation in plant community and canopy structure. In addition, variation in plant community and canopy could be beneficial to Karner blue in the long-term. In hot dry years Karner blue can be found using shady moist subhabitats, while in cool years, they are more strongly associated with sunny and partially sunny subhabitats.

Given the different habitat requirements of adult and larval stages, and the relatively low within habitat mobility observed for the Karner blue, it is important that canopy cover subhabitat types be within close enough proximity for butterflies to move easily between them (Lane 1999b) (refer to Within-Habitat Movement and Between-Site dispersal, below).

Associated Ants

Immature stages (egg, larva and pupae) of the Karner blue butterfly have a mutualistic relationship with ants. Larvae tended by ants (Figure 1) have a higher survival rate than those not tended by ants (Savignano 1990, 1994a; Lane 1999b), presumably because the ants provide some protection from the natural enemies of larvae. In addition, laboratory feeding studies have demonstrated that larvae tended by ants grow relatively rapidly and gain weight more rapidly per amount of food eaten (Grundel et al. 1998a). Ants benefit from this relationship by using as food, a liquid secreted from specialized glands on the larvae that contains carbohydrates and possibly amino acids (Savignano 1990).

Tending levels for late instar larvae are close to 100 percent. The percentage of early instar tending varied between studies. Both Savignano (1990) and Lane (1999b) observed that a lower percentage of early instar larvae were tended by ants, while Herms (1996) found all instar age classes to be tended at similar proportions (88 to 92 percent). Herms (1996) suggested that early instar larvae in her studies may have been tended by different ant species than in other studies, and that some ant species may be more likely to tend early instars. Several ant species have been observed to tend Karner blue larvae (Table 2). Some species of ants appear to provide greater protection than other species. For example, larvae last tended by *Formica lasiodes* had significantly higher survival than those last tended by other ant species (Savignano 1990, 1994a).

During pupal survival studies, Lane (1999b) observed eight ant species to be associated with Karner blue pupae (Table 2). One species of ant built nests of dead vegetation around the pupae. Pupae within these nests were observed to emerge as adults, but how the ants influence pupal development or survival is not clear.

At the Crossgates Mall site in New York, Spoor (1993) observed ants (*Myrmica* sp.) removing eggs of Karner blue from lupine stems. Removal rates were sometimes exceedingly high (39 to 74 percent of eggs missing in one series of observations). Whether these eggs were killed or reared by the ants is unknown. A species of *Myrmica* in Europe carries larvae of the large blue butterfly (*Maculinea arion*) into its nests, where the butterfly larvae then feed on the ants' larvae (Thomas 1980). Spoor (1994, and pers. comm. 2002) also observed *Monomorium emarginatum* opening eggs and pulling larvae out whole or in two pieces.

Although ants appear to be important in the life cycle of the Karner blue, it is uncertain if it is necessary to manage habitat to ensure their presence. The interaction between Karner blue and ants appears to be facultative, and the ants appear to be opportunistic in tending, so that any species that is present might tend the larvae and pupae. In contrast, the apparent variation in protection provided by different ant species could influence Karner blue abundance and population dynamics, and therefore methods to manage the habitat to encourage more beneficial ant interactions may merit consideration.

Within-Habitat Movement and Between-Site Dispersal

Dispersal has not been carefully defined in the Karner blue literature. Dispersal usually refers both to the movement of individuals within and between suitable habitat sites. Because these two types of movements have different ecological implications, they will be separated in this discussion. The movement of individuals away from their natal site of suitable habitat, leaving the site and potentially finding another site will be referred to as dispersal between sites and will include dispersal from sites. Movement that remains in a habitat site (or within the local subpopulation) will be called within-habitat movement. Because suitable habitat sites vary in size, the frequency of these types of movement will vary from site to site. Dispersal from sites may lead to recolonization events, while movement within sites can result in greater use of the site, but will not contribute to recolonization. Karner blue butterfly movements range from relatively short within habitat movements to dispersal movements between sites greater than 1000 meters (1093 yards) apart that are separated by unsuitable habitat. Refer to APPENDIX G (Table G1) for a summary of the within-habitat movement and between-site dispersal studies discussed below.

<u>Within-habitat movement</u>

Nearly all researchers that have examined Karner blue dispersal concluded that Karner blue movements within sites are relatively low and short with nearly all movement less than 100 to 200 meters (110 to 220 yards) (Fried 1987, Givnish et al.1988, Lawrence and Cook 1989, Sferra et al. 1993, Welch 1993, Bidwell 1994, Lawrence 1994, Fuller 1998, King 1998, Knutson et al. 1999) (refer to APPENDIX G, Table G1). Knutson et al. (1999) found that 75 percent of the movements recorded were less than 100 meters (110 yards). The mean distance moved per day ranged from 32 meters ($\pm$3 meters) (Bidwell 1994) to 191 meters ($\pm$52.5 meters) (35 to 209 yards) (Lawrence and Cook 1989). Mean distance moved per day tended to be shorter at the relatively more closed IDNL sites, ranging from 46.4 to 55.0 meters (51 to 60 yards) (Knutson et al. 1999) than in the open landscape of Necedah, where dispersal ranged from 48.2 to 173.2 meters (53 to 189 yards) (King 1998). However, the distances reported by King (1998) are averages of within habitat movements and between site dispersal. Because he recorded many longer dispersal distances, averages are expected to be lower for within habitat movement alone.

Lane (1994a) measured within-habitat flight distances by following individuals and marking all landing points. The average flight distance between points was 4.99 meters (5.5 yards) for males and 1.49 meters (1.6 yards) for females, i.e. most within-habitat flights were short distances, but adults took many small flights in a day (Lane 1994a). The total distance traveled was also calculated from flight data on individuals (time per activity, and distance, angle, and direction of

Table 2. Ant species tending Karner blue butterfly larvae and pupae.

Ant Species Tending Larvae	Locality	Reference
Aphaenogaster rudis	Ont	Packer (1991)
Brachymyrmex debilis Emery	MN, WI	Lane (1999)
Camponotus americanus Mayr	NY	Savignano (1994a)
Camponotus ferrugineus	WI	Bleser (1992)
Camponotus novaeboracensis Fitch	NY	Savignano (1994a)
Camponotus pennsylvanicus	Ont	Packer (1991)
Crematogaster ashmeadi	WI	Bleser (1992)
Crematogaster cerasi Fitch	NY	Savignano (1994a)
Crematogaster lineolata (Say)	MI	Herms (1996)
Dolichonderus (Hypoclinea) plagiatus Mayr	NY, WI	Savignano (1994a), Lane (1999)
Dolichonderus mariae Forel	MI, WI	Herms (1996), Lane (1999)
Dolichonderus pustulatus Mayr	MI	Herms (1996),
Formica difficilis Emery	NY	Savignano (1994a)
Formica exsectoides	Ont	Packer (1991)
Formica fusca	WI	Bleser (1992)
Formica lasioides Emery	NY	Savignano (1994a)
Formica montana	WI	Bleser (1992)
Formica (Neoformica) incerta Emery	NY, MN, WI	Savignano (1994a), Lane (1999)
Formica (Neoformica) nitidventris Emery	NY	Savignano (1994a)
Formica (Neoformica) schaufussi Mayr	NY, MI	Savignano (1994a), Herms (1996)
Formica neogatates Emery	MI	Herms (1996)
Formica obscuripes Forel	WI, MI	Herms (1996), Lane (1999)
Formica obscuriventris Mayr	MI	Herms (1996)
Formica querquetulana Wheeler	NY	Savignano (1994a)
Formica schaufussi	WI	Bleser (1992)
Formica subnuda Emery	WI	Lane (1999)
Formica subsericea Say	NY, MI, WI	Savignano (1994a), Herms (1996), Lane (1999)
Lasius alienus Foerster	NY, MN, WI	Savignano (1994a), Lane (1999)
Lasius neoniger Emery	NY, MI	Savignano (1994a), Herms (1996)
Monomorium emarginatum DuBuois	NY	Savignano (1994a)
Monomorium pharaonis (L.)	MI	Herms (1996)
Myrmica americana Weber	NY, MI, MN, WI	Savignano (1994a), Herms (1996), Lane (1999)
Myrmica emeryana Forel	MN, WI	Lane (1999)
Myrmica fracticornis Emery	NY, MI	Savignano (1994a), Herms (1996)
Myrmica lobifrons	MN, WI	Lane (1999)
Myrmica punctiventris	Ont	Packer (1991)
Myrmica sculptilis	NY	Savignano (1990)
Paratrechina parvula Mayr	NY	Savignano (1994a)
Prenolepsis imparis (Mayr)	MN	Lane (1999)
Tapinoma sessile Say	NY, WI, MN	Bleser (1992), Savignano (1994a), Lane (1999)
Tetramorium caespitum	WI	Bleser (1992)
Ant Species Tending Pupae	Locality	Reference
Crematogaster lineolata (Say)	WI	Lane (1999)
Dolichonderus tashenbergi (Mayr)	WI	Lane (1999)
Formica obscuripes Forel	WI	Lane (1999)
Lasius alienus Foerster	WI	Lane (1999)
Lasius neoniger Emery	WI	Lane (1999)
Leptothorax sp.	WI	Lane (1999)
Myrmica emeryana Forel	WI	Lane (1999)
Tapinoma sessile Say	WI	Lane (1999)

flight) (Lane 1999b). Based on the average total square displacement per minute, after five days (the average life span of Karner blues), most of the butterflies would be expected to be within a 2.5 hectares area (1 acre). Individuals engaged in certain sets of behaviors (e.g., oviposition, roosting, testing for oviposition site) may be expected to move farther and be within a 32 hectare (13 acres) circular area after five days. Grundel et al. (1998b) also observed short movement distances, particularly for females. During one minute observation periods, only 8.4 percent of females moved greater than 10 meters (11 yards). The overall picture that emerges is that within-habitat movements of the Karner blues are short and frequent.

Between-Site Dispersal

There is a fair amount of variation in dispersal tendency of Karner blues between habitat sites as demonstrated by various dispersal studies. Distances between populations that are likely to facilitate recolonization in a metapopulation most likely fall in the range of 0.5-2 kilometers (0.31-1.24 miles) and will depend on the nature of the habitat, especially canopy cover between habitat sites. For a detailed discussion of between-site dispersal refer to APPENDIX G, INCREASING THE COLONIZATION RATE OF SUBPOPULATIONS WITHIN A METAPOPULATION, Between-Site Dispersal and Table G1.

Dispersal barriers

Many factors have been suggested to be dispersal barriers for Karner blue butterflies. Anecdotal evidence has indicated that many geographic, vegetational, and human-constructed structures might act as dispersal barriers, including four-lane highways with heavy traffic in urban or semi-urban areas, steep embankments and cliffs, forested areas if no openings such as trails or roads are present, and residential and commercial areas (including paved parking lots and roads). Scientific evidence supporting any of these speculations is absent.

Dispersal corridors

Little data exists regarding dispersal corridors for Karner blues. It is widely believed that open-canopied areas through wooded landscapes provide the Karner blue with a dispersal corridor, but except for anecdotal observations, this hypothesis has remained unproven. Welch (1993) found that dispersing butterflies almost always followed canopy openings along fencerows, woodland trails, or small gaps in the canopy, stopping frequently to bask in the sun. During these between-site movements, open-canopied areas may be needed for thermoregulation (Lane 1994c), orientation (Welch 1993), or both. Based on observations of Karner blue movement patterns at IDNL (a more closed habitat area), Grundel et al. (1998b) suggest that patches of several 25 meter (27 yards) openings, positioned less than 300 meters (328) from a neighboring patch, will allow the butterfly to persist in the patch and disperse. Thus, dispersal corridors may be formed by a network of partially connected canopy gaps and trails (refer also to APPENDIX G, INCREASING THE COLONIZATION RATE OF SUBPOPULTAIONS WITHIN A METAPOPULATION, Facilitating Directed Dispersal Using Corridors, Corridors and Living Corridors).

HABITAT/ECOSYSTEM

Structure

The physical features that affect Karner blue butterfly habitat vary across its geographic distribution. The western part of the range is subject to greater continental effects, which include greater annual variation in temperature, lower precipitation, and greater year-to-year variation in precipitation. Average annual precipitation is higher in the eastern part of the range than in the western part of the range. Annual variation in precipitation is generally less than 10 percent of normal in the East, but more variable in the West at 15 percent of normal. In the East, the annual range in temperature is less than 28^{o}C, but in the West the annual range is greater than 28^{o}C. Thus, in the West, Karner blue habitat will be subjected more frequently to drought and temperature extremes, such as cool springs or hot summers, than in the East.

Throughout its range, the Karner blue butterfly was historically associated with native barrens and savanna ecosystems, but it is now associated with remnant barrens and savannas, highway and powerline right-of-ways, gaps within forest stands, young forest stands, forest roads and trails, airports, and military camps that occur on the landscapes previously occupied by native barrens and savannas. Almost all of these contemporary habitats can be described as having a broken or scattered tree canopy that varies within habitats from 0 to between 50 and 80 percent canopy cover, with grasses and forbs common in the openings. The habitats have lupine, the sole larval food source, nectar plants for adult feeding, critical microhabitats, and attendant ants. The stature and spacing of trees in native savannas is somewhat variable, reflecting differences in soils, topography and climate (Nuzzo 1986), and the distribution of trees in contemporary habitat is similarly diverse. Soils are typically well drained sandy soils which influence both plant growth and disturbance frequency. These conditions are generally wet enough to grow trees but dry enough to sustain periodic fires (Breining 1993). Topography is diverse and includes flat glacial lakebeds, dune and swale lakeshores, and steep dissected hills.

In order to restore viable metapopulations of Karner blues to the landscape, it will be important to establish and maintain the early successional habitat that the butterfly depends upon. This entails assuring that appropriate disturbance and/or management regimes (e.g., prescribed fire, mechanical management, etc.) necessary to renew existing habitat or to create new habitat are incorporated into management plans for the species.

<u>Remnant native habitats</u>

Barrens are often separated from savannas on the basis of soil type, plant species and form, fire frequency, etc.; however, the classification is not consistent among systems. For example in the Midwest Oak Ecosystems Recovery Plan (Leach and Ross 1995), barrens are considered to be a treeless type of savanna, and by this definition, most Karner blue habitat would be considered savanna, but not barrens. In other classification systems, savannas are wet/mesic habitats with burr oak and other mesic oak species, while barrens are xeric with 20-80 percent canopy cover on sandy soils. To further confuse this issue, Karner blue habitat in Minnesota is classified as dry oak savanna, barrens subtype (MNDNR 1993). Given the lack of a generally accepted classification system, in this document "oak and pine barrens and savanna" ("barrens and savanna" in short) will be used to describe the types of ecosystems providing habitat for the Karner blue.

Most of the eastern range of Karner blue habitat is dominated by pitch pine (*Pinus rigida*), scrub oak (*Quercus ilicifolia*), or both. This ecosystem has been referred to as the pitch pine barrens, Northeast pine barrens, or (Albany) pine bush (Dirig 1994, Schweitzer and Rawinski 1987). Karner blue habitat around Saratoga, New York, appears to resemble oak savanna (Schweitzer 1990).

In the Midwest, black oak (*Quercus velutina*), white oak (*Q. alba*), pin oak (*Q. ellipsoidalis*), bur oak (*Q. macrocarpa*), jack pine (*Pinus banksiana*), or any combination of these dominate suitable Karner blue habitat. Composition can vary from predominantly oak, especially black or pin, to mixtures of oak and jack pine, to predominantly jack pine. Black and pin oak dominated communities have been classified by Curtis (1959) as oak barrens. Those dominated by black oak, with or without white oak and jack pine, are referred to as oak barrens. Sites dominated by jack pine, such as portions of central and northwest Wisconsin where prescribed burns have not eliminated the pines, are called jack pine barrens.

Some of the common species found in the understory of these barrens and savanna habitats are big bluestem grass (*Andropogon gerardii*), blueberry (*Vaccinium angustifolium*), little bluestem (*Schizachrium scoparium*), Indian grass (*Sorghastrum nutans*), butterfly weed (*Asclepias tuberosa*), sweet fern (*Comptonia peregrina*), spotted knapweed (*Centaurea maculosa*), *Rubus* spp., soapwort (*Saponaria officinalis*), beebalm (*Monarda fistulosa*), bracken fern (*Pteridium aquilinum*), New Jersey tea (*Ceanothus americanus*), and goat's rue (*Tephrosia virginiana*).

Dune and swale habitats are one of the most biologically diverse in the Great Lakes Basin (Rankin and Crispin 1994), originally extending along the shore of Lake Michigan from southern Wisconsin through the Chicago and Gary metropolitan areas and north into southwestern Michigan. The dunes are in close proximity to the swales, creating an extreme diversity of regularly alternating subhabitats from xeric, sandy upland habitats to wetlands, and back to uplands and again to wetlands over distances of less than 50 meters. Karner blue populations can be found in the uplands, which are oak barrens habitats, but adults will forage on nectar-producing plants in the adjacent wetlands.

The spatial characteristics and arrangement of habitat patches also appears to be important for Karner blue butterfly populations (Greenfield 1997, Lane 1999). Habitat patches supporting the Karner blue in the Allegan SGA, Michigan, were found to have an edge density more than two times as large as patches without Karner blue butterflies (Greenfield 1997). Habitats with a large amount of edge would tend to have a high proportion of partial canopy subhabitat, one of the key habitats for Karner blue (refer to Subhabitats above). The arrangement of habitat patches, in particular distance between patches, has been correlated with the presence and abundance of Karner blue butterflies (Greenfield 1997, Lane 1999). Greenfield (1997) found that stands with Karner blue butterflies and lupine were significantly more concentrated, i.e. had a lower mean nearest neighbor distance [69.9 meters, (76.4 yards)]. Consistent with these findings are results from comparative studies between the densely populated habitats in Wisconsin and sparsely populated sites in Minnesota. In Wisconsin sites, habitat patches are essentially contiguous, whereas in Minnesota habitat is separated into many patches, often separated by more than 100 meters (110 yards) of dense oak woodland (Lane 1999).

Other contemporary habitats

Karner blues also occur in many other habitats managed for various purposes. These include powerline and highway rights-of-way, airport safeways, young managed forest stands, open areas within managed forest stands, along forest trails and roads, on military bases, and many other such areas. These areas all have soils that are suitable for lupine growth, an open canopy, and management that causes soil disturbance or suppression of perennial shrub and herbaceous vegetation (such as by mowing, brush-hogging, logging, chemical control, or prescribed fire). These habitats are very diverse vegetationally, and support herbaceous species that co-occur with lupine in the native remnant barrens and savanna habitats.

Renewal of Habitat for Karner Blues

Karner blue habitat is maintained in the balance between its decline from canopy closure and its renewal from external disturbance (Shuey 1997). Natural disturbances, such as fire (Chapman 1984) and large animal grazing (Hobbs and Huenneke 1992), that open canopy have decreased since the time of European settlement; thus, this balance is largely maintained by management activities (refer to APPENDIX G). These management activities intervene to influence the rates at which suitable habitat declines in quality and is renewed. Thus, an understanding of both natural factors and the interaction with management is essential to understanding the maintenance of Karner blue habitat. It is likely that the gradients in temperature and precipitation that occur from the eastern to western part of the range of Karner blue butterfly affect these rates. In the drier more variable climates of the western part of the range, it might be predicted that rates of canopy closure will be slower and rates of natural renewal, such as fire will be faster, which would result in a natural landscape with more early successional barrens and savanna and healthier Karner blue populations.

Many ecological processes act on Karner blue habitat to maintain populations of the butterfly. In the native barrens and savanna habitats, many factors, including deliberate fire, wildfire, disease, such as oak wilt, and herbivory, probably interacted to maintain the native vegetation and the associated Karner blue populations. In habitats dominated by anthropogenic activities, many management activities probably have been inadvertently beneficial to Karner blue butterfly. In general, the relation between specific management practices and Karner blue populations is not well characterized, yet the persistence of Karner blue on these managed ecosystems suggests a basic compatibility between Karner blue and alternate land uses that would merit additional study. For example, in New York, approximately half of the Karner blue subpopulations occur on powerline rights-of-way, and the largest subpopulation occurs on annually mowed airport lands (Smallidge et al. 1996). In Wisconsin, Karner blues persist on forested landscapes. Prescribed fire and targeted removal or suppression of trees and shrubs are methods commonly suggested for renewing Karner blue habitat, and are discussed in APPENDIX G and reviewed below. However, research to date has not identified a single management practice that correlated well with abundance of Karner blue or vegetation patterns (Smallidge et al. 1996, Swengel 1998, King 2000), which suggests that many management factors could be beneficial to the butterfly.

Remnant native habitats

The native barrens and savanna ecosystem and its unique combination of species developed from the interplay of natural disturbance processes, edaphic factors, climate, etc. (Forman 1979, Tester 1989, Faber-Langendoen 1991). Fire is recognized as the key element maintaining savanna vegetational structure and species composition (Tester 1989, Haney and Apfelbaum 1990, Faber-Langendoen 1991, Wovcha et al. 1995). Fire influences ecosystem dynamics by decreasing soil nitrogen and organic matter and raising pH (Tester 1989). It exposes mineral soils and reduces woody plant cover, conditions required by many savanna adapted species (Payne and Bryant 1994), and clears the understory but does not eliminate the adapted tree species. These trees survive by resisting fire with thick barks, by resprouting, or by germinating seeds after disturbance by fire. These setbacks of the woody vegetation maintain a mixture of open- to densely-canopied patches of habitat (Nuzzo 1986, Shuey undated). Fire suppression in recent history has resulted in succession of these barrens and savannas to woodlands.

Mammalian grazing, burrowing, trampling, etc., are considered by some to be a critical element in maintaining the oak savanna ecosystem (Hobbs and Huenneke 1992, Swengel 1994). Elk (*Cervus elapus*) and bison (*Bison bison*) are likely to have once grazed and browsed in Minnesota and Wisconsin (Hamilton and Whitaker 1979, Jackson 1961). During spring, elk feed extensively on grasses, sedges, and weeds. During summer, grasses, shrubs, and trees are eaten, and the diet shifts solely to shrubs and trees during fall. Bison feed on species similar to those consumed by domestic cattle, primarily grasses. Deer browse and occasionally graze on legumes and other selected plants. Deer are at very high population levels at some sites with Karner blue. For example, an average of 60-80 deer per square mile occur in the Whitewater WMA in Minnesota (Jon Cole, Whitewater WMA, pers. comm. 1996). Browsing by deer probably has helped to maintain the open canopy that is characteristic of savanna by killing or suppressing tree seedlings. In some areas browsing is so high on oak and jack pine seedlings and selected herbaceous species that several age classes of trees are missing (Cynthia Lane, pers. comm. 1995). If browsing by deer continues at these levels, regeneration of trees may be insufficient to maintain savanna. Similarly, deer grazing may reduce reproduction and survival of herbaceous plant species, such as lupine (Packer 1994, Straub 1994) (Dale Schweitzer, pers. comm. 1994).

It is possible that extirpation of bison and elk and increased numbers of deer have resulted in changes to the structure and species composition of the remnant barrens and savanna ecosystem. At the Whitewater WMA, grass litter has accumulated in open areas and certain age classes of trees are missing. In Ontario, extremely high deer populations consumed from 30 percent to 90 percent of the lupine plants in some areas, and probably contributed to the extirpation of the Karner blue butterfly (Boyonoski 1992, Packer 1994, Schweitzer 1994a).

Soil disturbances created by small mammals, such as plains pocket gopher (*Geomys bursarius*), can also affect the composition and abundance of oak savanna plant species (Reichman and Smith 1985, Davis et al. undated). For example, the savanna herb *Penstemon* *grandiflorus* (Scrophulariaceae) has increased growth rates and earlier reproduction when growing on areas disturbed by the northern plains gopher (Davis et al. undated). Lupine germination and growth on gopher mounds has not been studied; however, the early successional disturbance-associated niche of lupine suggests that it might benefit from gopher disturbances.

Insects and diseases that remove canopy trees have also contributed to the persistence of barrens and savannas in the central United States. Many remnants of high quality oak savanna are in areas where canopy trees have died as a result of oak wilt (*Ceratosystis fagacearum*). Two-lined chestnut borer (*Agrilus bilineatus* Weber), jack pine budworm (*Choristoneura pinus* Freeman), and gypsy moth (*Lymantria dispar* L.) are likely to reduce canopy cover in over-grown barrens areas (Coulson and Witter 1984).

Soil type and topography have contributed to the maintenance of barrens and savanna species composition and structure. The sandy well-drained soils characteristic of Karner blue habitat retain little moisture. These xeric conditions reduce growth of woody species (Burns and Honkala 1990) (Klaus Puettmann, UM-St. Paul, pers. comm. 1995), and only species tolerant of these conditions persist. In combination with soil type, many savanna species owe their persistence to topographic effects, especially in the unglaciated driftless regions in Wisconsin and Minnesota (Wilde et al. 1948, Lane 1994a). The steep slopes exhibit natural slumping, creating exposed mineral soil that favors early successional species. Many of these slopes are south and southwest in aspect, further enhancing their xeric quality and resulting in further suppression of woody plant species. In addition, during spring snowmelt and summer rain storms, several valleys experience erosion, exposing the mineral soils that benefits early successional species, such as lupine.

<u>Other contemporary habitats</u>

The maintenance of Karner blues in contempory habitats such as on forest lands, right-of-way corridors, military lands, or airports, requires the maintenance of the early successional habitat required by the Karner blue.

Silvicultural practices can have beneficial or detrimental effects on Karner blue, many of which are summarized in Lane (1997). For example, in some parts of Jackson, Juneau, Wood, and Burnett counties in Wisconsin, summer harvest, road building and maintenance, site preparation, tree planting, slash burning, and other activities appear beneficial to lupine and the Karner blue. Within this complexity of management activity, however, it is important to focus on how various practices affect the balance between local extirpation of butterflies in a stand and recolonization of stands by butterflies. Forestry practices disturb habitat and butterflies in ways that can be related to the type of disturbance (mechanical, chemical, or prescribed fire), its spatial extent (area affected), its intensity (direct effect on the soil, lupine, and Karner blue), and seasonal timing. The effects of these management practices will be quite diverse, but these effects can be categorized as direct effects on populations of the butterfly, effects on important plant species, such as lupine, nectar plants, and competing plants, and effects on the soil that influences these plant responses. All of these effects will depend on many habitat characteristics, such as the spatial distribution and abundance of plant resources, site quality and topography, the previous history of the site, and the recent history of management. Because there is little scientific information for using silvicultural practices to enhance Karner blue butterfly, management planning should take an adaptive management approach.

Because silvicultural practices are implemented to achieve multiple management goals, there will be inevitable tradeoffs between achieving the various goals. For example, at a particular site, a manager may desire maximum immediate financial returns, minimal risk on investment, maximum sustained yields, optimal wildlife game animal production, and increased Karner blue butterfly populations. In most cases, it will not be possible to optimize simultaneously all economic and wildlife goals. Instead, it will be necessary to understand which silvicultural practices are compatible with each of these many possible goals and which practices create trade-offs among them. For some managers, such compatible practices may be those that, for example, enable sufficient financial return while supporting sufficient butterflies. Forest management activities vary considerably, and a better understanding of the complexities of management and their consequences for the Karner blue butterfly in the working landscapes is needed.

Silvicultural practices continually evolve as demand and technology changes. For example, because red pine fiber is now preferred to jack pine fiber in pulp processing, there has been a shift to replacing jack pine plantations with red pine plantations in many commercial forests. The effect of this shift on the Karner blue is not known, but because red pine has a denser canopy at similar stand densities and is grown on a longer rotation than jack pine, this shift may result in declines of the butterfly over the long term.

The monitoring program of the Wisconsin Statewide HCP in Wisconsin is providing insight into the effects of siliviculture on the Karner blue. Information from Plum Creek Timber Company (Lorin Hicks, in litt. 2002) notes that 54 percent of their young red pine plantations had lupine present, and 25 percent of the stands with lupine supported Karner blues. Their data also shows that prior to harvest, 28 percent of mixed oak/jack pine stands had lupine present prior with 25 percent of the stands supporting Karner blues. This information supports the existence of Karner blue on young red pine stands and to a lesser extent in older mixed stands; however, it will be important to learn how Karner blues persist on forest lands dominated by red pine stands as the stands age and whether lupine and nectar plants would regenerate after harvest of mature stands [refer to Recovery Task 5.25 (d)]. Measures should be considered on forest lands that maintain early successional habitat, dispersal corridors, and forest openings; these measures include less dense plantings and creation of wider roads, trails, and landing sites that can serve as habitat and dispersal corridors for the butterfly (Lane 1997). The effects of silvicultural practices on Karner blue should be evaluated carefully through an adaptive management process.

Information from the Wisconsin DNR's HCP compliance audit program is showing that shifting mosaic habitat patterns occur on HCP forest partner lands due to the spatial arrangements of age classes and harvest rotations. These habitat patterns are likely responsible for the persistence of Karner blues on these lands (refer to PART I, DISTRIBUTION, Rangewide Distribution of Karner Blues, Wisconsin). About 227,191 acres are currently managed in Wisconsin with the goal of maintaining a shifting mosaic of habitat on HCP partner lands. It is anticipated that many non-partner lands have been and will continue to be managed in this manner into the future. The Wisconsin DNR believes that the demand for forest products over the next century or more is expected to perpetuate Karner blue habitats in Wisconsin, much as it has in the past (Darrell Bazzell, in litt. 2002). The HCP monitoring data is and will continue to be valuable in furthering our understanding of the ability of forest lands to support viable populations of Karner blues [refer to PART II, RECOVERY TASKS, Task 5.25(e)]

Understory legumes, such as lupine, can raise soil nitrogen levels, improve rates of mineral cycling, reduce surface runoff and soil erosion, and may improve soil organic matter content, soil structure, and cation exchange capacity, and inhibit soil-borne pathogens (Turvey and Smethurst 1983, Smethurst et al. 1986). Many of these effects could benefit forestry production. Although a potential cost might be competition between lupine and the establishing of trees, in many situations it may aid production goals to encourage the growth of existing lupine and associated Karner blue butterflies, as long as it is not necessary to plant lupine.

Military training appears beneficial to the Karner blue when managed appropriately. The Fort McCoy Military Reservation contains some of the largest populations of Karner blues in Wisconsin (Leach 1993, Bleser 1994), with over 93 percent of the lupine patches occupied by the butterfly (Wilder 1998). It appears that military training activities, particularly inadvertent fires caused by artillery and mechanical disturbance by tracked vehicles, have created a mosaic of successional states similar to those in native habitats. Several studies have examined the effects of tank traffic on Karner blue butterflies and/or their habitat (Bidwell 1994, Maxwell and Givnish 1996, Maxwell 1998, Smith et al. 2002). Comparative studies relating the intensity of training activities to the density of butterflies suggest that these activities have been beneficial to the Karner blue (Bidwell 1994, Smith et al. 2002). Maxwell and Givnish (1996) and Smith et al. (2002) evaluated the effect of tank traffic on plots of established lupine at Fort McCoy, Wisconsin. In both cases greater lupine abundance was associated with areas where track vehicles had traveled as compared with areas where no tracked vehicles had traveled. Maxwell and Givnish (1996) suggested that this kind of traffic causes greater soil disturbance than ORV traffic, and could be comparable to some of the traffic during site preparation and harvest of commercial forest stands. They found that tank traffic crushed emerging lupine plants. Yet, within several weeks, seedling germination was observed on the disturbed soil, and the crushed plants re-grew with a three-week delay in developmental phenology. In the following year, plants on the disturbed areas developed about two weeks faster than the surrounding plants. Smith et al. (2002) measured the greatest lupine abundance in the median strip between vehicle ruts, although lupine regrowth was observed in the ruts and on eroded margins of the tracked vehicle trails. Maxwell and Givnish (1996) concluded that mechanical disturbance could create greater heterogeneity in lupine development. However, Smith et al. (2002) cautioned that repeated disturbance by tracked vehicles might have a negative effect on lupine because of repeated disturbance/damage to lupine roots and/or repeated duff removal.

Areas disturbed by tracked vehicles also had higher nectar plant abundance and lower shrub cover as compared with areas unaffected by tracked vehicles (Smith et al. 2002). However, because of experimental design constraints, it was not possible to determine if tracked vehicle traffic contributed to the reduction of shrub cover or if areas with low shrub cover were preferentially selected as easy routes.

Historical disturbances were also responsible for the pattern and abundance of Karner blue habitat at Fort McCoy (Bidwell 1995, Maxwell 1998). Maxwell (1998) found lupine frequency to be significantly higher in areas of military disturbance. Military caused fire may be one of the primary factors influencing Karner blue habitat and abundance at Fort McCoy (Smith et al. 2002). Some of the largest lupine patches occur in the ordnance impact area, a portion of which is burned each year by military activities.

Although Maxwell's (1998) study plots were monitored to assess the effects of prescribed burns, they were often subjected to light military traffic with untracked vehicles which resulted in an immediate flush of new seedlings in closed canopied plots. Her research indicates that the efforts to regenerate lupine in late successional sites may benefit from disturbance to soils to reactivate the seed bank.

Maintenance of suitable Karner blue butterfly habitat on rights-of-way and near airport runways in New York has been studied by Smallidge et al. (1996). The effects of eight management methods and two management modes (broadcast or selective mechanical and/or herbicide treatments) on Karner blue abundance and several habitat characteristics were examined. No clear pattern was detected between management scheme and vegetation patterns. However, both Karner blue and lupine abundance were greater at sites that had been more recently managed. Broad-scale applications of broad-spectrum herbicides can be detrimental to existing lupine in these habitats, but could be beneficial if they suppress lupine competitors and enable lupine to establish. Smallidge et al. (1996) suggest that frequent mechanical treatments or applications of herbicides (using the appropriate type, methods and timing) will be effective in maintaining suitable Karner blue habitat**.** Disturbance activities related to building, mowing, and grading activities in rights-of-way possibly can have beneficial effects on lupine and butterflies, but the magnitude and direction of the effects may depend on the scale and timing of the activity. Refer to APPENDIX G, REDUCING LOCAL EXTIRPATION RATES, Improving and Maintaining Karner Blue Habitat). Much work has been done by utility companies and highway departments (partners to the HCP) in Wisconsin to alter the timing of mowing in order to minimize the take of the butterfly, while still promoting habitat conditions that favor the butterfly (Darrell Bazzell, <u>in</u> <u>litt</u>. 2002)

<u>Prescribed fire</u>

Fire has been widely regarded as an effective means of maintaining an early successional habitat suitable for growth of lupine in native barrens/savanna ecosystems (Payne and Bryant 1994). Fire influences savanna/barrens structure and composition in many ways including reducing woody plant cover, increasing the abundance of some species while decreasing the abundance of others, and exposing mineral soil. Fire also volatilizes nitrogen (returning it to the atmosphere) while leaving much phosphorus behind in ash; together with opening the canopy, these two processes should strongly favor plants associated with nitrogen fixing bacteria, such as lupine.

When using fire as a management tool, it is important to recognize the balance between Karner blue (and other insect) mortality in the short term, and improvement in the quality of their savanna/barren habitats in the long term (Givnish et al. 1988, Andow et al. 1994, Maxwell and Givnish 1996, Swengel and Swengel 1997, Schultz and Crone 1998). In addition, the use of prescribed burn for habitat restoration will require different considerations than when fire is used for habitat maintenance. Some of the key factors to consider in developing habitat restoration and maintenance plans that include prescribed fire as a tool are: 1) site history and current condition, 2) amount of direct Karner blue mortality likely to occur during the fire, 3) potential for Karner blues to reoccupy the site, 4) characteristics of prescribed fire, 5) response of lupine and nectar plants to fire, and 6) other habitat responses. Because each recovery unit presents a unique combination of many of these key factors, it is important to develop site specific fire management plans for each Karner blue population. Refer to Appendix G for a review of each of the key factors noted above, background research relative to these factors, and recommendations regarding the use of fire.

Removal and suppression of trees and shrubs

Tree and shrub removal and suppression via mechanical means (mowing, brush-hogging and tree girdling), or with herbicides, can be effective ways of reducing canopy cover when timed and conducted in ways to minimize harm to the Karner blue, lupine, and nectar plants. Tree harvesting operations that remove canopy and disturb soil can have beneficial effects on lupine and Karner blue. Smallidge et al. (1995) recorded a greater percent of lupine cover on sites managed with herbicides. An Arsenal-Accord mix has been used to reduce woody cover in rights-of-way management in New York, and observations suggested that the response was positive for lupine (Scott Shupe, Niagara Mohawk, pers. comm. 2002). Infrequent mechanical removal may actually increase woody plant density because of re-sprouting after herbicide application or cutting (Smallidge et al. 1996). Karner blue sites mowed in late summer in Wisconsin were found to support an abundance of larvae the following spring (Swengel 1995). In general, many of the methods for removing and suppressing tree and shrub canopy can have a net positive effect on lupine and the Karner blue and should be timed and carried out in ways that minimize harm to the butterfly and its food resources (lupine and nectar plants). The effects of these management practices should continue to be documented in a wide range of Karner blue habitat types. Refer to APPENDIX G, for further information and guidance on use of these management tools.

Associated Species

Remnant native Karner blue habitats are home to an impressive variety of additional rare and imperiled plants and animals, but the healthy communities once associated with barrens and savanna habitats have declined dramatically because of habitat conversion, fragmentation, and disruption of disturbance regimes. The unique ecological conditions created by the xeric sandy soils, drought-like conditions, and frequent fire disturbances produced a suite of species that, because of their specialized adaptations, rarely occur outside of barrens and savanna habitats. Thus, although the Karner blue butterfly is perhaps the most frequently referenced member of this highly specialized community, many other regionally and globally rare species also depend on these same habitats. Because barrens and savannas are rare habitats in many of the states that have Karner blues, many of the species restricted to these habitats are regionally imperiled. The ecologies of many of these species are not well enough understood to know how adapted these species are to other contemporary anthropogenic habitats. APPENDIX D provides state lists of Federal and state imperiled species and species of concern known to be associated with savanna and barrens communities in states with designated recovery units for the Karner blue. These lists were compiled by the state agencies responsible for rare species. Consequently, not all of the species listed will be found in occupied or occupiable Karner blue habitat, and not all of the species that are rare in Karner blue habitat will be listed. These listings indicate that restoring, preserving, and managing these dynamic barrens and savanna habitats is anticipated to benefit not only the Karner blue, but other rare species associated with them (Table 3*)*. Management plans for the Karner blue should include management strategies that are compatible with other rare species that share its habitat (refer to APPENDIX G).

The Kirtland's warbler, *Dendroica kirtlandii* in Wisconsin is the only federally-listed endangered species included in these lists. The bald eagle, *Haliaeetus leucocephalus* in Michigan, and prairie bush clover, *Lespedeza leptostachya* in Wisconsin are federally-listed as threatened.

Table 3. Number of designated state endangered, threatened, or special concern species potentially associated with Karner blue habitats (for each state with extant Karner blue populations). The number of species that are listed as Federal endangered, threatened, or species of concern is in parentheses. The number of invertebrates does not include the Karner blue, and not all federally-listed species are listed by each state.

State	Vertebrates	Invertebrates	Plants
New Hampshire	0 (0)	3 (0)	3 (0)
New York	6 (0)	0 (1)	3 (1)
Michigan	11 (3)	14 (2)	50 (4)
Indiana	8 (3)	2 (1)	24 (2)
Wisconsin	26 (5)	41 (5)	50 (5)
Minnesota	2 (1)	3 (0)	7 (0)

In Wisconsin, Kirk (1996) conducted a thorough review of the rare species associated with dry prairie, barrens, and savannas in Wisconsin. Forty-one species were identified as associated with Karner blue habitat in the known range of the butterfly, of which 24 were further reviewed. Ten of the species (seven butterflies, two tiger beetles and the sharp-tailed grouse) were considered to have a high Karner blue association. Kirk (1996) discusses the taxonomy, range, habitat, life history, and management concerns for all 24 species. A companion document by Borth (1997) provides further information including management recommendations for 10 of the rare butterfly species discussed in Kirk (1996).

THREATS TO SURVIVAL

The most important threats to the Karner blue range wide are habitat loss, which has been accompanied by increased fragmentation of the remaining suitable habitat, and habitat alteration primarily resulting from vegetational succession. Related to these is the threat of incompatible management stemming from conflicting and potentially conflicting management objectives. Large-scale disturbances, such as large wildfire and unusual weather, are also threats to Karner blue populations. More detailed discussion of the threats to Karner blues in each recovery unit is provided in APPENDIX B. Threats in Wisconsin are not as imminent as in some other portions of the range because implementation of the Wisconsin Statewide HCP by its 26 partners plays a significant role in the conservation of the butterfly. Overall, the partners have committed to implementation of the HCP's conservation program on about 252,299 acres of land in Wisconsin (WDNR 2000, WDNR 2002a).

Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

As noted above, the most significant threat to the Karner blue range wide is habitat loss, alteration, and destruction. Habitat loss has resulted in a reduction in the number of Karner blue subpopulations, habitat fragmentation, and smaller-sized occupied sites. Habitat alteration has reduced the abundance and quality of the Karner blue's food resources (lupine and nectar plants) and subhabitat diversity. Non-management of habitat has resulted in habitat loss over time due to ecological succession. Loss to commercial, industrial, and residential development is more a threat in areas where Karner blue populations are in close proximity to cities or desirable recreational lands (e.g. West Gary, Indiana, the Glacial Lake Albany Recovery Unit in NY, and Concord, New Hampshire, and the Morainal Sands Recovery Unit in Wisconsin).

<u>Loss and alteration of native habitat</u>

The major threat to native habitats is conversion to alternate uses, such as agriculture, forestry, industrial, residential and commercial development, and road construction. Originally, barrens and savanna were widespread in the central United States but rare in the eastern United States. In both regions, there has been a precipitous decline in these habitats. Remaining barrens and savanna usually consist of isolated patches that persist because of droughty soils, insects and disease, and human disturbance such as mowing, light grazing, and intermittent prescribed or wild fires.

The major threat to the survival of the Karner blue butterfly in native habitats is habitat alteration resulting from vegetation succession from barrens and savanna habitat to woodlands and forests. Other threats include incompatible management actions for other wildlife and natural areas goals that do not take into account the needs of the butterfly, such as restoration and maintenance of native vegetation, encouragement of game animals, and recreational use (refer to <u>Types of incompatible management</u>, below). Human use of these native habitats and adjacent developed habitats has often resulted in suppression of disturbance and decline of Karner blue butterfly populations. Although wildlife and other management goals are often compatible with enhancement for Karner blues, too vigorous a pursuit of these other goals can be detrimental to the butterfly.

<u>Loss and alteration of other contemporary habitats</u>

The Karner blue butterfly inhabits several non-native habitats, including some silvicultural habitats, mowed rights-of-way, and roadside edges. Some of these habitats are being lost to commercial and residential development. Agricultural impacts that could pose threats include use of pesticides near Karner blue sites, conversion of large acres (e.g., in Wisconsin) to cropland (e.g., potato fields), cranberry beds, or hog farms. However, agriculture in sandy soil areas favored by the Karner blue may diminish in Wisconsin over time as it is becoming increasingly costly, and therefore less profitable to support agriculture on sandy soils.

Global warming is expected to reduce agriculture on these more arid soils over the next century (Darrell Bazzell, in litt. 2002).

Some silvicultural habitats that are suitable for Karner blues are being converted to residential and commercial uses, and others to intensive forestry practices that may affect the ability of these lands to support Karner blues. Conversion of former jack pine plantations to red pine could result in a loss of Karner blue habitat because red pine canopy is thicker and closes more rapidly. In addition, it is questionable whether lupine will regenerate after harvest of mature stands, but this requires confirmation (refer to PART I, HABITAT/ECOSYSTEM, Renewal of Habitat for Karner Blue, Other contemporary habitats).

Silvicultural habitats that are suitable Karner blue habitats degrade as the trees mature and the canopy closes. This is a natural part of the production cycle, and as long as other silvicultural habitat is opened up within dispersal distances of extant Karner blue butterfly subpopulations, such as by harvesting (creating a shifting mosaic of habitat), a metapopulation may remain at viable levels. Silvicultural habitats supporting Karner blues can degrade in more subtle ways, such as by changing the management objective for land that was previously suitable for the butterfly. Shifting objectives can change the balance between the duration of a Karner blue subpopulation on a site and the proportion of total area that is suitable for the butterfly. For example, suppose a particular silvicultural objective results in canopy closure occurring ten years after planting, and maturation and harvest in year 40. If a Karner blue subpopulation occupies a site for those 10 years before canopy closure, then 25 percent of the land managed for that objective (10 out of 40 acres) could support habitat suitable for the Karner blue butterfly. If the land is managed for a different objective, so that canopy closure occurs faster and subpopulations can only persist for 6 years, and stand maturation takes 60 years, then only 10 percent of the land managed for this objective could have habitat suitable for Karner blue. The exact percentage will vary from year to year depending on the proportion of the land harvested, variation in growth among sites, and changes in management objectives for a particular site. The longer the subpopulation can persist at higher population numbers, in general, the better for the butterfly. Currently in Wisconsin, the HCP monitoring program is demonstrating that Karner blues are persisting on forested landscapes, however questions remain as to the impact of various forest operations on the butterfly (refer to PART II, RECOVERY TASKS, Task 5.25)

The Karner blue butterfly also inhabits power line and railroad rights-of-way (Smallidge et al. 1996, WDNR 2000). If these are managed with herbicides or mowing during the late spring to the early summer, lupine and nectar plants would be suppressed, reducing habitat quality for the Karner blue butterfly as well as butterfly numbers. On some roadside corridors, native vegetation is being replaced by more uniform, exotic vegetation. On other corridors, ORV use is degrading habitat. It has been suggested that development of dedicated ORV trail systems may alleviate this problem (Scott Shupe, Niagara Mohawk, in litt. 2002).

Types of incompatible management

Incompatible management practices threaten some populations of Karner blues and can occur when land managers have several management goals and they either are unaware how pursuit of these other goals could have detrimental effects on the Karner blue or they judge the trade-off with its detrimental effect on the butterflies to be acceptable. Incompatible management practices can occur as described below:

1. <u>Pesticide Use</u>

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. Application of herbicides in Karner blue butterfly occupied areas is best done after lupine and nectar plants senesce.

Most insecticides are not target-specific and can kill most insects in the treated area including the Karner blue butterfly. In laboratory tests, even the relatively specific insecticide, *Bacillus thuringiensis kurstaki* (*Btk*), used to control the gypsy moth killed about 80 percent of the Karner blue larvae fed Btk treated lupine leaves (Herms 1997). Because the timing of Btk applications for gypsy moth control typically coincides with the larval stage of the Karner blue, application of this insecticide results in Karner blue mortality (Herms 1997). Individuals and agencies (e.g. U.S. Forest Service) wishing to use Btk for gypsy moth suppression are encouraged by the Service to use alternative, non-lethal control methods in Karner blue butterfly areas. Miller (1990) found that *Btk* reduced the number of non-target Lepidoptera species and suggested that if any of the species had been limited in its distribution, it would have been at high risk of becoming extirpated. The effect of biological control agents on non-target insects is poorly documented. Analysis of the effects of releases of the biological control agent *Trichogramma nubilale* (an egg parasitoid) (Andow et al. 1995) showed the risk to be small. An examination of the introduced insect predator *Coccinella septempunctata* (seven-spotted ladybird beetle) in Karner blue habitat (N.A. Shellhorn, UW-Madison, pers. comm. 1997**)** suggests that the risk could vary with predator density, prey density, and microhabitat. The direct or indirect effects of fungicide applications on the Karner blue butterfly is not known. Refer also to APPENDIX G, REDUCING LOCAL EXTIRPATION RATES, Improving and Maintaining Karner Blue Habitat, <u>Pesticides</u>.

2. <u>Mowing</u>

While mowing can be an effective management tool (Swengel 1995), some precautions are warranted. Mowing between late spring and early summer is anticipated to have detrimental effects on Karner blue populations. Mowing can damage lupine, eliminating food for larvae. Although mowing may reduce shade and competition, it could also favor plant species not used by the Karner blue (Givnish et al. 1988). Mowing during adult nectaring periods can greatly reduce flower number and nectar availability. Mowing of lupine and nectar plants before seeds mature and disperse could reduce reproduction of these food plants, and have a long-term detrimental effect on Karner blues. In addition, mowing can kill larvae that are present, and may crush eggs laid on lupine plants. Refer to APPENDIX G, <u>Alternatives to fire management</u> for more information and guidance regarding mowing.

3. Prescribed fire

Fire is being used as a management and restoration tool (sometimes in conjunction with mechanical management) on several Karner blue sites e.g., the Albany Pine Bush Preserve (Albany, New York), Necedah NWR (Wisconsin), and at several Wisconsin DNR properties with positive effects for the Karner blue. Fifty years of fire and mechanical management on the Crex Meadows and Fish Lake WAs in Wisconsin have produced 12,000 acres of quality barrens habitat and monitoring has demonstrated the maintenance of a Karner blue population on the property. Necedah NWR currently manages about 500 acres of savanna habitat for the butterfly, mostly through a prescribed burning program.

While prescribed fire is a very useful management and restoration tool, it may threaten Karner blue populations e.g., if the burning is conducted on the majority of the habitat at one time, and if high intensity fires are used at frequent intervals. For a review of the effects of fire on the Karner blue and its food resources and for guidance on use of fire in Karner blue butterfly habitat refer to APPENDIX G.

4. Deer and grouse management

High deer densities can devastate Karner blue butterfly habitat and cause direct mortality by ingestion of larvae (Packer 1994, Schweitzer 1994a). Schweitzer recommends that deer populations be managed to levels where no more than 15 percent of lupine flowers are consumed (Schweitzer 1994a), but this recommendation has not been rigorously tested. Fencing may be useful in some situations to exclude deer from habitat areas. New economic solar powered electric fencing is currently available (David Wagner, University of Connecticut, in litt. 2002). Ruffed grouse habitat does not support lupine, because the dense, shrub vegetation favored by these game birds casts too much shade to allow lupine to thrive. Because Karner blues can occur on lands managed for sharptail grouse, burn management should be designed to promote conservation of the butterfly as well as grouse. Currently brush prairies that support sharptail grouse at Crex Meadows WA also provide the best habitat for Karner blues (Paul Kooiker, WDNR, pers. comm. 1997).

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Collection of the Karner blue butterfly has occurred in the past (USFWS 1992a and 1992b), but is not considered a significant factor in population decline. In the parts of its range where only a few small populations remain, however, extensive collections could have a detrimental effect. Although it has been suggested that collecting of three Karner blue butterflies in Illinois in the Kenosha Potential RU (refer to APPENDIX B) may have contributed to the extirpation of the butterfly in this RU, it is highly unlikely that this could have been the main cause of extirpation.

Disease or Predation

Very little research has been conducted on the natural enemies of the Karner blue butterfly, so the significance of these biotic factors as threats to the butterfly cannot be definitively stated. Similar to most other insects, the mortality of Karner blue immature life stages is very high (Savignano 1990, Lane 1994b). Part of this mortality is caused by predators, parasitoids, or pathogens (Savignano 1990). Larval predators include pentatomid stink bugs (*Podisus maculiventris*), wasps (*Polistes fuscatus* and *P. metricus*), ants (*Formica schaufussi* and *F. incerta*) (Savignano 1990, 1994a), spiders (Packer 1987), and ladybird beetles (*Coccinella septempunctata*) (Schellhorn et al. unpublished data). Four larval parasitoids have been reared from field collected larvae: a tachinid fly (*Aplomya theclarum*), a braconid wasp (*Apanteles* sp.), and two ichneumonid wasps (*Neotypus nobilitator nobilitator* and *Paranoia geniculate*) (Savignano 1990). Several insect predators have been observed attacking adults, including spiders, robber flies, ambush bugs, assassin bugs, and dragonflies (Packer 1987, Bleser 1993). Disease pathogens of the Karner blue butterfly have not been identified, but probably exist.

It is unknown whether birds or mammals cause significant mortality at any life stage of the Karner blue. Bird beak-marks are occasionally observed on adult wings. Direct mortality to Karner blue larvae by deer browse can have a detrimental effect on the butterfly (Schweitzer 1994a).

Plant diseases of lupine could reduce its food quality or render it unsuitable, resulting in larvae mortality or reduced adult fecundity. Lupine leaves are attacked by both powdery mildew (*Erysiphe polygoni*) and a leaf rust (*Puccinia andropogonis*). Research on the effect of powdery mildew on Karner blue butterfly host plant quality is inconclusive. Maxwell (1998) found lower densities of larvae in areas where the proportion of lupine with mildew was the greatest. However, Grundel et al. (1998a) fed mildew infected leaves to larvae in laboratory feeding studies and measured more rapid larval development on post-flowering mildewed leaves than on comparable uninfected lupine.

Of particular interest is how fragmentation and degradation of habitat influences the population dynamics of natural enemies and competitors of the Karner blue butterfly and lupine, and the ultimate effect on Karner blue metapopulations. For example, the abundance of predators and parasitoids varies with tree canopy cover and therefore some subhabitats may provide refuges for Karner blue (Lane 1994b, Schellhorn et al. unpublished data).

Inadequate Regulatory Mechanism

While most states still supporting butterfly populations have legislation that protects the butterfly (refer to PART I, CONSERVATION MEASURES, State Protection), provisions for protection and management of the habitat are incomplete to non-existent (USFWS 1992a and 1992b). This is an important gap in that loss and degradation of suitable habitat are primary reasons for population extirpation and decline in numbers, and recovery of the species will depend on ensuring an adequate base of suitable habitat. Implementation of management agreements, development of conservation easements, and outright land purchase could be used to ensure the habitat base. Other, more flexible regulatory mechanisms could be developed to ensure this habitat base.

Populations of Karner blues that occur on Federal and state lands are protected from destruction, but Federal and state land managers might not manage actively for appropriate savanna or barrens habitat. Developing streamlined procedures for incorporating concerns for Karner blue butterflies into current management plans is recommended in this plan.

Other Natural or Man-made Factors Affecting Its Continued Existence

Stochastic events, such as unusual weather, can detrimentally affect Karner blue populations. Spring and summer drought can stress lupine and may reduce larval populations, and reduce flowering of nectar plants (Cynthia Lane, pers. comm. 1996) which may result in greater adult mortality. Cool springs can delay lupine emergence until after egg hatch (Lane, unpublished data). Cold, wet weather during the flight periods reduces the time available for oviposition and could increase adult mortality. A combination of summer drought and cool, wet springs is one of the suspected causes of population extirpation in Ontario (Packer 1994, Schweitzer 1994b) although habitat damage also contributed to extirpation. In particular home building in some key lupine areas at the Port Franks Estate site and logging at the Port Franks Bowl site were detrimental. The greatest impact of the logging was thought to be the removal of one large shade tree in the center of the most suitable habitat area at the Port Franks Bowl site. The reduction in shade increased light levels which may have made the site more susceptible to drought (Packer 1994).

Heavy browse by mammals (e.g., deer, rabbit, woodchuck), or insect herbivores on lupine in Karner blue areas can also have a detrimental effect. Larvae may starve if lupine is severely defoliated. Browse or herbivory on the flowers or fruits can reduce lupine seed and possibly affect the long-term survival of the lupine population (Straub 1994). Insect herbivores, such as painted lady larvae *(Vanessa cardui)* and blister beetles, can defoliate high percentages of the lupine in an area, which may result in larval starvation.

Large-scale wildfire could destroy a large metapopulation. These events are infrequent, but potentially devastating. Although these rare events would have large detrimental effects that last for several years, it is possible that the metapopulation could recover if enough healthy unburned populations existed nearby or if the fire left patches of unburned refuge areas.

Aggressive exotic (non-native) plant species may pose a threat by out-competing other plant species required by the Karner blue butterfly. Orange hawkweed (*Hieracium aurantiacum*), leafy spurge *(Euphorbia esula*), crown vetch *(Coronilla varia),* white sweet clover *(Melilotus alba),* and Pennsylvania sedge (*Carex pennsylvanicus*) can dominate some Karner blue habitats and reduce lupine and the diversity and abundance of nectar plants available to the Karner blue adults. Spotted knapweed (*Centaurea maculosa*) is used as a nectar plant, but its dominance can reduce the diversity of nectar plants, increasing the risk of extirpation of the subpopulation. In the absence of management, dense cover of buckthorn (*Rhamnus catharticus*), American hazelnut (*Corylus americana*), black locust *(Robinia pseudoacacia),* or other woody shrubs will eventually eliminate lupine.

Global warming may also pose a threat to the Karner blue. A hotter longer growing season may cause a reduction in the habitat quality of some areas by causing early senesce of lupine. Recovering Karner blues in the more northern recovery units of its existing range should help address this concern.

CONSERVATION MEASURES

Many conservation efforts have been initiated to conserve and recover the Karner blue butterfly and its habitat. These activities are briefly summarized here; some are discussed in more detail in PART II, RECOVERY TASKS, and/or in APPENDICES A and B.

Federal Regulatory Protection

"Take"

Section 9 of the Endangered Species Act as amended in 1973 (Act) prohibits any person subject to the jurisdiction of the United States from "taking" federally listed threatened and endangered species. "Take" is defined as harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting these species. It is also unlawful to attempt such acts, solicit another to commit such acts, or cause such acts to be committed. Regulations implementing the Act (50 CFR 17.3) further define harm to include significant habitat modification or degradation that results in the killing or injury of wildlife by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering. "Harass" means an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to breeding, feeding, or sheltering.

Federal permits

Section 10 of the Act provides for the issuance of two types of permits that may be granted to authorize activities prohibited under Section 9:

- Section 10(a)(1)(A): permits for scientific purposes or to enhance the propagation or survival of a listed species (also called recovery permits);

- Section 10(a)(1)(B): permits for "take" that is "incidental to, and not the purpose of, carrying out an otherwise lawful activity."

Several section 10(a)(1)(A) permits have been issued for Karner blue butterfly research and management activities, including research on the butterfly's habitat preferences, its response to various barrens management activities such as mowing and burning, and its response to various forestry practices. Other studies have focused on the effect of herbicides on lupine, nectar plants, and Karner blue butterfly eggs; the effect of *Bacillus thuringiensis kurstaki* (*Btk*, an insecticide used in gypsy moth suppression) on Karner blue larvae, and on butterfly dispersal in forested and open landscapes. Permits have also been issued to study the genetic composition of Karner blue butterfly populations across its range, and for reintroduction efforts in Ohio, Indiana and New Hampshire.

Results of many research efforts have contributed to the conservation and recovery of the Karner blue. Results from the research work demonstrating that *Btk* results in Karner blue larvae mortality has, and continues to be used, in the Service's consultation work with the U.S. Forest

Service's gypsy moth spraying programs in Michigan and Wisconsin. As a result of this research, spray programs have been designed to minimize harm to the Karner blue butterfly. Habitat related work by several researchers has demonstrated the importance of maintaining heterogeneity of habitats (open and closed) to further the recovery of the species; of special note has been the increased understanding of the value of shady forested areas as oviposition sites for the Karner blue, leading to the Service's recommendations in this plan (refer to APPENDIX G), as well as other recovery and conservation related plans, for the establishment of habitat heterogeneity in restoration and enhancement projects. Dispersal research at Necedah National Wildlife Refuge (NWR) has been instrumental in the design of their fire management program. Overall research related to the dispersal abilities of the Karner blue has increased our understanding of this aspect of the butterfly's behavior and is reflected in the recovery goals and management recommendations in this plan.

A Safe Harbor Policy has been established by the Service and the National Marine Fisheries Service (NMFS) (USFWS and NMFS 1999). This policy encourages private landowners to voluntarily conserve threatened and endangered species. Under a Safe Harbor Agreement, a private landowner would agree to create, restore or maintain habitats, and/or manage their lands so that listed species will benefit. In return, the Service provides assurances that future landowner activities will not be subject to restriction from the Act above those applicable to the property at the time of enrollment in the agreement. The Service issues section 10(a)(1)(A) permits to cover private landowner agreements under the Safe Harbor policy. One Safe Harbor approach to Karner blue butterfly conservation is currently being developed in northwest Indiana by The Nature Conservancy in concert with the reintroduction of the butterfly to West Gary (refer to Reintroduction/Translocation below).

Applicants for "incidental take" permits (ITP) issued pursuant to section 10(a)(1)(B) must prepare a conservation plan that specifies the impacts of the "take," steps that will be taken to minimize and mitigate the impacts, funding that will be available to implement these activities, and an evaluation of alternative actions to the "take" that the applicant considered. For all but low-impact Habitat Conservation Plans (HCP), the Service or its designee must prepare an accompanying National Environmental Protection Act compliance document (Environmental Assessment or Environmental Impact Statement). HCPs should clearly identify measures that will ensure conservation of listed species. HCPs also have the potential to contribute to recovery of listed species, especially region-wide HCPs. HCPs cannot mandate recovery. However, HCPs also cannot preclude recovery, and generally they contribute to recovery of species. This recovery plan can be consulted for guidance on development of conservation measures and consideration of recovery goals for the Karner blue. Two "incidental take" permits were issued by the Service for the Karner blue in 1999. The first to the Town of Rome (Adams County, WI) for roadway maintenance and construction work, and the second to the Wisconsin DNR for the Wisconsin Statewide HCP for the Karner Blue Butterfly. The statewide HCP was developed by the DNR along with 25 partners, including eight County Forest and Recreational Departments, private forest industry, The Nature Conservancy, various utility companies, and the Wisconsin Departments of Agriculture and Transportation. The Michigan DNR is currently working on developing a statewide HCP for the Karner blue butterfly.

Section 7 consultation

Section 7(a)(2) of the Act requires Federal agencies, in consultations with the Service to insure that any actions authorized, funded, or carried out by such agencies, are not likely to jeopardize the continued existence of endangered or threatened species. Section 7(a)(1) also requires that these agencies use their authorities to further the conservation of federally-listed species. Section 7 obligations relative to the Karner blue have resulted in several informal and formal consultations for projects such as road construction (Federal Highway Administration), recreational development (U.S. Army Corps of Engineers), solid waste landfill approvals (U.S. Environmental Protection Agency), management activities (National Park Service, U.S. Fish and Wildlife Service), military activities (Fort McCoy and Hardwood Range), and gypsy moth suppression programs (U.S. Forest Service).

Some Federal land managers such as the Department of Defense (Fort McCoy), U.S. Forest Service (Huron-Manistee National Forest [NF]), and Necedah National Wildlife Refuge (NWR) are conducting research activities and participating in conservation efforts that go beyond those required to avoid take. The National Biological Service (now the U.S. Geological Survey) has provided funding to assist with several of the research and management efforts underway for development of the Wisconsin Statewide HCP for Karner blue; these efforts will likely also contribute to the recovery of Karner blue.

Memorandum of Understanding

In September 1994, fourteen Federal agencies, including the Service, National Park Service, US Army Corps of Engineers, Federal Highway Administration, and Department of Defense signed a Memorandum of Understanding (MOU) affirming their commitments to carry out programs for the conservation of federally listed species and the ecosystems on which they depend, including cooperation in the implementation of recovery plans.

State Protection

The Karner blue butterfly is state listed as endangered in Minnesota, New York, New Hampshire, Indiana, and Ohio. In Michigan, it is listed as threatened, and in Wisconsin as a species of special concern. In Indiana, the Karner blue butterfly is listed as endangered, and is protected on state-designated nature preserves. On March 2, 1999, the State of Indiana passed a resolution urging the Indiana DNR to monitor the status of the Karner blue and to do everything it could to keep the species alive and thriving within the state. Except for Indiana, all of the states' endangered species laws and regulations prohibit take of state-listed species for various purposes. It is not listed in Illinois because it has been extirpated from the state. Although the Karner blue is not state-listed in Wisconsin, the Wisconsin DNR has a cooperative agreement with the Service committing the state to furthering the conservation and recovery of federally listed species including the Karner blue butterfly.

Other state and local regulations have also protected Karner blue butterfly and its habitat. At the Crossgates Mall in Albany, New York, protection of Karner blue habitat resulted from the need for two permits: a wetland permit required by Articles 24 and 25 of the state's Environmental Conservation Law, and a water discharge permit regulated by the state's Pollution

Discharge Elimination System program. In another case, mitigation for not meeting the City of Albany's green space requirements resulted in barrens restoration adjacent to an existing Karner blue site. In Minnesota, access and hunting activities in at least one Karner blue area at the Whitewater WMA have been limited by the regulations pertaining to use of state wildlife management areas.

Other Related Recovery Plans

Midwest Oak Ecosystem Recovery Plan

This plan by Leach and Ross (1995) supports the restoration of oak savanna habitats (for Karner blue as well as many associated species). This plan promotes current and future efforts to restore oak savannas in the Midwest and suggests certain goals, strategies, and possible actions that will move recovery efforts forward. The plan notes that only about 0.02 percent of the presettlement high quality savannas remain. Some of the recovery work associated with Karner blue will involve restoration of these rare habitats.

Ontario, Canada Recovery Plan and recovery efforts

Extirpation of the Karner blue in Ontario has been attributed to a number of interacting factors including canopy closure and alteration of habitat by pine plantations, disruption of natural fire regimes, habitat loss and fragmentation due to human incursion and three consecutive years of drought (1987-89). Oak savanna habitat is the most endangered habitat type in Canada and current recovery efforts are aimed both at habitat restoration and at reintroduction of Karner blue.

Only two of the several historic sites in southern Ontario have been occupied by the Karner blue in recent years. The first site is in Lambton County (Lambton Site) on the southeastern shore of Lake Huron and is composed of two areas: 1) Pinery Provincial Park (Park) near Goderich, and 2) a nearby Karner blue sanctuary (Sanctuary) operated by Lambton Wildlife Inc. The second site is the Manestar Tract of the St. Williams Crown Forest about mid-way along the north shore of Lake Erie, near Long Point. The last adults were seen at the Sanctuary in 1990 and at the Manestar Tract in 1991.

Biological inventories of the Lambton sites and Manestar Tract are ongoing. Recovery efforts include monitoring populations of other insects to identify species at risk, active habitat restoration including small-scale burns, brushing, manual cutting and clearing, seeding, habitat protection via fencing, signage, public education, and creation of corridors between prospective subpopulation sites. One problem at the Park has been the removal of the herb layer by the overly large deer population thus depleting the seed bank. Deer culls have occurred in several recent years, and an annual deer count has been implemented. The reduced deer impact has been obvious with the shrub layer responding and forbs flowering and seeding again.

A recovery plan for the Karner blue butterfly in the province of Ontario has been developed (Schweitzer 1993), an Ontario Karner Blue Recovery Team has been formed, and a Recovery Document is being rewritten to adhere to the Recovery of Nationally Endangered Wildlife (RENEW) guidelines (a Federal program to recover species at risk). A strategy for the recovery of the Karner blue butterfly in Ontario has been developed (Previtt 1994). That strategy entails habitat restoration work at both of the sites noted above and the captive rearing of Karner blues for reintroduction in the future. The Metro Toronto Zoo has been working on captive rearing protocols and will oversee the rearing and release of butterflies. Metro Zoo and York University have been doing micro-habitat analysis, which will help identify suitable release sites and donor sites. It is likely that the first release of Karner blues will be at the Lambton site followed by the St. Williams site. A Service export permit and Canadian import permit will be necessary to allow transfer of the Karner blues from the U.S. to Ontario.

