Please note that all location information has been removed from this document to protect Minnesota's Karner Blue Butterfly populations

A REPORT ON SURVEYS FOR THE KARNER BLUE BUTTERFLY AND OTHER RARE INSECTS AT WHITEWATER WILDLIFE MANAGEMENT AREA

With an Assessment of
Habitat Quality and Recommendations for
Management and Monitoring

February 16, 2009

Prepared By:
James Bess
OTIS Enterprises
13501 south 750 west
Wanatah, IN 46390

Prepared for:
Jaime Edwards, SE Region Nongame Specialist
Minnesota Department of Natural Resources
2300 Silver Creek Rd NE
Rochester, MN 55906

TABLE OF CONTENTS

LIST OF FIGURES

Figures 1-5 have been removed to protect the Karner blue butterfly population.

LIST OF TABLES

Tables 1 and 2 have been removed to protect the Karner blue butterfly population.

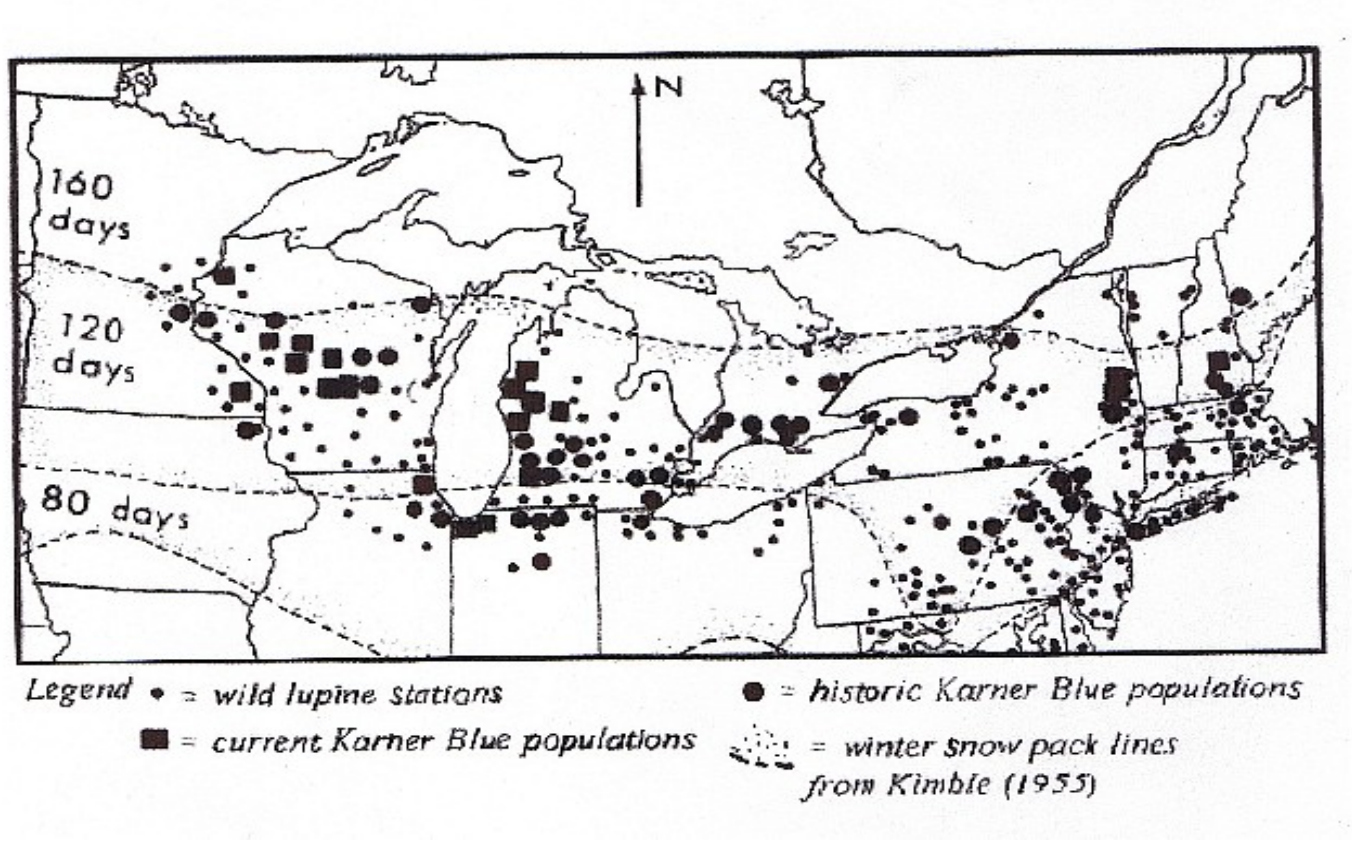
1.0 BACKGROUND

1.1 KARNER BLUE BUTTERFLY: HISTORICAL PERSPECTIVE

One of the classic animal species associated with sandy oak barrens in the northern United States is the Karner blue butterfly (*Lycaeides melissa samuelis* Nabakov). This butterfly was originally described by William Henry Edwards as "*Rusticus scudderi*", from specimens collected at Karner (now "Center"), New York in 1861 and a specimen collected by Saunders in Ontario. The novelist Vladimir Nabakov, also an avid Lepidopterist, revised the *Lycaeides* species complex of "blues" in the 1940's, renaming the Karner blue *Lycaeides melissa samuelis* in 1944. In a letter to Robert Dirig, Nabakov gave three reasons for elevating the Karner blue to specific status; constancy in the structure of the male genitalia, monophagy on wild lupine and the failure to interbreed/intergrade with the western Melissa blue (*Lycaeides melissa melissa*). Both the names "*scudderi*" and "*samuelis*" refer to the great early American Lepidopterist, Samuel H. Scudder who first "discovered" and wrote about this species in North America (see Scudder, 1889, 1891). Nabakov wrote about the Karner blue in his novel, Pnin (Nabakov, 1989)

1.2 WILDFIRE, THE KARNER BLUE AND ITS HABITAT

The Karner blue was historically known to occur from Massachusetts west through New York and the Lower Great Lakes Region to Minnesota (USFWS, 2001).



[***Above Map Reproduced from Dirig, 1997***]

Throughout its range, this species was and is found in open, oak and oak-pine barrens (also referred to as woodlands or savannas) that exhibit a high degree of openness in the canopy; grow on droughty, sandy soils and have a rich herbaceous flora dominated by grasses and wildflowers (Andow et al., 1994; Clough, 1992; Cryan, 1978; Dirig, 1976; Martin, 1990; Packer, 1987; Papp, 1993; Peteroy, 1998; Scudder, 1889;

US FWS, 2001). These barrens are often associated with sand prairies, woodlands, forest and wetlands in a complex matrix set on dissected, sandy glacial outwash. A characteristic wildflower in this system is lupine (*Lupinus perennis*), the sole foodplant for the Karner blue's caterpillars (see Savignano, 1990; Scudder, 1888).

In the Midwest, barrens occupied by the Karner blue are dominated by black oaks (*Quercus velutina*). Historically, black oak barrens experienced frequent, periodic fires (see Henderson and Long, 1984) and many of the plants occurring in them require fire for reproduction and continued survival. In the absence of fire, these communities rapidly succeed into closed canopy oak woodlands and forests having a very sparse or non-existent herbaceous flora, conditions unsuitable for the survival of the Karner blue. In fact, the Karner blue and lupine appear to prefer recently burned habitat, with lupine and nectar sources tending to be more vigorous and producing greater biomass (possibly of improved quality) compared to non-burn years (see Bernays and Chapman, 1994; Boyonski, 1992; Celebrezze, 1996; Chew and Robbins, 1989; Dolinger, et al., 1973; Dudt and Shure, 1994; Grigore, 1992; Grundel, 1994; Grundel et al., 1998a-b, 2000; Knapp and Seastedt, 1986; Mattson, 1980; Peet et al., 1975; Zaremba and Pickering, 1994).

It has been well documented that most North American, grass-dominated plant communities (such as prairies and barrens) burned with relative frequency in the past (Bayley and Odum, 1976; Bancroft, 1977; Cohen, 1974; Cohen, et al. 1984; Cypert, 1961; Duever, et al. 1986; Forman, 1979; Foster and Glaser, 1986; Garren, 1943; Glasser, 1985; Henderson and Long, 1984; Higgins, 1986; Komarek, 1971: Lotan, 1981; Loveless, 1959; Penfound, 1952; Schwegman and Anderson, 1984; Thompson, 1959; Weaver and Alderson, 1956; Wells, 1931, 1942). Fire is known to regulate vegetation structure, which has a reciprocal influence on fire frequency (Anderson et al., 1970; Anderson and Brown, 1986; Anderson et al., 1999; Auclair, et al., 1973; Bancroft, 1977; Cohen et al., 1984; Daubenmire, 1968; Duever, et al., 1986; Forman, 1979; Glasser, 1985; Henderson and Long, 1984; Kozlowski and Ahlgrens, 1974; Schwaegman and Anderson, 1984; Tester, 1989; Wade, et al., 1980; Weaver, 1954; Weaver and Fitzpatrick, 1934; Wells and Boyce, 1953; Wright and Bailey, 1982).

The human suppression of wildfires since ~1900 is among the more profound changes to the North American environment in the past 5,000 years, particularly to habitat for the Karner blue butterfly (see Nuzzo, 1996; Schweitzer, 1991). In the absence of fire, many formerly open grass-dominated plant communities have quickly succeeded to shrublands and closed canopy forests. Many of the plants occurring in these communities are also "fire-dependent", meaning they require periodic fire for their long-term survival (Anderson et al., 1970; Arend and Scholtz, 1969; Daubenmire, 1968; Hulbert, 1969, 1981; Knapp and Seastadt, 1986; Peet et al., 1975; Thor and Nichols, 1973; Tilman, 1987; Weaver, 1954; Weaver and Fitzpatrick, 1934; Whitford and Whitford, 1978; Wright and Bailey, 1982). Wild lupine and many Karner blue nectar sources are among these fire-dependent plants.

Therefore, understanding the habitat requirements of the Karner blue butterfly requires a basic understanding of the dynamics of black oak barrens in general, as the two are inextricably linked in this portion of the butterfly's range. Black oaks dominate only in areas where major environmental disturbances (i.e. fire and drought) periodically open the tree canopy (Fowells, 1965). Black oaks are uniquely adapted to these kinds of habitat: they are short-lived (seldom exceeding 150 yr.), sprout prolifically after injury or death of above ground parts, and are fairly tolerant of low to medium intensity fires once they reach several meters in height (Fowells, 1965). Black Oak acorns germinate in the late spring, and therefore by-pass the potentially severe fire season (Korstian, 1927). Other tree species associated with this habitat-type are less fire tolerant. White oak acorns, for example, germinate in the fall, making the seedlings immediately vulnerable to fall and early spring fires. It is in this type of ecosystem that the growth characteristics of

black oak allow it to compete successfully with other less fire tolerant trees to form pure stands (Swan, 1970).

Most ecologists now recognize that fire is a particularly important factor in maintaining these communities (Curtis, 1959; Haney and Apfelbaum, 1990; Kozlowski and Ahlgren, 1974; and Lorimer, 1977). A detailed study of the fire history of two Karner blue-occupied black oak barrens in northwest Indiana found "frequency and intensity of fire strongly influence stand structure and succession" (Henderson and Long, 1984). They authors went on to speculate that, without fire, black oak dominated communities would be replaced by late-successional forests, as initially described by Cowles (1899). It is in this "mid-successional", fire and drought-maintained community that many species of plants and animals have adapted and survived: the Karner blue butterfly is one such example.

