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The Effect of Military Training Activity on Eastern Lupine and the Karner Blue Butterfly at Fort McCoy, Wisconsin, USA

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ABSTRACT / The US Department of Defense (DOD) manages over 10.1 million ha of land, much of which is used for training military personnel. However, vast sections receive little or no use, and military lands have become refuges for many species. At Fort McCoy, Wisconsin, USA, populations of the endangered Karner blue butterfly (*Lycaeides melissa samuelis*) are found in oak and pine barren communities where wild lupine (*Lupinus perennis*), a perennial forb required by Karner blue butterfly larvae, still occurs. Oak and pine barren communities are disturbance-dependent, and the barrens ecosystems in the Midwest have declined in extent by 98% because of fire suppression, succession, and habitat fragmentation. We studied the effects of disturbance by military manuever training on the density of lupine and Karner blue butterfly at Fort McCoy. We also wanted to determine whether military training activity could enhance Karner blue butterfly habitat.

At locations where tracked vehicles had driven through lupine patches, the abundance of lupine and nectar-producing plants was greater in the median strip between vehicle ruts than in vehicle ruts or 5 m outside the vehicle ruts. The proportion of lupine stems with Karner blue butterfly larvae feeding sign (the ratio of stems fed upon to stems examined) was greater in areas where military vehicles had traveled than where they had not. The proportion of lupine stems with feeding sign and lupine stem density was also positively related to the occurrence of prior bivouacs and fires caused by military munitions. Shrub and forest canopy abundance were lower in areas traveled by tracked vehicles. At the scale of the lupine patch, lupine abundance and the proportion of lupine stems with feeding sign were positively correlated with military training activities, suggesting that maintenance of lupine habitat can be achieved in concert with military training.

The US Department of Defense (DOD) manages over 10.1 million ha of land (Boice 1996a), much of which is used for training military personnel of the Army, Navy, Air Force, and Marine Corps. However, vast sections of this land receive very little or no use (Boice 1996a). In areas surrounding military installations, habitat degradation, intensive agriculture, urbanization, and industrialization have made military lands among the last refuges for many species (Walker 1995, Boice 1996a, Goodman 1996, Martin and others 1996). Over 200 federally listed and additional candidate species occur on DOD lands (Boice 1996b, Goodman 1996).

KEY WORDS: Karner blue butterfly; *Lycaeides melissa samuelis*; Endangered species; Lupine, *Lupinus perennis*; Military training; Disturbance

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The US Army manages 4.9 million ha (Shaw and Diersing 1989) of DOD lands. Prior to implementation of the Endangered Species Act in 1973, the Army utilized its lands with relatively few restrictions. Intense training in some areas resulted in the loss of vegetative ground cover, changes in species composition, soil compaction, and soil erosion (McDonagh and others 1979, Diersing and others 1988, Greene and Nichols 1995). Unrestricted use and habitat deterioration also impacted wildlife species (Severinghaus and others 1980, Severinghaus and Severinghaus 1982, Diersing and Severinghaus 1984, 1985, Anderson and others 1986, Giese and others 1989, Stephenson and others 1996). However, the National Environmental Policy Act and the Endangered Species Act required all landholders, including the military, to ensure that their actions did not jeopardize listed species or result in the destruction or adverse modification of critical habitat.

Because the Army's primary peacetime mission is to be prepared for combat operations (Walker 1995), the Army must ensure that soldiers are properly trained. DOD recognizes, however, that all military services must be wise land stewards (Boice 1996a, Goodman 1996). Consequently, all DOD agencies have been directed (1) to provide for a sustained use of land, sea, and air resources, while protecting valuable natural and cultural resources for future generations; (2) to meet all legal requirements of the Endangered Species Act; and (3) to protect compatible multiple use of these resources (Boice 1996a). Thus, the Army must carefully blend training activities with conservation to ensure the future sustainability of their lands; this requires knowledge of the affected species and habitat, and the effects of military training activities on the habitat and the species.

On Fort McCoy, Wisconsin, USA, an endangered species of concern is the Karner blue butterfly (*Lycaeides melissa samuelis*). The Karner blue butterfly formerly occurred from Minnesota eastward across the Great Lake States and southern Ontario, and northeastward to Massachusetts and New Hampshire (Fish and Wildlife Service 1992). Land use changes such as habitat fragmentation, succession, and fire suppression have led to the extirpation of the Karner blue butterfly from much of its former range (Givnish and others 1988, Dirig 1994, Lane 1994, Shuey 1997, Smallidge and Leopold 1997). In 1992 the Karner blue butterfly was federally listed as endangered (Fish and Wildlife Service 1992). Remnant populations still persist in Minnesota, Michigan, Indiana, New Hampshire, New York, and Wisconsin where wild lupine (*Lupinus perennis*) provides the exclusive food source for the Karner blue butterfly larvae (Shapiro 1974, Fish and Wildlife Service 1992, Bleser 1993). Loss of lupine through land use change has contributed to Karner blue butterfly population declines (Haack 1993, Lawrence 1994).

Karner blue butterfly larvae are solely dependent upon wild lupine, which is patchily distributed. Lupines flourish on sandy soils (Bleser 1994, Dirig 1994, Lawrence 1994) in frequently disturbed areas of pine or oak savannas. Karner blue adults depend upon other flowering plants from which nectar can be obtained (e.g., *Arabis lyrata, Coreopsis lanceolata, Melilotus alba, Monardo punctata, Rubus flagellaris, Solidago speciosa*) and usually choose the nectar species with the greatest total number of flowers or flowering heads (Grundel and others 2000). Karner blue butterflies have low vagility (Bidwell 1995), with maximum distances moved by individual butterflies typically less than 100 m (Knutson and others 1999); thus, the butterfly population may be quite sensitive to the spatial distribution of both lupine and nectar plants. Karner blue butterflies have two generations or broods per year. Spring-brood larvae typically hatch from overwintering eggs in mid- to late April, and adults emerge from pupating larvae in late May. Adult females oviposit in June before dying, and the second brood period usually begins in mid- to late July. Variation in emergence of adults between years ranges from 2 to 5 weeks in spring and 2.5 to 6 weeks in summer (Swengel and Swengel 1999).