U.S. efforts to recover the Karner blue are being shared with members of the Ontario Recovery Team to help promote recovery of the butterfly in Ontario consistent with the framework for cooperation established between the U.S. Department of Interior and Environment Canada as described in "Conserving Borderline Species" (Ministry of Public Works and Government Services Canada and U.S. Department of the Interior, Fish and Wildlife Service 2001).

Reintroduction/Translocation

Four translocation efforts are ongoing. Three of them are reintroductions, one each in Ohio, New Hampshire, and Indiana, and one is an accelerated colonization project in Minnesota. Along with reintroducing Karner blues, each project also includes habitat restoration and management activities.

The Ohio reintroduction effort is in its fifth year with the goal of restoring a viable population of Karner blues to the oak openings of northwest Ohio. The first butterflies from this program were released at TNC's Kitty Todd Nature Preserve in the summer of 1998. The butterflies were raised at the Toledo Zoo in Toledo, Ohio, with the donor population coming from Michigan. The reintroduction is part of an overall conservation plan for the butterfly developed by the Ohio Karner Blue Butterfly Recovery Team (Ohio DNR 1998). The five-year effort has resulted in the restoration of the Karner blue to Ohio and the development of successful captive propagation techniques (Toledo Zoo, 2002) (refer to APPENDIX I, CAPTIVE REARING AND CAPTIVE PROPAGATION). During 2002, the Karner blue butterfly was present at three sites within the Kitty Todd Nature Preserve with 212 butterflies recorded at one site (Peter Tolson, Toledo Zoo, pers. comm. 2002). Monitoring the Karner blue population at the Kitty Todd Nature Preserve remains important in tracking the success of the reintroduction effort and determining whether additional work will be needed to establish a viable butterfly population.

The reintroduction program in Concord, New Hampshire began in 2000, the year the native population went extinct (Amaral 2000). The goal of the program is to restore a viable population of Karner blues to the Concord pine barrens. Initial efforts by the New Hampshire Fish and Game Department (F&G Department) to captive rear Karner blues from the few remaining eggs from New Hampshire butterflies failed as none of the eggs hatched. Because the taxonomic work (microsatellite and mtDNA data) from Nice et. al. (2000) indicated that the Concord, New Hampshire, Karner blue population was closely related to the Saratoga, New York, population, butterflies from the Saratoga Airport are being use in the reintroduction project. Donor Karner blue eggs from the Saratoga Airport were captive reared in 2001 and

2002, with 23 and 70 Karner blues (respectively) released at the Concord Municipal Airport (Steve Fuller, pers. comm. 2002). The Federal Aviation Administration (FAA) is assisting with the project, as a result of their section 7 consultation with the Service on the construction of military facilities at the Concord Airport.

A reintroduction program began in West Gary, Indiana, in 2000 as well, shortly after the last Karner blues were recorded from that area. TNC is using donor Karner blue females obtained from the IDNL to captively rear butterflies. In 2001 and 2002, 250 and 850 Karner blue pupae (respectively) were transferred to one TNC property in West Gary. The pupae were placed in protective nets from which the adults emerged. The goal of the project is to restore a viable Karner blue population to the dune and swale system of West Gary. Karner blues were found at a second site in West Gary in 2002 which likely resulted from a single adult reared in 2001 dispersing about 0.7 miles to that site (Paul Labus, TNC, pers. comm. 2002; TNC 2002). The reintroduction effort appears successful thus far and will be monitored to determine whether future captive rearing efforts are needed. For further information on this reintroduction project refer to the following web site: http://nature.org/wherewework/northamerica/states/indiana/.

A translocation project to accelerate Karner blue colonization of restored habitat was started at Whitewater WMA in southeastern Minnesota in 1999 (Lane 1999a). Female Karner blues from the WMA were used to captive rear butterflies that were released in 1999, 2001, and 2002 to Lupine Valley. During 2001, Karner blues were seen during first flight in Lupine Valley, indicating some success of the translocation effort.

Future reintroductions or translocation projects are being planned or considered at TNC's Quincy Bluff and Wetland Preserve (Glacial Lake Wisconsin RU), Illinois State Beach Park (Kenosha Potential RU), in western New York (Tonawanda Potential RU); in the east management unit of IDNL (Indiana Dunes RU), and in Ontario, Canada.

Recovery tasks include the need to continue to refine protocols and guidelines for reintroductions/translocations; to continue the reintroduction efforts at Concord, New Hampshire, West Gary, Indiana, and Toledo, Ohio; and the accelerated colonization work in Minnesota (refer to PART II, RECOVERY TASKS). APPENDIX I contains translocation guidelines for the Karner blue butterfly; these guidelines can be used to assist managers in deciding when and how translocation could be used to enhance management and recovery efforts. Schweitzer (1994a) also provides guidelines relative to translocation and reintroduction of the Karner blue.

Captive rearing

Research and management of Karner blues has entailed captive rearing in some situations. Captive rearing protocols developed by Lane and Welch (1994) and by VanLuven (1994a) have been used successfully to raise hundreds of larvae for research purposes and/or for population supplementation. TNC in New Hampshire uses VanLuven's protocol to overwinter second brood eggs from the Concord, New Hampshire site. An overwintering protocol for Karner blue eggs has also been developed by Curt Meehl and Cynthia Lane (Lane, unpublished data) in Wisconsin. Herms (1996) utilized captive rearing in her studies of the effect of the insecticide *Btk* on Karner blue. Captive rearing can be used as a tool in reintroduction strategies, and many of the components for a successful captive propagation effort have been developed (Toledo Zoo, 2000). The Metro Toronto Zoo (Zoo) has captive-reared eastern tailed blues (*Everes comyntas*), as a model for captive propagation of the Karner blue for reintroduction purposes in Ontario. While they have successfully reared larvae, they have yet to determine how to overwinter and to mass produce butterflies.

Role of Federal Lands and Programs in Recovery Efforts

Protection of the Karner blue butterfly on Federal lands is important because of the direct benefits gained for the butterfly and other rare species associated with barrens habitat and because these recovery programs serve as examples to non-Federal partners. Federal agencies are also conducting several research projects that will contribute to understanding the impact of management activities on the Karner blue. The following Federal agencies are involved (or are anticipated to be involved) in the recovery of the Karner blue butterfly at six locations, contributing to the recovery of 12 of the metapopulations needed for delisting:

- Department of Defense: Fort McCoy and Hardwood Range, WI,
- Federal Aviation Administration: Concord, NH
- National Park Service: Indiana Dunes National Lakeshore, IN,
- U.S. Fish and Wildlife Service:
  Great Bay NWR, NH *Necedah NWR, WI*
  Meadow Valley State WA (which is part of Necedah Wildlife Management Area), and the
- U.S. Forest Service: Huron-Manistee National Forest, MI.

Table B1 (APPENDIX B) identifies Federal lands as well as other lands where recovery of Karner blue butterfly metapopulations is possible.

Private Land Initiatives

The efforts of private landowners in helping to conserve and protect the Karner blue butterfly will be important to achieving recovery goals throughout the range of the Karner blue, and especially in the more fragmented portions of the range (New York, New Hampshire, and Indiana). A brief review of some private landowner efforts in the various states are noted below.

In Wisconsin, as of July 1998, 22 private landowners have signed voluntary conservation agreements with the Wisconsin Department of Natural Resources for the conservation of Karner blues on their lands (Darcy Kind, WDNR, pers. comm. 2002). These landowners are agreeing not to adversely impact the butterfly or its habitat on their property. Some of these landowners are taking very proactive measures to assist restoration of populations including the planting of lupine and nectar plants, and the expansion of savanna/barrens habitat. In addition, the Wisconsin Department of Agriculture, Trade and Protection (DATCP) is working with private property owners on protection of Karner blue butterfly habitat from pesticide uses.

TNC's registry site program in Indiana maintains a record of those landowners who own significant parcels of land (including known and high potential Karner blue sites) and informs the landowners of their ecological significance. Registry landowners are encouraged to manage their lands for its ecological significance, and to contact TNC when they decide to sell their property.

Several efforts are assisting with habitat management work in New York's Saratoga Sandplains (refer also to APPENDIX B, RECOVERY UNITS, Glacial Lake Albany RU). The Boy Scouts of America actively promoted conservation of the Karner blue on their camp property with assistance from a Partners for Wildlife grant (see below). Specfically, an interpretive trail related to the Karner blue was developed, and the Boy Scouts created a merit badge program designed to involve scouts in Karner blue habitat enhancement work. The TNC has since become owners of the camp and will soon be transferring it to the state. (Gerald Barnhart, NY DEC, in litt. 2002). In addition, two parcels of land in the Saratoga Sandplains have been donated to TNC and two additional landowners are enrolled in TNC's stewardship program for the Karner blue. Several parcels are pending donation.

Two private landowners in Newago County, Michigan, have registered their land with The Nature Conservancy as volunteer stewards for Karner blue.

Federal funding is available through the Service's Partners for Wildlife Program to assist in the restoration of upland habitats including savannas and barrens. Funds from this program have supported barrens/savanna restorations at several sites in Wisconsin including on state, county, TNC, and private lands. In New York this program has funded the use of a hydro-ax to clear over 270 acres in the Albany Pine Bush, Saratoga West, and Saratoga Sandplains recovery areas. The program also provided fencing to protect habitat at a Boy Scout camp in New York's Saratoga Sandplains.

Other Service programs that can assist private landowners are the Landowner Incentive, Stewardship Incentive, and Recovery Land Acquisition Grant Programs. The Natural Resource Conservation Service's Wildlife Habitat Improvement Program (WHIP), and the Farm Service Agency's Conservation Reserve Enhancement Program (CREP) can assist private landowners in the restoration and/or management of their lands.

Education and Outreach Activities

Many education and outreach activities have occurred or are ongoing throughout the range of the Karner blue. These activities vary from designating the Karner blue as the official butterfly of the City of Concord, to puppet shows, displays, educational presentations and walks focusing on the Karner blue and its habitat. The Karner blue has inspired a Boy Scout merit badge program and is the focus of many fact sheets, brochures, and education leaflets. The American Zoological and Aquarium Association (AZA) hosted a Karner Blue Butterfly Recovery Implementation Workshop in Toledo, Ohio in June 2002 that played a key role in bringing together parties interested in helping to recover the butterfly. Additional detail on educational and outreach activities in the states supporting the Karner blue is discussed in APPENDIX J.

RECOVERY STRATEGY

The goal of this recovery plan is to perpetuate viable metapopulations of the Karner blue butterfly 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. Thirteen ecological regions are identified, called "recovery units" (RUs), based on known variation in physiography, climate, and vegetation, and potential geographic genetic variation in Karner blue populations (refer to APPENDIX B, RECOVERY UNITS). Within each RU, the number of viable populations is determined based on the distribution of known populations or the need to improve existing populations. All 13 RUs supported Karner blues at the time of listing (1992).

Wisconsin and western Michigan now harbor the largest metapopulations of Karner blues that occur in the greatest amount of area in the geographic range of the species. The goal for these areas is to stabilize and maintain, and in some cases expand, the populations that now occur. Because of the significance of these two states as the centers of Karner blue abundance, more RUs and more metapopulations are established in these areas than in other parts of the range. These multiple RUs should protect the species against wide-scale declines in either state.

The RUs in New Hampshire, New York, Minnesota, parts of Indiana, and possibly parts of Michigan have imperiled populations, some of which have recently gone extinct and are currently being restored through reintroduction efforts. The goals for these areas are to protect existing habitat (both occupied and unoccupied sites), to increase, stabilize and maintain the populations and to continue on-going reintroduction or accelerated colonization efforts. Fewer metapopulations are established in these RUs because fewer populations are present and less habitat is available.

Six potential RUs are also identified. These potential RUs have no identified recovery goals, but recovery in these areas would be beneficial to the species if viable metapopulations were recovered in these RUs. Therefore, the Service in consultation with the Recovery Team will consider whether recovery in a potential RU can count towards the recovery goals. If so, the population in the recovery unit could offset one of the populations in the next nearest recovery unit(s) (refer to APPENDIX B, POTENTIAL RECOVERY UNITS).

For purposes of recovery planning, a metapopulation is defined as a "population of populations" (refer to APPENDIX E, POPULATION STRUCTURE, Spatial Structure of Karner Blue Butterfly Metapopulations). No one theoretical metapopulation structure is advocated for the Karner blue, rather, the broad definition focuses on those factors that would restore healthy metapopulations including sufficient suitable habitat, connectivity of subpopulations, and management. Persistence of metapopulations is governed by the balance between extirpation of subpopulations and recolonization of unoccupied suitable habitat sites. However, a useful strategy is to manage the population structure to be more like a core-satellite or patchy metapopulation structure, thereby reducing management costs. APPENDICES E, F, and G provide guidance on the restoration and management of viable and large viable metapopulations of Karner blue butterflies.

A viable metapopulation of Karner blue butterflies must be large enough, and be managed and monitored to persist indefinitely over time. The management and monitoring system must buffer the metapopulation against adverse disturbances and threats to survival, maintain suitable habitat over time in an appropriate spatial structure, and identify appropriate responses to potential declines in the metapopulation. Adaptive management for improving or maintaining Karner blue metapopulations is essential. Several adaptive strategies can be pursued, including adapting management to change the structure of the metapopulation, changing the geographic base of the metapopulation over time, and reducing monitoring as the duration of successful management increases. In addition, this definition should discourage a minimalist perspective; if the metapopulation can be made larger and more secure, management and monitoring costs can be reduced.

The recovery strategy relies in part on Federal lands (refer to PART I, CONSERVATION MEASURES, Role of Federal Lands and Programs in Recovery Efforts). Federal efforts are focused on ecosystem recovery, restoration of native habitats, and incorporation of butterfly conservation measures into existing activities such as forestry and military activities. State efforts on state owned or managed lands are also anticipated to contribute to recovery. Contact needs to be made with other private entities (e.g., counties, municipalities, private landowners, etc.) to explore collaborative efforts for the conservation and recovery of the butterfly (refer to Table B1, APPENDIX B). Native habitat restoration is encouraged on all lands where recovery of the Karner blue will occur, but it is recognized that public landowners may have competing goals. Working with private landowners is anticipated to be needed to achieve, or enhance recovery in nearly all RUs. Because some private landowners may not wish to participate in recovery efforts, or will have competing management goals, it will be necessary to explore collaborative efforts that factor in private landowner concerns. Recovery must maintain flexibility with respect to these concerns. Approaches that start with a recovery plan and proceed to recruit willing partners may not always be effective. An alternative is to start recovery by assessing interest and willingness, creating incentives to increase participation, and developing a specific recovery plan for a viable population around these willing participants.

Priority 1 recovery activities are those necessary to prevent the extinction or irreversible decline of Karner blue butterflies in a RU. Priority 1 activities have been identified in the Merrimack/Nashua River System (New Hampshire), Glacial Lake Albany (New York), Ionia, Newago, and Paleozoic Plateau (Michigan), the Indiana Dunes (Indiana), and Paleozoic Plateau (Minnesota) RUs. In the Merrimack/Nashua River System RU in Concord, New Hampshire, it is essential to improve habitat and continue the reintroduction effort on lands with cooperative management agreements. Tree canopy cover should be decreased and lupine established at all sites, and nectar plants must be increased at the Main Site. Monitoring of the population is important to analyze the success of the recovery effort. In the Glacial Lake Albany RU in New York, populations have declined precipitously because habitat has been converted to incompatible uses and degraded by canopy closure from unchecked growth of brush. At all sites, it is necessary to protect the existing suitable and restorable habitat so that it is possible for the butterfly to recover. In addition, it is necessary to stop and reverse succession on these lands and develop and implement plans and activities that will lead to the establishment of viable populations. In the Ionia RU in Michigan, the only populations are associated with the Flat River SGA, but there is no agreement to manage these areas for Karner blue. These areas are subject to heavy ORV use and they are near a powerline right-of way. So it is essential to contact appropriate parties and seek their participation in cooperative efforts to prevent the potential extirpation of the butterfly. In the Newago RU in Michigan, only a portion of the area of potential habitat has been surveyed, and the emphasis is on surveys to enable effective recovery planning. This RU has a complex mixture of land ownership and until the area has been adequately surveyed it will be difficult to prevent an irreversible decline caused by conversion of habitat to incompatible uses. In the Paleozoic Plateau RU in Minnesota, much of the habitat near the small population has degraded from canopy closure, and there is considerable unoccupied, apparently suitable habitat in adjacent valleys. To prevent extirpation, it is essential to expand suitable habitat near occupied sites, to continue implementing the management plan, and to move adults by accelerated translocation to adjacent valleys to expand the population. In the Indiana Dunes RU, the reintroduction program in West Gary should continue until a sufficient number of Karner blues are restored to the site to meet recovery goals. Priority 1 research needs are expected to complement and facilitate these priority 1 recovery tasks. Finally, there is a need to develop cost-effective monitoring methods so that the effects of management can be quantified and the status of the populations can be tracked. Because Wisconsin has almost one-half of the recovery goals for the Karner blue range wide, many of them involving the recovery of large viable populations, and because the Wisconsin DNR is very concerned about it's ability to demonstrate recovery of this proportion, a priority 1 recovery task has been included in this plan to further identify streamlined monitoring methods that are more habitat based for documenting the presence of 6,000 butterflies (refer to PART II, RECOVERY TASKS, Task 3.4)

Priority 2 recovery activities are those necessary to prevent a significant decline in the butterfly population or the quality of its habitat in a RU. There are many priority 2 tasks range wide. The following provides a simplified summary of them. Many of the priority 2 tasks focus on ways to maintain and encourage management practices to create and maintain suitable habitat. These include educational efforts to reduce or modify pesticide use on habitats with Karner blue and lupine, programs to contact private landowners, developing incentives for participation in recovery programs encouraging certain forest management practices to keep the canopy partially open, and implementing mechanisms to guarantee a land base on which viable metapopulations can persist. In addition, there is a need to put the management practices on firmer scientific footing so that they can be reliably used. Recovery tasks include incorporating Karner blue management planning into the on-going management planning processes at each site. Finally there is a need to develop cost-effective monitoring methods so that the effects of management can be quantified and status of the populations can be tracked.

In this recovery plan, priority 3 tasks are also necessary for recovery and include, as appropriate, recovery of Karner blue metapopulations in potential RUs. Most of the priority 3 tasks provide the essential support to guarantee the persistence of viable populations of Karner blue indefinitely into the future. Delisting and possibly reclassification will be difficult without accomplishing many of these tasks.

PART II. RECOVERY

RECOVERY OBJECTIVE

The objective of this recovery plan is to perpetuate viable metapopulations (VPs) and large viable metapopulations (LPs) of the Karner blue butterfly in the major physiographic, vegetational and climatic regions, henceforth called "recovery units" (refer to APPENDIX B, Figures B1-B4) throughout the range of the butterfly. This would allow reclassification and ultimately removal of this species from the Federal list of "Endangered and Threatened Wildlife and Plants" (50 CFR 17.11 and 17.12). The Karner blue butterfly may be considered for reclassification to threatened status and ultimately delisting when the recovery criteria outlined below are met. It is estimated that full recovery of the species will take about 20 years.

Reclassification Criteria

Criterion 1

Establish VPs and LPs of Karner blues in 13 recovery units (RUs) as specified in Table 4 (refer to "Reclassification" column).

Criterion 2

Each VP shall have:

1. a management and monitoring plan, that is approved by the USFWS prior to the fifth consecutive year of monitoring, that will be implemented into the future and include:
    a. suitable buffering of the metapopulation against adverse disturbance and threats to survival,
    b. maintenance of a diverse and appropriate successional array of suitable Karner blue habitat (refer to APPENDIX G), and
    c. identification of appropriate responses to potential metapopulation declines, and
2. a sufficient number of individuals in an appropriate metapopulation structure, maintained for at least 5 consecutive years. The number of individuals shall be at least 3,000 first or second brood adults in the final year of evaluation and in four of the five years overall. In all years, the number of adults shall be greater than 1,500 in one of either the first or second brood. In some circumstances the 3,000 level may be too high or too low (refer to APPENDIX E).
3. connectivity between subpopulations so that the average nearest-neighbor distance between subpopulations is no more than 1 kilometer (0.62 miles), and the maximum distance between subpopulations is no greater than 2 kilometers (1.24 miles). In some

Table 4. Metapopulation goals by recovery unit for the Karner blue butterfly.

Recovery Unit (RU) (refer to APPENDIX B)	State	* Recovery Goals[1]	
		Reclassification	Delisting
Merrimack/Nashua River System	NH	1VP[2]	1VP[2]
Glacial Lake Albany	NY	3VP	3VP
Ionia	MI	2VP or 1LP	2VP or 1LP
Allegan	MI	2VP	1VP + 1LP
Newaygo	MI	2VP	1VP + 1LP
Muskegon	MI	2VP	2LP
Indiana Dunes	IN	3VP	3VP
Morainal Sands	WI	1LP[3]	2LP or 2VP + 1LP[3]
Glacial Lake Wisconsin	WI	2VP + 2LP	2LP + 2VP west of river[4] + 1VP east of river[4]
West Central Driftless	WI	1VP + 3LP	1VP + 3LP
Wisconsin Escarpment and Sandstone Plateau	WI	1VP	1LP
Superior Outwash	WI	2VP	2VP or 1LP
Paleozoic Plateau	MN	2VP or 1LP	2VP or 1LP

Summary of Goals:	VPs	LPs	No. of VPs and LPs	Total Minimum No. of VPs and LPs
Reclassification:	19-23	6-8	19 VPs and 8 LPs (27) or 23VPs and 6 LPs (29)	27
Delisting:	13-21	11-16	13 VPs and 16 LPs (29) or 21 VPs and 11 LPs (32)	29

Notes:

1 The attainment of these recovery goals should not be strongly influenced by whether a subpopulation near a boundary of a RU is in or out of the RU. Subpopulations near or on the boundary of a RU can count towards recovery in that RU. Subpopulations near or on the boundary between two RUs can count towards recovery in either, but not both RUs.

2 VP = viable population LP = large viable population

3 The LP composed of the Hartman/Emmons/Welch complex in the Morainal Sands RU should be reevaluated in 5 years to document progress towards increasing the area of suitable habitat, and to reevaluate the potential of the area to support a LP.

4 The Wisconsin River.

* **The Wisconsin recovery goals will be re-evaluated by the Recovery Team (refer to Task 6.3)**

cases the 1 kilometer dispersal distance may be too far (refer to APPENDIX G, INCREASING THE COLONIZATION RATE OF SUBPOPULATIONS WITHIN A METAPOPULATION)

The management and monitoring systems and the buffering capacity and structure of the metapopulation are all linked (refer to APPENDICES G and H).

Each LP shall have in addition to Criterion 2.1

4. a larger areal extent and more suitable habitat than required for a minimum VP, specifically:

   a. an areal extent of at least 10 contiguous square miles (10 mi^2), in which approximately 10 percent or more of the area has suitable habitat (i.e., an equivalent of about 640 acres of suitable habitat in a 10 square mile area);

   b. the suitable habitat is distributed over two-thirds of the 10 square mile area.

5. a more robust metapopulation structure with larger numbers of individuals than a VP, specifically:

   a. connectivity between subpopulations so that the average nearest-neighbor distance between subpopulations is no more than 1 kilometer (0.62 miles), and the maximum distance between subpopulations is no greater than 2 kilometers (1.24 miles). In some cases the 1 kilometer (0.62 miles) dispersal distance may be too far. For subpopulations greater than 2 kilometers from their nearest-neighbor, validation that dispersal is occurring is needed prior to including that subpopulation into the LP (refer to APPENDIX G, INCREASING THE COLONIZATION RATE OF SUBPOPULATIONS WITHIN A METAPOPULATION)

   b. at least 6,000 adult butterflies maintained for at least 5 consecutive years. At least 6,000 first or second brood adults shall be present in the final year of evaluation and in 4 of the 5 years overall;

6. reduced monitoring and management requirements compared to those required for a VP (refer to APPENDIX F, LARGE VIABLE METAPOPULATION)

Delisting Criteria

Criterion 1

Establish VPs and LPs of Karner blues in 13 RUs as specified in Table 4 (refer to "Delisting" column).

Criterion 2

Same as Criterion 2 above for reclassification with the addition that each VP shall be demonstrably self-reproducing, shall be maintained at or above minimum allowable population sizes, and shall be managed and monitored under the specified management and monitoring plans for at least 10 consecutive years. Each LP, after the initial 5 years of monitoring for reclassification purposes, shall be monitored sufficiently to demonstrate that the LP is being maintained (this should not require as intensive monitoring as for reclassification purposes, refer to APPENDIX H).

Refer to APPENDIX B, Table B1 for potential locations of metapopulations across the species range.

Note: The above noted reclassification and delisting criteria are preliminary, and may be revised on the basis of new information. Refer also to RECOVERY TASKS, Task 6.3, pertaining to the re-evaluation of recovery goals for Wisconsin.

RATIONALE

Management of a Viable Metapopulation (Refer also to APPENDIX G)

Purpose

Management is essential to maintain the metapopulation, to respond in the event that the metapopulation begins to decline, and to buffer the metapopulation from the influences of various sources of environmental variation that could adversely affect the metapopulation. Thus, a management plan must specify how each of these three functions will be met.

Specificity

A management plan shall be developed for each metapopulation that is required in Criterion 1 for reclassification, delisting or both.

Management risks

If a metapopulation is a minimum VP, there is little room for management error, and the management system must use methods that have been proven to have a beneficial effect on Karner blue metapopulations and do not put any part of the metapopulation at risk of long term reduction. If the metapopulation is larger than the minimum, then more experimental management can be encouraged to provide the evidence to justify reducing the costs of maintaining the viable population. A metapopulation is large enough to allow experimental management if it can reasonably be anticipated that failure of the management experiment to maintain Karner blue will not result in a total population less than a minimum VP. In those parts of Wisconsin and Michigan where the Karner blue butterfly is abundant and suitable habitat is spatially extensive, greater management risks are allowable.

Management strategy

Management shall maintain the minimum VP by maintaining an appropriately disturbed habitat mosaic and facilitating the use of suitable habitat by the Karner blue. The mosaic shall be managed so that suitable habitat does not decline in total area or in the number of suitable habitat sites, and so that the degree of connectivity among occupied and occupiable sites is maintained. A shifting mosaic of suitable habitat may be appropriate in many cases, allowing annual variation in the area of suitable habitat. Management practices shall be designed and implemented to renew suitable habitat at appropriate rates. If the renewal rate is too low, habitat will deteriorate (for example, by succession), eliminating Karner blues from sites; and if it is too high, then local Karner blue subpopulations may have insufficient time to recover from the disturbance. Refer to APPENDIX G for more specific management guidelines.

Monitoring of a Viable Metapopulation (Refer to APPENDIX H)

Purpose

The monitoring system of a viable metapopulation shall provide (1) timely information on any decline in the metapopulation or the habitat mosaic, and (2) information on the status of the metapopulation, its associated habitat and the potential adverse disturbances and threats to survival. Monitoring shall be frequent and precise enough so that declines or reductions can be detected in enough time that improvements to management can be implemented.

Specificity

A monitoring system shall be developed for each metapopulation that is required in Criterion 1 for reclassification, delisting, or both.

Use of information

A decision framework for how the information from the monitoring activities will be used in making management decisions shall be specified. Action triggers, such as a decline in the metapopulation or an adverse change in the habitat mosaic, shall be identified, and the changes in management action that must be implemented consequent to the action trigger shall be specified. Communication and implementation routes must be clarified so that management practices can be modified and modifications can be implemented in a timely manner if the action triggers are reached.

Monitoring strategy

Monitoring shall occur frequently during the initial period of maintaining a viable metapopulation. It may be relaxed as confidence accrues that the management system does maintain the metapopulation and habitat mosaic above that needed for a minimum VP. It shall be increased in frequency if new threats to the metapopulation are identified. A minimum VP shall be monitored intensively. If the metapopulation is greater than the minimum, then monitoring may be less intensive. Refer to APPENDIX H for specific monitoring requirements and guidelines for minimum VP and LPs.

Buffering Capacity

Specificity

The buffering capacity of a viable metapopulation shall be evaluated for each metapopulation that is required in Criterion 1 for reclassification, delisting, or both. There is no ideal habitat or habitat mosaic that buffers against all adverse disturbances and threats to survival.

Identification of adverse disturbances and threats to survival

All actual and potential local and large-scale adverse disturbances and threats to survival shall be identified for each viable population. Such disturbances include natural and anthropogenic disturbances, including, but not limited to, unusual weather, storms, wildfire, and land use policy and practices. Not all disturbances will be detrimental to all metapopulations. Some threats include development of habitat for alternate uses (residential, commercial, road building, or other uses), conservation plans and road and power line maintenance plans that do not consider Karner blue, herbicides that harm lupine, insecticides, succession, and incompatible or excessive prescribed fires.

Need to mitigate adverse disturbances and threats

Mitigation strategies for all identified adverse disturbances and threats shall be developed and implemented. Identified adverse disturbances and threats may be mitigated by the management system, the monitoring decision framework, or by the structure of the metapopulation.

Population Structure (Refer to APPENDIX E)

Each VP and LVP is likely to have its own unique population structure. The following provide minimum characteristics that all metapopulations should meet. A population might not meet all of these minimum characteristics, but still be considered viable, if in the process it effectively exceeds these minimum characteristics. For example, occupied habitat may be so close together that subpopulations cannot be identified because they all blend together. In this case, if all of the other characteristics are met, then the population may be considered viable.

Components of metapopulation structure

There are minimum structural thresholds below which a metapopulation is unlikely to be viable, even with substantial management and monitoring. These thresholds will involve a combination of the following five structural characteristics: total metapopulation size (number of butterflies), number of subpopulations, size of the subpopulations (number of butterflies in the subpopulations), connectivity of the subpopulations, and the diversity and quality of the array of suitable habitat.

Redundancy

All metapopulations should have more than one subpopulation. Because the best management plan may have design flaws, and errors in implementation can occur, and because of the threat of large-scale catastrophic disturbance, it is necessary and desirable to maintain a larger metapopulation than would be necessary in a risk-free, constant environment. More research is necessary to show that a VP could be maintained on a single site.

Necessary metapopulation structure

A VP shall have (refer to APPENDIX E):

1. At least 3,000 first or second brood adults in the entire metapopulation. The 3,000 number may be too low to define a VP if, for example, the buffering capacity of the supporting habitat is insufficient, resulting in large population fluctuations. It may be above the actual minimum number required for viability if, for example, the metapopulation is well buffered against environmental variation.

2. Connectivity between subpopulations so that the average nearest-neighbor distance between subpopulations is no more than 1 kilometer (0.62 miles), and the maximum distance between subpopulations is no greater than 2 kilometers (1.24 miles). In some cases the 1 kilometer (0.62 miles) dispersal distance may be too far. For subpopulations greater than 2 kilometers from their nearest-neighbor, validation that dispersal is occurring is needed prior to including that subpopulation into the LP. If significant dispersal barriers are present, shorter dispersal distances are needed. If the total metapopulation size is larger, then the degree of connectivity can be less (refer to APPENDIX G, INCREASING THE COLONIZATION RATE OF SUBPOPULATIONS WITHIN A METAPOPULATION)

3. Although there may be essential minimum area requirements for a minimum VP, these requirements cannot be specified without additional research.

Specificity

The minimum criteria for metapopulation structure are specified in very broad terms. The metapopulation structure that is necessary to maintain a viable population may not be the same in different metapopulations because it will depend on the management and monitoring systems, the details of metapopulation structure, and the buffering capacity of the metapopulation. Consequently, the metapopulation structure that is necessary to maintain a viable metapopulation should be specified for each population.

Occupancy of sites

A metapopulation may be specified with geographically fixed subpopulation sites, such as in metapopulations where potential suitable habitat is not abundant. All of these sites and associated subpopulations can be identified as essential for the maintenance of the viable metapopulation, whether they are occupied or occupiable sites.

STEPDOWN RECOVERY OUTLINE

1. Protect and manage the Karner blue and its habitat to perpetuate viable metapopulations of Karner blue butterflies.

    1.1. Monitor population trends, habitat and distribution in RUs and search for new populations/occupied habitats in unsurveyed areas.

        1.11. New Hampshire
        1.12. Minnesota
        1.13. Michigan
        1.14. New York
        1.15. Indiana
        1.16. Wisconsin

    1.2. Continue/start management activities for all metapopulations in RUs.

        1.21. New Hampshire
        1.22. Minnesota
        1.23. New York
        1.24. Michigan
        1.25. Indiana
        1.26. Wisconsin

    1.3. Develop and implement protection and management plans for metapopulations within RUs and integrate into management operations

        1.31. Develop a management and monitoring plan for each metapopulation that addresses all recovery metapopulation criteria detailed in PART II, RECOVERY OBJECTIVE.

            1.311. Minnesota
            1.312. New York
            1.313. Indiana
            1.314. Michigan
            1.315. Wisconsin
            1.316. New Hampshire

        1.32. Implement the management and monitoring program for each metapopulation in the RU.

            1.321. Implement the management plan.

                1.321.1. New Hampshire
                1.321.2. Minnesota

1.321.3. New York
1.321.4. Wisconsin
1.321.5. Indiana
1.321.6. Michigan

1.322. Implement strategies to guarantee the long-term availability of the geographic land base for the viable metapopulations.

1.322.1. New Hampshire
1.322.2. New York
1.322.3. Indiana
1.322.4. Michigan
1.322.5. Wisconsin
1.322.6. Minnesota

1.323. Implement the monitoring plans.

1.323.1. New Hampshire
1.323.2. Minnesota
1.323.3. New York
1.323.4. Indiana
1.323.5. Michigan
1.323.6. Wisconsin

1.4. Protect existing Karner blue butterfly populations.

1.41. Review Federal, state and private activities.

1.411. Section 7 Federal responsibilities
1.412. Section 10(a)(1)(A) scientific permits
1.413. Section 10(a)(1)(B) incidental take permits

1.42. Develop standardized conditions for scientific permits
1.43. Identify mechanisms to streamline the Federal permit process for private landowners

1.5. Develop recovery implementation strategies to promote recovery.

2. Evaluate and implement translocation where appropriate.

2.1. Continue to develop and refine protocols and guidelines for translocation.

2.11. Continue to develop protocols, guidelines and selection criteria for translocation.
2.12. Incorporate research findings on captive propagation into protocols.

2.2. Implement translocations in RUs.

2.21. Initiate/continue augmentation and reintroductions and accelerated colonization.

2.211. New Hampshire
2.212. Minnesota
2.213. New York
2.214. Indiana
2.215. Other sites as need develops

2.3 Consider additional reintroductions if necessary in PRUs.

2.31. Ohio
2.32. Other sites as need develops

3. Develop rangewide and regional management guidelines.

3.1. Continue development of Karner blue butterfly Forest Management Guidelines.
3.2. Develop guidelines for protection of Karner blues from biocides.
3.3. Continue development of Karner blue management guidelines.
3.4. Continue development of standardized monitoring protocols for the Karner blue

4. Develop and implement information and education program.

4.1. Continue to develop outreach material on Karner blue life history and conservation.
4.2. Inform local and county governments of Karner blue RUs.
4.3. Encourage private landowners to conserve the Karner blue butterfly.
4.4. Assess the needs, goals, and outcomes for public outreach.

5. Collect important ecological data on the Karner blue and associated habitats.

5.1. Priority 1 research

5.11. Habitat management relative to the Karner blue
5.12. Lupine propagation
5.13. Karner blue translocation methods
5.14. Alternative habitat restoration methods
5.15. Remote sensing
5.16. Glacial Lake Albany RU metapopulation decline

5.2. Priority 2 research

5.21. Karner blue dispersal
5.22. Dispersal corridors and barriers
5.23. Ecosystem management
5.24. Karner blue monitoring
5.25. Forest management research

5.26. Highly dispersed metapopulations

5.3. Priority 3 research

5.31. Ecology of local populations
5.32. Effects of human activities
5.33. Browse threshold
5.34. Re-establishment of lupine
5.35. Population structure
5.36. Taxonomic research
5.37. Monitoring protocols using non-adult life stages
5.38. Effects of atmospheric nitrogen on lupine

6. Review and track recovery progress.

6.1. Develop a clearinghouse for Karner blue data, progress reports, metapopulation plans, HCPs, guidance documents, and other relevant information.
6.2. Conduct Recovery Team meetings every 2-3 years to evaluate progress.
6.3. Revise plan as appropriate
6.4. Hold periodic meetings to promote recovery and information sharing.

Note: Refer to APPENDIX B, Table B-1 for potential locations of metapopulation centers across the species range.

RECOVERY TASKS

1. Protect and manage the Karner blue butterfly and its habitat to perpetuate viable metapopulations of Karner blue butterflies.

Many Karner blue butterfly metapopulations are currently vulnerable to short-term decline, and interim protection, management and monitoring measures are required to maintain and/or stabilize them until more comprehensive site-specific metapopulation management plans can be developed and implemented.

1.1 Monitor population trends, habitat and distribution in RUs with imperiled metapopulations, and search for new populations and occupied habitat in unsurveyed areas.

Because some Karner blue metapopulations are imperiled, and because it may take several years to implement successful long-term management and monitoring plans, interim monitoring of these imperiled metapopulations is essential. Interim monitoring will provide the timely information required to adjust habitat management and protection activities over the next few years, ensuring that Karner blue populations do not decline before recovery activities can be fully implemented.

The full extent of some metapopulations in Wisconsin and Michigan is not known. Additional surveys will be required before effective metapopulation recovery plans can be developed and implemented.

1.11 New Hampshire

The last native Karner blues in Concord were gone by 2000, the year a reintroduction program began. Monitoring of both flights is important to assess the success of the on-going reintroduction program and to further develop interim management strategies. This intensive monitoring will be essential into the foreseeable future.

1.12 Minnesota

The Karner blue populations at the Whitewater WMA are at such a precarious state that monitoring of both flights and determining how butterflies use the ongoing restoration experiments is necessary to make management decisions. This intensive monitoring will be essential into the foreseeable future.

1.13 Michigan

There is no comprehensive monitoring strategy in place that predicts current population trends. The distribution of the Karner blue in the Newago RU is poorly known. Additional butterfly surveys on public and private lands will be required before an adequate strategy for protecting Karner blue in this RU can be developed.

Ongoing inventory and monitoring work is essential within the Muskegon RU to determine near-term trends in Karner blue populations and to determine the extent of Karner blue distribution within the landscape.

1.14 New York

The downward trend in numbers and occupancy of habitat of most populations in the Glacial Lake Albany RU must be carefully monitored. Many existing sites are under intense pressure to be converted to incompatible uses, and protection of suitable sites, whose occupancy status is unknown, is frequently challenged. Declining habitat quality must be documented to motivate the need for active management. Unknown populations must be located and protected.

1.15 Indiana

The last Karner blues were seen in West Gary in 2000 and a reintroduction program is ongoing to restore the butterfly to that area. Ongoing monitoring of the West Gary metapopulation is essential to the success of the reintroduction effort. The two metapopulations in the IDNL are not as precarious, but annual monitoring is still required.

1.16 Wisconsin

Monitoring of the Yellow River Focus Area adjacent to the east boundary of Necedah NWR located in the Glacial Lake Wisconsin RU is needed to determine if Karner blue populations exist and to assess whether they can contribute to achieving the recovery goals of this RU.

1.2 Continue/start management activities for all metapopulations in RUs.

Karner blue metapopulation persistence is under immediate threat in some RUs, mainly due to poor habitat quality. Immediate implementation of efforts to counter these threats is necessary. These preliminary management efforts will be a positive first step towards stabilizing the metapopulations and implementing longer-term management to maintain viable metapopulations.

1.21 New Hampshire

Because of the precarious state of the Concord Karner blue population, intensive habitat improvement and expansion is necessary including lupine and nectar source enhancement through artificial planting and seeding. Although lupine is relatively abundant at the Main Site and the Concord Airport site, it is sparse at the Service's Great Bay NWR conservation easement (Easement). Newly established lupine plants must be protected from herbivores. Nectar availability is a limiting factor for Karner blues at the Main and the Airport sites, especially during dry summers.

Habitat management to control woody encroachment at the Main Site is also needed in the short-term by working closely with the Public Service of New Hampshire and private landowners to (mechanically) manage vegetation. Other management needs include mechanical vegetation management and controlled burns to improve habitat at the Service easement, and at the Concord Airport, monitoring of the mowing regime of the safeways at the airport, and working with the City to adjust the timing and height of mowing as appropriate.

1.22 Minnesota

Continued small and large scale experimental habitat restoration is recommended in the Whitewater WMA Management Plan (Lane 1994c) for increasing this population which is at low levels and could decline further. On-going restoration projects should continue, especially those near occupied sites and additional restoration activities conducted as needed based on these results.

1.23 New York

All of the Karner blue metapopulations in New York require intensive habitat improvement to upgrade habitat quality. Most sites are not under management and may become unsuitable for Karner blues in the next few years, thus leading to possible extirpation of the species at some sites.

In the Albany Pine Bush Preserve (Preserve) metapopulation, four subpopulation sites have been managed for Karner blues. In 1998, the parking lot between the southern and northern parts of the Apollo Drive subpopulation was removed, and the site was planted with lupine and nectar species. More recently, another 10 acres was cleared and planted within dispersal distance of the Apollo Drive site. The southern part of the Apollo Drive subpopulation has been acquired by the Preserve Commission; however, the much larger number of butterflies in the northern part requires protection from use and habitat management. The only other subpopulation on Preserve land, the Willow Street Powerline, is managed by Niagara Mohawk and the Preserve Commission to remove woody species (although until 1998 removal was very limited). The subpopulation at the Crossgates Mall (including both the Hill and Powerline section) continues to be intensively managed through removal of competing and invasive vegetation and planting of desirable species. Lupine and nectar plants have been seeded at the Curry Road site which is being acquired by the Preserve. Lupine and nectar plants were established in Fort Hunter Powerline (the only subpopulation site in Schenectady County) and should be monitored and maintained. Management is needed at all other subpopulation sites to prevent their loss, to expand the sites, and to develop needed dispersal corridors.

The Saratoga Sandplains metapopulation has been severely reduced because of the loss of sites or conversion to land uses incompatible with Karner blue butterflies. Management efforts by the Wilton Wildlife Preserve and Park, The Nature Conservancy (TNC), and private landowners is crucial in preserving, managing and enlarging the remaining clusters of Karner blue subpopulations in the heart of the area. Until recently, actual management has been limited. Large-scale management has recently begun at a former Boy Scout Camp now owned by TNC. Nectar and lupine were planted at the NSComp and Edee Road Sandpit sites now owned by the state. Attempts to re-establish nectar species at key sites should continue, and all sites should be managed for Karner blues as needed and possible. Large-scale improvement projects should continue when more land is brought under management capability, either through acquisition or agreements, and more funding becomes available.

In the Saratoga West metapopulation area, both the Saratoga Spa State Park and the Saratoga Airport have agreements for mowing that should be maintained. Active improvement of habitat has been limited in the past. Intensive efforts to increase lupine and nectar at the airport and state park have only begun in recent years. Seventy-two acres of new Karner blue habitat is currently planned for restoration adjacent to the Saratoga Airport and will be managed under a revised agreement between the state and Saratoga County. Smaller scale habitat improvement continues at the Spa Park and Route 45 sandpit sites. Another site has recently become part of a village park, and although a management plan for the habitat has not been worked out yet, permission for needed habitat improvements has been given and should be conducted. All other sites are in need of management to preclude loss due to habitat succession.

1.24 Michigan

Habitat improvement work is essential within the RU in Michigan. In the Ionia RU (Flat River SGA), management to secure the metapopulation from threats from ORV use and rights-of-way management needs to be implemented. The Newaygo and Muskegon RUs will require protection from ORV use and commercial and residential development. Habitat improvement work will include increased connectivity between sites and improvement of individual sites to assure Karner blue survival until a comprehensive plan is developed.

1.25 Indiana

Rapid expansion and improvement of Karner blue habitat for the West Gary metapopulation is critical to the success of the reintroduction program. Ongoing habitat restoration at Ivanhoe dune and swale will provide additional buffering from catastrophic events and allow for development of a larger Karner blue metapopulation. Habitat management work required in the Service's Biological Opinion for the Karner blue at IDNL should continue.

1.26 Wisconsin

Habitat restoration, enhancement and/or management activities are needed on all properties where recovery efforts are focused. Ongoing barrens management activities on state [e.g., Sandhill WA, Glacial Lake Grantsburg Work Unit (Crex Meadows and Fish Lake State WAs), Black River State Forest, Emmons Creek State Fisheries Area], Federal (Necedah NWR, Fort McCoy), and private properties (Mr. Bob Welch, TNC) are already occurring and should continue (refer also to 1.315).

1.3 Develop and implement management and monitoring plans for metapopulations within RUs and integrate into ongoing management operations.

Each metapopulation must be deemed viable as defined in PART II, RECOVERY OBJECTIVE of this Plan. In addition to its traditional biological connotations, the term viable as used here for Karner blue butterflies includes long-term mechanisms for management and monitoring of butterflies and their habitat as integral components of viability. In many cases, such as when Federal- or state-managed lands are essential to recovery; the plans can be integrated into existing plans for public land management.

1.31 Develop a management and monitoring plan for each metapopulation that addresses all recovery metapopulation criteria detailed in PART II , RECOVERY OBJECTIVE.

No two Karner blue supporting ecosystems are the same, and approaches to ensuring metapopulation viability in each area will by necessity be different. Yet the principles guiding the planning and on-the-ground management decisions at every locality are the same, and revolve around improving the colonization/extirpation balance. Local factors and conditions must be incorporated into decisions concerning Karner blue recovery. For example, the history of previous habitat management, conversion, and fragmentation constrain current options. Other management objectives, such as forestry and wildlife management, ecosystem recovery, and other endangered species, should be assessed for compatibility with the practices required to sustain the Karner blue. While many of these other management objectives (e.g. sharptail grouse management at Crex Meadows WA) are anticipated to be compatible with management for the Karner blue, some management prescriptions may need modifying to enhance the recovery of the butterfly (e.g. frequency and location of prescribed burns, enhancement of corridors to ensure dispersal, etc.). The objectives of all management programs should be integrated into the management and monitoring plan for the butterfly. No one management unit is likely to satisfy all management objectives, but every site should attempt to satisfy as many as possible within real world ecological, sociological and financial constraints. Refer to the recovery criteria and APPENDICES G and H for guidance on development of management and monitoring plans.

1.311 Minnesota

Paleozoic Plateau RU

Modify existing Karner blue butterfly management and monitoring plan for the Whitewater WMA (Lane 1994c) to incorporate recovery criteria necessary to meet the recovery objectives for this RU and to preclude loss of subpopulations that are at risk due to low numbers.

1.312 New York

Glacial Lake Albany RU

Incorporate Federal and state recovery guidance for the Karner blue butterfly and its support habitats into the existing preserve design for the Albany Pine Bush Preserve (Albany Pine Bush Preserve Commission 1993). Incorporate Federal and state recovery criteria into the existing Site Conservation Plan for the Saratoga Sandplains Macrosite (Pickering 1994), and develop into a metapopulation management plan. Contact local governments (Town of Wilton and Saratoga County) and non-governmental organizations to explore cooperative efforts to formulate plans. Develop a preserve design for the Saratoga West metapopulation through involvement of the state recovery team and cooperative efforts with local governments (Towns of Milton and Saratoga Springs, City of Saratoga Springs, and Saratoga County) and non-governmental organizations. Through involvement in the state recovery planning process, encourage incorporation of protection designs and management strategies into local municipality planning projects.

1.313 Indiana

Indiana Dunes RU

Modify existing management plans for West Gary (Shuey, undated) and the IDNL to incorporate recovery criteria necessary to meet recovery goals. The recovery implementation plan for

West Gary should include Lake County Parks Natural Areas, TNC holdings and adjacent private landowner stewardship plans.

1.314 Michigan

Modify existing management and/or master plans to incorporate recovery criteria necessary to meet recovery goals. Evaluate permit options and develop procedures to cover multiple take activities on multiple sites resulting from management activities of the Karner blue butterfly.

Allegan RU

Modify existing management plans for Allegan SGA.

Ionia RU

Modify existing management plans for Flat River SGA and adjacent private lands.

Muskegon RU

Modify existing management plans for Huron-Manistee NF and adjacent private landowner stewardship plans.

Newago RU

Modify existing management plans for Huron-Manistee NF and adjacent private landowner stewardship plans.

1.315 Wisconsin

State property planning will be done via DNR-HCP implementation and state master planning.

Morainal Sands RU

Modify existing management and/or master plans to incorporate recovery criteria necessary to meet recovery goals for properties within the Hartman/Emmons/Welch complex which include Hartman Creek State Park, Emmons Creek State Fishery Area, National Park Services' Ice Age Trail segment, and privately owned "Welch" forest crop law stand. In addition, seek to develop protection agreement with Mr. Welch for Sawyer Prairie, and with other willing private landowners in this complex as needed and available. Incorporate recovery guidance into management and/or master plans for Greenwood and White River Marsh State WAs. Pursue State Natural Area designation of state lands.

Glacial Lake Wisconsin RU

Modify existing management and/or master plans to incorporate recovery criteria necessary to meet recovery goals for (1) Meadow Valley State WA (via the ITP for the Wisconsin Statewide HCP, section 7 consultation for this federally owned property, and DNR Master Planning), (2) Necedah NWR (via section 7 consultation process), (3) Sandhill State WA (via the ITP for the HCP), and (4) Quincy Bluff Natural Area.

Incorporate recovery guidance for the Karner blue into conservation measures for the Air National Guard Hardwood Range (Hardwood Range) via section 7 consultation. Because the Hardwood Range site is not large enough to support a Karner blue metapopulation, contact Wood and Juneau County's Forest and Parks Departments to explore collaborative efforts for the recovery of the metapopulation in this portion of the RU. Also determine whether Necedah NWR can be of assistance (relative to the Yellow River Focus Area) with this effort.

West Central Driftless RU

Modify existing management and/or master plans as needed to incorporate recovery criteria necessary to meet recovery goals for (1) Black River State Forest (via the ITP for the Statewide HCP and DNR master planning) and Fort McCoy Military Reservation (via section 7 consultation process). Contact the Jackson County Forest and Parks Department to explore ways to develop collaborative efforts for the recovery of a LP in this portion of the butterfly's range.

Wisconsin Escarpment and Sandstone Plateau RU

Because some of the larger habitats for the Karner blue occur on county forest lands in this RU, contact the Forest and Parks Departments of Eau Claire and Clark Counties to explore collaborative efforts for the recovery of an LP in this portion of the butterfly's range. Also contact some of the HCP utility partners, and the Eau Claire and Clark County's Highway Commissions to explore their willingness to participate in recovery efforts.

Superior Outwash RU

Modify existing management and/or master plans to incorporate recovery criteria necessary to meet recovery goals for (1) Glacial Lake Grantsburg Work Unit (Crex Meadows and Fish Lake State WAs), combined with Governor Knowles State Forest (via the ITP for the HCP). Also contact the Burnett County Forest Department to explore collaborative partnership efforts to help recover a LP in this portion of the range**.**

1.316 New Hampshire: Merrimack/Nashua River Systems RU

Modify existing Karner blue butterfly management and monitoring plans to incorporate recovery criteria and guidance necessary to meet recovery goals for this RU. This will entail reviewing and amending as necessary, the Concord Pine Barrens Preserve Design, the Concord Airport and Service Easement Plans, and the management plan for the Main Sites.

1.32 Implement the management and monitoring plan for each metapopulation in the RU.

1.321 Implement the management plan.

Metapopulation-specific management plans must be implemented in ways to ensure that management will persist into the indefinite future if populations are to qualify as VPs and LPs.

1.321.1 New Hampshire

Merrimack/Nashua River Systems RU

It is crucial to maintain existing habitat and restore degraded habitats for the Karner blue at Concord due to the declining and precarious nature of the population.

1.321.2 Minnesota

Paleozoic Plateau RU

Restore habitat and create fire breaks to expand and protect populations that are at risk of decline due to low numbers at the Whitewater WMA.

1.321.3 New York

Glacial Lake Albany RU Pine Bush Preserve

Maintain and restore Karner blue habitat according to the modified Pine Bush Preserve Plan to expand and improve habitat quality. Restore connectivity between subpopulations through appropriate habitat management. Coordinate habitat management between the Preserve Commission and private land managers to enhance metapopulation health and function.

Saratoga Sandplains

Maintain and restore habitat according to the modified Saratoga Sandplains management plan. Enhance metapopulation connectivity with appropriate habitat management. Coordinate management among managers of lands protected for the Karner blue, municipalities and private landowners.

Saratoga West

Maintain and restore habitat according to the newly developed Saratoga West management plan. Enhance metapopulation connectivity with appropriate habitat management. Coordinate management among managers of lands protected for the Karner blue, municipalities and private landowners.

1.321.4 Wisconsin

Morainal Sands RU

(1) Hartman/Emmons/Welch complex: Enhance connectivity between subpopulations and expand openings via appropriate management. Minimize affects from public use, including mountain bikes along Ice Age Trail through habitat areas.

(2) Greenwood State WA: Continue prairie/savanna restoration efforts via appropriate management.

(3) White River Marsh State WA: Begin restoration of additional potentially suitable habitat that surrounds smaller core areas.

Glacial Lake Wisconsin RU

(1) Meadow Valley State WA: Establish barrens restoration and management project, working as necessary with Necedah NWR to complement its efforts on adjoining lands. Incorporate results of barrens management into management activities at this site and Sandhill State WA using adaptive management principles.

(2) Necedah NWR: Continue barrens restoration and management efforts across property, and maintain appropriate disturbance regime. Evaluate effects of various disturbance techniques in progress and incorporate results using adaptive management principles.

(3) Air National Guard Hardwood Range: Develop and maintain appropriate disturbance regime, establish firebreaks where needed and enhance habitat as needed.

(4) Sandhill State WA: Continue habitat restoration and maintenance efforts. Delay mowing of County Highway X until after September.

(5) Quincy Bluff Wetland Preserve: Continue barrens restoration efforts, augmented with lupine propagation and/or Karner blue translocation/reintroduction if necessary.

West Central Driftless RU

(1) Black River State Forest/Jackson County Forest: Maintain positive disturbance regime via wildlife management and silvicultural practices throughout Indian Grave Creek Barrens Complex and Dike 17 complex, using permanent core populations at designated areas and trails and roads as corridors to extent possible. Develop connectivity between those populations around Dike 17 refuge and those north of Highway 54 in Staffon and Cemetery Road areas. Delay mowing along occupied and connecting roadsides until after September.

(2) Fort McCoy: Maintain positive disturbance regimes through military, silvicultural, and wildlife practices

to establish and maintain two LPs (one each on the North and South Post), and to conserve Karner blues south of State Highway 16. Establish connectivity between the North Post LP and Habelman Road area of Black River State Forest south of I-94 compatible with military operations.

(3) Monroe County Forest: Contact Monroe County Forest and Fort McCoy to explore collaborative efforts to maintain a positive disturbance regime compatible with military operations on DOD-leased lands as needed to enhance Karner blue populations at Fort McCoy.

Wisconsin Escarpment and Sandstone Plateau RU

Contact Eau Claire and Clark County's Forestry and Parks Departments to explore collaborative efforts to maintain a positive disturbance regime via silvicultural and wildlife management practices throughout Coon Fork–South Fork–Canoe Landing complex. Explore designation of permanent core population areas and the use of trails and roads as connecting corridors to the extent possible.

Superior Outwash RU

Continue barrens restoration and maintenance efforts at Crex Meadows and Fish Lake WAs, plus the Kohler-Peet Barrens area on Governor Knowles State Forest. Contact Burnett County Forest Department to explore collaborative efforts to establish and maintain connectivity between Crex Reed Lake Barrens and Kohler Peet Barrens. Also contact various HCP utility partners (e.g., Northwestern Wisconsin Electric Co.), Burnett County Highway Department, and various municipalities to explore enhancement and connectivity via various rights-of-way corridors.

1.321.5 Indiana

Indiana Dunes RU

Restore habitat on public (including IDNL) and private lands to expand/improve Karner blue habitat quality. Restore connectivity in West Gary by restoring fire suppressed habitat remnants. Coordinate habitat management activities between state, private and Federal managers to enhance Karner blue metapopulation function/health.

1.321.6 Michigan

Allegan RU

Maintain existing habitat and restore suitable habitats for the Karner blue on public and private land in the RU. Maintain sufficient habitat to meet the metapopulation objectives. Continue barrens restoration projects within the RU with emphasis on connectivity between subpopulations, expansion of existing sites, and enhancement of habitat attributes within sites. This may be done by a number of different methods (e.g., cutting, brush hogging or burning). Landscape-scale burns may be desirable where ownership and site management allows.

Ionia RU

Maintain existing habitat and restore suitable habitats for the Karner blue on public and private land in the RU. Maintain sufficient habitat to meet the metapopulation objectives. Continue barrens restoration projects within the RU with emphasis on connectivity between subpopulations, expansion of existing sites, and enhancement of habitat attributes within sites. This may be done by a number of different methods (e.g., cutting, brush hogging or burning). Landscape-scale burns may be desirable where ownership and site management allows.

Muskegon RU

Maintain existing habitat and restore suitable habitats for the Karner blue on public and private land in the RU. Maintain sufficient habitat to meet the metapopulation objectives. Continue barrens restoration projects within the RU with emphasis on connectivity between subpopulations, expansion of existing sites, and enhancement of habitat attributes within sites. This may be done by a number of different methods (e.g., cutting, brush hogging or burning). Landscape-scale burns may be desirable where ownership and site management allows.

Newago RU

Maintain existing habitat and restore suitable habitats for the Karner blue on public and private lands in the RU. Maintain sufficient Karner blues to meet the metapopulation objectives. Protection from ORV and development is needed. Prairie and barrens restoration projects should continue through cutting, nectar and lupine propagation and burning.

1.322 Implement strategies to guarantee the long-term availability of the geographic land base for the viable metapopulations.

In all RU except the Paleozoic Plateau RU in Minnesota, it will be necessary to guarantee the long-term availability of the geographic land base of each viable metapopulation. Most plans will identify important Karner blue habitat areas which need to be available long-term. This might be accomplished by land acquisition from willing land owners, conservation easements, management agreements, HCPs, or other means. These efforts should be taken in a timely fashion. As the Service and its partners seek to work with willing landowners on the recovery of endangered species, and some of the key butterfly sites are on private lands, it is important to explore collaborative recovery efforts with these landowners. Brief reviews of land protection needs are described in Task 1.322.1 through Task 1.322.6.

1.322.1 New Hampshire

Merrimack/Nashua River Systems RU

An informal management agreement currently exists with the electrical utility company that manages vegetation at the Main Site; obtain a formal management agreement or conservation easement for the Main Site. Monitor City of Concord and Federal Aviation Administration implementation of Concord Airport Master Plan Update (City of Concord 1996), review proposals for new construction and facility improvements, recommend locations and project designs that minimize loss of Karner blue habitat. Manage/restrict ORV use at the Main Site and Service Easement. Work with City of Concord to implement the management agreement for the Airport.

1.322.2 New York

Land acquisition is needed in the Albany Pine Bush, Saratoga Sandplains and Saratoga West metapopulation areas. Conservation easements and other protection will be needed at all three areas. Private landowner cooperation regarding ORV use and prescribed burning will be especially important. Establish a cooperative protection and management entity for the Saratoga West area (the management entity for Saratoga Sandplains is the Wilton Wildlife Preserve and Park). Work with the state, city, town, and private landowners in and near the Albany Pine Bush, Saratoga Sandplains, and Saratoga West metapopulation sites to include Karner blue preserve design concepts into local planning to facilitate restoration of one metapopulation in each area.

1.322.3 Indiana

Indiana Dunes RU

Land acquisition is needed in the West Gary population. Habitat protection is expected at the West Gary population site and both metapopulations associated with the IDNL.

1.322.4 Michigan

Allegan RU

Promote long-term, cost efficient management strategies and work with private landowners to develop cooperative management agreements that minimize loss of Karner blue habitat. Maintain regular contact with utilities that manage rights-of-way on the Allegan SGA to update management agreements.

Ionia RU

Develop strategies to manage/restrict ORV use on Flat River SGA. Maintain regular contact with utilities that manage rights-of-way on the Flat River SGA to update management agreements.

Muskegon RU

Habitat protection within the metapopulation, especially in areas threatened by development, is expected in the Huron-

Manistee NF boundary. Land acquisition may be considered if the lands are necessary for recovery and other agreements are inadequate to ensure recovery.

Newago RU

Habitat protection within the metapopulation, especially in areas threatened by development, is expected in the Huron-Manistee NF boundary. Land acquisition may be considered if the lands are necessary for recovery, and other agreements are inadequate to ensure recovery.

1.322.5 Wisconsin

Morainal Sands RU

Consider designation of Emmons Creek/Hartman Creek State Park and Ice Age Trail complex as State Natural Areas; pursue conservation easement or other permanent protection with private owners in the complex.

Glacial Lake Wisconsin RU

If Karner blue sites in the Yellow River Focus Area are necessary to establish a viable metapopulation in this RU, agreements with willing landowners should be explored to ensure long-term maintenance of these sites. Land acquisition may be considered from willing landowners if the sites in the Yellow River Focus Areas are necessary for recovery and other agreements are inadequate to ensure recovery.

West Central Driftless RU

Consider designation of Indian Grave Creek Barrens as a State Natural Area.

1.322.6 Minnesota

Paleozoic Plateau RU

Coordinate and implement recovery activities at the Whitewater WMA.

1.323 Implement the monitoring plans

Because monitoring is included as a key component of Karner blue metapopulation viability, implementation of an appropriate monitoring plan is essential. As explained in PART II, RATIONALE, Monitoring of a Viable Metapopulation, monitoring programs should be designed to provide essential feed back to managers so that the effectiveness of management can be evaluated and management can be adapted. Consequently, the monitoring protocol will likely be slightly different for each metapopulation.

1.323.1 New Hampshire

Merrimack/Nashua River System RU

Implement the monitoring plan. Track the phenology, numerical abundance and extent of habitat utilized by first and second brood Karner blue butterflies at the three subunits (Main Site, Easement and Airport) in this RU.

1.323.2 Minnesota

Paleozoic Plateau RU

Implement the monitoring plan. Monitor Karner blue populations, habitat and habitat occupancy as recovery and habitat restoration activities are implemented.

1.323.3 New York

Glacial Lake Albany RU

Implement the monitoring plan. Monitor Karner blue populations, habitat and habitat occupancy as recovery and habitat restoration activities are implemented. Coordinate monitoring on public and private lands.

1.323.4 Indiana

Indiana Dunes RU

Implement the monitoring plan. Monitor Karner blue populations, habitat and habitat occupancy as recovery and habitat restoration activities are implemented. Coordinate monitoring on public and private lands.

1.323.5 Michigan

Allegan RU

Implement the monitoring plan. Monitor Karner blue populations, habitat and habitat occupancy as recovery and habitat activities are implemented. Coordinate monitoring on public and private lands. Ensure monitoring protocol is reliable and efficient across extensive acreage.

Ionia RU

Implement the monitoring plan. Monitor Karner blue populations, habitat and habitat occupancy while recovery and habitat restoration activities are implemented.

Muskegon RU

Implement the monitoring plan. Coordinate monitoring efforts to meet criteria for viable population objectives. Ensure monitoring protocol is efficient, accomplishable, reliable, and portrays population trends for metapopulations.

Newago RU

Implement the monitoring plan. Coordinate monitoring efforts to meet criteria for viable population objectives. Ensure monitoring protocol is efficient, accomplishable, reliable, and portrays population trends for metapopulations.

1.323.6 Wisconsin

In all RUs, implement the respective monitoring plans for each metapopulation. Coordinate recovery monitoring efforts with those developed for the statewide HCP to avoid duplication of effort. Ensure monitoring protocol is efficient and doable across extensive acreage involved. This may require a modified monitoring protocol involving subsampling of habitats (refer to Recovery Task 3.4)

1.4 Protect existing Karner blue populations

1.41 Review Federal, state and private activities

Federal, state and private activities that may affect the habitat or result in the taking of Karner blue butterflies should be reviewed to the extent possible under Federal and state law. Appropriate measures should be taken to protect the butterfly and its habitat due to proposed activities. The States of New Hampshire, New York, Michigan, Minnesota, and Ohio have regulations regarding the potential of Karner blues. Although the Karner blue is not listed in Wisconsin, it is a species of Special Concern and the WDNR, through a cooperative agreement with the Service is committed to furthering the conservation and recovery of the species (refer to PART I, CONSERVATION MEASURES, State Protection). Three Federal regulatory review processes are discussed below.

1.411 Section 7 Federal responsibilities

Under section 7(a)(1) of the Act, Federal agencies are directed to utilize their programs to conserve threatened and endangered species. Section 7(a)(2) requires Federal agencies to consult with the Service to insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of listed species, nor destroy or adversely modify critical habitat (no critical habitat has been designated for the Karner blue butterfly). Federal programs and consultations with the Service should strive to implement recovery goals for the Karner blue butterfly to the maximum extent possible.

Formal section 7 consultations for the Karner blue butterfly have been completed for Federal actions in Wisconsin, Michigan, Indiana, New York, and New Hampshire. The guidance and information in this plan should be used when reviewing Federal projects and programs and when developing biological opinions.

Consultations are expected to continue in all states with occupied Karner blue habitat, with the greatest number of them taking place in Wisconsin and Michigan which support the majority of butterfly sites. Refer to PART I, CONSERVATION MEASURES, Federal Regulatory Protection, Section 7 consultation for overview of consultation activities.

1.412 Section 10(a)(1)(A) scientific permits

Scientific permits (also called recovery permits) under section 10(a)(1)(A) of the Act are issued by the Service to researchers for scientific purposes or to enhance the propagation or survival of the listed species. They also can be used to authorize take of the butterfly for management activities that contribute to the survival of the species. Due to the intense interest in research pertaining to the Karner blue butterfly, the Service has issued several scientific permits in the past, and anticipates issuing more in the future to address still unanswered research needs, management and recovery questions. Research permit applications should be well thought out, designed to minimize harm to the species, and reviewed by appropriate experts to ensure meaningful results. Scientific permits may also be used to encourage Safe Harbor approaches to conservation of the Karner blue butterfly. Refer to PART I, CONSERVATION MEASURES, Federal Regulatory Protection, Federal permits for further information on research permits, and the Safe Harbor approach to conservation.

1.413 Section 10(a)(1)(B) incidental take permits

Section 10(a)(1)(B) of the Act provides for the issuance of "incidental take" permits for the take of federally-listed animals such as the Karner blue butterfly for actions not authorized, funded or carried out by Federal agencies (see 1.411 above); namely, most state, county, municipal and privately owned lands. Applicants for an incidental take permit must develop a habitat conservation plan (HCP), and except for low-effect HCPs, must also develop an accompanying NEPA document. The Service has currently issued two “incidental take” permits involving the Karner blue. The first to the Town of Rome (Adams County), Wisconsin, and the second to the Wisconsin DNR for the Wisconsin Statewide HCP for the Karner Blue Butterfly (refer to PART I, DISTRIBUTION, State Distribution of Karner blues, Wisconsin, and CONSERVATION MEASURES, Federal Regulatory Protection, Federal permits). The Michigan DNR is currently taking the lead on development of a statewide HCP for the Karner blue in Michigan.

1.42 Develop standardized conditions for scientific permits

To expedite the processing of section 10(a)(1)(A) scientific permits (refer to 1.412 above), and to ensure uniformity of data rangewide, standardized permit conditions should be developed and provided to Service and state offices that may be involved in Karner blue butterfly scientific permit activities.