The presence of Karner blue butterflies is associated with a number of plant community attributes that appear to be essential for supporting the species in an area over time. First, and most critical of these is the presence of wild lupine, the only known food source for the larval stage of the Karner blue. Wild lupine is typically found in areas that are sandy, fairly open and dry. In addition, adult KBB's require flower nectar that they obtain from a number of different flowering plants associated with oak barrens. Fire is crucial to the survival of many herbaceous plants associated with black oak barrens. In degraded remnants of these habitat-types, prescribed burning relaxes competition from invading, non-fire adapted species, thus allowing fire-adapted species such as lupine to proliferate and expand into newly opened areas (Anderson and Brown, 1986; Crow, 1988; Daubenmire, 1968; Dorney and Dorney, 1989; Grimm, 1984; Henderson, 1982; Henderson and Long, 1984; Johnson, 1985; Kline, 1984; Packard, 1988; Schwaegman and Anderson, 1984; Tester, 1989; White, 1983; Wright and Bailey, 1982). Fire also reduces canopy cover of woody species through direct mortality of living, above-ground parts. This allows more sunlight to reach the soil surface, resulting in increased photosynthetic productivity in the herbaceous flora (Dorney, 1981; Lorimer, 1985).

Burning reduces leaf litter accumulation and allows the soil to dry out, thereby excluding plants adapted to more mesic habitats. This also allows a greater amount of sunlight to reach the soil surface (Bray, 1958; Hulbert, 1969). Removal of duff allows the sun to warm the soil in early spring, resulting in early germination of seeds and activation of dormant buds (Anderson et al., 1970; Arend and Scholtz, 1969; Hulbert, 1969, 1981; Knapp and Seastadt, 1986; Peet et al., 1975; Thor and Nichols, 1973). Researchers have also found that many fire-adapted plants produce seeds that require fire-related scarification for germination (Daubenmire, 1968; Wright and Bailey, 1982). The burning of leaf litter has been shown to create a nutrient flux that stimulates growth in fire-adapted plants (Tilman, 1987; Whitford and Whitford, 1978). In addition, fire increases the soil pH, excluding species adapted to acidic environments (Bray, 1958).

1.3 HABITAT FRAGMENTATION

Coupled with the suppression of wildfires is the fragmentation of the landscape through human land use activities. While logging may have actually helped create habitat for the Karner blue, other silvicultural activities, particularly pine plantations, destroyed large acreage of former habitat in Michigan and Wisconsin. Farming, especially on sandy, marginal soils, led to rapid erosion and loss of topsoil, greatly changing the character of the local flora, even when tilling has ceased. The fragments of native plant communities that now dot the landscape are set in a matrix of anthropogenic habitats often unusable, if not openly hostile, to native organisms like the Karner blue. These anthropogenic areas lack lupine, nectar sources, shade and resting places required by the Karner blue butterfly and it's larvae. In many open habitats, non-native grasses and weedy forbs dominate, excluding lupine and other native species. Formerly open, fire-maintained woodlands have overgrown with shrubs, vines and young trees, making

them unsuitable as KBB habitat. Humans spray broad-scale pesticides to control insect and plant pests on their crops, often inadvertently spraying adjacent natural areas as well. In the case of forest pests such as the gypsy moth (*Lymantria dispar*), Karner blue habitat may be directly targeted for pesticide application (e.g. *Bacillus thuringiensis*).

1.4 HISTORIC DECLINE OF THE KARNER BLUE

Therefore, since the 1940's, and especially since the 1960's, fire suppression and habitat fragmentation associated with increased agricultural, industrial and residential development have greatly decreased the amount of suitable Karner blue butterfly habitat (see Schweitzer, 1991). This has occurred across the butterfly's entire range to such an extent that, since 1900, it has experienced a 99.98 percent population reduction; status surveys conducted in the late 1980's and early 1990's found it had been extirpated from Illinois, Massachusetts, Ohio, Ontario, and Pennsylvania (Schweitzer, 1991). This precipitous decline in numbers resulted in the emergency listing of the Karner blue butterfly as a Federally Endangered Species in 1992 (Clough, 1992). Subsequently, the butterfly was formally listed as a federally endangered species on 14 December 1993 (Federal Register, Vol. 57, pp. 59236-59244). Currently, the largest remaining populations of this species occur in Indiana, Michigan, New York and Wisconsin (see US FWS, 2003).

1.5 MINNESOTA KARNER BLUE POPULATIONS

In Minnesota, the Karner blue butterfly was historically known from two counties: Anoka and Winona (see Cuthrell, 1990). The Anoka County population occurred along a roadside within the Cedar Creek Natural Area, but roadwork in the early 1980's destroyed the local lupine colony and extirpated the population of Karner blues. The Winona County population was located within the Whitewater Wildlife Management Area (WMA) and is commonly referred to as the "XXXXX3" site. In 1990, Cuthrell discovered additional populations of the Karner blue at Whitewater WMA, most of which were small and located near the XXXXX3 site. The following year, Cynthia Lane conducted intensive population and habitat characterization studies on the largest of these populations (one of the new sites, called XXXXX1). By this time, the XXXXX3 population had become very small, with only a few individuals observed in 1991. Lane also identified additional populations of the Karner blue butterfly within the WMA.

In 2003, the population at XXXXX1 plummeted in numbers (see Lundquist and Edwards, 2006). Since that time, very few Karner blues have been observed at the XXXXX1 Site and other historic locations appear to contain no KBB's. The MNDNR is very concerned about this development and personnel have implemented restoration efforts in an attempt to reverse this decline. The current study's objectives were to survey the known KBB habitat areas at Whitewater WMA and report on the status of the Karner blue population(s) and their habitat. We also proposed to collect information regarding additional rare Lepidoptera associated with the Oak barrens remnants and provide Habitat Restoration and Management Recommendations regarding the KBB and other rare oak barrens Lepidoptera.

2.0 METHODS

2.1 SITE DESCRIPTIONS

Historically the Karner blue butterfly was known from 6 discrete subpopulations within the Whitewater WMA. All occurred in oak barrens habitat along XXXXX, at the bases of the adjacent limestone/dolomite bluffs. These Oak barrens are characterized (in their pristine state) by widely spaced black oak (*Quercus velutina*) and/or northern pin oak (*Quercus ellipsoidalis*), with a patchy to nonexistent shrub layer and a rich herbaceous flora dominated by fire-adapted grasses, wildflowers and lupine. All of these sites have suffered from human-induced fire suppression and habitat fragmentation over the past 100 years, with a resultant increase in cover by woody species and a reduction in the cover and vigor of the herbaceous flora, particularly lupine. Non-native invasive plants have also colonized and degraded much potential habitat for the KBB at the WMA. Recently, a Prescribed Fire Program has been introduced at the Sites and restoration efforts have been undertaken to remove woody invasive species and enhance lupine populations through seeding (see Lundquist and Edwards, 2006).

For reasons not completely known, the butterfly underwent a population crash at Whitewater in ~2003 and is now known to occur at only a single site within the WMA (XXXXX1). Of the known occupied and historic locations, the four largest and highest quality Sites were selected for surveys in 2008:

2.1.1 XXXXX1

XXXXX1a is the currently occupied Site, and butterflies occur primarily in the central portion. The Site is 131 acres and is a mixture of open, high quality Oak barrens, fire suppressed Oak Woodland and degraded Sand Prairie. The boundaries of the Site identify the Plainfield Sand that is the characteristic Soil Type for these communities in the WMA. A few high quality bluff prairies occupy the limestone bluffs on the northern perimeter of XXXXX1.

XXXXX1b is a small (41 acre) historic location, where a single male KBB was observed in 1991 (see Lane, 1991). Karner blues have not been observed here since, and the Site is primarily closed canopy oak woodland, with a small oak barrens remnant on the SW slope of the sand bench. Until recent restoration was conducted, both Sites were heavily overgrown with young oaks, aspen and non-native honeysuckles.

2.1.2 XXXXX2

Karner blues were discovered here, by Cuthrell, in 1990 and Lane observed them again in 1991. The species has not been observed here again since that time, despite several recent surveys. This Site consists of a fairly large oak barrens remnant (132 acres total) and an old jackpine plantation that was cut and seeded to prairie in the 1990's. The planting then filled in with honeysuckle, which was brush hogged and treated with herbicide. Additional cutting and spraying of honeysuckle has occurred here, as well as localized prescribed burning. The formerly occupied habitat has not been burned. Lupine is plentiful along a steep dune blowout and on the southern edge of the upper slopes on the south boundary of the Site, and has responded well to fire. Even with the recent management activities, much of the Site remains closed canopy oak woodland with little herbaceous flora, conditions unsuitable for the Karner blue.

2.1.3 XXXXX3

This is the original population discovered at Whitewater back in the 1960's (?). There are two previously occupied areas within the Valley itself, but butterflies were most recently observed in the east-central portion of the XXXXX3. XXXXX3 is 67 acres of Oak barrens and Woodland on a south-facing sand bluff, roughly half of which is either closed-canopy, fire suppressed Oak barrens/Woodland or has been

degraded through past overgrazing and has a large amount of non-native *Poa*. To the west is a large area of open, degraded Sand Prairie, which spreads to the north in a complex of degraded prairie, barrens and fire suppressed woodlands. Management activities have been focused on the central portion of the XXXXX3 that was historically occupied.

2.1.4 XXXXX4

The XXXXX4 Site is diverse and contains relatively large amounts of lupine, although only 16 acres in size. This XXXXX4 was historically occupied in the 1990's, but KBB's disappeared shortly thereafter. In the late 1990's, butterflies were translocated from XXXXX1 (on more than one occasion) in an attempt to re-populate the Site. However, conversations with MNDNR personnel indicate that only a few adults were observed the following year and then none during subsequent surveys. Restoration activities have begun here as well, including honeysuckle removal and soil scarification.

2.2 OBJECTIVES

The main objective of this project was to survey for the Karner Blue Butterfly at known historic localities within the Whitewater WMA and provide information regarding to their location, abundance and habitat conditions. We also conducted surveys for additional rare butterflies and moths occurring on the study sites. For the 2008 field season, we performed the following work:

1. Repeated, intensive field surveys for the Karner Blue Butterfly at 4 oak savanna/barrens remnants;

2. Searched for other rare butterflies in conjunction with the Karner Blue surveys;

3. Conducted initial, cursory moth surveys, employing bucket-style light traps and light sheets for sampling rare moths at each of the 4 sites during each of the four sampling/survey periods;

4. Provided MNDNR with monthly updates on the survey's progress and any rare species encountered;

For Reporting purposes, we were contracted to:

5. Provide a final report containing information on any Karner Blue Larvae or Butterflies observed, their location, plant associations and habitat characteristics;

6. Provide information on any additional rare butterflies and moths observed or collected during the surveys. Information on known distribution, food plants, habitat use and general rarity will also be provided for these species when known;

7. Provide Whitewater WMA Land Managers with potential management options for each of the survey sites as pertains to rare Lepidoptera conservation.

8. Provide recommendations for future survey efforts, should the results of our surveys warrant them.

2.3 KARNER BLUE BUTTERFLY SURVEYS

Survey methods for larvae and adults of the Karner blue butterfly followed previously approved guidelines used in surveys for this species (see Weaver/Boos, 1994). The methods used in deriving population estimates are as follows:

2.3.1 Surveys for KBB Larvae

Surveys for Karner blue butterfly larvae were concentrated around known lupine populations. Larval surveys were conducted using a combination of cues to initially locate larvae, including the presence of chewed leaves, flowers and buds, and the presence of ants and larval excrement (or "frass"). The larvae of the Karner blue butterfly range from 12-15mm in length when fully mature. They are pale green in color (matching the shade of their foodplant), with a whitish lateral stripe running longitudinally along the dorsal edge of the spiracles. The larvae are also physically and behaviorally adapted to a life in close association with ants. These adaptations have involved the development of a thick cuticle (skin), honeydew and pheromone producing organs to attract ants, and a generally sluggish demeanor.