The oak and pine barrens in which lupine occurs are disturbance-dependent systems in which the presettlement fire regime was characterized by frequent low-intensity fires (Apfelbaum and Haney 1989). Midwest oak barrens have declined by 98% from their original extent (Nuzzo 1986), largely because of fire suppression, leading to losses of Karner blue butterfly (Lawrence and Cook 1989) and lupine (Haack 1993, Shuey 1997). Military training has replaced fire as the primary disturbance in the Fort McCoy oak barrens ecosystem (Larsen 1992). Lupine occurs at Fort McCoy in open disturbance-maintained habitat, some of which is produced by military training (Bidwell 1995, Wilder 1995).

We were interested in determining the impact of military training on Karner blue butterfly populations and whether military training could be used to manage Karner blue butterfly habitat. We considered three possible hypotheses: (1) maneuver training acts affects the density of lupine and Karner blue butterfly; (2) maneuver training damages lupine, resulting in decreased densities of lupine and Karner blue butterfly; and (3) maneuver training has no impact on lupine and Karner blue densities. We examined these hypotheses and the effects of military training first at the local scale—the level of a lupine patch—then at a broader scale—the total available area on Fort McCoy—and asked the following questions to elucidate our hypotheses:

1. Of the total available area on Fort McCoy, which lands are suitable for maneuver training, and where does lupine occur in relation to these suitable maneuver areas?
2. In areas where tracked vehicles, bivouac, and fire disturbances occur across lupine patches, what are the subsequent responses of lupine and Karner blue butterfly?
3. At the broad-scale, does lupine occur at a greater abundance in areas more frequently used by the military?

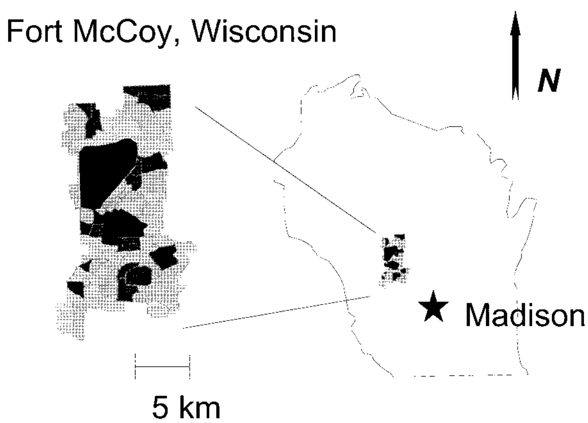

Figure 1. Location of Fort McCoy in west-central Wisconsin. Shaded sections represent training areas. Areas shaded in black are off-limits to training and include the ordnance impact area and the cantonment area.

Methods

Study Area

Fort McCoy is a 24, 106-ha military training area located within the driftless area of Wisconsin (Figure 1). Fort McCoy occurs in an ecotone between the northern coniferous forest and central hardwood forest (Larsen and Mello 1993) and between eastern forests and western prairies (Directorate of Public Works 1998). Fort McCoy is characterized by oak and pine barren communities, which typically contain sandy soils and are dominated by grasses, forbs, shrubs, and scattered stands of trees (Curtis 1971). Major tree species on Fort McCoy include jack pine (*Pinus banksiana*), northern pin oak (scrub oak) (*Quercus ellipsoidalis*), northern red oak (*Q. rubra*), white oak (*Q. alba*), and black oak (*Q. velutina*) (Larsen and Mello 1993, Mello and Hutchinson 1990). Major shrubs include hazelnut (*Corylus americana*), dogwood (*Cornus foemina*), speckled alder (*Alnus rugosa*), and blackberry (*Rubus sp.*) (Larsen and Mello 1993). Herbaceous species include bunchberry (*Cornus canadensis*), goldenrod (*Solidago sp.*), and downy phlox (*Phlox pilosa*). Prairie plants such as spiderwort (*Tradescantia virginiana*), flowering spurge (*Euphorbia corollata*), big bluestem (*Andropogon geradi*), little bluestem (*A. scoparius*), and leadplant (*Amorpha canescens*) occur in the understory (Larsen and Mello 1993). Over 80% of the soils on Fort McCoy are sand, and slopes range from 0 to 45% (Directorate of Public Works 1998).

The climate of Fort McCoy is continental (Directorate of Public Works 1998). Spring often comes late and is mixed with warm and cold periods. Spring temperatures generally average 7, 14, and 19°C in April, May, and June, respectively (Midwestern Climate Center, Champaign, Illinois, USA). Summers are warm, with several hot and humid periods. Summer average temperatures are generally 21 and 20°C for July and August, respectively (Midwestern Climate Center). Winter tends to be long, cold, and snowy.

Fort McCoy was established through purchases of farm- and ranchland from 1909 to 1942 (PAO 1994). Its primary mission is to provide for the training of, and therefore, to ensure the readiness of, reserve and active-component military forces (PAO 1994). Today, Fort McCoy is intensively used by Active, Reserve, and National Guard soldiers of the Army, Air Force, Navy, and Marine Corps. About 100,000 soldiers use Fort McCoy each year (PAO 1994), with most intensive use occuring from May through October. During our study, Fort McCoy was divided into 76 training areas plus off-limits areas including the ordnance impact area, housing area, ski hill, and natural areas.

