APPENDIX G

MANAGEMENT GUIDELINES – BALANCING TRADE-OFFS IN DEVELOPING AND IMPLEMENTING KARNER BLUE RECOVERY PLANS

To restore viable metapopulations of Karner blues to the landscape, it will be important to establish and maintain the early successional habitat on which the butterfly depends. This entails assuring that appropriate disturbance and/or management regimes (e.g., prescribed fire, mechanical management, etc.) necessary to renew existing habitat or to create new habitat are incorporated into management plans for the species. In addition, maintaining metapopulation dynamics depends upon spatially arranging subpopulations to facilitate colonization of butterflies from occupied to unoccupied sites. This appendix includes guidance and information on management of habitat for the Karner blue, and on creating conditions that will facilitate and increase the colonization rate of subpopulations within a metapopulation. These guidelines are based on currently available information on the biology of the Karner blue and its habitat. As more information is obtained, these guidelines may be updated.

All biological communities are dynamic, and localized extirpation of subpopulations is a natural phenomenon. Thus, the loss of one local subpopulation of a rare butterfly is not necessarily detrimental to the survival of the species if new local subpopulations are founded at the same rate as others become extirpated. Unfortunately, human activities have increased the rate of localized extirpation for many butterflies, while limiting the possibilities of new local subpopulations becoming established. If butterfly diversity (and all biological diversity) is to remain at its present level throughout the United States, a conscious effort must be directed towards preserving a significant percentage of the countryside in native ecosystems.

The Karner blue occurred as a series of metapopulations arrayed from Minnesota eastward through Canada to New England. Several of these metapopulations are now extirpated, and as outlined in this plan, the continuing loss of metapopulations is incompatible with recovery. However, the situation is further complicated because the Karner blue can thrive in some managed ecosystems, which can result in conflicts in management objectives that need to be resolved. Moreover, each metapopulation is composed of a series of individual local populations or subpopulations, each of which is prone to local extirpation. Metapopulations themselves depend upon a balance between subpopulation extirpation and subpopulation creation following recolonization of unoccupied habitats. Ideally, the individual occupied and unoccupied Karner blue habitat sites that together compose the metapopulation are arrayed spatially in such a way as to facilitate interchange of butterflies between the sites. Maintaining a persistent metapopulation requires that, at a minimum, dispersing butterflies find and colonize unoccupied sites at the same rate that subpopulations become extirpated. In robust metapopulations, the colonization rate greatly exceeds the local extirpation rate and most suitable habitat is occupied. In precarious metapopulations the colonization rate is only slightly larger than the extirpation rate; at equilibrium, any factor that negatively influences either rate can result the collapse of the metapopulation. Thus occupancy rate is a good measure of the robustness and fragility of a metapopulation.

There are two complementary approaches for influencing this balance: increasing the rate at which unoccupied sites are colonized, and/or decreasing the local extirpation rate. Land managers must consciously consider factors that influence both portions of the equation during both the development of the management plan for a Karner blue metapopulation, as well as during the implementation of that plan while managing Karner blue support ecosystems. As discussed in the section on population structure above, changing these rates can also affect the functioning of the metapopulation. When extirpation rates are reduced low enough at a site or cluster of sites, the metapopulation will function more like a core-satellite metapopulation, and when recolonization rates become very high, it will function more like a patchy metapopulation. When recolonization rates are not high and extirpation rates are not low, then the metapopulation will function more like a true metapopulation.

The colonization and extirpation rates will be strongly affected by local site conditions (e.g. habitat quality, dispersal corridors), the management of which will provide the means to improve Karner blue metapopulations. Equally important, however, are broad-scale factors, such as weather, wildfire, and unregulated urban sprawl, that can influence colonization and extirpation rates across all of the local sites in an entire metapopulation. Management at this broad-scale provides buffering capacity for the metapopulation. Management plans and activities must consider both scales of management to ensure persistence of the metapopulation.

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

INCREASING THE COLONIZATION RATE OF SUBPOPULATIONS WITHIN A METAPOPULATION

Increasing the rate that butterflies colonize suitable habitat within a metapopulation can have a very positive effect on the viability of the metapopulation. A high colonization rate tips the recolonization-extirpation balance in favor of recolonization, because if colonization rates are high enough, nearly all suitable habitat will be colonized every year and nearly all will remain occupied every year. Indeed, if colonization rates are high enough, then the metapopulation ceases to function as a true metapopulation and assumes the functional characteristics of a patchy metapopulation (refer to APPENDIX E, POPULATION STRUCTURE. Spatial Structure of Karner Blue Butterfly Metapopulations). Because a patchy metapopulation will be more resilient to disturbances to subpopulations than a true metapopulation, management can shift emphasis to manage the average subpopulation rather than focus specific efforts on each subpopulation.

Between-Site Dispersal

The recovery criteria (PART II, RECOVERY OBJECTIVE, Reclassification Criteria, and Delisting Criteria) includes establishing connectivity between subpopulations so that the average nearest-neighbor distance between subpopulations is no more than 1 kilometer (0.62 miles), and the maximum distance between subpopulations is no greater than 2 kilometers (1.24 miles). In some cases the 1 kilometer (0.62) dispersal distance may be too far, in others the 2 kilometer distance may not be far enough. For subpopulations greater than 2 kilometers from their nearest-neighbor, validation that dispersal is occurring is needed prior to including that subpopulation into the LP. The appropriate separation distance between subpopulations will depend on the site characteristics, especially the extent of canopy cover between habitat sites. Table G1 summarizes available information on between-site dispersal and within-habitat movements and indicates canopy cover between habitat sites. Managers can use this information to determine the appropriate spacing of subpopulations to facilitate dispersal by reviewing the results of studies with site characteristics and canopy cover between sites most similar to the landscapes that they are managing. If the landscape they are managing differs from those in the studies, then separate dispersal studies should be done to determine appropriate distances between subpopulations. One way to demonstrate dispersal is to create new habitat patches in unoccupied areas and monitor for occupancy of Karner blues. A discussion of the dispersal information in Table G1 follows.

The primary methods that have been used to determine dispersal distances and rates for the Karner blue butterfly are noted on Table G1 and are mark-release-recapture (MRR) (Schweitzer 1979; Fried 1987; Bidwell 1994; Lawrence 1994; King 1994, 1998) and focal animal sampling or tracking of individual butterflies (Welch 1993, Grundel et al. 1998b, Lane 1999). Although MRR methods have been the most cost-effective method of obtaining information on dispersal, because they rely on detecting the rare long-distance recapture and a sampling intensity that declines with distance, they tend to underestimate the number and distance traveled by dispersing individuals.

Obviously, the greater the distance separating sites of suitable habitat and the more dense the canopy closure between habitat, the lower the odds that butterflies will locate unoccupied habitat. Two factors influence this: the decreasing likelihood that a Karner blue butterfly will fly greater distances especially with increasing intervening canopy cover, and the decreasing probability that a dispersing butterfly will encounter or find a particular site at greater distances. Dispersal of the Karner blue may be enhanced by developing dispersal corridors to guide dispersing butterflies towards more distant habitat sites, or increasing the size of the distant habitat site because larger targets might be easier to find (refer to Facilitating Directed Dispersal Using Corridors, below).

As the dispersal studies demonstrates, Karner blue butterflies are not particularly strong flyers compared to many other species of butterflies. Most dispersal studies have documented very few between-site dispersal events and limited dispersal distances (Fried 1987, Givnish et al. 1988, Lawrence and Cook 1989, Sferra et al. 1993, Welch 1993, Bidwell 1994, Lawrence 1994, Fuller 1998, Knutson et al. 1999).

Generally, the more open the habitat, the greater amount of between-site dispersal can be expected and the longer the dispersal distances. Dispersal distances up to 1.05 kilometers (0.65 miles), 1.3 kilometers (0.81 miles), and 1.6 kilometers (1 mile) have been recorded from rights-of-ways (ROWs) and/or trail areas in studies by Lawrence and Cook (1989), Schweitzer (1979), and Bidwell (1994) respectively. Welch (1993) recorded dispersal up to 1.7 kilometers (1.05 miles) in mixed (but mostly open) habitat. King (1998), documented the greatest amount of between-site dispersal and longest dispersal distances for the Karner blue. His study sites at Necedah NWR were each about 100 hectares (247 acres) in size, and were separated from each other by more than 1,150 meters (0.7 miles) of mostly open wetland habitat. About 11 percent of butterflies marked during the second flight made at least one inter-population dispersal of 1,150 meters (0.7 miles) or more. Of all marked butterflies, (429) 7.5 percent made at least one inter-population dispersal of 1500 meters (0.93 miles) or more. Of the Karner blues located greater than three times, movements greater than 1,500 meters (0.93 miles) were even more common (8.5 percent, n=354) (King 1998). Ten percent of all Karner blues with multiple captures were shown to travel at least 2.3 kilometers (1.4 miles) during the second flight of 1995 (less than 50 butterflies), and one individual female traveled at least 6.6 kilometers (4.1 miles) during the same flight (USFWS 2001, King unpublished data). These longer flights (1,500 meters – 6.6 kilometers) at Necedah NWR reflect the sum of within-habitat movements and between-site dispersal.