Due to their small size, green color, and reclusive nature, larvae of the Karner blue butterfly can be difficult to survey for. However, there are two widely used identifying characters for determining the presence of larvae (Savignano, 1990; Swengel, 1995, 1998; Weaver/Boos, 1997). These characters fall into two categories; damage to lupine plants caused by larval herbivory, and the presence of associated ants on the lupine plants. Larval surveys at the Whitewater sites were conducted using the presence of feeding damage to locate potential Karner blue larvae and the association of ants, frass and/or actual larval observation used to confirm an occurrence.

2.3.2 Identification of Larval Feeding Sign

When feeding damage was observed on a lupine plant, it was categorized into one of three classes:

1. *Karner Blue Larval Feeding Sign:* This included one or more of the following; clear "windows" chewed through the epidermis and mesophyll layers of leaves, larval excrement, ants, Karner blue larvae.

2. *Tortricid Moth Feeding Sign:* This included the following; leaves webbed together with silk, numerous small, puncture holes in lupine leaves, brown leaves, and non-Karner blue appearing larvae occurring in the webbed leaves.

3. *Other:* This included feeding that was caused by neither Karner blue or Tortricid moth larvae. Usually actual larvae are associated with this feeding. Species observed feeding on lupine in the past have include: *Autographa precationis, Colias eurytheme, Erynnis baptisiae, Erynnis persius, Haploa confusa, Homorthodes furfurata, Lithophane laticinerea, Spaelotis clandestina, Spodoptera ornithogalli, Vanessa cardui* and an unidentified species of spanworm moth (family Geometridae: Bess, pers. obs.).

If feeding sign appeared to have been caused by a Karner blue larva (but no larva found) the observation was recorded in the daily count as a larval occurrence if it met the following criteria:

1. Several lupine leaves had extensive skeletonization, or flower buds were eaten, to the extent that a larva could have matured from the amount of feeding indicated.

2. No other herbivorous insect larvae were located on the lupine plant and none of the leaves were webbed with silk.

3. Ants occurred on or near the lupine plant showing the feeding sign.

4. Other Karner blue larvae or adults were located in the general vicinity (~20 foot radius).

2.3.3 KBB Larval Brood Surveys: Data Recording

When a larva was located, the following data were recorded on daily field data sheets:

1.GPS location and location on map;

2.Location of larva(e) on the lupine plant; flowers, buds, leaves or main stem.

3.Feeding sign; chewed flowers, chewed new leaves, or skeletonized mature leaves.

4.Presence of attending ants; yes or no.

At no time during the surveys were larvae handled and no searches for larvae in detritus were attempted. This minimized the potential for dislodging larvae and/or disturbing attending ants. Larval observations were plotted on a site map and GPS coordinates were recorded for use in tracking the location and movements of the Karner blue population(s) at each of the sites surveyed. Larval occurrences were marked with individually numbered pin flags during the spring brood surveys to prevent the re-counting of spring brood feeding sign during the summer surveys.

2.3.4 Surveys for Karner Blue Butterfly Adults

Karner blue butterfly adults are much more mobile than their larvae and therefore have greater dispersal capabilities. Adults of this species feed on nectar from a variety of flower species and may occur at least 0.25 miles from the nearest colony of lupine. Nectar source concentrations were identified and adult brood surveys were centered around these and known lupine populations. An observation was included as a Karner blue occurrence only if a positive identification was made by the observer. This species has a distinctive pattern unlike any other local butterfly and a subtly distinctive flight behavior, which allows a trained observer to distinguish it from other species of more common blue butterflies, such as the eastern tailed blue (*Everes comyntas*) and the spring azure (*Celastrina ladon*). Surveys were timed for late morning and again in late afternoon, when many butterfly species are actively feeding, thus making them more readily visible to observers.

2.3.5 KBB Adult Brood Surveys: Data Recording

When adults were encountered, the following data were entered on daily field data sheets:

1.Time of observation.

2.GPS coordinates of observation.

3.Behavior: flying, mating, nectaring, ovipositing, or resting.

4.Map location within the individual Survey Site.

5.Associated nectar plant species (if any).

6.Associated habitat type: old field, oak barrens, open prairie, oak woods.

Adult observations were also be marked on maps for use in monitoring the movements of Karner blue butterflies within each of the Survey Sites. GPS Coordinates were recorded to verify the location of each observation.

2.4 KARNER BLUE BUTTERFLY POPULATION ESTIMATES

2.4.1 Larval Population Estimates

Population estimates for each larval brood are a combination of actual larval observations and definite feeding sign occurrences. Larval surveys are considered more accurate than adult surveys in predicting total population size due to the sedentary nature of the larvae and the fact that trained surveyors find them easy to locate.

2.4.2 Adult Population Estimates

Population estimates for the adult broods will be made using a modified version of the methods outlined in Pollard (1977). This involves sampling for the species in question along a permanent, pre-determined transect. A weekly mean number of adults occurring within the area surveyed is then determined from these surveys (the sum of daily observation totals, divided by the number of days surveyed). This number is then used to compare population estimates between sites and between years.

2.5 SURVEYS FOR ADDITIONAL RARE LEPIDOPTERA

2.5.1 Visual Surveys for Rare Butterflies

Visual surveys involved walking through representative portions of habitat and recording the species of butterflies observed. Voucher specimens of difficult taxa were collected and stored with appropriate data for future identification. Patches of flowers, known foodplants and other attractive features were targeted for intensive survey effort. The primary goal of this sampling method is to gather information on the greatest number of taxa while reducing the need to kill large numbers of specimens.

2.5.2 Surveys for Rare Moths

Lights for attracting nocturnal insects were operated in the form of "garbage can" light traps and light-sheets. Garbage can light traps consist of a five-gallon bucket fitted with a funnel over the top and a light source suspended above. Insects are attracted to the light, fall into the funnel and, through a hole at the bottom, into the bucket. Ethyl acetate was placed in the bucket to euthanize samples. These traps were run in representative areas throughout each of the Sampling Sites from dusk to dawn.

Light-sheets consist of a white sheet suspended on a line between two trees (or posts) with a light suspended in front. Insects are attracted to the light, land on the sheet and can be identified and/or collected with sampling containers. These lights are typically run for shorter periods of time, depending on weather conditions. Lights were operated on each night (3) of the three sampling periods, as conditions allow. We attempted to place at least one light trap at each of the four survey sites on each night we sample.

2.5.3 Rare Lepidoptera: Data Recording

For additional rare Lepidoptera species observed or collected during this survey effort, the following data were collected:

1. GPS coordinates of observation.
2. Map showing location of observation/collection within the individual Survey Site(s).
3. Associated habitat type: old field, oak barrens, open prairie, oak woods.
4. An estimate of relative abundance.
5. Information on regional/national distribution and biology (if known).

For state-protected species, voucher specimens will be provided to MN DNR staff for deposition in the University of Minnesota Entomological Collection. All other specimens are housed in the OTIS Enterprises Entomological Research Collection or discarded, depending on their condition and significance to this and other projects.

2.6 TIMING OF SURVEYS

Karner blue fieldwork was scheduled to occur during three critical sampling periods, beginning in May and continue through mid-August of 2008. These times were:

1. Spring Larval Brood (mid May),
2. Summer Larval Brood (late Jun-early July), and
3. Summer Adult Brood (late July-mid August).

However, unseasonable cool weather throughout much of Spring and Summer (coupled with localized droughty conditions) greatly delayed the appearance of many Lepidoptera species, particularly the Karner blue. Therefore we were forced to adjust our surveys to account for the unpredictable weather patterns. Ultimately, a total of 7 visits were made to Whitewater in 2008 to survey for the Karner blue butterfly. Individual survey dates were reduced in duration (2-3 days each) given our ability to easily cover 2-3 sites in a day, thus allowing time for the additional surveys. Our actual survey dates were as follows:

1. May 19-21; Initial Site Visits and Spring Larval Brood Surveys
2. May 26-27; Initial Spring Adult Brood Surveys
3. June 9-10; Second Spring Adult Brood Surveys
4. June 24-25; Third Spring Adult Brood Surveys; Initial Summer Larval Brood Surveys
5. July 8-9; Summer Larval Brood Surveys
6. August 7-9; Initial Summer Adult Brood Surveys
7. August 23-25; Final Summer Adult Brood Surveys

Spring Brood larval surveys occurred in mid-May. Lupine was already in flower during the May 19-21 surveys, but larvae were apparently slow to develop, requiring us to conduct a second survey in late May (26-27) to ensure we had adequately covered all of the lupine patches and to search for any early adults. We returned on June 9-10 to check for KBB adults and conduct additional Lepidoptera surveying and sampling.

Summer Brood larval surveys were conducted in late June (24-25), when most of the lupine plants were still green and succulent and larvae are typically near full-grown. However, adult Karner blues were observed at this time, indicating a greatly delayed Spring flight period. We decided to forgo larval surveys at this time and continued looking for butterflies, given that at least part of the population would be in either the egg or young larval stage, making them difficult to locate.

We returned on July 8-9 to survey for larvae again, but roughly half of the lupine was in a condition not really conducive to surveying, with many of the plants senescing, making feeding sign near impossible to detect. We walked through the XXXXX1 and XXXXX3 sites, but only observed a few instances of potential feeding sign at XXXXX1, in the primary habitat area, where restoration work had occurred this past dormant season.

From these initial field observations, we estimated that the Summer brood of the KBB would be 10-14 days delayed from typical. We contacted MNDNR staff (Jaime Edwards) to determine when Summer adult brood surveys might best be conducted, given the apparent delay in the season. Jaime surveyed the XXXXX1 Site in late July and found no KBB, so we delayed our summer brood surveys until August 7-9. A final survey and sampling trip was undertaken August 23-25.

RESULTS

Sampling Effort was divided between surveys for the Karner blue butterfly and other rare species as follows:

Survey Dates	Hours Surveyed	
	KARNER BLUE	RARE LEPIDOPTERA
May 19-21:	24	12
May 26-27:	16	8
June 9-10:	16	8
June 24-25:	16	8
July 8-9:	16	8
August 7-9:	24	12
August 23-25:	24	12
Totals:	**136**	**68**

3.1 KARNER BLUE LARVAL SURVEYS

Spring brood surveys were conducted in the third week of May, a little late in the season, but given the late Spring, we believed this would allow us to adequately survey for feeding sign and, hopefully, larvae. Overall, Lupine was in excellent condition during our surveys, given the recent Spring rains. Weather was warm and overcast to partly cloudy, typically excellent conditions for conducting larval surveys. We located all lupine patches within each of the 4 Sites and surveyed these thoroughly for signs of KBB larval feeding. All "KBB-like" feeding sign was noted on field forms and GPS readings taken of the locality. Each locality was then marked with an identifying pin flag and flagging tape.

The Summer Brood is typically 3-4 times the size of the Spring Brood and the larvae generally easier to locate. However, the unusual weather caused a delay in the emergence of the Spring Brood, which led to a delay (and likely protraction) of the Summer Larval Brood. This was coupled with rapid senescence of the lupine plants throughout much of the open barrens by the time we conducted our Summer Brood surveys in July. This made identification of potential KBB feeding sign difficult to impossible. Given the difficulties we had with conducting Summer Larval Brood Surveys, the following results are for the Spring Brood Surveys only.

3.1.1 XXXXX1

We found larval feeding sign of the Karner blue butterfly at XXXXX1 during the Spring Brood, in the "bowl" marked as the "primary KBB area" on Map 1. However, we observed only one actual larva (May 21, 2008), which was feeding on leaves and flower buds and attended by ants. We flagged this and 10 subsequent observations of larval feeding sign. The larva appeared full grown and we may have been at the tail end of the spring larval brood period. We flagged all observations and recorded GPS info, date and feeding sign observations. Nearly all observations were in the recently restored areas on the dune face and the "XXXXX" on the semi-level top of the dune, where brush had been cut and treated with herbicide [see Map 1].