Field Sampling

During the spring and summer of 1996 and 1997, we conducted field work at Fort McCoy to study the effects of military training on lupine and Karner blue butterfly. To determine which lands were suitable for maneuver training and where lupine occured in relation to these suitable maneuver areas, we reclassified forest cover data from Fort McCoy's geographic information system (GIS) database (Aslesen unpublished data) using ArcView (1998). Lands were reclassified into four military land-use categories (go, slow-go, no-go, and off-limits) based upon the potential of a military tracked vehicle to traverse the terrain (HQ Dept. Army 1992). Open grassy areas, meadows, and areas where forest tree densities were low were classified as go areas (not restricted to maneuver). Areas of medium tree density were classified as slow-go areas (partially restricted to maneuver). Areas of high tree density and wetlands were classified as no-go (restricted to maneuver). Housing areas, lakes, red-pine plantations (revenue crop), and the ordnance impact area (unexploded ordnance) were classified as off-limits. For a detailed list of all reclassifications, see Appendix 1. A map of lupine patches, also obtained from the Fort McCoy GIS, was overlaid on the military land-use classes to determine the area of intersection. Lupine patches were mapped based on a thorough search of Fort McCoy by field workers during spring when the lupine was blooming. In the impact area, where munitions are exploded, mapping was done from a helicopter. ANOVA was used to determine if the mean area in lupine and the mean lupine density (Leach 1993) differed among the four

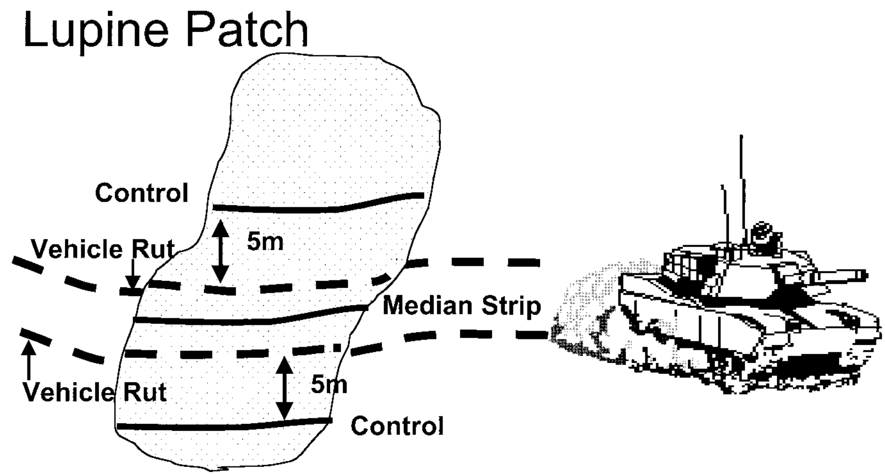

Figure 2. The location of five transects used for measuring the effect of tracked vehicle disturbance through each lupine patch: the median vegetation strip between the ruts, within each vehicle rut, and 5 m outside of each vehicle rut (the reference).

categories of military land-use (SAS Institute, Inc. 1989).

At places where maneuver training occurred in lupine patches, the impacts of tracked vehicles on lupine and Karner blue butterfly were studied in 26 plots that contained vehicle trails (two ruts created by one or more vehicles). Vehicle traffic affects the site by compacting soil and damaging or removing above-ground vegetation. Each vehicle rut was ~5–7 cm deep, typical of the depth to which a tracked vehicle disturbs the soil (Larsen and Mello 1993); wheeled vehicles did not produce visible signs of disturbance. Sixty-two permanent plots (60 × 100 m) had been established on Fort McCoy in 1995 to assess effects of military training on vegetation (Lipyanic 1995, Wilder 1995). Each plot was visited at approximately 2- to 3-week intervals during spring and summer of 1995 and 1996 (Wilder personal communication); the date of the visit was recorded, and the locations of lupine and of military traffic across each plot were mapped. We studied 109 lupine patches during 1996 and 1997 (Smith unpublished data). We selected the 26 study plots with vehicle trails along with adjacent areas (5 m to the outside of each vehicle rut) without visible sign of disturbance from these 171 potential plots.

At each sampling plot, we established five 20-m transects: one transect along the median vegetation strip between the ruts (treatment), one transect within each of the ruts (treatment), and one transect at a distance 5 m from the outside of each rut (reference) (Figure 2). Each transect was divided into 20 regularly spaced points. At each point along each transect, the point intercept technique (Bonham 1989) was used to record vegetative ground cover as bare ground, ground litter (dead twigs, leaves, or vegetation), grass, nectar plant (any flowering plant) (Savignano 1994), shrub, fern, moss, or lupine. Presence or absence of forest canopy was recorded at the vertical projection above each point. The data recorded within the two vehicle ruts were combined, and the data recorded 5 m outside of each rut were combined. Proportions of vegetative ground cover and forest canopy coverage were computed for the treatment and reference transects. A paired *t* test (SAS Institute, Inc. 1989) was used to determine if the mean ground vegetation cover differed between each treatment or between each treatment and the reference.

To determine the effects of tracked vehicle traffic on Karner blue butterfly use of the lupine patch, we measured the proportion of lupine stems fed upon by larval butterflies. Five 0.5-m × 1-m quadrats were placed on the ground at regular intervals along each transect such that each quadrat contained at least one lupine plant. Within each quadrat, the leaves on each lupine stem were examined for the presence of larvae feeding sign: small holes, paired holes, or skeletonized leaves (window panes) (Swengel and Swengel 1993, Swengel 1995). Feeding sign correlates well with larval abundance and with subsequent adult abundance (Swengel 1995) and was used as an index of Karner blue butterfly abundance for several reasons. Larvae and adults emerge asynchronously, with adult emergence occurring within approximately a 1-month period (Swengel and Swengel 1999). An individual adult lives <14 days, and censusing of adults is strongly influenced by weather and time of day. Larvae are very difficult to find and can be dislodged easily from lupine plants during sampling and not counted. Larvae feeding sign is also a permanent record of larvae presence or absence within a growing season, and feeding sign from the second flight is readily distinguishable from that of an earlier flight. Plants senesce each winter, so herbivory from prior years does not confound current-year measurements. Thus, feeding sign is an optimal index of patch occupancy. A lupine stem was defined as a separate stalk originating at ground level. The total number of stems and the total number of stems with larvae feeding sign were tallied for each quadrat, and the average proportion of stems with feeding sign were computed for each treatment and reference. Proportion data were log-transformed prior to analysis, and a paired t test (SAS Institute, Inc. 1989) was used to determine if the proportion of lupine stems with feeding sign differed between each treatment or between each treatment and the reference.