1.43 Identify mechanisms to streamline the Federal permit process for private landowners

Presence of an endangered species on private lands can result in additional costs and concerns for the landowner, especially in relation to the future value and use of the property. Because all "take" of a listed species must be authorized via a Service permit, streamlining the permit process could address some of these private landowners concerns. In addition, streamlining these procedures might encourage private landowners to participate in recovery (private landowners cannot be mandated to recover federally listed species).

Streamlined regulatory approaches to authorize "take" of the Karner blue butterfly include use of low-effect incidental take permits on an individual landowner basis, and programmatic, regional, or statewide incidental take permits (USFWS and NMFS 1996) that include a strategy to cover private landowners. The Wisconsin Statewide HCP for the Karner blue butterfly includes a participation strategy that covers "incidental take" for a select group of private landowners and provides a mechanism to extend permit coverage to new partners in the conservation program, thereby not only streamlining the permit process but eliminating it for some private landowners.

Another tool offered by the Service to encourage private landowner participation in conservation and recovery of listed species that can be considered is the Safe Harbor Agreement (refer to PART I, CONSERVATION MEASURES, Federal Regulatory Protection, Federal permits). A Safe Harbor approach to Karner blue butterfly conservation is currently being developed by TNC in northwest Indiana in concert with the Karner blue reintroduction effort to West Gary.

1.5 Develop recovery implementation strategies to promote recovery

It is important to encourage public participation in implementation of recovery actions. Private landowners are key to recovery in several areas of the Karner blue's range because their lands support existing butterfly populations. The Service and its partners seek to work with willing landowners on the recovery of threatened and endangered species; collaborative efforts with key landowners to promote recovery should be explored.

Participation strategies/plans should be developed as appropriate that provide a framework for recovery. Members to this process should include representatives of all interested parties that could be affected by implementation of the recovery actions and/or could assist with recovery, including Federal and state agencies, and private landowners (e.g., companies, private citizens and conservation groups). Education and outreach activities (refer to Task 4. Develop and implement information and education program below) may provide a vital link for involving important stakeholders in development of recovery strategies, especially in recovery areas that include or affect private lands. Karner blue butterfly state working groups should consider serving as leads for these efforts.

The New York State Working Group is developing a state recovery plan which provides a general recovery framework. Site specific management plans for the metapopulation sites will be appended as part of the plan. The planning process will involve local governments, non-profits, and interested and affected parties.

2. Evaluate and implement translocation where appropriate

Translocation efforts include population augmentation, accelerated dispersal and reintroductions (refer to APPENDIX I). The reintroduction of the Karner blue to historic habitats and translocations of the butterfly to unoccupied habitat (augmentation) or areas with low population densities (accelerated dispersal) within developing metapopulations (with an extant Karner blue population) are anticipated to enhance or accelerate the rangewide recovery effort. Protocols and guidelines should be developed and refined to ensure that translocation procedures are both appropriate and likely to be successful.

2.1 <u>Continue to develop and refine protocols and guidelines for translocation</u>

Before translocation of Karner blue butterflies occurs, the conditions necessary for ensuring metapopulation viability should be assessed. Moving butterflies in the absence of suitable or adequate habitat is not a wise use of resources. Before these relatively drastic measures are attempted, there should be a realistic expectation of long-term success based on the presence of adequate Karner blue habitat, ongoing habitat management and restoration efforts, and the capacity for Karner blue/habitat management and monitoring. For example, factors causing the failure of the native population should be remedied prior to any translocation effort. An example of a plan addressing pertinent issues relative to a reintroduction project can be found in the Ohio DNR's Conservation Plan for the Karner blue in Ohio (Ohio DNR 1998).

2.11 <u>Continue to develop protocols, guidelines, and selection criteria for translocation</u>

Ecosystems or habitats identified as potential translocation sites should meet certain minimum habitat quality and management criteria. A protocol detailing the assessment of these minimum criteria needs to be developed to ensure that sites are suitable before actions are taken. This protocol will spell out the conditions under which Karner blue translocation is appropriate and should follow the habitat and buffering criteria outlined in PART II, RATIONALE, Buffering Capacity for viable populations (refer also to APPENDIX G). Several methods are being used to move Karner blues from donor sites and to release sites and should be reviewed and synthesized in a guidance document. Evaluation of the Toledo Zoo's captive propagation efforts (Toledo Zoo 2002), the Ohio DNR's Karner blue conservation plan (Ohio DNR 1998), the population augmentation efforts in Minnesota, and the on-going reintroduction efforts in New Hampshire and Indiana should be examined to help further develop and document successful translocation protocols.

2.12 Incorporate research findings on captive propagation into protocols

As new ecological data are generated, and as experience with rearing protocols accumulates, timely refinements should be incorporated into the standardized captive propagation protocols. The Toledo Zoo's Captive Propagation Handbook for the Karner Blue (Toledo Zoo 2002) currently provides good guidance on captive propagation techniques. Additional research is being conducted by the Toledo Zoo to help refine their protocols the results of which should be incorporated into the protocols as appropriate (refer to Appendix I, CAPTIVE REARING AND CAPTIVE PROPAGATION).

2.2 Implement translocation in RUs

The habitats and Karner blue numbers in some populations in RUs have declined to the point that the butterfly's persistence is very precarious. In these cases, actions such as accelerated colonization to expand the metapopulation and population augmentation to boost butterfly numbers may be required to prevent metapopulation decline. These tools may be useful for speeding recovery in a metapopulation, by increasing metapopulation densities and accelerating dispersal faster than might otherwise occur. Reintroductions to historic habitat are necessary in some RUs to re-establish metapopulations that have been extirpated.

2.21 Initiate/continue reintroductions and accelerated colonization

For a review of on-going augmentation and reintroduction efforts across the range refer to PART I, CONSERVATION MEASURES, Reintroduction/Translocation). Captive rearing of Karner blues will be an integral part of most translocation programs. In some cases, it may be desirable to use captive propagation techniques to raise Karner blues. Captive propagation involves producing Karner blue butterflies for release from a permanent captive breeding population. With this technique a portion of the progeny are released to the wild, while the population is maintained in captivity. This method should be used when large numbers of butterflies will be needed for release over a long period of time, or when a local population is in immediate danger of extinction.

2.211 New Hampshire

Continue the reintroduction effort in Concord, New Hampshire. Captive rearing and release of adults to augment this site is on-going and needs to be continued until population densities/levels increase to viable population levels.

2.212 Minnesota

Karner blue numbers in Minnesota are precariously low. Captive rearing of adults and larvae (begun in 1999) to accelerate colonization to Lupine Valley should continue.

2.213 New York

Karner blue numbers in nearly all of the Glacial Lake Albany RU are precariously low. Captive rearing of adults to accelerate colonization to an unoccupied but apparently high-quality site may greatly increase metapopulation buffering and may increase the probability of Karner blue persistence in the state.

2.214 Indiana

The on-going reintroduction in West Gary, Indiana should continue until population densities/levels increase to viable population levels.

2.215 Other sites as need develops

If translocation efforts are determined to be an appropriate tool for use at other RUs, plans should be developed and implemented on an as needed basis to restore or recover viable metapopulations. Reintroduction may be necessary at TNC's Quincy Bluff and Wetland Preserve property in the Glacial Lake Wisconsin RU once sufficient habitat has been restored.

2.3 Consider additional reintroductions if necessary in PRUs

Because recovery of Karner blues in PRUs could contribute to the plan's goal of restoring viable populations throughout the range of the butterfly reintroductions to these areas may be appropriate and could serve to offset recovery goals in other portions of the range (refer to APPENDIX B, POTENTIAL RECOVERY UNITS).

2.31 Ohio

Continue the reintroduction program as appropriate to restore a viable population of Karner blues to the oak openings of northwest Ohio.

2.32 Other sites as need develops

Reintroduce Karner blues to other PRUs should such action be determined beneficial and appropriate to the recovery of the species.

3. Develop rangewide and regional management guidelines

While each metapopulation will have its own management and monitoring plan, some of the protocols and management practices can be standardized throughout the species range. The development of generic Karner blue guidelines will simplify RU-specific plan development.

3.1 Continue development of Karner blue butterfly Forest Management Guidelines

Several Karner blue populations occupy commercial and public forest lands such as Huron-Manistee NF in Michigan, and state and county forest lands in Wisconsin. Because much of the Karner blue butterfly landscape in the Midwest is forest land, it is important to understand the effects of forest management practices on the butterfly and its habitat and to be able to assess how practices can be modified to conserve the butterfly. Forest Management Guidelines (Guidelines) for the Karner blue butterfly have been developed by Lane (1997). They are available from the Service's Green Bay Field Office (2661 Scott Tower Drive, New Franken, Wisconsin 54229) and should be updated as new information becomes available.

The Guidelines review various forest management operations (e.g., planting, harvesting, site preparation, and thinning) and identify what is known about the effects of these practices on the Karner blue butterfly and its habitat. In addition, the Guidelines identify how the practices could be compatible with, or enhance conservation of the butterfly (e.g., through the use of woods roads as dispersal corridors, or stand thinning to promote lupine persistence). They also identify research questions that need addressing to further assess the impact of forest management practices on the butterfly and its habitat. It is anticipated that the Guidelines would be used by landowners involved in managing forests and by wildlife managers; the guidelines may also assist private landowners in the development of habitat conservation plans.

3.2 Develop guidelines for protection of the Karner blues from biocides

Several Karner blue populations occupy commercial and public forest lands subject to broadcast or spot herbicide treatment, or gypsy moth control measures, or they occur near urban developments where mosquito control is an issue. In addition, some Karner blue sites are near agricultural fields where insecticide or herbicide application could affect the butterfly. Incompatible use of insecticides and herbicides has the potential to extirpate or debilitate Karner blue populations. Thus, it is important to develop guidelines for the protection of the butterfly and essential components of its habitat (e.g., wild lupine and nectar plants) from pesticides. Pesticide protection guidelines should be incorporated into permits, management plans, and habitat conservation plans. Data from past and ongoing research efforts should be consulted during guideline formulation as should appropriate state administrative units.

Herbicides are used to control vegetation along roadways and utility corridors and in forestry management. Guidelines pertaining to pesticide use have been incorporated into APPENDIX G and should be revised as new information becomes available.

Formulations of *Btk* (*Bacillus thuringiensis kurstaki*) are currently used in the Midwest for control of gypsy moth. The following guideline is currently recommended by the Service for *Btk*: No aircraft broadcasting of *Btk* should occur within one-half mile of any Karner blue butterfly sites. Distances of less than one-half mile may be acceptable on a case by case basis by building in precautions to minimize drift (refer also to APPENDIX G).

New York State DEC requires that aerial spraying of the mosquito adulticide Scourge remain outside of a 100 foot buffer area around occupied Karner blue butterfly sites in the Towns of Wilton and Northumberland in the Saratoga Sandplains and cannot take place when wind drift would make conforming to the requirement doubtful.

The Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) has a landowner contact program designed to assist landowners, especially agricultural landowners, to avoid "take" of the Karner blue from pesticide applications, and is developing comprehensive pesticide use guidelines for the Karner blue. These guidelines should be finalized and updated as new information becomes available.

3.3 <u>Continue development of Karner blue management guidelines</u>

Several Karner blue RUs are centered on multi-use public and private lands, several of which are managed in part for wildlife production and hunting. Because many of these areas are important for the recovery of the Karner blue, it is important that land managers understand the impact of wildlife management practices on Karner blue populations and adjust accordingly given pre-existing constraints. Generic Karner blue management guidelines should provide overviews of current practices and suggest alternative practices when appropriate to minimize potential negative impacts from wildlife management. The WDNR has produced a set of wildlife management guidelines for the Karner blue (WDNR 1998, WDNR 2000) for use by its land manager and other interested parties. APPENDIX G provides management guidelines that should be revised as new information becomes available.

3.4 <u>Continue development of standardized monitoring protocols for the Karner blue</u>

Standardized monitoring protocols can be developed that could be applicable throughout the range of the species. Because monitoring needs will be different in each metapopulation, there is no need to use the same monitoring method throughout the range. Instead, a set of suitable, standard monitoring methods can be developed. Although this will not enable direct comparisons across the range, the monitoring systems will be refined to provide the best information to the local manager. Ongoing monitoring efforts in all RUs should serve as the starting point in development of these protocols (refer to APPENDIX H).

Two priority monitoring tasks are needed. The first is to evaluate existing methods for extrapolating Karner blue adult population sizes from transect counts (e.g., straight line, Pollard-Yates, and meandering transects) and to clarify these methods or conduct further research if needed to clarify protocols. The second is to determine if habitat-based monitoring can be used to reduce monitoring requirements for large viable populations with the goal of producing a more cost effective yet reliable protocol**.**

4. **Develop and implement information and education program**

The assistance of private landowners will be crucial for successful recovery in many RUs, including Merrimack/Nashua River System, Glacial Lake Albany, Newago, Muskegon, Indiana Dunes, Morainal Sands, and Glacial Lake Wisconsin, and possibly West Central Driftless, Wisconsin Escarpment/Sandstone Plateau, and Superior Outwash RUs. Private landowner participation in recovery is especially important in the Glacial Lake Albany RU where few sites are in public ownership, and even those sites may not have wildlife management as their primary goal (e.g., Saratoga County Airport).

In general, private landowners are likely to fall into the following three types: (1) those whose primary goal is to be involved in recovery, (2) those who want to use their land for multiple purposes, and are willing to trade-off among these purposes, and (3) those who want to use their land for one dominant use that is not related to Karner blue conservation and would include uses that are detrimental to the butterfly. The information and education programs may have several goals. For example, they can be used to assist the type (1) landowners, to encourage participation by type (2) and (3) landowners, and to diffuse potentially adverse public relations that might originate with some of the landowners. Information and education programs can be designed to recruit willing participants to meet identified recovery goals, or to identify willing participants who can assist in goal identification and planning on how to meet those goals. Private landowners will need to make their own decisions and determine the degree of participation in recovery they are willing to make. Information and education programs can be useful for facilitating this process.

4.1 <u>Continue to develop outreach materials on Karner blue life history and conservation</u>

In some portions of the Karner blue's range where the general public is aware and interested in the butterfly, there is little in the way of standardized information available to them. Information detailing the life history, habitat requirements, and habitat enhancement activities need to be developed and made available to public and private landowners. Educational materials on prescribed burning and the values of non-forest habitats (barrens and savannas) will be especially important for the Glacial Lake Albany and Glacial Lake Wisconsin RUs. Outreach materials and efforts should include reaching schools, scouting clubs, Americorps programs, and gardening clubs (especially in the Glacial Lake Albany RU) whose interest in butterfly gardening may be helpful in efforts to improve habitat. A part of the planned Wilton Wildlife Preserve and Park in Saratoga Sandplains includes a visitor's center within the area of the metapopulation, which would inform visitors about the Karner blue and other species present in the local environment. The visitor's center will include a butterfly garden featuring some of the native species on which the Karner blue depends. Refer to PART I, CONSERVATION MEASURES, Education and Outreach Activities, and APPENDIX J for information on education and outreach activities across the range.

Educational posters and pamphlets that can be used across the range of the Karner blue are needed. For instance a poster highlighting the value of oak savanna and pine barren habitats across the range and including photos of the Karner blue and other rare species associated with these habitats would provide multiply educational value and serve multiple states. Development of a template for a Karner blue pamphlet that could be used by all states to tailor make their own pamphlets is also needed. Development of a web site where Karner blue materials could be obtained and used by all would enhance and streamline outreach efforts.

4.2 Inform local governments of Karner blue RUs

Because Karner blue populations often occur on locally owned public lands which are not necessarily managed for biodiversity, it will be vital to inform the local agencies that manage these lands about the Karner blue and its potential for occurrence on their lands. Seeking partnerships with local governments (units smaller than the state) to help conserve the butterfly will help ensure that local land use decisions are compatible with recovery.

4.3 Encourage private landowners to conserve the Karner blue butterfly

Provide educational/outreach materials, including management guidelines and recommendations, to private organizations and individuals to assist in the development of their own Karner blue conservation initiatives. Work with local governments and private groups to develop informational and educational materials. Continue or initiate landowner contact programs to reach people in key habitat areas. As the Service and its partners seek to work with willing landowners on the recovery of endangered species, and some of the key butterfly sites are on private lands, it is important to contact these landowners to explore collaborative conservation efforts for the butterfly. Use existing Federal programs to encourage partnerships with private landowners and assist with financial costs associated with habitat restoration work. Federal programs that can provide landowner assistance are the Service's Partners for Wildlife Program, USDA's Natural Resource Conservation Service's Wildlife Habitat Incentive Program (WHIP), and the Farm Service Agency's Conservation Reserve

Enhancement Program (CREP). State stewardship and land management programs (e.g. Wisconsin) can also provide assistance. Existing and future environmental education centers, visitor's centers, etc., should be encouraged to become involved in education and outreach activities associated with the Karner blue butterfly.

4.4 Assess the needs, goals, and outcomes for public outreach

Although it is clear that public outreach programs are essential for recovery of the Karner blue butterfly, the goals of public outreach programs are often poorly defined. It is critical to define the needs, goals and outcomes of public outreach programs before substantial efforts are made. For example, development of an outreach program at IDNL could reach thousands of visitors per year and serve an important role in raising public awareness both locally in Indiana and nationally. An assessment of the best strategy to approach recovery on private lands near Miller Woods (part of IDNL) may be needed. Assessing the best way to approach public outreach in the Glacial Lake Wisconsin RU (especially around Necedah NWR, Necedah Wildlife Management Area, and Sandhill State WA) is crucial to support the recovery effort and savanna restorations in this RU. Support from the local communities, including forest owners and hunters, is essential.

5. Collect important ecological data on the Karner blue and associated habitats

Research is a crucial component of Karner blue recovery. Research activities that are necessary for successful Karner blue recovery are presented below. Table 5 includes a summary of research that the Recovery Team deemed interesting but not necessary for Karner blue recovery.

It is envisioned that research would be conducted by one or more agencies and other partners if available. Federal agencies that may assist with research include the Service, U.S. Geological Survey, U.S. Forest Service, Department of Defense (e.g. Fort McCoy), and the Federal Aviation Administration. State agencies anticipated to assist include the state DNRs (or DEC in NY) and Natural Heritage Programs in states where Karner blues occur. Other parties that should be contacted to explore their assistance with research tasks include partners to the Wisconsin Statewide HCP such as County Forest Departments, industrial forest landowners, and other private companies. Assistance from various universities, private landowners (including TNC) is also anticipated.

5.1 Priority 1 Research

5.11 Habitat management relative to the Karner blue butterfly

Determine the effects of habitat management on Karner blue butterfly populations and identify how to implement beneficial management practices to conserve or improve butterfly populations for application in the Glacial Lake Albany (New York), Merrimack-Nashua (New

Hampshire), and Paleozoic Plateau (Minnesota) RUs where populations are severely declining or at risk of loss. This research should focus on: (a) developing methods to improve the habitat of occupied sites while avoiding or minimizing harm to Karner blue, and (b) developing methods to increase the size of suitable sites and promote rapid (1-2 years) colonization. Studies on effective ways to control invasive exotic (non-native) species while avoiding or minimizing impacts on the Karner blue, lupine, and nectar plants are also needed.

5.12 Lupine propagation

Determine how to grow lupine from seed and to establish and maintain large populations of lupine and nectar plants efficiently, especially in the Glacial Lake Albany (New York) and Merrimack-Nashua (New Hampshire) RUs where populations are declining or may be lost.

5.13 Karner blue translocation methods

Continue to develop methods for translocation of Karner blue butterflies, focusing especially on release methods and methods to evaluate the impact of these releases on Karner blue butterfly abundance. This research is especially crucial for application at sites with declining butterfly populations. Research needs relative to captive propagation (as identified by the Toledo Zoo) include whether older females can be induced to lay viable eggs, the effect of diet on male fertility and female fertility and fecundity, and the optimal larval density on a lupine plant (refer to APPENDIX I, CAPTIVE REARING AND CAPTIVE PROPAGATION).

5.14 Alternative habitat restoration methods

Develop habitat restoration techniques, in addition to fire, that improve Karner blue populations. These techniques may include mowing, grazing, cultivating, and applying herbicides to control woody growth.

5.15 Remote sensing

Continue to develop remote sensing capabilities to identify lupine sites especially for use on the larger landscapes in Wisconsin and for use in the Muskegon and Newago RUs of Michigan that contain larger landscapes that could be losing yet unknown populations. Research using satellite imagery to identify lupine is underway by the Wisconsin DNR and the UW-Stevens Point (WDNR 2002b).

5.16 Glacial Lake Albany RU metapopulation decline

Determine the causes of Karner blue decline in the Glacial Lake Albany RU and how to mitigate them. This is critical in this RU because of low population numbers at most sites, and potential for the loss of some sites.

5.2 Priority 2 Research

5.21 Karner blue dispersal

Conduct research on the population structure of the Karner blue, especially focusing on dispersal rates in relation to distance between lupine sites, area of lupine sites, and the spatial distribution of the sites. Work is needed in open habitats, savanna/barrens habitat, and especially in forested and urban-suburban habitats.

5.22 Dispersal corridors and barriers

Determine factors necessary to create dispersal corridors and the factors that comprise dispersal barriers.

5.23 Ecosystem management

Develop methods for improving or restoring ecosystems that are compatible with the Karner blue butterfly.

5.24 Karner blue monitoring

If needed, develop and verify cost-effective and statistically reliable methods for monitoring the Karner blue butterfly (refer also to Task 3.4).

5.25 Forest management research

Determine the effects of forest management practices on the Karner blue and identify how to implement beneficial management practices to conserve or improve populations. Work is needed in all relevant forestry environments, especially red pine. Specific research topics are:

(a) What is the economic cost of reducing stand density to create or support Karner blue habitat? Emphasis should be on evaluating the effects of various levels of canopy reduction, in relation to tree basal area, productivity and Karner blue populations.

(b) What are the effects of clear cutting and site preparation on the Karner blue and its habitat? Emphasis should be on what happens during conversion from hardwood to pine, and on comparing site preparation methods, including chemical site preparation and planting, amount of surface disturbance for site preparation (low/medium/high), and use of prescribed fire (feasibility and effects).

(c) What are the effects of clearcut without conversion? Emphasis should be on determining when such clearcuts occur and the influence of the season of harvest (e.g., growing season versus dormant season and frozen versus unfrozen ground).

d) Can lupine and nectar plants regenerate on lands previously supporting mature red pine stands?

(e) Can the existing shifting mosaic of habitat on Wisconsin forest lands (e.g., in Jackson, Eau Claire and Clark Counties) support viable metapopulations of Karner blues consistent with the recovery criteria?

5.26 Highly dispersed metapopulations

Develop management practices for aggregations of occupied sites that are highly dispersed geographically (many sites greater than one mile from the next nearest site), so that they can be managed as a viable metapopulation (e.g., in the Superior Outwash or Morainal Sands RU).

5.3 Priority 3 Research

5.31 Ecology of local populations

Determine the relation between habitat structure and Karner blue butterfly populations. This entails a complex set of research issues, which may include: (a) determine why some sites support extremely high densities of the Karner blue (e.g., the Crossgates Mall site and numerous sites in the western part of the species range); (b) determine how the butterflies react behaviorally to their habitat; (c) develop a better understanding of the role of ants in Karner blue butterfly populations e.g., further examine the role of ants relative to parasitism and predation of eggs and larvae, and (d) determine the relation between nectar availability and female fecundity. It is not possible to anticipate all of the needed information on the ecology of local populations that is necessary for recovery. Thus, it is essential that proposed research in this area clearly identify why the research is necessary for recovery.

5.32 Effects of human activities

Determine how management and human use of rights-of-way influence the Karner blue butterfly (positively and negatively), especially in those areas where rights-of-way are essential for recovery. Assess how to develop positive interactions with people to enlist their support in developing and maintaining butterfly habitat.

5.33 Browse thresholds

Determine browsing thresholds on lupine by deer and woodchucks that present significant problems to persistence of lupine and acceptable Karner blue habitat in New Hampshire, New York, and Minnesota.

5.34 Re-establishment of lupine

Determine how lupine re-establishes on sites where a tree canopy has been opened and where lupine was not known to occur before the canopy was opened by evaluating the relative importance of a seed pool, rootstock survival, and recolonization. Determine how fire, light regime, and soil moisture interact to affect lupine abundance over successional time scales. This research should be designed to be directly applicable to those areas where lupine establishment has been problematic (e.g., the Albany Pine Bush).

5.35 Population structure

Determine actual/potential Karner blue metapopulation structure at highly fragmented sites to project how these metapopulations may persist as viable metapopulations, focusing on metapopulations in the Merrimack/Nashua River System RU, the Glacial Lake Albany RU, the Ionia RU, West Gary in the Indiana Dunes RU, and the Morainal Sands RU.

5.36 Taxonomic research

Determine if *Lycaeides melissa samuelis* should be divided into two or more subspecies focusing on whether “western” populations are sufficiently differentiated from “eastern” populations. Proposed genetics works of this type should be reviewed by knowledgeable geneticists prior to conducting the work.

5.37 Monitoring protocols using non-adult life stages

Determine how quantitative sampling of non-adult life stages can be used to estimate adult population size.

5.38 Effects of atmospheric nitrogen on lupine

Determine if atmospheric nitrogen affects lupine growth. Because atmospheric nitrogen does affect other plant growth, such as aspen, it could affect lupine growth as well (Tom Givnish, UW-Madison, pers. comm. 2002).

6. Review and track recovery progress

6.1 Develop a clearinghouse for Karner blue data, progress reports, metapopulation plans, HCPs, guidance documents, and other relevant information

Easy access to relevant Karner blue information will be essential for success of the Karner blue recovery process. A single collection and distribution point, with a commitment to providing relevant planning and educational materials will streamline this process and will facilitate Karner blue recovery. Currently, the Service's Green Bay Field Office (GBFO) in Wisconsin is maintaining a collection of research and outreach materials related to the Karner blue. The GBFO should also develop and maintain appropriate forms to track the recovery of each metapopulation.

6.2 Conduct Recovery Team meetings every 2-3 years to evaluate progress

Successful recovery of the Karner blue will require adaptive management and oversight. Meetings of the Recovery Team and interested parties will allow the Team members to review progress, learn of new research, review the impact of management practices on the Karner blue, discuss unanticipated developments, revise strategies, revise guidance documents and adjust priorities on an as needed basis. This would help ensure that Karner blue recovery stays on track. Meetings should start one year after publication of the final approved Recovery Plan. Additional meetings to address recovery-related issues as they arise may be appropriate as well (refer to Task 6.3 below).

6.3 Revise Plan as appropriate

The Karner Blue Butterfly Recovery Plan cannot address every future development and contingency. As such, it will likely need to be revised/updated at regular intervals to better reflect current conditions, and incorporate new research findings. Revisions should be made every five years or sooner as appropriate.

A priority issue is the re-evaluation of the status of the Karner blue in Wisconsin and the recovery goals for that state. Based on updated and detailed information on the distribution and occurrence of the Karner blue and its habitat in Wisconsin (refer to Part I, DISTRIBUTION, State Distribution of Karner Blues, Wisconsin), the Recovery Team will further review the data on the distribution, status, and threats to the species in the state and re-evaluate the recovery goals and recovery criteria for Wisconsin. If changes to the goals are warranted based on this review, the Service plans to make appropriate revisions to the recovery goals and recovery plan within 18 months of approval of the Final Plan.

6.4 Hold periodic meetings to promote recovery and information sharing

Sharing information on Karner blue research, habitat management techniques, monitoring, and adaptive management efforts in a forum that allows for discussion, problem solving, and assessment of effectiveness is important to recovery. State working groups should take the lead on working on recovery goals related to their state and meet on annual basis. Recovery partners and other interested parties including private land owning stakeholders should be involved in meetings as appropriate. Put state working group leaders on a web site.

Table 5. Research that is NOT a priority for recovery.

I. GENETIC STRUCTURE

1. Determine the genetic structure of the Karner blue butterfly range wide.

While research to determine if there are subspecific divisions within the Karner blue butterfly has been identified as a priority 3 research task, additional detailed research on the genetic structuring of Karner blue populations is considered unnecessary for recovery. Although this additional information could be useful in translocation efforts, the present translocation guidelines (APPENDIX I) provide sufficient guidance for these efforts at this time.

One of the fundamental assumptions of the recovery strategy is that RUs will preserve geographic genetic variation. Genetic studies would enable this assumption to be tested. Although such a test would be beneficial, in an ideal situation, it is doubtful that information on genetic structure would change the recovery strategy. A negative result is difficult to prove, and it would take considerable resources and time to compile a convincing case that Karner blue populations are not genetically structured. Moreover, even if the negative result could be adequately supported, it is only one of several assumptions underlying the recovery strategy. It would be more expedient to use the limited resources and time to recover the species. A positive result is likely to verify the assumption but would not change the recovery strategy.

II. DEFINITION OF A VIABLE POPULATION

1. Determine if 3,000 butterflies are too few or too many to comprise a viable population.
2. Determine if 6,000 butterflies are too few or too many to comprise a large metapopulation.
3. Determine if the Saratoga Airport is truly a viable population.

While the Recovery Team recognizes that the 3,000 butterfly criterion for a minimum viable metapopulation and the 6,000 butterfly criterion for a large viable metapopulation can be criticized, both are reasonable working definitions on which to base recovery. Moreover, it is doubtful that research on this issue would change the recovery strategy in any major way. For example, such research might demonstrate that these criteria are high or low by 600 or more butterflies. The Recovery Plan already provides flexibility to modify the number of butterflies needed for a viable population and provides guidance for when modifications are likely to be needed (refer to APPENDICES E and F). Relative to the 6,000 requirement for a LP, this is not intended to generate a burdensome or absolute sampling requirement. For instance, if a metapopulation has somewhat under the 6,000 criteria, yet the metapopulation stability has been demonstrated, and other recovery criteria are met, the metapopulation may be sufficient to qualify as a LP. Another example may be a metapopulation that generally has very high numbers (e.g., 10,000 Karner blues) and the numbers dropped to 5,000 for two years. The Service in conjunction with the recovery team will determine on a case by case basis if situations like these could qualify as LPs. It should be noted that to meet the 6,000 criterion, a metapopulation size larger than the 6,000 should be strived for (refer to APPENDIX F). Because of the flexibility built into the plan to allow modification of the 3000 and 6,000 criteria, additional research on this issue is currently not considered necessary for recovery. Should new information become available that warrants re-assessment of these criteria, the criteria can then be re-evaluated and revised if appropriate.

Although there is some controversy about whether the Saratoga Airport population is a viable population, it is widely recognized that expansion of that population into nearby habitat is needed and would buffer the population against any disaster that might occur at the airport. Because current efforts are being made to expand this population into nearby habitats, the issue is probably moot. If expansion becomes difficult, it will be necessary to develop a management plan that would ensure persistence of this population, and that would minimize the risk of its loss.

III. OTHER RESEARCH TOPICS

1. Determine the impact of armed forces training activities on the Karner blue butterfly (includes vehicle traffic and bombing practice).
2. Determine the significance of predation on Karner blue viability.

Although both of these research topics are significant, neither is considered a priority for recovery as research goals. Armed forces training activities appear to be playing a significant role in the management of Karner blue populations at Fort McCoy, Wisconsin, by maintaining disturbance regimes, and therefore are a low priority for research (refer to PART I, HABITAT/ECOSYSTEM, Renewal of Habitat for Karner blues, Other contemporary habitats). However research to improve management of Karner blue populations at this location may be beneficial. Moreover, Fort McCoy will probably continue to be an excellent location for conducting research that is necessary for recovery and applicable to other parts of the species range. In a similar way, research on predation will probably become necessary in some part of the species range, but a research project aimed at determining the significance of predation would be a misplaced effort.

LITERATURE CITED

Albany Pine Bush Preserve Commission. 1993. Preserve management plan and final environmental impact statement for the Albany Pine Bush Preserve. Albany, New York. 152pp.

Amaral, Michael. 2000. A proposal to translocate Karner blue butterflies (*Lycaeides melissa samuelis*) from New York to New Hampshire. Prepared for the New York State Department of Environmental Conservation and the U.S. Fish and Wildlife Service Region 5, Endangered Species Office by the Senior Endangered Species Specialist, New England Field Office, Concord, New Hampshire. 16 pp.

Andow, D.A., R.J. Baker, and C.P. Lane (eds.). 1994. Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. 222 pp.

Andow, D.A., C. P. Lane and D. M. Olson. Use of *Trichogramma* in maize – estimating environmental risks. *In* H.M.T. Hokkanen and J.M. Lynch (eds.), Biological Control: Benefits and Risks. Cambridge University Press, Cambridge. 1995. pp. 101-118.

Apfelbaum, S. I. and A. Haney. Management of degraded oak savanna remnants in the upper Midwest: Preliminary results from three years of study. *In* J. Ebinger (ed.), *Proceedings of the Oak Woods Management Workshop.* Peoria, Illinois. 1991. pp. 81-89.

Baker, R. J. The Karner blue butterfly: 1993 and beyond. *In:* Andow, D., R. Baker, and C. Lane (eds), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota - St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 163-169.

Bernays, E. A. and R. F. Chapman. 1994. Host-plant Selection by Phytophagous Insects. Chapman and Hall, New York. 312 pp.

Bidwell, A. D. 1994. Mark-release-recapture of Karner blue butterflies (*Lycaeides melissa samuelis*) at Fort McCoy Military Reservation. Report submitted to the U.S. Fish and Wildlife Service (Region 3), Fort Snelling, Minnesota.

Bidwell, A. D. 1995. Karner blue butterfly habitat disturbance and habitat spatial relationships on the South Post of Fort McCoy Military Reservation (masters thesis). University of Wisconsin – Stevens Point. 109 pp.

Bidwell, A. D. 1996. A habitat evaluation plan for the Karner blue butterfly. Report submitted to the Wisconsin Department of Natural Resources, Bureau of Endangered Resources, Madison, Wisconsin. 26 pp.

Bleser, C.A. 1992. Status survey, management and monitoring activities for the Karner blue butterfly *(Lycaeides melissa samuelis)* in Wisconsin 1990-1992. Report submitted to the U.S. Fish and Wildlife Service, Fort Snelling, Minnesota, by the Wisconsin Department of Natural Resources, Bureau of Endangered Resources, Madison, WI. 88 pp.+ appendices.

Bleser, C. A. 1993. Status survey, management and monitoring activities for the Karner blue butterfly (*Lycaeides melissa samuelis*) in Wisconsin. Final Report submitted to the U.S. Fish and Wildlife Service. 86 pp.

Bleser, C.A. Karner blue butterfly survey, management and monitoring activities in Wisconsin: 1990 - Spring 1992. *In*, Andow, D., R. Baker, and C. Lane (eds), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota – St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 153-162.

Borth, Robert J. 1997. Karner blue management implications for some associated Lepidoptera of Wisconsin barrens. Unpublished report to the partners of the Wisconsin Statewide Habitat Conservation Plan for the Karner Blue Butterfly. Wisconsin Gas, Milwaukee, WI. 35 pp.

Boyonoski, A. 1992. Factors affecting the establishment and maintenance of *Lupinus perennis* (wild lupine) (masters thesis). University of Guelph**.**

Breining, G. Nov/Dec1993. The case of the missing ecosystem. Nature Conservancy. pp. 10-15.

Burns, R. M. and B. H. Honkala (technical coordinators). 1990. Silvics of North America: Volume 2, Hardwoods. Agricultural Handbook - 654, U.S.D.A. Forest Service, Washington, D.C., Volume 2, 877 pp.

Celebrezze, T.M. 1996. Spatial patterning of lupine *(Lupinus perennis):* implications for metapopulation viability analysis of the endangered Karner blue butterfly (*Lycaeides melissa samuelis*) (master's thesis). University of Wisconsin, Madison. 66 pp.+ maps.

Chapman, K.A. 1984. An ecological investigation of native grassland in southern lower Michigan (master's thesis). Western Michigan University, Kalamazoo, Michigan.

Chew, F. S. and R. K. Robbins. Egg-laying in butterflies. *In* R. I. Vane-Wright and P. R. Ackery (Eds.) The Biology of Butterflies, Princeton University Press, Princeton, New Jersey. 1989. pp. 65-80.

City of Concord. March 1996. Concord Airport Master Plan Update. Prepared for the City of Concord, New Hampshire, by Rist-Frost-Shumway Engineering, P.C. Laconia, New Hampshire.

Coulson, R. N. and J. A. Witter. 1984. Forest Entomology: Ecology and Management. John Wiley and Sons, New York.

Cryan, J.F. and R. Dirig. 1978. A Report on the Status of the Karner Blue Butterfly (*Lycaeides melissa samuelis* Nabokov) in New York State. Report to the New York State Department of Environmental Conservation (response to the proposed rulemaking by the Fish and Wildlife Service, U.S. Department of the Interior, which designates this insect as Threatened). 15 pp.

Curtis, J. T. 1959. The Vegetation of Wisconsin: an Ordination of Plant Communities. The University of Wisconsin Press, Madison. 657 pp.

Cuthrell, D. L. 1990. Status of the Karner blue butterfly, *Lycaeides melissa samuelis* Nabokov, in Minnesota 1990. Report submitted to the Minnesota Non-game Wildlife Program.

Cuthrell, D. L. and M. L. Rabe. 1996. Status of the Karner blue butterfly *(Lycaeides melissa samuelis)*, in the Ionia Recovery Unit of Michigan. Prepared by the Michigan Natural Features Inventory, Lansing, Michigan for the U.S. Fish and Wildlife Service. 22 pp.

Davis, M. A., A. Duke, B. Ritchie, N. Graf, and K. Gregg. Undated. Multiple disturbances and the dynamics of pattern and persistence in a sand plain oak woodland. Draft report on research results, Macalester College.

Dirig, R. Karner's famous blue butterfly. *In* Rittner, D. (ed.), Pine Bush-Albany's last frontier. Pine Bush Historic Preservation Project, Albany, New York. 1976. pp. 197-210, 250-252.

Dirig, R. Historical notes on wild lupine and the Karner blue butterfly at the Albany Pine Bush, New York. *In* Andow, D. A., R. Baker, and C. Lane (eds), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota – St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 23-36.

Dolinger, P. M., P. R. Ehrlich, W. L. Fitch and D. E. Breedlove. 1973. Alkaloid and predation patterns in Colorado lupine populations. *Oecologia* 13: 191-204.

Dudt, J. F. and D. J. Shure. 1994. The influence of light and nutrients on foliar phenolics and insect herbivory. *Ecology* 75(1): 86-98.

Edwards, J. 2002. Summary for Karner blue butterfly fieldwork – 2001 field season. Unpublished Report, Minnesota Nongame Wildlife Program, St. Paul. 6 pp.

Elliot, J. N. 1973. The higher classification of the Lycaenidae (Lepidoptera): a tentative arrangement. *Bulletin of the British Museum of Natural History* (Entomology) 28: 373-500.

Faber-Langendoen, D. 1991. Community structure at Allison savanna: the impact of settlement and fire management. Final report to the Minnesota Chapter of The Nature Conservancy, Minneapolis, Minnesota.

Forman, R. T. 1979. Pine barrens: Ecosystem and landscape. Academic Press, New York.

Fried, C. S. September 1987. Dispersal of the Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov) in the Albany Pine Bush. Report submitted to the Endangered Species Unit of the New York State Department of Environmental Conservation.

Fuller, S. G. 1998. Interim Report: Summary of individual mark recapture. 1998. S.U.N.Y. College of Environmental Science and Forestry.

Fuller, Steven G. 2002. Comment letter to USFWS on Karner blue butterfly recovery plan.

Givnish, T. J., E. S. Menges, and D. F. Schweitzer. 1988. Minimum area requirements for long-term conservation of the Albany Pine Bush and Karner blue butterfly: an assessment. (Vol. IV, Appendix T). Report to the City of Albany from Malcolm Pirnie, Inc., Albany, New York. 95 pp. + figures.

Gleason, H. A. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada, second edition. The New York Botanical Garden. New York.

Grigore, M. 1992. The short-term effect of fire on wild lupine (*Lupinus perennis* L.). Masters thesis, University of Toledo, Ohio.

Grundel, R. 1994. The effects of lupine quality and habitat fragment quality on larval feeding intensity in the Karner blue butterfly (*Lycaeides melissa samuelis*). Report to the U.S. Fish and Wildlife Service (Region 3), Fort Snelling, Minnesota.

Grundel, R., N.B. Pavlovic, and C.L. Sulzman. 1998a. The effect of canopy cover and seasonal change on host plant quality for the endangered Karner blue butterfly *(Lycaeides Melissa samuelis).* Oecologia 114: 243-50.

Grundel, R., N. B. Pavlovic, and C. L. Sulzman. 1998b. Habitat use by the endangered Karner blue butterfly in oak woodlands: the influence of canopy cover. *Biological Conservation* 85: 47-53.

Grundel, R., N. B. Pavlovic and C. L. Sulzman. 2000. Nectar plant selection by the Karner blue butterfly (*Lycaeides melissa samuelis*) at the Indiana Dunes National Lakeshore. *American Midland Naturalist* 144: 1-10.

Haack, R. A. The endangered Karner blue butterfly (Lepidoptera:Lycaenidae): biology, management considerations and data gaps. *In* Proceedings of the 9th Central Hardwood Forest Conference, (in press). USDA Forest Service, North Central Forest Experiment Station, General Technical Report. 1993.

Hamilton, W.J. and J.O. Whitaker, Jr. 1979. Mammals of the Eastern United States. Comstock Publishing Associates, a division of Cornell University Press, Ithaca, New York.

Haney, A. and S. I. Apfelbaum. Structure and dynamics of Midwest oak savannas. *In* J. M. Sweeney (ed.), Management of Dynamic Ecosystems. Wildlife Society, West Lafayette, Indiana. 1990. pp. 19-30.

Herms, C. P. 1996. The endangered Karner blue butterfly (Lepidoptera: Lycaenidae) in Michigan: Habitat suitability, potential impacts of gypsy moth (Lepidoptera: Lymantriidae) suppression, and laboratory rearing (masters thesis) Michigan State University. 180 pp.

Herms, C. P., D. G. McCullough, D. L. Miller, L. Bauer and R. A. Haack. 1996. Laboratory rearing of *Lycaeides melissa samuelis* (Lepidoptera: Lycaenidae) an endangered butterfly in Michigan. *The Great Lakes Entomologist* 29: 63-75.

Herms, C. P., D. McCullough, L. S. Bauer, R. Haack, D. L. Miller and N. R. Dubois. 1997. Susceptibility of the endangered Karner blue butterfly (Lepidoptera: Lycaenidae) to *Bacillus thuringiensis* var. *kurstaki* used for Gypsy moth suppression in Michigan. *The Great Lakes Entomologist* 30: 125-141.

Higgins, L. G. 1985. The correct name for what has been called *Lycaeides argyrognomon* in North America. Journal of the Lepidopterists' Society 39:1 45-146.

Hobbs, R. J. and L. F. Huenneke. 1992. Disturbance, diversity and invasion: implications for conservation biology. *Conservation Biology* 6: 324-337.

Jackson, H. T. 1961. Mammals of Wisconsin. The University of Wisconsin Press, Madison.

King, R. 1994. Annual summary for Necedah National Wildlife Refuge. Necedah NWR, Necedah, Wisconsin. 13pp.

King, R. S. 1998. Dispersal of Karner blue butterflies (*Lycaeides melissa samuelis)* on Necedah NWR. Transactions of the Wisconsin Academy of Science, Arts and Letters. 86:101-110.

King, R. S. 1998. Spatial ecology, dispersal patterns and monitoring methods for the Karner blue butterfly, *Lycaeides melissa samuelis* on Necedah National Wildlife Refuge. Report submitted to the National Fish and Wildlife Foundation, U.S. Fish and Wildlife Service, and the Forest Industry.

King, R. S. 2000. Habitat management for the Karner blue butterfly (*Lycaeides melissa samuelis*): evaluating the short-term and long-term consequences. Necedah National Wildlife Refuge, Necedah, Wisconsin.

Kirk, K. December 1996. The Karner blue community: Understanding and protecting associated rare species of the barrens. Report to the U.S. Fish and Wildlife Service, Green Bay Field Office, Green Bay, Wisconsin. 95 pp. (Also occurs in WDNR 2000 referenced document.)

Klots, A. B. 1979. A Field Guide to the Butterflies: North America East of the Great Plains. Houghton Mifflin Co., Boston. 349pp.

Knutson, R. 1995. Karner blue butterfly travel distance recorded at Indiana Dunes National Lakeshore Inland Marsh 2nd brood (1994). Report to US Fish and Wildlife Service, January 31, 1995.

Knutson, R. L., J. R. Kwilosz and R. Grundel. 1999. Movement patterns and population characteristics of the Karner blue butterfly (*Lycaeides melissa samuelis*) at Indiana Dunes National Lakeshore. *Natural Areas Journal* 19: 109-120.

Lane, C. 1993 . Ecological studies and habitat restoration for the Karner blue butterfly *(Lycaeides melissa samuelis* Nabokov): 1993 Progress Report. Report submitted to the U.S. Fish and Wildlife Service, Green Bay, Wisconsin, Field Office, and the Minnesota Department of Natural Resources, St. Paul, Minnesota.

Lane, C. 1994a. Habitat preferences of the Karner blue butterfly in Minnesota. *In* D.A. Andow, R. Baker and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape, Minnesota Agricultural Experiment Station, University of Minnesota - St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 63-72.

Lane, C. 1994b. Ecological studies and habitat restoration for the Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov). Progress report to the U.S.F.W. Service and the Minnesota Department of Natural Resources. 32pp.

Lane, C. 1994c. Whitewater Wildlife Management Area. Management Plan for the oak savanna ecosystem, focusing on habitat restoration for the Karner blue butterfly. University of Minnesota, St. Paul, Minnesota. Prepared for the Minnesota Department of Natural Resources (St. Paul) and the U.S. Fish and Wildlife Service (Fort Snelling, Minnesota). 59pp. + figures.

Lane, C. Karner blue habitat suitability: considerations for oak savanna management in Minnesota. *In* Stearns, Forest and K. Holland (eds.), Proceedings of the 1993 Midwest Oak Savanna Conference. U.S. Environmental Protection Agency. Chicago, Illinois. June 1995. Available at: http://www.epa.gov/glnpo/oak/oak93/lane.htm

Lane, C. 1997. Forest management guidelines; developing management plans compatible with Karner blue butterfly persistence. Prepared for the Wisconsin Department of Natural Resources, Madison, Wisconsin and the U.S. Fish and Wildlife Service, Green Bay Field Office, Green Bay, Wisconsin. 124 pp.

Lane, C. 1999a. Translocation and population monitoring of the Karner blue butterfly at the Whitewater Wildlife Management Area. 1999 Final Report prepared for the Minnesota DNR by Blufflands Ecological Services, Maiden Rock, Wisconsin. 46 pp.

Lane, C. 1999b. Benefits of heterogeneous habitat: oviposition preference and immature performance *of Lycaeides melissa samuelis* Nabokov (Lepidoptera: Lycaenidae) (Ph. D. dissertation) University of Minnesota – St. Paul. 185 pp**.** Available from: University Microfilm Service in Ann Arbor, Michigan 1-800-521-0600.

Lane, C. and R. Dana. The status of the Karner blue butterfly in Minnesota. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota - St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 113-122.

Lane, C. and Welch, R. 1994. Rearing Karner blue butterflies for experimentation, re-establishment and supplementation. University of Minnesota, St. Paul, Minnesota (C. Lane) and Waupaca Field Station, Waupaca, Wisconsin (R. Welch). 18pp.

Lane, C. and S. J. Weller. A review of *Lycaeides* Hubner and Karner blue butterfly taxonomy. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota - St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 5-21.

Lawrence, W. S. Karner blue butterfly populations in the Allegan State Game Area, Michigan. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota – St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 53-62.

Lawrence, W. S. and A. C. Cook. 1989. The status and management of Karner blue (*Lycaeides melissa samuelis*) populations in the Allegan State Game Area, Michigan. Unpublished report to The Nature Conservancy, Michigan Field Office, East Lansing, Michigan. 57 pp.

Leach, M. 1993. Status and distribution of the Karner blue butterfly at Fort McCoy, Wisconsin: Final report on a two-year status survey. Prepared by The Nature Conservancy, Wisconsin Chapter, for the Natural Resources Management Division, Fort McCoy Military Reservation, United States Army, Fort McCoy, Wisconsin. 50 pp. + appendix.

Leach, M. K. and Ross, L. (eds.). 1995. Midwest oak ecosystems recovery plan: a call to action. Midwest Oak Savanna and Woodland Ecosystem Conference, Springfield, Missouri. 113pp.

Martin, M. Karner blue butterfly in Indiana: 1990 status survey for the U.S. Fish and Wildlife Service. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 97-105.

Masters, J. H. 1972. A new subspecies of *Lycaeides argyrognomon* (Lycaenidae) from the eastern Canadian forest zone. Journal of the Lepidopterists' Society 26: 150-154.

Mattson Jr., W.J. 1980. Herbivory in relation to plant nitrogen content. *Annual Review of Ecological Systematics* 11:119-61.

Maxwell, J. The importance of shade for the Karner blue butterfly. *In* Conference Program: Midwest Oak Savanna And Woodland Conference. Madison, Wisconsin. 1997. Page 43.

Maxwell, J. A. 1998. The conservation of the Karner blue butterfly (Lycaeides melissa samuelis Nabokov): Ecological studies on habitat creation and management (Ph.D. dissertation) University of Wisconsin – Madison. 193 pp.

Maxwell, J. and T. Givnish. 1994. Research on the Karner blue butterfly at Fort McCoy, Wisconsin: Progress report for the 1993 field season. Report to the U.S. Fish and Wildlife Service and U.S. Department of the Army.

Maxwell, J. and T. Givnish. 1996. Research on the Karner blue butterfly at Fort McCoy, Wisconsin. Progress report for the 1995 field season. Report submitted to the U.S. Fish and Wildlife Service and the U.S. Department of the Army. 30 pp. + tables.

Miller, J. C. 1990. Effects of a microbial insecticide, *Bacillus thuringiensis* Kurstaki, on nontarget Lepidoptera in a spruce budworm-infested forest. Journal of Research on the Lepidoptera 29: 267-276.

Miller, L. D. and F. M. Brown. Lycaenidae. *In* R.W. Hodges (ed.) Checklist of the Lepidoptera of America North of Mexico. E.W. Classey Limited and the Wedge Entomological Research Foundation, London. 1983. 284pp. pp. 53-57.

Minister of Public Works and Government Services Canada in cooperation with the U.S. Department of the Interior, Fish and Wildlife Service. 2001. Conserving borderline species. A partnership between the United States and Canada. ISBN: 0-662-85509-4, 25 pp.

Minnesota Department of Natural Resources. 1993. Minnesota's Native Vegetation: A Key to Natural Communities. Version 1.5, Natural Heritage Program, Biological Report Number 20.

Nabokov, V. 1943. The Nearctic forms of Lycaeides Hub. (Lycaenidae, Lepidoptera). Psyche 50: 87-99.

Nabokov, V. 1944. Notes on the morphology of the genus *Lycaeides* (Lycaenidae, Lepidoptera). Psyche 50: 104-138.

Nabokov, V. 1949. The Nearctic members of the genus *Lycaeides* Hubner (Lycaenidae, Lepidoptera). Bulletin of the Museum of Comparative Zoology 101: 479-541.

Nabokov, V. 1952. On some inaccuracies of Klots' Field Guide. The Lepidopterists' News. 6:41.

Nabokov, V. 1975. Novelist as Lepidopterist. The New York Times Magazine, July 27, p. 46.

Nabokov, V. Letter to Robert Dirig. *In* Nabokov, D. and M. J. Brucolli (eds.), Vladimir Nabokov, Selected Letters, 1940-1977. Harcourt Brace Jovanovich, Bruccoli Clark Layman, San Diego. 1989. 582 pp. 549-550.

New Hampshire Fish and Game Department. 2002. Summary of 2001 Karner blue butterfly (Lycaeides melissa samuelis) recovery activities, Concord pine barrens, New Hampshire. NH Fish and Game Department, Concord, New Hampshire. 7 pp.

Nice, C.C., G. Gelembiuk, N.Anthony, and R. ffrench-Constant. 2000. Population genetics and phylogeography of the butterfly genus *Lycaeides*. April 21, 2000 report to the U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 43 pp.

Nielsen, M. and L. Ferge. 1982. Observations of *Lycaeides argyrognomon Nabokov* in the Great Lakes Region (Lycaenidae). Journal of Lepidopterists' Society. 36(3), pp. 233-234.

Nuzzo, V. A. 1986. Extent and status of Midwest oak savanna: Presettlement and 1985. Natural Areas Journal 6: 6-36.

Ohio Department of Natural Resources. 1998. Ohio conservation plan, Karner blue butterfly. Prepared by the Ohio Karner Blue Butterfly Recovery Team for Ohio DNR, Division of Wildlife, Findlay, Ohio. 31 pp.

Opler, P. A. 1992. A Field Guide to Eastern Butterflies. Houghton Mifflin Co., Boston, New York, London. 396 pp.

Opler, P. A. and G. O. Krizek. 1984. Butterflies East of the Great Plains. The John Hopkins University Press. 294 pp.

Ownby, G. B.and T. Morley. 1991. Vascular Plants of Minnesota: A Checklist and Atlas, University of Minnesota Press, Minneapolis.

Packer, L. 1987. Status report on the Karner blue butterfly, *Lycaeides melissa samuelis*, Nabokov, in Canada. A report prepared for the World Wildlife Fund and the Ontario Ministry of Natural Resources, Wildlife Branch, Nongame Program. 66 pp.

Packer, Lawrence. Status of two butterflies, Karner blue (*Lycaeides melissa samuelis*) and frosted elfin (*Incisalia irus*), restricted to oak savanna in Ontario. *In* G.M. Allen, P. F. J. Eagles, S. D. Price (eds.), Conserving Carolinian Canada. University of Waterloo Press. 1991. pp. 253-271.

Packer, L. 1994. The extirpation of the Karner blue butterfly in Ontario. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota. 1994. Miscellaneous Publication 84-1994. pp. 143-151.

Packer, Lawrence, J.S. Taylor, D.A. Savignano, C. A. Bleser, C. P. Lane, and L.A. Sommers. 1998. Population biology of an endangered butterfly, *Lycaeides melissa samuelis* (Lepidoptera; Lycaenidae): genetic variation, gene flow, and taxonomic status. Canadian Journal of Zoology 76:320-329.

Papp, C. 1993. Habitat study of the endangered Karner blue butterfly (*Lycaeides Melissa samuelis* Nabokov) in Michigan oak savanna. Preliminary report submitted to the Department of Natural Resources, Wildlife Division, Michigan.

Payne, N. F. and F. C. Bryant. 1994. Techniques for wildlife habitat management of uplands. McGraw-Hill, Inc., New York.

Peteroy, A. 1998. 1998 Karner blue butterfly monitoring results: Concord Pine Barrens, New Hampshire. The Nature Conservancy. Concord, New Hampshire.

Pickering, M. 1994. Site conservation plan for the Saratoga Sandplains Macrosite. The Nature Conservancy, Eastern New York Chapter. 29pp.

Previtt, P. 1994. Strategy for recovery of the Karner blue butterfly in Ontario. Ministry of Natural Resources, Ontario, Canada. 9pp.

Rankin D. and S. Crispin. 1994. The conservation of biological diversity in the Great Lakes ecosystem: issues and opportunities. Report Submitted to U.S. Environmental Protection Agency.

Ravenscroft, N.O.M. 1994. The ecology of the chequered skipper butterfly *Carterocephalus palaemon* in Scotland. II. Foodplant quality and population range. *Journal of Applied Ecology* 31: 623-30.

Reichman, O. J. and S. C. Smith. 1985. Impact of pocket gopher burrows on overlying vegetation. *Journal of Mammology* 66: 720-725.

Savignano, D. A. 1990. Field investigations of a facultative mutualism between *Lycaeides melissa samuelis* Nabokov (Lycaenidae), the Karner blue butterfly, and attendant ants (Ph.D. dissertation). University of Texas, Austin.

Savignano, D. A. 1994a. Benefits to Karner blue butterfly larvae from association with ants. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 37-46.

Savignano, D. A. 1994b. The distribution of the Karner blue butterfly in Saratoga County, New York. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 73-80.

Schellhorn, N. A., C. Lane, and D. M. Olson. (unpublished). The risk of an introduced biological control agent (*Coccinella septempunctata*) to an endangered insect (*Lycaeides melissa samuelis*).

Schultz, C. B. and E. E. Crone. 1998. Burning prairie to restore butterfly habitat: a modeling approach to management tradeoffs for the Fender's blue. *Restoration Ecology* 6: 244-52.

Schweitzer, D.F. 1983. Preliminary report on rare Lepidoptera of the Concord, New Hampshire pine barrens. U.S. Fish and Wildlife Service, New England Field Office, Concord, New Hampshire.

Schweitzer, D. F. 1989. Fact sheet for the Karner blue butterfly with special reference to New York. Unpublished report, The Nature Conservancy. 7pp.

Schweitzer, D.F. 1990. The 1990 Status of Selected Karner Blue Remnants in Saratoga and Albany Counties, New York with a Discussion of Monitoring Methods. Report to New York State Department of Environmental Conservation Endangered Species Unit. 21 pp. + Appendix.

Schweitzer, D.F. 1992. The status of the Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov) at Indiana Dunes National Lakeshore, with special consideration of planning of prescribed burns at major sites. Research report prepared for the National Park Service, Porter, Indiana. 30 pp.

Schweitzer, D. 1993. A recovery plan for the Karner blue butterfly *(Lycaeides melissa samuelis Nabokov)* for the province of Ontario, with discussions of other rare oak savanna species. Prepared for the Ontario Ministry of Natural Resources, Pinery Provincial Park, RR2, Grand Bend, Ontario NOM 1T0. 63pp.

Schweitzer, D. 1994a. Recovery goals and methods for Karner blue butterfly populations. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 185-193.

Schweitzer, D. 1994b. Prioritizing Karner blue butterfly habitats for protection activities. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 173-183.

Schweitzer, D. F. and T. J. Rawinski. 1987. Element Stewardship Abstract for the Northeastern Pitch Pine Barrens, The Nature Conservancy (internal document). 23 pp.

Scott, J. A. Lycaenidae. *In* The Butterflies of North America. Stanford University Press, Stanford. 1986. pp. 347-414.

Scudder, S.H. 1889. The butterflies of the eastern United States and Canada with special reference to New England. Vol. II: Lycaenidae,Papilionidae, Hesperidae. Cambridge, Massachusetts. pp. 962-969.

Sferra, N.J., D.N. Ewert, C.A. Clampitt, H.E. Ballard, Jr., J.M. Aguiar and T. Darnell. 1993. Management of oak savanna and oak barrens habitat in Newaygo and Muskegon Counties, Michigan, for Karner blue butterflies *(Lycaeides melissa samuelis)* and other oak savanna invertebrates. Final Results. The Nature Conservancy, Unpublished Report. 25 pp**.**

Shuey, J. A. 1997. Dancing with fire: ecosystem dynamics, management, and the Karner blue (*Lycaeides melissa samuelis* Nabokov) (Lycaenidae). *Journal of the Lepidopterists Society* 51: 263-269.

Shuey, J. undated. A West Gary, Indiana Karner blue reserve design encompassing dune and swale oak barrens communities. The Nature Conservancy, Indiana Field Office, Indianapolis, Indiana. 14 pp. + figures.

Smallidge, P. J. and D. J. Leopold. 1996. Community characteristics and vegetation management of Karner blue butterfly (*Lycaeides melissa samuelis*) habitats on rights-of-way in east-central New York, USA. *Journal of Applied Ecology* 33: 1405-1419.

Smethurst, P. J., N. D. Turvey and P. M. Attiwell. 1986. Effect of *Lupinus* spp. on soil nutrient availability and the growth of *Pinus radiata* D. on seedlings on a sandy podzol in Victoria, Australia. Plant and Soil 95: 183-190.

Smith, M. A., M. G. Turner and D. H. Rusch. 2002. The effect of military training activity on Eastern lupine and the Karner blue butterfly at Fort McCoy, Wisconsin, USA. *Environmental Management* 29: 102-115.

Sommers, L. A. and P. E. Nye. Status, research and management of the Karner blue butterfly in New York. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 129-134.

Spoor, R. P. 1993. Studies on the eggs and larvae of the Karner blue butterfly at Crossgates Mall. Report to the New York State Department of Environmental Conservation, Endangered Species Unit, December 12, 1993.

Spoor, R. P. and Nickles. Fate of eggs of second brood Karner blue butterfly females. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 47-52.

Straub, B. 1994. Effects of White-tailed deer browsing on lupine. Report to the University of Minnesota Undergraduate Research Opportunity Grants Program.

Sucoff, Edward. 1997. Effect of three herbicides on the vegetative growth and flowering of wild lupine, final report 2nd year observations. Department of Forest Resources, University of Minnesota – St. Paul. 3 pp.

Sucoff, Edward. 1998. Effect of exposing eggs to herbicides on the development of Karner blue butterfly. Department of Forest Resources, University of Minnesota – St. Paul. 7 pp.

Swengel, A. B. and S. R. Swengel. 1993. Observations of Karner blues and the barrens butterfly community in Wisconsin. Manuscript (December 1993), 909 Birch Street, Baraboo, Wisconsin. 36 pp. + appendices.

Swengel, A. B. 1994. Observations on the effects of fire on Karner blue butterflies. *In* Andow, D.A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 81-86.

Swengel, A. B. 1995. Observations of spring larvae of *Lycaeides melissa samuelis* (Lepidoptera: Lycaenidae) in central Wisconsin. Great Lakes Entomologist 28: 155-170.

Swengel, A. B. and S. R. Swengel. 1996. Factors affecting abundance of adult Karner blues (*Lycaeides melissa samuelis*) (Lepidoptera: Lycaenidae) in Wisconsin Surveys 1987-95. *The Great Lakes Entomologist* 29: 93-105.

Swengel, A. B. and S. R. Swengel. 1997. Co-occurrence of prairie and barrens butterflies; applications to ecosystem conservation. *Journal of Insect Conservation* 1: 131-44.

Swengel, A. B. and S. R. Swengel. 1998. Density-dependent and –independent behaviors of the adult Karner blue (*Lycaeides melissa samuelis*) (Lepidoptera: Lycaenidae). *The Great Lakes Entomologist* 31: 59-7.

Swengel, A. B. 1998. Effects of management on butterfly abundance in tallgrass prairie and pine barrens. Biological Conservation 83: 77-89.

Swengel, A. B. and S. R. Swengel. 1999. Timing of Karner blue (Lepidoptera: Lycaenidae) larvae in spring and adults in spring and summer in Wisconsin during 1991-1998. *The Great Lakes Entomologist* 32, (1-2): 79-96.

Swengel, A. B. and Swengel, S. R. 2000. Variation in timing and abundance of Elfins (Callophrys)(Lepidoptera: Lycaenidae) in Wisconsin during 1987-1999. *The Great Lakes Entomologist* 33: 45-68.

Tester, J. R. 1989. Effects of fire frequency on oak savanna in east-central Minnesota. Bulletin of the Torrey Botanical Club 116: 134-144.

The Nature Conservancy. 2002. 2001 progress report for the Indiana office of The Nature Conservancy's Karner blue butterfly re-introduction at Ivanhoe Nature Preserve, Gary, Indiana. The Nature Conservancy, Southern Lake Michigan Rim Program,Whiting, Indiana. 3 pp.

Thomas, J. A. 1980. The extinction of the large blue and the conservation of the black hairstreak butterflies (a contrast of failure and success). *Rep. Inst. Terr. Ecol*. 1979: pp. 19-23.

Toldeo Zoo. 2002. Propagation handbook for the Karner blue butterfly, *Lycaeides melissa samuelis*). The Toldeo Zoo, Toledo, Ohio. 14 pp. + appendix.

Trick, Joel A. 1993. Wisconsin Karner blue butterfly 1993 survey results. U.S. Fish and Wildlife Service, Green Bay, Wisconsin. 14 pp.

Turvey, N. D. and P. J. Smethurst. 1983. Nitrogen fixing plants in forest plantation management. Forest Science 9: 233-259.

U.S. Fish and Wildlife Service. 1992a. Endangered and threatened wildlife and plants; determination of endangered status for the Karner blue butterfly. Proposed rule. Federal Register 57(13):2241-2246.

U.S. Fish and Wildlife Service. 1992b. Endangered and threatened wildlife and plants; determination of endangered status for the Karner blue butterfly. Final rule. Federal Register 57(240):59236-59244.

U.S. Fish and Wildlife Service. Biological assessment of management practices on the Necedah National Wildlife Refuge. Necedah NWR, Necedah, Wisconsin. 21 pp. + attachments.

U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1999. Safe harbor agreements and candidate conservation agreements with assurances; announcement of final safe harbor policy; announcement of final policy for candidate conservation agreements with assurances; final rule and notices. *Federal Register* Notice 64 (116): 32706-32736.

U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1996. Endangered Species Habitat Conservation Planning Handbook. 105 pp. + appendices.

VanLuven, D. E. 1993. Status report on the Karner blue butterfly and associated management activities. U.S. Fish and Wildlife Service, Concord, New Hampshire. 25 pp.

VanLuven, D. 1994a. 1993 Karner blue butterfly (*Lycaeides melissa samuelis*) captive rearing results: Concord Pine Barrens, New Hampshire. The Nature Conservancy, New Hampshire Field Office, Concord, New Hampshire.

VanLuven, D. E. 1994b. 1994 plant propagation results: Concord Pine Barrens, New Hampshire. Report to the U.S Fish and Wildlife Service, New Hampshire Field Office, Concord, New Hampshire. 12 pp.

Warren, M. S. 1987. The ecology and conservation of the heath fritillary butterfly, *Mellicta athalia*. II. Adult population structure and mobility. *J. of Applied Ecology* 24: 483-489.

Waterman, P. G. and S. Mole. 1989. Extrinsic factors influencing production of secondary metabolites in plants. In Bernays, E.A. (ed.), Insect-plant Interactions. CRC Press, Boca Raton. pp.107-134.

Welch, R. J. 1993. Dispersal and colonization behavior in the Karner blue butterfly (*Lycaeides melissa samuelis*) in central Wisconsin. Final report to U.S. Fish and Wildlife Service, Green Bay Field Office, Wisconsin. 50 pp. + appendices.

Wilde, S. A., P. B. Whitford, and C. T. Youngberg. 1948. Relation of soils and forest growth in the driftless area of southwestern Wisconsin. Ecology 29: 173-180.

Wilder, Timothy. 1998. Karner blue butterfly, summary of 1997 field activities on Fort McCoy. Prepared by Fort McCoy, Directorate of Training and Mobilization (DTM), Range Division, Fort McCoy, Wisconsin for the U.S. Fish and Wildlife Service. 29 pp. + appendices.

Wilsmann, L. Status of the Karner blue butterfly in Michigan. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 107-112.

Wisconsin Department of Natural Resources, Bureau of Endangered Resources. 1998. Wildlife Management Guidelines for Karner Blue. Wisconsin Department of Natural Resources, Madison, Wisconsin. 42 pp.

Wisconsin Department of Natural Resources. 2000a. Wisconsin statewide Karner blue butterfly habitat conservation plan and environmental impact statement. PUBL-SS-947-00. Wisconsin Department of Natural Resources, Madison. 386 pp. + appendices. Available from the HCP Coordinator at 877-452-7637.