We also observed another 10-12 instances of larval feeding sign in the " XXXXX1-3" site, the next western-most valley, immediately adjacent to the primary site [see Map 1]. This site contained extensive patches of lupine on south and west facing slopes and looks ideal for the Karner blue butterfly. However, subsequent surveys during the Summer brood period found only a single adult male, although it is quite likely the unusual weather patterns in 2008 negatively affected our ability to survey effectively for this butterfly.

The " XXXXX " on the East side of XXXXX1, upslope from the "bowls" where the bulk of the population occurs, had extensive lupine but only a few Karner blues have ever been observed there. During the Spring brood period, we surveyed the bench area extensively on multiple occasions, but only found a few instances of apparent KBB larval feeding sign, all on the extreme southern end, immediately adjacent to the recently burned portion of XXXXXb. Again, no larvae were observed here, despite extensive searches.

3.1.2 XXXXX2

XXXXX2 has an extensive lupine population, especially on the blowout and west/south-facing slopes. Only a few instances of kbb-like feeding sign were observed. No larvae were found however. Most of the feeding sign was observed on the easternmost "ridge" in the historically occupied area. Lupine also appears to be scattered around the edge of the former jackpine plantation and surveying here in the future may be warranted. This site should continue to be restored and managed as Oak barrens/Karner blue habitat, as it contains several very interesting insects and would be an excellent candidate for future KBB re-introduction efforts.

3.1.3 XXXXX3

The XXXXX3 site looks like very good habitat for the butterfly but very few instances of feeding sign were observed on the lupine, none convincingly Karner blue. No larvae were found, despite extensive searching and the lupine plants appeared vigorous throughout the Site. No observations were flagged. We did observe several Gorgone checkerspot butterflies (*Chlosyne gorgone*), a rather rare to uncommon dry prairie/barrens butterfly whose larvae feed on the flowers of a number of sunflower (*Helianthus*) species, particularly *Helianthus rigidus* and *Helianthus occidentalis*, both of which are common at this and the other Oak barrens/Sand Prairie sites within the WMA. The Persius/columbine duskywing skipper was also observed on a few occasions.

3.1.4 XXXXX4

A few instances of kbb-like feeding sign were observed at XXXXX4, but no larvae were found. This site looks like ideal Karner blue habitat and should have the butterfly. We observed the Persius/columbine duskywing here, as well as another characteristic barrens species, the silvery blue (*Glaucopsyche*

lygdamus), whose larvae feed on veiny pea (*Lathyrus venosus*). The Olympia marblewing was also observed/collected here, and the larval food plant, lyre-leaved rock cress (*Arabis lyrata*) was locally common on the exposed, south-facing, sandy slopes having minimal vegetation.

All observations of kbb-like feeding sign and rare butterflies were flagged and recorded on field forms or in our field notes. The barrens on west-facing slopes in the valley immediately west of XXXXX4 have small sand prairie remnants with gramma grasses (*Bouteloua hirsuta*) and should be sampled for rare *Bouteloua* specialists and other barrens insects in the future.

3.2 KARNER BLUE ADULT SURVEYS

3.2.1 Spring Adult Brood Surveys

Although our proposal did not include Spring Adult Brood Surveys, we visited all of the major Karner Blue sites at least twice during the Spring Flight Period. This was done primarily to determine when adults were actually emerging, so we could conduct Summer Larval Brood Surveys at appropriate times. This proved more difficult than we imagined, as weather conditions were cold and wet through much of the Spring, greatly delaying and protracting adult emergence.

Given that the only Spring Brood larval observation was at XXXXX1, we concentrated much of our survey effort for adults on this site. However, we managed to walk through XXXXX2, XXXXX3 and XXXXX4 Sites twice under appropriate conditions during the typical Spring Flight Period (May 24-June 15). Despite thoroughly surveying appropriate habitat at each of the sites, only two adults were observed (June 24, 2008), both at the XXXXX1 Site and in close proximity to the Spring larval observation. These late occurrences strongly suggested that the phenology of this butterfly was greatly delayed in 2008 and not necessarily in sync with its food plant, lupine.

3.2.2 Summer Adult Brood Surveys

Because of the late occurrence of the Spring Brood and our inability to perform Summer Larval Brood surveys, we were at a bit of a loss in determining when best to conduct the Summer Adult Brood surveys. As stated previously, we estimated that the Summer Brood of the KBB would be 10-14 days delayed from typical. We contacted MNDNR staff (Jaime Edwards) to determine when Summer Adult Brood surveys might best be conducted, given the apparent delay in the season. Jaime surveyed the XXXXX1 Site in late July and found no KBB flying, so we delayed our summer brood surveys until August 7-9. On the 7th, Jaime and I surveyed XXXXX1, XXXXX3 and XXXXX4 and saw no adult KBB's or even many other butterflies. The weather was hot, dry and a high-pressure system had been in place for a couple days. The weather broke and on the 9th, two male KBB's, both fresh, we observed in the Primary Area at XXXXX1.

A final survey and sampling trip was undertaken August 23-25, at which time several males and a female KBB were observed at XXXXX1, in both the XXXXX and the XXXXX "subsites". One male was also observed nectaring at *Monarda punctata* in the sand prairie restoration on the sand flats at the Southwest end of the XXXXX1a Site and adjacent to the Eastern end of the XXXXX1b site. These individuals were slightly worn, but still in pretty good shape and it is our belief that the Summer adult brood extended into early September in 2008. No adult KBB's were observed at any of the other Sites, despite thorough surveys.

3.3 ADDITIONAL RARE LEPIDOPTERA

3.3.1 Rare Butterflies

Despite the absence of Karner blues from much of the habitat surveyed, we did observe other rare butterflies. These included the dusted skipper (*Atrytonopsis hianna*), which was locally common at all four sites, especially XXXXX1 and XXXXX3. This is a classic dry prairie species and typically associated with the Karner blue on high quality habitat containing abundant little bluestem (*Schizachyrium scoparium*), the preferred larval food plant. The adults feed on nectar from a variety of flowers, especially *Arabis lyrata* and *Lithospermum* spp. The larvae feed until late summer, then hibernate partially grown in silk-lined tubes in little bluestem clumps, making them fire sensitive. Another characteristic barrens species observed during our surveys was the roadside skipper (*Amblyscirtes vialis*), whose larvae feed on a number of smaller bunch grasses such as *Panicum* spp. It's life history is much like that of the dusted skipper, although the roadside skipper appears to produce a second brood in SE Minnesota, with adults flying again in August. The second brood larvae overwinter to start the Spring generation. We also observed and collected several individuals of a duskywing skipper (*Erynnis* spp.) that is either the Persius duskywing (*Erynnis persius*) or the columbine duskywing (*Erynnis lucillius*). Both are quite rare, the Persius duskywing being the rarer of the two. We think we may have both and specimens will be sent off to an authority for verification. These Persius/lucillius duskywings were common at all four of our Study Sites.

The gorgone checkerspot (*Chlosyne gorgone*) was observed at all of our study sites in 2008, being most abundant at XXXXX3, esp. in the XXXXX along the XXXXX at the entrance to the Site. This area resembles degraded Sand Prairie and is dominated by *Helianthus rigidus*, little bluestem and other bunchgrasses. Larvae of *C. gorgone* were abundant on *H. rigidus* and *Ratibida pinnata* during summer, but disappeared by mid-August. Apparently only a spring brood was produced. This is a classic Great Plains species of Dry Prairies and is uncommon to rare and local throughout the Upper Midwest. The Olympia marblewing (*Euchloe olympia*) is a rare sand prairie/barrens species associated with the Karner blue throughout its midwestern range. It is quite local in Minnesota, being known from 12 scattered counties, five in the Southern half and only two in the Southeast (Winona and Wabasha). The adults fly in early spring and larvae feed on lyre-leaved rock cress (*Arabis lyrata*), tower mustard (*Arabis glabra*) and other *Arabis* species, maturing and pupating by early summer. The pupa overwinters on dried plant stems near the ground.

The silvery blue (*Glaucopsyche lygdamus*) was observed and collected at XXXXX3, where the larval foodplant veiny pea (*Lathyrus venosus*) is common. This is the first record of this rare and local butterfly from Whitewater WMA The larval foodplant was observed at the other study sites but no butterflies were seen. This species has suffered marked population reductions in the past 40 years throughout much of it's former Midwest range, likely as a result of fire suppression and continued degradation of its preferred habitat, barrens and open woodland. The silvery blue overwinters as a pupa attached to dried plant stems in the leaflitter and should be considered fire-sensitive. Leonard's skipper (*Hesperia leonardus*) is a characteristic barrens species typically found on Karner blue habitat, although not exclusively. It prefers dry sand prairie and barrens having a diversity of bunch grasses (on which the larvae feed) and abundant late season nectar sources such as *Liatris aspera* and *Vernonia* spp. The adults are strong fliers and very wary. This beautiful butterfly overwinters as young larvae in silk-lined shelters in bunchgrass clumps, making them fire sensitive. However, this species was observed at all of the Study sites in 2008, especially in areas that had been recently burned, indicating a preference for recently burned habitat.

Additional notable butterflies include the Crossline Skipper (*Polites origenes*), a typical barrens associate with a life history similar to *Amblyscirtes vialis*, except *P. origenes* is single-brooded. *Polygonia progne* is found in high quality woodlands and barrens where wild currants and gooseberries (*Ribes* spp.) are abundant. These shrubs were largely eradicated from many areas during the early and mid-20th Century, as they serve as alternate hosts to the White Pine Rust disease. *Polygonia progne* is known from throughout the northern half of Minnesota, becoming rare south of the Twin Cities.

3.3.2 Rare Moths

Bluff Prairie-Associated Species

Catocala abreviatella is a classic Bluff Prairie species, the larvae feeding on the developing foliage and flower heads of leadplant (*Amorpha canescens*). This moth is very rare and local, the bulk of its known populations occurring in the Driftless Region of SW Wisconsin and SE Minnesota. However, prior to our 2005-2006 surveys of the Bluffland State Parks, it was unknown from the Region (see Bess, 2006, 2007; Metzler, et. al, 2005). *Dichagyris grotei* is another rare bluff prairie associate, the larvae feeding on false boneset (*Kuhnia eupatoroides*). It was collected at XXXXX1 in the barrens and on the bluff prairie, and at XXXXX3, in the degraded sand prairie. The recently discovered *Dichagyris reliqua* ("The Relic") is known from ~12 populations in the world, nearly all occurring on high quality bluff prairies along the Niagaran Escarpment and Driftless region of Wisconsin, Minnesota, Manitoulin Island - Canada and strange, disjunct populations in the Pine Barrens of New Jersey, NW Florida and NE Wyoming (LaFontaine, 2004).

In 2008, I collected a single male of *D. reliqua* at XXXXX3, in the degraded sand prairie, and another on the XXXXX near the XXXXX1 KBB sites. This is undoubtedly one of the rarest insects in eastern North America and primarily endemic to the Niagaran Escarpment around the Great Lakes. The record from XXXXX3 is particularly interesting, as it is only the third population known to occur on sandy soils. The larvae feed on *Sporobolus heterolepis* in the Midwest (LaFontaine, 2004). The New Jersey population occurs in an area that is frequently burned (as does the MN population at Great River Bluffs SP), so the species appears to be somewhat fire-insensitive or fire-positive. Both species of *Dichagyris* were collected as state records for MN in 2006 at Great River Bluffs (see Bess, 2006, 2007).

Faronta rubripennis is a classic Tallgrass Prairie species, the larvae feeding on the developing seeds of switchgrass (*Panicum virgatum*) and Indiangrass (*Sorghastrum nutans*). Previously known from only 2 populations in the State, this is the first record from the SE. *Pyrausta laticlavia* is a species of prairies and Sand Barrens along the southern Atlantic Coastal Plain and southern Great Plains. The larvae feed on horsemint (*Monarda punctata*). This is a new record for Minnesota and a considerable range extension to the NW. T*arachidia binocula* is found in localized colonies throughout the Great Plains, where the larvae feed on sunflowers. In the Midwest, this moth is quite rare and local, associating strongly with *Coreopsis palmata*, *Helianthus occidentalis* and *H. rigidus* (Bess, pers. obs.). *Tricholita notata* was previously known from only a single location in the State (Norman Co.). Surveys in 2006-2007 discovered populations on the Bluff Prairies of Winona Co. In 2008, we collected a few males from the Bluff Prairie adjacent to the XXXXX1 Site. The species overwinters as partially grown larvae, feeding in the spring on the developing foliage of *Solidago rigida* and *Silphium terebinthenaceum*.

