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OBSERVATIONS ON *LYCAEIDES* IN THE NORTHERN MIDWEST, USA (LEPIDOPTERA: LYCAENIDAE)

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ABSTRACT.– On transect butterfly surveys during 1990-99, we recorded northern blues (*Lycaeides idas nabokovi*) in forest openings in northeastern Wisconsin, Karner blues (*L. melissa samuelis*) in barrens in central and northwestern Wisconsin, and melissa blues (*L. m. melissa*) in prairies in western Minnesota and adjoining North and South Dakota. Each taxon was surveyed within that part of its range where only that taxon is known to occur. We compared identification features described in field guides to our photographs of multiple individuals of all three taxa. These features were subtle and overlapping among taxa in midwestern individuals. Accurate field identification is applicable to populations but not isolated individuals, and must be based on a number of individuals, in conjunction with range and habitat characteristics. All three taxa tolerated some habitat degradation, based on their nectar visits to exotic plants and the vegetative characteristics of occupied sites. But northern and Karner blues were localized in distribution, where they might reach relatively high densities (individuals observed per hour), while the melissa blue occurred in more vegetation types but generally lower densities. Density (i.e., detectability) of Karner and melissa blues (the two analyzable taxa) increased with rising temperature and during later hours in the survey day and decreased with increasing wind speed. Males of sexed individuals averaged 70% for Karner blue and 78% for melissa blue. Although Karner and melissa blues in this study occurred in similar latitudinal ranges, they did not show consistent seasonal correspondence in their flight period curves. The single observation date of northern blues, which had a relatively high density, fell between two low-density Karner blue dates (one in the spring generation, the other in the summer), and consisted of 83% males.

KEY WORDS: behavior, conservation, detectability, diel periodicity, endangered species, Ericaceae, *Everes*, exotic plants, Fabaceae, field identification, flight period, Great Lakes, hostplants, Karner blue, Leguminosae, *Lycaeides*, Melissa blue, Minnesota, Nearctic, nectar visits, North Dakota, oviposition, phenology, Polyommatinae, prairie, sex ratio, South Dakota, Wisconsin.

Lycaeides idas (L. 1761) (formerly confused with the strictly Palearctic *L. argyrognomon*) (Bersträsser 1779) (Higgins, 1985) and *Lycaeides melissa* (W. H. Edwards 1873) have very similar adults and widespread and overlapping ranges in North America, the former more boreal than the latter (Scott, 1986). One subspecies of *L. idas* and two subspecies of *L. melissa* occur in the midwestern United States (Lane and Weller, 1994).

The Great Lakes subspecies of the northern blue (*L. idas nabokovi* Masters 1972) has been recorded in the United States in northern Minnesota, northeastern Wisconsin, and the upper peninsula of Michigan (Huber, 1981; Opler, 1995; Bureau of Endangered Resources, 1999; Nielsen, 1999). Ovipositions in these states were reported on and near dwarf bilberry (*Vaccinium caespitosum* Michx., Ericaceae), with which females closely associate (Nielsen and Ferge, 1982; Nielsen 1999). Adults occur in a single midsummer generation in openings in mixed Canadian-zone forest (Opler and Krizek, 1984). This butterfly is legally listed as state-endangered in Wisconsin, state-threatened in Michigan, and "special concern" in Minnesota (Minnesota Department of Natural Resources, 1995b; Bureau of Endangered Resources, 1999; Nielsen, 1999).

The Karner blue (*L. melissa samuelis* Nabokov 1944) is federally listed as endangered in the United States, state-listed in most states of its range, and considered extirpated in Canada. This butterfly has two complete life cycles per year, feeds only on wild lupine (*Lupinus perennis* L., Fabaceae) as a larva throughout its range, overwinters as an egg, and has a rather narrow generally east-west historical range at the northern end of wild lupine's range, from eastern Minnesota through northwestern and central Wisconsin, across the Great Lakes states and southern Ontario to New England (Iftner *et al.*, 1992; Dirig, 1994; Lane and Weller, 1994; Layberry *et al.*, 1998).

The melissa blue [*L. m. melissa* (W. H. Edwards 1873)] is a widespread, multivoltine inhabitant of many open habitats such as meadows, prairies, scrub, and alfalfa fields, where its larvae feed on a variety of native and exotic herbaceous and shrubby legumes (Opler and Krizek, 1984; Scott 1986). In Iowa, on the southeastern edge of its range (Lane and Weller, 1994), this butterfly is relatively rare (Schlicht and Orwig, 1998) but in Minnesota, also at its easternmost extent (Lane and Weller, 1994), the melissa blue has no conservation status (Cutler *et al.*, 1988; Minnesota Department of Natural Resources, 1995b).