Lesser amounts of dispersal and/or dispersal distances are noted in studies where the intervening habitats are mixed or more closed or where the habitat was open but limited in extent (e.g., Sferra it al. 1993). In New York, Schweitzer (1979) captured only 4 percent of about 50 marked individuals about 1.3 kilometers (0.81 miles) away, and he observed little dispersal in the Concord, New Hampshire population, where less than one percent of the marked individuals crossed a narrow, little-used road separating two large habitat patches (Schweitzer 1979 in Givnish 1988, Dale Schweitzer, TNC, pers. comm. 1996). Fried (1987) captured only 1.3 percent of the recaptures (total recaptured = 224) dispersing between three sites that were approximately 400 to 700 meters (437 to 765 yards) apart. The habitat matrix between Fried's study sites was mixed, composed primarily of dense woods or low shrubs, although dirt paths connected them. In Wisconsin, Bidwell (1994) captured 2.9 percent of the marked individuals (total number marked = 724) dispersing between habitat sites. Two thirds of the dispersal events recorded were between the two close sites (50 meters apart); the rest were longer distances up to 1,600 meters (1 mile). In Michigan, during the second flight, Lawrence (1994) marked 538 individuals on sites 0.5 to 2.5 kilometers (0.3 to 1.6 miles) apart in a more closed habitat area and recaptured 142 butterflies. No individual was recaptured at a site other than at the original marking site during the first and second flights. Lawrence suggested that between site dispersal in his study area was probably uncommon because butterflies were marked and recaptured frequently, which would have enabled them to observe such dispersal if it had been common. Similarly, no long-distance dispersal between sites was observed during studies at the more closed IDNL sites even though large numbers of butterflies were marked (n=1959 1st flight, n=3654 2nd flight), (Knutson et al. 1999).

In studies on the Heath fritillary butterfly (*Mellicta athalia*) in England, Warren (1987) found an average of 1.5 percent dispersal between-sites. He argued that if similar rates of

Table G1. Summary of Karner blue butterfly between-site dispersal and within-habitat movement studies.

MRR = mark-release-recapture, ISD = dispersal between sites, MDM = mean distance per move, MDD = mean distance moved per day, Range = distance between two most distant captures. KBB = Karner blue butterfly. Character of canopy between habitat openings categorized as " open," "mixed," "closed," or "unknown" based on site descriptions. To convert kilometers to miles multiply the kilometers by 0.621; to convert meters to yards multiply the meters by 1.093; to convert meters to miles multiply the meters by 0.0006214.

STUDY	DATE	FLIGHT	LOCATION	STUDY SITE DESCRIPTION	CANOPY BTWN SITES	METHOD	RESULTS
King 1998	1995	1st flight 2nd flight	WI, Necedah National Wildlife Refuge, North, South and East Rynearson sites	3 sites, open landscape with oak barrens and wet meadow habitats abutting large water impoundments. Distances between sites = 1150, 1550, 2250 m (1.3 miles) of unsuitable habitat (water impoundments, wetlands with out lupine or nectar plants).	OPEN	MRR	203 marked 1st flight, 12% recapture rate 236 marked 2nd flight, 26% recapture rate ISD: 1st flight = 7.4%, 2nd flight = 11.2 % ***Between-site and within-habitat distances moved:*** Males: 1st flight, 456.9 ± 261.7 m MDM 108.6 ± 32.7 m MDD 457.0 ±261.9 RANGE 2nd flight, 214.7 ± 31.8 m MDM 119.5 ± 7.5 m MDD 373.6 ± 98.6 RANGE Females: 1st flight, 69.8 ± 17.5 m MDM 48.2 ± 12.1 MDD 73.3 ± 13.8 m RANGE 2nd flight, 359.2 ± 27.4 m MDM 173.2 ± 13.1 MDD 613.7± 167.1 RANGE ***Between-site distances moved***: 11% of marked 2nd flight KBBs made at least one between-site dispersal of 1150 m (0.7 miles) or more. 7.5 % of all marked KBBs made at least one between-site dispersal of 1500 m (0.93)

STUDY	DATE	FLIGHT	LOCATION	STUDY SITE DESCRIPTION	CANOPY BTWN SITES	METHOD	RESULTS
Lawrence & Cook 1989, Lawrence 1994	1989	1st flight 2nd flight	MI, Allegan SGA	1st flight: 1 site, open linear habitat – pipeline ROW, 2.1 km long, several large lupine patches 2nd fight: 8 sites – mixed oak forest and fields, 0.5 to 2.5 km apart	OPEN CLOSED	MRR	134 marked 1st flight, 29% recapture rate 538 marked 2nd flight, 26% recapture rate **Within- habitat distances moved** 1st flight: Males: 248 m $\pm$ 64 m MDM 191 m $\pm$ 52.5 m MDD Longest distance = 1.05 km *male results skewed, most movements less than the mean with a few individuals moving long distances Females: 203 m $\pm$ 41 m MDM 162 m $\pm$ 40 m MDD Longest distance = 0.55 km 2nd flight: (distance moved between-sites) No butterflies captured in sites other than where they were originally marked
Sferra et al. 1993	1990-1992 (data summa-rized for 1992 only)	1992- 1st and 2nd flight	MI, Huron-Manistee National Forest, Oak Ave. ROW	Powerline ROW, 30 m x 0.8 km with sand prairie strip bordered by white pine plantation to west, dirt road/oak savanna to east.	OPEN (study sites confined to ROW)	MRR	143 marked 1st flight, 27.3% recapture rate ?? marked 2nd flight, 36.5% recapture rate 1st flight: 67% of recaptured stayed within 200m 2 adults used entire 0.8 km strip 1 male traveled 100 m in just 20 minutes
Fuller 1998	1998	2nd flight	NY, Geyser Road powerline ROW	Powerline ROW (mostly open – some scattered clumps of shrubs)	OPEN	MRR	1091 marked, 51.8 % recapture rate Prop. of indiv. captured out of "home" patch =Males: 0.501, Females: 0.377. KBB rarely dispersed to habitat patches > 500 m from natal patch. Females less likely to disperse from high-density pops., more likely to leave low density pops.

STUDY	DATE	FLIGHT	LOCATION	STUDY SITE DESCRIPTION	CANOPY BTWN SITES	METHOD	RESULTS
Fried 1987	1987, July 10-27	2nd flight	NY, Albany Pine Bush, 3 sites along Willow Street	1) abandoned sand pit, 2) path along power line, 3) shady site with aspens and pitch pine. Very small sites, approx. 305-460 m apart, connected by dirt paths through dense woods or low shrubs, some nectar along paths and one opening with no lupine between 2 sites	MIXED	MRR Jolly	224 marked, 55% recapture rate 3 of 224 ISD[2] ***Between- site distances*** Males : 1 @ 460 m Females: 1 @ 150 m, 1 @ 305 m 8 males moved along dirt paths 2.4 % of recaptures were dispersing male bias in captures ***Population estimates:*** 1) 89 2) 154 3) 47
Bidwell 1994	1994, July 19 – Aug. 11	2nd flight	WI, Fort McCoy, South Post	3 sections of 30 m x 1 km training area boundary ROW. Scattered lupine, diverse nectar, open with shrubby oak. Bordered by oak woods with >75% canopy closure. Dense band of birch with >75% canopy extended across ROW for 50 m of ROW length, 5 m wide trail through birch, no lupine, little nectar	MIXED	MRR	724 marked total, 24% to 62% recapture rate ISD: 21 total (2.9%). 14 KBB (12 males, 2 females) crossed birch band, ISD between sites 1000 m apart. 1 male 1600 m over 2 days, 1 female 1195 m. ***Between- site and within-habitat distances moved:*** (dispersal distance data combined for 3 sites) Males: 91% moved < 400 m RANGE[5] 99 m $\pm$ 9m MDD Females: 91% moved < 200 m RANGE 32 m $\pm$ 3 MDD

STUDY	DATE	FLIGHT	LOCATION	STUDY SITE DESCRIPTION	CANOPY BTWN SITES	METHOD	RESULTS
Welch 1993	1993	1st flight 2nd flight	WI, Hartman Creek State Park Complex & Welch sites, 11 sites	Cluster of small-medium sized openings separated by oak forest and/or pine plantation. Barriers were mixed conifer/deciduous fence row and wooded habitat margins, 200-415 m wide	MIXED	Focal-animal sampling (followed adults)	78 total observed: 50 were ≤ 406 m from lupine patch, 4 (5%) moved > 1 km. Worn individuals dispersed farther than fresh: Males: 65-1140 m (ave. 530 m) Females: 85-565 m (ave. 285 m) Longest distance observed = 1 male, 1.7 km from nearest lupine, 2nd flight (open habitats + shaded wooded fence line) Female observed flying through forest, 2-3 m off ground. Flying, then landing, from one sunlit branch to the next. **Relatively Closed habitats** (>50% cover, perimeter enclosed) * 4 adults 270 to 792 m from one lupine opening to another on forest trail with 85% cover, 3 were males (24 total obs.) * 7 adults moved 88 to 352 m between small openings with lupine along sunlit openings, often returning to original patch (13 total obs.) * 1 male flying into canopy and crossing 11 m high crown of trees to enter next lupine area **Open habitats** (<50% canopy, some perimeter opens to field or corridor) * 1 male 523 m from lupine patch, flew along roadside ROW on wooded edge * 37 butterflies observed 55 – 1350 m from lupine (23 = males) (Welch Tract) * 3 adults crossed 108-320 m woodland via corridors (between Casey site and Welch Tract)