Barrens-Associated Species

Agrotis volubilis is an uncommon species of northern Oak barrens and Sand Prairie; rare and previously unrecorded this far south. The larval stages are unknown, but closely related species feed on grasses and forbs, overwintering partially grown in the detritus layer. The record from XXXXX1 is new for the

Bluffland Region (only the third for the State) and represents on of the southernmost occurrences. *Ethmia fuscidepella* is a rare, barrens restricted species collected at XXXXX3 in late June. It is Monophagous as a larva on the genus *Lithospermum*, and this is the first record of this moth from Minnesota. *Euxoa obeliscoides* occurs in a narrow band along the US-Canadian border, west to the Rockies and south in the mountains to New Mexico. It is associated with high quality barrens and dry woodland throughout its range, being generally rare to uncommon and intensely local in occurrence. The barrens and prairie remnants of SE Minnesota's bluffland region appear to harbor robust populations of this species, as it was found in good numbers at a couple of our Bluffland study sites in 2005-2007. The immature stages are undescribed, but it most likely overwinters in the detritus layer as a partially grown larva, making it potentially fire sensitive. The larvae are probably general feeders on barrens grasses and forbs.

Additional Barrens taxa include scrub oak feeders like the Scarlet Underwing Moth (*Catocala coccinata*) and Melsheimer's Sack-Bearer Moth (*Cicinnus melsheimeri*). *Catocala coccinata* is a rare to uncommon and local species of high quality oak barrens, the females preferring to oviposit on small, open-grown oaks (see Sargent, 1976). *Cicinnus melsheimeri* is associated primarily with pitch pine-scrub oak barrens along the north Atlantic coast and scattered Oak barrens locations in the Appalachians and around the southern Great Lakes. This is a new record for this moth from MN and a major range extension to the northwest. Melsheimer's sack-bearer is considered critically endangered throughout much of its range (see Wagner, et. al., 2003). *Cycnia inopinatus* is another classic barrens species, the larvae feeding on the flowers and developing seedpods of *Asclepias tuberosa* and *A. verticillata* (prob. also *A. hirtella* and *A. viridiflora*). The moth occurs only in close proximity to these plant species and was previously unrecorded from Minnesota. *Habrosyne gloriosa* is a rarely observed species associated with cool, mesic woodlands, barrens and fens. The larvae have been reared from Ninebark (*Physocarpus*) in the Northeast (Wagner, 2005).

Hadena capsularis and *Hadena ectypa* are two woodland/barrens associated species, their larvae Oligophagous on the flowers and seedpods of pinks (family Caryophyllaceae). *Hadena ectypa* is the rarest of the two and is monophagous on *Silene stellata*. A rather large population of this plant occurs along the entrance bluff to XXXXX3 and larvae were found feeding here in August of 2008. This is the first modern record of this moth from Minnesota. Additional larvae were located at XXXXX2, in the formerly occupied Karner blue habitat. *Pygarctia spraugei* is a highly local and generally rare species occurring in dry sand prairie and barrens where the larval foodplant, flowering spurge (*Euphorbia corollata*), occurs in abundance. This moth (as with most tiger moth species in our region) overwinters as a full grown larva or pupa in the leaflitter and should be considered fire-sensitive. The record from XXXXX1 is only the third from MN and first for the Bluffland Region. *Schinia nundina* larvae feed on the developing seeds of *Solidago speciosa* and the adults are found resting on or near this plant. Only recently recorded from MN (Bess, 2007), this beautiful Midwestern moth species is rare and local, range-wide. *Ulolonche modesta* is found in barrens on sand dunes along the Atlantic Coast and around the Great Lakes, where it is closely associated with Karner blue habitat. This is the first record of this rare moth from Minnesota. The larval stages are unknown.

Boreal Disjunct Species

Our bluffland surveys of 2005-2007 identified several boreal Lepidoptera species having disjunct populations in the cool ravines and Bluff Prairies of SE Minnesota (see Bess, 2008a). In 2008, we collected another interesting moth at the XXXXX1, a species of *Abagrotis* that appears to be *placida* (Grote). *Abagrotis placida* is a species of boreal and western montane conifer forests/barrens. While we still need to send this specimen off for verification, our identification is relatively certain. This is a major range extension for this species and one of only 3 recent records for MN, all new to the State (see Bess,

2008b). *Sideridis rosea* was recently found in the Bluffland region as a state record, and a single specimen was taken at XXXXX1 in 2008. The larvae are apparently general feeders on forbs and shrubs. *Polia purpurissata* is more typically associated with boreal barrens and swamp forest, the larvae feeding on a number of shrubs such as *Alnus, Betula, Myrica, Populus, Salix* and *Viburnum*. *Zanclognatha theralis* is a boreal detritivore, the larvae feeding on dead leaves, needles and twigs, typically under conifers.

Southern Disjunct Species

Given the close proximity to the Mississippi River and its moderating effect on the local climate, a number of southern species occur in the Bluffland Region, not as strays, but as breeding populations on the northern edge of their range. At Whitewater WMA, we found some very interesting southern species in 2008, insects that are uncommon or rare even in their central home range. These include *Heterocampa subrotata*, a prominent moth previously unrecorded from Minnesota and more typically associated with Floodplain Forest along the southern edges of the Great Plains. The larvae feed on hackberry, which is present in the region, and also at the north edge of its range. A single fresh male specimen was collected in the rich woodland that occurs on the bluff at the entrance road leading to the XXXXX3 Site. Two other species, *Catocala micronympha* and *Catocala nebulosa*, were also taken here, having recently been recorded from Great River Bluffs as State Records (Bess, 2007). *Catocala micronympha* is an uncommon species of southeastern oak woodlands and barrens, while *C. nebulosa* is a species of bottomland forest where the larval foodplants, Black Walnut (*Juglans nigra*) and Butternut (*Juglans cinerea*) are common.

Wetland Species

Despite the heavily degraded nature of much of the wetland habitat adjacent to our study sites, we managed to collect a couple of interesting wetland species in our light traps. These included *Capis curvata*, a rare and local sedge and rush borer, typically associated with high quality, boreal wetlands (esp. fens). This moth was recently recorded from Cook and Lake Counties as new to the State (Bess, 2008). *Leucania insueta* is another species of alkaline boreal wetlands, previously known in the Bluffland region only from Frontenac State Park (Wabasha Co.). *Leucania linita* was historically associated only with salt marshes and wet prairies on the Atlantic Coastal Plain. In the 1980's, populations were discovered in the Midwest, during initial surveys of fen insects in southern Michigan (Bess, 1988). Additional colonies have since been discovered in Prairie Fens and Wet Sand Prairies across northern Indiana (Bess, 1999, 2008), NE Illinois and (most recently) NE Minnesota (Bess, 2008).

4.0 KARNER BLUE BUTTERFLY POPULATION ESTIMATES

Given the low number of observations, formal population estimates from XXXXX1 would be impossible with the 2008 data. However, I believe a rough estimate can be drawn from the Spring Larval Brood, combining the one larva with the ~20 other observations of feeding sign. Using a conservative estimate that we observed half of the actual larvae present in 2008, would provide a Spring Brood Estimate of ~40 individuals, or a very small population. Summer Brood population size is typically anywhere from 4 to 10 times the size of the Spring Brood, providing a Summer Brood estimate of 160 to 400 individuals. I would recommend the more conservative estimate of no more than 160 individuals in the 2008 Summer Brood and my gut feeling is that the real number is half of that (~80).

5.0 KARNER BLUE BUTTERFLY HABITAT ASSESSMENTS

This section is a discussion of the quality of the Oak barrens habitat observed at Whitewater WMA as it relates to the long-term survival of the Karner blue butterfly and other rare grassland Lepidoptera. Both

Occupied Habitat and Unoccupied Habitat are discussed, with sections on Lupine frequency and cover, Nectar Source abundance and diversity, and general "quality" of the Oak barrens remnants.

5.1 Occupied Habitat [XXXXX1]

The XXXXX1 site was discovered by David Cuthrell in 1990, during initial, statewide surveys for the Karner blue prior to its listing as a Federally Endangered Species (see Cuthrell, 1990). At the time, Mr. Cuthrell observed approximately a dozen individuals during the Summer Adult Brood. In 1991, Cynthia Lane conducted an intensive KBB population and habitat characterization study at the Whitewater WMA (see Lane, 1992). Ms. Lane observed between 2 and 14 individuals during her daily walkthrough surveys, greatly in excess of the numbers she observed at the XXXXX3 Site (see below). It was her belief that the XXXXX1 population was larger than the XXXXX3 population, as shown by her data analysis.

The Site occurs on a sand outwash bench on the North side of an East-West trending limestone bluff on the East bank of the XXXXX. The top of the bench is relatively level, undulating and was recently cleared of much of it's timber and underbrush. There was also a fire in the recent past that burned much of the Bench. The herbaceous layer here is fairly diverse, with bunch grasses, lupine and a number of flowering forbs/nectar sources scattered throughout, although the area is heavily invaded with bluegrasses and smooth brome. Pennsylvania sedge forms monocultures in localized areas. A small valley with an old 2-track on the Southwestern end of the bench is the highest quality habitat and contains abundant lupine. Karner blues have been observed here infrequently.

The primary habitat at XXXXX1 occurs on a series of old blowouts or "bowls" along the north side of the sandy XXXXX. These dune faces are quite tall, 30-60ft in height. Their base is a nearly level valley floor along an intermittent stream. The dune faces are vegetated with a rich mixture of Oak barrens vegetation, but much of the habitat is fire suppressed and covered with woody growth and leaflitter. However, in areas that have been intensively managed with fire and manual cutting/herbicide application, the herbaceous vegetation is of high quality. Overall the habitat looks very similar to Karner blue habitat on the sand dunes in NW Indiana, where I have worked for the past 15 years.

5.1.1 Lupine

Lupine at the XXXXX1 Site is patchy in distribution, being most abundant in a couple of the N-facing XXXXX and along the Southwest portion of the XXXXX. Lupine is also scattered throughout the remainder of the Site, particularly on South and West-facing slopes, but much of this is growing in shade or in heavy brush, conditions not preferred by the Karner blue. The recent removal of woody species at the primary dune area (containing the bulk of the KBB population) was instrumental in restoring critical, additional habitat at XXXXX1. Lupine responded with very vigorous growth in 2008 and contained abundant nectar sources. This is currently the highest quality KBB habitat in the WMA.

5.1.2 Nectar Sources

Quite a few Karner blue nectar sources were observed growing at XXXXX1. Spring Brood nectar sources observed in 2008 include:

*Achillea millefolium**
Amorpha canescens
Apocynum andraesifolium
Arabis canadensis
Arabis glabra
Arabis lyrata
*Berteroa incana**
Campanula rotundifolia
Commandra umbellata
Cornus racemosa
Erigeron annuus
Erigeron strigosus
Fragaria virginica
Galium boreale
Lithospermum canescens
Lithospermum caroliniense
Lupinus perennis
Melilotus spp.*

Phlox pilosa	*Rubus flagellaris*	*Rudbeckia hirta*
Rosa (*setigera*?)	*Rubus occidentalis*	*Tephrosia virginiana*

Known and potential Spring Brood nectar sources were fairly scarce in the occupied habitat, and major nectar species from elsewhere in the butterfly's range (e.g. *Coreopsis lanceolata* and *Potentilla simplex*) were absent. *Arabis lyrata, Commandra, Fragaria, Rubus* spp., *Erigeron annuus, Phlox pilosa, Rudbeckia hirta, Vaccinium* spp. and *Zizia aptera* were the most frequently observed Spring nectar sources, although only *Erigeron, Fragaria, Phlox* and *Rubus* spp. were abundant and distributed widely across the Site.