Wisconsin Department of Natural Resources. 2002a. The Wisconsin Karner blue butterfly habitat conservation plan annual report of activities for calendar year 2001. Wisconsin DNR, Bureau of Endangered Resources and Division of Forestry, Madison, Wisconsin. 6 pp. + appendices and attachments.

Wisconsin Department of Natural Resources. 2002b. Detecting the presence of wild lupine utilizing large-scale remote sensing multi-spectrum satellite imagery. Report prepared by the Wisconsin DNR, Madison, Wisconsin for the U.S. Fish and Wildlife Service. 8 pp.

Wovcha, Daniel S, B.C. Delany, and G.E. Nordquist. 1995. Minnesota's St. Croix River Valley and Anoka Sand Plain: A Guide to Native Habitats. Minneapolis: University of Minnesota Press.

Zaremba, R. E., M. Pickering, and B. Hunt. 1991. Preliminary results of 1990 lupine (*Lupinus perennis*) propagation project in the Albany Pine Bush. Report to the New York State Department of Environmental conservation Endangered Species Unit and the City of Albany.

Zaremba, R. E. and M. Pickering. Lupine ecology and management in New York state. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota-St. Paul. 1994. Miscellaneous Publication 84-1994. pp. 87-93.

PART III. IMPLEMENTATION

The following Implementation Schedule outlines actions and estimated costs for the recovery program in the United States portion of the Karner blue butterfly's range for the next three years. It is a guide for meeting the objectives discussed in PART II, RECOVERY OBJECTIVE.

The Implementation Schedule lists and ranks recovery tasks, provides task descriptions and duration, identifies responsible agencies, and provides estimated costs. This schedule will be reviewed periodically until the recovery objective is met, and priorities and tasks will be subject to revision. Tasks are presented in order of priority.

Key to Implementation Schedule

Column 1: Task Priority

Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2: An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to meet the recovery objectives.

Column 2: Task Number

The number from the STEPDOWN RECOVERY OUTLINE (refer to PART II).

Column 3: Task Description

A short description of the recovery task which coincides with the STEPDOWN RECOVERY OUTLINE (PART II)

Column 4: Task Years

The number of years that it is expected to take before the task is completed. An asterisk (*) indicates that the task is on-going and will be carried out as necessary. A plus (+) means that the task may take longer than the stated number of years to complete.

Column 5: USFWS

This designates the U.S. Fish and Wildlife Service (USFWS) Region(s) and programs involved in carrying out the task; 3 = Region 3 and 5 = Region 5. ES = Ecological Services and NWR = National Wildlife Refuges (Necedah or Great Bay NWR).

Column 6: Other

This lists the other agencies, organizations, and participants that are expected to be involved in completing the task. A key to the acronyms is provided here. KBB = Karner blue butterfly.

AZA	American Zoological and Aquarium Association and members
APBPC	Albany Pine Bush Preserve Commission
CC	City of Concord, New Hampshire
CPBIT	Concord Pine Barrens Interagency Team (TNC, USFWS, NH Natural Heritage Inventory, and NHDFG)
DATCP	Department of Agriculture, Trade and Consumer Protection (Wisconsin)
DOD	Department of Defense (Fort McCoy and/or Air National Guard Hardwood Range)
FAA	Federal Aviation Administration
IDNL	Indiana Dunes National Lakeshore
INWG	Indiana (KBB) Working Group (USFWS, TNC, IDNL, USGS-BRD INDNR)
INDNR	Indiana Department of Natural Resources
LG	Local governments
MNDNR	Minnesota Department of Natural Resources
MIDNR	Michigan Department of Natural Resources
MIWG	Michigan (KBB) Working Group (MNFI, MIDNR, Huron-Manistee NF, USFWS, North Central Forest Experiment, TNC, Michigan State University at East Lansing)
MNFI	Michigan Natural Features Inventory
NHDFG	New Hampshire Department of Fish and Game
NPS	National Park Service
NRCS	National Resource Conservation Service (USDA)
NYDEC	New York Department of Environmental Conservation
NYWG	New York (KBB) Working Group
OFA	Other Federal Agencies (e.g., U.S. Environmental Protection Agency, U.S. Department of Housing and Urban Development, Federal Highway Administration)
OHDNR	Ohio Department of Natural Resources
OPRHP	Office of Parks, Recreation and Historic Preservation (NY)
OTHERS	Other willing landowners e.g., utility companies, highway departments, private landowners, WI HCP partners, etc.
RT	Recovery Team
TNC	The Nature Conservancy
UNIV	University(s)
USGS-BRD	U.S. Geological Survey, Biological Resource Division
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
WDNR	Wisconsin Department of Natural Resources
WWPP	Wilton Wildlife Preserve and Park

Columns 7-9: FY1, FY2, and FY3

The estimated cost for carrying out the task during fiscal year 1 (FY1), fiscal year 2 (FY2), and fiscal year 3 (FY3). Costs are listed in thousands of dollars. TBD means costs are yet to be determined.

Column 10: Comments

Explanatory comments. For more detailed information, refer to RECOVERY TASKS (PART II).

HCP	Habitat Conservation Plan
P1	Priority 1 task
P2	Priority 2 task
P3	Priority 3 task
RU	Recovery Unit
TBD	To be determined
WMA	Wildlife Management Area

Table 6. Implementation table for the Karner blue butterfly recovery plan**.**

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
1	1.11	Monitor population trends, habitat and distribution in New Hampshire	3	5	ES	TNC	1.5	1.5	1.5	Two flights
1	1.12	Survey for new and monitor existing subpopulations in Minnesota.	3+	3	ES	MNDNR	5	5	5	Monitor existing pops and restored habitats at Whitewater WMA
1-2	1.13	Monitor population trends, habitat and distribution in Michigan	3	3	ES	USFS, MNFI, MIDNR	70	30	20	Survey in Ionia RU-P1; Survey in Muskegon RU-P2
1	1.21	Continue/start management activities for New Hampshire	3+	5	ES, NWR	TNC , OTHERS FAA, CC	30	48	21	Concord sites
1	1.22	Continue/start management activities for Minnesota	5+	3	ES	MNDNR	80	80	80	Continue work at Whitewater WMA
1	1.23	Continue/start management activities for New York	3+	5	ES	NYDEC, TNC, OTHERS WWPP, APBPC	75	75	75	Albany Pine Bush, Saratoga Sandplains and Saratoga West
1	1.311	Develop protection and management plans for Minnesota	2	3	ES	MNDNR	2	2	0	Incorporate recovery guidance into Whitewater WMA Plan

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
1	1.321.1	Implement the management plan in New Hampshire	5+	5	ES	NHDFG, TNC, FAA	5	5	5	Concord metapopulation
1	1.321.2	Implement the management plan in Minnesota	5+	3	ES	MNDNR	0	50	50	Restore habitat and create firebreaks
1	1.322.2	Implement long term land protection strategies in New York	5+	5	ES	NYDEC, TNC, LG, WWPP, OTHERS APBPC	10,000	10,000	12,000	Estimated land purchases
1	2.211	Continue reintroduction in New Hampshire	5+	5	ES	TNC, NHDFG	5	5	5	On-going
1	2.212	Continue accelerated colonization in Minnesota	5+	3	ES	MNDNR	20	20	20	Continue population augmentation
1	2.214	Continue reintroduction in Indiana	3	3	ES	TNC, INDNR	--	--	--	Funding currently covered by TNC
1-3	3.4	Continue development of standardized monitoring protocols for the Karner blue	3	3	ES, NWR	WDNR, MIDNR, RT, USGS-BRD	0	20	20	Clarify methods for extrapolation of transect counts to population counts and for monitoring LPs, (refer also to Task 5.24) - P1

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
1	5.11	Research – Habitat management relative to Karner blue butterfly	5+	3, 5	ES	NYDEC, CPBIT, MNDNR, WDNR, MIDNR, TNC, IDNL, USFS, DOD, USGS-BRD, RT, OTHERS	40	40	40	Priority on research aimed for application in NH, NY, and MN
1	5.12	Research - Lupine propagation	5+	3	ES	NYDEC, NHDFG, TNC (NY), TNC (NH), OTHERS, NRCS APBPC	10	10	10	Priority in NY and NH
1	5.13	Research - Karner blue butterfly translocation methods	5+	3, 5	ES	MNDNR, OHDNR, NYDEC, TNC, NHDFG	15	15	15	
1	5.14	Research - Alternative habitat restoration methods	5+	3, 5	ES	TNC, NYDEC, MIDNR, MNFI, WDNR, MNDNR, USFS, NHDFG, OTHERS	80	80	80	Especially needed in NH, NY, and MN

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
1	5.15	Research - Remote sensing	2	3	ES	USFS	26	26	0	To identify lupine patches, especially in Muskegon and Newago RUs (MI)
1	5.16	Research - Glacial Lake Albany population decline	5+	5	ES	NYDEC, TNC, UNIV	10	10	10	
1-2	5.24	Research - Karner blue butterfly monitoring	3+	3, 5	ES, NWR	NYDEC, MNFI, WDNR, TNC,USGS-BRD, UNIV	30	30	30	If needed, further research cost-effective and statistically reliable monitoring methods for LPs (refer also to Task 3.4).
1-3	6.3	Revise plan as appropriate	*	3	ES	RT	0	0	8	Re-evaluate recovery goals for Wisconsin – P1.
2	1.14	Monitor population trends, habitat and distribution in New York	3+	5	ES	NYDEC, TNC , APBPC	20	20	20	Interim until plan is in place
2	1.15	Monitor population trends, habitat and distribution in Indiana	3	3	ES	TNC, IDNL	1	1	1	West Gary
2-3	1.16	Monitor population trends, habitat and distribution in Wisconsin	3	3	ES, NWR	TBD	3	3	0	Search for recovery sites in the Yellow River Focus Area of Glacial Lake Wisconsin RU-P3

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
2	1.24	Continue/start management activities for Michigan	3+	3	ES	USFS, MNFI, MIDNR	37.5	37.5	37.5	Habitat management, enhancement and protection activities
2	1.25	Continue/start management activities for Indiana	5+	3	ES	IDNL, TNC	40	40	40	Most habitats are fire suppressed and require brush and/or tree removal
2	1.26	Continue/start management activities for Wisconsin	3+	3	ES	WDNR, OTHERS, DOD	29	26	26	Federal, state and private property
2-3	1.312	Develop protection and management plans for New York	3	5	ES	NYDEC, APBPC, TNC (NY), LG, OTHERS, WWPP, OPRHP	20	5	5	Saratoga West-P2
2	1.313	Develop protection and management plans for Indiana	2	3	ES	IDNL, TNC OTHERS	20	5	5	West Gary and IDNL
2-3	1.314	Develop protection and management plans for Michigan	2	3	ES	USFS, MNFI, OTHERS, MIDNR	0	60	60	Ionia and Newago RUs-P2

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
2	1.315	Develop protection and management plans for Wisconsin	3	3	ES, NWR	WDNR, TNC, DOD, OTHERS	20	10	5.5	Includes revising management and/or master plans for county, state, and Federal properties
2	1.321.3	Implement the management plan in New York	5+	5	ES	NYDEC, TNC (NY), LG, OTHERS	100	100	100	Land acquisition needed
2	1.321.4	Implement the management plan in Wisconsin	5+	3	ES, NWR	WDNR, OTHERS, TNC , NPS, DOD,	48	63.5	63.5	
2	1.321.5	Implement the management plan in Indiana	5+	3	ES	IDNL, TNC, OTHERS	15	15	15	
2	1.321.6	Implement the management plan in Michigan	5+	3	ES	USFS, MNFI, DNR, OTHERS	170	170	170	Implement plan in 4 RUs
2	1.322.1	Implement long term land protection strategies in New Hampshire	3+	5	ES, NWR	NHDFG, TNC, FAA, OTHERS	5	5	250	Some land acquisition possible in 3rd year
2	1.322.3	Implement long term land protection strategies in Indiana	5+	3	ES	TNC, OTHERS, IDNL	500	500	500	Estimated land purchases

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY: USFWS REGION	RESPONSIBLE PARTY: USFWS PROGRAM	RESPONSIBLE PARTY: OTHER	COST ESTIMATES ($000) Year 1	COST ESTIMATES ($000) Year 2	COST ESTIMATES ($000) Year 3	COMMENTS
2-3	1.322.4	Implement long term land protection strategies in Michigan	5+	3	ES	USFS, MIDNR, MNFI, OTHERS	15	56	50	Ionia RU-P2
2	2.213	Initiate translocation efforts in New York	5+	5	ES	NYDEC, TNC	0	0	50	
2	3.1	Continue development of Karner blue Forest Management Guidelines	3	3	ES	WDNR, , USFS, UNIV, OTHERS	4	3	4	
2	3.2	Develop guidelines for protection of Karner blues from biocides	3+	3	ES	WDNR, DATCP, NYDEC	3	1	1	
2	5.21	Research - Karner blue dispersal	5+	3, 5	ES, NWR	NYDEC, MNFI, WDNR, TNC, USFS, DOD, USGS-BRD, UNIV	30	30	30	Especially in forested and urban/ suburban habitats
2	5.22	Research – Dispersal corridors and barriers	5+	3, 5	ES	NYDEC, WDNR, TNC, USGS-BRD, USFS, UNIV	10	10	10	
2	5.23	Research – Ecosystem Management	5+	3, 5	ES, NWR	NYDEC, MNFI, MNDNR, WDNR, TNC, USGS-BRD	20	20	20	

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
2	5.25	Research - Forest management research	5+	3	ES	WDNR, USFS, MNFI, OTHERS, USGS-BRD, UNIV	0	32	45	Identify and implement beneficial management practices, especially in red pine
2	5.26	Research - Highly dispersed metapopulations	5+	3, 5	ES	WDNR, OTHERS, UNIV	20	20	20	Identify appropriate management
3	1.316	Develop protection and management plans for New Hampshire	3	5	ES, NWR	NHDFG, TNC, FAA, CC	2.5	0.5	0.5	Minimal cost to update existing plans
3	1.322.5	Implement long term land protection strategies in Wisconsin	5+	3	ES, NWR	WDNR, OTHERS, NPS	5	15	5	State Natural Area designations and pursuit of conservation agreements
3	1.322.6	Implement long term land protection strategies in Minnesota	5+	3	ES	MNDNR	2	2	2	Coordinate activities in Whitewater WMA
3	1.323.1	Implement the monitoring strategies in New Hampshire	5+	5	ES	TNC	1.5	1.5	1.5	
3	1.323.2	Implement the monitoring strategies in Minnesota	5+	3	ES	MNDNR	2	2	2	Monitor both flights, 3 times each flight

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
3	1.323.3	Implement the monitoring strategies in New York	5+	5	ES	NYDEC, TNC, APBPC, WWPP, OTHERS	0	10	40	Begins after plan is developed
3	1.323.4	Implement the monitoring strategies in Indiana	5+	3	ES	IDNL, TNC	0	0	5	Begins after metapopulation plans are developed
3	1.323.5	Implement the monitoring strategies in Michigan	3+	3	ES	USFS, MNFI, MIDNR	0	20	60	Annually to every three years as populations stabilize
3	1.323.6	Implement the monitoring strategies in Wisconsin	5+	3	ES, NWR	WDNR, DOD, OTHERS	66	68.5	68.5	
3	1.411	Review Federal, state and private activities – section 7 Federal responsibilities under the Act	5+	5, 3	ES	OFA, WDNR, MNFI, NHDFG, NYDEC	3.5	3.5	3.5	Possible costs for surveys
3	1.412	Review Federal, state and private activities – section 10(a)(1)(A) scientific permits under the Act.	*	5, 3	ES	MNDNR, MIDNR, NHDFG, NYDEC	0	0	0	
3	1.413	Review Federal, state and private activities – section 10(a)(1)(B) incidental take permits per the Act	*	5, 3	ES	WDNR, TNC	5	2	2	Wisconsin Statewide HCP under development

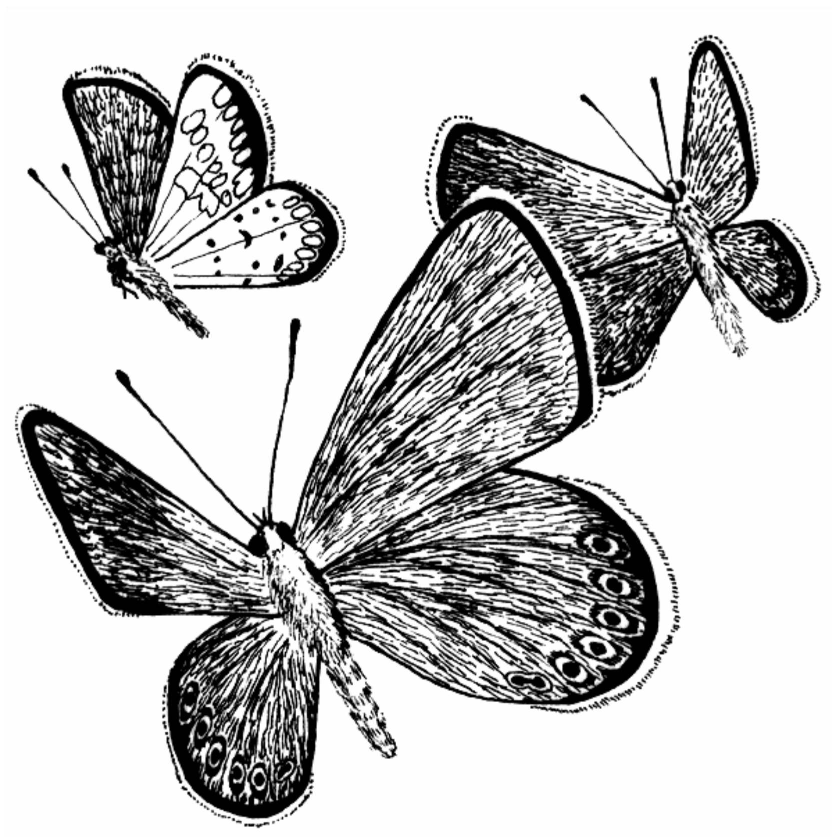
PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
3	1.42	Develop standardized conditions for scientific permits	1-2	5, 3	ES	NHDFG, NYDEC, MIDNR	0	0	0	
3	1.43	Explore mechanisms to streamline Federal permit process for private landowners	*	3, 5	ES	WDNR OTHERS	2	2	5	To encourage private landowners to participate in recovery
3	1.5	Develop recovery implementation strategies to promote recovery	3	3, 5	ES	WDNR, MIWG, OTHERS, CPBIT, NYWG, MNDNR, INWG,	10	10	10	Promote public participation
3	2.11	Continue to develop and refine protocols/guidelines/selection criteria for reintroduction	2-3	5, 3	ES	NYDEC, NHDFG, TNC, AZA, OHDNR	10	10	10	
3	2.12	Incorporate research findings on captive propagation into protocols	1-3	5	ES	AZA, NHDFG	15	10	5	
3	2.215	Implement translocation at other sites in RUs, if necessary	5		ES	TBD	TBD	TBD	TBD	Possibly needed at Quincy Bluff (WI) NY and INDNL
3	2.31	Consider additional reintroduction efforts in Ohio	3	3	ES	AZA, OHDNR, TNC, OTHERS	TBD	TBD	TBD	Reintroduction program started in 1998.
3	3.3	Continue development of Karner blue management guidelines	3+	3	ES	WDNR, UNIV	0	2	2	

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
3	4.1	Continue to develop outreach material on Karner blue life history and conservation	3+	3, 5	ES	AZA,WDNR, MNFI, USFS, NYDEC, TNC, OTHERS	67	12	12	
3	4.2	Inform local governments of Karner blue butterfly recovery units	1-3	3, 5	ES	WDNR, MNFI, OTHERS, NYDEC, TNC	6	6	6	
3	4.3	Encourage private landowners to conserve the Karner blue butterfly.	3+	3, 5	ES	WDNR, NYDEC, TNC, OTHERS, DNR	40	35	20	
3	4.4	Assess the needs, goals, and outcomes for public outreach	3+	3, 5	ES, NWR	AZA, WDNR, TNC, IDNL, NYDEC, MNFI, MIDNR	20	10	10	15K for Glacial Lake WI RU; need work at Miller Woods, IN
3	5.31	Research - Ecology of local populations	5+	3, 5	ES	NYDEC, MNFI, MNDNR, MIDNR, WDNR, TNC, IDNL, APBPC, WWPP, OTHERS, UNIV	30	30	30	Should be distributed over several projects

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
3	5.32	Research - Effects of human activities	3+	3, 5	ES	NYDEC, WDNR, TNC, MNFI	15	15	15	Focus on rights-of-way and developed areas
3	5.33	Research - Browse thresholds	2	3, 5	ES	NYDEC, MNDNR, DOD, USFS, APBPC	5	5	0	Deer and woodchuck
3	5.34	Research -Re-establishment of lupine	3+	3, 5	ES	NYDEC, MNDNR, TNC, OTHERS	5	5	5	Establishment after canopy is opened in areas where lupine is limiting
3	5.35	Research - Population structure	5+	3, 5	ES	NYDEC, TNC	30	30	30	Focus on highly fragmented metapopulations: NH, Saratoga, NY, Ionia RU, West Gary, IN, Morainal Sands RU
3	5.36	Taxonomy research	2	3,5	ES	TBD	TBD	TBD	TBD	
3	5.37	Develop monitoring protocols using non-adult life stages	2	3,5	ES	NHDFG, USGS-BRD	TBD	TBD	TBD	
3	5.38	Research the effects of atmospheric nitrogen on lupine	2	3.5	ES	TBD	TBD	TBD	TBD	
3	6.1	Develop a clearinghouse for Karner blue butterfly data and information	3+	3, 5	ES		2	2	2	Review annually
3	6.2	Conduct Recovery Team meetings	3+	3, 5	ES	RT, AZA	5	5	5	Annual

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY			COST ESTIMATES ($000)			COMMENTS
				USFWS		OTHER	Year 1	Year 2	Year 3	
				REGION	PROGRAM					
3	6.4	Hold periodic meetings to promote recovery and information sharing	*	3, 5	ES	AZA,WDNR, MIWG, INWG, MNDNR, NYWG, CPBIT	0	20	0	Large meeting once every 3 - years.

APPENDICES



APPENDIX A

GLOSSARY

ACCELERATED COLONIZATION: Moving Karner blue butterfly eggs, larvae, pupae, or adults from an occupied site to an unoccupied site of suitable habitat within the same metapopulation. Also called accelerated dispersal (refer also to APPENDIX I).

ACT: Endangered Species Act as amended in 1973.

ADAPTIVE MANAGEMENT: A method of using known information, hypotheses, and information gained while managing a system to alter management practices so that the management objectives can be more readily attained. Adaptive management may be used to improve the management system in a relatively risk-free way, it can be used to reduce management risk and uncertainty, or it can be used to choose among management alternatives with unknown or uncertain effects. This last use is also called experimental management.

AUGMENTATION: Moving eggs, larvae, pupae, or adults from an occupied site within a metapopulation to another occupied site (subpopulation) within that same metapopulation that has low numbers in order to keep the metapopulation at viable levels (refer also to APPENDIX I).

Bt: Insecticidal formulations with *Bacillus thuringiensis*.

Btk: Insecticidal formulations with *Bacillus thuringiensis kurstaki*.

CAPTIVE REARING: Raising eggs, larvae, or pupae collected from wild subpopulations to an older stage for release back into the wild. This could also be called head-starting.

CAPTIVE PROPAGATION: Producing life stages for release from a permanently captive breeding colony. Part of the progeny would be released in the wild, part would be retained to breed and lay eggs in captivity. This method could be used when large numbers of butterflies will be needed for releases over an extended period of time, and we wish to avoid draining the source population.

CORE AREA: A large area of habitat mosaic containing occupied sites that is managed so that the Karner blue is very likely to persist indefinitely, barring unforeseen catastrophe. This area might be 320-1280 acres (0.5-2 mi^2). A core area is smaller than a large viable metapopulation (LP), and can be smaller than a minimum viable metapopulation (VP). Both LPs and VPs can be structured to have a core area that is the intensively managed part of the metapopulation, surrounded by a less intensively managed part of the metapopulation (refer to APPENDIX F).

DISPERSAL BARRIER: An area of unsuitable habitat that impedes the movement of Karner blue butterflies. Butterflies may avoid or be incapable of moving through such habitat, or mortality risk may be higher in these areas. The barriers may be absolute or occasional. No examples of dispersal barriers have been scientifically documented, but some possible examples may include: four-lane highways with heavy traffic in urban or semi-urban areas; steep embankments and cliffs; forested areas if no openings such as trails or roads are present; and residential and commercial areas (including paved areas).

DISPERSAL CORRIDOR: A pathway in the landscape that Karner blue butterflies follow during their dispersal from one patch of suitable habitat to another. A dispersal corridor may include unoccupied suitable habitat. Dispersal corridors might be useful for connecting habitat sites that are separated by unsuitable habitat. Characteristics that might improve suitability as a dispersal corridor include: a linear aspect, dominated by grasses, substantial number of flowering nectar plants, essentially canopy-free at least down the middle, having a dense wall of trees or shrubs along the sides, and being sunny for a significant part of the day. Presence of lupine in corridors is not essential, but is highly recommended.

DNR: Department of Natural Resources.

DOD: (United States) Department of Defense.

EA: Environmental Assessment.

EIS: Environmental Impact Statement.

ESA**:** Endangered Species Act as amended in 1973, administered by the U.S. Fish and Wildlife Service.

EXPERIMENTAL MANAGEMENT: A type of adaptive management where management alternatives with unknown or uncertain effects are evaluated during the management process to allow the manager to choose among the alternatives.

FRAGMENTATION: Refers to the spatial structure of the subpopulations within a metapopulation. A metapopulation with less dispersal of butterflies among subpopulations is more fragmented than another with more dispersal. Fragmentation arises from several causes, including the existence of substantial dispersal barriers between sites, and scattered, disjunct sites.

HABITAT MOSAIC: The contiguous assemblage of habitats in an area with which a metapopulation of Karner blues is associated. This term is used to refer to the contiguous assemblage of suitable and unsuitable habitats.

HCP: Habitat Conservation Plan.

INSTAR: a larval development stage, between molts. Karner blue has four instars, or four larval development stages.

LARVA: Immature butterfly stage, also called caterpillar.

LOCAL POPULATION: see subpopulation

LP: Large viable metapopulation as defined by the recovery criteria.

METAPOPULATION: A population of spatially distributed subpopulations. In this document, a metapopulation is recognized as having several possible types of structures–a true metapopulation, a core-satellite metapopulation, or a patchy metapopulation–and gradations among them.

MICROHABITAT: Subdivisions of habitat based on small scale variations in topography and soil moisture (e.g. gopher mounds, topographic differences cause by slope or aspect).

NEPA: National Environmental Policy Act.

NWR: National Wildlife Refuge.

OCCUPIED PATCH: see occupied site.

OCCUPIED SITE (occupied patch): An area of suitable habitat that has a Karner blue subpopulation associated with it.

OCCUPIABLE SITE: An area of suitable or restorable habitat, which may or may not be occupied by Karner blue butterflies, that is incorporated into a management plan to perpetuate a viable metapopulation.

ORV: Off-road vehicle.

OVIPOSIT: Egg laying by female Karner blue butterflies.

PATCH: see site.

PHENOLOGY: The temporal pattern of occurrence of a biological event during the annual seasonal cycle (e.g., breaking of dormancy, flowering, seed set, butterfly emergence).

PUPA: Immature, non-feeding life stage of the Karner blue during which it transforms from a larva to an adult.

REINTRODUCTION: Moving eggs, larvae, pupae, or adults from one or more existing metapopulations to help create another metapopulation in a separate geographic area within the historic range of Karner blue where there are no contemporaneous subpopulations of the butterfly (refer also to APPENDIX I).

RESTORABLE HABITAT: An area of habitat with the ecological potential to be managed to have the attributes of suitable habitat. It may or may not contain lupine.

SELF-REPRODUCING: Able to produce a subsequent generation without direct human intervention during that generation cycle. Examples of direct human intervention include captive rearing and release, augmentative release, and natural enemy exclusions.

SENECENSE: Aging and dying back of plants, as when lupine dies back in the late summer.

SERVICE: United States Fish and Wildlife Service.

SILVICULTURE: The theory and practice of controlling forest establishment, composition, structure and growth.

SGA: State Game Area.

SITE (patch): An area of suitable habitat or restorable habitat that is separated from other suitable habitat; separation distance will vary depending on the nature of the intervening habitat and the dispersal ability of the Karner blue through that habitat type (refer to APPENDIX G and Table G1).

SUBHABITAT: Subdivisions of habitat based on variations in larger topographic differences e.g. canopy cover, and soil moisture.

SUBPOPULATION (local population): A self-reproducing population of Karner blue that is associated with a site / patch.

SUITABLE HABITAT: Habitat that is sufficient to support a reproducing subpopulation of Karner blue. This will require sufficient larval resources (lupine that is accessible and usable), adult resources (nectar plants that are accessible and usable), adult roosting sites,
oviposition sites, pupation sites, and protection of all necessary life stages from mortality. Suitable habitat cannot be defined absolutely because it will vary across the species range. The area of suitable habitat includes the entire area of larval and adult resources and contiguous intervening areas.

TAKE: As defined by the Endangered Species Act, take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect a federally-listed threatened or endangered species, or to attempt to engage in any such conduct.

TNC: The Nature Conservancy.

TRANSLOCATION: Any artificial movement of eggs, larvae, pupae, or adults from one location to another. The following are all examples of translocation: accelerated colonization, augmentation, and reintroduction.

UNOCCUPIED SITE: An area of suitable habitat that does not have a Karner blue subpopulation associated with it.

VP: Minimum viable metapopulation as defined by the recovery criteria.

WA: Wildlife Area.

WMA: Wildlife Management Area.

APPENDIX B

RECOVERY UNITS, POTENTIAL RECOVERY UNITS, AND HISTORIC SITES

HISTORIC DISTRIBUTION

The historic northern limit of the butterfly corresponds roughly with the northern limit of lupine (Dirig 1994), but the current distribution indicates that the butterfly has contracted away from this limit. Many of the most northern populations of Karner blue have been extirpated, such as at Norway, Maine; Webster, New Hampshire; Watertown, New York; throughout Ontario, Canada; Marinette and Oconto Counties, Wisconsin (L. F. Gall, Yale University, Peabody Museum, pers. comm. 1997), (Dirig 1994), and Anoka, Minnesota. Lupine has been reported from as far north as northern Vermont, and Elk Rapids, Michigan, but there are no records of the Karner blue from these sites. The only populations of Karner blues now near the northern limit of lupine occur within the Superior Outwash RU in Wisconsin.

The historic western limit of the butterfly roughly corresponds with the western limit of lupine (Dirig 1994), and butterfly distribution appears to have contracted away from this limit as well. Although lupine occurs as far west as central Minnesota, the western-most record of Karner blue is at Anoka, Minnesota, approximately 50 miles to the east. The Anoka population was extirpated sometime after 1984. The Iowa populations on the southwest fringe of the range are also extirpated. Currently, the western-most populations of Karner blue occur in the Superior Outwash RU and at the Whitewater WMA in southeast Minnesota in the Paleozoic Plateau RU.

The historic eastern limit of the butterfly roughly corresponds with the eastern limit of lupine. One historic record for the Karner blue exists for Conneticut (Robert Dirig, Cornell University, New York, in litt. 2002) but the actual location (state) from which the specimen was collected is not entirely certain. No historic or current records of Karner blue exist in Rhode Island, eastern Massachusetts, or eastern Long Island, as these native habitats were converted to incompatible human uses long ago, so the previous presence of the butterfly cannot be verified. Nonetheless, based on the biology of the butterfly and information on the native habitats, the butterfly probably inhabited these areas in the past. The eastern-most historic records of Karner blue exist from southwest Maine and throughout the Merrimack River valley system in New Hampshire and Massachusetts, but currently, this eastern-most population has contracted to a very small population near Concord, New Hampshire.

Unlike the other geographic limits, the historic southern limit of the butterfly does not correspond to the southern distribution of lupine. The distribution of lupine extends farther south than the Karner blue in the eastern United States along the eastern Appalachian Mountains and the Atlantic Coastal Plain, and in the central United States, in Illinois (Dirig 1994). Some of the historic records of the Karner blue along this southern limit are uncertain. The southern-most record near Coyington, Indiana is probably erroneous. A specimen associated with this record could not be found and lupine has not been recorded from near this locality. The records from several Pennsylvania localities could not be confirmed. These localities are recorded by Dirig

(1994) and were reported to him by Dr. A. Shapiro. The Recovery Team corresponded with Dr. Shapiro, who stated that he could not locate a specimen corresponding with any of his reported Pennsylvania localities. The only confirmed record in Pennsylvania is from Wayne County. Several of the New York records along the Delaware River are confirmed with specimens (Robert Dirig, in litt. 2002), so it is possible that Karner blues occurred in the neighboring areas in Pennsylvania. The New Jersey record may be erroneous, although labeled specimens exist. Schweitzer (Dale Schweitzer, pers. comm. 1996) suggested that the specimens were unlikely to have been collected from New Jersey and may have been mislabeled New York specimens. The record from Brooklyn, New York has been confirmed. The lack of correspondence of the southern limits of the Karner blue and lupine has not been adequately addressed. Dirig (1994) suggested that the southern limit of Karner blue may follow the band of 80-100 days continuous winter snow cover, which he hypothesized was necessary for high overwintering egg survival. Many other hypotheses could explain the southern distribution limit of the Karner blue butterfly.

Despite this uncertainty, similar to the other geographic limits, the distribution of the Karner blue has contracted away from its historic southern limit. Populations have been extirpated from southern New York, Pennsylvania, Ohio, Illinois, and Iowa. In Indiana, the distribution has contracted. Once present throughout northern Indiana, it now occurs only in a few localities in northwestern Indiana, associated with the dune fields and dune and swale complexes near the southern end of Lake Michigan.

RECOVERY UNITS

Recovery Units (RUs) are established to preserve possible geographically associated genetic variation and to buffer against large-scale stochastic variation, such as regional variation in weather or catastrophic disturbance, by providing an adequate number of widely dispersed metapopulations in a wide range of habitat types. Many RUs are essential for delisting to ensure that the species is maintained throughout its historic and current range and to provide the redundancy necessary to guard against regional management failures after delisting and region-wide catastrophes. All RUs supported Karner blues at the time of listing (1992).

Thirteen RUs are identified for the Karner blue (refer to Figures B1-B4). The boundaries of these RUs are not meant to be interpreted strictly, but are meant to indicate the potential geographic extent of the Karner blue based on current information about the location of suitable habitat. Thus, the attainment of recovery goals should not be strongly influenced by whether a subpopulation near a boundary of a RU is in or out of the RU. Subpopulations near or on the boundary of a RU can count towards recovery in that RU, but not in more than one RU.

Suitable habitats for Karner blue typically are associated with sandy soils and native habitats and include xeric savanna and barrens habitats. The RUs described below are distinguished by variation in glacial geology, soils, floristics, ecosystem type, climate, barriers to dispersal, or any combination of these factors. In Minnesota, Wisconsin, and Michigan most of these variations have been summarized consistently in a regional landscape classification system as described in Albert (1995). The remaining five states with RUs have similar, but independent ecoregion classification systems. Any of these defining factors could induce local adaptations in the Karner blue, which in turn could be critical in the recovery of the species. In addition, these factors create a complex of ecological conditions that would buffer the species against regional metapopulation declines. These RUs are listed below starting from the eastern part of the butterfly's geographic range to the western part of the range.

It is generally acknowledged that Wisconsin and Michigan now harbor the largest numbers of Karner blues that occur on the greatest amount of area in the historic geographic range of the species. Consequently, these areas become key areas of concern to stabilize the species against further decline and recover the species. Because of the significance of central Wisconsin and western Michigan as the centers of Karner blue abundance, more RUs are established in these regions than in other parts of the range. These multiple RUs in the apparently most suitable habitat for the Karner blue will protect the species against wide-scale declines. In the event that a particularly severe disturbance causes extirpation of Karner blue in one of these RUs, others are likely to remain and harbor metapopulations that eventually can recolonize the extirpated RU.

The 13 RUs are described below. Information reviewed includes each RU’s distinguishing ecological features, the status of the Karner blue in the RU, and potential threats to the species. Table B1, below, lists the possible locations of the metapopulations needed for recovery in each RU.

Merrimack/Nashua River System RU (New Hampshire/Massachusetts)

Location

This RU is located in southern New Hampshire and northeast Massachusetts, in six counties (Merrimack, Hillsborough, Rockingham, Belknap, Middlesex and Essex), and is associated with the pine barrens habitats near the Merrimack and Nashua River system. This is the eastern-most extant location for the Karner blue and is separated from the nearest subpopulation by over 100 miles.

Karner blue distribution

The historic distribution of the Karner blue butterfly in central New England is thought to have covered parts of all of the six counties noted above (Helmbolt and Amaral 1994), and records indicate that it occurred as far north as Webster, New Hampshire. The last native Karner blue population in New England, which occurred in the Concord Pine Barrens in Concord, New Hampshire, was extirpated in 2000.

Threats

All native habitat north and south of Concord has been converted to industrial, commercial, and residential uses that are incompatible with a viable Karner blue metapopulation. Around Concord, the 300 acres of restorable habitat continues to be threatened by development (Helmbolt and Amaral 1994, City of Concord 1996). A retail mall was constructed on the outer edges of the Concord Pine Barrens and will encourage further development of this area (USFWS

Figure B-1. Map showing range-wide recovery units for the Karner blue butterfly.

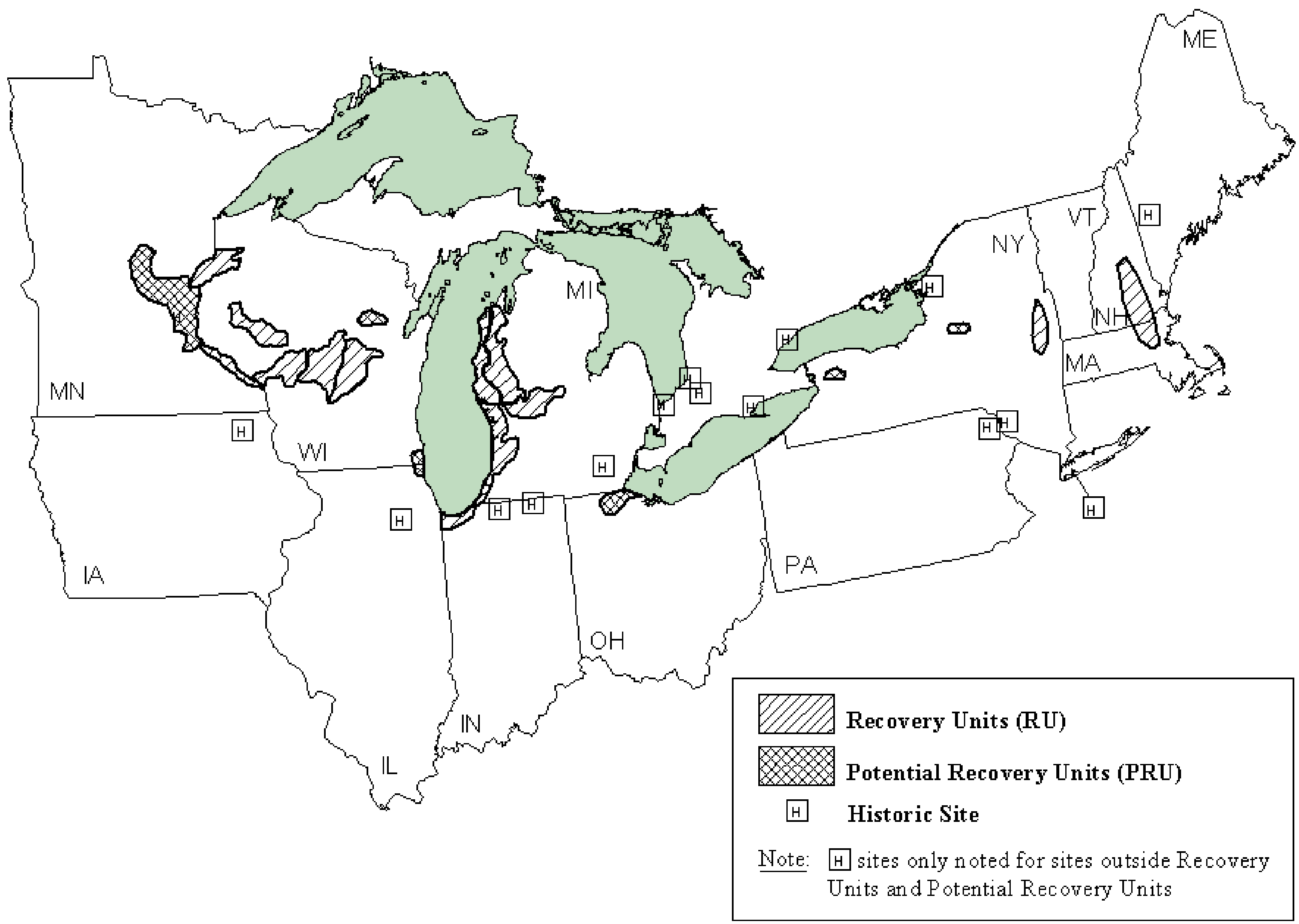


Figure B-2 Karner blue butterfly recovery units in Massachusetts, New Hampshire and New York.

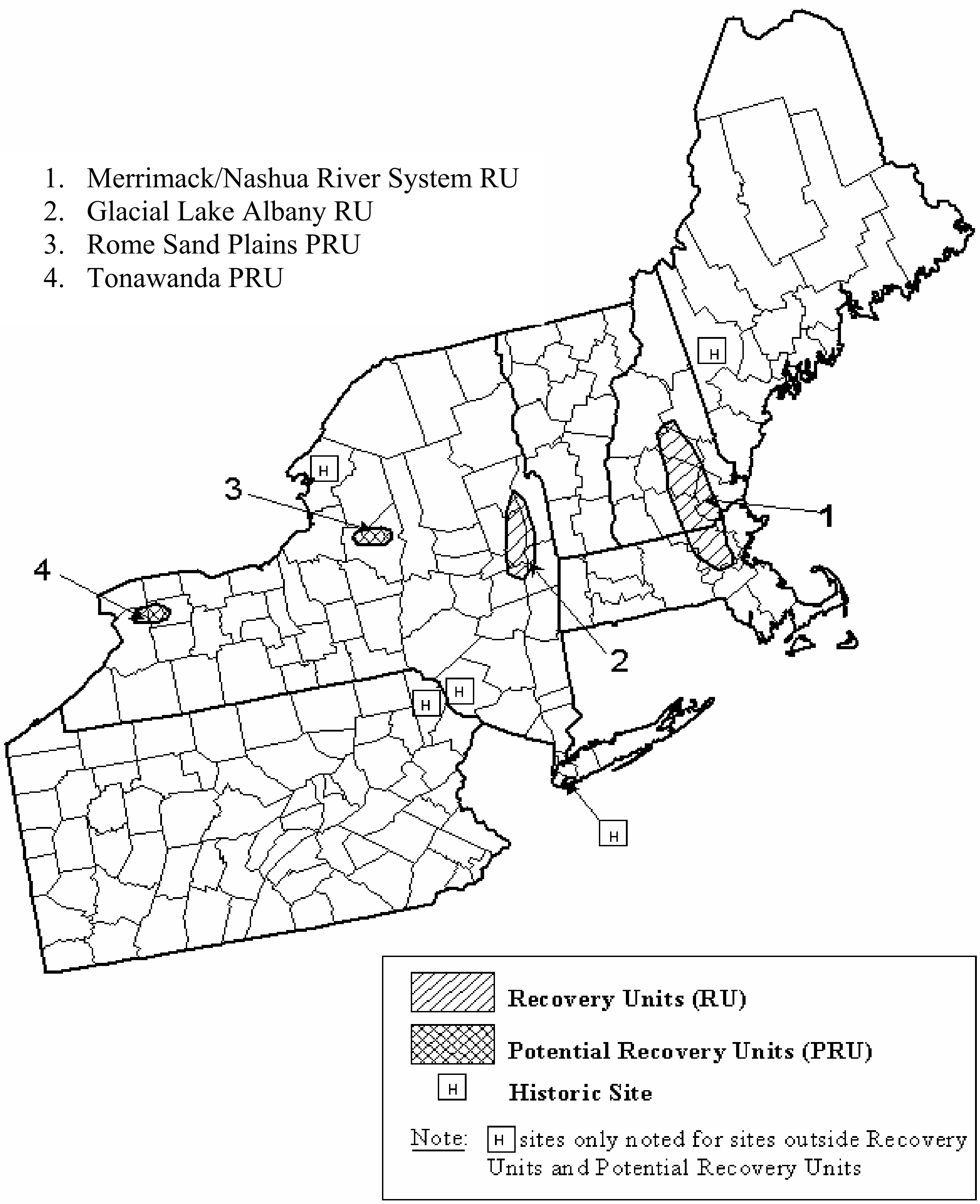


Figure B-3 Karner blue butterfly recovery units in Indiana, Michigan and Ohio.

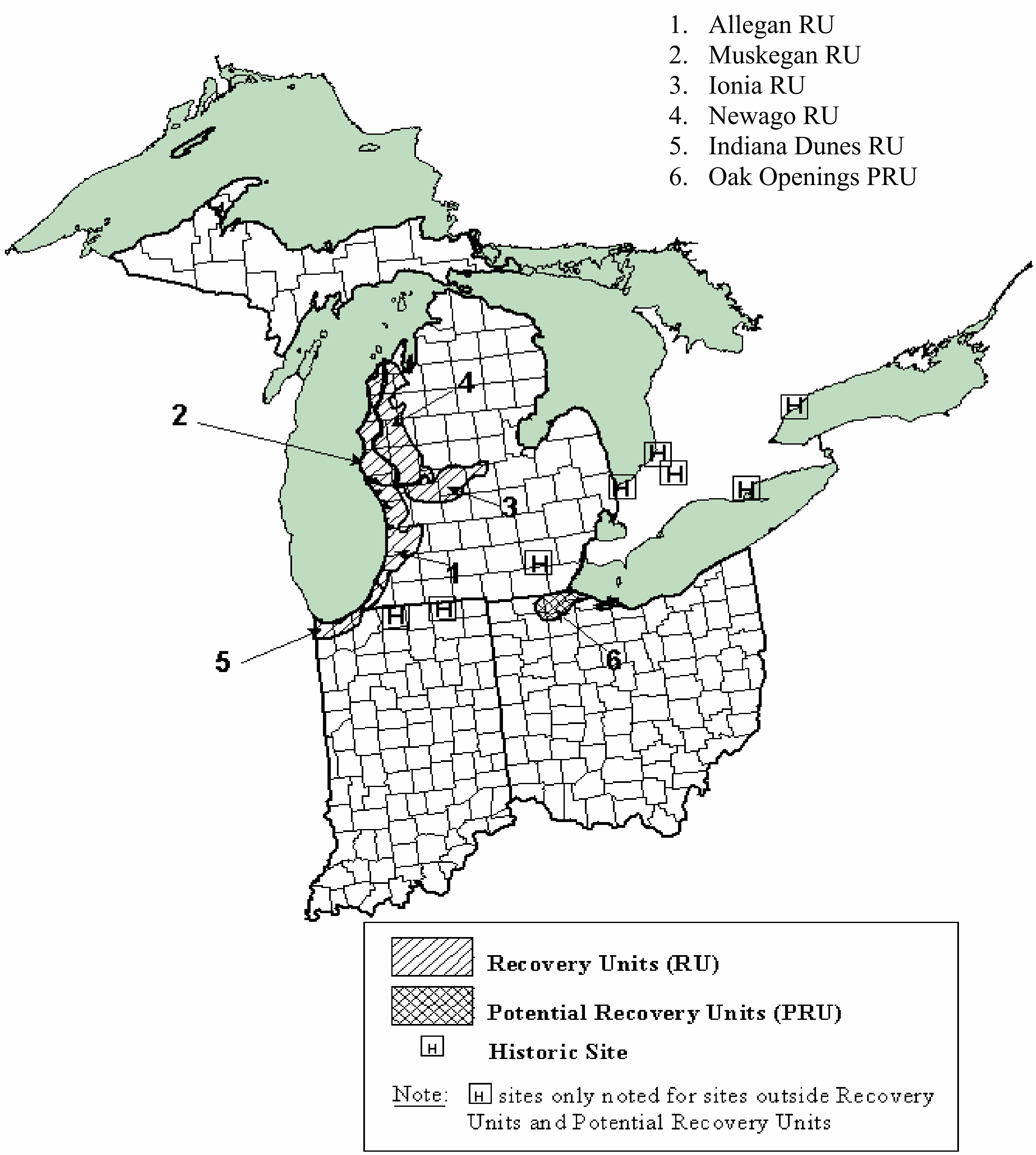
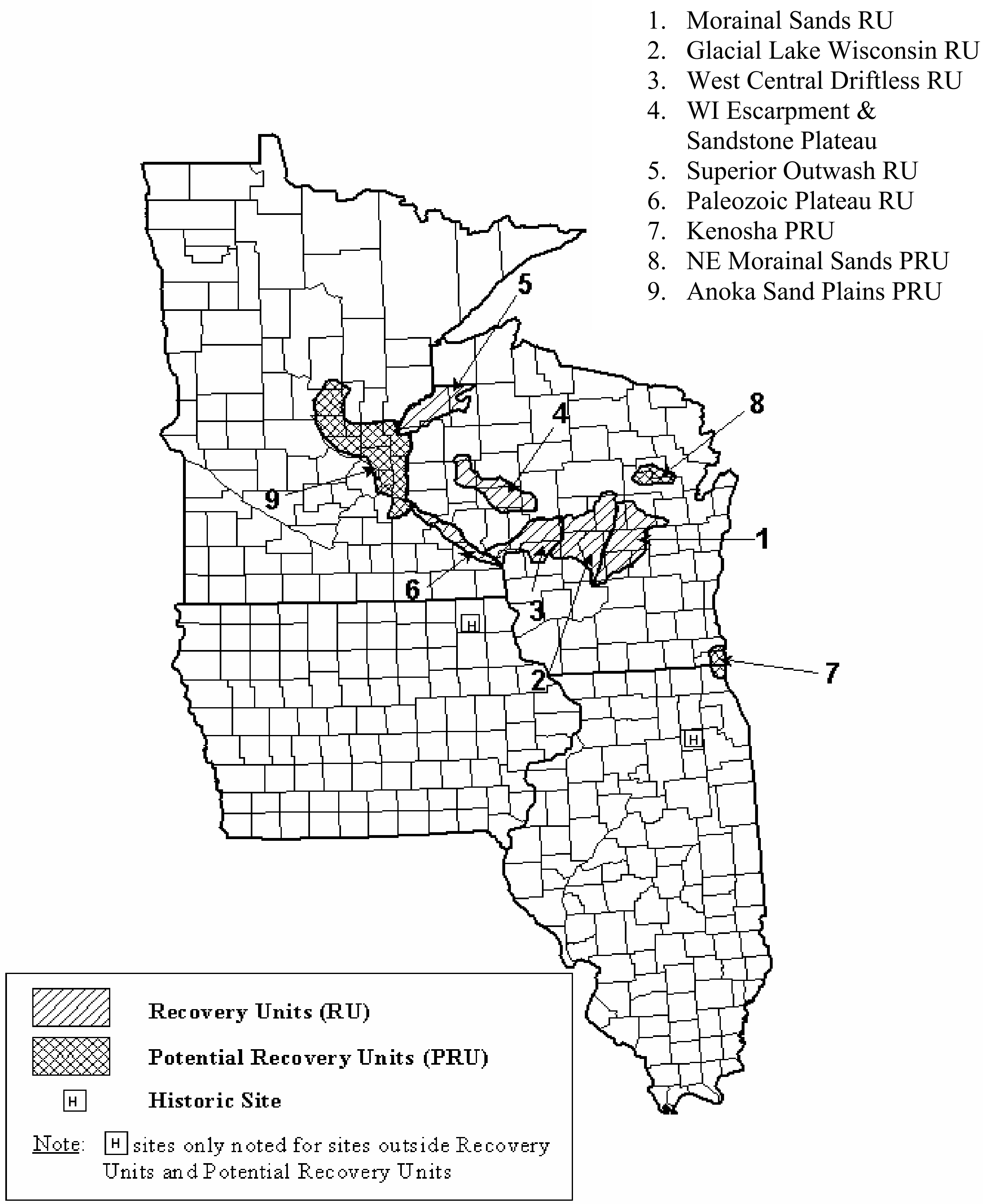


Figure B-4 Karner blue butterfly recovery units in Illinois, Minnesota and Wisconsin.



1992a and 1992b). Road extensions and industrial park expansion have further fragmented and degraded remaining habitat (Michael Amaral, USFWS, pers.comm. 1994). Construction of military facilities has also impacted the area (USFWS, in litt. 2000). The last two sites that were occupied by native Karner blues, were threatened by habitat succession due to fire suppression and lack of management (Main Site), and by the lack of nectar plants (Airport Site) (Helmbolt and Amaral 1994).

Protection and management

The Service and several other public and non-governmental conservation organizations, most notably TNC, have undertaken significant protection and enhancement efforts for the Karner blue in Concord. The Service has secured a permanent conservation easement (managed by the Great Bay NWR) from the City of Concord on 28 acres of pine barrens, historically occupied by the Karner blue. TNC has a management agreement with the Public Service Company of New Hampshire for vegetation management at the Karner blue Main Site. The management plan written for the Concord Pine Barrens (VanLuven 1994) identifies over 560 acres of "fire suppressed pitch pine/scrub oak barrens" remaining within the Concord area with nearly 400 acres recommended for management. The Service and other conservation agencies have developed a Conservation Management Agreement with the City of Concord for Karner blue protection and recovery on more than 250 acres of potential suitable habitat (grassy openings of airport safeways) at the Concord Airport (VanLuven 1994). Management efforts at Concord include the planting of thousands of lupine seeds, mechanical thinning of vegetation, prescribed mowing and burning, nectar species propagation and planting, herbivore control, and off-road vehicle (ORV) control. A project to reintroduce the Karner blue to the Concord pine barrens began in 2001 (refer to PART I, CONSERVATION MEASURES, Reintroduction/Translocation).

Glacial Lake Albany RU (New York)

Location

This RU is located in east central New York, in four counties (Warren, Saratoga, Schenectady and Albany), and is associated with the sand deposit outwash from glacial Lake Albany. The climate and vegetation is believed to be similar across this RU, although the northern section receives more precipitation. The original vegetation in the Albany and Queensbury Sandplains areas is pitch pine-scrub oak barrens, where it has not recently been under agriculture. The pine-oak savanna vegetation in the Saratoga region is of unclear origin, possibly being an artifact of previous land use or the expression of dry pine-oak woodland that has been burned recurrently.

Karner blue distribution

The oldest know U.S. record for the Karner blue is 1869 from the Albany pine bush (Robert Dirig, in litt. 2002). The remaining areas inhabited by Karner blue butterflies in New York are the Albany Pine Bush, parts of Saratoga County, including the Saratoga County Airport, and a very small part of Warren County. All of these areas are on the bed of glacial Lake Albany (Sommers and Nye 1994). The Karner blue inhabits approximately 70 localities (which

Table B1. Potential locations of metapopulations by recovery unit

Recovery Unit (RU)	State	Recovery Goals[1]		Potential Locations
		Reclassification	Delisting	
Merrimack/Nashua River System	NH	VP	VP	Concord (includes Great Bay NWR)
Glacial Lake Albany	NY	VP VP VP	VP VP VP	Albany Pine Bush Saratoga Sandplains Saratoga West
Ionia	MI	2VP or 1 LP	2VP or 1LP	Flat River SGA
Allegan	MI	VP VP	VP LP	Allegan SGA Allegan SGA and private lands
Newaygo	MI	2VP	VP + LP	Huron-Manistee NF and private lands
Muskegon	MI	2VP	2LP	Huron-Manistee NF and private lands
Indiana Dunes	IN	2VP VP	2VP VP	IDNL West Gary on TNC and other private lands
Morainal Sands	WI	(1LP)	LP VP or LP VP or LP	Hartman/Emmons/Welch Complex White River Marsh State WA Greenwood State WA
Glacial Lake Wisconsin	WI	LP LP (2VP)	LP LP VP VP VP east of Wis. River	Necedah NWR Meadow Valley State WA Sandhill State WA Hardwood Range – Air National Guard Quincy Bluff (TNC)
West Central Driftless	WI	VP 2LP LP	VP 2LP LP	Black River State Forest Fort McCoy Jackson County Forest (possibly)
Wisconsin Escarpment and Sandstone Plateau	WI	VP	LP	Eau Claire and Clark County Forests (possibly)
Superior Outwash	WI	2VP	2VP or 1LP	Glacial Lakes Grantsburg Work Unit (Crex Meadows and Fish Lake State WAs)
Paleozoic Plateau	MN	2VP or 1LP	2VP or 1LP	Whitewater WMA

[1] Refer to PART II, RECOVERY OBJECTIVE, Table 4. **The Wisconsin recovery goals will be re-evaluated by the Recovery Team (refer to Task 6.3).**

( ) = location of metapopulation not designated to a specific site, can occur at any location

Summary of Goals:	VPs	LPs	No. of VPs and LPs	Total Minimum No. of VPs and LPs
Reclassification:	19-23	6-8	19 VPs and 8 LPs (27) or 23VPs and 6 LPs (29)	27
Delisting:	13-21	11-16	13 VPs and 16 LPs (29) or 21 VPs and 11 LPs (32)	29

LP = Large Viable Metapopulation
NF = National Forest
NWR = National Wildlife Refuge
SGA = State Game Area
TNC = The Nature Conservancy
VP = (Minimum) Viable Population
WA = Wildlife Area
WMA = Wildlife Management Area

can be clustered into 56 subpopulations), many of which are extremely small. Three metapopulation areas have been identified: The Albany Pine Bush, Saratoga West, and the Saratoga Sandplains.

Threats

The Saratoga Airport Site, a treeless area maintained by mowing, now supports the largest population in New York, and has remained large for several years. Efforts are underway to connect this population with nearby sites. The major threats to this subpopulation are events that would degrade the uniform habitat. It is vulnerable to weather events, such as drought or storms, or wildfire that could result from airport operations. It is also vulnerable to adverse management conducted contrary to the management agreement for the site. It is important to ensure that occupied suitable habitat occurs nearby so that the airport subpopulation could be repopulated if necessary. Other sites with small subpopulations of Karner blue, including those in the Albany Pine Bush, are threatened by development, isolation from other subpopulations, and/or degradation of habitat. Conservation in the Queensbury area may be helpful in recovering Karner blues in the Glacial Lake Albany RU. While recovering the Karner blue in the Queensbury area is not a goal of this plan it is a state recovery goal.

Protection and management

Several measures have been implemented to protect the Karner blue in the Albany Pine Bush (Pine Bush), Saratoga Sandplains, and Saratoga West areas of New York.

The Albany Pine Bush Preserve Commission (Commission) was established in 1988 by the New York State Legislature to protect the pine bush community. The Commission is cooperatively managed by the landowners in the Pine Bush including New York State DEC, New York State Office of Parks, Recreation and Historic Preservation, the City of Albany, two towns and TNC. A detailed protection and management plan has been developed for the Preserve and has undergone several revisions. An initial trust fund was established from tipping fees at the City of Albany's landfill for Preserve management. Since 1994 funding for the operation of the Commission has been provided by the New York State Environmental Protection Fund, involved municipalities, endowment income, and private and Federal sources. Funding for acquisition and management of the Preserve and review of development projects that affect it are vital contributions to the recovery of Karner blue butterfly in the Pine Bush.

There has been active management for lupine within the Albany Pine Bush for the past seven years. Lupine has been planted in several areas under experimental conditions to study methods for producing effective lupine populations and to establish new lupine populations near remnant butterfly populations. A fire management program was begun in 1990 with the main goal of restoring the pitch pine scrub oak barrens natural community, which historically supported the largest populations of Karner blues in the state. The Commission has a large workforce of volunteers who regularly assist with management and maintenance of the Preserve.

Habitat protection for the Karner blue in the Albany area is also occurring at a few sites in the Town of Guilderland and at the Crossgates Mall owned by Pyramid Corporation. As a result of a state permit for building the Mall during the late 1980's, a five acre occupied site adjacent to the Mall was set aside and a fund established to provide for management of the site into perpetuity (this subpopulation is now the largest in the Pine Bush Preserve). Expansion of the Mall during the 1990's resulted in the dedication of an additional 10 acres for Karner blue management along a powerline right-of-way adjacent to the original five acres. Management of these sites has included removal of invasive vegetation, planting of lupine and other species associated with the habitat, and fencing to exclude deer and prevent unauthorized entry.

In the Saratoga Sandplains area, the Town of Wilton has agreed to join with the state and Federal agencies and TNC in the creation of the 3000 acre "Wilton Wildlife Preserve and Park" (WWPP), the heart of which will contain a core population of Karner blues. Protection of the butterfly is envisioned through acquisition, easements, and management agreements. The area will be managed for the butterfly and passive recreation (bike/hike/ski trails). As with Albany, the cooperation of the Town of Wilton in reviewing development that might harm recovery efforts in this area will be essential, as will their help with funding. This preserve will add to the protection measures already in place at some small localities in the Town of Wilton and at a camp previously owned by the Boy Scouts of America. The WWPP continues to forge relationships with local businesses and volunteers. Volunteers, WWPP and NYDEC staff have cleaned up two Karner blue subpopulation sites, removed woody vegetation and planted native vegetation using equipment donated by a large hardware store distribution center.

Two Saratoga West sites are protected by memorandums of understanding (MOUs) between the New York State DEC and the managing entities for these sites: Saratoga County Airport (Saratoga County Department of Public Works), and Saratoga Spa State Park (NYS Office of Parks, Recreation, and Historic Preservation). The New York State DEC advises the landowners on best management practices to limit disturbance to the butterflies. Management under the MOUs includes use regulations, mowing regimes and improvement of habitat through plantings. A third site is expected to be protected this year with a similar agreement with the Village of Ballston Spa as the site becomes part of a newly dedicated public park.

Niagara Mohawk Corporation (NIMO) along with the New York State DEC and the Albany Pine Bush Preserve Commission, are actively managing for Karner blues along powerline corridors in New York State. NIMO has undertaken research to characterize lupine habitat along powerlines and to research management impacts to lupine areas. New York is also in the midst of preparing a State Recovery and Management Plan for the Karner blue. TNC has contracted with private nurseries to grow lupine, which, along with nectar plants, is being planted near several extant Karner blue localities in the Glacial Lake Albany RU. Refer also to PART I, CONSERVATION MEASURES, Private Land Initiatives.

Ionia RU (Michigan)

<u>Location</u>

This RU is located in central lower Michigan, in four counties (Kent, Montcalm, Gratiot, and Ionia), and is associated with oak or jack pine barrens scattered through sandy morainal soils near the Flat River. These are medium and coarse textured ground moraines with rolling topography. Uplands are dominated by beech-sugar maple forest and hardwood swamps that occupy poorly drained sites; this corresponds to ecoregion sub-subsection III.6.1 as described in Albert (1995). It is one of the warmer Michigan RUs, and contains the Flat River SGA.

Threats

The major threats in this RU are habitat loss from agriculture, extreme soil scarification from farming, and intensive logging followed by burning. The most immediate threat is potential disruption of occupied sites at the Flat River SGA by ORV use, especially during the winter.

Protection and management

Several management considerations have been developed for the Flat River SGA (Cuthrell and Rabe 1996). Refer also to PART I, CONSERVATION MEASURES, Private Lands Initiatives.

Allegan RU (Michigan)

Location

This RU is located in southwest Michigan, in five counties (Muskegon, Ottawa, Allegan, Van Buren, and Berrien), and is associated with oak or white pine barrens scattered through the Allegan lake plains. It corresponds to ecoregion subsection III.5 as described in Albert (1995). The climate is unique, being warm and strongly influenced by Lake Michigan. As a result, there is a long growing season with reduced daytime temperatures and considerable fall and winter precipitation. Northern floristic elements occur further south and southern floristic elements occur further north in this RU than areas further inland. Allegan SGA occurs in this RU.

Threats

Nectar may be limiting during the second flight period (Lawrence and Cook 1989). Habitat degradation from shading by closed canopies is probably the major threat (Wilsmann 1994).

Protection and management

Restoration work at the Allegan SGA has included selective diameter cuts in oak woodlands adjacent to known Karner blue populations to facilitate the restoration of oak-pine barrens and expansion of butterfly habitat (Michigan DNR 1994). Refer also to PART I, CONSERVATION MEASURES, Private Lands Initiatives.

Newaygo RU (Michigan)

Location

This RU is located in west central Michigan, in six counties (Mason, Lake, Oceana, Newaygo, Mecosta, and Montcalm), and is associated with oak or white pine barrens scattered throughout the Newaygo outwash plain and sandy terminal moraines. It corresponds to ecoregion subsection IV.3 as described in Albert (1995). Topography is relatively flat and the climate is colder and more variable than the other Michigan RUs. Oaks and pines dominate the sandy soils. Portions of the Huron-Manistee National Forest occur in this RU.

Threats

While several large areas are protected by public ownership, research and funding are needed to manage habitat to preserve the Karner blue butterfly as well as meet other needs (Wilsmann 1994). Some factors limiting metapopulation survival include inadequate nectar sources during the second flight and shading by closed canopies (Wilsmann 1994).

Protection and management

Refer to discussion in Muskegon RU below.

Muskegon RU (Michigan)

Location

This RU is located in west central Michigan along Lake Michigan, in four counties (Mason, Oceana, Newaygo, and Muskegon), and is associated with oak or white pine barrens scattered through the Manistee sand lake plain. It corresponds to ecoregion subsection IV.4 as described in Albert (1995). Climate is moderated by Lake Michigan similar to the Allegan RU, but is colder and more variable than the Allegan RU. There is considerable topographic relief in some parts of this RU. Portions of the Huron-Manistee National Forest occur in this RU.

Threats

While several large areas are protected by public ownership, research and funding are needed to manage habitat to preserve the Karner blue butterfly as well as meet other needs (Wilsmann 1994). Some factors limiting metapopulation survival include inadequate nectar sources during the second flight and shading by closed canopies (Wilsmann 1994).

Protection and management

Huron-Manistee NF has initiated a program in the Muskegon and Newaygo RUs to restore dry sand prairie/oak barrens ecosystems on national forest lands. Twenty-four "Potential Karner Blue Management Units" have been delineated in the NF, encompassing about 128,000 acres of forest lands and management recommendations have been developed for these units. Of

900 acres of planned restoration work, 450 acres have been restored which includes restoration of 120 acres via timber sales. There is another 300 acres of restoration planned which should be completed soon. Other management and restoration efforts include prescribed burning, selective cutting and brush hogging of woody encroachment within occupied patches, corridor creation, soil scarification or discing to control *Carex spp*. and enhance colonization of native species, planting of native prairie and oak barrens species, leaving uncut hardwoods and/or pine to discourage ORV use from damaging sites, and road closures to protect extant and potential Karner blue sites (Schuetz 1996) (Joe Kelly, pers. comm. 1998). Refer also to PART I, CONSERVATION MEASURES, Private Land Initiatives.