STUDY	DATE	FLIGHT	LOCATION	STUDY SITE DESCRIPTION	CANOPY BTWN SITES	METHOD	RESULTS
Schweitzer 1979 (in Givnish et al. 1988)			NY, Albany Pine Bush	None of the sites fully open	MIXED	MRR	Greatest distance moved = 1.3 km between Gipp Road and Crossgates Hill Dispersal observed along roads & trails, occasionally over tree tops Givnish et al. (1988) concluded effective inter-population dispersal of up to about 0.8 km (given a substantial source population)
Knutson et al. 1999	1994, 1995, 1996	1st flight 2nd flight	IN, Indiana Dunes National Lakeshore, 4 sites and supplemental survey areas	4 sites: 1) Oak savanna/marsh complex with moderately dense woody veg. and sand-mined areas, 2) oak savanna/marsh with open fields, 3) oak savanna with open understory, 4) linear habitat along former railroad track, dune ridge with moderate canopy Millers Woods - flat, homogenous site, open understory. Movements > 300m, 2 x freq. of 2 other sites	CLOSED .	MRR	1959 marked 1st flight, approx. 30-33% recapture rate 3654 marked 2nd flight, approx. 12-31% recapture rate ISD : No movements observed between study sites. ***Within-habitat distances moved:*** MDD - 50.3 m (sexes & flights pooled) Males: 51.2 $\pm$ 2.7 m Females: 48.0 $\pm$ 4.5 m 1st flight: 55.0 $\pm$ 3.5 m 2nd flight: 46.4 $\pm$ 3.0 m RANGE - 73.4 m $\pm$ 2.3 RANGE (sexes & flights) Males: 76.9 $\pm$ 2.8 m Females: 64.9 $\pm$ 4.3 m 1st flight: 84.5 $\pm$ 4.1 m 2nd flight: 65.0 $\pm$ 2.7 m 75% of movements less than 100m* Maximum distance moved = 989 m

dispersal were observed in other areas not sampled, that a fairly substantial proportion of adults might be emigrating from the populations studied and arriving at new habitat areas (Warren 1987). For the Karner blue, it is unclear if observed rates of between-site dispersal will limit recolonization of suitable habitat. The dispersal rates observed at Necedah NWR indicate that recolonization can be extensive in open habitats.

Tracking individual butterflies has also been done to determine within-habitat movements and between-site dispersal distances (Welch 1993, Grundel et al. 1998b, Lane 1999). Welch (1993) located potentially dispersing butterflies by searching areas 200 meters (220 yards) from lupine sites. The number of dispersers and distance each moved was recorded for spring and summer flights, along with wing-wear (fresh and worn individuals), sex, and habitat types (open and closed canopy). A total of 78 butterflies were observed. The largest number of dispersers were fresh males in open habitat during the first flight. Numbers of dispersers were lower during the second flight. Average dispersal distances were farthest for worn males in open habitat, ranging from 65 to 1,140 meters (71 yards to 0.71 miles) and averaging 530 meters (580 yards). Dispersal distances for worn females ranged from 85 to 565 meters (93 to 618 yards) in open habitat with an average of 285 meters (312 yards). The longest distance observed by Welch (1993) was by a male that was 1.7 kilometers (1.06 miles) from the nearest lupine patch.

There has been no critical examination of the methods and the data associated with dispersal. Without clear information on the sampling intensity at different distances from the release points, it is difficult to interpret the results. None of the dispersal information has been summarized to provide an estimate of the functional relationship between distance and the probability of dispersal. Definitive studies on insect dispersal frequently uncover unanticipated high frequencies of movement and distances far greater than expected.

The differences observed in dispersal distances between the various study sites suggests that there is a fair amount of variation in dispersal tendency between sites. They also demonstrate that males generally disperse further than females. In summary successful dispersal between habitat sites greater than 2.3 kilometers (1.4 miles) or more apart (King 1998) in open areas is likely rare Consequently, to maintain the colonization rate at a level that can easily compensate for local extirpations (and to facilitate exchange of the genetic material between subpopulations) suitable habitat should be separated by lesser distances. Distances between subpopulations that are likely to facilitate recolonization in a metapopulation are likely to fall in the range of 0.5-2 kilometers (0.31-1.24 miles); this distance could be lesser or greater and will be dependent on the nature of the habitat, especially canopy cover, between habitat sites. More distant and/or closed habitats might need to be linked with dispersal corridors to other sites to enhance connectivity, or might need to be managed to function independently from the main metapopulation. These independent, distant sites would not contribute directly to the stability of the main metapopulation under typical conditions, but could contribute to buffering the metapopulation against large-scale adverse events.

The size of the management unit can affect recolonization rates. If large areas of contiguous habitat were managed as smaller discrete sites, then when a part of the area is restored, for example using fire, colonists could simply 'diffuse' in from the edges of adjacent unburned habitat.

Number of Dispersing Female Karner Blue Butterflies

Larger numbers of butterflies will disperse from larger subpopulations of Karner blues if the proportion of dispersers is the same for any size subpopulation. For example, if five percent (a totally hypothetical number) of females were likely to disperse, a population of 200 adults (both sexes) would yield five dispersing females while a population of 400 would yield ten. Thus, another approach to increasing the rate of colonization is to manage some or all of the occupied habitat to produce maximal numbers of Karner blue butterflies, which in turn would maximize the number of dispersing females. Indeed, if the relationship between the number of dispersing females and subpopulation densities were density dependent, so that high densities increase the proportion of the subpopulation inclined to disperse, then larger populations will create even more potential colonists. Limited observations suggest that dispersal is greater as habitat quality declines (Fried 1987) (Dale Schweitzer, pers. comm. 1997), but this needs to be rigorously evaluated.

Facilitating Directed Dispersal Using Corridors

In many of the ecosystems that support the Karner blue, most dispersing females may never locate suitable habitat with host plants upon which to lay eggs. Many simply leave their natal habitat and move into hostile adjacent habitats, never locating even nearby sites of suitable habitat. There are two approaches to establishing effective dispersal corridors, neither of which are proven, which may help guide dispersing Karner blues to suitable destinations.

Corridors

Corridors of open canopy, which provide adult resources, such as nectar, and roosting sites, can be used to connect patches of suitable habitats. Typically railroad and powerline rights-of-way (ROWs) as well as roads and trails through wooded areas are believed to be corridors of this sort. The idea that dispersing Karner blues will somehow follow these corridors and be guided to a destination at the other end is untested, and it is possible that abnormally high densities of adult food resources such as nectar-producing flowers in these ROWs might actually draw adults out of less resource-rich suitable habitats. Butterflies may merely concentrate in the ROWs, but not follow them to other suitable habitats.

Living corridors

Living corridors provide both larval and adult resources and can be used to connect habitat patches. While living corridors will not have adequate suitable habitat to support a subpopulation, the essential habitat components would be in place for dispersing adults to use. Thus, dispersing females could lay eggs within the corridor itself, and would not need to fly the entire distance separating habitat patches before locating suitable host plants. Potentially, the next generation of Karner blues would be that much closer to the connected suitable habitat site, and would be more likely to complete the trek to that site. In many areas, such as the Albany Pine Bush in New York and Gary, Indiana, living corridors can and do support small Karner blue populations that contribute to the overall functioning of the metapopulation.

Identification and Protection of Refugia

A viable Karner blue metapopulation will be comprised of many subpopulations on sites with suitable habitat. A minimum number of colonists could be ensured if refugia, where Karner blue subpopulations persist for long periods of time at high densities, can be identified and protected. These refugia will provide a continual supply of colonists for the entire metapopulation and could serve to ensure that some colonists will be available to recolonize unoccupied suitable habitat. In any metapopulation some of the sites are more likely to persist for longer periods of time than other sites. These sites might be identified as management experience accumulates. If these sites were managed to produce maximal numbers of butterflies, then they could function as refugia. Sites where subpopulations persist for long periods of time at low density might be called low-density refugia. Low-density refugia will not contribute substantially to recolonization.

REDUCING LOCAL EXTIRPATION RATES

The probability that a subpopulation will be extirpated is related to the size of the subpopulation (larger subpopulations are less likely to be extirpated than smaller subpopulations), and the temporal variation in subpopulation size (more variable subpopulations are more likely to be extirpated). For example, if for some reason 99% of the eggs fail to overwinter, a subpopulation of 1000 eggs will produce only 10 first instar larvae, while a subpopulation of 10,000 eggs will produce 100. Larger subpopulations simply have a better chance of surviving density independent sources of mortality because ultimately, there are more survivors. Consequently, there are two basic strategies for reducing local extirpation rates. The first is to improve and maintain the suitability of the habitat for Karner blue so that they are less likely to be extirpated, and the second is to manage disturbances on site so they do not inadvertently cause the extirpation of the butterfly and indeed, may contribute to the improvement or renewal of suitable habitat.