Summer Brood Nectar Sources at XXXXX1 include:

Asclepias tuberosa	*Euphorbia corollata*	*Monarda fistulosa*
Asclepias verticillata	*Gnaphalium obtusifolium*	*Monarda punctata*
Ceanothus americanus	*Helianthus divaricatus*	*Ratibida pinnata*
Coreopsis palmata	*Helianthus occidentalis*	*Rudbeckia hirta*
Dalea candida	*Helianthus rigidus*	*Teucrium canadense*
Dalea purpurea	*Heliopsis helianthoides*	

* = non-native species.

Summer Brood nectar sources are more frequent at XXXXX1, with *Coreopsis palmata, Dalea purpurea, Helianthus rigidus, H. occidentalis, Monarda punctata* and *Rudbeckia hirta* being the most commonly encountered species. However, *Asclepias tuberosa* and *A. verticillata* are preferred nectar sources of the Karner blue, along with *Coreopsis palmata*, the *Helianthus* spp. and *Monarda punctata*.

5.1.3 Oak Barrens

As a result of continued habitat degradation and fragmentation, likely coupled with extreme weather conditions during the late 1990's and early 2000's, the KBB population at XXXXX1 crashed in 2003, indicating something was definitely wrong. In 2006 an intensive effort was undertaken to begin restoring the Oak barrens habitat at XXXXX1 and other Sites known to be Karner blue habitat. This restoration work involved the removal of non-native honeysuckle shrubs (*Lonicera tartarica*), the clearing of additional woody growth from diverse, lupine-covered dune slopes and the institution of a prescribed fire program.

Currently, much of the barrens at this Site is suffering from either fire suppression or invasion by non-native grasses. The North-facing XXXXX that contain the bulk of the KBB population are nearly completely covered with a woody canopy of oaks, cherries and, locally, jackpine. To create suitable Karner blue habitat, much of this woody vegetation, including many large (>8inch DBH) trees, will need to be cut and the stumps treated with herbicide to prevent re-sprouting. I recommend reducing canopy cover along the length of the N-facing XXXXX to 30-50 percent, with a goal of isolated patches of mixed-age oaks and native shrubs, set in a matrix of native grasses, lupine and Karner blue nectar sources. This may require localized timber harvesting in addition to typical restoration activities. A program of prescribed fire should also be coupled with this effort, to remove leaflitter and promote the growth of fire-adapted, Oak barrens plants critical to the survival of the Karner blue butterfly. Fire will also prepare the site for seeding with lupine and other key Oak barrens species.

Another substantial threat is the abundance of smooth brome and bluegrasses (*Poa compressa* and *P. pratensis*) along both the valley floor/streambeds and on the more level Bench Area above the N-facing dunes. While the valley floor is heavily degraded and could benefit from liberal herbicide application to clear smooth brome and other weedy species, the Bench area has quite a bit of native vegetation. Native species include lupine, Junegrass (*Koeleria macrantha*), side-oats gramma (*Bouteloua curtipendula*), leadplant (*Amorpha canescens*) and tickseeds (*Coreopsis* spp.), all of which are critical to the Karner blue as either resting sites or food sources. Care will need to be taken here to use herbicides specific to cool-season grasses and apply at times that will not kill off the Junegrass or other Monocots.

5.2 UNOCCUPIED HABITAT (XXXXX2, XXXXX4 AND XXXXX3 SITES]

The unoccupied oak barrens remnants at Whitewater WMA that we surveyed in 2008 are superficially similar to the XXXXX1 Site, except that all are smaller in size. The XXXXX3 and XXXXX4 sites both appear to be ideal Karner blue habitat, but both are highly isolated and lupine is restricted to a narrow band along the base of the dune slopes and on the edges of the valley floor. These low areas are frost pockets early and late in the season, possibly making them more extreme in temperature fluctuations and ultimately too stressful for the Karner blue to survive. Canopy closure and a general lack of nectar sources are also key issues at all sites visited. Despite these limitations, the three sites discussed below (and the marginal habitats adjacent to them) were all found to contain rare Oak barrens or Dry Prairie associated Lepidoptera and all could serve as potential Karner blue re-introduction sites, if habitat restoration and management efforts are continued and expanded.

5.3 XXXXX2 SITE

Both the XXXXX2 and adjacent XXXXX3 Sites were known to have Karner blue's present as recently as 1991 (Lane, 1992). However, surveys in the past few years have found no adults present (J. Edwards, pers. comm., 2008). The XXXXX3 Site was not surveyed in 2008. XXXXX2 is fairly large (132 acres at present) and occurs on a broad sand terrace, part of which was planted to jackpine plantation and subsequently cut and planted with prairie species. This area has since overgrown with young oaks and needs some aggressive management to reduce woody cover and restore the prairie/barrens vegetation. The southern edges of this terrace slope off fairly rapidly and are bisected by a small, intermittent tributary of the XXXXX, which has cut a deep valley (ravine), the face of which contains blowouts of varying size. The larger and westernmost of these blowouts is covered with thousands of lupine plants. The upper slopes also contain lupine on their southernmost edges. The valley floor is very weedy, dominated by smooth brome, with scattered lupine and other Oak barrens species.

5.3.1 Lupine

XXXXX2 contains a substantial amount of lupine, with a population well into the 10's of thousands of clumps. Unfortunately, much of the site has full canopy closure, shading out the herbaceous flora and providing a dense layer of leaflitter. The bulk of the lupine occurs on the steep blowouts at the south edge of the Site, where the sandy soil slumps regularly, keeping woody vegetation to a minimum. The remainder of XXXXX2 (including much of the former pine plantation) contains little or no lupine.

5.3.2 Nectar Sources

Nectar sources at XXXXX2 were scarce and limited to the blowouts and edges of the barrens, proper. The former jackpine plantation has quite a few nectar sources present, but it is also very weedy and overgrown with woody species such as oaks, cherries and blackberries (*Rubus alleghaniensis* and others). The non-native mullein (*Verbascum thapsis*) was extremely common along the open trail in 2008. Observed nectar species included *Arabis lyrata, Asclepias tuberosa, Coreopsis palmata, Euphorbia*

corollata, Helianthus occidentalis, H. rigidus, Melilotus spp., *Monarda fistulosa, M. punctata, Rosa* sp., *Rubus* spp., *Tephrosia virginiana* and *Vaccinium* spp. However, these were infrequent in occurrence and restricted mostly to the blowouts and barrens edges.

5.3.3 Oak Barrens

This Site would greatly benefit from continued and expanded restoration activities, particularly manual cutting/herbicide application and prescribed fire. I strongly recommend restoring the former Jackpine Area to open prairie/barrens and expanding restoration to include the adjacent XXXXX3 Site and goat prairies on the adjacent bluffs. The valley floor at the base of the blowouts needs aggressive herbicide application to remove invasive grasses and prepare the area for planting with lupine, nectar sources and other Oak barrens plants. Ultimately, XXXXX2 and XXXXX3 should be connected to the XXXXX1 Site through restoration of the intervening habitats.

5.4 XXXXX3 SITE

This was the original (and for many years, only) population of Karner blue butterflies known at Whitewater WMA. By the early 1990's, when Cuthrell and Lane made their surveys, this population was apparently on the decline, with less than a half dozen individuals observed during the Summer Brood daily counts. These low numbers indicate a population in crash mode and by 2005 the species was no longer present. We observed no adults in 2008 and saw little feeding sign of any kind on the lupine.

5.4.1 Lupine

Despite lacking the Karner blue, XXXXX3 contains quite a bit of lupine, with 10-20,000 clumps observed along the south-facing slope that makes up the bulk of this fairly small site. Most of the lupine appeared healthy and vigorous, with plants in the open being larger than those in the shade, in general.

5.4.2 Nectar Sources

A fairly diverse assortment of nectar sources was observed at this site, with the majority being found on the edges of the barrens and in the sand flats at the western edge of the Site and along the edge of the XXXXX. *Arabis lyrata, Coreopsis palmata, Euphorbia corollata, Fragaria virginica, Helianthus rigidus, H. occidentalis, Monarda punctata* and *Vaccinium* spp. were most frequently encountered. Much of the Barrens proper does not contain nectar sources, is heavily wooded and has a fairly dense leaflayer.

5.4.3 Oak Barrens

This site, like all the others, is suffering from historic fire suppression and resultant overstocking of woody species. Fire suppression has also led to a reduced vigor in the herbaceous layer, particularly in lupine and other, fire-adapted, flowering species. Invasive grasses such as smooth brome and Canada bluegrass have invaded the valley floor and level blufftops, probably as a result of past overgrazing and attempts at pasture reclamation. These will need to be controlled with herbicide and the area replanted with appropriate forbs and grasses. Restoration efforts should be greatly expanded here, to include the open flats to the west, north and south.

Ultimately this Site should be connected to the XXXXX and XXXXX4 Sites by creating a habitat corridor along both the uplands and lowlands. The *Phalaris*-choked, former wetlands along the base of the bluffs and in the lowlands between XXXXX3 and XXXXX4 should be restored to wet prairie/marsh, with a seeding effort aimed at providing additional nectar sources for the Karner blue that would encourage movement along the proposed dispersal corridor.

5.5 XXXXX4 SITE

XXXXX4 is superficially identical to the XXXXX3, except that it has proportionally more lupine and a greater abundance of nectar sources. The site is also quite small (16 acres). We saw several instances of what appeared to be good larval feeding sign at this site in 2008, but no adult KBB's were observed, despite repeated surveys.

5.5.1 Lupine

Lupine is relatively abundant here, forming large monocultures in the small openings in the eastern half of the Site, along the base of the sand dunes/bluff. Lupine was especially vigorous on a low bench along the edge of the stream valley. The lupine all appeared healthy and vigorous, and we observed KBB-like feeding sign on several clumps of lupine in this area. The persius duskywing, another rare lupine specialist, was common at this Site.

5.5.2 Nectar Sources

Nectar sources at XXXXX4 are as for XXXXX3, with a possibly greater increase in frequency and diversity within the barrens proper. Nectar sources were concentrated along the base of the dunes, in the small openings containing lupine and in a small prairie at the entrance to the Site.

5.5.3 Oak barrens

The Oak barrens at XXXXX4 have been actively managed for several years now, with a combination of manual cutting/herbicide application to control woody species and a prescribed fire program to promote herbaceous growth and retard the growth of woody species. As with XXXXX3, an expanded restoration program is recommended, including the valley floor, blufftops, sand flats and intervening wetland areas.

6.0 DISCUSSION AND RECOMMENDATIONS

As mentioned throughout this report, the oak barrens remnants at Whitewater WMA (as elsewhere) have suffered a long history of human use and neglect, from grazing, silviculture and tilling to fire suppression and the introduction of non-native species. Currently, the most obvious of these human threats are fire suppression and invasive plants, with the majority of the oak barrens seen in 2008 having unnaturally dense canopies of young trees and shrubs, with a dense layer of leafy detritus on the ground. The herbaceous layer in these sites was non-existent. In most of the few remaining open areas, non-native plant species like smooth brome (*Bromus inermis*) and bluegrasses (*Poa compressa* and *P. pratensis*), have invaded previously grazed areas, especially on valley floors and level blufftops. Smooth brome in particular excludes nearly all other plant life and is a major threat to the long-term survival of Oak barrens habitat within the WMA. Invasive shrubs and trees such as ash, boxelder, cherries, maples and non-native species like autumn olive and Tartarian honeysuckle fill in open areas and form a dense underbrush in formerly open woodlands and barrens.