For this paper, we assembled data and photographs from our observations in midwestern states that would provide useful information for effective field identification and surveying of these three butterflies. We compared features described in field guides and reference works to our photographs of dorsal and ventral surfaces of both sexes representing multiple individuals of each. We also tabulated feeding visits and described the habitats we observed for each taxon. The relative densities and sex ratios we recorded for each taxon were compared by date, and influences of weather and daily timing on observed densities were tested for the two taxa observed in analyzable numbers (Karner and melissa blues). Such information should prove useful for designing and implementing survey procedures to study and monitor populations of these taxa.

METHODS

Study Sites and Surveys

During 1988-99, we conducted transect surveys of adult butterflies along similar routes on each visit to each site, as described in Swengel (1996, 1998) and Swengel and Swengel (1996, 1997). These surveys occurred in tallgrass prairie (Illinois, Iowa, Minnesota, Missouri, North Dakota, Wisconsin), mixed-grass prairie (South Dakota), and pine-oak barrens and openings (Wisconsin). The study sites were deliberately selected for their conservation interest; i.e., they were known or predicted to support habitat-specialized butterflies. Most prairies were preserves, while the barrens and openings had a diversity of ownerships and land uses, including preserves, government-owned forest reserves for timber harvest, military reservation, and rights-of-way for highways and

TABLE 1. Survey effort at sites ever recording each blue, and number of individuals recorded, during 1990-99. For melissa blue only, we did not attempt to sex all observed individuals. Time spans for surveys of spring and summer Karner blue broods overlap because this was determined individually for each year, and timing varied considerably among years.

	Northern blue	Karner blue/spring	Karner blue/summer	Melissa blue
N unit surveys	6	1084	801	738
Range of survey dates	24 June	13 Apr-26 Jun	22 Jun-6 Sep	18 Jun-20 Aug
Total survey time	2.6	288.6	212.5	213.2
Total survey kilometers	3.2	590.0	440.8	374.5
Total individuals	100	6986	10180	431
Males	83	4796	6460	250
Females	17	1854	3095	46
Unsexed	0	336	625	135 [1]

[1] Only 9 individuals we tried to sex were recorded as unsexed; we did not attempt to sex the remaining 126 unsexed individuals.

utility lines. All sites could not be visited each year, but most were visited more than once. Survey times and locations were selected especially to study habitat-specialist butterflies as classified in Swengel (1996, 1998), including Karner and northern blues but not melissa blue.

Walking at a slow pace (1.5-2 km/hr) on parallel routes 5-10m apart, the we counted all adult butterflies observed ahead and laterally, to the limit of species identification (possibly with binoculars after detection) and our ability to track individuals. Within a site, we designated a new unit (i.e., subsite) whenever the habitat along the route changed markedly by vegetation type, management, and/or vegetative quality (categorized as degraded, semi-degraded, or undegraded, depending on diversity and abundance of native and exotic flora). We based these vegetative classifications on Curtis (1959), Wendt (1984), The Nature Conservancy (1988, 1994), and Minnesota Department of Natural Resources (1995a), as well as brochures and unpublished information from the managing agencies. We tried to avoid double-counting an individual, either within or among units, during a survey. For each unit, we recorded temperature, time spent surveying, wind speed, percent cloud cover, and percent time the sun was shining. Surveys happened during a wide range of weather conditions and times of day. Occasionally surveys occurred in intermittent light drizzle (so long as butterfly activity was apparent), but not in continuous rain. Route distance was estimated based on site maps and land features, such as road junctions at borders of "sections" (square mile grids systematically placed by land surveyors). Data from each unit were separately kept. Butterfly nomenclature follows Ferris (1989).

The three study taxa can be readily sexed in the field based on dorsal wing patterns. Starting in 1990, we systematically recorded the sex (if possible) of all observed individuals of Karner and northern blues. When we recorded the sex of any melissa blues at a site, we did so systematically throughout the survey, but on other surveys we chose not to record the sex of melissa blues.

From this survey dataset, we identified sites where we had ever recorded any of these three taxa. We limited analysis to 1990-99, since few surveys and no sexing of observed individuals occurred before then. At no site did we record more than one species of these taxa. We observed the northern blue on 24 June 1998 in forest openings in northeastern Wisconsin (Forest/Langlade, Marinette, Oconto Counties). We did not visit these sites on any other date. We observed the Karner blue each year during 1990-99 in barrens in central and northwestern Wisconsin (Burnett, Clark, Eau Claire, Green Lake, Jackson, Juneau, Monroe, Portage, Waushara, Wood Counties). We recorded the melissa blue each year during 1990-97 in prairies in western Minnesota (Chippewa, Clay, Douglas, Lincoln, Lyon, Norman, Otter Tail, Pipestone, Pope, Swift, Wilkin Counties), southeastern North Dakota (Ransom, Richland Counties), and northeastern South Dakota (McPherson County). We did not visit these sites in 1998-99. Table 1 presents summary statistics on the surveys at these sites.