Managing subpopulations and their associated suitable habitat to reduce extirpation rates is most readily done on a subpopulation by subpopulation basis. This implies that for most metapopulations, this approach will not be used on all subpopulations in a metapopulation, but only on selected ones. For minimum viable metapopulations, it would be beneficial to reduce the likelihood of extirpation associated with the more precarious subpopulations so that most subpopulations are maintained. In larger metapopulations, however, effort could be shifted to reduce the likelihood of extirpation in some of the larger, healthier subpopulations or clusters of subpopulations. If the likelihood of extirpation can be reduced so that the subpopulation or cluster is likely to persist for a long time into the future, then the metapopulation will function less like a true metapopulation and assume some of the functional characteristics of a core-satellite metapopulation. Because persistence of a core-satellite metapopulation depends mostly on the fate of the core subpopulation or core cluster, management efforts may be able to shift to focusing on maintaining the core subpopulations and the means of dispersal (close enough distances, dispersal corridors, etc.) to the surrounding constellation of satellite subpopulations. It would no longer be necessary to manage each satellite subpopulation individually, but it would be possible to set up management to maintain a balance between the creation and destruction or degradation of suitable habitat associated with those satellite subpopulations.

Improving and Maintaining Karner Blue Habitat

Based on our current knowledge of the biology of this butterfly, recommendations to improve habitat suitability, which can be factored into both short- and long-term management strategies are provided below.

Pesticides

Avoid using insecticides in association with the Karner blue. Most insecticides are toxic to Karner blue butterfly larvae. Even though some insecticides may be used to maintain or improve habitat, use of insecticides is discouraged. One example of an insecticide used in Karner blue habitat is *Bacillus thuringiensis* var. *kurstaki (Btk)* used to control the gypsy moth which causes defoliation of trees. Experimental testing of the effect of *Btk* on Karner blues found it caused mortality of Karner blue larvae (Herms et al. 1997). If insecticide use is necessary, it should be used at a time when Karner blue larvae and adults are not susceptible to the insecticide, its residues, or its metabolic by-products. The Service recommends that no aircraft broadcasting of *Btk* should occur within one-half mile of any Karner blue butterfly sites. Distances of less than one-half mile may be acceptable on a case by case basis by building in precautions to minimize drift (refer also to APPENDIX G). Other insect control tactics might be substituted for insecticides, but the potential detrimental effects of these other control tactics should be considered before they are used.

Research to date suggests that the herbicides, Accord (glyphosate) and Accord + Oust (sulfometuron methyl) (with Entry II surfactant), can be used with minimal direct impact on the Karner blue butterfly. In addition, there are indications that Accord-Arsenal may be effective in reducing woody cover with positive effects on lupine populations. Research has shown that Karner blue eggs treated with Accord + Garlon 4 (triclopyr ester) have resulted in 22 percent fewer adults hatch than in controls; translated to field conditions, it is anticipated that this would result in a 2 percent reduction of adults (Sucoff 1998). Herbicides should be used with care to minimize impacts to the Karner blue.

The effects of herbicides on the growth and flowering of lupine and select nectar plants has been examined through various studies (Smallidge et al. 1996, Sucoff 1997) (Scott Shupe, Niagara Mohawk, pers.comm. 2002). Sucoff (1997) applied three herbicide treatments, Accord, Accord + Oust, and Accord + Garlon 4 (all with Entry II surfactant), to lupine and nectar plants in late August through early September. Results showed that lupine percent cover and number of stems per meter squared were not significantly different between control and treated plots. Nectar plant responses varied. Some species showed a sudden increase, others an initial reduction followed by a gradual increase in number and or coverage. On two of three sites there was no significant effect of the herbicide on numbers of flowers or flower-bearing stems. On a third site, however, both of these variables were significantly lower on herbicide treated plots. More research would further our understanding of the effect of herbicides on nectar plant survival and flowering.

To minimize the impact of herbicides on the Karner blue and its food plants, herbicide applications made during the butterfly's flight period should be limited to spot application with hand operated equipment only, using pesticide certified or experienced personnel trained to identify the butterfly and lupine. The applicator should avoid trampling lupine plants. Aerial and ground application of pesticides should be done outside of the Karner blue flight season. Following these guidelines as well as the additional pesticide use guidelines described in the Wisconsin Statewide HCP for the Karner blue butterfly (WDNR, 2000) should minimize impacts to the butterfly.

Area of suitable habitat

In general, larger sites of suitable habitat are better for Karner blue (recognizing that discrete, somewhat isolated sites also have some advantages), and will support larger subpopulations. Large sites can be managed as a number of adjacent discrete units, allowing for recolonization from directly adjacent, undisturbed habitats. However, a metapopulation composed of just a few (<5) large patches that are located too near each other may be very susceptible to extirpation by wildfire or disease epidemics.

For recovery purposes, it is recommended that the area of suitable habitat in sites be greater than 0.25 hectares (0.62 acres). Subpopulations on sites as small as or smaller than 0.25 hectares may be highly susceptible to extirpation. To reduce the probability of extirpation in these small sites, the habitat could be managed to support a high population density of Karner blues (many host plants, nectar sources, and good subhabitat).

There is no theoretical upper limit to the size of suitable habitat. Realistic management constraints, however, should be factored into managing "sites" approaching or greater than 500 ha (1,235 acres or ~2 square miles).

Lupine density

Make adequate lupine available in a variety of subhabitats. Excellent Karner blue habitat supports abundant lupine. Small habitat patches (0.25 ha or 0.62 acres) are recommended to have at least 500 lupine stems to be considered as suitable habitat (2,000 per ha or 810 per acre). As the area of a site increases, so should the number of lupine stems, although the relationship is not linear. Larger patches (>5 hectares or 12.3 acres) are recommended to have more than an average of 0.1 lupine stems per square meter (1,000 per hectare or 405 per acre). Of course, the higher the lupine density the higher the potential subpopulation density of Karner blues.

When planting lupine, seed should be collected from native local wild lupine plants to ensure the maintenance of the genetic integrity of the local lupine population. Consult your State Natural Heritage Program for guidance on seed collection (refer also to Appendix I, CONSIDERATIONS RELATIVE TO LUPINE).

Lupine can be threatened by numerous factors. Exceptionally high densities of deer, rodents, or very high livestock stocking rates can damage lupine. Animal control, animal exclusion, or management for lower animal densities may be necessary. Lupine does poorly in dense shade, so canopy cover should be maintained low enough for lupine to reproduce but high enough for seedlings to survive (perhaps between 30 to 70 percent on average over the entire site; refer to Habitat heterogeneity below). Thus, succession should be managed to maintain a diverse, relatively open canopy.

Mechanical management (e.g., mowing or cutting), as well as grazing can be used to enhance lupine if it is done at the right time, however precautions should be taken to minimize the effects of such activities on the Karner blue and its habitat (refer to Alternatives to fire management, below).

Off-road vehicle (ORV) traffic can have a positive or negative effect on lupine depending on whether the ORV paths destroy lupine (potentially negative effect) or function to keep the canopy open and create germination sites (potentially positive effects). Exotic invaders may reduce lupine (some sedges in relatively mesic habitats), but other may be significant nectar sources (white clover). There are no simple rules for increasing lupine.

Nectar resources

Make several potential nectar sources available for each generation because annual variation in flowering phenology means that a particular species may not be available for adults in every year. Adult butterflies require food to survive. While it is likely that in the absence of nectar sources, adults will manage to mate and lay some eggs, without food the number of eggs laid will be greatly diminished. It is also possible that inadequate nectar at a site could result in increased dispersal of butterflies to find nectar (Loertscher et al. 1995). Because mortality of immature caterpillars is very high and most die, subpopulations that chronically experience low fecundity (actual number of eggs laid) because there is no adult food are at risk of extirpation. Thus, the absence of adult nectar sources can be limiting and jeopardize a subpopulation. This problem is most pronounced during the summer flight period, when the number of flowers blooming is reduced because of summer dry spells in oak and pine barrens and savannas. Excellent

Karner blue habitats have a variety of potential nectar sources available for both the spring and summer broods. Poor habitats should be enhanced by planting or encouraging suitable nectar plant species (native forbs and others) that will provide nectar during both flight periods under the range of foreseeable environmental conditions (droughts, cool springs, cool summers, etc). Alternately, habitats adjacent to Karner blue habitats, such as wetlands and mesic prairies and other mesic or xeric habitat, can be managed to provide nectar-producing flowers.

Many of the comments under the lupine density section above apply in a similar way to nectar plant management. Nectar plants, however, will flower more abundantly and produce more copious amounts of nectar in sunny. Thus encouragement of nectar will require a more open habitat than that needed to improve lupine. Grazing, succession, mowing, ORV traffic, and exotic invaders may detrimentally affect nectar plant species, but there are no simple rules for improving nectar resources. If nectar plants were believed to be limiting, a useful precaution would be to delay mowing until after the nectar plants had set seed, usually in mid-October.