The only high quality barrens remnants were those currently being managed as Karner blue butterfly habitat. However, their small size and highly isolated nature greatly limits the ability of these remnants to support Karner blue butterfly populations over the long-term. In order to protect the last remaining population of Karner blue butterflies in Minnesota, an aggressive and sustained, large-scale, restoration effort is needed at Whitewater WMA.

6.1 CREATION OF A KARNER BLUE METAPOPULATION MANAGEMENT AREA

The overall goal of this restoration effort should be the creation of a **Karner Blue Metapopulation Management Area** within the Whitewater WMA. Currently, the only habitat appearing even marginally suitable for the Karner blue butterfly occurs within the actively managed portions of the four sites discussed in this Report. XXXXX1 contains the greatest amount of potential KBB habitat and has obviously had an intensive amount of restoration work done in the past several years. The other sites contain varying amounts and quality of habitat and have also had habitat restoration/management activities aimed at removing non-native shrubs, opening the oak canopy and enhancing the herbaceous layer through scarification and seeding. Despite their current lack of KBB, all of these sites contained rare grassland Lepidoptera in 2008, and have great value as refugia for these species and as potential re-introduction sites for the Karner blue.

6.1.1 Development of Oak Barrens Dispersal Corridors

The Metapopulation Management Area should incorporate all of the historic and currently occupied habitat, as well as suitable buffer lands around and between the Sites that will be restored to a condition suitable for use as habitat by Karner blue larvae and/or adults. The development of high quality "Oak Barrens Dispersal Corridors" between the current and historic habitats at the WMA will be key to the long-term survival of the Karner blue butterfly in Minnesota. The creation of these connecting Corridors will require extensive, manual tree and shrub removal, removal of non-native grass cover, expansion of the Prescribed Fire Program and elimination of agricultural activities, in some cases.

6.1.2 Lupine and Nectar Source Seeding

Coupled with the more basic restoration activities of fire, cutting and herbicide application, should be a program of actively seeding lupine, Karner blue nectar sources and perennial bunchgrasses into areas of newly restored habitat. Nectar species to concentrate on include *Amorpha canescens, Arabis canadensis, A. glabra, A. lyrata, Asclepias tuberosa, A. verticillata, A. viridiflora, Ceanothus americanus, Coreopsis lanceolata* (not recorded here, but native to SE MN), *C. palmata, C. tripteris, Dalea spp., Euphorbia*

corollata, Helianthus occidentalis, H. rigidus, Monarda punctata, *Rudbeckia hirta* and *Veronicastrum virginicum*. Seed and nursery stock used in this restoration work should all derive from local genetic sources, preferably within the WMA or County, whenever possible.

6.1.3 Expansion of Prescribed Fire Program

It is also recommended that each of the current and historically occupied oak barrens remnants covered in this Report be divided into Burn Units. Despite the adaptation of its foodplant and nectar sources to fire, the Karner blue butterfly is actually susceptible to death from fire during the dormant season (October – May), during which time most prescribed burning occurs. The butterfly overwinters as an egg attached to dried vegetation from the previous growing season, making them highly flammable. Other rare grassland/barrens insects have similar life histories, which should be taken into account by land managers when developing burn programs for grasslands and barrens under their care. Occupied Karner blue habitat should never be burned in its entirety in any given year. Burning the entire area would not only be detrimental to the Karner blue butterfly, but to other insects as well (Borth, 1997; Bulan and Barrett, 1971; Cancelado and Yonke, 1970; Evans, 1984; Evans and Rodgers, 1983; Hansen, 1986; Lussenhop, 1976; Opler, 1981; Panzer et al., 1995).

Historically, wildfires burned across the landscape in a mosaic pattern, leaving some sites unburned, while others were charred to the soil. This left unburned "refugia" for fire-sensitive species (like the Karner blue) that could then re-populate areas of newly restored habitat. Unfortunately, this is no longer the case. The highly fragmented and isolated nature of the Nation's few, high quality oak barrens remnants does not allow for landscape level burns to occur as they did in the past. Also, isolated populations of rare species occurring in these habitat fragments are now much more susceptible to localized, catastrophic events. A hot burn through the single occupied valley at Whitewater, for example, could prove catastrophic to the KBB given the low number of individuals being observed in recent years.

Therefore, Land Managers need to mimic these landscape burns, but on a smaller scale and in a much more controlled way. A useful tool in doing this is the designation of Burn Units. Burn Units should be delineated such that an entire population of a particular rare species, in this case the Karner blue butterfly, is not contained in a single Unit. This will protect at least a portion of the population from immolation during Fire Management, while providing newly restored habitat for these protected individuals to then re-populate. No one Unit should contain the bulk of the high quality habitat at a particular Site, again to protect rare, fire-sensitive insects from being accidentally extirpated, while allowing for adequate management and maintenance of the habitat.

The Burn Units should be fired on a rotational basis, with no more than 25 percent of occupied habitat burned in any given year. Adjacent Burn Units should have two full growing seasons between burns. This will allow sufficient time for fire-sensitive species to move back into recently restored habitat. By leaving high quality, unburned refugia when conducting burns, populations of rare grassland species can be adequately protected while still ensuring the adequate restoration and maintenance of fire-maintained habitats. Refugia should contain a representative cross-section of the vegetation occurring in the area(s) being burned, and all adjacent Burn Units should not be fired in the same or subsequent years, leaving two growing seasons between burns on adjacent Units.

6.2 INITIATION OF A KBB CAPTIVE BREEDING PROGRAM

Given the very low numbers of Karner blue observed at XXXXX1 in the past few years, it is strongly recommended that a captive breeding program be implemented to augment the wild population at this Site and to provide individuals for re-populating historically occupied habitat within the WMA. It is our

understanding that such a project was carried out in the past (Lane, 1999a) and should be re-instated. Great care needs to be taken in maintaining a sterile growing area, but other States have had success with mass rearing and translocating this species (see Amaral, 2000; Herms et al., 1996; The Nature Conservancy, 2002; Toledo Zoo, 2002; VanLuven, 1994).

7.0 CONCLUSIONS

From our observations in 2008, a review of past literature regarding the Karner blue at Whitewater WMA and nearly 30 years of experience with the butterfly throughout its range, we have concluded the following:

1. The oak barrens and sand prairie remnants at Whitewater WMA are highly fragmented and fire suppressed;

2. The Karner blue butterfly population at the XXXXX3 Site suffered a catastrophic event sometime in the past 10 years and is now considered extirpated from this Site;

3. The resident Karner blue butterfly population at XXXXX1 suffered a catastrophic event in 2003 and is currently in crash mode;

4. Drastic Measures Are Needed to Rectify this Situation;

5. First Priority is to Designate a Karner Blue Butterfly Metapopulation Management Area within the WMA having legal, binding protection and designated funding;

6. Expand and intensify current restoration program at Historic and Occupied Sites and begin expanding restoration to adjacent degraded habitats;

7. Begin an immediate captive rearing program using MN stock to help build up the XXXXX1 population and begin releases into restored, historically occupied, habitats; and

8. Implement long-term Vegetation and Karner Blue Butterfly Population Monitoring Programs.

It is highly likely that the historically hot and droughty weather over the past 10 years, along with habitat fragmentation and wildfire suppression, have played a major part in the decline of the Karner blue butterfly at Whitewater WMA. With global warming predicted to continue through the foreseeable future, continued stresses on this localized and highly significant population will continue. Therefore, it is imperative that measures be taken to expand available habitat for this species, particularly in more cool and humid portions of the Valleys that will hopefully help the species withstand the continued onslaught on its habitat.

8.0 BIBLIOGRAPHY

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. Concord, New Hampshire. 16 pp.

Anderson, K. L., E. F. Smith, and C. E. Owensby. 1970. Burning bluestem range. *Journal of Range Management* 23:81-92.

Anderson, R. C. and L. E. Brown. 1986. Stability and instability in plant communities following fire. *American Journal of Botany* 73:364-368.

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.

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.

Arend, J. L. and H. F. Scholz. 1969. Oak forests of the Lake States and their management. USDA Forest Service, North Central Forest Experiment Station Research Paper NC-31. 36pp.

Bacone, J., R. Campbell, G. Wilhelm, 1979. Presettlement vegetation of the Indiana Dunes National Lakeshore. United States Department of the Interior National Park Service Publication, Indiana Dunes National Lakeshore, Porter, Indiana.

Barden, L. 1978. Regrowth of shrubs in grassy balds of the southern Appalachians after prescribed burning. *Castanea* 43:238-246.

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

Bess, J. 1997. A report on the insect fauna of the Pigeon River Fish and Wildlife Area: LaGrange and Steuben Counties, Indiana. Unpublished report to the Indiana Department of Natural Resources.

Bess, J. 1998. A report on the moth fauna of the Kankakee Sands and Grand Prairie Natural Regions of Indiana: with special emphasis on remnant-dependent taxa. Unpublished report to the Indiana Department of Natural Resources.

Bess, J.A., R.M. Strand and L.A. Wilsmann. 1989. Status of the Karner blue butterfly, *Lycaeides melissa samuelis* Nabokov, in the Manistee National Forest. Report to the Huron-Manistee National Forest, Michigan. 42 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.

Biswell, H. 1977. Giant Sequoia Fire Ecology. University Extension Course X417.4. University of California, Davis.

Black, S. H., and D. M. Vaughan. 2005. Species Profile: *Lycaeides melissa samuelis*. In Shepherd, M. D., D. M. Vaughan, and S. H. Black (Eds). *Red List of Pollinator Insects of North America*. CD-ROM Version 1 (May 2005). Portland, OR: The Xerces Society for Invertebrate Conservation.

Bleser, C.A. 1993. Status survey, management, and monitoring activities for the Karner blue butterfly in Wisconsin, 1990-1992. Madison: Wisconsin Department of Natural Resources, Bureau of Endangered Resources.

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**.**

Brady, N. C. 1974. The Nature and Properties of Soils. Eighth Edition. MacMillan Publishing, New York.

Bray, J. R. 1958. The distribution of savanna species in relation to light intensity. *Canadian Journal of Botany* 36:671-681.

Bulan, C. A. and G. W. Barrett. 1971. The effects of two acute stresses on the arthropod component of an experimental grassland ecosystem. *Ecology* 52(4):597-605.

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.

Cancelado, R. and T.R. Yonke. 1970. Effects of prairie burning on insect populations. *Journal of the Kansas Entomology Society* 43:274-281.

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.

Chan, P. K. and L. Packer. 2004. When is a site restored? Studies of the suitability of five oak savannah habitats in Ontario for reintroduction of the Karner Blue Butterfly (*Lycaeides melissa samuelis*). Sixteenth Int'l Conference, Society for Ecological Restoration, Aug. 24-26, Victoria, Canada.

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. 1989. 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.

Clough, M. W. 1992. Endangered and threatened wildlife and plants: determination of endangered status for the Karner Blue butterfly. Federal Register 57 (240): 59236-59244.

Cowles, H. C. 1899. Dune floras of Lake Michigan. *Botanical Gazette* 27:95-117, 167-202, 281-308, 361-391.

Crow, T. R. 1988. Reproductive mode and mechanisms for self-replacement of northern red oak (*Quercus rubra*)- a review. *Forest Science* 34:19-30.

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. 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.

Daubenmire, T. 1968. Ecology of fire in grasslands. *Advances in Ecological Research* 5:209-266.

Dirig, R. 1997. Karner blue: Sing Your Purple Song. North American Butterfly Association, December, 1997 Issue. http://www.naba.org/pubs/ab97a/p14.html

Dirig, R. 1994. 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.

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

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.

Dorney, C. H. and J. R. Dorney. 1989. An unusual oak savanna in northeastern Wisconsin: The effect of Indian-caused fire. *American Midland Naturalist* 122:103-113.

Dorney, J. R. 1981. The impact of native Americans on pre-settlement vegetation in southeastern Wisconsin. *Transactions of the Wisconsin Academy of Science Arts and Letters* 69:26-35.