Indiana Dunes RU (Indiana)

Location

This RU is located in northwestern Indiana, in three counties (Lake, Porter and LaPorte), and is associated with the Lake Michigan Border Section and Chicago Lake Plain Section of the Northwestern Morainal Natural Region of Indiana (Homoya et.al. 1985). This is a remarkably diverse region. The Lake Michigan Border Section consists of a strip of dunes, interdunal ponds (pannes), and beaches that borders Lake Michigan. The dunes are composed of a mosaic of oak barrens, jack pine barrens, dry to mesic mixed hardwood forest, and sand prairie. The Chicago Lake Plain Section has a ridge and swale and lacustrine topography on the former site of Glacial Lake Chicago. The natural vegetation, including oak barrens and savannas are on acidic soils, although areas of calcareous substrate occur locally. Although glacial geology of these two areas is distinct and the vegetation somewhat different, they are classified as one RU because they are in a small area.

The largest populations of the Karner blue butterfly in Indiana are within and nearby the Indiana Dunes National Lakeshore (IDNL) (Martin 1994, Schweitzer 1994) and protected from further development. A significant number of subpopulations occur on private land adjacent to the Lakeshore. Subpopulations on private lands are threatened by habitat conversion to unsuitable uses. Another habitat site is protected by The Nature Conservancy (Martin 1994). The remnant habitat along railroad right-of-ways may be critical in linking populations, but it is not currently managed or protected. Other subpopulations occur on county-owned lands (Martin 1994) and in Gary (Shuey undated).

Threats

Threats to the subpopulations in Gary are poor habitat quality and fragmentation of the habitat. The greatest threats to Karner blue subpopulations at IDNL are loss of habitat from succession to oak woodland and from wildfires sparked by passing trains (Randy Knutson, IDNL, pers. comm. 1998).

Protection and management

TNC has drafted a management plan for West Gary (Shuey, undated), a landscape fragmented by urban and residential development. Habitat restoration efforts have focused on optimizing the 60-acre Ivanhoe dune and swale site in West Gary, last occupied by the Karner blue in 1996 or 1997 (John Shuey, TNC, pers. comm. 2002), and restoring additional unoccupied land at the preserve. Several acres of overgrown oak barrens have been thinned, over 2000 lupine seedlings were planted in 1996 and efforts continue to encourage recovery of the understory. A reintroduction project was started in 2001 to restore a viable population of Karner blue to the West Gary area (refer to PART I, CONSERVATION MEASURES, Reintroduction/Translocation).

IDNL is managing its Karner blue savanna sites with fire. They are also planning to conduct burns in their east unit (currently unoccupied by the Karner blue) in hopes of creating additional suitable habitat for the butterfly. If successful, they are considering establishing a population in the east unit that would entail translocating the butterfly to this area from other location(s) in the preserve (Randy Knutson pers. comm. 1998). Refer also to PART I, CONSERVATION MEASURES, Private Land Initiatives.

Wisconsin RUs

Protection and Management:

It should be noted that for all of the Wisconsin RUs discussed below, additional work is being done by partners to the Wisconsin Statewide HCP to help conserve and, in some cases, recover, the Karner blue on Wisconsin's working landscape. There are 26 partners to the HCP including the Wisconsin DNR (lead), several forestry companies, eight county forests, ten utility companies, the TNC, and the Wisconsin Departments of Transportation and Agriculture. These partners are implementing management strategies on their lands (which include forest lands, rights-of-ways, and habitat restoration sites), to conserve and protect the Karner blue. This entails modifying many of their practices to minimize or avoid harming the butterfly. Some are involved in restoration projects. In 2001, Jackson County Forest and Parks Department established the Bauer Brockway Barrens, and is actively involved in restoring 170 acres of the jack pine barrens ecosytem. All partners are conducting educational and outreach activities on an annual basis. Several pamphlets and brochures on the Karner blue have been produced as a result of these efforts, presentations made, and news articles written all encouraging conservation of the butterfly. Black River Falls in Jackson County, Wisconsin, hosts a Karner Blue Butterfly Festival every summer. For more information on the HCP and partner activities refer to PART I, DISTRIBUTION, State Distribution of Karner Blues, Wisconsin and the Wisconsin Statewide HCP (WDNR 2000).

Morainal Sands RU (Wisconsin)

Location

This RU is located in east central Wisconsin, in seven counties (Portage, Waupaca, Outagamie, Waushara, Adams, Marquette and Green Lake), and is associated with a mosaic of morainal sand deposits (ground and terminal moraine), outwash, and pitted outwash. This RU includes all of ecoregion sub-subsection V.1.4 and a small portion of ecoregion sub-subsection VIII.3.1 as described in Albert (1995). The topography is diverse, ranging from rolling ground moraines to steeper, hummocky terminal moraines. Sandy soils predominate but are also diverse in glacial origin. Floristically, this RU was originally dominated by oak forest with high levels of northern pin oak, and areas of oak savanna and tallgrass prairie on outwash plains. Climatically, this area has a longer growing season (120-150 days) and more precipitation than either the Glacial Lake Wisconsin or West Central Driftless RUs.

Karner blue butterfly populations in this RU are more widely scattered, small and fragmented than in other RUs in Wisconsin. The largest population in this RU occurs in a complex of state and private lands in Portage County.

Threats

Threats include habitat fragmentation and loss from agricultural, residential and commercial developments, silvicultural activities, and succession to closed canopy resulting from lack of appropriate disturbance through management. It will be important to work with forest land managers to encourage modification of management practices to ensure persistence of the Karner blue butterfly. It will be especially important to work with private landowners in this RU to restore and manage habitat, and to create effective dispersal corridors for the butterfly.

Protection and management

Management for Karner blues is underway to restore a viable metapopulation at a complex of three properties in Waupaca County: Hartman Creek State Park, Emmons Creek Fisheries Area (FA), and on adjacent private lands (Welch Tract). A 65-acre restoration including the planting of lupine and prairie forbs is underway at Emmons Creek FA. Mr. Welch, an adjacent private landowner is actively engaged in oak savanna restoration and management for the Karner blue and other rare species on about 100 acres of land. He and the Service (through the Partners for Fish and Wildlife Program) are working successfully with other private landowner in the area on habitat restoration projects for the Karner blue as well. Mr. Welch's education and outreach activities play a significant role in the recovery of the Karner blue in this RU.

Habitat restoration work is also on-going at the White River Marsh and Greenwood State WAs to expand and/or manage habitat. The Service's Partners for Fish and Wildlife Program has provided assistance for habitat restoration work at the White River Marsh State WA.

Glacial Lake Wisconsin RU (Wisconsin)

Location

This RU is located in central Wisconsin, in seven counties (Jackson, Wood, Portage, Waushara, Adams, Juneau, and Monroe), and is associated with glaciolacustrine deposits from Glacial Lake Wisconsin. This RU corresponds to ecoregion sub-subsections V.1.2 and V.1.3 as described in Albert (1995). Topography is flat to gently rolling. Soils are formed primarily on outwash and lacustrine sand, and include large areas of poorly drained mineral and organic soils sometimes intermingled with well drained Plainfield and Friendship sands. In the eastern half, Plainfield sands predominate. Floristically, this RU includes the most extensive areas of marsh and sedge meadow in the state, and many Atlantic Coastal Plain elements. Tamarack and black spruce were dominant in poorly drained areas. Jack pine and pin oak dominated the droughty soils, varying from closed canopy forests to open barrens. Climatically, this RU has the shortest growing season of the central Wisconsin RUs (shorter than 120 days in low areas subject to late spring and early fall frost), and lower winter snowfall.

One of the larger complexes of local populations in this RU is at Necedah NWR. Other sites with the potential to support larger populations include Meadow Valley and Sandhill State WAs. Several of the sites that support viable metapopulations are on publicly administered lands, which will facilitate long-term protection and management (Bleser 1993). Some land east of the Wisconsin River still needs to be surveyed. Hardwood Range and TNC's Quincy Bluff and Wetland Preserve (Quincy Bluff) occur in this RU. TNC is working toward reintroduction of the Karner blue at Quincy Bluff.

Threats

Habitat loss has occurred from succession to closed canopy resulting from lack of disturbance through appropriate management, and shading from closed canopy forests and conversion to pine plantations. Habitat loss has also occurred from management priorities that are not as compatible with maintaining the Karner blue (e.g., possibly deer management), agricultural conversions, ill-timed roadside mowing, some military land uses, and some recreational uses (e.g., ORV use). It will be important to contact forest land managers to explore cooperative partnerships to conserve the Karner blue in this RU.

Protection and management

Active management for Karner blues is underway at several state properties, including Sandhill State WA, and at Necedah NWR. Management actions include the restoration of savanna and barrens habitat at Necedah NWR and Sandhill State WA via forest cuts, and habitat management using mowing, prescribed burning, and herbicide treatments. TNC is restoring savanna habitat at its Quincy Bluff and Wetland Preserve in Adams County in anticipation of reintroducing the Karner blue to the property in the future. Refer also to PART I, CONSERVATION MEASURES, Private Land Initiatives).

West Central Driftless RU (Wisconsin)

Location

This RU is located in west-central Wisconsin, in two counties (Jackson and Monroe) and possibly others to the south and west pending surveys (La Crosse, Trempealeau, and Vernon), and is associated with glaciolacustrine deposits to the north and unglaciated upland sandstone to the south and west, plus sand terraces of the Lower Black River. This RU corresponds to ecoregion sub-subsections V.1.1., IV.2. and IV.1 as described in Albert (1995). Topography ranges from flat sand plain and outwash plain (portions with numerous exposed sandstone buttes), to deeply dissected Paleozoic plateau with considerable topographic relief in areas never glaciated. Soils include the very droughty, infertile Tarr and Boone sands in Jackson and Monroe counties, influenced by loess deposits and underlying Cambrian sandstones. Soils in this RU are the most infertile of all the Wisconsin RUs and less productive than those of the Glacial Lake Wisconsin and Morainal Sands RUs. Floristically, jack pine–northern pin oak barrens were prevalent on the sand plains, while the sandstone plateau supported a mosaic of oak forest, oak savanna, and oak brushlands with tallgrass prairie on ridge tops and on south/southwest slopes. Climatically, this RU has a longer growing season than the Glacial Lake Wisconsin RU. The growing season can be longer than elsewhere in the central sands region of Wisconsin, as long as 170 days. Annual average precipitation is lower in this RU than it is in the Glacial Lake Wisconsin and Morainal Sands RUs (precipitation decreases from east to west in Wisconsin).

By 1996, several areas in this RU were known to support large complexes of local populations especially Fort McCoy, Black River State Forest, Jackson County Forest, and Monroe County Forest. Many of these populations occurred in areas of substantial disturbance from activities such as forest fires, road building, military operations and forest harvest and regeneration. Several of the sites that may be supporting viable metapopulations are on publicly administered lands, which will facilitate long-term protection and management (Bleser 1993). Relatively little land remains to be surveyed.

Threats

Threats to this RU are similar to those in Glacial Lake Wisconsin. It will be important to work with various land managers including forest managers to encourage modification of management practices to ensure persistence of the Karner blue butterfly.

Protection and management

Fort McCoy is actively involved in managing for Karner blues. They have established "core" areas that will be more intensely managed for the butterfly, are engaged in education and outreach activities, and started recovery monitoring in 1997. In addition they have sponsored dispersal (Bidwell 1994) and habitat management research (Maxwell and Givnish 1994, 1995, 1996; Maxwell 1998). Lupine has been planted and is being monitored at a promising barrens site in the Black River State Forest.

Wisconsin Escarpment and Sandstone Plateau RU (Wisconsin)

Location

This RU is located in northwest Wisconsin, in five counties (Barron, Chippewa, Eau Claire, Clark, and Dunn) and possibly two more pending surveys (Pepin, and Buffalo). This RU follows the sandy glacial outwash terraces of the Eau Claire, Chippewa, and Red Cedar Rivers and their tributaries, which lie within a larger sandstone plateau not glaciated for several hundred-thousand years. The RU corresponds to ecoregion sub-subsections IV.2, IX.4.3. and IV.1 as described in Albert (1995). Topography is level along the broad stream deposits; soils are well drained and infertile. Floristically, sand terraces supported jack pine-northern pin oak barrens; uplands surrounding these terraces supported various dry to mesic forest types, oak savanna and oak brushlands with tallgrass prairie on ridge tops and south/southwest slopes. Climatically this RU has a shorter growing season than most of the central Wisconsin RUs, lower minimum winter temperatures, and receives greater snowfall.

By 1996, several areas in Eau Claire and Dunn Counties were known to support populations of Karner blue. More recent surveys have revealed many small subpopulations in this RU in the Coon Fork–South Fork–Canoe Landing complex. Several of the sites that may be able to support a viable metapopulation are on publicly administered lands, which will facilitate long-term protection and management (Bleser 1993). Much less land remains to be surveyed in this RU. Contact should be made with the county forests explore collaborative partnerships to conserve the Karner blue.

Threats

Habitat loss has occurred from silvicultural land uses, succession, commercial, urban and residential development, ill-timed roadside mowing, conversion to agriculture, and some recreational uses. Threats may also include incompatible insecticide treatment e.g. for gypsy moth suppression. Habitat fragmentation should be addressed through corridor creation and enhancement. It will be important to contact land managers including forest managers to explore collaborative efforts to conserve the Karner blue.

Protection and management

Through a Section 7 consultation with Rural Development, Karner blues are being protected as part of a habitat restoration plan at a wastewater treatment site in Eau Claire County. The National Resource Conservation Service in that county is also actively engaged in assisting private landowners with restoration projects for the Karner blue.

Superior Outwash RU (Wisconsin)

Location

This RU is located in far northwestern Wisconsin and possibly east-central Minnesota, in three counties (Burnett, Polk and Washburn), and is associated with an interlobate area with extensive plains of pitted outwash. This RU corresponds to ecoregion sub-subsection X.1 as described in Albert (1995). Topography varies from flat outwash plains to hummocky areas where glacial meltwater rivers left deposits on masses of stagnant ice as described in Albert (1995). Soils are deep loamy sands. Jack pine-northern pin oak barrens were the dominant vegetation, with red and white pine on hilly, fire-protected areas. Climatically, this RU has a shorter growing season than the other Wisconsin RUs; late-spring frosts are common and have been observed to kill wild lupine and oak scrub in low-lying areas. This is the northern geographical limit of wild lupine, and the northern-most occurrence of the Karner blue.

By 1996, several areas in this RU were known to support complexes of local populations including: Glacial Lakes Grantsburg Work Unit (Crex Meadows and Fish Lake State WAs) and the Kohler-Peet Barrens area in the Governor Knowles State Forest. Several of the sites that may be supporting viable metapopulations are on publicly administered lands, which will facilitate long-term protection and management (Bleser 1993).

Threats

Habitat loss has occurred for reasons similar to those in the previous three RUs. Threats at Fish Lake and Crex Meadows WA include woody encroachment (e.g., hazel and blueberry), and frost damage.

Protection and management

Active management for the Karner blue is underway at Glacial Lakes Grantsburg Work Unit (Crex Meadow and Fish Lake State WA) in this RU.

Paleozoic Plateau RU (Minnesota)

Location

This RU is located in southeast Minnesota, in nine counties (Dakota, Goodhue, Wabasha, Dodge, Olmstead, Winona, Mower, Fillmore, and Houston), and is associated with oak savanna-barrens subtype habitat primarily on Plainfield sand deposits along river terraces in an unglaciated region with considerable topographic relief, corresponding to ecoregion subsection II.5 as described in Albert (1995). Floristically, the dominant trees in the savanna are black oak and jack pine. This is the closest locality of Karner blues to the known distribution of *Lycaeides melissa melissa*, the Melissa blue butterfly. The climate is cold and variable with high precipitation. In this RU, the Karner blue butterfly now occurs only in the Whitewater WMA (Lane and Dana 1994).

Threats

The major threat to the Whitewater WMA population is habitat degradation from succession. In other parts of the RU, such as east-central Minnesota, some habitat is protected from development or conversion, but it has not been managed in ways conducive to creating and maintaining habitat for Karner blue butterfly. Parts of these areas are being developed rapidly for commercial and residential uses that are incompatible with the Karner blue.

Protection and management

The Minnesota DNR is implementing a management plan at the Whitewater WMA (Lane 1994) to conserve and protect the Karner blue. Work thus far has included a deer browse study, and habitat restoration work including tree girdling and burning. A project to accelerate colonization was begun at the WMA in 1999 (refer to PART I, CONSERVATION MEASURES, Reintroduction/Translocation).

POTENTIAL RECOVERY UNITS

Potential RUs are areas in which the Karner blue occurred historically or may exist in low numbers [Northeast Morainal Sands (Wisconsin) and Kenosha (Wisconsin/Illinois) potential RUs], and in which sufficient restorable and suitable habitat occurs that potentially could support a viable metapopulation of Karner blue butterflies. Because the actual historic distribution of the Karner blue was probably much more extensive than that indicated by confirmed historic distribution records, this listing of potential RUs probably underestimates considerably a complete listing of potential RUs. Six potential RUs are identified in this plan (Refer to Figures B1-B4).

This plan identifies no recovery goals for potential RUs. However, recovery in these areas could benefit the Karner blue if successful and contribute to the plan's goal of restoring viable populations throughout the range of the butterfly. Therefore tasks associated with recovery in potential RUs have been given a priority 3 ranking. The Service in consultation with the Recovery Team will consider whether recovery in a potential RU can count towards the recovery goals. If so, the population in the recovery unit could offset one of the populations in the next nearest recovery unit(s) e.g. a recovered population in the Oak Openings Potential RU (Ohio) could offset the need for a viable population in the Ionia, Allegan (Michigan), or Indiana Dunes RUs. Recovery in the Rome Sandplains Potential RU could offset the need for one viable population in the Glacial Lake Albany RU (New York).

Rome Sand Plains Potential RU (New York)

Location

This potential RU is located in central New York, in Oneida County, and is associated with sand deposits of similar origin as Glacial Lake Albany, including a large dune field. The climate is similar to the northern section of the larger Glacial Lake Albany RU. In some sections, the vegetation remains as pine barrens or oak-pine woodlands; the remaining vegetation is degraded but restorable. Historic records of Karner blues, though unverified (Robert Dirig, in litt. 2002), exist for this potential RU.

Protection and management

Survey efforts in the Rome Sand Plains Potential RU in 1995 revealed the presence of minimal lupine at most sites, degraded pine barrens, and no Karner blues. Only one large site was located which supported several thousand lupine stems. Frosted elfins, a Karner blue associate, were located at two of these sites.

A resource management team has been formed to guide management of the Rome Sand Plains. Management will be for multiple uses and include restoration of pine barrens and reintroduction of the Karner Blue. Team members include the NY DEC, TNC, City of Rome, local landowners, snowmobile clubs and Isaac Walton League. In 1998, the Boy Scouts were involved in a small lupine planting project on state lands in the sandplains.

Tonawanda Potential RU (New York)

Location

This potential RU is located in western New York, in two counties (Erie and Genesee), and is associated with a large, contiguous glacial origin sand deposit. This potential RU is one of two RUs in the United States that form potential geographic connections between the eastern and western parts of the current range of Karner blue (this connection includes extirpated populations in Ontario that may be restored; refer to PART I, CONSERVATION MEASURES, Other Related Recovery Plans, Ontario, Canada Recovery Plan and Recovery Efforts). Current vegetation is second growth woodland, and the climate is strongly influenced by Lake Ontario, with considerable fall and winter precipitation and moderated climatic extremes.

There are Karner blue butterfly specimens from as recently as the early 1970's in this potential RU, but no butterflies have been observed since then. Suitable habitat occurs on the Tonawanda Indian Reservation but conducting thorough surveys for butterflies has not been possible. Based upon limited observations of the area, Zaremba (Bob Zaremba, TNC, pers. comm. 1996) suggests a few hundred acres of potentially suitable habitat may exist in the area.

Protection and management

Limited survey efforts were conducted in 1995 and 1996 in the Tonawanda Potential RU in the western portion of the state. No new Karner blue butterfly localities were identified here, however remnant barrens habitat was present on the Tonawanda Indian Reservation (an historic Karner blue locality). The Iroquois NWR and adjacent Oak Orchard Wildlife Management Area began working on barren restoration (lupine planting) and management in 1995-96. Reintroduction of Karner blue is being considered here in the future.

Oak Openings Potential RU (Ohio)

Location

This potential RU is located in northwest Ohio, in four counties (Lucas, Fulton, Henry and Wood), and is associated with unusually thick sands, up to fifty feet thick, underlain by glacial till that is 50 percent clay. Water drains through the sand but cannot get through the clay till, and the lower parts of the sand remain saturated, creating a remarkable amount of diversity. This potential RU is one of two areas in North America that form potential geographic connections between the eastern and western parts of the current range of Karner blue (this includes extirpated populations in Ontario that may be restored; refer to PART I, CONSERVATION MEASURES). Historically, the vegetation is oak barrens and oak savannas interspersed with tall grass, xeric and wet prairies. Native Americans probably kept the vegetation open with frequent fires.

Karner blue butterflies were last seen in Ohio in 1988 (Grigore and Windus 1994). The butterfly occurred historically in northwestern Ohio in an area known as the Ohio Oak Openings Geological Area (Shuey et. al. 1987a, 1987b). The Ohio Oak Openings now covers a total of

9,000 acres within a 150 square mile area and is owned by five governmental and non-profit organizations. Four hundred acres are being actively managed to improve native habitat, but no site is larger than 100 acres. The Ohio Division of Natural Areas and Preserves, Toledo Metroparks, The Nature Conservancy, and other agencies are restoring portions of the Oak Openings.

Protection and management

In 1998, the Ohio DNR, Division of Natural Areas and Preserves finalized the "Ohio Conservation Plan for the Karner Blue Butterfly" (Ohio DNR, 1998). As part of Ohio's conservation efforts, the Ohio DNR, Toledo Zoo, Michigan DNR, and TNC are working jointly on a project to reintroduce the Karner blue to the oak openings of northwest Ohio (refer to PART I, CONSERVATION MEASURES, Reintroduction/Translocation).

Kenosha Potential RU (Wisconsin/Illinois)

Location

This potential RU is located in northeast Illinois and southeast Wisconsin, in Lake (Illinois) and Kenosha (Wisconsin) counties, and is associated with lake deposit sands. Seemingly high quality Karner blue habitat is protected in several state and county parks, but the total area available is limited and may not be sufficient to support a viable metapopulation. Although the Karner blue butterfly was considered extirpated from this potential RU in 1992 (when the last butterfly was seen), Melissa Pierson a butterfly surveyor, recorded one Karner blue from Illinois State Beach Park in August of 2001 (Kris Lah, USFWS, in litt. 2001).

Protection and management

Efforts are underway to restore the Karner blue to Illinois State Beach Park (Park) in Lake County, which occurs within this potential RU. The Park supports an array of habitat types including oak savannas and remnant native prairies. The Illinois Department of Natural Resources (DNR) has restored habitat at Illinois Beach State Park and the Spring Bluff Forest Preserve, located north of the Park with the goal eventually of reintroducing Karner blue butterflies to the Park. This work was funded during 1996-1998 by the U.S. Environmental Protection Agency's (EPA) Great Lakes National Program Office. Additional funding will be needed in subsequent years to continue the restoration work and to proceed with reintroduction of the Karner blue if still considered appropriate.

Northeast Morainal Sands Potential RU (Wisconsin)

Location

This potential RU is located in northeast Wisconsin, in four counties (Menominee, Oconto and Shawano and Marinette), and is associated with stagnation moraine and glacial outwash. This RU corresponds to ecoregion sub-subsections IX.1 and IX.3.4 as described in Albert (1995). It is characterized by extensive sandy outwash plains supporting jack pine barrens and narrow terminal moraine ridges separated by outwash with sandy soils, has higher snowfall than other Wisconsin RUs, and very cold winters. Wild lupine reaches its northeastern geographic limits in Wisconsin in this potential RU. This is the only known contact area with *Lycaeides idas*, the northern blue butterfly. Karner blues occur on Menominee Indian Tribal lands in this RU.

<u>Protection and management</u>

Educational and information presentations on the Karner blue have been given to the Menominee Indian Tribe. The Service and other agencies have assisted with Karner blue butterfly surveys.

Anoka Sand Plain Potential RU (Minnesota)

<u>Location</u>

This potential RU is located in east central Minnesota, in fourteen counties (Morrison, Mille Lacs, Kennebec, Pine, Stearns, Benton, Sherburne, Isanti, Chisago, Anoka, Washington, Hennepin, Ramsey, and Dakota), and is associated with an outwash plain from glacial meltwaters and outwash terraces of the Mississippi River. This corresponds to ecoregion subsection II.3 as described in Albert (1995). This is the western-most historical geographic occurrence of the Karner blue. This relatively flat area is dominated by bur oak and northern pin oak on sandy soils and is floristically distinct from the Paleozoic Plateau RU and the Superior Outwash RU. Climate here is cooler and drier than the Paleozoic Plateau RU to the south.

<u>Protection and management</u>

Surveys for the Karner blue butterfly have been done at Sherburne NWR, but no Karner blue butterflies have been sighted here to date.

RECOGNIZED HISTORIC SITES

The historic distribution of Karner blue probably included all savanna and barrens habitats that could support lupine and that are within the historic and currently known range of Karner blue butterfly. In addition, it is possible that the distribution extended further north, east and south, at least for some periods of time. Thus, this listing of historic sites, which is based on confirmed records of existing specimens, probably underestimates considerably a realistic listing of actual historic sites. Ten recognized historic sites have been identified. The New Jersey sites, which are commonly considered to be historic sites, are not recognized here, although this decision is scientifically debatable.

There are no recovery goals for historic sites. These sites in are considered nonessential for the recovery of the species, and beyond this listing, will not be considered further in this document. Recovery in historic sites would be beneficial to the species, but this recovery plan does not identify use of any resources for recovery at these historic sites.

Norway Barrens Historic Site (Maine)

This site is located in the former Norway Barrens near Norway, Maine. A specimen was recorded from this locality prior to 1874. No restorable communities remain, and no contemporary record of Karner blue exists in this region.

Watertown (Clayton) Historic Site (New York)

This site is located near Watertown, New York.

Brooklyn Historic Site (New York)

This site is located in Brooklyn, New York. Intense urban development eliminates the possibility for recovery at this site.

Sullivan/Delaware Historic Site (New York/Pennsylvania)

This site is located in Pennsylvania (Wayne and possibly Luzerne, Pike, and Clinton counties), and New York along the upper reaches of the eastern branch of the Susquehana River and the upper Delaware River. This site is geologically dissimilar to other sites supporting or considered to have the potential to support the Karner blue elsewhere. It is speculated that the original habitat of Karner blue was riverside gravel/ sandy areas periodically scoured by floods of the Delaware River. The headwater dams on both branches of the Delaware would have reduced this means of producing open habitat for lupine and Karner blue. Currently, the riverside lands are either very steep or flat with considerable residential and recreational use, and no suitable habitat base remains.

Maumee Lake Plain Historical Area (Michigan)

This area is located in southeast Michigan, in six counties (Monroe, Lonawee, Wayne, Washtenaw, Macomb and Oakland). It is probably ecologically continuous with the Oak Openings Potential RU and extirpated sites in Ontario. This area has sandy soils, and is heavily urbanized and suburbanized by Detroit and associated municipalities.

La Grange County Historic Site (Indiana)

This site is located in northeast Indiana, in La Grange County. This area once supported extensive oak barrens, but conversion to agricultural use and fire suppression have eliminated almost all potential Karner blue habitat. Extensive restoration would be necessary to re-establish the Karner blue butterfly here.

St. Joseph County Historic Site (Indiana)

This site is located in north-central Indiana, in St. Joseph County. This area once supported extensive oak barrens, but conversion to agricultural use and fire suppression have eliminated almost all potential Karner blue habitat. Extensive restoration would be necessary to re-establish the Karner blue butterfly here.

Kendell County Historic Site (Illinois)

This site is located in northeast Illinois, in Kendell County.

Iowa Historic Site (Iowa)

This site is located in northeast Iowa and possibly was contiguous historically with the Paleozoic Plateau RU.

<u>Note</u>: Historic sites also occur in Ontario, Canada and can be noted on Figure B1.

LITERATURE CITED

Albert, D.A. 1995. Regional Landscape Ecosystems of Michigan, Minnesota and Wisconsin: A Working Map and Classification. Gen. Tech. Rep. NC-178. St. Paul, Minnesota: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 250 pp.

Bidwell, A. D. 1994. Mark-release-recapture of Karner blue butterflies (*Lycaeides Melissa samuelis*) at Fort McCoy Military Reservation. Report submitted to the U.S. Fish and Wildlife Service (Region 3), Fort Snelling, Minnesota. 50 pp.

Bleser, C. A. 1993. Status survey, management and monitoring activities for the Karner blue butterfly (*Lycaeides melissa samuelis*) in Wisconsin. Final Report submitted to the U.S. Fish and Wildlife Service. 86 pp.

City of Concord. March 1996. Concord Airport Master Plan Update. Prepared for the City of Concord, New Hampshire, by Rist-Frost-Shumway Engineering, P.C. Laconia, NH.

Cuthrell, D. L. and M. L. Rabe. 1996. Status of the Karner blue butterfly *(Lycaeides melissa samuelis)*, in the Ionia Recovery Unit of Michigan. Prepared by the Michigan Natural Features Inventory, Lansing, Michigan for the U.S. Fish and Wildlife Service. 22 pp.

Dirig, R. Historical notes on wild lupine and the Karner blue butterfly at the Albany Pine Bush, New York. *In* Andow, D. A., R. Baker, and C. Lane (eds), Karner Blue Butterfly: A Symbol of a Vanishing Landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 23-36.

Grigore, M. T. and J. L. Windus. Decline of the Karner blue butterfly in the Oak Openings of northwest Ohio. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner Blue Butterfly: A Symbol of a Vanishing Landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 135-142.

Helmbolt, K. M. and M. Amaral. Status of the Karner blue butterfly in New Hampshire, *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner Blue Butterfly: A Symbol of a Vanishing Landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 123-128.

Homoya, M. A., D.B. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Proceedings of the Indiana Academy of Science. 94:245-268.

Lane, C. 1994. Whitewater Wildlife Management Area. Management Plan for the oak savanna ecosystem, focusing on habitat restoration for the Karner blue butterfly. University of Minnesota, St. Paul, Minnesota. Prepared for the Minnesota Department of Natural Resources (St. Paul) and the U.S. Fish and Wildlife Service (Fort Snelling, Minnesota). 59pp. + figures.

Lane, C. and R. Dana. The status of the Karner blue butterfly in Minnesota. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner Blue Butterfly: A Symbol of a Vanishing Landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series).

Lawrence, W. S. and A. C. Cook. 1989. The status and management of Karner blue (*Lycaeides melissa samuelis*) populations in the Allegan State Game Area, Michigan. Unpublished report to The Nature Conservancy, Michigan Field Office, East Lansing, Michigan. 57 pp.

Martin, M. Karner blue butterfly in Indiana: 1990 status survey for the U.S. Fish and Wildlife Service. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 97-105.

Maxwell, J. and T. Givnish. 1994. Research on the Karner blue butterfly at Fort McCoy, Wisconsin: Progress report for the 1993 field season. Report to the US Fish and Wildlife Service and U.S. Department of Defense, December, 1993.

Maxwell, J. and T. Givnish. 1995. Research on the Karner blue butterfly at Fort McCoy, Wisconsin: Progress report for the 1994 field season. Unpublished report to the U.S. Fish and Wildlife Service and the Department of the Army.

Maxwell, J. and T. Givnish. 1996. Research on the Karner blue butterfly at Fort McCoy, Wisconsin. Progress report for the 1995 field season. Report submitted to the U.S. Fish and Wildlife Service and the U.S. Department of the Army. 30 pp. + tables.

Maxwell, J. A. 1998. The conservation of the Karner blue butterfly (Lycaeides melissa samuelis Nabokov): Ecological studies on habitat creation and management (Ph.D. dissertation) University of Wisconsin – Madison. 193 pp.

Michigan Department of Natural Resources. 1994. Karner blue management, protection, research, and management of Michigan's rare insect species. Study performance report prepared for the U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 2pp.

Ohio Department of Natural Resources, Division of Natural Areas. 1998. Ohio Karner blue butterfly conservation plan. Columbus, Ohio, 28 pp.

Schuetz, T. 1996. Summary of survey, management, and monitoring activities. Karner blue butterfly dry sand prairie/oak barrens ecosystem. FY 1995. Prepared for the Huron-Manistee National Forest, Michigan. 37pp.

Schweitzer, D. Prioritizing Karner blue butterfly habitats for protection activities. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 173-183.

Shuey, J. undated. A West Gary, Indiana Karner blue reserve design encompassing dune and swale oak barrens communities. The Nature Conservancy, Indiana Field Office, Indianapolis, Indiana. 14pp. + figures.

Shuey, J. A., J. V. Calhoun and D. C. Iftner. 1987a. Butterflies that are endangered, threatened, and of special concern in Ohio. Ohio Journal of Science 87: 98-106.

Shuey, J. A., E. H. Metzler, D. C. Iftner, J. V. Calhoun, J. W. Peacock, R. A. Watkinns, J. D. Hooper and W. F. Babcock. 1987b. Status and habitats of potentially endangered lepidoptera in Ohio. *Journal of the Lepidopterists' Society*. 41: 1-12.

Sommers, L. A. and P. E. Nye. Status, research and management of the Karner blue butterfly in New York, *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 129-134.

USFWS (U.S. Fish and Wildlife Service) 1992a. Endangered and threatened wildlife and plants; determination of endangered status for the Karner blue butterfly. Proposed rule. Federal Register 57(13):2241-2246.

USFWS 1992b. Endangered and threatened wildlife and plants; determination of endangered status for the Karner blue butterfly. Final rule. Federal Register 57(240):59236-59244.

VanLuven, D. E. 1994. Site conservation plan for the Concord pine barrens, Concord, New Hampshire. Prepared by The Nature Conservancy, New Hampshire Field Office, Concord, NH for the U.S. Fish and Wildlife Service, Concord, NH. 12pp. + figures and appendices.

Wilsmann, L. Status of the Karner blue butterfly in Michigan. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp.107-112.

Wisconsin Department of Natural Resources, Bureau of Endangered Resources. 1994. Guidelines for determining the presence of the Karner blue butterfly on forest tracts. Wisconsin Department of Natural Resources, Madison, Wisconsin. 4pp. + map.

Wisconsin Department of Natural Resources. 2000. Wisconsin statewide Karner blue butterfly habitat conservation plan and environmental impact statement. PUBL-SS-947-00. Wisconsin Department of Natural Resources, Madison. 386 pp. + appendices. Available from the HCP Coordinator at 877-452-7637.

APPENDIX C

PLANTS USED FOR NECTAR BY ADULTS

Table C1 provides a list of all of the nectar plants reported to be used by Karner blue adults. Some of these records may be based on single observations of one individual, while others represent hundreds of observed uses. These records are based on observing at least one adult to probe a flower with its mouth parts. In the majority of cases, feeding was further confirmed by observing the adult to remain with its mouth parts in a single flower or floret for some period of time after initial probing.

Table C1. Nectar plant species reported to be used by the Karner blue butterfly. Scientific names follow Ownby and Morley (1991), Gleason and Cronquist (1991) or Swink and Wilhelm (1994).

Scientific name	Common name	Location	Reference
-------------------------First brood adult nectar sources-------------------------			
---------------------Herbaceous species---------------------			
Achillea millefolium L.	Common yarrow	WI, IN	2,7,14,15
Anenome cylindrica Gray	Thimbleweed	WI,IN	7,15
Arabis lyrata L.	Sand-cress	IN,MN,ON,WI	2,5,7,8,10,9,14,15
Arenaria serpyllifolia L.	Thyme-leaved sandwort	ON	10
Baptisia bracteata var. *glabrescens* (Larisey) Isely (*leucophaea*)	Prairie wild indigo	WI	2,14
Berteroa incana (L.) DC.	Hoary alyssum	WI	2,7
Centaurea biebersteinii (*maculosa*) DC.	Spotted knapweed	WI	7
Cerastium sp.	Chickweed	WI	7
Chrysanthemum leucanthemum L.	Ox-eye daisy	WI	7
Commandra umbellata (L.) Nutt.	Bastard toadflax	MI	11,13
Coreopsis lanceolata L.	Lance-leafed coreopsis	IN	8,15
Coreopsis tripteris *L.*	Tall coreopsis	IN	15
Erigeron strigosus Muhl.	Daisy fleabane	WI	2
Euphorbia corollata L.	Flowering spurge	WI,IN	9,15
Euphorbia podperae (*esula*) Croizat	Leafy spurge	WI	7,9
Fragaria virginiana Duchesne	Strawberry	NY,WI,IN	3,7,15
Gaylussacia baccata (Wang.) K. Koch	Huckleberry	IN	15
Geranium maculatum L.	Wild geranium	ON	10
Hedyotis (Houstonia) longifolia (Gaetrn.) Hook.	Longleaved houstonia	MN,WI	5,7,9,14
Helianthemum canadense (L.) Michx.	Frostweed	NH,IN	1,15
Hieracium aurantiacum L.	Orange hawkweed	WI	2,7,9,14
Hieracium sp.	Hawkweed	ON,NH,WI	1,2,10
Krigia biflora (Wlt.) Blake	Two-flowered Cynthia	WI	2,14
Liatris Spp.	Blazing star	IN	15
Lithospermum canescens (Michx.) Lehm.	Hoary puccoon	IN	15
Lithospermum caroliniense (Walt.) MacM.	Hairy puccoon	ON,WI,IN	2,10,15
Lupinus perennis L.	Wild lupine	MI,NH,OM,WI,IN	1,2,7,9,10,11,14,15
Medicago lupulina L.	Black medic	WI	2,7
Melilotus officinalis (L.) Pallas	Yellow sweet clover	IN,WI	2,7,8

Table C1. (continued)

Scientific name	Common name	Location	Reference
Pedicularis canadensis L.	Lousewort	WI	2,14
Phlox pilosa L.	Downy phlox	IN	8,15
Potentilla recta L.	Rough-fruited cinquefoil	WI	2
Potentilla simplex Michx.	Common cinquefoil	WI,MI,IN	2,7,13,14,15
Potentilla sp.	Cinquefoil	MI,NY	3,11
Rosa carolina L.	Carolina rose	IN	15
Rumex acetosella L.	Sheep sorel	WI	2
Senecio pauperculus Michx.	Ragwort	WI	7
Senecio sp.	Ragwort	WI	2,9
Smilacina racemosa (L.) Desf.	False spikenard	WI	2,7
Smilacina stellata (L.) Desf.	Star-flow. fals. sol. seal	WI	2,14
Solidago sciaphila Steele	Cliff goldenrod	WI	7
Tephrosia virginiana (L.) Pers.	Goat's rue	NY	3
Tradescantia ohiensis Raf.	Spiderwort	IN	15
Trifolium hybridum L.	Alsike clover	WI	2,14
Trifolium pratense L.	Red clover	WI	7
Trifolium repens L.	White clover	WI	2
Viccia villosa Roth.	Hairy vetch	WI	2
Viola pedata L.	Bird foot violet	NY,WI	2,3,13
Zizia aurea (L.) Koch	Golden alexanders	WI	2
---------------------Woody species---------------------			
Amelanchier sp.	Juneberry	ON	10
Ceanothus herbaceus (ovatus) Raf.	Red root	WI	7
Ceanothus sp.	New jersey tea	WI	2
Physocarpus opulifolius (L.) Maxim.	Common ninebark	WI	7
Prunus sp.	Wild plum	NY	3
Rubus allegheniensis Porter	Blackberry	WI	7
Rubus flagellaris Willd.	Dewberry	IN,MI,WI	7,6,8,13,15
Rubus sp. or sPP. (IN)	Bramble	IN,MI,MN,WI	2,5,8,11,9,14,15
Salix humilis Marsh.	Prairie willow	WI	2, 7
Vaccinium sp.	Blueberry	NY,IN	3,15
Vitis riparia Michx.	River grape	MN	5
-------------------------Second brood adult nectar sources-------------------------			
---------------------Herbaceous species---------------------			
Achillea millefolium L.	Common yarrow	IN,MI,MN,WI	2,5,7,8,11,14
Amorpha canescens Pursh	Lead plant	WI	2,7,9,14
Apocynum androsaemifolium L.	Spreading dogbane	NH,NY	1,12
Arabis lyrata L.	Sand-cress	IN,WI	2,7,8,14
Asclepias incarnata L.	Swamp milkweed	IN	15
Asclepias syriaca L.	Common milkweed	NH,NY,WI	2,7,12
Asclepias tuberosa L.	Butterfly-weed	IN,MI,MN, NY,ON,WI	2,3,4,5,6,7, 8,10,11,13,15
Asclepias verticillata L.	Whorled milkweed	MI,WI,IN	2,7,8,11,9,13,15
Aster sp.	Aster	WI	2,13
Aureolaria pedicularia (L.) Raf.	Fern-leaved false foxglove	WI	2
Aureolaria sp.	False foxglove	WI	2,13
Berteroa incana (L.) DC.	Hoary alyssum	NY,WI	2,4

Table C1. (continued)

Scientific name	Common name	Location	Reference
Campanula rotundifolia L.	Harebell	MN,WI	1,2,9,14
Centaurea biebersteinii (maculosa) DC.	Spotted knapweed	MI,NY,WI	2,3,4,7,11,13,14
Chrysanthemum leucanthemum L.	Ox-eye daisy	WI	7
Coreopsis lanceolata L.	Lance-leaved coreopsis	MI	11
Coreopsis palmata Nutt.	Stiff tickseed	WI	7,9,14
Coreopsis sp.	Coreopsis	WI	2
Dianthus armeria L.	Deptford pink	MI	11
Erigeron annuus (L.) Pers.	Daisy fleabane	MI,MN	5,11
Erigeron canadensis		WI	9
Erigeron strigosus Muhl.	Daisy fleabane	WI,IN	2,7, 9,15
Erigeron sp.	Fleabane	IN,WI,MI	2,8,13,14
Euphorbia corollata L.	Flowering spurge	IN,MI,MN,WI	1,2,5,6,7,8,11,13, 14,15
Euphorbia podperae (esula) Croizat	Leafy spurge	WI	2,7
Euthamia graminifolia (*Solidago graminifolia*) (L.) Nutt	Grass-leaved goldenrod	NH,WI	2,12,14
Froelichia floridana (Nutt.) Moq.	Cottonweed	WI	7
Galium sp.	Bedstraw	WI	2,14
Gnaphalium obtusifolium L.	Sweet everlasting	MN,WI	1,2,5,9,14
Hackelia deflexa (Wahlenb.) Opiz	Stickseed	MN	5
Hedyotis (Houstonia) longifolia (Gaetrn.) Hook.	Longleaved houstonia	WI	2,14
Helianthemum canadense (L.) Michx.	Frostweed	WI	9
Helianthus divaricatus L.*	Woodland sunflower	IN,MI	8,11,15
Helianthus occidentalis Riddell	Western sunflower	MN,WI,IN	2,5,7,9,14,15
Helianthus sp.	Sunflower	NH,NY,MI,WI	2,11,12,14
Hieracium aurantiacum L.	Orange hawkweed	WI	2,7,9,14
Hieracium pilosella L.	Mouse ear hawkweed	MI	11
Hieracium sp.	Hawkweed	MI	11
Hypericum perforatum L.	Common St.John's wort	MI	11
Krigia biflora (Walt.) Blake	Two-flowered Cynthia	WI	2,14
Lespedesa capitata Michx.	Bush clover	WI	2,14
Liatris aspera Michx.	Rough blazing star	MI,WI	2,6,7,11,9,14
Liatris cylindracea Michx.	Dwarf blazing-star	ON,WI	2,7,9,12,14
Liatris sPP.	Blazing-star	IN	15
Lilium philadelphicum L.	Wood lily	NH	1
Linaria canadensis (L.) Dum.-Cours.	Old-field toad flax	WI	2
Linaria vulgaris Hill	Butter-and-eggs	WI	2
Lithospermum caroliniense (Walt.)MacM	Hairy puccoon	WI	2
Lobelia spicata Lam.	Pale-spike lobelia	WI	7
Lotis corniculatus L.	Birdsfoot trefoil	MI,WI	2,11,14
Lupinus perennis L.	Wild lupine	NY,WI	2,12,14
Lycopus americanus Muhl.	Water-horehound	IN	15
Lysimachia sp.	Loosestrife	WI	2,14
Lythrum alatum Pursh.	Winged loosestrife	IN	15
Medicago lupulina L.	Black medic	WI	2,7,9
Medicago sativa L.	Alfalfa	WI	2
Melilotus alba Medic.	White sweet clover	IN,MN,WI	2,5,7,8,9,14,15
Melilotus officinalis (L.) Pallas	Yellow sweet clover	MN,WI	2,5,7
Monarda fistulosa L.	Wild bergamot	IN	8,9,14,15
Monarda punctata L.	Horsemint	IN,MI,MN,NY, ON,WI	2,3,4,5,6,7, 8,9,10,11,14,15

Table C1. (continued)

Scientific name	Common name	Location	Reference
Oenothera sp.	Evening primrose	WI	2,13
Petalostemon candidum (Willd.) Michx.	White prairie clover	WI	2,7,9
Petalostemon purpureum (Vent.) Rydb.	Purple prairie clover	WI	2,7
Phlox pilosa L.	Downy phlox	IN	15
Polygala polygama Walt.	Racemed milkwort	MI	11
Polygonum sp.	Knotweed	WI	2,14
Potentilla recta L.	Rough-fruited cinquefoil	IN	15
Potentilla simplex Michx.	Common cinquefoil	WI	2,14
Pycanthemum virginianum L.	Mountain-mint	IN	15
Rosa carolina L.	Carolina rose	IN	15
Rosa sp.	Wild rose	WI	2,14
Rudbeckia hirta (serotina) L.	Black-eyed susan	MI, MN,ON,WI,IN	2,5,7,9,10,11,14,15
Saponaria officinalis L.	Soapwort	NY,IN	3,15
Scutellaria epilobiifolia	Marsh skullcap	IN	15
Smilacina stellata (L.) Desf.	Star-flow. fals. sol. seal	WI	2,14
Solidago ptarmicoides (Nees) Boivin (*Aster ptarmicoides*)	Upland white aster	WI	2,9
Solidago speciosa Nutt.	Showy goldenrod	WI,IN	13,15
Solidago sp.	Goldenrod	IN,NH,WI	1,2,8,14
Spiraea tomentosa L.	Meadowsweet	WI	14
Talinum rugospermum Holz.	Fameflower	WI	2
Tephrosia virginiana (L.) Pers.	Goat’s rue	IN	8,14,15
Tradescantia ohiensis Raf.	Spiderwort	IN	15
Tradescantia virginiana L.*	Virginia spiderwort	MI	11
Trifolium arvense L.	Rabbit-foot clover	WI	2,14
Trifolium hybridum L.	Alsike clover	WI	2,14
Trifolium pratense L.	Red clover	WI	2,7,14
Trifoliium repens L.	White clover	WI	2,7,14
Vicia villosa Roth.	Hairy vetch	WI	2,14
---------------------Woody species---------------------			
Ceanothus americanus L.	New Jersey tea	IN,NH,NY,ON,WI	1,2,3,4,8,10,14,15
Ceanothus herbaceus (ovatus) Raf.	Red root	ON	10
Rhus copallinia	Winged sumac	IN	14

References: 1= Bidwell, in Helmbolt and Amaral 1994, 2 = Bleser 1992, 3 = Dirig 1976, 4 = Fried 1987, 5 = Lane, pers. comm. 1994, 6 = Lawrence 1994, 7 = Leach 1993, 8 = Martin 1994, 9 = Maxwell and Givnish 1994, 10 = Packer 1987, 11 = Papp 1993, 12 = Schweitzer, pers. comm. 1994, 13 = Sferra and Darnell 1993, 14 = Swengel and Swengel 1993, 15 = Grundel and Pavlovic 2000.

LITERATURE CITED

Bleser, C.A. 1992. Status survey, management and monitoring activities for the Karner blue butterfly *(Lycaeides melisa samuelis)* in Wisconsin 1990-1992. Report submitted to the U.S. Fish and Wildlife Service, Fort Snelling, Minnesota, by the Wisconsin Department of Natural Resources, Bureau of Endangered Resources, Madison, Wisconsin. 88 pp.+ appendices.

Dirig, R. Karner's famous blue butterfly. *In* Rittner, D. (ed.), Pine Bush-Albany's Last Frontier. Pine Bush Historic Preservation Project, Albany, New York. 1976. pp. 197-210, 250-252.

Fried, C. S. September1987. Dispersal of the Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov) in the Albany Pine Bush. Report submitted to the Endangered Species Unit of the NewYork State Department of Environmental Conservation.

Gleason, H.A. and A. Cronquist. 1991. Manual of Vascular Plants of the Northeastern United States and Adjacent Canada, second edition. The New York Botanical Garden. New York.

Grundel, Ralph and N.B. Pavlovic. 2000. Nectar plant selection by the Karner blue butterfly (Lycaeides melissa samuelis) at the Indiana Dunes National Lakeshore. American Midland Naturalist. 144:1-10.

Helmbolt, K. M. and M. Amaral. Status of the Karner blue butterfly in New Hampshire. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner Blue Butterfly: A Symbol of a Vanishing Landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 123-128.

Lawrence, W. S. Karner blue butterfly populations in the Allegan State Game Area, Michigan. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 53-62.

Leach, M. 1993. Status and distribution of the Karner blue butterfly at Fort McCoy, Wisconsin: Final report on a two-year status survey. Unpublished report for the Natural Resources Management Division, Fort McCoy Military.

Martin, M. Karner blue butterfly in Indiana: 1990 status survey for the U.S. Fish and Wildlife Service. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 97-105.

Maxwell, J. and T. Givnish. 1994. Research on the Karner blue butterfly at Fort McCoy, Wisconsin: Progress report for the 1994 field season. Report to the US Fish and Wildlife Service and U.S. Department of Defense, Fort McCoy, Fort McCoy, Wisconsin.

Ownby, G. B .and T. Morley. 1991. Vascular Plants of Minnesota: a Checklist and Atlas, University of Minnesota Press, Minneapolis.

Packer, L. The status of two butterflies, Karner blue *Lycaeides melissa samuelis*) and frosted elfin (*Incisalia irus*), restricted to oak savanna in Ontario. *In* G.M. Allen, P.F.J. Eagles, and S.D. Price (eds.), Conserving Carolinian Canada. Waterloo, Ontario, Univ. Waterloo Press. 1987. pp. 253-271.

Papp, C. 1993. Habitat study of the endangered Karner blue butterfly (*Lycaeides Melissa samuelis* Nabokov) in Michigan oak savanna. Preliminary report submitted to the Department of Natural Resources, Wildlife Division, Lansing, Michigan.

Sferra, N.J., D.N. Ewert, C.A. Clampitt, H.E. Ballard, Jr., J.M. Aguiar and T. Darnell. 1993. Management of oak savanna and oak barrens habitat in Newaygo and Muskegon Counties, Michigan, for Karner blue butterflies *(Lycaeides melissa samuelis)* and other oak savanna invertebrates. Final Results. The Nature Conservancy, Unpublished Report. 25 pp.

Swengel, A. and S. Swengel. 1993. Observations of Karner blues and the barrens butterfly community in Wisconsin. Manuscript (December 1993), 909 Birch Street, Baraboo, Wisconsin. 36 pp. + appendices.

Swink, F. and G. Wilhelm. 1994. Plants of the Chicago region, 4th ed. Indiana Academy of Sciences, Indianapolis. 921 p.

APPENDIX D

ASSOCIATED FEDERAL AND STATE IMPERILED SPECIES

The following tables (Tables D1-D6) list the Federal and state imperiled species associated with Karner blue habitat in each state that has a recovery goal for Karner blue. These tables were compiled by an appropriate state authority based on state records. These lists are not comparable among the states for several reasons. Each state has placed different amounts of effort into surveying Karner blue habitat, so some states have more complete information than others. Moreover, some states have limited (to some extent) their lists to those species likely to be associated with habitat actually occupied by Karner blue, while others have not. Finally, many states have listed species that are likely to occur within or adjacent to Karner blue butterfly habitat, but because the adjacent habitats are different in different states, the included species are variable. These lists indicate the tremendous biological variability that exists across the geographic range of the Karner blue, and suggests that recovery of the Karner blue might help maintain other rare and imperiled species that share its habitat.

Table D1. New Hampshire imperiled species associated with Karner blue habitats. Data provided by the New Hampshire Natural Heritage Inventory.

Scientific Name	Common Name	State Status	Federal Status
--------------Rare Invertebrates--------------			
Acronicta lanceolaria	a dagger moth	S3	
Agrotis stigmosa	a noctuid moth	SU	
Anomogyna elimata		S3/S4	
Aphantesis carlotta		SU	
Apharatera purpurea	a noctuid moth	S2	
Apodrepanulatrix liberaria		S1/S2	
Atrytonopsis hianna	dusted skipper	S3?	
Catacola sp.		S1/S2	
Cerma cora	a bird dropping moth	S1/S2	
Chaetaglaea cerata	a noctuid moth	S2/S3	
Chaetaglaea tremula	a noctuid moth	S?	
Chytonix sensilis	a noctuid moth	S1/S2	
Cucullia speyeri		S3	
Erastria coloraria	Broad-lined catopyrra		
Erynnis brizo brizo		S2	
Erynnis p. persius	Persius dusky wing	E	
Euchlaenia madusaria	a looper moth	S1	
Eumacaria latiferrugata		S2/S4	
Euxoa pleuritica	a noctuid moth	S1	
Glena cognataria		S3?	
Grammia phyllira	Phyllira tiger moth	SH(S1)	
Hemaris gracilis		S2/S3	
Hesparia metea	cobweb skipper	S3	

continued

Table D1 (continued). New Hampshire imperiled species associated with Karner blue habitats. Data provided by the New Hampshire Natural Heritage Inventory.

Scientific Name	Common Name	State Status	Federal Status
Incisalia irus	Frosted elfin	E	
Lapara coniferarum		S1/S2	
Lithophane thaxteri		SU	
Lycia rachelae		S2	
Metarranthis apiciaria		S1	
Papaipema lysimachiae	a noctuid moth	SU	
Platyperigea meralis		S1	
Satyrium edwardsii	Edward's hairstreak	S3	
Xylena thoracica		S2	
Xylotype capax		S2	
Zale curema		S2	
Zale submediana		S2	
Zanclognatha martha	a noctuid moth	T	
--------------Rare Vascular Plants--------------			
Asclepias amplexicaulis	a milkweed	T	
Hudsonia ericoides	golden heather	T	
Lupinus perennis	blue lupine	T	

State Status Codes: E=endangered, T=threatened, S1 = critically imperiled, S2 = imperiled, S3 = rare or uncommon, SH = historical, SU = possibly in peril.

Table D2. New York imperiled species associated with Karner blue habitats. Data provided by the New York Natural Heritage Program.

Scientific Name	Common Name	State Status	Federal Status
--------------Rare Birds--------------			
Accipiter cooperii	Cooper's hawk	SC	
Buteo lineatus	Red-shouldered hawk	SC	
Caprimulgus vociferus	Whip-poor-will	SC	
Chardeiles minor	common nighthawk	SC	
Vermivora chrysoptera	Golden-winged warbler	SC	
--------------Rare Reptiles and Amphibians--------------			
Carphophis amoenus	Worm snake	SC	
Clemmys guttata	Spotted turtle	SC	
Heterodon platychinos	Eastern hognose snake	SC	
Sacphiopus holbrookii	Eastern spadefoot toad	SC	
Terrapene carolina	Eastern box turtle	SC	
--------------Rare Invertebrates--------------			
Acronicta albarufa	Albarufian dagger moth	SU	FSC
Aphareta dentata	a noctuid moth	SU	
Erastria coloraria	Broad-lined catopyrra	SU	
Cerma cora	a bird dropping moth	SU	
Chaetaglaea cerata	a noctuid moth	SU	
Chtonix sensilis	a noctuid moth	SU	
Erynnis martalis	mottled dusky wing	SC	
Erynnis persius	Persius dusky wing	E	

continued

Table D2 (continued). New York imperiled species associated with Karner blue habitats. Data provided by the New York Natural Heritage Program.

Scientific Name	Common Name	State Status	Federal Status
Atrytonopsis hianna	Dusted skipper	SU	
Callophrys irus	Frosted elfin	T	
Hemileuca maia	Barrens buckmoth	SC	
Incisalia henrici	Henry's elfin	SC	
Itame sp1	a geometrid moth	SU	
Lithophane lepida lepida	Pine pinion moth	E	
Macrochilo bivittata	a noctuid moth	SU	
Satyrium edwardsii	Edward's hairstreak	SU	
Zanclognatha martha	a noctuid moth	SU	
--------------Rare Vascular Plants--------------			
Cyperus houghtonii	Houghton umbrella sedge	R	
Cyperus schweinitzii	Schweinitz faltsedge	R	
Poa paludigena	Slender marsh bluegrass	E	FSC

State Status Codes: SU=status unknown, T=threatened, E=endangered, R=rare, SC=special concern.
Federal Status Codes: E=endangered, T=threatened, FSC=Federal species of concern (these are the former Federal C2 candidate species).

Table D3. Michigan imperiled species associated with Karner blue habitats. Data provided by the Michigan Natural Features Inventory.

Scientific Name	Common Name	State Status	Federal Status
--------------Rare Mammals--------------			
Cryptotis parva	least shrew	T	
Microtis pinetorum	woodland vole	SC	
--------------Rare Birds--------------			
Buteo lineatus	red-shouldered hawk	T	
Haliaeetus leucocephalus	bald eagle	T	T
Nycticorax nycticorax	black-crowned night heron	SC	
--------------Rare Reptiles & Amphibians--------------			
Clemmys guttata	spotted turtle	SC	
Clemmys insculpta	wood turtle	SC	
Clonophis kirtlandii	Kirtland's snake	E	FSC
Elaphe o. obsoleta	black rat snake	SC	
Sistrurus c. catenatus	eastern massasauga	SC	C
Terrapene c. carolina	eastern bow turtle	SC	
--------------Rare Invertebrates--------------			
Atrytonopsis hianna	dusted skipper	T	
Erynnis p. persius	Persius dusky wing	T	

(continued)

Table D3 (continued). Michigan associated imperiled species

Scientific Name	Common Name	State Status	Federal Status
Hesperia ottoe	Ottoe skipper	T	
Incisalia henrici	Henry's elfin	SC	
Lepyronia gibbosa	Great Plains spittlebug	T	
Incisalia irus	frosted elfin	T	
Oecanthus pini	pinetree cricket	SC	
Orphulella p. pelidna	barrens locust	SC	
Papaipema sciata	Culvers root borer	SC	
Pygarctia spraguei	Sprague's pygarctia	SC	
Schinia indiana	phlox moth	E	FSC
Scudderia fasciata	pine katydid	SC	
Spartiniphaga inops	spartina moth	SC	
Speyeria idalia	regal fritillary	E	FSC
--------------Rare Vascular Plants--------------			
Arabis missouriensis var. *deamii*	Missouri rock cress	SC	FSC
Aster sericeus	western silvery aster	T	
Bouteloua cutipendula	side-oats gramma grass	T	
Carex albolitescens	greenish-white sedge	SC	
Carex festucacae	fescue sedge	SC	
Cirsium hillii	Hill's thistle	SC	FSC
Cyperus flavescens	yellow nut-grass	SC	
Echinodorus tenellus	dwarf burhead	E	
Eleocharis atropurpurea	purple spike-rush	E	
Eleocharis engelmannii	Engelman's spike-rush	SC	
Eleocharis melanocarpa	black-fruited spike-rush	SC	
Eleocharis microcarpa	small-fruited spike-rush	T	
Eleocharis tricostata	three-ribed spike-rush	T	
Festuca scaberlla	rough fescue	T	
Fuirena squarossa	umbrella grass	T	
Gentiana puberulenta	downey gentian	E	
Geum triflorum	prairie smoke	T	
Hemicarpha micrantha	dwarf bulrush	SC	
Hibiscus moscheutos	swamp rose-mallow	SC	
Hypericum gentianoides	gentian-leaved St. John's-wort	SC	
Isoetes engelmannii	Engelman's quilwort	E	
Juncus biflorus	two-flowered rush	SC	
Juncus brachycarpus	short-fruited rush	T	
Juncus scipoides	scirpus-like rush	T	
Juncus vaseyi	Vasey's rush	T	
Lechea pulchella	Leggett;s pinweed	T	
Linum sulcatum	furrowed flax	SC	
Lycopodium appressum	appressed bog clubmoss	T	
Panicum longifolium	long-leaved panic-grass	T	
Platanthera ciliaris	yellow fringed orchid	T	
Polygala cruciata	cross-leaved milkwort	SC	
Polygonium careyi	Carey's samrtweed	T	
Potemogeton bicupulatus	waterthread pondweed	T	
Prunus allechaniensis var *davisii*	Alleghany plum	SC	FSC

(continued)

Table D3 (continued). Michigan associated imperiled species

Scientific Name	Common Name	State Status	Federal Status
Psilocarya scirpoides	bald rush	T	
Pycnathemum verticillatum	whorled mountain mint	SC	
Rhexia virginica	meadow-beauty	T	
Rhexia mariana var *mariana*	Maryland meadow-beauty	T	
Rhynchospora macrostachya	tall beak-rush	SC	
Rotata ramosior	tooth-cup	SC	
Scirpus hallii	Hall's bulrush	E	FSC
Scirpus torreyi	Torrey's bulrush	SC	
Scleria pauciflora	few-flowered nut-rush	E	
Scleria reticularis	netted nut-rush	T	
Scleria triglomertata	tall nut-rush	SC	
Sisyrinchium atlanticum	Altantic blue-eyed grass	T	
Sisyrinchium strictum	blue-eyed grass	SC	
Sporobolus heterolepis	prairie dropseed	T	
Trichostema dichotomum	bastard pennyroyal	T	
Triplasis purpurea	sand grass	SC	

State Status Codes: SC=special concern, T=threatened, E=endangered.
Federal Status Codes: E=endangered, T=threatened, FSC=Federal species of concern (these are the former Federal C2 candidate species), C=candidate.

Table D4. Indiana imperiled species associated with Karner blue habitats. Data provided by the Indiana Natural Heritage Data Center.

Scientific Name	Common Name	State Status	Federal Status
--------------Rare Mammals--------------			
Spermophilus franklinii	Franklin's ground squirrel	T	
--------------Rare Birds--------------			
Botaurus lentiginosus	American bittern	E	
Chlidonias niger	back tern	E	FSC
Rallus elegans	king rail	E	
Rallus limicola	Virginia rail	SC	
--------------Rare Reptiles & Amphibians--------------			
Ambystoma laterale	blue-spotted salamander	SC	
Emydoidea blandingii	Blanding's turtle	E	FSC
Sistrurus catenatus catenatus	eastern massasauga	T	FSC
--------------Rare Invertebrates--------------			
Atrytonopsis hianna	dusted skipper	T	
Hesperia ottoe	Ottoe skipper	E	

(continued)

Table D4 (continued). Indiana associated imperiled species

Scientific Name	Common Name	State Status	Federal Status
Hesperia leonardus	Leonardus skipper	R	
Lycaena xanthoides	great copper	SU	
Problema byssus	bunchgrass skipper	R	
Schinia indiana	phlox moth	SU	FSC
Schinia gloriosa	glorius flower	SU	
--------------Rare Vascular Plants--------------			
Amelanchier humilis	running serviceberry	E	
Arctostaphylos uva-ursi	bearberry	R	
Arenaria stricta	Michaux's stitchwort	R	
Aristida intermedia	slim-spike three-awn grass	R	
Buchnera americana	bluehearts	E	
Carex crawei	crawe sedge	SC	
Carex richardsonii	Richardson sedge	E	
Carex brunnescens	brownish sedge	E	
Carex aurea	golden-fruited sedge	R	
Carex eburnea	ebony sedge	R	
Carex garberi	elk sedge	SC	
Cirsium hillii	Hill's thistle	E	FSC
Coeloglossum viride var *virescens*	long-bract green orchis	T	
Cornus rugosa	roundleaf dogwood	R	
Cornus canadensis	bunchberry	SU	
Cypripedium calceolus var *parviflorum*	small yellow lady's-slipper	R	
Cypripedium x *andrewsii*	Andrew's lady's-slipper	E	
Cypripedium candidum	small white lady's-slipper	R	
Diervilla lonicera	northern bush-honeysuckle	R	
Eleocharis geniculata	capitate spike-rush	T	
Eriophorum angustifolium	narrow-leaved cotton-grass	R	
Gerardia skinneriana	pale false foxglove	E	
Juncus scirpoides	scirpus-like rush	T	
Juncus balticus var *littoralis*	Baltic rush	R	
Ludwigia sphaerocarpa	globe-fruited false-loosestrife	E	
Melampyrum lineare	American cow-wheat	R	
Pinus banksiana	jack pine	R	
Platanthera clavellata	small green woodland orchis	R	
Platanthera hyperborea	leafy northern green orchis	T	
Prunus pensylvanica	fire cherry	R	
Rhus aromatica var *arenaria*	beach sumac	T	
Salix cordata	heartleaf willow	T	
Satureja glabella var *angustifolia*	calamint	E	
Scirpus subterminalis	water bulrush	R	
Sisyrinchium montanum	strict blue-eyed-grass	E	
Solidago simplex var *gillmanii*	sticky goldenrod	T	
Solidago ptarmicoides	prairie goldenrod	R	
Spiranthes lucida	shining ladies'-tresses	R	
Spiranthes magnicamporum	Great Plains ladies'-tresses	E	
Thuja occidentalis	northern white cedar	E	
Tofieldia glutinosa	false asphodel	R	

(continued)

Table D4 (continued). Indiana associated imperiled species

Scientific Name	Common Name	State Status	Federal Status
Triglochin palustre	marsh arrow-grass	T	
Utricularia purpurea	purple bladderwort	R	
Utricularia cornuta	horned bladderwort	T	
Utricularia minor	lesser bladderwort	E	

State Status Codes: SU=status unknown, SC=special concern, T=threatened, E=endangered, R=rare. Federal Status Codes: E=endangered, T=threatened, FSC=Federal species of concern (these are the former Federal C2 candidate species).