While many non-native plant species are used by the Karner blue as nectar sources, planting non-native species for this purpose is not recommended. One concern with non-natives, in particular those that are invasive, is that they may out-compete native nectar sources or lupine.

Habitat heterogeneity (Appropriate successional array)

Promote heterogeneity in the habitat, such as heterogeneity in vegetation, management practice, subhabitat and microhabitat, timing of management, and habitat structure. An excellent habitat will have considerable diversity in microtopography, aspect, hydrologic regime, and tree canopy cover (varying from 0-90% cover in the habitat) within a typical flight range of a Karner blue butterfly [probably 200-500 meters (219-547 yards)]. This diversity will create microclimatic diversity that will enable Karner blue butterflies to locate readily preferred oviposition sites and preferred roosting sites despite variation in weather from year to year. For example, xeric sites with southern exposure are likely to be poor habitat for the Karner blue in typical years because the temperature gets very hot for larvae, and the lupine senesces rapidly. In cool wet years, however, these sites may be excellent sites for Karner blue. Conversely, shady, mesic sites may be poor habitat in typical years because lupine grows poorly in the shade under competition from other forbs and grasses, and the cool temperatures delay development of larvae, which will expose them to predators and parasitoids for a longer period of time. In hot, dry years, however, these shady mesic sites may be the best habitat for Karner blue and be the key to their survival in the site. In addition, rapid degree-day accumulation during hot years will accelerate the onset of butterfly weed flowering (an excellent adult nectar source) more that it accelerates the onset of the second flight of the Karner blue. Habitats with diverse subhabitats and microhabitats are likely to support a wider variety of nectar-producing plants as well as moderate the impact of environmental extremes of flowering phenology. Diverse, heterogeneous habitat will not optimize Karner blue subpopulations in any one year, but will enable them to persist in a site for many years.

It is important in developing Karner blue metapopulations, especially large viable metapopulations, to insure variation in the successional stage of habitat patches and/or subpopulation areas so that large areas of habitat do not simultaneously become unfavorable and to maintain subhabitat and microtopography diversity. Large viable populations should appear as a patchwork different successional stages on the landscape. Management should strive to maintain a shifting geographic mosaic that provides a balance between closed and open-canopy habitats important for maintaining these populations.

Other factors

Adult Karner blue butterflies require roosting sites. Grasses, shrubs, or any other vegetation that is taller than lupine and exposed to late afternoon sun may function as roosting sites. Roosting sites will not be limiting in typical habitats. A five percent cover in tall grass or other such vegetation probably provides sufficient roosting sites.

Improving Management for the Karner Blue

Habitat loss is the primary factor contributing to the decline of the Karner blue. The native habitats with which Karner blue is associated are oak and pine barrens and savannas. Conversion of these habitats to housing developments, industrial parks, and other intensive
human uses associated with urban and suburban development has in many cases irrevocably destroyed Karner blue habitat. Possible management responses to this destruction of native habitat include habitat protection using conservation easements, negotiated conservation plans, purchases of land from willing owners, or protective legislative or legal remedies. Conversion to agricultural and grazing lands has also resulted in substantial loss of native habitat and harm to the Karner blue. Conversion to some silvicultural land uses may be the main human uses that can be compatible with Karner blue; while some silvicultural practices are clearly beneficial to the butterfly and others are clearly harmful, the majority of these practices have uncertain effects (Lane 1997).

Where the habitat is managed for native vegetation or recreational human use, unimpeded succession is the leading contributor to habitat loss. Barrens/savanna communities are among the most dynamic in the northeast and Midwest United States. The open habitats that support Karner blue were originally maintained by a steady procession of wildfires and other periodic disturbances. The wildfires top-killed woody invasive plants while favoring fire-adapted dune and savanna communities. Other disturbances, such as grazing, oak wilt, late frosts, and local outbreaks of defoliating insects helped to create a mosaic of habitats ranging from open xeric grasslands to oak woodland. Without these disturbances, shade-tolerant and fire-sensitive species increase in density, and open barrens and savanna species decline. Moreover, management aimed mainly at enhancing certain game species has resulted in large areas of potentially suitable habitat to be rendered relatively poor habitat for Karner blues. The Wisconsin DNR Wildlife Management Guidelines provide additional suggestions that managers interested in barrens and savanna maintenance and restoration may be interested in considering (WDNR 1998, WDNR 2000). Guidelines for managing Karner blue metapopulations associated with silvicultural practices can be found in Lane (1997).

General guidance: (1) Plan not to use any management practice that is likely to have an adverse effect on an entire Karner blue subpopulation repeatedly within a time frame of two generations. (2) If a subpopulation is critical for the maintenance of the metapopulation, then subdivide the subpopulation into separate management areas. The number, design, and rotation of management areas should allow effective Karner blue re-colonization after the management practice from nearby unaffected areas. (3) On very small, isolated sites that have small populations of Karner blue, use management practices that are unlikely to harm the existing subpopulation, e.g., tree girdling instead of fire.

Size of management unit relative to size of habitat site

For small metapopulations near the minimum viable metapopulation criteria, suitable habitat sites, which support Karner blues, should be large enough so that each site could be divided into three or more management units. This would minimize the probability of local extirpation from management error while maintaining suitable habitat in the site. At the other extreme, with large viable metapopulation that occupy large areas of suitable habitat over several square kilometers, swaths of the habitat mosaic (occupied sites and surrounding matrix of habitat) may be managed as single management unit as long as adequate precautions are taken to ensure that there are nearby occupied habitats which can act as sources of potential colonists. Most managed metapopulations will likely fall between these extremes, with some sites within the metapopulation subdivided, and other sites within the metapopulation managed without subdividing.

Fire management

In using prescribed fire as a management tool, two general guidelines apply. The first is that the positive effects of fire on Karner blue habitat must be weighed against any negative impacts to the butterfly. Fire is known to be an important component in maintaining savanna/barrens habitat that acts by reducing accumulated plant litter, exposing bare soil, reducing nitrogen content of the soil, promoting increased soil temperatures, and setting back growth of plants that compete with native, desirable vegetation. However, fire can also have negative effects on the butterfly (and other invertebrates) such as direct mortality and/or reduction of food plants.

The second general guideline is that prescribed fire methods for restoring habitat will typically vary from those used for maintenance of habitat. For example, sites where lack of disturbance has allowed succession from savanna to forest to occur, more intensive methods will be needed in order to restore savanna/barrens structure than for maintaining sites where suitable habitat structure is present.

To adhere to the general guidelines and to develop appropriate site specific restoration/maintenance plans, many factors will need to be considered. As an aid in developing prescribed fire plans, an overview of relevant literature, followed by recommendations based on that literature, are provided below. Information is grouped in the following categories: 1) site history and current condition, 2) amount of direct Karner blue mortality likely to occur during the fire, 3) potential for Karner blues to reoccupy the site, 4) characteristics of prescribed fire, 5) response of lupine and nectar plants to fire and 6) other habitat responses.

1. Site history and current conditions:

Site history and characteristics are primary factors dictating whether prescribed fire is the best management tool for the site, and at what frequency/intensity/season fire should be used. For example, for sites that have succeeded to oak woodland or forest, mechanical means such as girdling or cutting, and/or herbiciding are often more effective than fire in restoring desired structure (Lane 1996). Alternatively, one intense crown fire may create responses similar to that observed for wildfire, i.e. canopy reduction (Swengel 2001). The size, shape and distribution of habitat patches, and the nature of intervening habitat will influence, among other variables, how many burn units should be created, what percent of each habitat patch can be burned, and how rapidly the Karner blue can recolonize burned sites.

Soil type will also influence whether and how frequently to burn. On very dry, sandy, exposed sites with very little accumulation of plant litter and minimal woody plant cover, very little immediate management may be needed. Burning such sites may only exacerbate the droughty conditions and cause premature lupine senescence – potentially resulting in insufficient food for second brood Karner blue larvae.

Knowledge of what species are present on a given site and their response to fire will also be important. Fire may either increase or decrease the abundance of invasive species and/or

native species that compete with lupine and nectar plants. Some rare plant species may respond adversely to fire and should be protected during burns.

Recommendations:

Prescribed fire plans should be site specific and based on the structure and composition of the current vegetation, and the spatial characteristics of Karner blue habitat patches. Site inventories should be conducted prior to developing the management plans and include information on species composition (native and non-native), canopy structure, soil type, slope and aspect, etc. For example, sites with dense vegetation between patches will require different considerations than those interspersed with open canopied vegetation types. Areas/sites with exposed and dry soils should be burned less frequently than those with more mesic conditions.