Analyses

We computed all statistics with ABstat 7.20 software (Parker, Colorado, USA). Observation rates (relative densities or abundances) were calculated for each taxon as individuals recorded per hour in each unit survey. It was necessary to standardize the data as observation rates because survey routes varied in length among units. Unit surveys were included in an analysis only if held on dates during the taxon's flight period (i.e., within the span of dates we observed adults of that taxon that year) at sites where we had ever recorded the taxon during these surveys. Analysis was performed at the scale of the unit rather than by site, because unit surveys within the same site varied, sometimes considerably, in vegetative characteristics and weather.

The Spearman rank correlation was used to test for significant patterns in relative density of the taxa observed in analyzable numbers (Karner and melissa blues) relative to geography (latitude, longitude), timing (beginning time of survey, crepuscularity, which was defined as the difference between 1200h CST and the time when the unit survey started), and weather (percent time sun was shining, percent cloud cover, temperature, and wind speed). The Mann-Whitney U test was used to test for differences in these factors between the unit surveys in the Karner and melissa blue analyses.

Sex ratio (percent of males of sexed individuals) and relative density (individuals/hour) of Karner and melissa blues were plotted by date. For sex ratio, we included a date only if >1 individual was sexed; for density, if >10 minutes of surveying, or any individuals, were recorded. In each graph (ratio or density), to maintain clarity while plotting each date for each taxon, values were grouped into categories. The percent of males was divided into three categories: >60% males, 40-60% males, and <40% males. Densities varied greatly between the two taxa, with a mean of 51.5 Karner blues per hour (range 0.2-713) on analyzed dates when any were recorded but 3.2 melissa blues per hour (range 0.2-8). As a result, the scale was calibrated somewhat differently for each taxon, so that comparable timings (e.g., peak and non-peak) in the flight period could be identified. Low density was defined as >0 and <10 for Karner blue but <1 for melissa blue; medium as ≥10 and <50 for Karner blue but ≥1 and <10 for melissa blue, and high as ≥50 for both (melissa blue had no values between 10 and 50). These definitions distributed the dates fairly evenly among categories, except that only one high-density date occurred for melissa blue. In that case, the high-density

Plate 1. Dorsal views of males of northern blue (top row) and Karner blue (middle row) in Wisconsin, and melissa blue (bottom row) in Montana (MT) and North Dakota (ND). Top row, left: Langlade Co., 24 Jun 1998; right: Marinette Co., 24 Jun 1998. Middle row, left: Jackson Co., 28 May 1991; middle: Jackson Co., 26 May 1992; right: Jackson Co., 4 Aug 1992. Bottom row, left: Burke Co. (ND), 23 Jun 1990; middle: Burke Co. (ND), 23 Jun 1990; right: Meagher Co. (MT), 10 Aug 1995.