Table D5. Wisconsin imperiled species associated with Karner blue habitats (dry prairie,barrens and savanna habitats). Data provided by the Wisconsin Natural Heritage Program

Scientific Name	Common Name	State Status	Federal Status
--------------Rare Birds--------------			
Ammodramus henslowii	Henslow's sparrow	SC	FSC
Ammodramus savannarum	grasshopper sparrow	SC	
Bartramia longicauda	upland sandpiper	SC	
Chondestes grammacus	lark sparrow	SC	
*Dendroica kirtlandii**	Kirtland's warbler	SC	E
Dolichonyx oryzivorus	bobolink	SC	
Icterus spurius	orchard oriole	SC	
*Lanius ludovicianus**	loggerhead shrike	E	FSC
Oporornis agilis	Conneticut warbler	SC	
*Pedioecetes phasianellus**	sharp-tailed grouse	SC	
Pooecetes gramineus	vesper sparrow	SC	
Spiza americana	dickcissel	SC	
Spizella pusilla	field sparrow	SC	
Sturnella neglecta	western meadowlark	SC	
Tympanuchus cupido	greater prairie-chicken	T	
Tyrannus verticalis	western kingbird	SC	
Tyto alba barn owl	E		
*Vermivora peregrina**	Tennessee warbler	SC	
Vireo bellii	Bell's vireo	T	
--------------Rare Reptiles & Amphibians--------------			
Clemmys insculpta	wood turtle	T	
Crotalus horridus	timber rattlesnake	SC	
*Emydoidea blandingii**	Blanding's turtle	T	FSC
*Ophisaurus attenuatus**	w. slender glass lizard	E	
Pituophis melanoleucus	bull snake	SC	
*Sistrurus catenatus catenatus**	eastern massasauga	E	C
Terrapene ornata	ornate box turtle	E	

(continued)

Table D5 (continued). Wisconsin associated imperiled species

Scientific Name	Common Name	State Status	Federal Status
--------------Rare Invertebrates--------------			
Aeropedellus clavatus	club-horned grasshopper	SC	
*Aflexia rubranura**	red-veined prairie leafhopper	SC	FSC
Atrytonopsis hianna	dusted skipper	SC	
Chlosyne gorgone carlota	Gorgone checker spot	SC	
Cicindela patruela patruela	a tiger beetle	SC	
Cicindela patruela huberi	a tiger beetle	SC	
Cicindela splendida	a tiger beetle	SC	
Eritettix simplex	velvet-striped grasshopper	SC	
Everes amyntula	western tailed blue	SC	
Erynnis baptisiae	wild indigo dusky wing	SC	
Erynnis martialis	mottled dusky wing	SC	
*Erynnis persius persius**	Persius dusky wing	SC	
Euchlaenia milnei	a looper moth	SC	FSC
Gastrocopta procera	wing snaggletooth snail	T	
Grammia phyllira	Phyllira tiger moth	SC	
Grammia oithona	Oithona tiger moth	SC	
Hesperia comma	Laurentian skipper	SC	
*Hesperia ottoe**	ottoe skipper	SC	
Hesperia leonardus leonardus	Leonard's skipper	SC	
Hesperia leonardus/pawnee	Leonard/Pawnee blend	SC	
*Hesperia metea**	cobweb skipper	SC	
Hesperotettix speciosus	a grasshopper	SC	
Incisalia henrici	Henry's elfin butterfly	SC	
*Incisalia irus**	frosted elfin butterfly	T	
Lycaedes idas nabokovi	northern blue butterfly	E	
Megacephala virginica	Virginia big-headed tiger beetle	SC	
Melanoplus flavidus	blue-legged grasshopper	SC	
Melanoplus obovatipennis	obvate-winged grasshopper	SC	
Oeneis chryxus strigulosa	chryxus arctic butterfly	SC	
Pardalophora phoenicoptera	orange-winged grasshopper	SC	
Phoetaliotes nebrascensis	large-headed grasshopper	SC	
*Phyciodes batesii**	tawny crescent spot	SC	FSC
Phytometra ernestinana	Ernestine's moth	SC	
Polyamia dilata	a prairie leafhopper	SC	
Psinidia fenestralis	long-horned grasshopper	SC	
Spharagemon marmorata	northern marbled locust	SC	
*Schinia indiana**	phlox flower moth	E	FSC
Speyeria idalia	regal fritillary	T	FSC
Tachysphex pechumani	a sand-loving wasp	SC	
Trachyrhachis kiowa	ash-brown grasshopper	SC	
Trimerotropis maritima	seaside grasshopper	SC	
--------------Rare Vascular Plants--------------			
Agalinis gattingeri	round-stemmed false foxgove	T	
Agalinis skinneriana	pale false foxglove	E	FSC

(continued)

Table D5 (continued). Wisconsin associated imperiled species

Scientific Name	Common Name	State Status	Federal Status
Agastache nepetoides	yellow giant hyssop	T	
Anemone caroliniana	Carolina anemone	E	
Anemone multifida var *hudsoniana*	Hudson Bay anemone	E	
Arsitida dichotoma	poverty grass	SC	
Artemisia dracunculus	dragon sagewort	SC	
Artemisia fridgida	prairie sagewort	SC	
Asclepias lanuginosa	wooly milkweed	T	
Asclepias purpurascens	purple milkweed	E	
Astragalus crassicarpus	prairie plum	E	
*Besseya bullii**	kitten tails	T	
Botrychium rugulosum	ternate grape fern	SC	
Cacalia tuberosa	prairie indian plantian	T	
Calylophus serrulatus	toothed evening primrose	SC	
Carex richardsonii	Richardson sedge	SC	
Cirsium flodmanii	Flodman's thistle	SC	
*Cirsium hillii**	prairie thistle	T	FSC
Dalea villosa	villous prairie clover	SC	
Diodia teres var *teres*	buttonweed	SC	
Eupatorium sessilifolium var *brittonianum*	upland boneset	SC	
*Gentiana alba**	yellowish gentian	T	
*Lespedeza leptostachya**	prairie bush clover	E	T
Lespedeza virginica	slender bush clover	T	
Leucophysalis grandiflora	white ground cherry	SC	
Liatris punctata var *nebraskana*	dotted blazing star	E	
Liatris spicata	marsh blazing star	SC	
Minuartia dawsonensis	northern rock sandwort	SC	
Nothocalais cuspidata	prairie dandelion	SC	
Ophioglossum vulgatum var *pseudopodum*	adder's tongue	SC	
*Opuntia fragilis**	brittle prickly pear	T	
Orobanche ludoviciana	Louisiana broomrape	SC	
Orobanche uniflora	one-flowered broomrape	SC	
Orobanche fasciculata	clustered broomrape	T	
Parthenium integrifolium	wild quinine	T	
Penstemon pallidus	pale beardtongue	SC	
Phlox bifida	cleft phlox	SC	
Polygala incarnata	pink milkwort	E	
Prenanthes aspera	rough white lettuce	E	
Rhamnus lanceolata var *glabrata*	lance-leaved buckthorn	SC	
Rhus aromatica	fragrant sumac	SC	
Ruellia humilis	wild petunia	E	
Scutellaria parvula var *parvula*	small skullcap	E	
Solidago sciaphila	cliff goldenrod	SC	
*Talinum rugospermum**	prairie fame-flower	SC	FSC
Thaspium barbinode	hairy meadow parsnip	E	
Thaspium trifoliatum var *flavum*	meadow parsnip	SC	

(continued)

Table D5 (continued). Wisconsin associated imperiled species

Scientific Name	Common Name	State Status	Federal Status
*Tomanthera auriculata**	eared false foxglove	SC	FSC
Vaccinium caespitosum	dwarf bilberry	E	
*Viola fimbriatula**	sand violet	E	

State Status Codes: SU=status unknown, SC=special concern, T=threatened, E=endangered. Federal Status Codes: E=endangered, T=threatened, FSC=Federal species of concern (these are the former Federal C2 candidate species), C=candidate.
* = priority species for consideration in Karner blue conservation planning that have been identified by the Wisconsin Department of Natural Resources.

Table D6. Minnesota imperiled species associated with Karner blue habitats. Data provided by the Minnesota Department of Natural Resources.

Scientific Name	Common Name	State Status	Federal Status
--------------Rare Reptiles & Amphibians--------------			
Coluber constrictor	blue racer	SC	
Emydoidea blandingii	Blanding's turtle	T	FSC
Heterodon platyrhinos	eastern hognose	SU	
Lampropeltis triangulum	milk snake	SU	
Pituophis melanoleucus	bull snake	SU	
--------------Rare Invertebrates--------------			
Cincindela patruela patruela	a tiger beetle.	SC	
Metaphiddippus arizonensis	a jumping spider	SC	
Sassacus papenhoei	a jumping spider	SC	
--------------Rare Vascular Plants--------------			
Aristida tuberculosa	sea beach needle grass	SC	
Asclepias amplexicaulis	clasping milkweed	SC	
Baptisia bracteata var *glabrescens*	prairie wild indigo	SC	
Desmodium illinoiensis	Illinois tick-trefoil	SU	
Helianthemum canadense	frostweed	SU	
Linaria canadensis	blue toad flax	SU	
Oenothera rhombipetala	rhombic-petaled evening primrose	SC	
Solidago sciaphila	cliff goldenrod	SC	
Talinum rugospermum	rough-seeded fameflower	E	
Tephrosia virginiana	goat's rue	SC	
Tradescantia ohiensis	spiderwort	SU	

State Status Codes: SU=status unknown, SC=special concern, PSC=proposed special concern, T=threatened, PT=proposed threatened, E=endangered.
Federal Status Codes: E=endangered, T=threatened, FSC=Federal species of concern (these are the former Federal C2 candidate species).

APPENDIX E

SPATIAL STRUCTURE OF A MINIMUM VIABLE METAPOPULATION

POPULATION STRUCTURE

Spatial Structure of Karner Blue Butterfly Metapopulations

Karner blue butterfly populations have a metapopulation structure. For the purposes of recovery planning, a metapopulation is defined as a "population of populations." Such a metapopulation is distributed across a landscape at relatively discrete sites. Each of the relatively discrete sites that harbors Karner blue butterflies will be referred to as a subpopulation (these are sometimes referred to as local populations, refer to APPENDIX A). In this definition of metapopulation there is no assumption about the relative importance of different subpopulations or about the significance or magnitude of dispersal between sites. Regardless, 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.

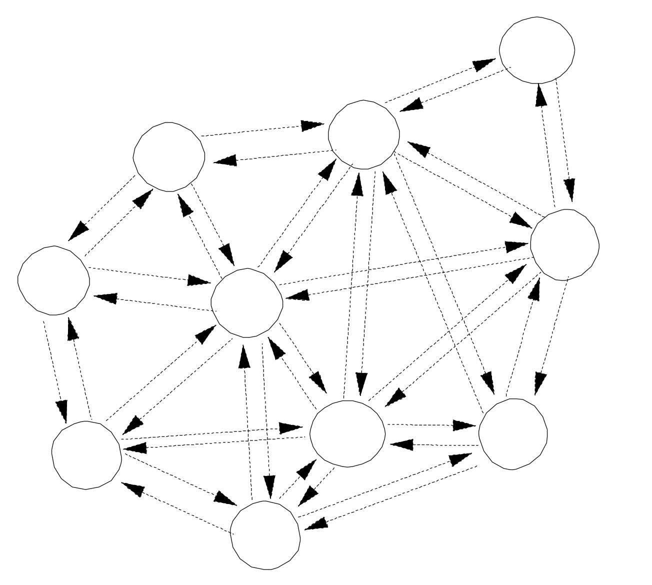


Figure E1. True metapopulation structure. The circles are suitable habitat and the lines are dispersal of butterflies.

We emphasize that under this definition, Karner blue populations can have very diverse structures. Our emphasis in this recovery plan is to use management to maintain these viable metapopulations and therefore we do not prescribe any particular structure as "ideal." What follows is a description of some examples of metapopulations that management might aim to maintain. These are only a small selection of the potential possibilities. It should become clear that if the "patchy population" can be readily attained, it may be more robust to disturbance than the others. This, however, should not be considered an "ideal" type because various constraints may make other structures preferable.

Several theoretical spatial population structures are consistent with our definition of metapopulation. Levins (1970) described a population structure that will be referred to for recovery purposes as a true metapopulation (Figure E1). This structure assumes that all subpopulations are subject to extirpation, and that the probability of extirpation is identical but independent (asynchronous) among subpopulations (the thin white circles in Figure E1 designate that each site is subject to extirpation). Recolonization is slow and occurs at a rate that increases when there are more subpopulations (the dotted lines in Figure E1 indicate that dispersal rates are low). Persistence of a true metapopulation requires that colonization of suitable, unoccupied habitat occurs at a greater rate than subpopulation extirpation. In a true metapopulation each subpopulation could contribute critically to metapopulation persistence. In other words, the destruction of even one subpopulation, or separation of subpopulations by dispersal barriers could result in the extinction of the entire metapopulation. This occurs only in the most precarious of true metapopulations, but this fact emphasizes that the persistence of a metapopulation is closely tied to both the spatial structure and persistence of all subpopulations and the rate of recolonization of all sites of suitable habitat. Management of true metapopulations must take into consideration all of these factors.

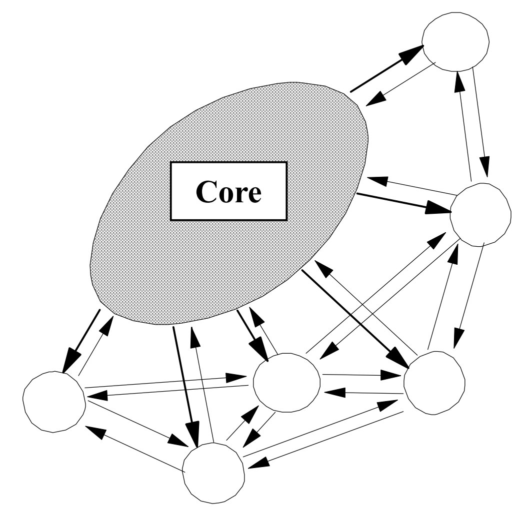


Figure E2. Core-satellite structure. Small circles are satellites to the larger, dark core.

Another theoretical structure consistent with our definition of metapopulation is the core-satellite or mainland-island (Boorman and Levitt 1973) structure (Figure E2). This structure differs from the true metapopulation structure by having at least one subpopulation that is immune to extirpation. This subpopulation is called the core; the core can have greater immunity to extirpation because of larger size, higher population numbers, better habitat, and so on (the shading in Figure E2 indicates that the core is not extirpated). The bay checkerspot butterfly exhibits this type of metapopulation structure (Harrison et al. 1988). Individuals can disperse between the core and satellite populations, but the core is essential for the persistence of the metapopulation (the importance of dispersal from the core to the satellites is indicated by the thicker dispersal lines from the core to the satellite populations). If satellite populations are extirpated, they are eventually recolonized from the core, but if the core is extirpated, then the satellites will fail too. Management of core-satellite metapopulations must focus on the core.

A third theoretical structure that fits our definition of a metapopulation is the patchy population (Figure E3). A patchy population is distributed in discrete sites (or patches) on the landscape, but has dispersal rates that are so high that the subpopulations do not fluctuate independently (the high dispersal rates are indicated by the thick lines connecting sites). Colonization is so rapid that high populations in one subpopulation rapidly disperse to increase population densities in all subpopulations, and subpopulations rarely are extirpated (the rarity of extirpation is indicated by the shading of the sites in Figure E3). The subpopulations actually function as a single integrated deme (a randomly

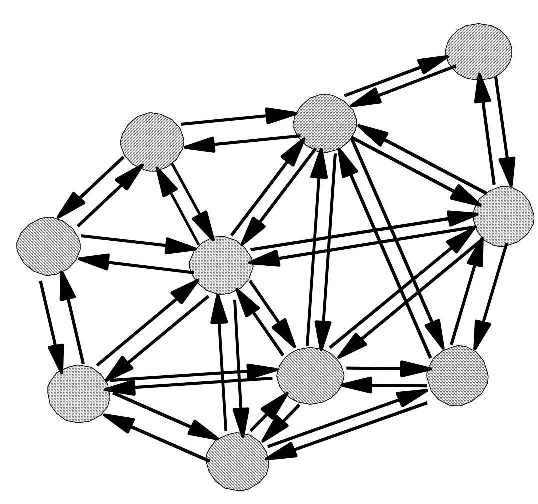


Figure E3. Patchy metapopulation structure. Sites are usually occupied and dispersal is very high.

mating population) and all subpopulations fluctuate in more or less in unison. In this case, the metapopulation only superficially has spatial structure because all subpopulations are interacting strongly. Persistence of a patchy population depends on the size and stability of the whole metapopulation and not as much on the structure and relations among subpopulations. Management of a patchy metapopulation can focus on the average behavior of subpopulations across all occupied sites rather than focusing on a few to many critical sites. Indeed, in the extreme, a patchy population might merge to such an extent spatially that it becomes one large patch. With an appropriate management plan, this could be considered a viable metapopulation.

In summary, a core-satellite structure implies that at least one site will never be extirpated (Probability of extirpation = 0), whereas in a true metapopulation all sites have equal probability of going extinct (Probability of extirpation = constant ≠ 0). These idealized structures represent extremes along a continuum of extirpation probabilities (Figure E4). Both of these structures (true metapopulation and core-satellite) assume that site colonization rates are not extremely high for any site. The patchy population structure, in contrast, assumes that colonization rates are very high for all sites. Thus, the patchy population represents an extreme along a continuum of recolonization rates, with both the true metapopulation and core-satellite structures on one end, and the patchy population structure on the other end of the continuum. Again, none of these extremes are likely to be accurate representations of actual metapopulations of the Karner blue butterfly. Management of a true metapopulation is likely to be more intensive than management of either a core-satellite or a patchy metapopulation, because of the need to keep track of each subpopulation individually in a true metapopulation. Consequently, one management strategy to reduce the cost of management is to use management to change the population structure to be more like a core-satellite or patchy metapopulation.

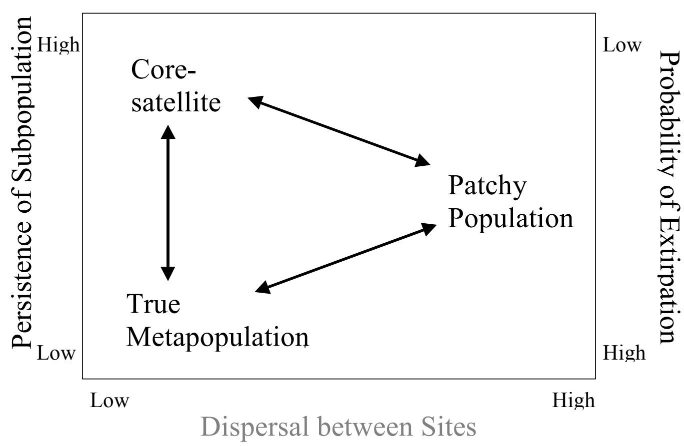


Figure E4. Dependence of population structure on local extirpation rate and between site dispersal rate.

Together these theoretical structures probably encompass all likely structures of actual Karner blue populations. Actual population structures of Karner blue butterfly are likely to be vastly more complex than any of these three common theoretical abstractions. For example, Karner blue metapopulations are unlikely to have a core-satellite structure because all sites are involved in successional processes that eliminate Karner blue followed by renewal events that rejuvenate habitat; a single site is unlikely to maintain a healthy, stable subpopulation of Karner blue butterflies indefinitely (Givnish et al. 1988). Management efforts can be used to reduce the probability of extirpation of a site, but it may be difficult to manage a single site so that it persists indefinitely into the future. It is also unlikely that Karner blue metapopulations have a true metapopulation structure. All sites will not have a uniformly high probability of extirpation, with some sites being more prone to extirpation than others, and the probability of extirpation among sites is probably correlated in time and space. Protection from extirpation probably exists at many sites that provide refugia from various types of disturbance but not others. For example, mesic areas would be temporary refugia from drought or fire, whereas xeric areas would be temporary refugia from the threats of cold weather and canopy closure. Consequently, the probability of extirpation is unlikely to be constant or independent across sites or at a single site over time. It is unlikely that Karner blue metapopulations are patchy metapopulations. This structure requires high rates of recolonization that integrate the local population dynamics of the spatially distributed metapopulation. Some metapopulations may appear to function as patchy populations because they occupy many sites and the sites are close together, however dispersal must be very high to integrate the population dynamics across the entire metapopulation. Even at the Necedah NWR in Wisconsin, where dispersal rates are the highest measured for Karner blue (King 1998), subpopulations do not fluctuate together (King 1994).

Figure E5 presents a hypothetical example to illustrate some of the complexity of the functioning of an actual metapopulation, showing how subpopulations might interact, suitable habitat is colonized, and occupied sites extirpated. In this example, three local populations are within a remnant of healthy barrens or savanna ecosystem (center oval), and other sites are associated with private and county forest lands or poor quality remnant barrens or savanna ecosystems. The sites are renewed by various disturbances or efforts to restore barrens/ savanna ecosystems. The sites decline in suitability for Karner blue according to plan or because of lack of management. In this example, the small group of subpopulations associated with the remnant healthy barrens or savanna ecosystem together function as a core group of subpopulations. Together they are managed so that one or more of them harbors a strong subpopulation of Karner blue butterfly, and when considered together, the Karner blue butterfly may persist indefinitely on them. This kind of metapopulation structure, with a core group of subpopulations, is intermediate to all of the theoretical abstractions described above, but preserves many of the management advantages of the core-satellite structure.

The broad metapopulation definition (a population of populations) used in this recovery plan enables development of robust viable metapopulations, because it focuses on the factors that create a healthy metapopulation (irrespective of the theoretical metapopulation structure), including sufficient suitable habitat to support a metapopulation, sufficient connectivity to promote recolonization, and management guidelines to aid decision-making. Because Karner blue metapopulations are likely to exhibit considerable variation in spatial structure, the factors (size, management, etc.) needed to establish viable metapopulations must be applicable to all possible spatial structures, including the many variants of true metapopulations, core-satellite metapopulations, and patchy metapopulations.

A viable metapopulation of Karner blues must be large enough, have a sufficient geographic base, and managed and monitored to persist indefinitely over time. The management and monitoring system must buffer the metapopulation against adverse disturbances and threats to survival, maintain suitable habitat over time in an appropriate spatial structure, and identify appropriate responses to potential declines in the metapopulation. This definition of viable metapopulation is elaborated on further below (refer to THE 3,000 MINIMUM METAPOPULATION SIZE below) and in APPENDIX F for a large viable population. It should be clear that the definition of a viable population does not depend on assuming that all metapopulations of Karner blue are true metapopulations. If a Karner blue metapopulation is in fact a true metapopulation, however, the definition of viable metapopulation should indicate what would be needed for this true metapopulation to be a viable one. Moreover, the definition of viable metapopulation does not encourage a minimalist perspective; if the metapopulation can be made more secure, the management and monitoring costs can decrease.

Management is a crucial component of a viable metapopulation, and because complete information is not available, adaptive management for improving or maintaining Karner blue metapopulations is essential. Several adaptive strategies can be pursued. Management can be adapted to change the structure of the metapopulation. In contemporary managed landscapes, we may impose a spatio-temporal structure on a metapopulation to create or maintain a metapopulation to be more like a core-satellite or patchy structure. These kinds of metapopulations may be more robust to disturbances and threats and will probably be less expensive to maintain. The geographic base of the metapopulation also can be managed adaptively over time. New areas can be added and old areas eliminated from the metapopulation as information about its functioning improves. Monitoring can be adapted as the duration of successful management increases. As confidence is gained in the management practices, the need for monitoring declines. APPENDIX G provides management guidelines for establishment of viable Karner blue metapopulations.

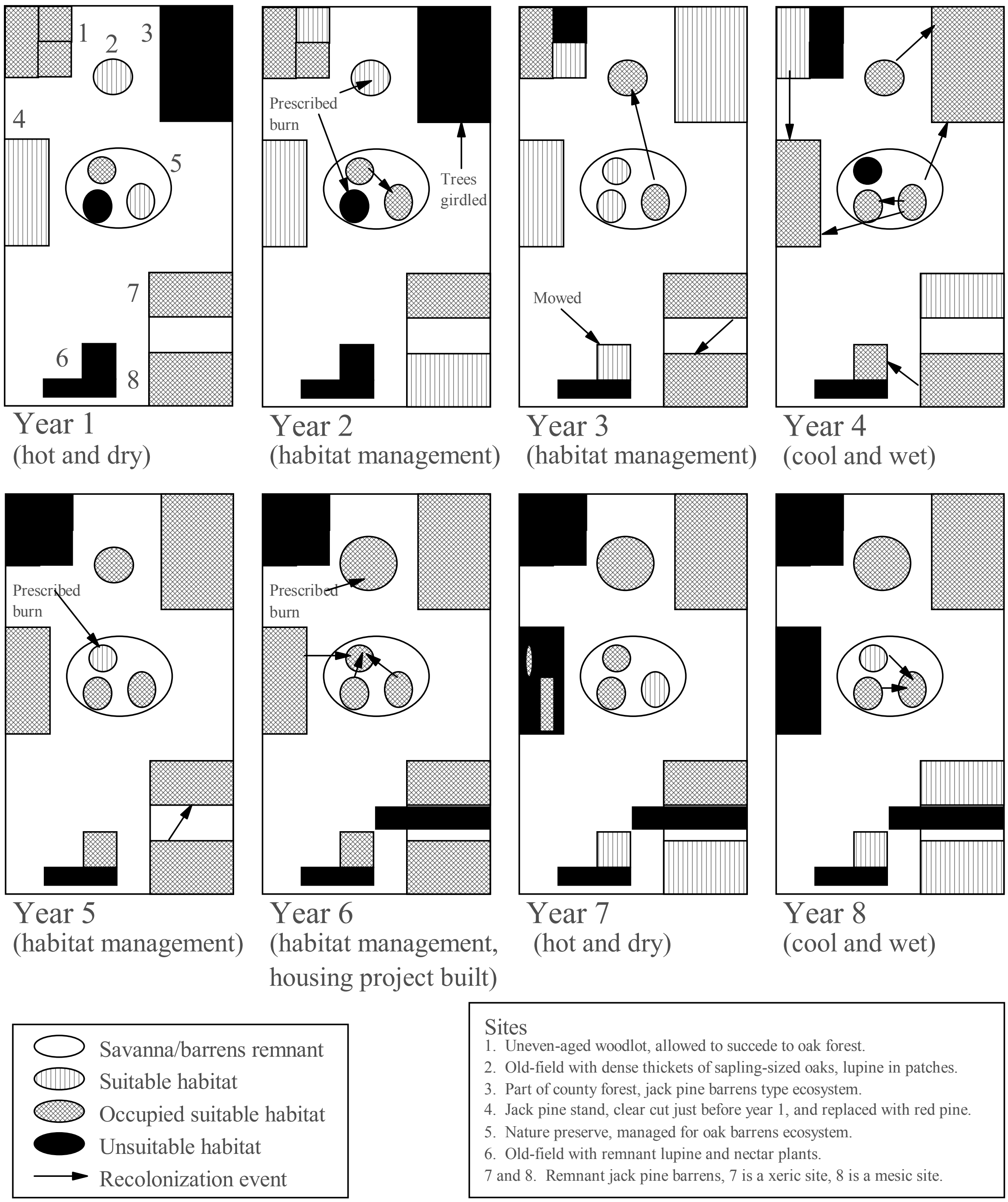
Metapopulation Persistence

Persistence of a Karner blue metapopulation will be governed by the balance between extirpation of subpopulations and recolonization of unoccupied sites of suitable habitat. Recolonization rates will be related to colonization rates and between site dispersal rates, and as these increase, occupancy of suitable habitat will increase and the metapopulation may become more integrated, functioning like a patchy metapopulation. Subpopulation extirpation rates will be related to the extent and quality of habitat and the rate that habitat degrades from factors such as canopy closure. If management activities operate to reduce the rate of extirpation for one or a cluster of subpopulations, the metapopulation becomes stabilized around the dynamics of that subpopulation(s), and functions more like a core-satellite metapopulation. Both the rate of recolonization and the rate of extirpation can be influenced by spatial structure of the habitat mosaic.

<u>Recolonization</u>

Recolonization rates will be affected by the rate and pattern of dispersal, and the availability of suitable habitat for colonization. The limited data suggest that the closer the sites and more open the intervening habitat, the more observed between-habitat movements. Therefore, recolonization rates are expected to be higher when there is a large number of suitable habitat sites per unit area, which reduces inter-site distance. Refer to APPENDIX G for suggestions that may help increase recolonization rates.

Figure E5. Schematic of a functioning Karner blue metapopulation in a working landscape. (The scale is approximately four miles long and two miles wide.)



Extirpation

Savignano (1994) demonstrated that extirpation of subpopulations does occur. She found that in Saratoga County, New York, only 52 percent of sites that had been recorded previously with Karner blues were still occupied in 1990. Informal observations by numerous researchers have confirmed that subpopulations of Karner blues become extirpated, but the reasons for extirpation remain poorly understood.

The probability of extirpation of a subpopulation may be affected most by the extent and quality of suitable habitat, and secondarily by chance events. Clearly, a healthy, abundant lupine population is essential for continued persistence of a subpopulation. Savignano (1994) showed that subpopulations on sites with more lupine are more likely to persist than those on sites with less lupine. Subhabitat diversity (as created by variation in canopy cover and possibly by variation in topography, aspect, and soil hydrology) probably should reduce the probability of extirpation, because immature survival is higher in shady subhabitats, by protecting against year-to-year environmental variation. The importance of nectar plants for persistence is less well documented. Lack of nectar plants appears to increase adult mortality rates (Clench 1967, Watt et al. 1979), and it is expected that a diversity of nectar plants would improve persistence. Different nectar plant species are differentially affected by variation in weather. For example, during the 1995 drought at Waupaca, Wisconsin, most of the lead plant (*Amorpha canescens*) flowers aborted, while hoary allysum (*Berteroa incana*) and horsemint (*Monarda punctata*) still flowered (Lane, unpublished data). Similarly, in New York the phenology of *Ceanothus americanus*, a major second brood nectar source, matches Karner blue phenology poorly in some years and quite well in others (Schweitzer, unpublished data).

It is widely believed that uninterrupted succession will cause extirpation (Givnish et al. 1988, Helmbolt and Amaral 1994, Sommers and Nye 1994, Grigore and Windus 1994, Packer 1994). Lupine is eliminated when tree canopy closure occurs (Celebrezze 1996), but the timing of extirpation of subpopulations of Karner blues is poorly understood (how much before or how much after canopy closure). Moreover, the rate of canopy closure is quite variable from site to site and heterogeneous within sites, so the overall importance of succession as a cause of extirpation may vary from location to location. Finally, management, or the lack thereof, can influence the rate of canopy closure. Indeed, the lack of management has allowed succession to proceed unimpeded in many habitats, which may have resulted in reduced lupine and reduced Karner blue populations (Givnish et al. 1988, Helmbolt and Amaral 1994, Grigore and Windus 1994, Packer 1994, Sommers and Nye 1994).

Larger areas of suitable habitat will tend to produce more butterflies, which will tend to protect the subpopulation from extirpation. Conversely, very low population numbers may be associated with an increased probability of extirpation because of chance environmental, demographic, and genetic events. Random environmental events can push already small subpopulations to extirpation. This may occur for example if a fragmented and sparsely populated subpopulation is burned by a wildfire. The remaining pockets of individuals and habitat may be so small that inability to find mates, inadequate lupine or nectar plant resources, or inbreeding depression may push the subpopulation to extirpation (Lawrence 1994). Recurrent drought may have been involved in the extirpation of the Ontario populations (Packer 1994, Schweitzer 1994). It is also thought that very small subpopulations are more susceptible to extirpation from demographic stochasticity (skewed sex ratio, chance birth or death rates) (Schonewald-Cox et al. 1983). For example, a widespread, but patchily distributed European lycaenid *Plebejus argus* L. has higher extirpation rates in small areas of suitable habitat than large ones (Thomas and Harrison 1992).

Spatial structure of habitat mosaic

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. The importance of these factors on metapopulation persistence has been inadequately investigated, but year-to-year variation in weather may be responsible for some of the large fluctuations in butterfly abundance that have been observed in Wisconsin (Bleser 1993, Cynthia Lane, pers. comm. 1996).

Variation in patch size and quality between local populations should increase persistence of a true metapopulation by producing asynchronous fluctuations in the density of subpopulations. A core-satellite structure might be stabilized against these large-scale disturbances by managing the metapopulation to have more than one core subpopulation or clusters of subpopulations. A patchy population might be stabilized by being spread over a large spatial area.

THE 3,000 MINIMUM METAPOPULATION SIZE

For the purposes of recovery, the number of Karner blue butterflies in a minimum viable population should be at least 3,000 first or second brood adults. This number may be too low or too high in some cases. Because the second brood usually is two- to four-times larger than the first brood, the 3,000 second brood figure may represent only 750 to 1,500 first brood adults. In some years or localities, however, the first brood may be larger than the second. In these cases a minimum viable population will have at least 3,000 first brood adults.

The need for at least 3,000 second brood adults is based on genetic, ecological, and management considerations. First, the Ontario Port Franks population was extirpated despite a second brood adult population of about 900 individuals (Packer 1994, Schweitzer 1994). In addition, many smaller populations have been extirpated in Ontario (Packer 1994), Ohio (Grigore and Windus 1994), New York (Sommers and Nye 1994, Savignano 1994), and Michigan (Wilsmann 1994), over periods of less than ten to twenty years. If 1,000 second brood individuals were susceptible to extirpation, then more would be needed to have a viable metapopulation. Theoretical genetics arguments suggest that to maintain genetic variation in a spatially dispersed population, each subpopulation should have an effective population size of at least 500 second flight butterflies and at least three such subpopulations should be maintained (for a definition of effective population size, refer to Crow and Kimura 1970). Thus somewhere between 1,500 and 2,000 butterflies represents a minimum viable metapopulation if there were no environmental variation and no potential for management failure. Because one or two such subpopulations are likely not to maintain a 500 effective population size, additional subpopulations are needed to maintain a metapopulation capable of preserving its genetic variation. Several ecological factors could cause population crashes in a Karner blue population. Butterfly populations might become so low that Allee effects, such as reduced mating and lower fertility, become problematic. Details related to population spatial structure, area occupied, connectivity among subpopulations, in addition to population size could put the population at risk to Allee effects. In addition, because the butterfly has only one host, factors that reduce the host will also reduce the butterfly, putting the butterfly at risk from factors affecting the plant and only indirectly affecting the butterfly. Finally, if habitat occupancy is low, the population is at risk to be extirpated from chance events, threats to the population, and adverse weather conditions. Together these genetic, ecological, and management considerations imply that a minimum viable metapopulation size of 3,000 adults is one that should maintain genetic variability and persist under management and local environmental variability. In addition, 3,000 butterflies is a population size that would appear to be readily attainable in many parts of the species range. The Concord, New Hampshire site supported an estimated 3,700 Karner blues in 1983 (Schweitzer 1983). There are more than 3,000 butterflies at the Saratoga airport in New York and at the Indiana Dunes National Lakeshore. The 3,000 number may be too low if, for example, the buffering capacity of the supporting habitat is low, or may be above the actual minimum number required for viability if, for example, the metapopulation is well buffered against environmental variation.

Additional research would clarify the sufficiency of the numeric value of this minimum metapopulation size, but such research is not essential for obtaining the recovery goals.

ALTERNATIVE VIABLE METAPOPULATION STRUCTURES

The components of metapopulation structure, which include the number of subpopulations, the distances that separate them, and the densities of Karner blues in each, interact so that there are many possible metapopulation structures that could give rise to a viable metapopulation. The following qualitative principles describe a few of these interactions. Additional research would establish additional principles and help quantify the following principles.

Subpopulation Considerations

1. A metapopulation with larger subpopulations (more butterflies in a subpopulation) can be more fragmented and still remain viable, compared to a metapopulation with smaller numbers of individuals but the same number of subpopulations. Larger subpopulations alleviate potential problems associated with mate-location, low dispersal rates, and population fluctuations.

2. The number of butterflies in a subpopulation should be at least 300. Metapopulations should be structured with a sufficient number of subpopulations and connectivity between subpopulations to support 300 butterflies during either the first or second flight. Subpopulations smaller than 300 may not be able to maintain genetic diversity in the long-term unless they are well connected with other subpopulations. Franklin

(1980) suggested that an effective population of 500 would be sufficiently large to be in mutation-drift balance for adequate long-term variability in quantitative traits. This figure has been proposed for use in managing endangered species (Frankel and Soulé 1981, Schonewald-Cox et al. 1983, Soulé and Wilcox 1980). Turelli (1984) used different and perhaps more realistic assumptions, and questioned whether mutation could maintain sufficient variability in an effective population as small as 500. Thus, our use of at least 300 individuals in a subpopulation is probably an underestimate of the number of individuals needed to maintain long-term genetic variation. Thus, if the subpopulations are as small as 300, it is essential that these subpopulations be closely linked together in the larger metapopulation. An additional consideration is that allelic diversity (the numbers of different alleles) is best preserved by subdividing a population (Parsons 1980, Lacy 1987).

3. A metapopulation with a higher density of butterflies per RU land area can have a smaller number of total butterflies and still remain viable, compared to a metapopulation with a lower density of butterflies. High densities alleviate potential problems associated with mate-location, low dispersal rates, and population fluctuations. High densities could possibly heighten risks of increased Karner blue mortality from diseases and specialized natural enemies, but these risks might not be realized until densities are substantially higher than those needed for recovery. If this risk is realized for some metapopulation, then measures should be taken to mitigate the effect.

Occupancy Rate Considerations

A very different way of characterizing metapopulation viability for the Karner blue is to use occupancy rate. A metapopulation might be deemed viable if the occupancy rate were sufficiently high (greater than eighty percent) and relatively constant from year to year. As discussed in other parts of this plan, occupancy rate can be an excellent measure of metapopulation robustness (higher occupancy rates imply a more robust metapopulation). The use of occupancy rate to characterize metapopulation viability, however, cannot be implemented until the concept of "unoccupied suitable habitat" is clearly defined and the intensity of the Karner blue search effort can be appropriately standardized. Unoccupied suitable habitat can be readily overestimated or underestimated, which could change the determination of viability of a metapopulation. In addition, the concept of occupation of habitat by the Karner blue is in part a function of the intensity of search for butterflies. The harder they are looked for, the more likely that lower and lower populations can be detected. The occupancy rate could be increased by intensifying the search for butterflies or decreased by reducing the intensity of the search for butterflies. Because the determination of metapopulation viability should not depend on sampling methods in this way, considerable efforts must be expended before a definition of metapopulation viability can be developed using occupancy rates (refer to APPENDIX G for a discussion on increasing colonization rates and reducing local extirpation rates.)

TRADE-OFFS BETWEEN METAPOPULATION STRUCTURE, MANAGEMENT, AND MONITORING

The three components of a viable metapopulation, viz., metapopulation structure, management, and monitoring, are not independent of each other. The following describe some of the major modes of dependency among them:

1. A metapopulation covering a large, diverse land area is better buffered against disturbance than one covering a small area. Large land bases provide buffering against catastrophic disturbances, disease, and minor climatic fluctuations. But if the metapopulation, which covers a large, diverse area, is fragmented, it is not likely to be well buffered against disturbance. Recolonization of unoccupied suitable habitat is a vital component of metapopulation persistence. Increased fragmentation slows the recolonization of unoccupied sites by decreasing the rate at which new or unoccupied sites are located and colonized successfully by dispersing females.

2. Large metapopulations covering large, diverse areas with many subpopulations should require less intensive management and monitoring. Small or isolated metapopulations will require more intensive management and monitoring. This reflects the changing importance of a particular subpopulation to the viability of a metapopulation at the two extremes. In a small or isolated metapopulation, loss of a single subpopulation could result in the loss of the entire metapopulation. In contrast, in a large metapopulation, loss of a single subpopulation may have little effect on the viability of the metapopulation.

3. The longer a metapopulation has persisted, the less intensive must be the monitoring system or the more experimental the management system can become. As experience increases in successfully managing a viable metapopulation, confidence in the management system grows, and it will be possible to either attempt to improve management efficiency through more experimental management or to reduce the level of monitoring.

LITERATURE CITED

Bleser, C. A. 1993. Status survey, management and monitoring activities for the Karner blue butterfly (*Lycaeides melissa samuelis*) in Wisconsin. Final Report submitted to the U.S. Fish and Wildlife Service. 86 pp.

Boorman, S. A. and P. R. Levitt. 1973. Group selection on the boundary of a stable population. *Theoretical Population Biology* 4:85-128.

Celebrezze, T.M. 1996. Spatial patterning of lupine *(Lupinus perennis):* implications for metapopulation viability analysis of the endangered Karner blue butterfly (*Lycaeides melissa samuelis*) (master's thesis). University of Wisconsin, Madison. 66 pp. + maps.

Clench, H. K. 1967. Temporal dissociation and population regulation in certain hesperiine butterflies. *Ecology* 48: 1000-1006.

Crow, J.F. and Kimura, M. 1970. An introduction to population genetics theory. Harper and Row, New York

Frankel, O. H. and M. E. Soulé. 1981. Conservation and Evolution. Cambridge University Press: Cambridge.

Franklin, I. R. Evolutionary change in small populations. *In* Soulé, M.E. and B.A. Wilcox (eds.), Conservation Biology: An Evolutionary-Ecological Perspective. Sinauer: Sunderland, Massachusetts. 1980. pp. 135-149.

Givnish, T. J., E. S. Menges, and D. F. Schweitzer. 1988. Minimum area requirements for long-term conservation of the Albany Pine Bush and Karner blue butterfly: an assessment. (vol. IV, Appendix T). Report to the City of Albany from Malcolm Pirnie, Inc., Albany, New York. 95 pp. + figures.

Grigore, M. T. and J. L. Windus. Decline of the Karner blue butterfly in the Oak Openings of northwest Ohio. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner Blue Butterfly: A Symbol of a Vanishing Landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 135-142.

Harrison, S., D. Murphy, and P. Ehrlich. 1988. Distribution of the bay checkerspot butterfly, *Euphydryas editha bayensis*: evidence for a metapopulation model. The American Naturalist 132: 360-382.

King, R. 1994. Annual summary for Necedah National Wildlife Refuge. Necedah NWR, Necedah, Wisconsin.

King, R. 1998. Spatial ecology, dispersal patterns and monitoring methods for the Karner blue butterfly, *Lycaeides melissa samuelis* on Necedah National Wildlife Refuge. Report submitted to the National Fish and Wildlife Foundation, U.S. Fish and Wildlife Service, and the Forest Industry.

Lacy, R. C. 1987. Loss of genetic diversity from managed populations: Interacting effects of drift, mutation, immigration, selection, and population subdivision. Conservation Biology 1: 143-158.

Lawrence, W. S. Karner blue butterfly populations in the Allegan State Game Area, Michigan. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 53-62.

Levins, R. Extinction. *In* M. Gerstenhaber (ed.) _Lectures on Mathematics in the Life Sciences. American Mathematical Society, Providence, Rhode Island. 1970. Vol. 2, pp. 77-107.

Packer, L. The extirpation of the Karner blue butterfly in Ontario. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp.143-151.

Parsons, P. A. Isofemale strains and evolutionary strategies in natural populations. *In* M. Hecht, W. Steere and B. Wallace (eds.), Evolutionary Biology. Plenum: New York. 1980. pp. 175-217.

Savignano, D. A. The distribution of the Karner blue butterfly in Saratoga County, New York. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 73-80.

Schonewald-Cox, C. M., S. M. Chambers, B. MacBryde and W. L. Thomas. (eds.) 1983. Genetics and conservation. Benjamin/Cummings: Menlo Park, California.

Schweitzer, D.F. 1983. Preliminary report on rare Lepidoptera of the Concord, New Hampshire pine barrens. U.S. Fish and Wildlife Service, New England Field Office, Concord, New Hampshire.

Schweitzer, D. Prioritizing Karner blue butterfly habitats for protection activities. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 173-183.

Sommers, L. A. and P. E. Nye. Status, research and management of the Karner blue butterfly in New York. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 129-134.

Soulé, M. E. and B. A. Wilcox. 1980. Conservation Biology: An Evolutionary-Ecological Perspective. Sinauer: Sunderland, Massachusetts.

Thomas, C. D. and S. Harrison. 1992. Spatial dynamics of a patchily distributed butterfly species. Journal of Animal Ecology 61: 437-446.

Turelli, M. 1984. Heritable variation via mutation-selection balance: Lerch's zeta meets the abdominal bristle. Theoretical Population Biology 25: 138-193.

Watt, W. B., D. Han, and B.E. Tabashinik. 1979. Population structure of Pierid butterflies. II A “native” population of Colias philodice eriphyle in Colorado. Oecologia (Berl.) 44:44-52

Wilsmann, L. Status of the Karner blue butterfly in Michigan. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul:

Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 107-112.

APPENDIX F

LARGE VIABLE METAPOPULATIONS

Large viable metapopulations are defined to provide managers with a greater number of suitable management and monitoring options, including the possibility of reducing costs, while simultaneously providing sufficient assurance that the metapopulation will contribute toward recovery and persist into the indefinite future. The definition and description of a metapopulation is provided in APPENDIX E, POPULATION STRUCTURE, and forms the necessary background to the discussion of large viable metapopulations below.

AREA AND HABITAT REQUIREMENTS

1. Every large viable metapopulation shall exist in an area of at least ten contiguous square miles (6,400 acres).[1] Ten square miles may be sufficient to buffer the metapopulation against many types of adverse natural disturbance. For example, of 320 naturally occurring wildfires between 1973 and 1994 in the thirteen Wisconsin counties that have Karner blue populations, the maximum wildfire size for fires greater than forty acres exceeded 6,400 acres only once. This was the spectacular 15,471 acre wildfire in Jackson County during 1977. The ten square mile area is also expected to contain diverse habitats and a variable topography that should further buffer Karner blue metapopulations against adverse natural disturbances. Finally, this area is considered large enough that extensive management practices (including any type of adaptive management), rather than intensive practices, could be effectively used.

2. Every large viable metapopulation shall have approximately ten percent of the total area (640 acres) as suitable habitat (see definition of suitable habitat). The ten percent criterion is intended to guarantee that the suitable habitat is sufficiently connected to other suitable habitat and that there is sufficient suitable habitat to justify extensive management practices. Connectivity requirements are made explicit in criterion (4) below, so the ten percent criterion acts more as a benchmark by which the amount of suitable habitat can be judged than as a strict requirement. For example, the measurement of the area of suitable habitat is sufficiently subjective that errors in measurement of twenty percent could be possible. The main source of this error is in how much of the habitat between lupine patches and between lupine and nectar patches is included in the measurement of suitable habitat. For measures that strictly define suitable habitat as that area that contains actively growing lupine, the measured area could be significantly smaller than for a measure that includes the areas between the lupine patches. For a more strict measure of suitable habitat, seven or eight percent suitable habitat may be sufficient as long as the total area is large enough so that the area of suitable habitat is large enough (for example, an area of 10,000 acres with seven percent suitable habitat would have 700 acres of suitable habitat, which would be a sufficient land base for a large viable metapopulation).

---

[1] The minimum area is ten square miles of contiguous land (equivalent to 6400 acres or 10 sections). More than ten square miles is acceptable. The area can be any shape, for example a 3.2 x 3.2 mile square, a 2 x 5 mile rectangle, a circle with a radius of 1.8 miles, oblongs, or any other shape. It is preferable to have an area that is compact or convex; a long skinny area, such as 0.5 x 20 miles or a starfish with long skinny arms is less preferred. This minimum area is NOT a ten mile square i.e. a square, 10 miles on a side (equal to 100 square miles).

3. Every large viable metapopulation shall have the suitable habitat distributed over two-thirds of the total area. For a minimum ten square mile area, the suitable habitat should be distributed over 6.7 square miles of the area. This requirement is essential so that suitable habitat is not all clumped into a couple of square miles. If it were clumped in this way, then the Karner blue metapopulation would also be clumped and less likely to be well-buffered against adverse natural disturbance. This requirement does not mean that suitable habitat must be permanently in place; a dynamic mosaic of suitable habitat interspersed with other habitats is also appropriate.

METAPOPULATION STRUCTURE

1. Every large viable metapopulation shall have all occupied sites no more than one kilometer (0.62 miles) from another occupied site on average. This connectivity criterion is similar to that for a minimum viable metapopulation. The main difference is that the spatial structure of dispersal corridors and barriers need not be managed explicitly, and the maximum distance separating occupied sites is no more than 2 kilometers. For example, if there are three large occupied sites, then one of the occupied sites could be 1.5 kilometers from its nearest occupied site if the other two are no more than 0.75 kilometers from each other. It is assumed that the large viable metapopulation either has many occupied sites or a few very large occupied sites. As described in APPENDIX E, these are conditions under which the connectivity requirements for a minimum viable metapopulation can be relaxed. For further guidance on dispersal considerations refer to APPENDIX G, INCREASING THE COLONIZATION RATE OF SUBPOPULATIONS WITHIN A METAPOPULATION.

2. Every large viable metapopulation shall have at least 6,000 adult butterflies. The Recovery Team deliberated at length on the minimum number of adult butterflies required for a large viable metapopulation. Suggestions ranged from 5,000 to 15,000, and the final decision was 6,000 adults. A review of Karner blue butterfly numbers and habitat information from Necedah NWR and Fort McCoy support this number as being reasonable and attainable. A minimum number is required because basing the determination of a large viable metapopulation only on habitat quality and quantity and butterfly presence/absence is insufficient to guarantee that there is a large metapopulation. It is possible for a Karner blue population to be distributed over a wide geographic area of suitable habitat, but to be rare everywhere. To avoid this possibility, it is necessary to establish some minimum metapopulation threshold to guarantee a sufficiently large metapopulation to merit designation as a large viable metapopulation. If an alternative approach can be developed that can document the existence of a large, robust metapopulation without counting butterflies it would be very useful.

   To meet the 6,000 criteria, a metapopulation larger than 6,000 should be strived for because populations can fluctuate up to 4-5 fold as demonstrated by data from Necedah NWR (Richard King, USFWS, in litt. 2002), and Fort McCoy (Tim Wilder, Fort McCoy, in litt. 2002). The greater the number of butterflies in the metapopulation the less intense the long term monitoring effort needed to demonstrate the 6,000 criterion. This is because managers will have greater flexibility to use less intensive methods for demonstrating the 6,000 criterion . We have not specified one specific sampling method for demonstrating sufficient population numbers in a large viable metapopulation. A variety of methods based on extrapolation from sampling the large metapopulation could be used to demonstrate the existence of 6,000 adults (refer to APPENDIX H for additional guidance on sampling methods). The 6,000 requirement is not intended to generate a burdensome or absolute sampling requirement. For instance, if a metapopulation has somewhat under the 6,000 criteria, yet population stability has been demonstrated, and other recovery criteria are met, the metapopulation may be sufficient to qualify as a LP. Another example may be a metapopulation that generally has very high numbers (e.g., 10,000 Karner blues) and the numbers dropped to 5,000 for two years. The Service in conjunction with the recovery team will determine on a case by case basis if situations like these would qualify as LPs.

3. It is recommended, but not required that a large viable metapopulation contains a core area(s). A core area is an area that contains suitable habitat in which the Karner blue butterfly can persist almost indefinitely (refer to definition of core area in APPENDIX A). A core area may contain several sites of suitable habitat interspersed with unsuitable habitat. The size of a core area was designated so that it could be attained in either a viable or a large viable metapopulation, while being consistent with the experience of the Recovery Team. This area might be 320-1280 acres (0.5-2 mi^2). These areas of suitable habitat in a core are not necessarily permanent sites. A core area may be an area particularly well-suited to the Karner blue or an area particularly easily managed for the butterfly. For some of the large viable metapopulations required for recovery, Federal land, state land, or both may be able to function as core areas.

APPENDIX G

MANAGEMENT GUIDELINES – BALANCING TRADE-OFFS IN DEVELOPING AND IMPLEMENTING KARNER BLUE RECOVERY PLANS

To restore viable metapopulations of Karner blues to the landscape, it will be important to establish and maintain the early successional habitat on which the butterfly depends. This entails assuring that appropriate disturbance and/or management regimes (e.g., prescribed fire, mechanical management, etc.) necessary to renew existing habitat or to create new habitat are incorporated into management plans for the species. In addition, maintaining metapopulation dynamics depends upon spatially arranging subpopulations to facilitate colonization of butterflies from occupied to unoccupied sites. This appendix includes guidance and information on management of habitat for the Karner blue, and on creating conditions that will facilitate and increase the colonization rate of subpopulations within a metapopulation. These guidelines are based on currently available information on the biology of the Karner blue and its habitat. As more information is obtained, these guidelines may be updated.

All biological communities are dynamic, and localized extirpation of subpopulations is a natural phenomenon. Thus, the loss of one local subpopulation of a rare butterfly is not necessarily detrimental to the survival of the species if new local subpopulations are founded at the same rate as others become extirpated. Unfortunately, human activities have increased the rate of localized extirpation for many butterflies, while limiting the possibilities of new local subpopulations becoming established. If butterfly diversity (and all biological diversity) is to remain at its present level throughout the United States, a conscious effort must be directed towards preserving a significant percentage of the countryside in native ecosystems.

The Karner blue occurred as a series of metapopulations arrayed from Minnesota eastward through Canada to New England. Several of these metapopulations are now extirpated, and as outlined in this plan, the continuing loss of metapopulations is incompatible with recovery. However, the situation is further complicated because the Karner blue can thrive in some managed ecosystems, which can result in conflicts in management objectives that need to be resolved. Moreover, each metapopulation is composed of a series of individual local populations or subpopulations, each of which is prone to local extirpation. Metapopulations themselves depend upon a balance between subpopulation extirpation and subpopulation creation following recolonization of unoccupied habitats. Ideally, the individual occupied and unoccupied Karner blue habitat sites that together compose the metapopulation are arrayed spatially in such a way as to facilitate interchange of butterflies between the sites. Maintaining a persistent metapopulation requires that, at a minimum, dispersing butterflies find and colonize unoccupied sites at the same rate that subpopulations become extirpated. In robust metapopulations, the colonization rate greatly exceeds the local extirpation rate and most suitable habitat is occupied. In precarious metapopulations the colonization rate is only slightly larger than the extirpation rate; at equilibrium, any factor that negatively influences either rate can result the collapse of the metapopulation. Thus occupancy rate is a good measure of the robustness and fragility of a metapopulation.

There are two complementary approaches for influencing this balance: increasing the rate at which unoccupied sites are colonized, and/or decreasing the local extirpation rate. Land managers must consciously consider factors that influence both portions of the equation during both the development of the management plan for a Karner blue metapopulation, as well as during the implementation of that plan while managing Karner blue support ecosystems. As discussed in the section on population structure above, changing these rates can also affect the functioning of the metapopulation. When extirpation rates are reduced low enough at a site or cluster of sites, the metapopulation will function more like a core-satellite metapopulation, and when recolonization rates become very high, it will function more like a patchy metapopulation. When recolonization rates are not high and extirpation rates are not low, then the metapopulation will function more like a true metapopulation.

The colonization and extirpation rates will be strongly affected by local site conditions (e.g. habitat quality, dispersal corridors), the management of which will provide the means to improve Karner blue metapopulations. Equally important, however, are broad-scale factors, such as weather, wildfire, and unregulated urban sprawl, that can influence colonization and extirpation rates across all of the local sites in an entire metapopulation. Management at this broad-scale provides buffering capacity for the metapopulation. Management plans and activities must consider both scales of management to ensure persistence of the metapopulation.

No two Karner blue supporting ecosystems are the same, and approaches to ensuring metapopulation viability in each area will by necessity be different. Yet the principles guiding the planning and on-the-ground management decisions at every locality are the same, and revolve around improving the colonization/extirpation balance. Other management objectives, such as forestry and wildlife management, ecosystem recovery, and management for other rare species, should be assessed for compatibility with the practices required to sustain the Karner blue. While many of these other management objectives are anticipated to be compatible with management for the Karner blue (e.g. sharptail grouse management at Crex Meadows WA), some management prescriptions may need modifying to enhance the recovery of the butterfly (e.g. frequency and location of prescribed burns, enhancement of corridors to ensure dispersal, etc.) or to protect other rare species. The objectives of all management programs should be integrated into the management and monitoring plan for the butterfly. No one management unit is likely to satisfy all management objectives, but every site should attempt to satisfy as many as possible within real world ecological, sociological and financial constraints. Refer to the recovery criteria and APPENDICES G and H for guidance on development of management and monitoring plans.

INCREASING THE COLONIZATION RATE OF SUBPOPULATIONS WITHIN A METAPOPULATION

Increasing the rate that butterflies colonize suitable habitat within a metapopulation can have a very positive effect on the viability of the metapopulation. A high colonization rate tips the recolonization-extirpation balance in favor of recolonization, because if colonization rates are high enough, nearly all suitable habitat will be colonized every year and nearly all will remain occupied every year. Indeed, if colonization rates are high enough, then the metapopulation ceases to function as a true metapopulation and assumes the functional characteristics of a patchy metapopulation (refer to APPENDIX E, POPULATION STRUCTURE. Spatial Structure of

Karner Blue Butterfly Metapopulations). Because a patchy metapopulation will be more resilient to disturbances to subpopulations than a true metapopulation, management can shift emphasis to manage the average subpopulation rather than focus specific efforts on each subpopulation.

Between-Site Dispersal

The recovery criteria (PART II, RECOVERY OBJECTIVE, Reclassification Criteria, and Delisting Criteria) includes establishing connectivity between subpopulations so that the average nearest-neighbor distance between subpopulations is no more than 1 kilometer (0.62 miles), and the maximum distance between subpopulations is no greater than 2 kilometers (1.24 miles). In some cases the 1 kilometer (0.62) dispersal distance may be too far, in others the 2 kilometer distance may not be far enough. For subpopulations greater than 2 kilometers from their nearest-neighbor, validation that dispersal is occurring is needed prior to including that subpopulation into the LP. The appropriate separation distance between subpopulations will depend on the site characteristics, especially the extent of canopy cover between habitat sites. Table G1 summarizes available information on between-site dispersal and within-habitat movements and indicates canopy cover between habitat sites. Managers can use this information to determine the appropriate spacing of subpopulations to facilitate dispersal by reviewing the results of studies with site characteristics and canopy cover between sites most similar to the landscapes that they are managing. If the landscape they are managing differs from those in the studies, then separate dispersal studies should be done to determine appropriate distances between subpopulations. One way to demonstrate dispersal is to create new habitat patches in unoccupied areas and monitor for occupancy of Karner blues. A discussion of the dispersal information in Table G1 follows.

The primary methods that have been used to determine dispersal distances and rates for the Karner blue butterfly are noted on Table G1 and are mark-release-recapture (MRR) (Schweitzer 1979; Fried 1987; Bidwell 1994; Lawrence 1994; King 1994, 1998) and focal animal sampling or tracking of individual butterflies (Welch 1993, Grundel et al. 1998b, Lane 1999). Although MRR methods have been the most cost-effective method of obtaining information on dispersal, because they rely on detecting the rare long-distance recapture and a sampling intensity that declines with distance, they tend to underestimate the number and distance traveled by dispersing individuals.

Obviously, the greater the distance separating sites of suitable habitat and the more dense the canopy closure between habitat, the lower the odds that butterflies will locate unoccupied habitat. Two factors influence this: the decreasing likelihood that a Karner blue butterfly will fly greater distances especially with increasing intervening canopy cover, and the decreasing probability that a dispersing butterfly will encounter or find a particular site at greater distances. Dispersal of the Karner blue may be enhanced by developing dispersal corridors to guide dispersing butterflies towards more distant habitat sites, or increasing the size of the distant habitat site because larger targets might be easier to find (refer to Facilitating Directed Dispersal Using Corridors, below).

As the dispersal studies demonstrates, Karner blue butterflies are not particularly strong flyers compared to many other species of butterflies. Most dispersal studies have documented very few between-site dispersal events and limited dispersal distances (Fried 1987, Givnish et al.

1988, Lawrence and Cook 1989, Sferra et al. 1993, Welch 1993, Bidwell 1994, Lawrence 1994, Fuller 1998, Knutson et al. 1999).

Generally, the more open the habitat, the greater amount of between-site dispersal can be expected and the longer the dispersal distances. Dispersal distances up to 1.05 kilometers (0.65 miles), 1.3 kilometers (0.81 miles), and 1.6 kilometers (1 mile) have been recorded from rights-of-ways (ROWs) and/or trail areas in studies by Lawrence and Cook (1989), Schweitzer (1979), and Bidwell (1994) respectively. Welch (1993) recorded dispersal up to 1.7 kilometers (1.05 miles) in mixed (but mostly open) habitat**.** King (1998), documented the greatest amount of between-site dispersal and longest dispersal distances for the Karner blue. His study sites at Necedah NWR were each about 100 hectares (200 acres) in size, and were separated from each other by more than 1,150 meters (0.7 miles) of mostly open wetland habitat. About 11 percent of butterflies marked during the second flight made at least one inter-population dispersal of 1,150 meters (0.7 miles) or more. Of all marked butterflies, (429) 7.5 percent made at least one inter-population dispersal of 1500 meters (0.93 miles) or more. Of the Karner blues located greater than three times, movements greater than 1,500 meters (0.93 miles) were even more common (8.5 percent, n=354) (King 1998). Ten percent of all Karner blues with multiple captures were shown to travel at least 2.3 kilometers (1.4 miles) during the second flight of 1995 (less than 50 butterflies), and one individual female traveled at least 6.6 kilometers (4.1 miles) during the same flight (USFWS 2001, King unpublished data). These longer flights (1,500 meters – 6.6 kilometers) at Necedah NWR reflect the sum of within-habitat movements and between-site dispersal.

Lesser amounts of dispersal and/or dispersal distances are noted in studies where the intervening habitats are mixed or more closed or where the habitat was open but limited in extent (e.g., Sferra it al. 1993). In New York, Schweitzer (1979) captured only 4 percent of about 50 marked individuals about 1.3 kilometers (0.81 miles) away, and he observed little dispersal in the Concord, New Hampshire population, where less than one percent of the marked individuals crossed a narrow, little-used road separating two large habitat patches (Schweitzer 1979 in Givnish 1988, Dale Schweitzer, TNC, pers. comm. 1996). Fried (1987) captured only 1.3 percent of the recaptures (total recaptured = 224) dispersing between three sites that were approximately 400 to 700 meters (437 to 765 yards) apart. The habitat matrix between Fried's study sites was mixed, composed primarily of dense woods or low shrubs, although dirt paths connected them. In Wisconsin, Bidwell (1994) captured 2.9 percent of the marked individuals (total number marked = 724) dispersing between habitat sites. Two thirds of the dispersal events recorded were between the two close sites (50 meters apart); the rest were longer distances up to 1,600 meters (1 mile). In Michigan, during the second flight, Lawrence (1994) marked 538 individuals on sites 0.5 to 2.5 kilometers (0.3 to 1.6 miles) apart in a more closed habitat area and recaptured 142 butterflies. No individual was recaptured at a site other than at the original marking site during the first and second flights. Lawrence suggested that between site dispersal in his study area was probably uncommon because butterflies were marked and recaptured frequently, which would have enabled them to observe such dispersal if it had been common. Similarly, no long-distance dispersal between sites was observed during studies at the more closed IDNL sites even though large numbers of butterflies were marked (n=1959 1st flight, n=3654 2nd flight), (Knutson et al. 1999).

In studies on the Heath fritillary butterfly (*Mellicta athalia*) in England, Warren (1987) found an average of 1.5 percent dispersal between-sites. He argued that if similar rates of

Table G1. Summary of Karner blue butterfly between-site dispersal and within-habitat movement studies.

MRR = mark-release-recapture, ISD = dispersal between sites, MDM = mean distance per move, MDD = mean distance moved per day, Range = distance between two most distant captures. KBB = Karner blue butterfly. Character of canopy between habitat openings categorized as " open," "mixed," "closed," or "unknown" based on site descriptions. To convert kilometers to miles multiply the kilometers by 0.621; to convert meters to yards multiply the meters by 1.093; to convert meters to miles multiply the meters by 0.0006214.

STUDY	DATE	FLIGHT	LOCATION	STUDY SITE DESCRIPTION	CANOPY BTWN SITES	METHOD	RESULTS
King 1998	1995	1^{st} flight 2^{nd} flight	WI, Necedah National Wildlife Refuge, North, South and East Rynearson sites	3 sites, open landscape with oak barrens and wet meadow habitats abutting large water impoundments. Distances between sites = 1150, 1550, 2250 m (1.3 miles) of unsuitable habitat (water impoundments, wetlands with out lupine or nectar plants).	OPEN	MRR	203 marked 1^{st} flight, 12% recapture rate 236 marked 2^{nd} flight, 26% recapture rate ISD: 1^{st} flight = 7.4%, 2^{nd} flight = 11.2 % ***Between-site and within-habitat distances moved:*** Males: 1^{st} flight, 456.9 ± 261.7 m MDM 108.6 ± 32.7 m MDD 457.0 ±261.9 RANGE 2^{nd} flight, 214.7 ± 31.8 m MDM 119.5 ± 7.5 m MDD 373.6 ± 98.6 RANGE Females: 1^{st} flight, 69.8 ± 17.5 m MDM 48.2 ± 12.1 MDD 73.3 ± 13.8 m RANGE 2^{nd} flight, 359.2 ± 27.4 m MDM 173.2 ± 13.1 MDD 613.7± 167.1 RANGE ***Between-site distances moved***: 11% of marked 2^{nd} flight KBBs made at least one between-site dispersal of 1150 m (0.7 miles) or more. 7.5 % of all marked KBBs made at least one between-site dispersal of 1500 m (0.93)

STUDY	DATE	FLIGHT	LOCATION	STUDY SITE DESCRIPTION	CANOPY BTWN SITES	METHOD	RESULTS
Lawrence & Cook 1989, Lawrence 1994	1989	1st flight 2nd flight	MI, Allegan SGA	1st flight: 1 site, open linear habitat – pipeline ROW, 2.1 km long, several large lupine patches 2nd fight: 8 sites – mixed oak forest and fields, 0.5 to 2.5 km apart	OPEN CLOSED	MRR	134 marked 1st flight, 29% recapture rate 538 marked 2nd flight, 26% recapture rate **Within- habitat distances moved** 1st flight: Males: 248 m ± 64 m MDM 191 m ± 52.5 m MDD Longest distance = 1.05 km *male results skewed, most movements less than the mean with a few individuals moving long distances Females: 203 m ± 41 m MDM 162 m ± 40 m MDD Longest distance = 0.55 km 2nd flight: (distance moved between-sites) No butterflies captured in sites other than where they were originally marked
Sferra et al. 1993	1990-1992 (data summa-rized for 1992 only)	1992- 1st and 2nd flight	MI, Huron-Manistee National Forest, Oak Ave. ROW	Powerline ROW, 30 m x 0.8 km with sand prairie strip bordered by white pine plantation to west, dirt road/oak savanna to east.	OPEN (study sites confined to ROW)	MRR	143 marked 1st flight, 27.3% recapture rate ?? marked 2nd flight, 36.5% recapture rate 1st flight: 67% of recaptured stayed within 200m 2 adults used entire 0.8 km strip 1 male traveled 100 m in just 20 minutes
Fuller 1998	1998	2nd flight	NY, Geyser Road powerline ROW	Powerline ROW (mostly open – some scattered clumps of shrubs)	OPEN	MRR	1091 marked, 51.8 % recapture rate Prop. of indiv. captured out of "home" patch =Males: 0.501, Females: 0.377. KBB rarely dispersed to habitat patches > 500 m from natal patch. Females less likely to disperse from high-density pops., more likely to leave low density pops.