2. Amount of direct Karner blue mortality likely to occur:

Fire can result in the mortality of Karner blue eggs, larvae and and adults (Maxwell and Givnish 1994, Swengel 1994, Maxwell 1998, Kwilosz and Knutson 1999). Available evidence suggests that eggs and larvae do not survive fire, but they can survive in burn units because burns are uneven or because areas within the burn unit have been excluded from fire (Bleser 1993, Swengel 1994, Swengel 1995, Kwilosz and Knutson 1999). Research by Maxwell and Givnish (1996) estimated 50 to 80 percent Karner blue larval mortality on burned plots. The areas where larvae survived in the burned plots were at the bases of tree boles and around downed logs, where the fires skipped. As part of prescribed fire management/research at IDNL, 50 to 300 meter squared areas were excluded from fire within several burn units at several sites. Even with these refugia, adult counts dropped substantially within the partially burned portions of one of the sites as compared with unburned portions of the same site following fire (Kwilosz and Knutson 1999). However, there were no net population declines at fire-managed sites, and the authors suggested that adults either survive fire within the burn unit or move into the burned area from nearby or adjacent unburned units. Further, monitoring has shown that the number of Karner blue butterflies counted per site has increased on sites managed with prescribed fire (Kwilosz and Knutson 1999). It is important to note that because of the large number of factors than can potentially influence Karner blue population fluctuations, and limitations in the experimental designs used, it is not possible in any current studies to determine whether the Karner blue population fluctuations observed were a result of prescribed fire.

Some adults are known to survive fire by moving. A study on two habitat sites at Necedah NWR showed that some Karner blue adults survived prescribed burns (King 1994, King 2002). Adult Karner blues were observed at Necedah NWR flying immediately in front of the flames. Other Karner blues may avoid fire by moving to nearby adjacent habitat or because of they are in areas skipped by the fire within the burn unit. King (1994) notes that because the level of mortality of Karner blues remains untested, prescribed burns should be used with caution.

Recommendations:

Direct mortality to Karner blues can be reduced by burning less frequently, burning only one portion of a site at a time, conducting "patchy" burns, and creating refugia prior to prescribed fires. Leaving areas of occupied Karner blue habitat unburned, particularly patches with abundant Karner blue, will help insure that a sufficient number of butterflies persist after the fire. "Patchy" burns are those that leave a mosaic of burned, partially burned, and unburned areas to act as natural refugia for

Karner blue eggs, larvae and adults. Refugia can be created prior to burning using several methods e.g., mowing around occupied lupine patches to create unburned islands, protecting areas with fire retarding foam, and using portable pumps and sprinklers to keep selected areas wet during fires. For large sites, refugia located near the center of the habitat may help facilitate recolonization. (Refer also to recommendations under No. 3 below)

3. <u>The potential for Karner blues to reoccupy the site</u>:

Recolonization of the burned areas can be facilitated by burning only a portion of a subpopulation or metapopulation, by insuring that occupied habitat is within dispersal distance of the burned area, and that sufficient numbers of butterflies remain to act as colonizers (Swengel 1996, Kwilosz and Knutson 1999). In order to burn only a portion of the Karner blue habitat area(s), it is usually necessary to divide the single subpopulation or metapopulation into several burn units. If a four-year fire return interval is used for instance, the habitat area should be divided into 5 burn units. It will be important to design prescribed fire plans so that a range of subhabitats (refer to Part I, LIFE HISTORY AND ECOLOGY, Subhabitats) are maintained within dispersal distance of occupied Karner blue sites.

Recolonization will also depend on how far and through what type of habitat butterflies need to disperse/move to reach suitable habitat. Karner blue movement varies considerably with habitat type/geographic location and for within-habitat versus between-habitat movements. Most within-habitat movements are less than 100 to 300 meters (109 to 328 yards), depending upon study site. At IDNL, where fragmented habitat and dense canopy areas present barriers to dispersal, butterflies were not observed moving between sites and 75 percent of the movements observed were less than 100 meters (109 yards) (Knutson et al. 1999). In contrast, dispersal distances of greater than 1,150 meters (0.7 miles) between sites were relatively common in the open habitat matrix of savanna and wetlands at Necedah National Wildlife Refuge (King 1998). Occupied habitat patches in Michigan were an average of 69.9 m (76 yards) apart. Refer to Table G1 above and PART I, LIFE HISTORY AND ECOLOGY, Within-habitat movement and between-site dispersal).

The time to recover from burning may vary due to the habitat features and dispersal barriers. Generally, Karner blues that have two broods per year recover more rapidly between fires then butterflies with only one brood per year (Swengel 1996, Swengel and Swengel 1996). At IDNL, selected areas were burned adjacent to other areas with Karner blue populations (Grundel 1994, Kwilosz and Knutson 1999). Compared to adjacent unburned areas, first brood leaf feeding in the burned areas was reduced to 6 percent of that of the unburned area (Grundel 1994). After a fall fire at one site, the relative abundance of Karner blues in the burned units dropped to 33 percent for the two broods following the fire (Kwilosz and Knutson 1999). Thus, even when source populations are nearby, fire can reduce populations for at least one year post-fire. At Fort McCoy, burns were conducted in an area surrounded by sites occupied by Karner blue (Maxwell 1998). First brood larval damage and adult populations were reduced, but the burn stimulated lupine growth, and second brood larval densities were 20 to 50 percent higher in the burned areas. The following year, adult populations were similar in the burned and unburned areas. Thus, when recolonization is high, Karner blue populations can recover rapidly from fires (Maxwell 1998).

It is expected that burned areas within dispersal distance of other large populations of Karner blues will be recolonized more quickly than those areas where butterfly populations are sparse. This is based on the fact that the percentage of butterflies dispersing between sites varies with site characteristics and it is likely that larger populations will have a larger number of individuals moving between sites.

Recommendations:

Recolonization of the burned area can be facilitated by burning only a fraction of the occupied portion of a site and by ensuring that occupied habitat is within dispersal distance. Since dispersal distances between sites vary considerably with habitat type, it will be important to evaluate recolonization distances on a site-specific basis (refer to Table G1)

Management plans should identify the number, design, and rotation of burn units that will allow effective Karner blue re-colonization, i.e. insure Karner blues are within easy dispersal distance of the area to be burned. Never burn an entire metapopulation or important subpopulation at one time. If a subpopulation is essential for the maintenance of a metapopulation, then subdivide the subpopulation into separate management areas. Use existing breaks in the vegetation, such as roads, trails, and wetlands as firebreaks. If possible, avoid scarifying the soil to create mineral soil firebreaks and mow instead. On very small, isolated sites that have small Karner blue populations or are important to maintaining the metapopulation, use alternative management practices such as tree girdling, brush hogging, tree cutting, or mowing instead of fire. For medium to large, isolated sites, dividing the site into a minimum of 3 burn units may be sufficient to insure Karner blue populations persist following fire. On very large sites, with abundant Karner blue butterflies, large sections of habitat can be burned as long as the burns are incomplete (areas are left unburned), and unburned occupied habitat occurs (preferably) adjacent to, or within easy dispersal distance of the burned site.

4. <u>Characteristics of prescribed fire</u>:

Frequency:

Prescribed fire frequency ranges from once every year (for restoring habitat) to once every few decades (for maintaining habitat). Givnish et al. (1988) provide a historical perspective on the issue of burn frequency. They analyzed historical fire records associated with the Albany Pine Bush and suggested that fires returned once every 6 to 18 years, with once in 10 years a likely average. Research at the IDNL suggests a fire interval of 3 to 4 years will create an oak savanna community (Cole, 1990). At the Cedar Creek Natural History Area, Tester (1989) found plant species richness to be highest in areas that were burned approximately every two years.

There is general consensus that more frequent burning is needed to restore habitat than to maintain habitat once structure and composition have been restored. Frequent fire (e.g. one fire in 2 to 3 consecutive years) has been used to restore savanna habitat. Once restored, fire frequency can be reduced. At this stage Haney and Apfelbaum (1990) suggest burn frequencies of 3 to 5 years. However, this may be too frequent to allow Karner blue populations to recover, and less frequent burning at every 6 to 18 years has been suggested (Givnish et al. 1988, Grigore 1992). Also, longer fire return intervals would allow young oaks to establish and grow to a size resistant to fire.

Recent research on the response of prairie insects to prescribed fire suggests that 3 to 4 year fire rotations will be compatible with maintaining insect biodiversity (Panzer 2002). The longer the fire return interval, the more time Karner blue populations will have to recolonize the site and rebuild population numbers. One hypothesis is that if colonization of the burned area by adults is slow or the population does not reproduce very fast, the detrimental effects of a burn could potentially last several generations. Conversely, if colonization is rapid and population growth high, then the effects of the burn could disappear rapidly. The available evidence supports these hypotheses, but additional research will be needed to confirm them.

Longer fire return intervals may be especially important on dry sites, where encroachment by woody vegetation is slow and where lupine densities tend to be lower. Conversely, on some sites, such as Crex Meadows in northeastern Wisconsin, more frequent burning is needed to maintain open savanna/barrens habitat and appears to be compatible with maintaining Karner blue populations. At Crex Meadows Karner blue butterflies are abundant, and habitat patches are close together, which is likely to facilitate rapid recolonization of burned areas. It is also important to consider the factors, which are often site specific that affect the rate of succession. These include species structure and composition, fuel loads, soil type, weather, the history of management on the site, and management subsequent to fire. In addition, significant grazing of woody species after fire could slow succession significantly.