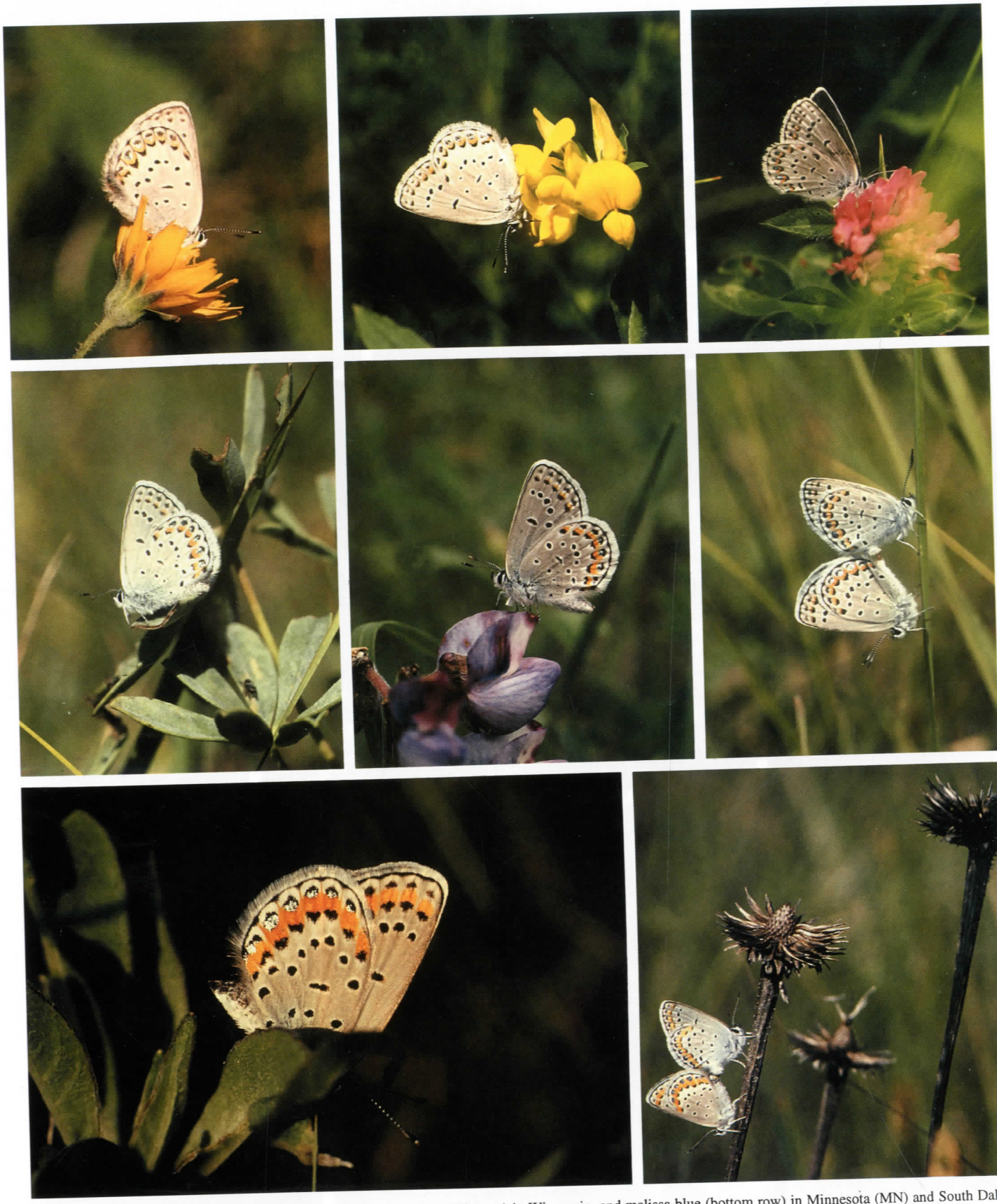


Plate 2. Ventral views of northern blue (top row) and Karner blue (middle row) in Wisconsin, and melissa blue (bottom row) in Minnesota (MN) and South Dakota (SD). Top row, left: Marinette Co., 24 Jun 1998; middle: Marinette Co., 24 Jun 1998; right: Langlade Co., 24 Jun 1998. Middle row, left: Jackson Co., 4 Aug 1992; middle: Jackson Co., 28 May 1991; right: Jackson Co., 5 Aug 1992. Bottom row, left: Cottonwood Co. (MN), 29 Jun 1989; right: McPherson Co., (SD), 24 Jun 1990.

value was a marked break in the distribution of density values for the taxon.

RESULTS

Field Identification

All individuals of each taxon analyzed in this study occurred within that portion of its range where only that taxon has been recorded (Bleser, 1994; Lane and Dana, 1994; Opler, 1995; Bureau of Endangered Resources, 1999). No northern blue site in this study had any noticeable wild lupine, which would have mostly finished blooming by that date, but would still developing pods and would not yet be senescing. We observed nearly all the Karner blues in lupine patches, with the few other individuals within 800 m of a lupine patch. All melissa blue observations in this study occurred well west of the recorded range of wild lupine in Minnesota (Dirig, 1994; Lane and Dana, 1994).

These three taxa are very similar in the blue dorsal surfaces of the males (Plate 1), in the iridescent blue spots distally bordering the orange spotting/banding on the ventral hindwing (Plate 2), and in the blue and black dorsal surfaces with some orange spotting/banding of the females (Plate 3). Characteristics of the ventral surfaces (both sexes) and dorsal females surfaces are suggested for field identification in the study region (Masters, 1972; Opler and Krizek, 1984; Scott, 1986; Opler, 1998; Glassberg, 1999). The black marginal line connecting thicker spots/triangles lines connecting thicker spots/triangles at the vein endings on the ventral hindwings is very thin or even discontinuous in northern blues, but continuous and wider in Karner and melissa blues (Plate 2). The ventral submarginal orange is paler and reduced in northern blues than Karner and melissa blues (Plate 2). The dark marginal line on the dorsal male forewing is thicker in the northern than Karner blue (Plate 1), but otherwise these two taxa are very similar. Further distinctions of the northern blue compared to melissa blue include the ventral orange generally broken into distinct spots (vs. the typically fused orange band in melissa blue) (Plate 2), and less orange, especially on the forewing, in the female dorsally (Plate 3). The melissa blue differs from the Karner blue by having the ventral submarginal orange fused into a spot-band (vs. separate spots in the Karner blue) (Plate 2), large orange and black ventral spots than the Karner blue's (which are in turn larger than the northern blue) (Plate 2), orange bands on both the dorsal forewings and hindwings of the female (vs. hindwing only in the Karner blue) (Plate 3), and the dark terminal border on the male dorsal forewing above is narrower (Plate 1).