STUDY	DATE	FLIGHT	LOCATION	STUDY SITE DESCRIPTION	CANOPY BTWN SITES	METHOD	RESULTS
Fried 1987	1987, July 10-27	2nd flight	NY, Albany Pine Bush, 3 sites along Willow Street	1) abandoned sand pit, 2) path along power line, 3) shady site with aspens and pitch pine. Very small sites, approx. 305-460 m apart, connected by dirt paths through dense woods or low shrubs, some nectar along paths and one opening with no lupine between 2 sites	MIXED	MRR Jolly	224 marked, 55% recapture rate 3 of 224 ISD[2] ***Between- site distances*** Males : 1 @ 460 m Females: 1 @ 150 m, 1 @ 305 m 8 males moved along dirt paths 2.4 % of recaptures were dispersing male bias in captures ***Population estimates:*** 1) 89 2) 154 3) 47
Bidwell 1994	1994, July 19 – Aug. 11	2nd flight	WI, Fort McCoy, South Post	3 sections of 30 m x 1 km training area boundary ROW. Scattered lupine, diverse nectar, open with shrubby oak. Bordered by oak woods with >75% canopy closure. Dense band of birch with >75% canopy extended across ROW for 50 m of ROW length, 5 m wide trail through birch, no lupine, little nectar	MIXED	MRR	724 marked total, 24% to 62% recapture rate ISD: 21 total (2.9%). 14 KBB (12 males, 2 females) crossed birch band, ISD between sites 1000 m apart. 1 male 1600 m over 2 days, 1 female 1195 m. ***Between- site and within-habitat distances moved:*** (dispersal distance data combined for 3 sites) Males: 91% moved < 400 m RANGE[5] 99 m $\pm$ 9m MDD Females: 91% moved < 200 m RANGE 32 m $\pm$ 3 MDD

STUDY	DATE	FLIGHT	LOCATION	STUDY SITE DESCRIPTION	CANOPY BTWN SITES	METHOD	RESULTS
Welch 1993	1993	1st flight 2nd flight	WI, Hartman Creek State Park Complex & Welch sites, 11 sites	Cluster of small-medium sized openings separated by oak forest and/or pine plantation. Barriers were mixed conifer/deciduous fence row and wooded habitat margins, 200-415 m wide	. MIXED	Focal-animal sampling (followed adults)	78 total observed: 50 were ≤ 406 m from lupine patch, 4 (5%) moved > 1 km. Worn individuals dispersed farther than fresh: Males: 65-1140 m (ave. 530 m) Females: 85-565 m (ave. 285 m) Longest distance observed = 1 male, 1.7 km from nearest lupine, 2nd flight (open habitats + shaded wooded fence line) Female observed flying through forest, 2-3 m off ground. Flying, then landing, from one sunlit branch to the next. **Relatively Closed habitats** (>50% cover, perimeter enclosed) * 4 adults 270 to 792 m from one lupine opening to another on forest trail with 85% cover, 3 were males (24 total obs.) * 7 adults moved 88 to 352 m between small openings with lupine along sunlit openings, often returning to original patch (13 total obs.) * 1 male flying into canopy and crossing 11 m high crown of trees to enter next lupine area **Open habitats** (<50% canopy, some perimeter opens to field or corridor) * 1 male 523 m from lupine patch, flew along roadside ROW on wooded edge * 37 butterflies observed 55 – 1350 m from lupine (23 = males) (Welch Tract) * 3 adults crossed 108-320 m woodland via corridors (between Casey site and Welch Tract)

STUDY	DATE	FLIGHT	LOCATION	STUDY SITE DESCRIPTION	CANOPY BTWN SITES	METHOD	RESULTS
Schweitzer 1979 (in Givnish et al. 1988)			NY, Albany Pine Bush	None of the sites fully open	MIXED	MRR	Greatest distance moved = 1.3 km between Gipp Road and Crossgates Hill Dispersal observed along roads & trails, occasionally over tree tops Givnish et al. (1988) concluded effective inter-population dispersal of up to about 0.8 km (given a substantial source population)
Knutson et al. 1999	1994, 1995, 1996	1st flight 2nd flight	IN, Indiana Dunes National Lakeshore, 4 sites and supplemental survey areas	4 sites: 1) Oak savanna/marsh complex with moderately dense woody veg. and sand-mined areas, 2) oak savanna/marsh with open fields, 3) oak savanna with open understory, 4) linear habitat along former railroad track, dune ridge with moderate canopy Millers Woods - flat, homogenous site, open understory. Movements > 300m, 2 x freq. of 2 other sites	CLOSED .	MRR	1959 marked 1st flight, approx. 30-33% recapture rate 3654 marked 2nd flight, approx. 12-31% recapture rate ISD : No movements observed between study sites. ***Within-habitat distances moved:*** MDD - 50.3 m (sexes & flights pooled) Males: 51.2 $\pm$ 2.7 m Females: 48.0 $\pm$ 4.5 m 1st flight: 55.0 $\pm$ 3.5 m 2nd flight: 46.4 $\pm$ 3.0 m RANGE - 73.4 m $\pm$ 2.3 RANGE (sexes & flights) Males: 76.9 $\pm$ 2.8 m Females: 64.9 $\pm$ 4.3 m 1st flight: 84.5 $\pm$ 4.1 m 2nd flight: 65.0 $\pm$ 2.7 m 75% of movements less than 100m* Maximum distance moved = 989 m

dispersal were observed in other areas not sampled, that a fairly substantial proportion of adults might be emigrating from the populations studied and arriving at new habitat areas (Warren 1987). For the Karner blue, it is unclear if observed rates of between-site dispersal will limit recolonization of suitable habitat. The dispersal rates observed at Necedah NWR indicate that recolonization can be extensive in open habitats.

Tracking individual butterflies has also been done to determine within-habitat movements and between-site dispersal distances (Welch 1993, Grundel et al. 1998b, Lane 1999). Welch (1993) located potentially dispersing butterflies by searching areas 200 meters (220 yards) from lupine sites. The number of dispersers and distance each moved was recorded for spring and summer flights, along with wing-wear (fresh and worn individuals), sex, and habitat types (open and closed canopy). A total of 78 butterflies were observed. The largest number of dispersers were fresh males in open habitat during the first flight. Numbers of dispersers were lower during the second flight. Average dispersal distances were farthest for worn males in open habitat, ranging from 65 to 1,140 meters (71 yards to 0.71 miles) and averaging 530 meters (580 yards). Dispersal distances for worn females ranged from 85 to 565 meters (93 to 618 yards) in open habitat with an average of 285 meters (312 yards). The longest distance observed by Welch (1993) was by a male that was 1.7 kilometers (1.06 miles) from the nearest lupine patch.

There has been no critical examination of the methods and the data associated with dispersal. Without clear information on the sampling intensity at different distances from the release points, it is difficult to interpret the results. None of the dispersal information has been summarized to provide an estimate of the functional relationship between distance and the probability of dispersal. Definitive studies on insect dispersal frequently uncover unanticipated high frequencies of movement and distances far greater than expected.

The differences observed in dispersal distances between the various study sites suggests that there is a fair amount of variation in dispersal tendency between sites. They also demonstrate that males generally disperse further than females. In summary successful dispersal between habitat sites greater than 2.3 kilometers (1.4 miles) or more apart (King 1998) in open areas is likely rare Consequently, to maintain the colonization rate at a level that can easily compensate for local extirpations (and to facilitate exchange of the genetic material between subpopulations) suitable habitat should be separated by lesser distances. Distances between subpopulations that are likely to facilitate recolonization in a metapopulation are likely to fall in the range of 0.5-2 kilometers (0.31-1.24 miles); this distance could be lesser or greater and will be dependent on the nature of the habitat, especially canopy cover, between habitat sites. More distant and/or closed habitats might need to be linked with dispersal corridors to other sites to enhance connectivity, or might need to be managed to function independently from the main metapopulation. These independent, distant sites would not contribute directly to the stability of the main metapopulation under typical conditions, but could contribute to buffering the metapopulation against large-scale adverse events.

The size of the management unit can affect recolonization rates**.** If large areas of contiguous habitat were managed as smaller discrete sites, then when a part of the area is restored, for example using fire, colonists could simply 'diffuse' in from the edges of adjacent unburned habitat.

Number of Dispersing Female Karner Blue Butterflies

Larger numbers of butterflies will disperse from larger subpopulations of Karner blues if the proportion of dispersers is the same for any size subpopulation. For example, if five percent (a totally hypothetical number) of females were likely to disperse, a population of 200 adults (both sexes) would yield five dispersing females while a population of 400 would yield ten. Thus, another approach to increasing the rate of colonization is to manage some or all of the occupied habitat to produce maximal numbers of Karner blue butterflies, which in turn would maximize the number of dispersing females. Indeed, if the relationship between the number of dispersing females and subpopulation densities were density dependent, so that high densities increase the proportion of the subpopulation inclined to disperse, then larger populations will create even more potential colonists. Limited observations suggest that dispersal is greater as habitat quality declines (Fried 1987) (Dale Schweitzer, pers. comm. 1997), but this needs to be rigorously evaluated.

Facilitating Directed Dispersal Using Corridors

In many of the ecosystems that support the Karner blue, most dispersing females may never locate suitable habitat with host plants upon which to lay eggs. Many simply leave their natal habitat and move into hostile adjacent habitats, never locating even nearby sites of suitable habitat. There are two approaches to establishing effective dispersal corridors, neither of which are proven, which may help guide dispersing Karner blues to suitable destinations.

<u>Corridors</u>

Corridors of open canopy, which provide adult resources, such as nectar, and roosting sites, can be used to connect patches of suitable habitats. Typically railroad and powerline rights-of-way (ROWs) as well as roads and trails through wooded areas are believed to be corridors of this sort. The idea that dispersing Karner blues will somehow follow these corridors and be guided to a destination at the other end is untested, and it is possible that abnormally high densities of adult food resources such as nectar-producing flowers in these ROWs might actually draw adults out of less resource-rich suitable habitats. Butterflies may merely concentrate in the ROWs, but not follow them to other suitable habitats.

<u>Living corridors</u>

Living corridors provide both larval and adult resources and can be used to connect habitat patches. While living corridors will not have adequate suitable habitat to support a subpopulation, the essential habitat components would be in place for dispersing adults to use. Thus, dispersing females could lay eggs within the corridor itself, and would not need to fly the entire distance separating habitat patches before locating suitable host plants. Potentially, the next generation of Karner blues would be that much closer to the connected suitable habitat site, and would be more likely to complete the trek to that site. In many areas, such as the Albany Pine Bush in New York and Gary, Indiana, living corridors can and do support small Karner blue populations that contribute to the overall functioning of the metapopulation.

Identification and Protection of Refugia

A viable Karner blue metapopulation will be comprised of many subpopulations on sites with suitable habitat. A minimum number of colonists could be ensured if refugia, where Karner blue subpopulations persist for long periods of time at high densities, can be identified and protected. These refugia will provide a continual supply of colonists for the entire metapopulation and could serve to ensure that some colonists will be available to recolonize unoccupied suitable habitat. In any metapopulation some of the sites are more likely to persist for longer periods of time than other sites. These sites might be identified as management experience accumulates. If these sites were managed to produce maximal numbers of butterflies, then they could function as refugia. Sites where subpopulations persist for long periods of time at low density might be called low-density refugia. Low-density refugia will not contribute substantially to recolonization.

REDUCING LOCAL EXTIRPATION RATES

The probability that a subpopulation will be extirpated is related to the size of the subpopulation (larger subpopulations are less likely to be extirpated than smaller subpopulations), and the temporal variation in subpopulation size (more variable subpopulations are more likely to be extirpated). For example, if for some reason 99% of the eggs fail to overwinter, a subpopulation of 1000 eggs will produce only 10 first instar larvae, while a subpopulation of 10,000 eggs will produce 100. Larger subpopulations simply have a better chance of surviving density independent sources of mortality because ultimately, there are more survivors. Consequently, there are two basic strategies for reducing local extirpation rates. The first is to improve and maintain the suitability of the habitat for Karner blue so that they are less likely to be extirpated, and the second is to manage disturbances on site so they do not inadvertently cause the extirpation of the butterfly and indeed, may contribute to the improvement or renewal of suitable habitat.

Managing subpopulations and their associated suitable habitat to reduce extirpation rates is most readily done on a subpopulation by subpopulation basis. This implies that for most metapopulations, this approach will not be used on all subpopulations in a metapopulation, but only on selected ones. For minimum viable metapopulations, it would be beneficial to reduce the likelihood of extirpation associated with the more precarious subpopulations so that most subpopulations are maintained. In larger metapopulations, however, effort could be shifted to reduce the likelihood of extirpation in some of the larger, healthier subpopulations or clusters of subpopulations. If the likelihood of extirpation can be reduced so that the subpopulation or cluster is likely to persist for a long time into the future, then the metapopulation will function less like a true metapopulation and assume some of the functional characteristics of a core-satellite metapopulation. Because persistence of a core-satellite metapopulation depends mostly on the fate of the core subpopulation or core cluster, management efforts may be able to shift to focusing on maintaining the core subpopulations and the means of dispersal (close enough distances, dispersal corridors, etc.) to the surrounding constellation of satellite subpopulations. It would no longer be necessary to manage each satellite subpopulation individually, but it would be possible to set up management to maintain a balance between the creation and destruction or degradation of suitable habitat associated with those satellite subpopulations.

Improving and Maintaining Karner Blue Habitat

Based on our current knowledge of the biology of this butterfly, recommendations to improve habitat suitability, which can be factored into both short- and long-term management strategies are provided below.

Pesticides

Avoid using insecticides in association with the Karner blue. Most insecticides are toxic to Karner blue butterfly larvae. Even though some insecticides may be used to maintain or improve habitat, use of insecticides is discouraged. One example of an insecticide used in Karner blue habitat is *Bacillus thuringiensis* var. *kurstaki (Btk)* used to control the gypsy moth which causes defoliation of trees**.** Experimental testing of the effect of *Btk* on Karner blues found it caused mortality of Karner blue larvae (Herms et al. 1997). If insecticide use is necessary, it should be used at a time when Karner blue larvae and adults are not susceptible to the insecticide, its residues, or its metabolic by-products. The Service recommends that no aircraft broadcasting of *Btk* should occur within one-half mile of any Karner blue butterfly sites. Distances of less than one-half mile may be acceptable on a case by case basis by building in precautions to minimize drift (refer also to APPENDIX G). Other insect control tactics might be substituted for insecticides, but the potential detrimental effects of these other control tactics should be considered before they are used.

Research to date suggests that the herbicides, Accord (glyphosate) and Accord + Oust (sulfometuron methyl) (with Entry II surfactant), can be used with minimal direct impact on the Karner blue butterfly. In addition, there are indications that Accord-Arsenal may be effective in reducing woody cover with positive effects on lupine populations. Research has shown that Karner blue eggs treated with Accord + Garlon 4 (triclopyr ester) have resulted in 22 percent fewer adults hatch than in controls; translated to field conditions, it is anticipated that this would result in a 2 percent reduction of adults (Sucoff 1998). Herbicides should be used with care to minimize impacts to the Karner blue.

The effects of herbicides on the growth and flowering of lupine and select nectar plants has been examined through various studies (Smallidge et al. 1996, Sucoff 1997) (Scott Shupe, Niagara Mohawk, pers.comm. 2002). Sucoff (1997) applied three herbicide treatments, Accord, Accord + Oust, and Accord + Garlon 4 (all with Entry II surfactant), to lupine and nectar plants in late August through early September. Results showed that lupine percent cover and number of stems per meter squared were not significantly different between control and treated plots. Nectar plant responses varied. Some species showed a sudden increase, others an initial reduction followed by a gradual increase in number and or coverage. On two of three sites there was no significant effect of the herbicide on numbers of flowers or flower-bearing stems. On a third site, however, both of these variables were significantly lower on herbicide treated plots. More research would further our understanding of the effect of herbicides on nectar plant survival and flowering.

To minimize the impact of herbicides on the Karner blue and its food plants, herbicide applications made during the butterfly's flight period should be limited to spot application with hand operated equipment only, using pesticide certified or experienced personnel trained to identify the butterfly and lupine. The applicator should avoid trampling lupine plants. Aerial and ground application of pesticides should be done outside of the Karner blue flight season. Following these guidelines as well as the additional pesticide use guidelines described in the Wisconsin Statewide HCP for the Karner blue butterfly (WDNR, 2000) should minimize impacts to the butterfly.

Area of suitable habitat

In general, larger sites of suitable habitat are better for Karner blue (recognizing that discrete, somewhat isolated sites also have some advantages), and will support larger subpopulations. Large sites can be managed as a number of adjacent discrete units, allowing for recolonization from directly adjacent, undisturbed habitats. However, a metapopulation composed of just a few (<5) large patches that are located too near each other may be very susceptible to extirpation by wildfire or disease epidemics.

For recovery purposes, it is recommended that the area of suitable habitat in sites be greater than 0.25 hectares (0.62 acres). Subpopulations on sites as small as or smaller than 0.25 hectares may be highly susceptible to extirpation. To reduce the probability of extirpation in these small sites, the habitat could be managed to support a high population density of Karner blues (many host plants, nectar sources, and good subhabitat).

There is no theoretical upper limit to the size of suitable habitat. Realistic management constraints, however, should be factored into managing "sites" approaching or greater than 500 ha (1,235 acres or ~2 square miles).

Lupine density

Make adequate lupine available in a variety of subhabitats. Excellent Karner blue habitat supports abundant lupine. Small habitat patches (0.25 ha or 0.62 acres) are recommended to have at least 500 lupine stems to be considered as suitable habitat (2,000 per ha or 810 per acre). As the area of a site increases, so should the number of lupine stems, although the relationship is not linear. Larger patches (>5 hectares or 12.3 acres) are recommended to have more than an average of 0.1 lupine stems per square meter (1,000 per hectare or 405 per acre). Of course, the higher the lupine density the higher the potential subpopulation density of Karner blues.

When planting lupine, seed should be collected from native local wild lupine plants to ensure the maintenance of the genetic integrity of the local lupine population. Consult your State Natural Heritage Program for guidance on seed collection (refer also to Appendix I, CONSIDERATIONS RELATIVE TO LUPINE).

Lupine can be threatened by numerous factors. Exceptionally high densities of deer, rodents, or very high livestock stocking rates can damage lupine. Animal control, animal exclusion, or management for lower animal densities may be necessary. Lupine does poorly in dense shade, so canopy cover should be maintained low enough for lupine to reproduce but high enough for seedlings to survive (perhaps between 30 to 70 percent on average over the entire site; refer to Habitat heterogeneity below). Thus, succession should be managed to maintain a diverse, relatively open canopy.

Mechanical management (e.g., mowing or cutting), as well as grazing can be used to enhance lupine if it is done at the right time, however precautions should be taken to minimize the effects of such activities on the Karner blue and its habitat (refer to Alternatives to fire management, below).

Off-road vehicle (ORV) traffic can have a positive or negative effect on lupine depending on whether the ORV paths destroy lupine (potentially negative effect) or function to keep the canopy open and create germination sites (potentially positive effects). Exotic invaders may reduce lupine (some sedges in relatively mesic habitats), but other may be significant nectar sources (white clover). There are no simple rules for increasing lupine.

Nectar resources

Make several potential nectar sources available for each generation because annual variation in flowering phenology means that a particular species may not be available for adults in every year. Adult butterflies require food to survive. While it is likely that in the absence of nectar sources, adults will manage to mate and lay some eggs, without food the number of eggs laid will be greatly diminished. It is also possible that inadequate nectar at a site could result in increased dispersal of butterflies to find nectar (Loertscher et al. 1995). Because mortality of immature caterpillars is very high and most die, subpopulations that chronically experience low fecundity (actual number of eggs laid) because there is no adult food are at risk of extirpation. Thus, the absence of adult nectar sources can be limiting and jeopardize a subpopulation. This problem is most pronounced during the summer flight period, when the number of flowers blooming is reduced because of summer dry spells in oak and pine barrens and savannas. Excellent Karner blue habitats have a variety of potential nectar sources available for both the spring and summer broods. Poor habitats should be enhanced by planting or encouraging suitable nectar plant species (native forbs and others) that will provide nectar during both flight periods under the range of foreseeable environmental conditions (droughts, cool springs, cool summers, etc). Alternately, habitats adjacent to Karner blue habitats, such as wetlands and mesic prairies and other mesic or xeric habitat, can be managed to provide nectar-producing flowers.

Many of the comments under the lupine density section above apply in a similar way to nectar plant management. Nectar plants, however, will flower more abundantly and produce more copious amounts of nectar in sunny. Thus encouragement of nectar will require a more open habitat than that needed to improve lupine. Grazing, succession, mowing, ORV traffic, and exotic invaders may detrimentally affect nectar plant species, but there are no simple rules for improving nectar resources. If nectar plants were believed to be limiting, a useful precaution would be to delay mowing until after the nectar plants had set seed, usually in mid-October.

While many non-native plant species are used by the Karner blue as nectar sources, planting non-native species for this purpose is not recommended. One concern with non-natives, in particular those that are invasive, is that they may out-compete native nectar sources or lupine.

Habitat heterogeneity (Appropriate successional array)

Promote heterogeneity in the habitat, such as heterogeneity in vegetation, management practice, subhabitat and microhabitat, timing of management, and habitat structure. An excellent habitat will have considerable diversity in microtopography, aspect, hydrologic regime, and tree canopy cover (varying from 0-90% cover in the habitat) within a typical flight range of a Karner blue butterfly [probably 200-500 meters (219-547 yards)]. This diversity will create microclimatic diversity that will enable Karner blue butterflies to locate readily preferred oviposition sites and preferred roosting sites despite variation in weather from year to year. For example, xeric sites with southern exposure are likely to be poor habitat for the Karner blue in typical years because the temperature gets very hot for larvae, and the lupine senesces rapidly. In cool wet years, however, these sites may be excellent sites for Karner blue. Conversely, shady, mesic sites may be poor habitat in typical years because lupine grows poorly in the shade under competition from other forbs and grasses, and the cool temperatures delay development of larvae, which will expose them to predators and parasitoids for a longer period of time. In hot, dry years, however, these shady mesic sites may be the best habitat for Karner blue and be the key to their survival in the site. In addition, rapid degree-day accumulation during hot years will accelerate the onset of butterfly weed flowering (an excellent adult nectar source) more that it accelerates the onset of the second flight of the Karner blue. Habitats with diverse subhabitats and microhabitats are likely to support a wider variety of nectar-producing plants as well as moderate the impact of environmental extremes of flowering phenology. Diverse, heterogeneous habitat will not optimize Karner blue subpopulations in any one year, but will enable them to persist in a site for many years.

It is important in developing Karner blue metapopulations, especially large viable metapopulations, to insure variation in the successional stage of habitat patches and/or subpopulation areas so that large areas of habitat do not simultaneously become unfavorable and to maintain subhabitat and microtopography diversity. Large viable populations should appear as a patchwork different successional stages on the landscape. Management should strive to maintain a shifting geographic mosaic that provides a balance between closed and open-canopy habitats important for maintaining these populations.

Other factors

Adult Karner blue butterflies require roosting sites. Grasses, shrubs, or any other vegetation that is taller than lupine and exposed to late afternoon sun may function as roosting sites. Roosting sites will not be limiting in typical habitats. A five percent cover in tall grass or other such vegetation probably provides sufficient roosting sites.

Improving Management for the Karner Blue

Habitat loss is the primary factor contributing to the decline of the Karner blue. The native habitats with which Karner blue is associated are oak and pine barrens and savannas. Conversion of these habitats to housing developments, industrial parks, and other intensive human uses associated with urban and suburban development has in many cases irrevocably destroyed Karner blue habitat. Possible management responses to this destruction of native habitat include habitat protection using conservation easements, negotiated conservation plans, purchases of land from willing owners, or protective legislative or legal remedies. Conversion to agricultural and grazing lands has also resulted in substantial loss of native habitat and harm to the Karner blue. Conversion to some silvicultural land uses may be the main human uses that can be compatible with Karner blue; while some silvicultural practices are clearly beneficial to the butterfly and others are clearly harmful, the majority of these practices have uncertain effects (Lane 1997).

Where the habitat is managed for native vegetation or recreational human use, unimpeded succession is the leading contributor to habitat loss. Barrens/savanna communities are among the most dynamic in the northeast and Midwest United States. The open habitats that support Karner blue were originally maintained by a steady procession of wildfires and other periodic disturbances. The wildfires top-killed woody invasive plants while favoring fire-adapted dune and savanna communities. Other disturbances, such as grazing, oak wilt, late frosts, and local outbreaks of defoliating insects helped to create a mosaic of habitats ranging from open xeric grasslands to oak woodland. Without these disturbances, shade-tolerant and fire-sensitive species increase in density, and open barrens and savanna species decline. Moreover, management aimed mainly at enhancing certain game species has resulted in large areas of potentially suitable habitat to be rendered relatively poor habitat for Karner blues. The Wisconsin DNR Wildlife Management Guidelines provide additional suggestions that managers interested in barrens and savanna maintenance and restoration may be interested in considering (WDNR 1998, WDNR 2000). Guidelines for managing Karner blue metapopulations associated with silvicultural practices can be found in Lane (1997).

General guidance: (1) Plan not to use any management practice that is likely to have an adverse effect on an entire Karner blue subpopulation repeatedly within a time frame of two generations. (2) If a subpopulation is critical for the maintenance of the metapopulation, then subdivide the subpopulation into separate management areas. The number, design, and rotation of management areas should allow effective Karner blue re-colonization after the management practice from nearby unaffected areas. (3) On very small, isolated sites that have small populations of Karner blue, use management practices that are unlikely to harm the existing subpopulation, e.g., tree girdling instead of fire.

Size of management unit relative to size of habitat site

For small metapopulations near the minimum viable metapopulation criteria, suitable habitat sites, which support Karner blues, should be large enough so that each site could be divided into three or more management units. This would minimize the probability of local extirpation from management error while maintaining suitable habitat in the site. At the other extreme, with large viable metapopulation that occupy large areas of suitable habitat over several square kilometers, swaths of the habitat mosaic (occupied sites and surrounding matrix of habitat) may be managed as single management unit as long as adequate precautions are taken to ensure that there are nearby occupied habitats which can act as sources of potential colonists. Most managed metapopulations will likely fall between these extremes, with some sites within the metapopulation subdivided, and other sites within the metapopulation managed without subdividing.

Fire management

In using prescribed fire as a management tool, two general guidelines apply. The first is that the positive effects of fire on Karner blue habitat must be weighed against any negative impacts to the butterfly. Fire is known to be an important component in maintaining savanna/barrens habitat that acts by reducing accumulated plant litter, exposing bare soil, reducing nitrogen content of the soil, promoting increased soil temperatures, and setting back growth of plants that compete with native, desirable vegetation. However, fire can also have negative effects on the butterfly (and other invertebrates) such as direct mortality and/or reduction of food plants.

The second general guideline is that prescribed fire methods for restoring habitat will typically vary from those used for maintenance of habitat. For example, sites where lack of disturbance has allowed succession from savanna to forest to occur, more intensive methods will be needed in order to restore savanna/barrens structure than for maintaining sites where suitable habitat structure is present.

To adhere to the general guidelines and to develop appropriate site specific restoration/maintenance plans, many factors will need to be considered. As an aid in developing prescribed fire plans, an overview of relevant literature, followed by recommendations based on that literature, are provided below. Information is grouped in the following categories: 1) site history and current condition, 2) amount of direct Karner blue mortality likely to occur during the fire, 3) potential for Karner blues to reoccupy the site, 4) characteristics of prescribed fire, 5) response of lupine and nectar plants to fire and 6) other habitat responses.

1. Site history and current conditions:

Site history and characteristics are primary factors dictating whether prescribed fire is the best management tool for the site, and at what frequency/intensity/season fire should be used. For example, for sites that have succeeded to oak woodland or forest, mechanical means such as girdling or cutting, and/or herbiciding are often more effective than fire in restoring desired structure (Lane 1996). Alternatively, one intense crown fire may create responses similar to that observed for wildfire, i.e. canopy reduction (Swengel 2001). The size, shape and distribution of habitat patches, and the nature of intervening habitat will influence, among other variables, how many burn units should be created, what percent of each habitat patch can be burned, and how rapidly the Karner blue can recolonize burned sites.

Soil type will also influence whether and how frequently to burn. On very dry, sandy, exposed sites with very little accumulation of plant litter and minimal woody plant cover, very little immediate management may be needed. Burning such sites may only exacerbate the droughty conditions and cause premature lupine senescence – potentially resulting in insufficient food for second brood Karner blue larvae.

Knowledge of what species are present on a given site and their response to fire will also be important. Fire may either increase or decrease the abundance of invasive species and/or native species that compete with lupine and nectar plants. Some rare plant species may respond adversely to fire and should be protected during burns.

Recommendations:

Prescribed fire plans should be site specific and based on the structure and composition of the current vegetation, and the spatial characteristics of Karner blue habitat patches. Site inventories should be conducted prior to developing the management plans and include information on species composition (native and non-native), canopy structure, soil type, slope and aspect, etc. For example, sites with dense vegetation between patches will require different considerations than those interspersed with open canopied vegetation types. Areas/sites with exposed and dry soils should be burned less frequently than those with more mesic conditions.

2. <u>Amount of direct Karner blue mortality likely to occur:</u>

Fire can result in the mortality of Karner blue eggs, larvae and and adults (Maxwell and Givnish 1994, Swengel 1994, Maxwell 1998, Kwilosz and Knutson 1999). Available evidence suggests that eggs and larvae do not survive fire, but they can survive in burn units because burns are uneven or because areas within the burn unit have been excluded from fire (Bleser 1993, Swengel 1994, Swengel 1995, Kwilosz and Knutson 1999). Research by Maxwell and Givnish (1996) estimated 50 to 80 percent Karner blue larval mortality on burned plots. The areas where larvae survived in the burned plots were at the bases of tree boles and around downed logs, where the fires skipped. As part of prescribed fire management/research at IDNL, 50 to 300 meter squared areas were excluded from fire within several burn units at several sites. Even with these refugia, adult counts dropped substantially within the partially burned portions of one of the sites as compared with unburned portions of the same site following fire (Kwilosz and Knutson 1999). However, there were no net population declines at fire-managed sites, and the authors suggested that adults either survive fire within the burn unit or move into the burned area from nearby or adjacent unburned units. Further, monitoring has shown that the number of Karner blue butterflies counted per site has increased on sites managed with prescribed fire (Kwilosz and Knutson 1999). It is important to note that because of the large number of factors than can potentially influence Karner blue population fluctuations, and limitations in the experimental designs used, it is not possible in any current studies to determine whether the Karner blue population fluctuations observed were a result of prescribed fire.

Some adults are known to survive fire by moving. A study on two habitat sites at Necedah NWR showed that some Karner blue adults survived prescribed burns (King 1994, King 2002). Adult Karner blues were observed at Necedah NWR flying immediately in front of the flames. Other Karner blues may avoid fire by moving to nearby adjacent habitat or because of they are in areas skipped by the fire within the burn unit. King (1994) notes that because the level of mortality of Karner blues remains untested, prescribed burns should be used with caution.

Recommendations:

Direct mortality to Karner blues can be reduced by burning less frequently, burning only one portion of a site at a time, conducting "patchy" burns, and creating refugia prior to prescribed fires. Leaving areas of occupied Karner blue habitat unburned, particularly patches with abundant Karner blue, will help insure that a sufficient number of butterflies persist after the fire. "Patchy" burns are those that leave a mosaic of burned, partially burned, and unburned areas to act as natural refugia for Karner blue eggs, larvae and adults. Refugia can be created prior to burning using several methods e.g., mowing around occupied lupine patches to create unburned islands, protecting areas with fire retarding foam, and using portable pumps and sprinklers to keep selected areas wet during fires. For large sites, refugia located near the center of the habitat may help facilitate recolonization. (Refer also to recommendations under No. 3 below)

3. The potential for Karner blues to reoccupy the site*:*

Recolonization of the burned areas can be facilitated by burning only a portion of a subpopulation or metapopulation, by insuring that occupied habitat is within dispersal distance of the burned area, and that sufficient numbers of butterflies remain to act as colonizers (Swengel 1996, Kwilosz and Knutson 1999). In order to burn only a portion of the Karner blue habitat area(s), it is usually necessary to divide the single subpopulation or metapopulation into several burn units. If a four-year fire return interval is used for instance, the habitat area should be divided into 5 burn units. It will be important to design prescribed fire plans so that a range of subhabitats (refer to Part I, LIFE HISTORY AND ECOLOGY**,** Subhabitats) are maintained within dispersal distance of occupied Karner blue sites.

Recolonization will also depend on how far and through what type of habitat butterflies need to disperse/move to reach suitable habitat. Karner blue movement varies considerably with habitat type/geographic location and for within-habitat versus between-habitat movements. Most within-habitat movements are less than 100 to 300 meters (109 to 328 yards), depending upon study site. At IDNL, where fragmented habitat and dense canopy areas present barriers to dispersal, butterflies were not observed moving between sites and 75 percent of the movements observed were less than 100 meters (109 yards) (Knutson et al. 1999). In contrast, dispersal distances of greater than 1,150 meters (0.7 miles) between sites were relatively common in the open habitat matrix of savanna and wetlands at Necedah National Wildlife Refuge (King 1998). Occupied habitat patches in Michigan were an average of 69.9 m (76 yards) apart. Refer to Table G1 above and PART I, LIFE HISTORY AND ECOLOGY, Within-habitat movement and between-site dispersal).

The time to recover from burning may vary due to the habitat features and dispersal barriers. Generally, Karner blues that have two broods per year recover more rapidly between fires then butterflies with only one brood per year (Swengel 1996, Swengel and Swengel 1996). At IDNL, selected areas were burned adjacent to other areas with Karner blue populations (Grundel 1994, Kwilosz and Knutson 1999). Compared to adjacent unburned areas, first brood leaf feeding in the burned areas was reduced to 6 percent of that of the unburned area (Grundel 1994). After a fall fire at one site, the relative abundance of Karner blues in the burned units dropped to 33 percent for the two broods following the fire (Kwilosz and Knutson 1999). Thus, even when source populations are nearby, fire can reduce populations for at least one year post-fire. At Fort McCoy, burns were conducted in an area surrounded by sites occupied by Karner blue (Maxwell 1998). First brood larval damage and adult populations were reduced, but the burn stimulated lupine growth, and second brood larval densities were 20 to 50 percent higher in the burned areas. The following year, adult populations were similar in the burned and unburned areas. Thus, when recolonization is high, Karner blue populations can recover rapidly from fires (Maxwell 1998).

It is expected that burned areas within dispersal distance of other large populations of Karner blues will be recolonized more quickly than those areas where butterfly populations are sparse. This is based on the fact that the percentage of butterflies dispersing between sites varies with site characteristics and it is likely that larger populations will have a larger number of individuals moving between sites.

Recommendations:

Recolonization of the burned area can be facilitated by burning only a fraction of the occupied portion of a site and by ensuring that occupied habitat is within dispersal distance. Since dispersal distances between sites vary considerably with habitat type, it will be important to evaluate recolonization distances on a site-specific basis (refer to Table G1)

Management plans should identify the number, design, and rotation of burn units that will allow effective Karner blue re-colonization, i.e. insure Karner blues are within easy dispersal distance of the area to be burned. Never burn an entire metapopulation or important subpopulation at one time. If a subpopulation is essential for the maintenance of a metapopulation, then subdivide the subpopulation into separate management areas. Use existing breaks in the vegetation, such as roads, trails, and wetlands as firebreaks. If possible, avoid scarifying the soil to create mineral soil firebreaks and mow instead. On very small, isolated sites that have small Karner blue populations or are important to maintaining the metapopulation, use alternative management practices such as tree girdling, brush hogging, tree cutting, or mowing instead of fire. For medium to large, isolated sites, dividing the site into a minimum of 3 burn units may be sufficient to insure Karner blue populations persist following fire. On very large sites, with abundant Karner blue butterflies, large sections of habitat can be burned as long as the burns are incomplete (areas are left unburned), and unburned occupied habitat occurs (preferably) adjacent to, or within easy dispersal distance of the burned site.

4. <u>Characteristics of prescribed fire</u>:

Frequency:

Prescribed fire frequency ranges from once every year (for restoring habitat) to once every few decades (for maintaining habitat). Givnish et al. (1988) provide a historical perspective on the issue of burn frequency. They analyzed historical fire records associated with the Albany Pine Bush and suggested that fires returned once every 6 to 18 years, with once in 10 years a likely average. Research at the IDNL suggests a fire interval of 3 to 4 years will create an oak savanna community (Cole, 1990). At the Cedar Creek Natural History Area, Tester (1989) found plant species richness to be highest in areas that were burned approximately every two years.

There is general consensus that more frequent burning is needed to restore habitat than to maintain habitat once structure and composition have been restored. Frequent fire (e.g. one fire in 2 to 3 consecutive years) has been used to restore savanna habitat. Once restored, fire frequency can be reduced. At this stage Haney and Apfelbaum (1990) suggest burn frequencies of 3 to 5 years. However, this may be too frequent to allow Karner blue populations to recover, and less frequent burning at every 6 to 18 years has been suggested (Givnish et al. 1988, Grigore 1992). Also, longer fire return intervals would allow young oaks to establish and grow to a size resistant to fire.

Recent research on the response of prairie insects to prescribed fire suggests that 3 to 4 year fire rotations will be compatible with maintaining insect biodiversity (Panzer 2002). The longer the fire return interval, the more time Karner blue populations will have to recolonize the site and rebuild population numbers. One hypothesis is that if colonization of the burned area by adults is slow or the population does not reproduce very fast, the detrimental effects of a burn could potentially last several generations. Conversely, if colonization is rapid and population growth high, then the effects of the burn could disappear rapidly. The available evidence supports these hypotheses, but additional research will be needed to confirm them.

Longer fire return intervals may be especially important on dry sites, where encroachment by woody vegetation is slow and where lupine densities tend to be lower. Conversely, on some sites, such as Crex Meadows in northeastern Wisconsin, more frequent burning is needed to maintain open savanna/barrens habitat and appears to be compatible with maintaining Karner blue populations. At Crex Meadows Karner blue butterflies are abundant, and habitat patches are close together, which is likely to facilitate rapid recolonization of burned areas. It is also important to consider the factors, which are often site specific that affect the rate of succession. These include species structure and composition, fuel loads, soil type, weather, the history of management on the site, and management subsequent to fire. In addition, significant grazing of woody species after fire could slow succession significantly.

Soil type and topography are important considerations when prescribing burn frequency. For example, steep south facing sand banks in Minnesota sites appear to remain open despite the absence of disturbance, other than occasional soil slumping. Alternatively, sites with soils containing higher organic matter or more mesic microsites may need to be burned relatively more frequently to control woody vegetation. At Crex Meadows and Fish Creek Lake WAs, canopy encroachment and reduced lupine growth occur by the fourth or fifth year after fire management (Darrell Bazzell, WDNR, in litt. 2002).

Intensity:

Fire intensity is thought to influence the amount of direct Karner blue mortality during a fire and what affect the fire has on vegetation. Fire intensity varies with wind speed, humidity, air temperature, burning techniques, fuel type, and quantity of fuel (Mobley et al. 1978, Henderson 1982). Even low intensity fire is expected to result in the mortality of Karner blues (Swengel 1993).

While some trees are likely to be completely killed or top killed by fire (such as jack or red pine), the response of other species (black, bur and pine oak) can vary with fire intensity. For example, low intensity fires may only remove lower branches and top kill young oaks, where high intensity fire may completely kill older, hollow black oak.

Low intensity burns are useful in maintaining sites where the canopy structure is open and where the purpose of the burn is to maintain savanna grass and forb composition. In addition, low intensity burns tend to be patchy, leaving refugia for fire sensitive species (Samways 1990, Swengel 1994).

Season:

Seasonal timing of fires is influential in determining the effects of fire on insects and vegetation (Henderson 1982, Higgins and Piehl 1989, Howe 1994). In general, those species active (growing, hatched, etc.) at the time of burning are more susceptible to damage (Anderson et al. 1970). For example, grasshoppers experienced higher mortality with late compared to early spring burns because insects are more active in late spring (Cancelado and Yonke 1970). Spring burns are effective in inhibiting Eurasian cool-season grasses, allowing greater growth by native warm-season grasses (Collins and Glenn 1988).

Conducting prescribed burns in summer has been suggested for controlling hardwood brush, as this is the season when naturally-occurring lightening fires tend to occur (Howe 1994). In addition, growing-season burns may favor species more than dormant season fires would. In general, dormant season fires (spring or fall) have not been found to be effective in reducing woody tree or shrub cover (Lane 1996, Maxwell and Givnish 1996). Some observations suggest that frequent fires may stimulate denser brush thickets due to increased resprouting (WDNR, 2000).

Recommendations:

Plan to use prescribed fire only according to how the current habitat reflects the needs of the butterfly (rather than a fixed time return interval). During the habitat restoration phase, it is expected that either more frequent burning and/or other means (mechanical, chemical, etc.) will be needed to create the desired structure and composition. In this case managers might use annual burns, but they should not expect to see Karner blue butterflies right away. After the native vegetation is restored a longer fire return interval is desirable (based on the habitat response to fire) to allow Karner blue more time to re-establish healthy populations. For small and/or isolated habitat patches, at least four-year rotations are recommended. For sites with abundant Karner blues, many habitat patches that are within dispersal distance, and that extend over large landscapes, shorter rotations can be used – especially if needed to maintain suitable habitat. However, where shorter rotations are needed to maintain open habitat, it is recommended that when and where possible, other methods to reduce woody vegetation, such as mowing, also be incorporated into habitat maintenance plans.

It is important that management plans are designed so that habitat patches within a metapopulation differ in time since fire, or other disturbance, to prevent all habitat patches from transitioning to unfavorable successional states simultaneously (Thomas Givnish, University of Wisconsin-Madison, pers. comm. 2002). Ideally, neighboring habitat patches should be managed so that they are at varying successional stages. This will allow the maintenance of suitable habitat within dispersal distance of habitat patches that are being lost due to succession. This results in a metapopulation structure that is a landscape mosaic of different aged vegetational states.

The season and intensity of burns should be varied. Season can be varied by alternating between conducting spring, summer and fall burns when possible, as dictated by the condition of the habitat and desired results. Similarly it will be advantageous to vary the intensity of burns, ranging from low to high intensity fires, depending upon what type of fire will best restore/maintain habitat and result in the least Karner blue mortality.

5. <u>The response of lupine and nectar plants to fire</u>:

The immediate, direct effects of fire on lupine plants and seeds may be positive, negative, or neutral. At the Oak Openings in Ohio, the short-term effects of a moderate intensity fire on established lupine plants were increased vegetative growth, flowering, and seed set (Grigore 1992). Nearly all of the seeds on the soil surface and new seedlings were killed. Seeds buried in the soil germinated at similar rates as those in unburned plots (Grigore 1992). At Fort McCoy, prescribed fire resulted in a short-term increase in the number of immature and flowering lupine (Maxwell 1998). Both of these studies indicate that burning may enhance flowering of established plants, and existing data suggest that germination of surviving seeds is not detrimentally affected by moderately intense burning.

Nectar plant species vary in their response to fire, in some cases influenced by the characteristics of the burn (refer to APPENDIX C). Some species are known to have seeds that persist in the soil including blueberry (*Vaccinium* sp.), huckleberry (*Gaylussacia baccata*), raspberry (*Rubus* sp.) and pin cherry (*Prunus pensylvanica*), while other species are able to resprout following fire, such as lead plant (*Amorpha canescens*) (White et al. 1975). For plant species not present in the seed bank or unable to resprout after fire, recolonization of the site will depend in large part on the proximity and abundance of propagules and the dispersal mechanism of the plant (White et al. 1975). Maxwell (1998) found that the following nectar plant species increased following fall and spring burns: sand-cress (*Arabis lyrata*), prairie wild indigo (*Baptisia bracteata* var. *glabrescens*), flowering spurge (*Euphorbia corollata*), bush clover (*Lespedeza capitata*), downy phlox (*Phlox pilosa*), black-eyed Susan (*Rudbeckia hirta*), and dewberry (*Rubus flagellaris*). She also found that western sunflower (*Helianthus occidentalis*) and horsemint (*Monarda punctata*) decreased with fire. In degraded habitats, King (2000) found *Rubus* spp. to increase in percent cover after summer and fall burns. Interestingly, Maxwell (1998) also documented differences in nectar plant responses to fire based upon season of fire and subhabitat. For example, fall burns were better for sand-cress and horsemint.

Prescribed fire may also influence the phenology of Karner blue nectar plants. Preliminary research examining the affects of growing season burns at IDNL suggests that flowering of some nectar plants may be delayed in comparison to unburned plants (Noel Pavlovic, IDNL, pers. comm. 2002). It is unclear whether or how delayed flowering might impact the Karner blue.

Recommendations:

Plant surveys should be done and the information incorporated into management planning. When known, and where possible, time prescribe fire to reduce undesirable, and promote desirable species. If possible, vary the seasonal timing of burns at a site. Fire has a different effect upon any given plant species depending on when it occurs, and repeated application of fire at the same time of the year may select for only a subset of the savanna/barrens plant community. Spring and fall burns will suppress many cool-season grasses, but spring burns may reduce lupine.

For many nectar plants the effects of fire on presence and abundance are not known. Therefore, prescribed fire should be applied within an adaptive management framework, and include pre- and post-treatment monitoring of the effects of fire on nectar plant species.

6. <u>Other habitat responses</u>:

Prescribed fire is often used to reduce the cover of woody or invasive species, and increase the cover of savanna/prairie species. Based on 20 years of prescribed fire management at Cedar Creek Natural History Area in Minnesota, Tester (1989) documented a reduction in tree density and total basal area/hectare – although the changes were not significant. He also detected an increase in prairie species and a decrease in forest species with fire management. At the Konza prairie in Kansas, fire frequency had a strong influence on plant species composition and diversity (Gibson and Hurlbert 1987), and frequent burning doubled the abundance of legumes (Towne and Knapp 1996).

However, not all fires are effective at reducing canopy cover in these ecosystems. Three growing season wildfires at the INDL over the last 15 years have shown that lower branches of oaks are killed and leaves can be scorched up to ten meters into the canopy (Noel Pavlovic**,** U.S. Geological Survey, pers. comm. 2002). In addition, while one of the wildfires (1986) top killed numerous large oaks, subsequent root sprouting of the oaks and other woody species resulted in very dense woody thickets (Martin 1994). Prescribed fires studies in Wisconsin and Minnesota did not reduce canopy cover (Lane 1996, Maxwell and Givnish 1996); indeed, girdling treatments and oak wilt caused greater canopy reduction than the fire treatments. Similarly, Cole et al. (1992) observed that black oak (*Quercus velutina*) stems greater than 5 meters in diameter were largely unaffected by prescribed burning at IDNL. It should be noted, however, that the prescribed burns conducted by Maxwell and Givnish (1996) were low-temperature, low-intensity events that crept through the understory under cool, marginal conditions.

The age and species of tree can influence response to fire. Following prescribed burning treatments in Minnesota (Lane 1996), younger black oaks were either killed or top killed and resprouted. Most adult oaks only had lower branches killed, whereas many older black oaks (which are prone to heart rot that results in hollow trunk centers) were completely killed by fire entering and burning inside the tree. Individual jack pine are unlikely to survive fire, but conditions following fire are often conducive to seed germination.

Prairie grasses, thought to be important for Karner blue roosting, vary in their response to fire, depending upon whether the grass species is cool-season or warm-season as well as which season fire management occurs (Henderson et al. 1988). In general, warm season grasses (which includes many, but not all prairie/savanna grasses) increased with burning, especially late spring burns.

Fire has been shown to both reduce and increase the abundance of species competing with Karner blue food plants**.** Pennsylvania sedge (*Carex pensylvanica*), often an intense competitor with Karner blue food plants, has been found to both increase and decrease in response to fire (Ahlgren 1960, Reich et al. 1990, Abrams 1991) and more information is needed to determine how fire will affect the abundance of this species. Dormant season fires may also stimulate sweet-fern, which can exclude lupine and other prairie elements (WDNR 2000).

Prescribed fire management can impact soil. Soil erosion can occur where slopes are steep and/or mineral soil is exposed. Soil compaction can occur with heavy machinery use, water trucks in particular, that are associated with prescribe fire management.

Recommendations:

As recommended above under other topics, prescribed fire plans will be most effective if tailored to species composition and structure at each site. The species, size, and density of trees will be an important consideration in developing fire regimes. Knowing what native or non-native invasive/competitive species are present at a site, and either tailoring or testing the effect of prescribed fire to reduce these species could be critical for promoting desirable species.

Plan prescribed fires to minimize soil erosion by avoiding intense fires on steep slopes and by avoiding driving heavy equipment during wet weather.

NOTE: Consideration of other rare species

The above considerations for use of fire management for Karner blues may not be sufficient to protect other rare butterflies associated with barrens and savanna habitat. As compared with some species of butterflies occurring in barrens/prairie habitats, the Karner blue is relatively tolerant to fire management, even with high mortality to immatures from fire. The Swengels (Swengel 1995, Swengel and Swengel 1996, Swengel and Swengel 1997) advise the use of haying, grazing or mowing, rather than fire to protect other rare insect species associated with savannas/prairies such as the ottoe skipper, Lenardus skipper, or regal fritillary butterfly.

Alternatives to fire management

In some habitat sites, the local situation may preclude the use of fire as a management tool. For example, some Karner blue subpopulations may be too important to risk extirpation from fire, or some sites may be located where burning is prohibited or is infeasible e.g., more urban areas. Moreover, in some sites other management practices may be more useful and effective or more economical than fire, e.g. mowing (refer to ***NOTE*** above).

Mowing has been used extensively in some states (e.g., New York and Wisconsin) to maintain suitable habitat, however mowing at the wrong time of year could result in reductions in lupine, nectar plants, and Karner blues. Lupine is an early season legume and usually completes its annual life cycle by early to mid-August. Karner blue butterfly eggs are frequently laid on the lower part of lupine plants and second flight adults are known to fly through most of August in many locales. Therefore, in order to minimize harm to the butterfly, mowing should generally be done after August 31 with the mower blade set at 6 - preferably 8 inches from the ground (this will minimize impacts on eggs that will be in the duff layer or on the lower part of lupine plants). If possible mowing should not be done until October or the first hard frost (at least in alternate years) so late-season flowering nectar plants can set seed and reproduce. Annual mowing should also be avoided if possible. To avoid impacts on Karner blues consider: 1) mowing in the winter over frozen ground conditions, 2) using a hand held weed whacker and hand cutting in small areas while avoiding Karner blue occupied lupine patches, or 3) using a side-mounted sickle-bar mower operated from the roadside or outside habitat areas. Mowing during the lupine life cycle will generally have a detrimental effect on lupine and the butterfly and should not be done at that time. The New York DEC is working on a management agreement with Saratoga County that will limit mowing of the airport to after October 15 and before December 31 to help conserve the Karner blue and the frosted elfin butterflies (NYSDEC, in litt. 2001). Karner blue habitat was probably maintained in the past at the airport because county mowers did not mow the airport until after they had finished all mowing responsibilities associated with road maintenance.

Mechanical and hand pruning of shrubs and small trees has also been used to open up Karner blue habitats. However, both of these methods generally require follow-up treatments to control root sprouting (using either prescribed fire or herbicides). Tree girdling, selective herbicide applications, tree harvest, and tree thinning can also be used to open up habitat. To minimize or avoid impacting the Karner blue, these types of activities are best done in occupied habitat during the winter under frozen ground conditions and snow cover.

Rotational grazing may be useful for suppressing competing vegetation, but probably not in the spring when larvae could be consumed with the vegetation.

All of these alternatives to fire management may have some adverse effects on Karner blue metapopulations, although some of these effects are likely to be minor. The greater the adverse effect of the management practice, the more attention should be paid to the disturbance return interval. If the adverse effect is quite large, as it probably is for fire, then return intervals must be carefully managed. If the adverse effect is minor, as it may be for hand pruning of low-density shrubs, then this is not as great a concern.

BROAD-SCALE MANAGEMENT FOR IMPROVING KARNER BLUE METAPOPULATIONS

Management goals at the broad-scale or landscape scale level should be designed to minimize the impact from large-scale detrimental events so that the metapopulation can emerge from the event with enough subpopulations intact that the metapopulation can return to its pre-event vigor. Many environmental events that are potentially detrimental to the Karner blue can extend over broad areas, such as large-scale wildfires, extended periods of extraordinary weather (summer-long hot droughts or extremely delayed and cool summers), or possibly disease epidemics. In these cases, local extirpation is likely to increase throughout the management area, perhaps to the point that the entire metapopulation has no chance of recovery. An appropriate management strategy is one that spreads the risk of extirpation from a particular event over individual subpopulations, such that some subpopulations are likely to survive the particular event intact. This requires an integrated approach towards spreading risk so that the metapopulation can survive the effects from multiple events. Managers should consider the following when managing to reduce risk of metapopulation loss.

Number of Subpopulations and Unknown Factors

Extirpations of subpopulations often have no apparent cause. For example, subpopulations often fluctuate independently from one another, and occasionally isolated subpopulations become extirpated. While there is likely some cause for these extirpations, in most cases habitat managers will not know the cause. To guard against an accumulation of many small effects leading to a major metapopulation reduction, managers should maintain some number of independent subpopulations. If each isolated subpopulation within the metapopulation is susceptible to random extirpation events, then increasing the number of subpopulations within the metapopulation will reduce the effect that isolated extirpations have on the metapopulation. At the low extreme, a metapopulation is composed of only two subpopulations. Additional subpopulations will be needed to guard against random extirpation events. Clear recommendations of the number needed cannot be provided at this time.

Area of Metapopulation

A metapopulation that occupies a small area (1-2 square kilometers or 0.38-0.76 square miles) may be at risk from events such as large-scale wildfire. While some individual Karner blues are likely to survive such an event, population densities within each subpopulation may be depressed to the point that the metapopulation cannot recover, and is extirpated within a few generations. One management response to this risk is to have the metapopulation occupy an area larger than the area of a typical wildfire (based on historical fire records).

Barriers

Many events such as wildfire or disease epidemics, flow across landscapes. Thus, barriers with the potential to stop their spread can play an important role in long-term metapopulation viability for the Karner blue. For example, in highly fragmented landscapes, such as in Gary, Indiana, wildfire is not likely to spread from one isolated habitat patch to the next and large-scale wildfire is not a likely threat to Karner blue (although the fragmentation itself creates problems associated with metapopulation connectivity). In less fragmented landscapes, firebreaks (such as wide roadways) may be incorporated into the metapopulation management plan to reduce the risk that a large-scale fire would destroy the majority of the metapopulation.

Similarly, disease epidemics are likely to spread throughout clusters of nearby Karner blue subpopulations. One way to protect against epidemics is to have a few subpopulations located at some distance away from their nearest neighbors so that interchange of adults is a relatively rare event. While this seems diametrically opposed to the earlier discussions that strongly recommend greater connectivity among subpopulations, having a few relatively more isolated subpopulations could reduce the risk of spread of disease.

Diversity of Habitat Among Occupied Sites

The adverse effects of many large-scale factors can be mitigated by increasing the diversity of sites in a metapopulation that support Karner blues. For example, wildfire may skip over mesic sites or sites with little fuel load, leaving behind pockets of Karner blues to repopulate adjacent areas. Similarly mesic sites may act as refuges for Karner blues during hot droughts, while xeric sites could be refuges during an unusually cool summer. The principles here are very similar to those discussed above under habitat heterogeneity, but in that section, the focus was on heterogeneity within occupied sites, whereas here, the emphasis is on heterogeneity among occupied sites. Either of these forms of heterogeneity may also have beneficial effects on other rare species associated with Karner blue habitat (refer to APPENDIX D).

Buffering the Metapopulation

Metapopulations should be buffered against catastrophic disturbances, disease, minor climatic fluctuations, and other disturbances that that could adversely affect the metapopulation. One example of buffering is to secure sufficient land to preclude fragmentation of the metapopulation by development and to provide variations in subhabitats and microclimates. Another example of buffering is the establishment of wide enough fire breaks in management areas to ensure only a subset of occupied habitat is burned at any one time and to reduce the impact of wildfires on the metapopulation.

LITERATURE CITED

Abrams, M. 1991. Post-fire revegetation of jack pine sites in Michigan: an example of successional complexities. Proceedings of the 17th Tall Timbers Fire Ecology Conference. Tall Timbers Research Station, Tallahassee, Florida. pp. 197-209.

Ahlgren, C. E. 1960. Some effects of fire on reproduction and growth of vegetation in northeastern Minnesota. *Ecology* 41: 431-45.

Anderson, K. L., E. F. Smith and C. E. Owensby. 1970. Burning bluestem range. *Journal of Range Management* 23: 81-92.

Andow, D. A., R. J. Baker and C. P. Lane. Research needs for management and recovery of Karner blue butterfly. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota – St. Paul. 1994. Miscellaneous publication 84-1994. pp. 153-162.

Bidwell, Andrew. 1994. Mark-release-recapture of Karner blue butterflies (*Lycaeides melissa samuelis*) at Fort McCoy Military Reservation. Report submitted to USFWS.

Bleser, C. A. 1993. Status survey, management and monitoring activities for the Karner blue butterfly (*Lycaeides melissa samuelis*) in Wisconsin. Final report submitted to the U.S. Fish and Wildlife Service. 86 pp.

Cancelado, R., and T. R. Yonke. 1970. Effect of prairie burning on insect populations. *Journal of the Kansas Entomological Society* 43: 274-81.

Collins, S. L. and S. M. Glenn. Disturbance and community structure in North American prairies. *In* J. J. During, J. A. Werger, and J. H. Williams (eds.), Diversity and Pattern in Plant Communities. The Haugue, Netherlands: SPB Scientific Publications, 1988. pp. 131-43.

Fried, C. S. 1987. Dispersal of the Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov) in the Albany Pine Bush. Report submitted to the Endangered Species Unit of the New York State Department of the Environmental Conservation.

Fuller, Steven G. 1998. Interim Report: Summary of individual mark recapture 1998. S.U.N.Y. College of Environmental Science and Forestry.

Gibson, D. J. and L. C. Hurlbert. 1987. Effects of fire, topography and year-to-year climatic variation on species composition in tallgrass prairie. *Vegetatio* 72(3): 175-185.

Givnish, T. J., E. S. Menges and D. F. Schweitzer. 1988. Minimum area requirements for long-term conservation of the Albany Pine Bush and Karner blue butterfly: an assessment. Report to the City of Albany from Malcom Pirnie, Inc. Albany, NewYork**.**

Greenfield, L. M. 1997. Habitat quality and utlilization analysis in a spatial context: the case of *Lupinus perennis* L. and *Lycaeides melissa samuelis* Nabokov, (Lepidoptera: Lycaenidae) (masters thesis) Michigan State University. 67 pp.

Grigore, M. 1992. The short-term effect of fire on wild lupine *(Lupinus perennis L.)* (masters thesis) University of Toledo – Toledo.

Grundel, R. 1994. The effects of lupine quality and habitat fragment quality on larval feeding intensity in the Karner blue butterfly (*Lycaeides melissa samuelis*). Report to the U. S. Fish and Wildlife Service (Region 3), Fort Snelling, Minnesota.

Haney, A. and S. Apfelbaum. 1990. Structure and dynamics of Midwest oak savannas. *In*, J. M. Sweeny (ed.), Managing Dynamic Ecosystems. Wildlife Society: West Lafayette, Indiana.

Henderson, R. 1982. Vegetation - Fire ecology of tallgrass prairie. *Natural Areas Journal.* 2, No. 3: 17-26.

Henderson, R. A., David L. Lovell and Evelyn A. Howell. 1988. The flowering responses of 7 grasses to seasonal timing of prescribed burns in remnant Wisconsin prairie. *In*, T. Gragg and J. Stubbendieck (eds.), Proceedings of the eighth North American Prairie Conference: Prairie Pioneers: ecology, history, and culture. pp. 7-10.

Herms, C. P., D. G. McCullough, L. S. Bauer, R. A. Haack, D. L. Miller and N. R. Dubois. 1997. Susceptibility of the endangered Karner blue butterfly (Lepidoptera: Lycaenidae) to *Bacillus thuringiensis* var. *kurstaki* used for gypsy moth suppression in Michigan. *The Great Lakes Entomologist* 30(4): 125 – 141.

Higgins, K. F and J. L. Piehl. 1989. Effects of fire in the northern Great Plains. EC-761. U.S. Fish and Wildlife Service, South Dakota State University, and U.S. Department of Agriculture.

Howe, H. F. 1994. Managing species diversity in tallgrass prairie: assumptions and implications. *Conservation Biology* 8, no. 3: 691-704.

King, R. S. 1994. Oak Barrens Restoration Plan. Forest Management Plan, Norman Brown. Necedah National Wildlife Refuge, Necedah, Wisconsin.

King, Richard S. 1998. Dispersal of Karner blue butterflies (*Lycaeides melissa samuelis* Nabokov) at Necedah National Wildlife Refuge. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 86:101-110.

King, R. S. 1998. Spatial ecology, dispersal patterns and monitoring methods for the Karner blue butterfly, *Lycaeides melissa samuelis* on Necedah National Wildlife Refuge. Report submitted to the National Fish and Wildlife Foundation, U.S. Fish and Wildlife Service, and the Forest Industry. 30 pp.

King, R. S. 2000. Habitat management for the Karner blue butterfly (*Lycaeides melissa samuelis*): evaluating the short-term and long-term consequences. Necedah National Wildlife Refuge, Necedah, Wisconsin. 16 pp. + figures and tables.

King, R. S. 2002. Do summer burns result in adult Karner blue butterfly mortality? (Wisconsin). *Ecological Restoration*. 20:143-144.

Knutson, R. L., J. R. Kwilosz and R. Grundel. 1999. Movement patterns and population characteristics of the Karner blue butterfly (*Lycaeides melissa samuelis*) at Indiana Dunes National Lakeshore. *Natural Areas Journal* 19: 2, 109-120.

Kwilosz, J. R. and R. L. Knutson. 1999. Prescribed fire management of Karner blue butterfly habitat at Indiana Dunes National Lakeshore. *Natural Areas Journal* 19: 98-108.

Lane, C. P. 1996. Population monitoring and habitat restoration for the Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov): 1995 Progress Report. Report submitted to the U.S. Fish and Wildlife Service and the Minnesota Department of Natural Resources.

Lane, C. P. 1997. Forest management guidelines; developing management plans compatible with Karner blue butterfly persistence. Prepared for the Wisconsin Department of Natural Resources, Madison, Wisconsin and the U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 124 pp.

Lawrence, W. S. 1994. Karner blue butterfly populations in the Allegan State Game Area, Michigan. In, Andow, D. Baker R. Lane C., editors. Karner blue butterfly; a symbol of a vanishing landscape. St. Paul, Minnesota: Agricultural Experiment Station, University of Minnesota. pp. 53-62.

Lawrence, William S. and Andrea C. Cook. 1989. The status and management of Karner blue (*Lycaeides melissa samuelis*) populations in the Allegan State Game Area, Michigan. A report submitted to The Nature Conservancy, Michigan Field Office.

Loertscher, M., A. Erhardt and J. Zettel. 1995. Microdistribution of butterflies in a mosaic-like habitat: The role of nectar sources. *Ecography*. 18:15-26.

Martin, M. L. 1994. Karner blue butterfly in Indiana: 1009 status survey for the U. S. Fish and Wildlife Service. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota AgriculturalExperiment Station, University of Minnesota – St. Paul. 1994. Miscellaneous publication 84-1994. pp. 97-105

Maxwell, J. A. 1998. The conservation of the Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov): Ecological studies of habitat creation and management (Ph.D dissertation) University of Wisconsin – Madison.

Maxwell, J. A. and T. J. Givnish. 1994. Research on the Karner blue butterfly at Fort McCoy, Wisconsin: Progress report for the 1993 field season. Report submitted to the U.S. Fish and Wildlife Service and the U.S. Department of the Army.

Maxwell, J. A. and T. J. Givnish. 1996. Research on the Karner blue butterfly at Fort McCoy, Wisconsin: Progress report for the 1994 field season. Report submitted to the U.S. Fish and Wildlife Service and the U.S. Department of the Army.

Mobley, H. E., R. S. Jackson, W. E. Balmer, W. E. Ruziska and W. A. Hough. 1978. A guide for prescribed fire in southern forests. U.S.D.A. Forest Service, Southeastern Area, Atlanta, Georgia.

Panzer R. 2002. Compatibility of prescribed burning with the conservation of insects in small, isolated prairie reserves. *Conservation Biology* 16:1-13.

Payne, N. F. and Bryant F. C. 1994. Techniques for wildlife management of uplands. McGraw-Hill, Inc., New York.

Reich, P. B., M. D. Abrams, D. S. Ellsworth, E. L. Kruger and T. J. Tabone. 1990. Fire affects ecophysiology and community dynamics of central Wisconsin oak forest regeneration. *Ecology* 71, No. 6: 2179-90.

Samways, M. J. 1990. Landforms and winter habitat refugia in the conservation of montane grasshoppers in southern Africa. *Conservation Biology* 4: 375-82.

Schultz, C. B. and E. E. Crone. 1998. Burning prairie to restore butterfly habitat: a modeling approach to management tradeoffs for the Fender's blue. *Restoration Ecology* 6: 244-52.

Schweitzer, Dale F. 1979. Further investigations relevant to the Crossgates population of Karner blue butterfly. Report to New York Department of Environmental Conservation and Jason M. Cortell and Assoc. Inc. 44 pp.

Sferra, Nancy J., David N. Ewert, Christopher Clampitt, Harvey Ballard, John M. Aguiar, and Traci Darnell. 1993. Management of oak savanna and oak barrens habitat in Newaygo and Muskegon counties, Michigan for Karner blue butterflies (*Lycaeides melissa samuelis*) and other oak savanna invertebrates: final results. East Lansing, Michigan: The Nature Conservancy.

Sucoff, Edward. 1997. Effect of three herbicides on the vegetative growth and flowering of wild lupine - final report 2nd year observations. Department of Forest Resources, University of Minnesota - St. Paul . 3 pp.

Sucoff, Edward. 1998. Effect of exposing eggs to herbicides on the development of Karner blue butterfly. Department of Forest Resources, University of Minnesota – St. Paul. 7pp.

Swengel, A. B. Observations of Karner blues and the barrens butterfly community in Wisconsin. 1993. Wisconsin. Report. 909 Birch Street, Baraboo, Wisconsin, 53913.

Swengel, A. B. 1994. Observations on the effects of fire on Karner blue butterflies. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota – St. Paul. 1994. Miscellaneous publication 84-1994. pp. 81-86.

Swengel, A. B. 1995. Observations of spring larvae of *Lycaeides melissa samuelis* (Lepidoptera: Lycaenidae) in central Wisconsin. *Great Lakes Entomologist* 28: 155-170.

Swengel, A. B. 1996. Effects of fire and hay management on abundance of prairie butterflies. *Biological Conservation* 76: 73-85.

Swengel, A. B. and S. R. Swengel. 1996. Factors affecting abundance of adult Karner blues (*Lycaeides melissa samuelis*) (Lepidoptera: Lycaenidae) in Wisconsin surveys 1987-95. *The Great Lakes Entomologist*. 29:93-105.

Swengel, A. B. and S. R. Swengel. 1997. Co-occurrence of prairie and barrens butterflies; applications to ecosystem conservation. *Journal of Insect Conservation* 1: 131-44.

Swengel, A. B. and S. R. Swengel. 2001. Effects of prairie and barrens management on butterfly faunal composition. *Biodiversity and Conservation* 10: 757-85.

Tester, J. R. 1989. Effects of fire frequency on oak savanna in east-central Minnesota. *Bulley of the Torrey Botanical Club* 116: 134-44.

Towne, E.G. and A. K. Knapp. 1996. Biomass and density responses in tallgrass prairie legumes to annual fire and topographic position. *American Journal of Botany* 83(2):175-179.

Welch, R. 1993. Dispersal and colonization behavior in the Karner blue butterfly (*Lycaeides melissa samuelis*) in central Wisconsin. Report submitted to the U.S. Fish and Wildlife Service, Green Bay Field Office, New Franken, Wisconsin.

White, Larry D., L. D. Harris, J. E. Johnston and D. G. Milchunas. 1975. Impact of site preparation on flatwoods wildlife habitat. *Proceedings of the Annual Conference of the Southeast Game and Fish Commission.* 20: 347-53.