Soil type and topography are important considerations when prescribing burn frequency. For example, steep south facing sand banks in Minnesota sites appear to remain open despite the absence of disturbance, other than occasional soil slumping. Alternatively, sites with soils containing higher organic matter or more mesic microsites may need to be burned relatively more frequently to control woody vegetation. At Crex Meadows and Fish Creek Lake WAs, canopy encroachment and reduced lupine growth occur by the fourth or fifth year after fire management (Darrell Bazzell, WDNR, in litt. 2002).

Intensity:

Fire intensity is thought to influence the amount of direct Karner blue mortality during a fire and what affect the fire has on vegetation. Fire intensity varies with wind speed, humidity,
air temperature, burning techniques, fuel type, and quantity of fuel (Mobley et al. 1978, Henderson 1982). Even low intensity fire is expected to result in the mortality of Karner blues (Swengel 1993).

While some trees are likely to be completely killed or top killed by fire (such as jack or red pine), the response of other species (black, bur and pine oak) can vary with fire intensity. For example, low intensity fires may only remove lower branches and top kill young oaks, where high intensity fire may completely kill older, hollow black oak.

Low intensity burns are useful in maintaining sites where the canopy structure is open and where the purpose of the burn is to maintain savanna grass and forb composition. In addition, low intensity burns tend to be patchy, leaving refugia for fire sensitive species (Samways 1990, Swengel 1994).

Season:

Seasonal timing of fires is influential in determining the effects of fire on insects and vegetation (Henderson 1982, Higgins and Piehl 1989, Howe 1994). In general, those species active (growing, hatched, etc.) at the time of burning are more susceptible to damage (Anderson et al. 1970). For example, grasshoppers experienced higher mortality with late compared to early spring burns because insects are more active in late spring (Cancelado and Yonke 1970). Spring burns are effective in inhibiting Eurasian cool-season grasses, allowing greater growth by native warm-season grasses (Collins and Glenn 1988).

Conducting prescribed burns in summer has been suggested for controlling hardwood brush, as this is the season when naturally-occurring lightening fires tend to occur (Howe 1994). In addition, growing-season burns may favor species more than dormant season fires would. In general, dormant season fires (spring or fall) have not been found to be effective in reducing woody tree or shrub cover (Lane 1996, Maxwell and Givnish 1996). Some observations suggest that frequent fires may stimulate denser brush thickets due to increased resprouting (WDNR, 2000).

Recommendations:

Plan to use prescribed fire only according to how the current habitat reflects the needs of the butterfly (rather than a fixed time return interval). During the habitat restoration phase, it is expected that either more frequent burning and/or other means (mechanical, chemical, etc.) will be needed to create the desired structure and composition. In this case managers might use annual burns, but they should not expect to see Karner blue butterflies right away. After the native vegetation is restored a longer fire return interval is desirable (based on the habitat response to fire) to allow Karner blue more time to re-establish healthy populations. For small and/or isolated habitat patches, at least four-year rotations are recommended. For sites with abundant Karner blues, many habitat patches that are within dispersal distance, and that extend over large landscapes, shorter rotations can be used – especially if needed to maintain suitable habitat. However, where shorter rotations are needed to maintain open habitat, it is recommended that when and where possible, other methods to reduce woody vegetation, such as mowing, also be incorporated into habitat maintenance plans.

It is important that management plans are designed so that habitat patches within a metapopulation differ in time since fire, or other disturbance, to prevent all habitat patches from transitioning to unfavorable successional states simultaneously (Thomas Givnish, University of Wisconsin-Madison, pers. comm. 2002). Ideally, neighboring habitat patches should be managed so that they are at varying successional stages. This will allow the maintenance of suitable habitat within dispersal distance of habitat patches that are being lost due to succession. This results in a metapopulation structure that is a landscape mosaic of different aged vegetational states.

The season and intensity of burns should be varied. Season can be varied by alternating between conducting spring, summer and fall burns when possible, as dictated by the condition of the habitat and desired results. Similarly it will be advantageous to vary the intensity of burns, ranging from low to high intensity fires, depending upon what type of fire will best restore/maintain habitat and result in the least Karner blue mortality.

5. <u>The response of lupine and nectar plants to fire</u>:

The immediate, direct effects of fire on lupine plants and seeds may be positive, negative, or neutral. At the Oak Openings in Ohio, the short-term effects of a moderate intensity fire on established lupine plants were increased vegetative growth, flowering, and seed set (Grigore 1992). Nearly all of the seeds on the soil surface and new seedlings were killed. Seeds buried in the soil germinated at similar rates as those in unburned plots (Grigore 1992). At Fort McCoy, prescribed fire resulted in a short-term increase in the number of immature and flowering lupine (Maxwell 1998). Both of these studies indicate that burning may enhance flowering of established plants, and existing data suggest that germination of surviving seeds is not detrimentally affected by moderately intense burning.

Nectar plant species vary in their response to fire, in some cases influenced by the characteristics of the burn (refer to APPENDIX C). Some species are known to have seeds that persist in the soil including blueberry (*Vaccinium* sp.), huckleberry (*Gaylussacia baccata*), raspberry (*Rubus* sp.) and pin cherry (*Prunus pensylvanica*), while other species are able to resprout following fire, such as lead plant (*Amorpha canescens*) (White et al. 1975). For plant species not present in the seed bank or unable to resprout after fire, recolonization of the site will depend in large part on the proximity and abundance of propagules and the dispersal mechanism of the plant (White et al. 1975). Maxwell (1998) found that the following nectar plant species increased following fall and spring burns: sand-cress (*Arabis lyrata*), prairie wild indigo (*Baptisia bracteata* var. *glabrescens*), flowering spurge (*Euphorbia corollata*), bush clover (*Lespedeza* *capitata*), downy phlox (*Phlox pilosa*), black-eyed Susan (*Rudbeckia hirta*), and dewberry (*Rubus flagellaris*). She also found that western sunflower (*Helianthus occidentalis*) and horsemint (*Monarda punctata*) decreased with fire. In degraded habitats, King (2000) found *Rubus* spp. to increase in percent cover after summer and fall burns. Interestingly, Maxwell (1998) also documented differences in nectar plant responses to fire based upon season of fire and subhabitat. For example, fall burns were better for sand-cress and horsemint.

Prescribed fire may also influence the phenology of Karner blue nectar plants. Preliminary research examining the affects of growing season burns at IDNL suggests that flowering of some nectar plants may be delayed in comparison to unburned plants (Noel Pavlovic, IDNL, pers. comm. 2002). It is unclear whether or how delayed flowering might impact the Karner blue.

Recommendations:

Plant surveys should be done and the information incorporated into management planning. When known, and where possible, time prescribe fire to reduce undesirable, and promote desirable species. If possible, vary the seasonal timing of burns at a site. Fire has a different effect upon any given plant species depending on when it occurs, and repeated application of fire at the same time of the year may select for only a subset of the savanna/barrens plant community. Spring and fall burns will suppress many cool-season grasses, but spring burns may reduce lupine.

For many nectar plants the effects of fire on presence and abundance are not known. Therefore, prescribed fire should be applied within an adaptive management framework, and include pre- and post-treatment monitoring of the effects of fire on nectar plant species.

6. <u>Other habitat responses</u>:

Prescribed fire is often used to reduce the cover of woody or invasive species, and increase the cover of savanna/prairie species. Based on 20 years of prescribed fire management at Cedar Creek Natural History Area in Minnesota, Tester (1989) documented a reduction in tree density and total basal area/hectare – although the changes were not significant. He also detected an increase in prairie species and a decrease in forest species with fire management. At the Konza prairie in Kansas, fire frequency had a strong influence on plant species composition and diversity (Gibson and Hurlbert 1987), and frequent burning doubled the abundance of legumes (Towne and Knapp 1996).

However, not all fires are effective at reducing canopy cover in these ecosystems. Three growing season wildfires at the INDL over the last 15 years have shown that lower branches of oaks are killed and leaves can be scorched up to ten meters into the canopy (Noel Pavlovic, U.S. Geological Survey, pers. comm. 2002). In addition, while one of the wildfires (1986) top killed numerous large oaks, subsequent root sprouting of the oaks and other woody species resulted in very dense woody thickets (Martin 1994).

Prescribed fires studies in Wisconsin and Minnesota did not reduce canopy cover (Lane 1996, Maxwell and Givnish 1996); indeed, girdling treatments and oak wilt caused greater canopy reduction than the fire treatments. Similarly, Cole et al. (1992) observed that black oak (*Quercus velutina*) stems greater than 5 meters in diameter were largely unaffected by prescribed burning at IDNL. It should be noted, however, that the prescribed burns conducted by Maxwell and Givnish (1996) were low-temperature, low-intensity events that crept through the understory under cool, marginal conditions.

The age and species of tree can influence response to fire. Following prescribed burning treatments in Minnesota (Lane 1996), younger black oaks were either killed or top killed and resprouted. Most adult oaks only had lower branches killed, whereas many older black oaks (which are prone to heart rot that results in hollow trunk centers) were completely killed by fire entering and burning inside the tree. Individual jack pine are unlikely to survive fire, but conditions following fire are often conducive to seed germination.