The response of lupine and Karner blue butterfly with time since tracked vehicle disturbance was also examined. Data from the median strip and in the vehicle ruts were combined to produce one measurement of the effect of a tracked vehicle driving across a lupine patch. We then calculated the time (in years) between the date of the tracked vehicle use (Wilder unpublished data) and the date we recorded our measurements. ANOVA was used to determine whether lupine abundance or proportion of lupine stems with feeding sign differed 1, 2, and >2 years following the disturbance.

Within our sample plots, one bivouac occurred in a lupine patch. The military vacated this site during the last week of June 1996. We recorded the total number of lupine stems, their height, and presence or absence of larvae feeding sign on visits to the lupine patch on 3 and 31 July 1996, 15 and 25 August 1996, and 2 and 24 June 1997. We compared stem heights, numbers of lupine stems, and the proportion of lupine stems with feeding sign over time. Lupine height is significantly correlated with length of Karner blue butterfly larvae (Swengel 1995).

One lupine patch was burned on 21 May 1997 in a fire caused by a munition fired into the ordnance impact area. We compared the patch vegetation the day after the fire to data we had collected on same patch during the spring and summer of 1996 and the summers of 1997. Lupine patch data were collected as described above.

We used two approaches to infer whether lupine and Karner blue butterfly occur at greater abundance in areas previously disturbed by tracked vehicles at Fort McCoy. First, we visited each of 109 lupine patches (Smith unpublished Ph.D dissertation 2001) during the summer of 1997 and assessed the likelihood that unimpeded tracked vehicle traffic would occur on the patch based on the land-use classification used by the Army. This likelihood was based upon the width of a military armored personnel carrier (2.69 m; HQ Dept. Army 1992) and the distance between trees, which determines accessibility. Within each lupine patch we measured, at breast height, the width between the two trees that were closest to each other, then the distance to the next closest tree, and so on, for a total of $N = 4$ widths. An average width between trees was computed for each patch, and each patch was categorized as either no-go, slow-go, or go for tracked vehicles based on average tree spacings of <4.8 m, 4.8–10.76 m, and >10.76 m, respectively. No-go (restrictive) referred to tree spacings more narrow than the turning radius of an armored personnel vehicle (4.8 m, HQ Dept. Army 1992); slow-go (partially restrictive) referred to an armored personnel vehicle being able to maneuver within 4 times its vehicle width (10.76 m); and go (unrestricted) referred to vehicle movement unimpeded by trees (>10.76 m tree spacing). ANOVA (SAS Institute, Inc. 1989) was used to test whether lupine density and the proportion of lupine stems with Karner blue butterfly feeding sign differed among the three access classifications.

Second, we examined Fort McCoy's training records and assumed that troop training history is a proxy for the level of disturbance in each training area. Training records for 1993–1995 were summarized for each of the 76 training areas (Watuski unpublished data). Using GIS, the map of lupine patches was overlaid on the training area map and the proportion of each training area in lupine habitat was computed. Regression was used to determine whether there was a linear relationship between the proportion of each training area in lupine and the frequency of use, the total number of troops, or the intensity of use (number of troops per visit) of each training area.

Results

Tracked-vehicle maneuver training can occur on 15,500 ha of Fort McCoy (65% of the total available land area) in areas categorized as go and slow-go (Table 1). Seventy-four percent of the area in lupine also occurs within these go and slow-go areas. Troops traveling on foot can use an additional 3252 ha (13% of the total available land area) in areas categorized as no-go (restrictive to maneuver) (Table 1). Approximately 5300 ha of land (22% of the total available land area) is off-limits to maneuver training. Among the military land-use categories (go, slow-go, no-go, and off limits), the mean lupine patch size differed ($F = 8.12$, $df = 3358$, $P < 0.01$). The largest lupine patches occurred in the off-limits areas ($P < 0.05$) (Duncan's multiple range test), in particular, the ordnance impact area.

Lupine abundance was greater at locations where tracked vehicles had driven than in areas where they

Table 1. Area of lupine within four military land use categories, Fort McCoy, Wisconsin

Military land-use categories[a]	Land Area on Fort McCoy [ha (%)]	Lupine area within three lupine densities[c] [ha (%)][b]			Total lupine area [ha (%)]
		Low	Medium	High	
Go	9,383 (39)	469 (30)	78 (5)	23 (1)	570 (36)
Slow Go	6,172 (26)	487 (31)	92 (6)	16 (1)	595 (38)
No Go	3,252 (13)	103 (7)	26 (2)	5 (1)	134 (10)
Off-limits	5,299 (22)	114 (7)	98 (6)	43 (3)	255 (16)
Column total	24,106	1,173	294	87	1,554

[a]For a detailed explanation of the reclassification of forest cover GIS data (Aslesen, unpublished data) to military land-use categories see Appendix 1.0 Military land use categories are based upon the potential of a military vehicle to traverse the terrain: Go (no restriction to military training)—open areas with low density of trees; slow-go (partially restrictive)—medium density of trees; no-go (restrictions)—high density of trees, or off-limits areas (e.g., housing), or ordnance impact area.

[b]Landscape of various lupine densities were classified by Leach (1993) based upon visual estimates of the average shortest distance between lupine plants: high (<5 ft), medium (5–25 ft), and low (>25 ft).