In our observations, many of these characteristics were subtle and overlapping among the taxa. This was particularly so for the black ventral line — rarely appearing distinctly discontinuous in northern blues and only slightly thicker in Karner and melissa blues (Plate 2) — and even more so for males dorsally. The most distinctive feature was the amount of orange on the female dorsal surfaces. Female Karner blues in Wisconsin had orange crescents on the hindwing and usually some orange on the forewing (either as a few orange spots or a vague band or halo of orange) but not as much as on the hindwing (Plate 3, two middle rows). This contrasts with the typical lack of orange on the front wing of female Karner blues in its eastern range (e.g., New York) (D. Savignano, pers. comm.; Glassberg, 1999: Plate 24, fig. 8), but they occasionally do show some orange here (R. Dirig, pers. comm.). In the Midwest, the usual amount of orange on the dorsal female of the Karner blue was noticeably greater than for northern blue but less than melissa blue (Plate 3). Nonetheless, Karner blues (e.g., Plate 3, 2nd row) might have nearly as much orange on both fore- and hindwings as a melissa blue with unusually little orange (Plate 3, 1st row rightmost picture), or nearly as little orange (e.g., Plate 3, 3rd row, middle picture) as a northern blue (Plate 3, 1st row, left two pictures).

Food and Habitat

Instances of adult feeding by northern and Karner blues were tabulated both as all recorded observations and as first observed behavior (Table 2). The former included more types of feeding substrates, while the latter allowed a more meaningful calculation of the percentage of individuals engaged in feeding. The northern blues had a higher rate of feeding, but were only observed in hot weather, while the Karner blues were seen in a wider range of conditions including relatively inclement weather when individuals were primarily inactive. Both sexes of all three taxa included exotic flowers in their nectar visits, especially northern blue (although these observations come from only a few sites on a single date). Karner blues nectared relatively more often, and relatively more at exotic flowers, in summer than spring.

We recorded northern blues in mesic and sandy dry forest openings and roadsides that were semi-degraded (i.e., contained some exotic plants, which northern blues readily visited for nectar). Karner blue populations occurred in sandy dry sites that were degraded, semi-degraded, or undegraded and contained tiny to large lupine patches (0.02-120 ha). Occasional individuals were in adjoining wetter habitats and places lacking lupine. We observed melissa blues in the full range of prairie soil moisture types from wet to dry, primarily in areas drier than mesic but also in sites with only mesic and/or wetter prairie. These sites were primarily semi-degraded and undegraded, but the sites we surveyed in melissa blue range emphasized such vegetation. Individuals occurred in degraded vegetation in one of the three sites where we surveyed such vegetation. We have also informally observed melissa blues, sometimes in locally dense numbers, in alfalfa fields adjacent to study sites. Melissa blues occurred in the full range of prairie patch sizes surveyed (16-3480 ha).

Weather and Daily Timing

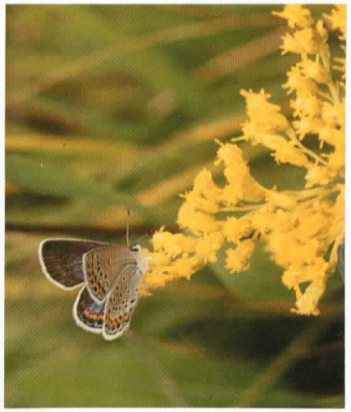
Relative density (individuals/hr, per unit survey) of the Karner blue increased significantly (and melissa blue non-significantly) with increasing temperature, both taxa increased significantly during later hours of the survey day, and melissa blue decreased significantly (and Karner blue non-significantly) with increasing wind speed (Table 3). Neither blue showed any influence from percent sunshine or crepuscularity. The only significant differences between the unit surveys in the Karner and melissa analyses were in wind speed and percentage of sunshine.

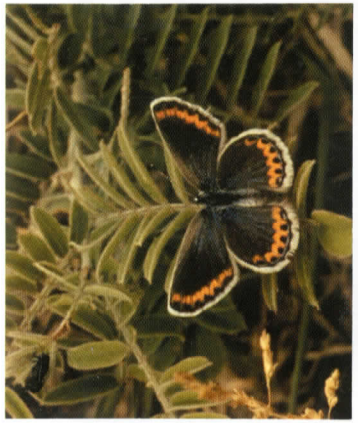
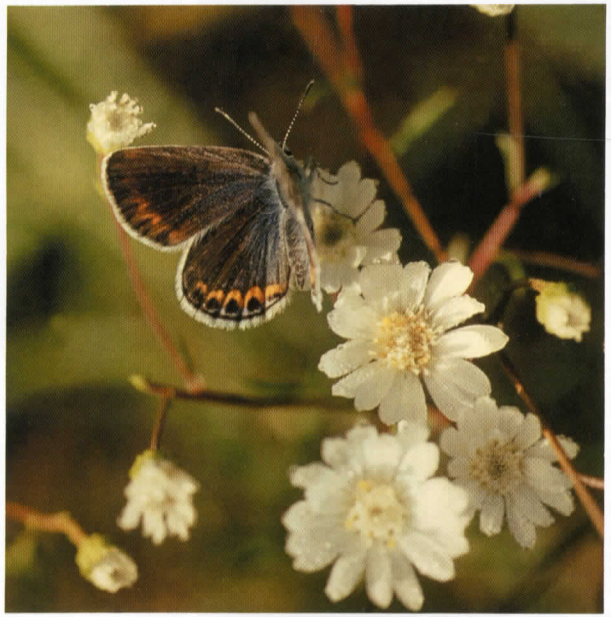
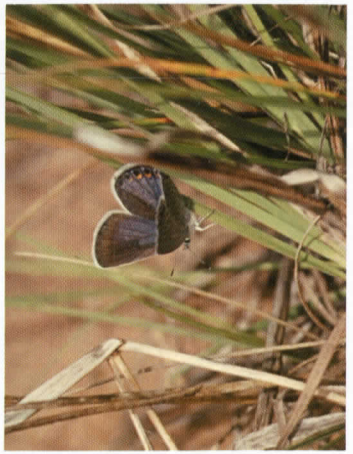
Abundance and Sex Ratio