Wisconsin Department of Natural Resources, Bureau of Endangered Resources. 1998. Wildlife Management Guidelines for Karner Blue. Wisconsin Department of Natural Resources, Madison, Wisconsin.

Wisconsin Department of Natural Resources. 2000. Wisconsin statewide Karner blue butterfly habitat conservation plan and environmental impact statement. PUBL-SS-947-00. Wisconsin Department of Natural Resources, Madison. 386 pp. + appendices. (Available from the Wisconsin DNR HCP Coordinator (608-261-6451) or the U.S. Fish and Wildlife Service Office in Green Bay, Wisconsin (920-866-1717).

APPENDIX H

MONITORING REQUIREMENTS AND GUIDELINES

MINIMUM VIABLE METAPOPULATION (VP)

Monitoring Requirements

A minimum viable population (VP) will have at least 3,000 individuals and a management and monitoring plan that buffers the VP against adverse disturbance and threats, maintains suitable habitat, and has appropriate responses to potential declines. The monitoring procedures will need to be designed specifically for each VP, so detailed monitoring requirements cannot be specified. Despite the variation in design, each monitoring system must provide the following information.

1. <u>Karner blue butterfly relative abundance</u>

   All subpopulations shall be monitored annually during either the first or second flight. Preference should be given to monitoring during the second flight unless monitoring during the first flight is more convenient. Preference should also be given to monitoring the same flight every year. In most cases, butterflies will be more abundant and easier to count during the second flight. Transect walks following standardized protocols are a suitable method. Ideally, they can be calibrated with mark-release-recapture estimates so that subpopulation size can be estimated, but this is not essential.

2. <u>Habitat suitability in relation to disturbances and threats</u>

   The monitoring system shall be developed in relation to identified adverse disturbances and threats to survival of the metapopulation. The monitoring system shall monitor the causes, if known, of the disturbances and threats, the subpopulation and habitat response to these disturbances and threats, or both. Monitoring of habitat in relation to potential threats shall be done initially and then every three years.

3. <u>Connectivity</u>

   The connectivity of subpopulations shall be monitored initially and every three years to confirm that subpopulations remain connected and that dispersal corridors remain functional. For example, lupine and nectar plant abundance might be recorded in relevant areas between subpopulations. Distances between subpopulations shall be monitored. The average nearest-neighbor distance between subpopulations should be no more than 1 kilometer (0.62 miles), and the maximum distance between subpopulations no greater than 2 kilometers (1.24 miles). In some cases the 1 kilometer distance may be too far (PART II, RECOVERY OBJECTIVE). Refer to APPENDIX G for guidance on establishing connectivity between subpopulations.

4. Quantity of suitable habitat

    The area of suitable habitat in occupied and occupiable sites in the metapopulation shall be monitored annually. This minimally will involve estimating the area of lupine and adult nectar plants in occupied and occupiable habitat (refer to APPENDIX A, definitions of suitable habitat and occupiable sites). Use of aerial photography may be a suitable method for monitoring the area of habitat once the methods are confirmed. The rate that lupine grows and enlarges the area it covers is an additional possible parameter that could be measured.

5. Habitat quality

    Habitat quality shall be evaluated annually. It may be easiest to evaluate during the first brood. Some method of documenting habitat quality at each subpopulation that will persist beyond the tenure of the data collector (such as photo-points) is necessary. Types and abundance of adult nectar for both generations, spatial distribution of canopy cover, and generation to generation variation in lupine quality might be monitored.

Action Triggers

An action trigger is the information obtained from monitoring that triggers some change in management activity. Action triggers will depend in part on the anticipated causes of metapopulation decline, which are the identified disturbances and threats to the metapopulation. In the following discussion an expected or observed decline in the metapopulation size of Karner blue butterfly is used to illustrate how an action trigger could be implemented. It is expected that each VP will have unique circumstances and therefore will have unique action triggers.

Known cause of metapopulation decline

For example, habitat destruction, such as transformation of Karner blue habitat into shopping centers, industrial parks or housing is a known cause of decline in metapopulations of Karner blue butterfly. The monitoring system could monitor plans to develop suitable Karner blue habitat. Any change in development plans on these sites could trigger a variety of actions, including contacts with landowners to encourage habitat protection, negotiation with the landowner to mitigate take, request for remedy from local or state governments, and legal remedies.

Suspected cause of metapopulation decline

For example, adverse weather for Karner blue, such as hot, dry weather that greatly accelerates lupine senescence could cause a decline in metapopulation size, but it would be difficult to prove that adverse weather was the main cause of the decline. Because this kind of weather is detrimental to Karner blue, metapopulations may be observed to crash during these years. Such a crash would trigger cause for concern; but one possible action is to wait until the next year. If during the next year, weather conditions are no longer detrimental for the Karner blue and the metapopulation does not exhibit signs of recovery on its own, then more intensive management to enhance Karner blue subpopulations should be initiated. Under these kinds of conditions, communication with managers of other metapopulations would be particularly useful.

Unknown cause of metapopulation decline

The metapopulation decline itself is the action trigger. Because of natural fluctuations in metapopulation size, an observed decline in metapopulation from one year to the next may or may not imply that the metapopulation is actually in decline. Thus, the action trigger should be related to the observed annual variation in the metapopulation, and an unexplained decline that persists over several years should trigger more serious actions. For a metapopulation with many subpopulations (more than ten), a potential trigger could be a decline in occupancy that persists for three years or an annual decline that exceeds two times the standard deviation of typical variation in occupancy (an occurrence of once in twenty years). For a larger metapopulation that has few subpopulations (less than or equal to ten), a potential trigger could be a decline in metapopulation density that persists for three years or an annual decline that exceeds two times the standard deviation of typical annual variation in metapopulation size (an occurrence of once every twenty years). For a minimum viable metapopulation, a potential trigger could be a decline in metapopulation density that persists for two years or an annual decline that exceeds 1.7 times the standard deviation of typical annual variation in metapopulation size (an occurrence of once every ten years). The response to these triggers may vary among metapopulations in the different recovery units.

LARGE VIABLE METAPOPULATION (LP)

Monitoring Requirements

The purpose of monitoring a large viable metapopulation (LP) is to determine that 1) the metapopulation is a LP for reclassification purposes, 2) that it remains large enough that it still can be considered a LP and qualify for delisting and 3) to determine when it no longer can be considered a LP. Action triggers are needed to determine when it is necessary to intensify management and monitoring efforts of the LP, and to determine when the metapopulation is just a VP and no longer a LP.

Minimally, the size of the LP and the habitat of the LP must be monitored.

1. Monitoring the size of the LP for reclassification purposes:

   To qualify for reclassification, the metapopulation should have at least 6,000 butterflies (confirmed by having demonstrated through monitoring that 6,000 butterflies are present 4 out of 5 years, or as otherwise approved by the Service in conjunction with the Recovery Team). In addition, the area of the metapopulation should be distributed over 6.67 contiguous square miles (of an approximate ten square miles total area), and about 640 acres (one square mile) of suitable habitat is present (refer to PART II, RECOVERY OBJECTIVE, Reclassification Criteria). To qualify for delisting, the LP should be monitored sufficiently to demonstrate that the LP is being maintained. In addition there must be a management plan in place that is implemented on the ground to maintain the metapopulation and a monitoring plan to detect trends in the metapopulation. The 6,000 requirement is not intended to generate a burdensome or absolute sampling requirement (refer to APPENDIX F, METAPOPULATION STRUCTURE)

Potential monitoring methods are described below.

a. Sample a subset of the metapopulation (as noted above) in a statistically meaningful way and extrapolate an estimate of the total metapopulation each year

b. Sample the largest subpopulations each year and demonstrate that the sampled subpopulations alone have more than 6,000 butterflies, a method being used by Fort McCoy (refer to No. 8 in EXAMPLES OF MONITORING FORMS AND METHODS NOW IN USE at the end of this APPENDIX). This approach should also document sampling effort and include methods to demonstrate that Karner blues are distributed in a sufficient number of habitat areas (subpopulations) to meet the required spatial distribution of the metapopulation.

c. Monitor a number of patches where one can see larger numbers of Karner blues in a visit (e.g. 50), multiply the number of Karner blues seen by 3 (e.g. 3 x 50 = 150), then add up the numbers of butterflies to get a conservative population estimate (Dale Schweitzer, pers.comm. 2002, Schweitzer 1994). It would be most beneficial to monitor during the peak flight when more Karner blues are present. This method should also entail demonstrating the spatial distribution of the butterfly across the metapopulation. Ideally, one may be able to monitor enough sites to demonstrate that 6,000 Karner blues are present and distributed across the metapopulation.

2. <u>Monitoring the size of an LP for delisting purposes</u>:

To demonstrate that the LP is being maintained after the initial 5 years of monitoring for reclassification purposes, monitoring should be sufficient to demonstrate maintenance of the LP and could entail the use of four-year running averages to calculate populations numbers (refer to Table H1). Monitoring could include the following steps.

a. For any of the monitoring methods used, calculate a four-year running average population size and/or sampling effort and record the four-year trend. If the population size is not estimated every year, the four-year average is the average of the estimates during a four year period. For example, if the population size had been estimated in 2 of the 4 years, then the average of those two estimates should be considered the four-year average.

b. If the four-year running average population size/sampling effort is larger than the minimum criteria for an LP (6,000), then no additional action is required. However, if the four-year trend demonstrates decreasing metapopulation sizes (or the need to increase the sampling effort to confirm the minimum 6,000 butterflies), then analysis of the cause of the decline should be made and implementation of reliable and feasible alterations in management to improve the metapopulation undertaken as appropriate.

c. If the four-year running average metapopulation is smaller than the minimum criterion for an LP (6,000) then determine the cause and alter management and associated monitoring appropriately. During the next year, alter management to increase the metapopulation. Continue monitoring and estimating the four-year running average. Intensified monitoring can be implemented to improve precision.

d. If the four-year running average metapopulation size remains below the minimum for five sequential years, then the metapopulation must be considered a minimum viable metapopulation. Management and monitoring must be changed to conform to the requirements for a minimum viable metapopulation or steps taken to reestablish the LP.

Table H1. Examples of four-4 year running averages

	Reclassification Monitoring			Delisting Monitoring					
	Year -3	Year -2	Year -1	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Estimated population	9,000	5,000	10,000	8,000	6,000	NA	7,000	NA	11,000
Four-year average	--	--	--	8,000	7,250	8,000	7,000	6,500	9,000

Note: The use of other streamlined monitoring methods for documenting the presence of 6,000 butterflies may be appropriate as well. Recovery tasks in this plan include the further development of monitoring protocols (refer to PART II, RECOVERY TASKS, Task 3.4). If monitoring methods are developed by other than the Recovery Team, they should be reviewed by the Service or the recovery team for approval prior to implementing.

Monitoring the habitat of the LP

Suitable habitat shall be monitored to ensure that the spatial requirements of an LP are maintained. The extent and distribution of extant and potentially suitable habitat might be monitored using remote sensing (such as aerial photos or satellite imagery). This can be keyed to detection of exposed mineral soil, ground layer vegetation, and characteristic tree cover. Ground truthing is strongly suggested. It may be conducted less than annually (three to five years), and the frequency of monitoring should be related to an analysis of threats. Monitoring the quantity of available lupine-supporting habitat is also recommended. Research on the use of satellite imagery to detect lupine is currently ongoing (WDNR 2002b).

METHODS FOR ESTIMATING ABUNDANCE OF BUTTERFLIES

Mark-release-recapture and four types of transect monitoring methods are described below for consideration by managers when designing a Karner blue monitoring program. There are no methods that provide absolute estimates of butterfly abundance. No method is very precise except when conducted nearly to the point of being a census of the population. Most of the methods have a high degree of repeatability, especially when conducted under similar environmental conditions.

Mark-Release-Recapture

Mark-release-recapture (MRR) research involves capturing and marking individuals on one occasion and returning to the site and capturing individuals on at least one additional occasion and counting the number of unmarked and marked animals which are captured. Some researchers believe the MRR method is the most accurate method used to estimate butterfly numbers in most situations (Gall 1985; Schweitzer 1994). This method is also viewed as cost prohibitive for most situations because it requires multiple sample efforts (Thomas 1983, Schweitzer 1994).

When MRR is used to obtain population estimates, caution is urged when interpreting the results because MRR requires a number of assumptions (Opler 1995). One significant assumption related to estimating Karner blue butterfly numbers is that marked individuals might leave the area. Emigration out of an area will lower the portion of marked to unmarked individuals, which will inflate resulting population estimates (Brown and Boyce 1996). Another assumption of MRR is that each individual must have an equal chance of being captured in subsequent visits to a site (Gall 1985). A concern with MRR population estimates is that they can be highly variable (Pollard and Yates 1993). However this is generally not the case if samples are frequent enough (daily or nearly so for the Karner blue), sample gaps are avoided, and mark intensity is high from day 1 or 2 through the rest of the effort (Gall 1985, Schweitzer 1994). MRR formulae allow for daily error estimates and these should be used to assess reliability of the daily estimates.

When there is significant movement between nearby habitat sites, both should be well sampled and the data pooled. When emigration is substantial, which has been observed at Necedah National Wildlife Refuge, the resulting population estimates will be inflated (Brown and Boyce 1996). This concern can be addressed by marking frequently (usually daily) and maintaining a high mark intensity. With some species MRR population estimates are suspect because of the large estimated variances (Pollard and Yates 1993). For the Karner blue populations examined by Schweitzer (1994), variances were low because mark intensities were very high (> 50%) and sampling was conducted daily. Gaps between samples (occasionally only a single missed day) and low mark intensities commonly induce large fluctuations in population estimates. Associated daily variances (confidence intervals) will almost always be helpful in identifying unreliable estimates when they occur. Thus, the assumptions pertaining to MRR appear to be reasonably well met with the Karner blue butterfly, providing precautions are taken in the sampling regime (Schweitzer 1994).

Generally MRR should not be used annually for population monitoring because of the expense and effort involved. MRR must be used to calibrate transect counts when greater accuracy is needed (Dale Schweitzer, TNC, in litt. 2002), but most monitoring probably will rely on transect methods. Directly comparing data collected using the same methods rather than comparing them to MRR estimates will often lead to more accurate inferences, especially if the MRR period is brief. MRR is recommended only when an accurate population size estimate is needed.

Only experienced persons should do MRR because it involves handling individuals at least once and often several times. Schweitzer (1994) considers an injury rate of 1% of all individuals processed one or more times to be "high" and 5% "excessive." Refer to Schweitzer (1994) for several suggestions for keeping the injury rate low.

A variety of software packages exist for estimating absolute population estimates from MRR data. If the software is available analyses by two or more models should be attempted. The Jolly-Seber method should be included, and the software "Jolly" (Pollock et al. 1990) has received wide use among Karner blue researchers. Capture histories are entered into this software to provide a population estimate.

When MRR is used one should either cover most of the flight period for at least one sex, or concentrate sampling near the known peak of the flight. Sampling the entire flight period will require more than two weeks of daily sampling. MMR data should always be recorded and analyzed by sex. A pooled sex analysis can also be conducted. Sampling should be conducted every day, and if the sample period is five days or less, no days should be missed, except for bad weather. On the first day, sampling should start early to mark intensely. Throughout the period, a mark intensity of at least 50% should be maintained. Substantial recapture sample sizes should be attained every day, but excessive amounts of time should not be wasted in small sites, unless necessary on the first day. Spending too much time in small sites could cause excessive disturbance to the butterfly (and its habitat) and disrupt normal activity. Schweitzer (1994) provides suggestions pertaining to Karner blue MRR, and Gall (1985) provides references for a general review of the topic. Schweitzer, however, has observed that if almost all individuals are marked shortly after eclosion (emergence from pupae as adults), population estimates can be less than the actual number marked (Dale Schweitzer, pers. comm. 2000).

MRR will estimate population size only from the second day of sampling until the end. No estimate can be made for the first day, and the estimate on the last day is usually not very reliable, so good estimates can be obtained only from days two through n-1. If the sample period is not the entire flight period (at least for the sex being analyzed) then the brood size estimate will not be for the entire brood. Schweitzer (1994) suggested that the actual brood size could be estimated by tripling the mean daily estimate for the peak of the flight period. Schweitzer recommends sampling on at least five consecutive sample days, which should yield three good estimates. This short cut saves considerable time over a complete MRR study but it does not produce as good a population estimate. The peak period for the entire population typically lasts about ten days (based mainly on second brood data).

Transect Counts

Various types of transect counts are used commonly to monitor butterfly populations. They are excellent when relative population size needs to be known. They can be quite reliable for comparisons of the same site over time. The transects can be temporary (Pollard-Yates, Thomas, and Straight-line) or permanent (Straight-line and Meandering). The temporary transect methods require some skill to conduct them reliably, and the permanent transect methods require more time to set up. DISTANCE software can be used with transect counts to provide population estimates (Richard S. King, USFWS, pers. comm. 1999). DISTANCE software can be obtained free from the following web site: www.mbr.nbs.gov/software.html#distance.

1. <u>Pollard-Yates Transects</u>

   Pollard-Yates (PY) transect (Pollard and Yates 1993) counts are also referred to as "walk-through" or "loop" counts. To conduct PY counts an observer meanders through a site covering all the areas that look like good habitat. For Karner blue transects, an observer would target sampling of lupine patches and suitable nectar sources during the first or second flight. The route that the observer walks on a given unit can change from day to day as the locations of nectar sources and aggregations of butterflies change. While conducting PY counts observers record the number of butterflies seen within a fixed width from the transect or from an unlimited distance depending on how the data are to be used. The observer should also record the time spent conducting each count or the transect length. A limitation of PY counts is that they are representative of good habitat and are not representative of the entire site, thus it is recommended that they be used to measure year to year trends for individual sites (Pollard and Yates 1993). Necedah NWR uses PY transect data to derive Karner blue butterfly population numbers. The use of the PY transects is based on research by King (2000) who evaluated straight line survey, MRR, and PY sampling methods on study sites at the Necedah NWR. His data showed that population estimates derived from PY transects had the highest correlation with Karner blue butterflies found on study plots intensely sampled for the butterfly. Population estimates derived from straight-line-transects showed the second best correlation followed by MRR estimates.

2. <u>Thomas Transects</u>

   Thomas transects (Thomas 1983) are the same as PY transects except that the habitat is stratified and stratified sampling is used. Prior to conducting counts, an area is stratified into several relatively homogeneous cover types. Each cover type is then surveyed using the PY counts. This ensures that all significant subhabitats are surveyed, which differs from the PY counts where only the good habitat is surveyed. Indexes from each cover type can then be summed to provide a total index for each unit.

3. Straight-line Transects

Straight-line (SL) transects are established on each unit at random, and transects run in a straight line crossing any or all cover types that lay in the direction that the transect is run. Although used widely for songbird surveys, SL transects have not received much use among lepidopterists. SL transects offer the advantage of being unbiased in regard to cover type. SL transects provide observers with the ability to compare between units because the samples are unbiased. The unbiased samples provided by SL transects are the opposite of PY counts that only provide samples of what the observer deemed good habitat. Thomas transects also provide an unbiased sample of the entire unit but in a more cumbersome way. When conducting research where comparisons between units are required, SL transects can be effective. The main weakness of SL transects is that it is not unusual to miss large aggregations of butterflies. Consequently, for butterfly sampling, SL transects provide accurate information only when the coverage of the habitat is high (perhaps >50%).

4. Meandering Transects

Meandering transects have not been compared to the other methods, but they may combine some of the advantages of the other methods. A permanent transect that meanders through the habitat like a PY transect is established, and sampling is conducted along those marked transects. Permanent transects enable count data to be compared across observers. Establishing the transects requires skill, much like the PY transects, but once established they require less skill to maintain the sampling. Yearly variation in the location of nectar sources is not likely to influence transect counts for the spring flight, but could be an important consideration for summer flight counts (Swengel and Swengel 1998). Meandering transects are used for monitoring populations of Karner blue butterflies at Whitewater WMA, Minnesota.

All transect types can be used to provide relative population estimates. Relative population estimates are simply the number of individuals counted on a unit in a given year or other time period. Relative population estimates can be standardized by converting counts to butterflies/minute, butterflies/meter of transect, and/or density estimates. Relative population estimates should only be used to compare between time periods for a single spatial unit. Relative population estimates can be used to make comparisons between units only if habitats are similar and sampling effort is the same. Both Thomas and SL transect provide unbiased samples that can be extrapolated to the entire site. The Thomas method requires that each cover type within a unit be sampled individually. In many cases, PY and Meandering transects provide excellent population estimates, but these cannot be extrapolated to the entire site. Which method is best may vary among sites.

Density estimates from all transect types can be obtained by counting all the individuals within a fixed width on each side of the transect or by counting all individuals regardless of the distance from the transect and estimating the perpendicular distance to each individual. Fixed width counts require that the observer assume every individual within that fixed width is counted. All individuals outside the predetermined fixed width are ignored. The length of the transect is then multiplied by the fixed width to determine the sampled area. The sample area for a transect that was 1,000 meters long and had a fixed width of 3 meters would be 6,000 meters^2 because 3,000 meters^2 are sampled on each side of the transect. If 100 individuals were counted on this transect, the density estimate would be 0.017 individuals/meter^2 (100/6000).

Density estimates obtained from unlimited distance counts require that the observer determine the perpendicular distances to each individual. Counts of this type have been used widely by ornithologists and as a result there are several methods that can be used to estimate the size of the surveyed area. As it relates to the Karner blue butterfly, only the Effective-Strip-Width (ESW) method has received much use (Brown and Boyce 1996, Richard S. King, in litt. 1999). This method requires that the observer estimate the effective-strip-width (w_e), which is the distance off of each transect that every butterfly can assume to be counted (Buckland et al. 1993). Buckland et al. (1993) provide the equations and methods for estimating density from these data. The ESW method assumes that the distance to each individual is estimated accurately, that 100% of the individuals on the transect line are detected, and that individuals are not attracted or repelled by the observer before being detected (Buckland et al. 1993).

An advantage in using the ESW method is that w_e varies little between sites (Brown and Boyce 1996, Richard S. King, in litt. 1999). Brown and Boyce (1996) estimated a mean w_e of 1.99 meters for Karner blue butterfly. If observers are willing to extrapolate this estimate to all sites, estimating perpendicular distances will be unnecessary, which will make surveys less cumbersome. Density estimates, however, often will be no more useful than the transect count data for monitoring changes in butterfly populations. In these cases, PY transects will often suffice for monitoring.

All transect methods cannot account for unobserved individuals. Schweitzer (1994) found that even in a relatively small area, competent observers can miss most butterflies and males are about 1.3 times as likely to be observed as females. Several observers including Schweitzer find that ovipositing females are particularly likely to be overlooked.

It will often be useful to make a crude estimate of population size from transect data. For rough estimates of population size, the transect counts can be treated as daily population estimates. If the estimate is from near the peak of the flight period, it may be reasonable to triple the count to estimate total flight population size (Schweitzer 1994). Clearly, it is preferable to use the average of several dates rather than one. In theory at least one could make such crude population estimates based on any type of simple count data as well as more careful census data. Even a simple walk through count can be made and the results tripled (Schweitzer 1994) to give a population estimate. Whatever method is used the reliability of the estimate is unlikely to match that of a well conducted MRR. However, the savings in time and effort can be very substantial and sometimes the reliability of an MRR estimate is really not needed. Except with very small or very linear sites any population estimates generated from census methods can be assumed to be low since thy will be based only on counts of numbers seen on a given visit, and not on estimates of numbers actually present that day as in MRR (Dale Schweitzer, TNC, in litt. 2002).

EXAMPLES OF MONITORING FORMS AND METHODS CURRENTLY IN USE

Examples of several data forms and survey protocols used to monitor the Karner blue butterfly and its habitat are noted below. They may not meet all of the necessary monitoring requirements listed in this appendix, and some may go beyond these requirements. They are not specifically endorsed by the Recovery Team, but are provided as a guide and to indicate the diversity of approaches that are being used for monitoring.

1. <u>Pollard-Yates Butterfly Monitoring Method.</u> This is a summary of the Wisconsin DNR's adaptation of the Pollard-Yates method for monitoring the Karner blue butterfly. It includes detailed methods for pre-survey as well as survey work, a discussion of its strengths and limitations, and recommended weather conditions appropriate for monitoring.

2. <u>Karner Blue Transect Count Form.</u> This is a one-page data form that is used to record the data taken during a Pollard-Yates survey developed by the Wisconsin DNR. It includes space to record butterfly behaviors as well as numbers.

3. <u>Karner Blue Habitat Evaluation Form.</u> This is a two-page data form that is used to record habitat characteristics of the Karner blue developed by the Huron-Manistee NF in Michigan. It includes space to describe lupine, nectar plants, and canopy cover.

4. <u>Karner Blue Butterfly Habitat Evaluation Form.</u> This is a one-page form that is used to record Karner blue habitat characteristics. It includes space to sketch the site, describe threats to the site, and recommend management, and is used by the Huron-Manistee NF.

5. <u>Karner Blue Butterfly Presence/Absence Survey Protocol.</u> This is a protocol for conducting presence-absence surveys for the Karner blue butterfly used in Wisconsin. It includes instructions on when to survey, how to conduct the survey, and general methodological information. It was developed by the Biological Subteam of the Wisconsin Karner Blue Butterfly Statewide HCP Partnership.

6. <u>Recommendations for Conducting Wild Lupine Surveys</u>. This is a series of recommendations for conducting wild lupine (*Lupinus perennis)* surveys. It includes when and how to survey, instructions on mapping lupine, and a list of habitats where lupine is less likely to be found. It was developed by the Biological Subteam of the Wisconsin Karner Blue Butterfly Statewide HCP Partnership.

7. <u>Methods for Monitoring Karner Blue Butterflies at Necedah National Wildlife Refuge, Wisconsin.</u> This is a summary of Necedah National Wildlife Refuge's adaptation of the Pollard-Yates method for monitoring the Karner blue butterfly. It describes the detailed methods used, and methods for analyzing the data using the effective strip width method for estimating butterfly density.

8. Monitoring Protocol and Estimated Survey and Time Requirements for Monitoring Karner Blue Metapopulations at Fort McCoy, Wisconsin. This describes the straight-line transect monitoring protocol that is being used at Fort McCoy, Wisconsin, and provides estimates of the time costs involved in monitoring two metapopulations at Fort McCoy, which is about 60,000 acres.

The above forms can be obtained from:

Endangered Species Coordinator
U.S. Fish and Wildlife Service
2661 Scott Tower Drive
New Franken, Wisconsin 54229
(920) 866-1717
TTY users may contact us through the Federal Relay Service at (800) 877-8339

LITERATURE CITED

Brown, J. A. and M. S. Boyce. 1996. Monitoring of Karner blue butterflies (*Lycaeides melissa samuelis*) for the proposed Habitat Conservation Plan, Wisconsin. Report to the National Fish and Wildlife Foundation.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance Sampling. Chapman and Hall, London.

Gall, L. R. 1985. Measuring the size of Lepidopteran populations. Journal of Research on the Lepidoptera 24: 97-116.

King, Richard S. 2000. Evaluation of survey methods for the Karner blue butterfly on the Necedah Wildlife Management Area. Transactions, Volume 88, pp. 1-11.

Opler, P. A. Conservation and management of butterfly diversity in North America. *In* Ecology and Conservation of Butterflies. Chapman and Hall, London. 1995.

Pollard, E. and T. J. Yates. 1993. Monitoring Butterflies For Ecology and Conservation. Chapman and Hall, London.

Pollock, H. P., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. The Wildlife Society. Wildlife Monograph Volume 54, Number 1.

Swengel, A. B. and S. R. Swengel. 1998. Density-dependent and –independent behaviors of the adult Karner blue (*Lycaeides melissa samuelis*) (Lepidoptera: Lycaenidae). *The Great Lakes Entomologist* 31: 59-7.

Schweitzer, D. Prioritizing Karner Blue Butterfly Habitat for Protection Activities. *In* Andow, D. A., R. Baker, and C. Lane (eds.), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station. 1994. (Miscellaneous Publication Series). pp. 173-183.

Thomas, C. D. 1983. A quick method for estimating butterfly numbers during surveys. Biological Conservation 27: 195-211.

APPENDIX I

TRANSLOCATION GUIDELINES FOR THE KARNER BLUE BUTTERFLY

These guidelines are meant to assist agencies and organizations working on recovery of the Karner blue. Each instance where translocation is considered will be different, and it is hoped that these guidelines will encourage a hard look at what will be involved, the expected benefit to the species, and whether the expenditure of limited resources is warranted. In the early stages of recovery, some of these guidelines may apply more as states work toward viability than later. After viability is achieved, there should be monitoring and management in place that should substantially reduce the need for additional translocation or captive breeding.

Translocation in any form should be seen as a tool in recovery, but as with any tool, the need for it should be carefully considered. The actions taken should clearly further the goals for recovery within the particular recovery unit. Any translocation program should be done according to a plan that lays out clearly what the goals of the translocation are and how success will be defined (e.g. a self-sustaining population that does not need further artificial immigration of animals, some defined increase in the population, etc.). It must define how long the action will be done, what the evaluation period will be, and what steps will be taken if success is not achieved (i.e. continue or not continue). There should be sufficient funding to achieve the goals set forth in the plan. All captive rearing or captive propagation actions should be done in accordance with the U.S. Fish and Wildlife Service's (Service's) policy on controlled propagation, and appropriate state and Federal permits should be obtained prior to proceeding. The plan should include monitoring of the source populations for any detrimental effects of the translocation action.

Three types of translocations are discussed below: 1) accelerated colonization, 2) reintroduction, and 3) augmentation.

TRANSLOCATION TO UNOCCUPIED SITES

In the following scenarios, sites are <u>not currently occupied</u> by Karner blues although they may have been in the recent past or historically (sites are within historic range).

Accelerated Colonization

<u>Objective</u>

The objective is to speed up colonization of new or unoccupied suitable habitat to help create a viable metapopulation. This is especially appropriate where recovery actions are concentrated on increasing habitat and the number of occupied sites. This action should not take the place of establishing corridors and proper spatial arrangement of sites. The sources of animals for accelerated colonization are generally expected to be from within the particular metapopulation being managed (refer to SOURCE POPULATIONS FOR TRANSLOCATION, below).

<u>Scenarios when accelerated colonization would be appropriate</u>

1. A new habitat site is created or restored to a condition capable of supporting Karner blues, but

    a. there are no corridors connecting it with occupied sites, or it is too far from another occupied site to rely on natural dispersal to colonize the site, or

    b. the next nearest subpopulation is considered too small to expect effective dispersal and colonization.

2. A subpopulation within the defined metapopulation has been lost, and corridors/dispersal from nearby colonies would not be established for a long time (this assumes that suitable habitat remains or has been managed to make it suitable again). The dynamics of the metapopulation must be considered in this case: if the extinction/colonization rate of the metapopulation is balanced or has a high colonization rate, loss of the site may not be a problem requiring translocation. Managers should look at the action in terms of the overall viability of the metapopulation.

3. A subpopulation has been determined to be nonessential to the metapopulation (outlier, extremely marginal, etc) and/or has been slated for destruction by development. In addition to the required mitigation for "taking" Karner blues, it may be desirable to salvage some of the population and move them to unoccupied habitat in the metapopulation.

    <u>Note</u>: It would <u>not</u> be appropriate to move Karner blues to unsuitable habitat or in place of efforts to establish necessary connectivity within the metapopulation.

Reintroduction

<u>Objective</u>

Reintroduction would return the Karner blue to a part of its former range where it has been lost thus increasing the gross numbers of the species, its geographic distribution, and redundancy of metapopulations to buffer against large-scale catastrophe.

<u>Scenarios when reintroduction of Karner blues would be appropriate</u>

1. Reintroduction should only be considered when the necessary resources to fully complete the project are assured and will not limit other, higher priority recovery efforts in designated recovery units and designated metapopulations.

2. When the area historically had Karner blues but currently does not (e.g.. Tonawanda, New York, Ohio, Ontario, other historic or potential recovery units). All necessary resources for viability must be present or achievable. Further, the problems leading to the extirpation of the Karner blue must have been identified and addressed. Efforts should also be made to encourage local support for the project.

3. Within the historic range of the Karner blue but where definitive evidence of its past existence is lacking (e.g. Rome Sandplains, NY has anecdotal evidence but no specimen). As in No. 2 above, the criteria for viability must be present or achievable, and there must be support for the project.

   Note: It would be inappropriate to attempt to establish the Karner blue outside of its historic range (e.g.. Texas), where the landscape is not suitable for viability, or where there is not a firm commitment to long-term Karner blue management.

TRANSLOCATION TO OCCUPIED SITES

In the following scenarios, sites are currently occupied by the Karner blue butterfly:

Augmentation

Objective

The objective of translocation is to keep a metapopulation from becoming non-viable and to prevent a metapopulation within a recovery unit from disappearing.

The question of whether the number of Karner blues in a subpopulation has become too low will be determined by the manager most familiar with the history and environmental conditions of the subpopulation. In general, if a subpopulation shows a persistent drop in numbers over time, there should be a trigger-point identified that when reached, should trigger corrective action to address the decline. Augmentation may be a tool among several that can be used to address the decline.

Scenarios when augmentation of a subpopulation would be appropriate

1. When the subpopulation has become so low that it most certainly will be lost *and* there is no subpopulation connected or within dispersal distance to recolonize the site *and* loss of this subpopulation will bring the metapopulation below minimum viability criteria.

   Further conditions:

   a. Steps must be taken to identify and rectify the cause of the decline. Translocated animals may buy managers time against complete loss of the population, but unless the cause is addressed, the decline will probably continue.

b. The translocation plan for the population should include what will signal the end point for the action. Augmentation alone should not be viewed as the solution to a chronic decline problem.

c. The goals for the metapopulation must support the use of augmentation.

2. A subpopulation has been determined to be nonessential to the metapopulation (outlier, extremely marginal, etc) and/or has been slated for destruction by development. In addition to the required mitigation for "taking" Karner blues, it may be desirable to salvage some of the population and move them to a low or stressed subpopulation in the metapopulation or to start or augment a captive propagation colony.

SOURCE POPULATIONS FOR TRANSLOCATION

The choice of source populations for translocation programs will depend on many factors, four of which follow:

1. The Size of the Donor Subpopulations

Source subpopulations should be large enough so that the removal of animals will not impair their long-term viability. It is also desirable to take animals from more than one subpopulation for translocation to any particular site. Unless the source subpopulations are very large, they should be monitored both before and after animals are removed so that the effect, if any, can be evaluated. The translocation plan should include methods to monitor and evaluate the sources, and identify appropriate actions to correct adverse impacts, should they occur. In rare circumstances, a relatively small population may be the only alternative source. In this case, extreme precautions should be taken to assure that the numbers taken will not harm the subpopulation.

2. The Habitat Characteristics of the Source Compared to the Recipient Site

Animals from a source population whose local climatic conditions and microclimate are similar to the conditions at the recipient site may have a better chance of survival than animals from very different environments. This will often mean that subpopulations from within a metapopulation will be better suited for translocation within that metapopulation than ones from outside it, assuming they are large enough.

3. Genetics Information (whole section new)

If available, genetics information should be used to help identify the appropriate donor population. Generally, genetic studies of the Karner blue and differences in populations across its range are not complete and currently are not considered necessary for recovery (refer to PART I, RECOVERY TASKS, Table 5). Until there is contradictory information on the effects of genetic mixing, managers should try to use suitably sized sources from within the subject metapopulation. When this is not possible, the donor subpopulations should always come from areas that are most similar to the recipient local habitat conditions (e.g., soil moisture, temperature, etc) and geographically close to the habitat where introduction is planned.

Considerations regarding donor populations for captive breeding programs should be the same as discussed above. Donor subpopulations should not be put at risk to supply the program, and the progeny generated for a particular translocation should come from populations, which match the recipient habitat conditions.

Because it cannot be assumed that first and second brood Karner blues are genetically similar (Hugh Britten, University of South Dakota, in litt. 2002), it may be advantageous, in order to insure more genetic heterogeneity, to consider obtaining donor Karner blues from not only first, but second flight populations (Hugh Britten, pers.comm. 2002).

4. Permit Requirements

The translocation of insects across state lines is regulated by the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS), and any such translocation of Karner blues would require a permit from APHIS. Permits are also required from the Service and affected state agencies.

A Service export permit and Canadian import permit would be necessary to allow transfer of the Karner blues from the United States to Ontario, Canada.

CAPTIVE REARING AND CAPTIVE PROPAGATION

Many endangered species recovery programs have involved the release of animals born or head-started in captivity. This type of program may become useful for Karner blue recovery as a source for translocation in the future, especially if large, suitably matched source colonies are not available or practical to use for a translocation.

Head-starting, or *captive rearing* of Karner blue eggs taken from wild individuals to older life stages for release, has been done successfully (refer to PART I, CONSERVATION MEASURES, Reintroduction/Translocation). Captive rearing may be a necessary part of many translocation programs. Experts must make the decisions as to what life stage should be transported and released (i.e. maybe it is safest to transport eggs or larva, but adults may survive better when released), which brood period should be targeted for the releases, what the best techniques for release might be, and how to monitor the fate of the releases. Managers should look to those with experience in this type of program, as the potential for failure and loss of Karner blues is very real. The Toledo Zoo (Ohio), The Nature Conservancy (Indiana Office), the New Hampshire Fish and Game Department, and Minnesota DNR, are actively involved in translocation efforts and can be contacted for more information on their release methods which vary from the release of adults in Ohio (The Toledo Zoo 2002) to pupae (in release tents) in Indiana (Labus et al. 2002).

Captive propagation techniques for the Karner blue have been developed by the Toledo Zoo and are anticipated to evolve further. Captive propagation involves producing Karner blues for release from a permanently captive breeding population. Getting Karner blues to mate and lay viable eggs in artificial surroundings and finding a way to break winter diapause of the second brood eggs are some of the hurdles that need to be overcome to raise large number of Karner blues for translocation purposes. Karner blue mating at the Toledo Zoo seems to have been enhanced by placing newly emerging females in a netted enclosure with wild lupine and several (5) males. Hatching success of these eggs will be quantified in April 2003. Adult survival has been significantly improved (usually > 3 weeks) by daily hand-feeding using a 20% solution of raw local honey. Larvae are raised on netted lupine plants (5-10 larvae/ plant), usually without incident. Larvae raised on plants fertilized weekly have significantly higher body masses and body lengths than those raised on unfertilized plants (Peter Tolson, Toledo Zoo, pers. comm. 2002; Toledo Zoo, 2002)

The Toledo Zoo has developed a technique for overwintering eggs successfully which entails placing eggs suspended on chiffon fabric in chiffon fabric-covered mason jars which are sheltered from rain and placed in a shaded environment. In snowy conditions, the jars are loosely covered with a sheet of polyfilm to prevent melting snow from flooding the jars. This setup produces a high humidity environment similar to conditions that eggs in the wild are exposed to under the snow. Winter diapause is broken naturally by the onset of higher spring temperatures and increasing day length. In mid-March, the eggs are removed from the jars and placed on the soil of potted lupine plants covered with polyester netting.

There are two questions regarding captive propagation that the Toledo Zoo is currently working on. One is whether females can be induced to continue to lay viable eggs at older ages. Even though the Zoo can keep Karner blues alive up to four weeks, there appears to be fertility problems with older females, despite multiple mating opportunities. A second research question is the effect of diet on male fertility and female fertility and fecundity. While hand feeding of adults has been shown to be greatly superior to "natural" feeding on flowering nectar plants for enhancing adult survival, the effect of diet on adult reproductive capability remains a question. The Zoo also feels that the optimal larval density on a lupine plant needs research. They question whether fewer larvae on a plant would result in greater survival to adulthood, or if reducing the numbers of larvae on a plant (e.g., from 10 to 5) would ultimately result in fewer numbers of adults for release because of the increased facilities and personnel needed to maintain double the number of host plants (Peter Tolson, pers. comm. 2002).

CONSIDERATIONS RELATIVE TO LUPINE

The translocation of lupine to reintroduction sites from Karner blue butterfly donor sites in <u>not</u> recommended by the Recovery Team at this time. If there is a need to expand or restore lupine habitat at a translocation site, native lupine should be planted. In many states preservation of local plant population genetics is one of the missions their Natural Heritage Programs; individual states should be consulted for guidance on the use of native plants for reintroduction efforts. Releasing a potentially new lupine genotype into a translocation area is likely an irreversible step. If any co-evolution is necessary between the Karner blue and the lupine genotypes at the translocation site it is appears preferable that the butterfly adapts to its new food source. This is a risk adverse strategy - mixing lupines is irreversible, and any risks associated with mixing lupines would most likely be irreversibly as well. Reintroductions of the Karner blue in Ohio and New Hampshire have demonstrated that larvae produced from out-of-state donor populations grew and metamorphosed successfully on native lupine. Lupine is relatively easy to grow, and obtaining suitable amounts of native lupine for translocation work is doable.

LITERATURE CITED

The Toledo Zoo. 2002. Propagation handbook for the Karner blue butterfly, *Lycaeides melissa samuelis*). The Toledo Zoo, Toledo, Ohio. 14 pp. + appendix.

Labus, P., M. Norris, and J. Shuey 2002. 2001 progress report for The Indiana Office of The Nature Conservancy's Karner blue butterfly re-introduction at Ivanhoe Nature Preserve, Gary, Indiana. The Nature Conservancy, Southern Lake Michigan Rim Program, Calumet College, Whiting, Indiana. 3 pp.

APPENDIX J

EDUCATIONAL AND OUTREACH ACTIVITIES

This appendix provides information on educational and outreach activities ongoing in the various states that have recovery goals for the Karner blue.

New Hampshire

The Karner blue has been designated the official butterfly of the City of Concord as well as the state. Outreach efforts include a traveling display, a puppet show for children, a fact sheet and many meetings and contacts with local media and officials.

New York

Several outreach activities have taken place at the Crossgate Shopping Mall in Albany, New York including a puppet show for pre-schoolers and a public display on Karner blue and lupine barrens ecology. TNC has hosted a Karner blue "Awareness Event" (mailing and media). There are numerous public walks and talks focused on the Karner blue in the Pine Bush and at the Saratoga Spa State Park. Throughout the year, there is regular coverage of Karner blue butterfly issues in the local newspapers.

The Town of Wilton held a press conference to announce the "Wilton Wildlife Preserve and Park," (WWPP) and to honor two landowners protecting the Karner blue. TNC's newsletter has featured the voluntary efforts of a private landowner to protect Karner blue and its habitat. A Boy Scouts of America camp in the Wilton, New York area developed a interpretative trail and merit badge program focused on Karner blue. A visitors' center is planned for the Wilton Wildlife Preserve and Park with a butterfly garden and interpretive materials related to the Karner blue butterfly and the area's natural and cultural history.

The Albany Pine Bush Commission has developed a brochure describing their Native Plant Restoration Program and providing a list of nurseries where local stocks of native species can be obtained. Plans are in motion to revise the brochure to be appropriate for the entire Glacial Lake Albany area.

Teachers and students at the Farnsworth Middle School in Albany are very active in habitat management programs within the Albany Pine Bush Preserve, and have established a native plant butterfly garden at the school. Teachers there would like to be able to raise Karner blues some time in the future. The NYDEC and WWPP have established contacts with two local schools to involve children in habitat management and education about the Karner blue. The Geyser Road School in Saratoga West already has part of a Karner blue subpopulation on its property, and with guidance from DEC, will enlarge this habitat on school grounds. The Ballard Road School in Saratoga Sandplains has had educational presentations from WWPP staff and will be visiting the WWPP for educational trips and to help with habitat management projects.

The New York DEC distributes Karner blue fact sheets to interested teachers, students, and the public. Niagara Mohawk Power Corporation (NIMO) has erected signs identifying Karner blue habitat in their powerline rights-of-way to alert crews to these sensitive areas; they have also included Karner blue in a small field guide they have produced.

Michigan

The Huron-Manistee NF has developed an information and education plan that targets a variety of audiences to disseminate partnership and educational material. Focus groups include schools, the general public, local, state and Federal government agencies and commissions, conservation partners, the "Friends of the Huron-Manistee NF" group, and fellow forest service personnel. The effort is aimed at building support and educating the public about planned activities and to develop partnerships for future work. To accomplish these tasks the NF is using slide presentations, newspaper articles, radio and television spots, field trips and public meetings.

Other outreach efforts by the Michigan Natural Features Inventory have included a workshop on dry sand prairie and oak-pine barrens ecosystems targeted at site planners and resource professionals, and two slide/tape programs that have been developed for a general audience and professional biologists (John Paskus, Michigan NFI, pers. comm. 1997).

Indiana

The Indiana Dunes National Lakeshore (IDNL) has developed a Site Bulletin featuring the Karner blue at the Lakeshore; they are also developing an interpretive display on oak savannas at one of their overlook sites. A bumper sticker saying, "I Brake for Butterflies" is available at the Lakeshore.

Wisconsin

Many education and outreach efforts have or are taking place to encourage conservation of the Karner blue and its habitat in Wisconsin. Some of the major efforts include Wisconsin DNR's Karner blue butterfly training sessions for state, tribal and county foresters in Wisconsin as well as HCP partners, various talks given by state and Federal agency personnel to environmental groups, school groups and other interested parties, and the production of numerous state and Federal Karner blue butterfly "Fact Sheets." The Wisconsin DNR has developed a slide program on the Karner blue that has been shared with several agencies and groups. Necedah NWR has produced a slide show entitled "The Benefits of Barrens." Both Fort McCoy and the Wisconsin Public Service have produced signage featuring the need to protect Karner blue, which they post in areas occupied by the butterfly. Videos have been produced by the University of Wisconsin-Stevens Point, and by Chad Richards, a middle-school student in Waupaca (Wisconsin). A training video produced by Fort McCoy (Wisconsin) includes information on the butterfly. In October of 1996, the Wisconsin DNR in cooperation with the Service sponsored a "Landowner Recognition Celebration" recognizing private landowners who are voluntarily conserving Karner blue (as well as other rare species) on their lands.

Some of the Partners to the developing Wisconsin Statewide HCP are contributing significantly to education and outreach efforts focused on the Karner blue. Thilmany (a subsidiary of International Paper) produced a "Spotlight on the Environment" video featuring the Karner blue and HCP conservation effort in Wisconsin. As of June 1998 the video aired on various television stations across the country 1,186 times to an estimated audience size of 5,481,300. Alliant Energy (formerly Wisconsin Power and Light Company) developed a color brochure on the Karner blue butterfly and HCP partnership that has been made available to the public and resource agencies and is widely distributed in Wisconsin. Excel Energy Inc. (formerly Northern States Power Company) has sponsored the production of a pamphlet, with the help of a middle school student, entitled "Karner Blues Where Are You?" A Karner Blue Butterfly Festival has been held in Black River Falls, Wisconsin for the past several years.

Minnesota

A presentation about the Karner blue butterfly is given annually at Whitewater State Park.

Other Outreach Efforts

The Public Lands Interpretive Association (Association) has produced a Karner blue butterfly enamel pin available for purchase from the Association which is located at 6501 Fourth Street, NW; Albuquerque, New Mexico 87107 (505-345-9498). Another pin of the butterfly can be purchased from the gift shop at the Toledo Zoo, in Toledo Ohio (tzgifts@toledozoo.org).

The American Zoological and Aquarium Association (AZA) is taking an active role in helping to recover the Karner blue as part of their Butterfly Conservation Initiative (BFCI). The BFCI was established in 2001 to assist in the recovery of 22 federally-listed butterfly species in the United States and to increase public awareness of, and direct involvement in butterfly conservation efforts. In June 2002, AZA hosted a Karner Blue Butterfly Recovery Implementation Workshop that was held at the Toledo Zoo in Ohio. The workshop brought together 67 interested parties from 14 states and two Canadian provinces and resulted in several partnership efforts for the Karner blue. Among these is a partnership between TNC, New York State DEC, Seneca Park Zoo and the Mutual of Omaha, to create a “Karner Kids,” program where school children in Rochester, New York will grow wild lupine (from seed obtained from the Albany area) in Rochester and harvest the seed for distribution within the Albany Pine Bush Preserve. Other projects AZA members are assisting with as result of the workshop are the development of educational materials to increase private landowner awareness of Karner blues in Michigan, and work with school children in Concord, New Hampshire to raise and plant lupines to help restore the Karner blue site in Concord. Working with AZA partners in the recovery of listed species is consistent with the 1998 Memorandum of Understanding between AZA and the Service.

Web Sites

Noted below are web sites with Karner blue butterfly informational materials that can be used for educational purposes**:**

* Wisconsin DNR
  Environmental Education for Kids (EEK)!
  Karner Blue Butterfly

  http://www.dnr.state.wi.us/org/caer/ce/eek/critter/insect/Karner.htm

* The Roosevelt Wild Life Station (State University of New York - Syracuse)
  Conservation and Education Research
  Karner blue and the Pine-oak Barrens: Educational Modules

  http://www.esf.edu/resorg/rooseveltwildlife/research/karnerblue/karnermodules.htm

* U. S. Fish and Wildlife Service

  http://midwest.fws.gov/Endangered/insects/index.html#/karner

* The Nature Conservancy (West Gary, Indiana, Karner blue butterfly reintroduction)

  http://nature.org/wherewework/northamerica/states/indiana/preserves/art9126.html

APPENDIX K

PUBLIC COMMENTS ON THE TECHNICAL/AGENCY DRAFT RECOVERY PLAN

Following is the list of individuals and agencies that submitted comments on the Karner Blue Butterfly Technical/Agency Draft Recovery Plan. All comments have been reviewed and incorporated, as appropriate, into this recovery plan. Comments are on file in the Service's Green Bay Ecological Services Field Office, New Franken, Wisconsin. A review of the comments received from peer reviewers and responses to them are reviewed below as well.

LIST OF REVIEWERS

Peer Reviewers

Dr. Hugh Britten
University of South Dakota
414 East Clark Street
Vermillion, SD 57069-2390

Dr. Susan Harrison
Dept. of Environmental Science & Policy
University of California
One Shields Avenue
Davis, CA 95616-8576

Dr. David L. Wagner
Dept. of Ecology & Evolutionary Biology
University of Connecticut
75 North Eagleville Road Unit 3043
Storrs, Connecticut 06269-3043

Genetics Reviewers

Dr. Thomas Emmel
Division of Lepidoptera Research
Department of Zoology
University of Florida
P.O. Box 118525
123 Bartram Hall
Gainesville, FL 32611-8525

Greg W. Gelembiuk, Doctoral Student
Department of Zoology & Botany
University of Wisconsin – Madison
430 Lincoln Dr.
Madison, WI 53706

Dr. James Kruse, Systematic Entomologist
University of Alaska Museum
University of Alaska Fairbanks
907 Yukon Drive
Fairbanks, AK 99775-6960

Dr. Chris Nice
Department of Biology
Southwest Texas State University
601 University Drive
San Marcos, TX 78666

Dr. Laurence Packer
Department of Biology
York University
4700 Keele Street
N. York, Ontario M3J1P3

Dr. Robert K. Robbins, Research Entomologist
Smithsonian Institution
P.O. Box 37012
NHB Stop 127, Room E-514
Washington, DC 20013-7012

Dr. Susan J. Weller, Curator of Invertebrates
Bell Museum of Natural History
University of Minnesota
1980 Folwell Ave., 219 Hodson Hall
St. Paul, MN 55108

Agencies and Others

Gerald Barnhart, Director
New York State Department of Environmental Conservation
Division of Fish, Wildlife, and Marine Resources
625 Broadway
Albany, NY 12233-4750

Darrell Bazzell, Secretary
Wisconsin Department of Natural Resources
101 S. Webster St.
Box 7921
Madison, WI 53707-7921

Dr. T. Bently Wigley, Forest Wildlife Scientist
National Council of the Paper Industry for Air & Stream Improvement, Inc.
Department of Aquaculture, Fisheries & Wildlife, Clemson University
P.O. Box 340362
Clemson, SC 29634-0362

Kelly Bibb
U.S. Fish & Wildlife Service
1875 Century Blvd, Suite 200
Atlanta, GA 30345-3301

Michael Budzik, Chief
Division of Wildlife
Ohio Department of Natural Resources
1840 Belcher Drive
Columbus, OH 43224-1300

Phil Delphey, Endangered Species Coordinator
Twin Cities Field Office
U.S. Fish & Wildlife Service
4101 East 80th Street
Bloomington, MN 55425

Robert Dirig, Assistant Curator
L.H. Bailey Hortorium
462 Mann Library
Cornell University
Ithaca, NY 14853-4301

Bonita Eliason, Endangered Species Coordinator
Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55155-4025

Alan Fiero
Alton U. Farnsworth Middle School
6072 State Farm Road
Guilderland, NY 12084

Steven G. Fuller, Nongame Biologist
New Hampshire Fish and Game Department
2 Hazen Drive
Concord, NH 03301

Daniel D. Gonnering
Natural Resource Manager
Volk Field Combat Readiness Training Center
100 Independence Drive
Camp Douglas, WI 54618-5001

Ralph Grundel
U.S. Geological Survey
1100 N. Mineral Springs Road
Porter, IN 46304

Rita L. Hayen, Manager
Environmental Dept.
American Transmission Company
N19 W23993 Ridgeview Parkway
P.O. Box 47
Waukesha, WI 53187-0047

Catherine P. Herms, Research Associate
Ohio State University / OARDC
Dept. of Horticulture and Crop Science
1680 Madison Avenue
Wooster, OH 44691

Dr. Lorin Hicks, Director of Fish & Wildlife Resources
Plum Creek
112 Autumn Ridge Place
Brandon, MS 39047

Gary Birch, * IOC Member
Wisconsin Department of Transportation
4802 Sheboygan Ave., Room 451
Madison, WI 53707-7965

Lori Bowman, * IOC Member
WI Dept. of Agriculture,
Trade & Consumer Protection
P.O. Box 8911
Madison, WI 53718-8911

Nancy C. Braker, * IOC Chair
The Nature Conservancy
633 West Main Street
Madison, WI 53955

Rick Daily, * IOC Member
Clark County Forest
517 Court Street
Nashville, WI 54456

Dave Lentz, * IOC Member
WI Department of Natural Resources
P.O. Box 7921
Madison, WI 53707

Heidi Rahn, * IOC Member
Alliant Energy / WP&L
(Refer to address above)

Fred J. Souba, Jr., * IOC Member
Stora Enso North America, Corp.
P.O. Box 8050
Wisconsin Rapids, WI 54495-8050

Donna M. Laabs
N5230 County E. Road
De Pere, WI 54115

Donald J. Leopold, Professor
State University of New York
College of Environmental Science & Forestry
One Forestry Drive
Syracuse, NY 13210-2778

Joseph B. Kelly, Wildlife Biologist
Huron-Manistee National Forests
1755 South Mitchell Street
Cadillac, MI 49601

Mary M. Knapp, Supervisor
Ecological Services Field Office
U.S. Fish & Wildlife Service
6950 Americana Parkway, Suite H
Reynoldsburg, OH 43068-4127

Elizabeth McCloskey, Biologist
Northern Indiana Ecological Services Office
U.S. Fish & Wildlife Service
P.O. Box 2616
Chesterton, IN 46304-2616

Ray McQuiston
2219 Nondorf Street
Dyer, IN 46311

Rick Moser, Environmental Consultant
Wisconsin Public Service Corporation
700 North Adams Street
P.O. Box 19002
Green Bay, WI 54307-9002

Dr. Laurence Packer
Department of Biology
York University
4700 Keele Street
N. York, Ontario M3J1P3

Lori Pruitt
Bloomington Field Office
U.S. Fish & Wildlife Service
620 Walker Street
Bloomington, IN 47403-2102

Heidi Rahn, Environmental Consultant
Alliant Energy
4902 N. Biltmore Lane
P.O. Box 77007
Madison, WI 53707-1007

Don Rittner
Capital District Preservation Task Force
1726 Lenox Road
Schenectady, NY 12308

Dolores Savignano
U.S. Fish & Wildlife Service
4401 North Fairfax Dr.
Arlington, VA 22203

Sandra S. Schauer, Trustee
Marion R. Schauer Trust
7718 Weeping Willow Court
Franklin, WI 53132

Scott D. Shupe, Environmental Analyst
Niagara Mohawk
Environmental Affairs Dept., A-2
300 Erie Boulevard West
Syracuse, NY 13202

Ann Swengel, Vice President
North American Butterfly Association
909 Birch Street
Baraboo, WI 54311

James C. Zahasky, Jackson County Forest Admin.
Jackson County Forestry & Parks Department
W9790 Airport Road
Black River Falls, WI 54615

Deanna Zercher
409 Davis Lane
Lebanon, PA 17042

Russell Ziemba
1813 Highland Avenue
Troy, NY 12180

* IOC = Implementation and Oversight Committee, Wisconsin Statewide HCP for the Karner Blue Butterfly. One letter received from the IOC, signed by the seven members of the committee noted above.

SUMMARY OF PEER REVIEWERS COMMENTS AND RESPONSES TO THEM

Comment: A concern was expressed about the downplaying of fire because of the role it plays in maintaining the early successional habitat of the Karner blue. The commenter questioned whether this is due to unsuccessful regeneration of lupine after prescribed burns in areas where fire has been long suppressed, and if so that additional intervention (i.e. seeding to replace depleted seed banks) is needed.

Response: APPENDIX G of this plan has been expanded to include and consolidate information on the impacts of fire on the Karner blue and to clarify management recommendations relative to prescribed burns. The management guidelines recognize the use of prescribed fire as well as other management tools for maintaining the early successional habitat of the Karner blue and identifies measures that can be taken to minimize the impacts of these management tools on the butterfly. This plan also recognizes the need of restoring and maintaining a mosaic of early successional habitat for the Karner blue in order to establish viable populations of the butterfly (e.g., PART I, HABITAT/ECOSYSTEM and APPENDIX G). Lupine regeneration and recolonization in areas where fire has been long suppressed may be problematic and additional language, as well as a recovery task, have been added to the plan to reflect this (refer to PART I, LIFE HISTORY AND ECOLOGY, Lupine Food Resource, Other factors affecting lupine, and PART II, RECOVERY TASKS, Task 5.25).

Comment: One commenter expressed the need for clarity regarding the dispersal ability of the Karner blue and the definitions of “site” and “patch” in APPENDIX A (GLOSSARY).

Response: Table G1 summarizing Karner blue dispersal research has been incorporated into APPENDIX G of this plan and a more thorough discussion of dispersal provided. The studies demonstrate that there is a fair amount of variation in dispersal ability between sites depending on the canopy cover of the intervening habitat. The definition of “site” in APPENDIX A has also been revised for clarity and for compatibility with APPENDIX G.

Comment: One commenter expressed concern that there was no reference to lupine genetic structure relative to translocation of the host plant and pointed out that, as with the Karner blue, genetic considerations could affect the outcome of translocation efforts relative to lupine.

Response: Guidance has been added to APPENDIX I of this plan to clarify the Recovery Team’s recommendations regarding the translocation of lupine to reintroduction sites. The information summarizes why such translocations are not considered desirable at this time, one of the reasons is related to genetics concerns.

Comment: One commenter expressed the concern that genetics should play a stronger role in recovery planning, that the mtDNA data (from Nice et al. 2000) suggests a disjunction among Karner blue population in the eastern and western portion of the range and that translocations between these areas should not take place. The commenter also stated that translocation and management guidance should address genetic differences in first and second brood adults and that there was no mechanism in the plan to allow for monitoring the genetic health of Karner blue populations.

Response: Most of these concerns were addressed by adding language to the Taxonomy section of this plan (refer to PART I, TAXONOMY AND DESCRIPTION) and/or to APPENDIX I. The Recovery Team did not think monitoring the genetic health of the population was important to recovery. The guidance in this plan developed for establishing and managing viable metapopulations is anticipated to maintain the genetic health of Karner blue metapopulations. That guidance can be found in APPENDICES B, E, F, G, and I.

Comment: One commenter stated that the plan lacked concern for the population genetic structure of the Karner blue expressing some concern that translocations could be done with stock from "environmentally similar" regions if necessary. The commenter points out that there is a minor degree of concern for local adaptation, but almost none for maintaining the geographic architecture of neutral genetic variation that could be key to reconstructing the history of dispersal and evolution in the butterfly.

Response: The primary goal of this recovery plan is to perpetuate viable metapopulations of the Karner blue in the major ecological regions throughout its geographic range. Thirteen ecological regions are identified in this plan called "recovery units" and are based on known variation in physiography, climate, vegetation, and potential geographic genetic variation in the Karner blue populations [refer to APPENDIX B, and PART I, RECOVERY STRATEGY). The Recovery Team anticipates that this strategy will preserve the genetic variation of Karner blues throughout its range. Translocation guidelines (Appendix I) were also incorporated into this plan to help insure the genetic integrity of Karner blue butterfly populations.

Comment: One commenter expressed concerns about the broad definition of metapopulation adopted for this plan in that it lacked an explicit statement about spatial dispersion and connectivity among habitat patches for any given metapopulation. The commenter noted that all Karner blue metapopulations appear to be treated the same when it is clear that their potentially different metapopulation structures suggest that they should not be. The commenter suggested including a hypothesized metapopulation structure in the metapopulation description to provide a starting point for considering the impact of specific management activities.

Response: Additional language has been added to PART II, RECOVERY, RATIONALE**,** Population Structure and APPENDIX E of this plan noting that viable metapopulations and large viable metapopulations are likely to have their own unique population structure and that this plan is not prescribing an particular "ideal" structure. Guidance on establishing connectivity among habitat patches (subpopulations) is provided in APPENDIX G.

Comment: One commenter noted that the use of metapopulation dynamics as a conceptual framework seemed appropriate but pointed out that one metapopulation type was not mentioned that of a "nonequilibrium" metapopulation, i.e. local populations (subpopulations) that are so far apart that they are cut off from recolonization should they go extinct. The commenter also noted that in cases where habitats are lost and do not leave behind suitable habitats, the "rules" of metapopulation dynamics are less important than the "rules" of habitat dynamics (e.g. rates, intensities, and spatial patterns of disturbance and recovery).

Response: A "nonequilibrium" metapopulation was not mentioned in this plan as it is not a metapopulation structure we wish to aim for. We agree with the latter statement and language has been added to APPENDIX G of this plan recognizing the importance of maintaining a suitable array of habitat for the butterfly with appropriate disturbance to insure metapopulation persistence.

Comment: One commenter wondered if there was evidence for "random" local extinctions, i.e. ones that occur within still-suitable habitat, and if so whether these involve populations that are so small they have little bearing on the regional survival of the species.

Response: We think this is possible, especially in Wisconsin where many small populations are known to occur.

Comment: One commenter noted that it may be possible that single occurrences of the Karner blue are viable populations as long as there are processes (e.g. mowing) that can continuously maintain early-successional habitat.

Response: This may be possible and language has been added to APPENDIX E (POPULATION STRUCTURE**,** Spatial Structure of a Minimum Viable Metapopulation) noting this.

Comment: One commenter supported the plan's emphasis on monitoring noting that every 2-3 years the Recovery Team needs to determine what practices have had a demonstrably positive effect and which seem to be ineffectual or even detrimental to the recovery of the Karner blue.

Response: Recovery Task 6.2 (PART II, STEPDOWN RECOVERY OUTLINE) entails the holding of Recovery Team meetings every 2-3 years. Language has been added to this task to include review of the impact of management practices on the Karner blue at these meetings.

Comment: One commenter expressed the concern that understanding dispersal is critical to Karner blue butterfly management, that research items dealing with dispersal, corridors, and individual movements should be given a priority 1 rating and that high resolution genetic assays could aid these tasks.

Response: This plan assigns priority 2 and 3 ratings to these research tasks. Much is known about Karner blue butterfly dispersal and can be found summarized in APPENDIX G of this plan. The Recovery Team's view is that genetics plays a small role in the research items noted.

Comment: One commenter noted that it was unclear what role the <u>potential recovery units</u> play in the recovery process and suggested that translocations to potential recovery units be given a priority 3 rating.

Response: The role of the potential recovery units has been clarified in this plan and because they may play a role in recovery of the species, recovery tasks related to them have been assigned a priority 3 rating (refer to APPENDIX B)

Comment: One commenter suggested assigning a priority 2 rating to <u>captive rearing</u> and <u>translocation tasks</u>, as they are largely reserved for "emergency" situations.

Response: Because captive rearing and translocation are actions needed to prevent extinction or an irreversible decline in the species, these tasks were assigned a priority 1 rating.

Comment: One commenter noted that it may be worth considering <u>recovery criteria</u> that more strongly emphasizes the amount, quality, and spatiotemporal dynamics of the habitat rather than the number, sizes and spatial configurations of Karner blue populations. The commenter points out that this is may have the following additional advantages: (1) the power of monitoring would probably be increased, since populations fluctuate year to year, and (2) there may be greater benefits to other rare species.

Response: The recovery criteria currently include the need to maintain "a diverse and appropriate successional array of suitable Karner blue butterfly habitat" (PART II, RECOVERY). Language has been added to this plan to emphasize the importance of maintaining a shifting geographic mosaic of habitat on the landscape for the Karner blue (refer to APPENDIX G). Identifying the number, sizes, and spatial configuration of viable populations is consistent with the goals of recovery planning which include identifying quantitative and measurable recovery criteria. Recovery Task 3.4 has been expanded to include assessing whether a more habitat based monitoring method can be used to monitor large viable metapopulations in a cost effective yet reliable manner which should address this concern as well.

Comment: One commenter noted that it is critical that we learn more about the Karner blues <u>basic biology</u> in the next five years including the role of ants in the larval biology of the species. The commenter noted that research identified in the plan seems prudent and well considered.

Response: Recovery Task 5.31 of this plan identifies the need to develop a better understanding of the role of ants in Karner blue populations and has been expanded to include further examination of the role of ants relative to parasitism and predation of eggs and larvae.

Comment: One commenter expressed concern about the impact of white tailed <u>deer</u> on the Karner blue noting that in Connecticut deer are causing declines in frosted elfin populations. The commenter recommended research on the issue using new economical, solar powered electric fencing system to fence deer out of study sites.

Response: The Recovery Team believes that sufficient information is available that demonstrates that deer browse can negatively affect Karner blues which is reflected in this plan. Language has been added to this plan noting the availability of new economically solar powered electric fencing (refer to PART I, THREATS TO SURVIVAL).

Comment: One commenter stated that explicit translocation protocols need to be developed that include identifying source populations.

Response: The Translocation Guidelines in APPENDIX I of this plan provide recommendations on source populations for translocation efforts. Recovery tasks have also been identified to further develop translocation protocols (refer to Task 5.14). In addition researchers can review protocols currently being used in translocation projects in New Hampshire, Indiana, Minnesota, and Ohio.

Comment: One commenter noted that the recovery target of 29 self-sustaining and permanently protected and managed metapopulations appears to be a reasonable goal for full recovery noting that while stochastic processes makes assignment of hard target numbers somewhat arbitrary, it appeared the plan used available data to propose a conservative recovery goal for the Karner blue. The commenter noted that the plan allows for adjustment of recovery goals and other aspects of the plan as additional data becomes available. The commenter also states that the proposed monitoring and management tasks appear to be generally appropriated and sufficient for recovery.

Response: We agree.

Comment: Three commenters noted that the recovery plans appeared to have done a good job at outlining a recovery strategy for the Karner blue. Two commenters noted that the plan was comprehensive and thorough. One commenter agreed with the recovery plan's principal focus on land protection and the management of lupine. Support was also expressed for the first three priority 1 research tasks; habitat management, captive breeding, and lupine propagation.

Response: We appreciated these positive comments on the plan.