Table 2. Abundance of vegetation along transects, proportion of lupine stems with feeding sign, lupine stem height, and numbers of lupine and nectar stems within the median strip, vehicle ruts, and 5 m outside of vehicle ruts made by tracked vehicles driving through lupine patches during summer 1997, Fort McCoy, Wisconsin[a]

	Percent (mean ± SE)[b]		
	Median Strip	Inside Vehicle Ruts	5m Outside Vehicle Ruts[c]
Lupine	4.3 ± 0.008(A)[c]	2.9 ± 0.006(B)	2.4 ± 0.005(B)
Nectar	10.6 ± 0.018(A)	8.9 ± 0.014(AB)	7.6 ± 0.014(B)
Fern	4.9 ± 0.016(AB)	3.9 ± 0.013(B)	6.4 ± 0.022(A)
Bare	3.5 ± 0.014(A)	2.6 ± 0.0114(A)	1.7 ± 0.006(A)
Litter	37.3 ± 0.0369(B)	54.2 ± 0.033(A)	41.2 ± 0.034(B)
Grass	29.8 ± 0.0292(A)	23.7 ± 0.025(B)	30.1 ± 0.032(A)
Moss	1.7 ± 0.005(A)	0.2 ± 0.001(B)	0.3 ± 0.001(B)
Shrub	7.7 ± 0.017(B)[d]	3.7 ± 0.007(C)[d]	10.4 ± 0.024(A)[d]
Forest Canopy	61.4 ± 0.056(B)	64.5 ± 0.048(B)	84.5 ± 0.025(A)
Larvae FS[e]	0.629 ± 0.038(A)	0.643 ± 0.038(A)	0.541 ± 0.036(B)
Lupine height (cm)	24.00 ± 0.79(A)	22.34 ± 1.018(A)	24.61 ± 0.813(A)
Lupine stems (*N*)	47.2 ± 7.07(A)	31.27 ± 4.9(B)	37.77 ± 4.10(AB)
Nectar stems (*N*)	85.54 ± 10.64(A)	71.04 ± 9.72(B)	52.80 ± 9.10(C)

[a]$N = 26$ transects, averaging 20 m in length.

[c]Used as reference. Measurements were recorded at a distance of 5 m from the outside of the vehicle ruts.

[b]Across rows, means with the same letter are not significantly different ($P = 0.05$). Standard errors are calculated from the proportion and not the percent.

[d]Significant difference at $P = 0.10$.

[e]Ratio of lupine stems with larvae feeding sign to number of stems examined.

had not driven. The proportion of the transect in lupine was greater in the median strip transect (4.3%) ($P < 0.05$) than in either the vehicle ruts (2.4%) or 5 m outside the vehicle ruts (2.9%) (Table 2). The number of lupine stems was also greater in the median strip transect. The abundance of lupine growing in the ruts, however, was not significantly different from the abundance of lupine 5 m outside of the vehicle ruts, and lupine height was not significantly different across all three transects (Table 2).

The percent of the transect containing nectar plants was higher in the median strip than 5 m to the outside of the vehicle ruts. In addition, the number of nectar stems in the median strip was almost the number recorded 5 m outside of the ruts (Table 2).

The proportion of lupine stems with feeding sign was greater in areas used by tracked vehicle than in unused areas (Table 2). The proportions of lupine stems with feeding sign in the median strip and the vehicle ruts were greater than 5 m outside of the vehicle rut. The proportion of lupine stems with feeding sign did not differ between the median strip and the vehicle ruts.

Shrubs were most abundant in the areas 5 m outside of the vehicle trail, and least abundant within the vehi-

Table 3. Changes in number of lupine stems and minimum, maximum, and mean lupine stem heights following vacating of a bivouac site[ab] established on a lupine patch during late June 1996, Fort McCoy, Wisconsin

Date	# Lupine stems (N)	Height Min	Max	Mean ± SE	CV
3 Jul 96	30[b]	1.5	25	9.85[c] ± 1.25[c]	0.69
31 Jul 96	145	3.0	20	7.31 ± 0.228	0.38
15 Aug 96	132	2.0	25	9.24 ± 0.377	0.47
25 Aug 96	102	3.0	26	8.99 ± 0.410	0.46
2 Jun 97	184	4.0	16	9.00 ± 0.163	0.25
24 Jun 97	88	3.0	30	14.81 ± 0.667	0.42

[a]Actual disturbance ended on 3 July 1996 when National Guard soldiers returned to their home station, less than one week before our first visit. Data were measured within a 6 m × 10.5 m bivouac site.

[b]Thirteen of 30 stems were free standing with a mean height of 3.73 cm. Seventeen stems were flattened to the ground with a mean height of 14.53 cm, when stretched to their original length.

[c]Mean height for 3 July 1996 includes free standing lupine stems, and stems stretched to their original length.

cle trail (mean = 0.10). Forest canopy was greater in areas 5 m outside of the vehicle trail. Fallen leaves collected in the vehicle ruts, and 54% of the length of the ruts contained leaf litter (Table 2). However, there was no significant difference in the amount of bare ground measured across treatments and references ($P > 0.05$).

Using combined data from the median strip and the vehicle ruts, we found the proportion of the vehicle trail in lupine differed with 1, 2, or >2 years since disturbance by tracked vehicles ($F_{2,23} = 5.30$, $P < 0.02$). Lupine densities were highest 1 year after disturbance (mean ± SE: 0.061 ± 0.014), then declined during years 2 and >2 (0.017 ± 0.005 and 0.027 ± 0.008, respectively). Lupine densities in years 2 and >2 were significantly different from year 1 ($P < 0.05$), but not different from each other (Tukey's studentized test, $P > 0.05$). The proportion of stems with larval butterfly feeding sign was not different among the years of the study ($F_{2,20} = 0.005$, $P = 0.99$).

Lupine recovered quickly in one 6-m × 10.5-m bivouac that occurred in a lupine patch. The number of lupine stems increased from 30 to 145 within 21 days following the bivouac (Table 3). The number of lupine stems remained high the following year. The mean lupine height was ~9.5 cm, but maximum height (30 cm) in our 2-year study occurred in June 1997, approximately 13 months following the bivouac. The mean June 1997 height (14.81 cm) was similar to the mean height (14.53 cm) of lupine when the military established their bivouac (Table 3). (To obtain the mean height when the military established their bivouac, we measured the height of trampled lupine plants on 3 July 1996 by extending the trampled stem to its original length). Butterflies began using the lupine patch within the bivouac site during the same year of disturbance. By the spring and summer of 1997, 36%–44% of the lupine stems in the bivouac site contained larvae feeding sign (Table 4).

Table 4. Proportion of lupine stems with larvae feeding sign one year following bivouac disturbance of late June 96, Fort McCoy, Wisconsin[a]

Date	Stems with larvae feeding sign (N)	Stems examined (N)	Proportion with feeding sign[b]	SE
2 Jun 97	67	184	0.36	0.036
24 Jun 97	39	88	0.44	0.053

[a]Data were measured within a 6 m × 10.5 m bivouac site.