In the graph of relative density of Karner and melissa blues by date (Fig. 1), we used somewhat different definitions for the density categories because the two blues varied greatly in range of observed densities. This facilitated comparison of relative positioning on the flight period curve. Based on data only from sites where each taxon was ever recorded during this study, the Karner blue often reached higher densities (i.e., had steeper flight curves) than melissa blue. Since relatively few observation dates occurred for the melissa blue, the length of this blue's flight period is not apparent (see Table 4) and it is possible we might have recorded higher melissa blue densities if we had surveyed at other times.

One melissa blue observation date (18 June 1990) fell early enough in the season to compare to the spring Karner blue generation (Fig. 1). This date, our only one with high-density melissa blues, occurred well after high-density Karner blue dates in spring 1991-92, 1994-95, and 1997-98. We had no high-density Karner blue dates in spring 1990, 1993, 1996, and 1999.







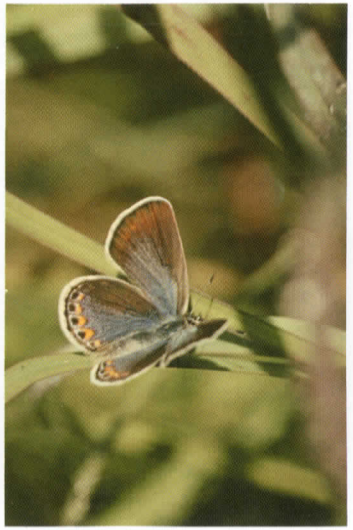
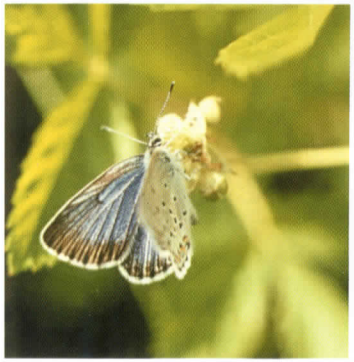




TABLE 2. Instances of feedings (probing with proboscis) recorded as the first observed behavior for northern and Karner blues. If visits were recorded to the feeding substrate as subsequent behavior(s), they are included in the total provided before the slash (/); this includes multiple visits by the same individual only if to a different feeding substrate (Karner blue only: 5 males in spring and 4 males and 3 females in summer). E = exotic (alien) plant species, based on Peterson and McKenny (1968).

	Northern blue		Karner blue/spring			Karner blue/summer		
	male	female	male	female	uns.	male	female	uns.
Mudpuddle	5	0	19/16	2	1	10	4	
Mudpuddle (urine)			1			6/5		
Probe								
Rubus sp., bramble berry						4	3	
canid/mammal feces			1	2		4	2	
human sweat			2			1		
shoelace						1		
sweaty camera strap						1		
Nectar								
E *Achillea millefolium*, yarrow			2			11	5/4	
Amorpha canescens, leadplant						10/7	2	2
Apocynum androsaemifolium, dogbane						3	1	1
Arabis lyrata, rock cress			64/44	11/10	1	14/11	6/5	
Asclepias ovalifolia, oval milkweed				2				
Asclepias syriaca, common milkweed							1	
Asclepias tuberosa, butterfly milkweed						91/89	34/32	15
Asclepias verticillata, whorled milkweed						2		
Aster sericeus, silky aster						1		
Aster laevis, smooth aster						3	6	
Aster ptarmicoides, upland white aster						34/29	17/15	1
Aster sp., aster (purple flower)						1		
Aster sp., aster (white flower)							2	
Aureolaria, false foxglove						1		
Baptisia leucophaea, creamy wild indigo			5					
Campanula rotundifolia, harebell							1	1
Ceanothus americanus, New Jersey tea						33/27	8/7	1
Ceanothus ovatus, red root			2	1				
E *Centaurea maculosa*, spotted knapweed						68/62	51/49	5
E *Chrysanthemum leucanthemum*, ox-eye daisy							1	
Comandra umbellata, star (bastard) toadflax			1	1				
Coreopsis sp., coreopsis						73/71	70/69	23
Erigeron sp., fleabane						29/24	7/5	1
Euphorbia corollata, flowering spurge			7/4			104/95	25/23	1
E *Euphorbia cyparissias*, cypress spurge			1					
Fragaria virgniana, strawberry			1					
Galium sp., bedstraw							1	
Gnaphalium obtusifolium, sweet everlasting						3	3/2	
Helianthemum canadense, frostweed			1/0					
Helianthus occidentalis, western sunflower						123/112	58/49	11/10
Helianthus strumosus, woodland sunflower						4/3	4	
Helianthus sp., sunflower						1		
E *Hieracium aurantiacum*, orange hawkweed	7/6	2	17/16	8/7	2	4	1/0	2
Hieracium sp., hawkweed			2					
Hieracium sp., hawkweed (yellow flower)	1		1/0	1		1	1	
Houstonia longifolia, longleaf bluets			11/10	5/4		3/2	5	
E *Hypericum perforatum*, common St. John's wort							1	
Krigia biflora, cynthia (false dandelion)	1	1	1				1/0	