Doyle, K. M., T. J. Fahey, and R. D. Paratley. 1987. Subalpine heathlands of the Mahoosuc Range, Maine. *Bulletin of the Torrey Botanical Club* 114:429-436.

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. (SE Region Nongame Specialist) 2002. Summary for Karner blue butterfly fieldwork – 2001 field season. Unpublished Report, Minnesota Nongame Wildlife Program, St. Paul. 6 pp.

Edwards, J. (SE Region Nongame Specialist) 2003. Karner blue butterfly habitat restoration at Whitewater wildlife management area. MN State Wildlife Grants Program Project Proposal submitted September 2003 in cooperation with the Red Wing Wildlife League.

Evans E. W. and R. A. Rodgers. 1983. Sampling grasshoppers (Orthoptera: Acrididae) on burned and unburned tallgrass prairie: night trapping vs. sweeping. *Environmental Entomology* 12:1449-1454.

Evans, E. W. 1984. Fire as a natural disturbance to grasshopper assemblages of tallgrass prairie. *Oikos* 43:9-16.

Ewert, D.N. and H.E. Ballard, Jr. 1990. Distribution and management of an indicator species of oak barrens, the Karner blue butterfly (*Lycaeides melissa samuelis*): pre-treatment population studies. Report to the Huron-Manistee National Forest, Michigan.

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. 106pp.

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

Fowells, H.A., ed. 1965. Silvics of forest trees of the United States. U.S. Department of Agriculture Agricultural Handbook No. 271. U.S. Government Printing Office, Washington, D. C. 762 pp.

Fralish, J.S., R.C. Anderson, J.E. Ebinger, and R. Szafoni (eds.). 1994. Proceedings of the North American Conference on Barrens and Savannas. Environmental Protection Agency.

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.

Givnish, T. J., E. S. Menges, and D. F. Schweitzer. 1988. Minimum area requirements for longterm 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 effects of fire on wild lupine (Lupinus perennis). Masters Thesis. The University of Toledo.

Grimm, E. C. 1984. Fire and factors controlling the Big Woods vegetation of Minnesota in the mid-nineteenth century. *Ecological Monographs* 54:291-311.

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. 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. 1998b. The effect of canopy cover and seasonal change on host plant quality for the endangered Karner blue butterfly (*Lycaeides milissa samuelis*). Oecologia 114: 243-250.

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.

Haney, A. and S. I. Apfelbaum. 1990. 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.

Hansen, J. D. 1986. Comparison of insects from burned and unburned areas after a range fire. *Great Basin Naturalist* 46:721-727.

Henderson, N. R. and J. N. Long. 1984. A comparison of stand structure and fire history in two black oak woodlands in northwest Indiana. *Botanical Gazette* 145:22-228.

Henderson, N.R. 1982. A comparison of stand dynamics and fire history in two black oak woodlands in northwestern Indiana. M.S. thesis. Utah State University, Logan.

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.

Hulbert, L.C. 1969. Fire and litter effects in undisturbed bluestem prairie in Kansas. *Ecology* 50:874-877.

Hulbert, L.C. 1981. Causes of fire effects in tall grass prairie. *Ecology* 69:46-58.

Johnson, P. S. 1985. Regeneration of oaks in the Lake States, pp. 98-109. In: J. E. Johnson (ed.), Proc. Challenges in oak management and utilization. Cooperative Extension Services, University of Wisconsin, Madison.

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.

King, R.S. 2003. Habitat management for the Karner blue butterfly. Ecological Restoration 21: 101-106.

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.)

Kleintjes, P.K., J.M. Sporrong, C.A. Raebel, and S.F. Thon. 2003. Habitat type conservation and restoration for the Karner blue butterfly: A Case Study from Wisconsin. Ecological Restoration 21: 107-115.

Kline, V. M. 1984. Wisconsin oak forests from an ecological and historical perspective, pp. 3-7. In: J. E. Johnson (ed.), Proc. Challenges in oak management and utilization. Cooperative Extension Services, University of Wisconsin, Madison.

Knapp, A. K. and T. R. Seastedt. 1986. Detritus accumulation limits productivity of tall grass prairie. *Bioscience* 36:662-668.

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.

Korstian, C. F. 1927. Factors controlling germination and early survival in oaks. Yale School of Forestry, Bull. no. 19. 115 pp.

Kozlowski, T. T., and C. E. Ahlgren, (eds). 1974. Fire and ecosystems. Academic Press, New York.

Kratz, T.K. and G.L. Jensen. 1983. Minnesota's landscape regions. Natural Areas Journal 3:33-44.

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. 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. P. 1993. 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. P. 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. P. 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. P. 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. 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, Green Bay Field Office, Green Bay, Wisconsin. 124 pp.

Lane, C. P. 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. P. 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. P. 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.

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

Lawrence, W. and A. Cook 1989. The status and management of Karner blue (Lycaeides melissa samuelis) populations in the Allegan State Game Area, Michigan. The Nature Conservancy, Michigan Chapter (unpublished). 58pp.

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 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.

Lorimer, C. G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. *Ecology* 58:139-148.

Lorimer, C. G. 1985. The role of fire in the perpetuation of oak forests, pp. 8-25. In: J. E. Johnson (ed.), Proc. Challenges in oak management and utilization. Cooperative Extension Services, University of Wisconsin, Madison.

Lussenhop, J. 1976. Soil arthropod response to prairie burning. *Ecology* 57(1).

Marschner, F.J. 1974. The original vegetation of Minnesota (compiled from U.S. General Land Office survey notes). 1930. USDA Forest Service. North Central Forest Experiment Station. St. Paul, MN.

Martin, M. 1990. 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. 110

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

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

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.

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.

Mosley, J. C., D. B. Wester, and S. C. Bunting. 1987. Estimating herbaceous yield from species frequency. *Northwest Science* 61:55-59.

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. 1957. Pnin. Doubleday and Co. New York, NY.

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

Nabokov, V. 1989. Letter to Robert Dirig. Pages 549-550 *in* Nabokov, D. and M.J. Brucolli (eds.), Vladimir Nabokov, selected letters, 1940-1977. Harcourt Brace Jovanovich, Bruccoli Clark Layman, San Diego, New York, London. 582 pp.

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. French-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.

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. 1981. Management of prairie habitats for insect conservation. *Journal of the Natural Areas Association* 1(4):3-6.

Opler, P. and O. Krizeg 1984. Butterflies east of the Great Plains: an illustrated natural history. 360 pp.

Packard, S. 1988. Chronicles of restoration: restoration and rediscovery of the tall grass savanna. *Restoration and Management Notes* 6:13-20.

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

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

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.

Panzer, R., D. Stillwaugh, R. Gnaedinger and G. Derkovitz 1995. Prevalence of remnant dependence among the prairie- and savanna-inhabiting insects of the Chicago region. Natural Areas Journal 15(2):101-116.

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.

Peet, M. R., T. C. Anderson, and M. S. Adams. 1975. Effects of fire on big bluestem production. *American Midland Naturalist* 94:15-26.

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.

Pollard, E. 1977. A method for assessing changes in the abundance of butterflies. Biological Conservation. 12:115-134.

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

Rabe, M.L. 2001. Special animal abstract for *Lycaeides melissa samuelis* (Karner blue). Michigan Natural Features Inventory. Lansing, MI.6 pp.

Savignano, D. A. 1990. Field investigations of a facultative mutualism between Lycaeides melissa samuelis Nabakov (Lycaenidae), the Karner blue butterfly, and attendant ants. PhD Dissertation, University of Texas at Austin. 119 pages.

Savignano, D.A. 1994. The distribution of the Karner blue butterfly in Saratoga County, New York. Pages 73-80 *in* Andow, D.A., R. Baker, and C.P. Lane (eds.), Karner blue butterfly: a symbol of a vanishing landscape. Minnesota Agricultural Experiment Station, University of Minnesota. Misc. Publ. 84-1994.

Schmalzer, P. A. and C. R. Hinkle. 1992. Species composition and structure of oak-saw palmetto scrub vegetation. *Castanea* 57:220-251.

Schroeder, R. L. and M. E. Keller. 1990. Setting objectives - A prerequisite of ecosystem management. Ecosystem Management: Rare Species and Significant Habitats. New York State Museum Bulletin 471. pp. 1-4.

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.

Schwaegman, J. E. and T. C. Anderson. 1984. Effects of eleven years of fire exclusion on the vegetation of a southern Illinois barren remnant, pp. 146-148. In: Proceedings of the Ninth North American Prairie Conference.

Schweitzer, D. F. 1992a. Fact Sheet for the Karner blue butterfly, with special reference to New York. Unpublished report to The Nature Conservancy. 7 pages.

Schweitzer, D. F. 1992b. The status of the Karner Blue Butterfly (*Lycaeides melissa samuelis* Nabakov) at the Indiana Dunes National Lakeshore, with special consideration of planning of prescribed burns at major sites. National Park Service, Indiana Dunes National Lakeshore.

Schweitzer, D. F. 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. F. 1994. Prioritizing Karner blue butterfly habitats for protection activities. Pages 173-183 in D.A. Andow, R.J. Baker and C.P Lane (eds), Karner blue butterfly: A symbol of a vanishing landscape. St. Paul: Minnesota Agricultural Experiment Station, University of Minnesota.

Scudder, S. H. 1888. Feeding habits of a lycaenid caterpillar. *Psyche* **5:**13.

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.

Scudder, S. H. 1901. My first namesake. *Ottawa Naturalist* 15**:**121-122.

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**.**

Smallidge, P.J., D.J. Leopold and C.M. Allen. 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.

Smith, S. D., S. C. Bunting, and M. Hironaka. 1986. Sensitivity of frequency plots for detecting vegetation change. *Northwest Science* 60:279-286.

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. 115

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.

Swan, R.R., Jr. 1970. Post-fire response of four plant communities in south central New York state. *Ecology* 51:1074-1082.

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. 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.

Swink F. and G. Wilhelm 1994. Plants of the Chicago region. Indiana Academy of Science. 921 pp.

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.

Thor, E. and G. M. Nichols. 1973. Some effects of fires on litter, soil, and hardwood regeneration. In: Proceedings in the Tall Timbers Fire Ecology Conference. 13:317-329.

Tilman, D. 1987. Secondary succession and the pattern of plant dominance along an experimental nitrogen gradient. *Ecological Monographs* 57:198-214.

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. 2001. Karner blue butterfly (*Lycaeides melissa samuelis*). Technical - Agency Draft Recovery Plan. Fort Snelling, Minnesota. 221 pp.

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.

VanLuven, D. 1994. 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. 1993. Status report on the Karner blue butterfly and associated management activities. U.S. Fish and Wildlife Service, Concord, New Hampshire. 25 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.

Weaver Boos Consultants, Inc. 1996. The Strategic Management Plan for Linear Corridors in Areas Inhabited by the Karner Blue Butterfly (Lycaeides melissa samuelis Nabakov). Unpublished Rpt. for The Linear Corridor Partners Wisconsin HCP Team.

Weaver Boos Consultants, Inc. 1997a. A report on status surveys for the Karner blue butterfly. Unpublished Report for National Steel Corporation to the U. S. Environmental Protection Agency (Confidential).

Weaver Boos Consultants, Inc. 1997b. Final Annual Report on Restoration and Monitoring Activities for the Karner blue butterfly. Unpublished Report for National Steel Corporation to the U. S. Environmental Protection Agency.

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.

White, A. S. 1983. The effects of thirteen years of annual burning on a *Quercus ellipsoidalis* community in Minnesota. *Ecology* 64:1081-1085.

Whitford, P. C. and P. B. Whitford. 1978. Effects of trees on ground cover in old-field succession. *American Midland Naturalist* 99:435-443.

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.

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

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.

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.

Wright, H. A. and A. W. Bailey. 1982. Fire Ecology. John Wiley and Sons, New York.

Zaremba, R. E. and M. Pickering. 1994. 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.

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.