[b]Ratio of lupine stems with larvae feeding sign to number of stems examined.

On 21 May 1997, a munition fired into the impact area caused a fire that burned one of our lupine patches. We visited the lupine patch the day after the fire and all of the understory vegetation had burned. Scant evidence of charred and scorched lupine stems was observed, and all above-ground vegetative parts were dead. We found our plot marker stakes and surveyed the vegetative remains along the length and width transects (Smith unpublished PhD dissertation 2001) using the point-intercept technique (Bonham 1989). All cover was ground litter. By the summer of 1997, however, much grass had emerged (45% of the transect) (Table 5) and lupine comprised 5% of the transect. Although the amount of lupine along the transect and the proportion of lupine stems with feeding sign had not achieved preburn levels by the summer of 1997, at sites within the patch where lupine was present, lupine densities during the summer following the fire were higher than during the previous sampling year (Table 5).

At the broad scale, we were unable to find evidence that military training between 1993 and 1995 affected lupine abundance. Neither the number of troops using a training area, their frequency of use, nor their intensity was significantly related to the proportion of the training area in lupine ($t = 0.829$, $P = 0.411$, $df = 52$; $t = 0.161$, $P = 0.873$, $df = 52$; $t = 0.643$, $P = 0.523$, $df = 52$, respectively). Results from ANOVA for lupine patches classified as go, slow-go, and no-go showed no significant relationship between spacing between trees and lupine stem density or the proportion of lupine stems with feeding sign (Table 6). Thus, lupine abundance at the broad scale did not appear to be related to levels military training.

Table 5. Abundance of vegetation along transects within a lupine patch prior to and after being burned on 21 May 1997 at Fort McCoy, Wisconsin

	Abundance (mean percent)			
Vegetation	3 Jul 96	26 Aug 96	22 May 97	11 Jul 97
Lupine	7.5	—[a]	0	5
Nectar	7.5	5	0	2.5
Ground litter	22.5	42.5	100	42.5
Grass	15	35	0	20
Shrub	45	15	0	17.5
Bare ground	0	0	0	12.5
Moss	0	0	0	0
Fern	2.5	2.5	0	0
P feeding sign[b]	0.618	0.786	0	0.413
Lupine stems/m^2[c]	3.40	1.4	0	6.23

[a]Lupine was senescent by this time. (We were unable to enter this patch any sooner because it was located within a maneuver area that was off-limits for most of July and August 1996).

[b]Ratio of lupine stems with larvae feeding sign to number of stems examined.

[c]Lupine density at places within the lupine patch where lupine was present.

Table 6. Results of analysis of variance to determine if proportion of lupine stems with larvae feeding sign, lupine density, and average proportion of each training area comprised of lupine differed among the three types of military land-use categories, Fort McCoy, Wisconsin[a]

	No-go (N = 50) Mean (SE)	Slow-go (N = 51) Mean (SE)	Go (N = 8) Mean (SE)	*P*
Feeding sign[b]				
Spring	0.329 (0.032)	0.362 (0.032)	0.417 (0.100)	0.54
Summer	0.234 (0.027)	0.239 (0.027)	0.192 (0.062)	0.81
Lupine density				
Spring	7.27 (0.525)	7.68 (0.719)	5.27 (0.679)	0.35
Summer	4.67 (0.346)	4.96 (0.395)	3.96 (0.637)	0.57
Proportion of training area in Lupine				
Spring	0.084 (0.009)	0.100 (0.012)	0.056 (0.020)	0.34
Summer	0.048 (0.007)	0.052 (0.010)	0.016 (0.009)	0.27

[a]No-go, slow-go, and go are based upon the ease at which a military vehicle can pass between the forest stems (spacing between forest stems: <4.8 m, 4.8–10.76 m, and >10.76 m for no-go, slow-go, and go, respectively).

[b]Ratio of lupine stems with larvae feeding sign to number of stems examined.

Discussion

Approximately 65% of the lands on Fort McCoy were classified as go and slow-go, and were available for either unrestricted or partially restricted maneuver training. However, 74% of all lupine occurred within these maneuver areas, so the likelihood of military training occurring in lupine habitats is high. Areas classified as no-go and off-limits contained only 26% of the total lupine. Lands classified as no-go can still be used for troop training on foot, but such activity would only impact 10% of the lupine, and a majority of this lupine was either medium or low density. Lands classified as off-limits contain the largest average patch sizes of lupine and the greatest area of high-density lupine. Most of this lupine occurred in the ordnance impact area in which some part of the area is burned each year by fire started from military munitions. Classifying military training lands by categories that describe the potential military land-use can help in understanding how species or habitats may be affected.

In our first hypothesis, we asked whether maneuver training had affected the density of lupine and Karner blue butterfly. Lupine abundance was greater in areas through which tracked vehicles had traveled than in areas where vehicles had not traveled. Lupine cover was greatest within the median strip between the vehicle ruts, but lupine regrowth was also observed within the vehicle ruts and on the eroded margins of the tracked vehicle trails. Mechanisms contributing to greater lupine abundance in the median strip may relate largely to lupine biology. Following disturbances, lupine genets produce clonal shoots that emerge as ramets (Grigore and Tramer 1996). Disturbance of lupine tends to increase seed set, scarify or crack the seed coat that leads to the breaking of seed dormancy, and increase vegetative growth (Quinlivan 1961, 1966, Bewley and Black 1982, Grigore and Tramer 1996). Higher levels of lupine in the median strip may represent sites at which seeds and emerging genets find the soils less compacted than in the vehicle ruts, yet shrub levels and canopy coverages are scant enough to provide conditions that are favorable for growth.

Sun and Liddle (1993) determined that plant height was the most sensitive indicator of trampling damage. However, across all treatments and references, we found no significant difference in lupine height during our study. Lupine plants responded more rapidly to disturbance than other vegetation, and in clipping experiments, Wilder (1998) determined that lupine could return to predisturbance plant height within 45 days of clipping. For tracked vehicle disturbances, plant height may not be a good indicator of trampling damage.