Plate 3. Dorsal views of females of northern blue (top row, left two pictures) in Wisconsin, melissa blue (top row, right two pictures) in Minnesota (MN) and North Dakota (ND), and Karner blue (middle two rows) in Wisconsin. Eastern tailed-blue [*Everes comyntas* (Godart 1824)] (bottom row, left picture) with unusually large orange spotting; Karner blues concentrating at nectar sources (bottom row, right two pictures). Top row, left two, leftmost: Langlade Co., 24 Jun 1998; middle left: Langlade Co., 24 Jun 1998. Top row, right two, middle right: Clay Co. (MN), 22 Jun 1988; rightmost: Burke Co. (ND), 23 Jun 1990. Second row, left: Wood Co., 7 Jun 1991; middle: Jackson Co., 4 Aug 1992; right: Burnett Co., 29 Jul 1992. Third row, left: Jackson Co., 4 Aug 1992; middle: Burnett Co., 29 Jul 1992; right: Burnett Co., 29 Jul 1992. Bottom row, left: Jackson Co., 6 Sep 1994; middle: Wood Co., 5 Aug 1992; right: Jackson Co., 27 Jul 1994.

		Northern blue		Karner blue/spring			Karner blue/summer		
		male	female	male	female	uns.	male	female	uns.
	Lespedeza capitata round-headed bush clover						13/11	10	
	Liatris aspera, rough blazingstar						21/17	14/8	1
	Liatris cylindracea, dwarf blazingstar						4/3	4	1
	Linaria canadensis, blue toadflax				1				
E	*Linaria vulgaris*, butter and eggs								4
	Lithospermum, puccoon					1			
	Lobelia spicata, pale spike lobelia						5	1	2
E	*Lotus corniculatus*, birdfoot trefoil	1	1				1	4	
	Lupinus perennis, wild lupine			39/30	16/15	1	1/0	3	
	Lysimachia sp., loosestrife						1	1	
E	*Melilotus alba*, white sweet clover						16/14	8	1
E	*Melilotus officinalis*, yellow sweet clover						1	1	
	Monarda fistulosa, wild bergamot						11/10	11/9	2
	Monarda punctata, horsemint						10/9	16/14	2
	Oenothera sp., evening primrose						1		
	Oxalis stricta, yellow wood-sorrel			2					
	Pedicularis canadensis, wood betony			2					
	Polygala sp., milkwort						5/3	1	
	Polygonum sp., smartweed						2		1
	Potentilla simplex, common cinquefoil			164/139	29/23	6	1/0		
	Potentilla tridentata, wineleaf cinquefoil			9/5			4	4	1
	Potentilla sp., cinquefoil	7							
E	*Prunella vulgaris*, heal-all (self-heal)							1	
	Rosa sp., wild rose							1/0	
	Rubus sp., bramble	2	5/4	44/34	28/21	4	2/1		
	Rudbeckia hirta, black-eyed Susan						62/58	30/29	28
	Senecio aureus, golden ragwort (groundsel)			2	1				
	Sisyrinchium campestre, blue-eyed grass			1					
	Smilacina racemosa, Solomon's plume			1					
	Smilacina stellata, starry Solomon's plume			1/0		1			
	Solidago graminifolia, grassleaf goldenrod						10	5	
	Solidago nemoralis, gray goldenrod							1/0	
	Solidago speciosa, showy goldenrod						140/127	120/115	33
	Solidago sp., goldenrod (plume inflorescence) [1]						24/22	9/7	1
	Spiraea tomentosa, steeplebush							4	
	Spiraea alba, meadowsweet						1		1
	Stachys palustris, hedge nettle						1		
	Tephrosia virginiana, goat's rue						1		
E	*Trifolium arvense*, rabbitfoot clover						25/19	36/32	3
E	*Trifolium hybridum*, alsike clover			1			8	2	
E	*Trifolium pratense*, red clover	6	1				2	2	
E	*Trifolium repens*, white clover	6	1						
	Vaccinium sp., blueberry			1/0					
	Verbena hastata, blue vervain						1/0		
	Viola pedata, birdfoot violet			8/6			3		
Total		36/35	11/10	414/332	108/91	17	1021/924	610/560	145/144
Percent of total recorded individuals [2]		42	59	7	5	5	14	18	23

[1] includes *Solidago nemoralis* and others.