Prairie grasses, thought to be important for Karner blue roosting, vary in their response to fire, depending upon whether the grass species is cool-season or warm-season as well as which season fire management occurs (Henderson et al. 1988). In general, warm season grasses (which includes many, but not all prairie/savanna grasses) increased with burning, especially late spring burns.

Fire has been shown to both reduce and increase the abundance of species competing with Karner blue food plants. Pennsylvania sedge (*Carex pensylvanica*), often an intense competitor with Karner blue food plants, has been found to both increase and decrease in response to fire (Ahlgren 1960, Reich et al. 1990, Abrams 1991) and more information is needed to determine how fire will affect the abundance of this species. Dormant season fires may also stimulate sweet-fern, which can exclude lupine and other prairie elements (WDNR 2000).

Prescribed fire management can impact soil. Soil erosion can occur where slopes are steep and/or mineral soil is exposed. Soil compaction can occur with heavy machinery use, water trucks in particular, that are associated with prescribe fire management.

Recommendations:

As recommended above under other topics, prescribed fire plans will be most effective if tailored to species composition and structure at each site. The species, size, and density of trees will be an important consideration in developing fire regimes. Knowing what native or non-native invasive/competitive species are present at a site, and either tailoring or testing the effect of prescribed fire to reduce these species could be critical for promoting desirable species.

Plan prescribed fires to minimize soil erosion by avoiding intense fires on steep slopes and by avoiding driving heavy equipment during wet weather.

NOTE: Consideration of other rare species

The above considerations for use of fire management for Karner blues may not be sufficient to protect other rare butterflies associated with barrens and savanna habitat. As compared with some species of butterflies occurring in barrens/prairie habitats, the Karner blue is relatively tolerant to fire management, even with high mortality to immatures from fire. The Swengels (Swengel 1995, Swengel and Swengel 1996, Swengel and Swengel 1997) advise the use of haying, grazing or mowing, rather than fire to protect other rare insect species associated with savannas/prairies such as the ottoe skipper, Lenardus skipper, or regal fritillary butterfly.

Alternatives to fire management

In some habitat sites, the local situation may preclude the use of fire as a management tool. For example, some Karner blue subpopulations may be too important to risk extirpation from fire, or some sites may be located where burning is prohibited or is infeasible e.g., more urban areas. Moreover, in some sites other management practices may be more useful and effective or more economical than fire, e.g. mowing (refer to ***NOTE*** above).

Mowing has been used extensively in some states (e.g., New York and Wisconsin) to maintain suitable habitat, however mowing at the wrong time of year could result in reductions in lupine, nectar plants, and Karner blues. Lupine is an early season legume and usually completes its annual life cycle by early to mid-August. Karner blue butterfly eggs are frequently laid on the lower part of lupine plants and second flight adults are known to fly through most of August in many locales. Therefore, in order to minimize harm to the butterfly, mowing should generally be done after August 31 with the mower blade set at 6 - preferably 8 inches from the ground (this will minimize impacts on eggs that will be in the duff layer or on the lower part of lupine plants). If possible mowing should not be done until October or the first hard frost (at least in alternate years) so late-season flowering nectar plants can set seed and reproduce. Annual mowing should also be avoided if possible. To avoid impacts on Karner blues consider: 1) mowing in the winter over frozen ground conditions, 2) using a hand held weed whacker and hand cutting in small areas while avoiding Karner blue occupied lupine patches, or 3) using a side-mounted sickle-bar mower operated from the roadside or outside habitat areas. Mowing during the lupine life cycle will generally have a detrimental effect on lupine and the butterfly and should not be done at that time. The New York DEC is working on a management agreement with Saratoga County that will limit mowing of the airport to after October 15 and before December 31 to help conserve the Karner blue and the frosted elfin butterflies (NYSDEC, in litt. 2001). Karner blue habitat was probably maintained in the past at the airport because county mowers did not mow the airport until after they had finished all mowing responsibilities associated with road maintenance.

Mechanical and hand pruning of shrubs and small trees has also been used to open up Karner blue habitats. However, both of these methods generally require follow-up treatments to control root sprouting (using either prescribed fire or herbicides). Tree girdling, selective herbicide applications, tree harvest, and tree thinning can also be used to open up habitat. To minimize or avoid impacting the Karner blue, these types of activities are best done in occupied habitat during the winter under frozen ground conditions and snow cover.

Rotational grazing may be useful for suppressing competing vegetation, but probably not in the spring when larvae could be consumed with the vegetation.

All of these alternatives to fire management may have some adverse effects on Karner blue metapopulations, although some of these effects are likely to be minor. The greater the adverse effect of the management practice, the more attention should be paid to the disturbance return interval. If the adverse effect is quite large, as it probably is for fire, then return intervals must be carefully managed. If the adverse effect is minor, as it may be for hand pruning of low-density shrubs, then this is not as great a concern.

BROAD-SCALE MANAGEMENT FOR IMPROVING KARNER BLUE METAPOPULATIONS

Management goals at the broad-scale or landscape scale level should be designed to minimize the impact from large-scale detrimental events so that the metapopulation can emerge from the event with enough subpopulations intact that the metapopulation can return to its pre-event vigor. Many environmental events that are potentially detrimental to the Karner blue can extend over broad areas, such as large-scale wildfires, extended periods of extraordinary weather (summer-long hot droughts or extremely delayed and cool summers), or possibly disease epidemics. In these cases, local extirpation is likely to increase throughout the management area, perhaps to the point that the entire metapopulation has no chance of recovery. An appropriate management strategy is one that spreads the risk of extirpation from a particular event over individual subpopulations, such that some subpopulations are likely to survive the particular event intact. This requires an integrated approach towards spreading risk so that the metapopulation can survive the effects from multiple events. Managers should consider the following when managing to reduce risk of metapopulation loss.

Number of Subpopulations and Unknown Factors

Extirpations of subpopulations often have no apparent cause. For example, subpopulations often fluctuate independently from one another, and occasionally isolated subpopulations become extirpated. While there is likely some cause for these extirpations, in most cases habitat managers will not know the cause. To guard against an accumulation of many small effects leading to a major metapopulation reduction, managers should maintain some number of independent subpopulations. If each isolated subpopulation within the metapopulation is susceptible to random extirpation events, then increasing the number of subpopulations within the metapopulation will reduce the effect that isolated extirpations have on the metapopulation. At the low extreme, a metapopulation is composed of only two subpopulations. Additional subpopulations will be needed to guard against random extirpation events. Clear recommendations of the number needed cannot be provided at this time.

Area of Metapopulation

A metapopulation that occupies a small area (1-2 square kilometers or 0.38-0.76 square miles) may be at risk from events such as large-scale wildfire. While some individual Karner blues are likely to survive such an event, population densities within each subpopulation may be depressed to the point that the metapopulation cannot recover, and is extirpated within a few generations. One management response to this risk is to have the metapopulation occupy an area larger than the area of a typical wildfire (based on historical fire records).

Barriers

Many events such as wildfire or disease epidemics, flow across landscapes. Thus, barriers with the potential to stop their spread can play an important role in long-term metapopulation viability for the Karner blue. For example, in highly fragmented landscapes, such as in Gary, Indiana, wildfire is not likely to spread from one isolated habitat patch to the next and large-scale wildfire is not a likely threat to Karner blue (although the fragmentation itself creates problems associated with metapopulation connectivity). In less fragmented landscapes, firebreaks (such as wide roadways) may be incorporated into the metapopulation management plan to reduce the risk that a large-scale fire would destroy the majority of the metapopulation.

Similarly, disease epidemics are likely to spread throughout clusters of nearby Karner blue subpopulations. One way to protect against epidemics is to have a few subpopulations located at some distance away from their nearest neighbors so that interchange of adults is a relatively rare event. While this seems diametrically opposed to the earlier discussions that strongly recommend greater connectivity among subpopulations, having a few relatively more isolated subpopulations could reduce the risk of spread of disease.

Diversity of Habitat Among Occupied Sites

The adverse effects of many large-scale factors can be mitigated by increasing the diversity of sites in a metapopulation that support Karner blues. For example, wildfire may skip over mesic sites or sites with little fuel load, leaving behind pockets of Karner blues to repopulate adjacent areas. Similarly mesic sites may act as refuges for Karner blues during hot droughts, while xeric sites could be refuges during an unusually cool summer. The principles here are very similar to those discussed above under habitat heterogeneity, but in that section, the focus was on heterogeneity within occupied sites, whereas here, the emphasis is on heterogeneity among occupied sites. Either of these forms of heterogeneity may also have beneficial effects on other rare species associated with Karner blue habitat (refer to APPENDIX D).

Buffering the Metapopulation

Metapopulations should be buffered against catastrophic disturbances, disease, minor climatic fluctuations, and other disturbances that that could adversely affect the metapopulation. One example of buffering is to secure sufficient land to preclude fragmentation of the metapopulation by development and to provide variations in subhabitats and microclimates. Another example of buffering is the establishment of wide enough fire breaks in management areas to ensure only a subset of occupied habitat is burned at any one time and to reduce the impact of wildfires on the metapopulation.

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(**Note**: This is an excerpt from the *word* document of the Final Karner Blue Butterfly Recovery Plan. Pagination varies slightly from the CD pdf version)