The damage to lupine from tracked vehicle traffic appeared almost immediately and negative effects persisted only through the same growing season. In the first year after tracked vehicle passage, lupine increased in abundance, then declined gradually over time. Pickart and others (1998) also found lupine recruitment to be highest in the year following a disturbance treatment, with emergence of new shoots ceasing by the fourth year. However, Kerkman (personal communication in Leach 1993) observed lupine growth to persist 4–10 years after the disturbance.

Repeated disturbance by tracked vehicles is likely to have a negative effect on lupine. Tracked vehicles disturb the top 5–7 cm of soil (Larsen and Mello 1993), and although the roots of the lupine might not be disturbed, Pickart and others (1998) concluded that repeated duff removal at the same site for at least 3 years depleted yellow lupine (*Lupinus arboreus*) seedbanks. We recommend tracked vehicle use not occur continually over the same site. Rather, we recommend a minimum of 1 year before the same site is revisited by tracked vehicles based upon the recovery time for lupine.

Nectar plant abundance was higher in areas traveled by tracked vehicles compared to areas unaffected by tracked vehicles. For many butterfly populations, including the Karner blue, nectar resources play an important role in the dispersal, direction, and length of movement (Gilbert and Singer 1973, Haack 1993, Leach 1993, Bleser 1994, Lane 1994). A lack of nectar plants, especially during the second brood period may render sites unsuitable for Karner blue butterfly (Bleser 1993, Leach 1993). Tracked vehicle activity on Fort McCoy does not appear to affect the availability of nectar resources for the Karner blue butterfly population.

Unlike Shaw and Diersing (1990), who found military tracked vehicle training in Piñon Canyon, Colorado, USA, to increase bare ground, we did not find a difference in the amount of bare ground across the references and treatments. Fort McCoy (33 in. of precipitation per year) (Midwestern Climate Center) is less arid than Piñon Canyon (12 in. of precipitation per year), (Shaw and Diersing 1990), and Fort McCoy vegetation may be able to regrow more quickly within the vehicle ruts. However, vehicle ruts on Fort McCoy fill with leaf litter falling from the oak canopy, which covers any exposed ground created by the tracked vehicle. On Piñon Canyon where the dominant vegetation is grassland (Shaw and Diersing 1990), there is much less litter to cover the soils following military training.

Shrub cover was less in areas used by tracked vehicles than in areas where tracked vehicles did not travel, consistent with observations made by others (Greene and Nichols 1995). Shrub cover was lowest in the vehicle ruts, greater in the median strip, and greatest 5 m outside of the vehicle trail. Sun and Liddle (1993) determined that trampling by vehicles provided more favorable growth conditions for lupine by eliminating competitors and thereby enhancing leaf production, number of flowering stems, and seed set in lupine (Grigore and Tramer 1996). Leach (1993) observed that lupine grew best in areas where the growth of taller herbaceous plants was limited, and Grigore and Windus (1994) and Lane (1994) determined that late successional habitats were indicative of conditions that were unfavorable to lupine and Karner blue butterfly. However, low shrub levels in areas traveled by military vehicle may instead result from drivers selecting routes of least resistance (i.e., fewer shrubs and trees). Nevertheless, more favorable conditions for lupine and Karner blue butterfly occurred where shrub abundance was low.

Forest canopy cover was also low in areas affected by tracked vehicles and higher in areas the vehicles avoided. Tracked vehicles drive around trees and avoid driving through areas with dense vegetation, but military vehicle traffic also hinders tree establishment. Although Greene and Nichols (1995) found no effect of military traffic on species richness of tree regeneration, effects will depend on the ecosystem and the intensity of use. Lupine and Karner blue butterfly occurrence are both generally higher in areas of reduced, or spatially heterogeneous, canopy cover (e.g., Smallidge and others 1996, Grundel and others 1998a,b).

The ratio of stems fed upon by Karner blue butterfly larvae to stems available was higher in areas used by tracked vehicles than areas unused. Thus, lupine patches that occurred in areas affected by tracked vehicles still provided suitable habitats in which adults chose to oviposit eggs. The attractiveness of the site for the butterflies may be related to a combination of higher lupine abundance, higher nectar levels, lower shrub amounts, or an intermediate density forest canopy (Maxwell 1998). Although there were significantly fewer lupine stems in the vehicle tracks, there was no significant difference in the ratio of stems fed upon to stems available between vehicle ruts and the median.

Following a bivouac, we observed the number of lupine stems, lupine density, lupine stem height, and the proportion of lupine stems with feeding sign to increase into the second year. Higher lupine abundance in the bivouac areas may be related to declines of up to 70% in woody understory (Trumbull and others 1994, Greene and Nichols 1995). Trampling by vehicles and people in bivouac sites may eliminate competitors and enhance lupine growing conditions (Sun and Liddle 1993). However, the species richness (Grime 1973) and the amount of primary production (Goldsmith 1974) will first rise and then fall as trampling gradually increases. Trumbull and others (1994) observed that repeated camping reduced density and species richness of overstory and understory vegetation and litter cover, and increased soil compaction and bare ground. During the period of our 2-year study, bivouac sites were not revisited by the military, whereas Trumbull and others (1994) studied 20 to 40 year-old military camping sites. Where bivouacs often occur, lupine is less abundant (Larsen and Mello 1993). We support the rotation of the locations of bivouac sites (Trumbull and others 1994) and recommend that, if bivouac sites occur on lupine patches, there should be a minimum of 1 year before another bivouac could occur at the same site.

Our second hypothesis was that maneuver training damages lupine, which results in decreased densities of lupine and Karner blue butterfly. We observed that maneuver training initially caused a negative impact on lupine, but subsequent responses were positive, and lupine and Karner blue butterfly appeared to benefit from the disturbance. However our study spanned only 2 years. Repeated training by either tracked vehicles or bivouac will likely reduce vegetation and cause long-term soil compaction (Trumbull and others 1994), having a negative effect on lupine and Karner blue butterfly (Larsen and Mello 1993). We recommend a long-term study to quantify the spatiotemporal dynamics of the lupine population and its relationship to training activity on Fort McCoy.

Our third hypothesis, that maneuver training has no impact on lupine and Karner blue densities, was not supported at the local scale, but we were unable to detect a significant impact of military training activities on lupine abundance at the broad scale. Of 149,500 troops using Fort McCoy during a 3-year period (Watuski unpublished data), neither the number of troops, their frequency, or their intensity, nor use of lands classified as no-go, slow-go, or go were significantly correlated with lupine abundance. This was a surprising result because most of the lupine patches had residual vehicle ruts resulting from many years of frequent disturbance. Fort McCoy has a long disturbance history that includes wheat farms, cattle and dairy ranches, logging operations, military training, fires, and the northern two thirds of Fort McCoy was previously an ordnance impact area. In addition, 86% of the lupine patches on Fort McCoy have been disturbed at least once between 1950 and 1992 (Bidwell 1995). Historical disturbances were were largely responsible for the patterns and abundance of lupine at Fort McCoy (Bidwell 1995). The lack of association we observed between recent broad-scale training patterns and lupine abundance is probably related to the recent policy at Fort McCoy for keeping troops out of lupine patches. During the period of our study, troops were given cards with a color photo of lupine and instructed to keep out of areas where these plants occur and to do no harm to the butterflies. A lack of a significant relationship between number, frequency, and intensity of troop use of training areas and the amount of lupine may be because troops avoided those areas in which lupine was growing.

Fire may also help explain the lack of a significant relationship between troop training activities and lupine at the broad scale. Fire occurs on Fort McCoy naturally, by accident, or from military use of pyrotechnics and munitions. At the broad scale, fire rather than military vehicle traffic could be responsible for the distribution of lupine and Karner blue across Fort McCoy. However, historical fire records of Fort McCoy are incomplete, and this effect cannot be rigorously assessed. Human-caused fires on Fort McCoy are often related to high numbers of troops. Further work should be done to determine the relationship between the numbers of fires and troops, and managers should consider the potential benefits of prescribed and natural fire. Fire or mechanical vegetation removal is part of the management for Karner blue butterflies at other locations (e.g., Smallidge and others 1996, Smallidge and Leopold 1997, Kwilosz and Knutson 1999).

The answer to whether military training can be used in lieu of fire as an ecosystem disturbance process is not conclusive. Fire effects on lupine include faster seed germination rates, and increased vegetative growth, numbers of stems, and seed set (Grigore and Tramer 1996). However, in very hot fires, 95% of newly germinated seedlings are killed and many lupine seeds fail to germinate (Grigore and Tramer 1996). In addition, all life stages of the Karner blue butterfly, particularly the eggs and larvae, are vulnerable to fire (Haack 1993, Bleser 1993, Bidwell 1995, Schweitzer 1991). Lupine may tolerate more frequent disturbance by military training than by fire. Fire return intervals of 5–10 years have been suggested for sustaining lupine (Apfelbaum and Haney 1989) with a minimum of 2 years (Bleser 1993, Grigore and Tramer 1996).

Military activities could be used as a habitat management tool similar to prescribed fire to provide a mosaic landscape with suitable habitat for Karner blue butterflies, but more information is needed on the frequency and intensity at which habitat and lupine plants can be disturbed and the recovery time (Lathrop 1983) needed between military training activities. In addition, the effects of repeated multiple disturbances (e.g., bivouac, tracked vehicle, wheeled vehicles) should be assessed. Based on such knowledge, military units could be assigned to train at specific locations based on a desired disturbance regime. Understanding the interaction between training intensities and ecosystem recovery rates can assist in minimizing ecological damage and land restoration costs.

We also recommend that natural resource managers record and summarize ecological data in ways that are understandable and readily transferable into military applications. Military personnel frequently need meaningful ecological information, such as forest stem spacing, stem diameter, shrub height, shrub density, canopy coverage, and identification of lands as go, slow-go, and no-go (HQ Dept. Army 1992). Ecological data could be collected and summarized in these formats to aid a commander in selecting lands upon which to train.

In 1995, then Army Chief of Staff Gen. Gordon R. Sullivan said the Army will not maintain readiness unless it integrates environmental protection into planning, daily operations, and training (Finch 1995). Walker (1995) recommended that each Army installation determine the level of training and testing activities that can be accommodated and still allow the land to remain sustainable. Goodman (1996) recommends ecosystem management. Further research should be done to assess the effects of military training activity across the oak barrens on Fort McCoy and to determine if other barrens-dependent species being considered for federal protection under the Endangered Species Act [e.g., the phlox moth (*Schinic indiana*), eastern massasauga rattlesnake (*Sistrurus catenatus c.*), Blanding's turtle (*Emydoidea blandingii*), loggerhead shrike (*Lanius ludovicianus*), and prairie fame flower (*Talinum rugospermum*)] (King 1996), can be protected under the same management strategy as the Karner blue butterfly.

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Appendix 1. Reclassification of forest land-cover categories from GIS data, Fort McCoy, Wisconsin

Forest cover types[a]	Military reclassification
Grass	Go
Rock/sand grass/bare	Go
Upland brush	Go
All low-density jack pine, oak, scrub oak, aspen	Go
All medium-density jack pine, oak, scrub oak, aspen	Slow-go
All high-density jack-pine, oak, scrub oak, aspen	No-go
Marsh/muskeg	No-go
Lowland grass/lowland brush/marsh muskeg	No-go
Lowland brush lowland/marsh	No-go
Swamp hardwoods	No-go
Stagnant tamarack	No-go
Minor lake	Off-limits
Hableman's lease	Off-limits
Hableman's marsh	Off-limits
Red pine plantations	Off-limits
North impact area	Off-limits
Urbanized development	Off-limits
Right-of-way	Off-limits
Rock/sand developed	Off-limits
Campground	Off-limits

[a]Aslesen unpublished data.

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