[2] For total recorded individuals, see Table 1.

TABLE 3. Mean and range of values for each weather and timing variable, and Spearman rank correlation coefficients of relative density (individuals/hr, per unit survey) with these factors, with * for P<0.05 and ** for P<0.01. N=1227 and 735 unit surveys, respectively, during the species' flight period (determined individually for each year) at sites where the species was ever recorded during these surveys. Times are in decimal format (e.g. 0630 hr CST = 6.5 hr; 15 min. before or after noon CST is 0.25 hr). Conditions that differed significantly (two-tailed P<0.05, Mann-Whitney U test) between Karner and melissa blue surveys were wind speed and percent sunshine (both P<0.0001).

	Karner blue				Melissa blue			
	mean	range	coefficient		mean	range	coefficient	
Percent sunshine	65.9	0-100	+0.043		59.2	0-100	-0.006	
Temperature (°C)	24.2	12.5-34.7	+0.185	**	24.1	14.2-32.2	+0.062	
Wind speed	9.0	0-37.8	-0.045		17.2	0-48.3	-0.114	**
Crepuscularity [1]	2.2	0.5.7	-0.017		2.3	0-5.7	-0.049	
Time of day (CST)	11.7	6.85-17.65	+0.206	**	11.8	6.73-17.69	+0.089	*

[1] number of hours from noon CST; a higher number is more crepuscular (i.e., nearer to sunrise/sunset)

TABLE 4. Cumulative flight period spans from decades of records for northern, Karner, and melissa blues, by state. Data for Michigan from Nielsen (1999); Minnesota from Nielsen and Ferge (1982); South Dakota from Marrone (1994); Wisconsin from Ebner (1970), Kuehn (1983), and Swengel and Swengel (1999); and all states but Michigan from The Lepidopterists' Society (1974-75, 1980-99).

State	Northern blue	Karner blue	Melissa blue
Iowa			4 Jun - 15 Oct
Michigan	3 June - 24 July	24 May - 26 Aug	
Minnesota	5 Jul - 28 Jul		30 May - 22 Aug
North Dakota			29 May - 22 Aug
South Dakota			16 May - 7 Oct
Wisconsin	23 June - 16 July	13 May - 6 Sep	

Survey dates for Karner and melissa blues were near each other in more years during summer (Fig. 1). Similar relative numbers (i.e., placement on the flight curve) occurred in mid-August 1992 and 1993, July-August 1994, and July 1997. However, low melissa blue densities immediately preceded high Karner blue densities in summer 1990-91, while medium melissa blue densities occurred in the period between the spring and summer Karner blue flight periods in July 1996.

On our single date for northern blues (24 June 1998), we recorded 38.5 individuals per hour, an intermediate- or high-density value for the other two blues. This date fell between two low-density Karner blue dates, one in the spring generation and the other in the summer (Fig. 1).

In cumulative flight spans based on decades of records in midwestern states of similar latitude (Table 4), Karner and melissa blues have similarly timed and broad spans, except that the latter has occurred much later in fall than the former. The northern blue likewise has similar timings in three Great Lakes states (Table 4). Based on northern blue numbers we recorded on 24 June 1998 (Table 1), its flight period most likely began some days earlier than the earliest published date for the species in the state. Its flight period likely extends earlier than available records in Minnesota as well, since oviposition was observed on the earliest reported date there.

The percentage values for males of sexed individuals (Fig. 2) averaged 70% (range 9-100%) for Karner blue and 78% (38-100%) for melissa blue; on 24 June 1998, 83% of northern blues were male (Table 1). On high-density dates (Fig. 1), the Karner blue averaged 70% males (range 38-92%) and melissa blue had 91% males (one date). For the Karner blue, protandry (male bias) was evident at the start of the spring and summer generations, which were distinct in timing. This could not be checked for melissa blue because of the paucity of observation dates per year. However, melissa blue observations were male biased in early July, as with the Karner blue at similar timing. In August, melissa blues were more male biased than Karner blues, although some late-season dates for Karner blue were also male biased. The melissa blue had only one date (19 August 1992) of female bias, or 7% of the 14 dates when we observed the taxon, compared to the Karner blue's 20 dates of female bias (18%) out of 109 dates we observed that taxon.

DISCUSSION

Field Identification

As a result of the subtlety and overlap in these blues' field identification characteristics, they were most useful when applied to a number of individuals at a locality, in conjunction with range and habitat characteristics. The recorded ranges of these three taxa are mutually exclusive in the midwestern United States (Opler, 1995; Glassberg, 1999; Nielsen, 1999), except that northern and Karner blues have both been recorded in one county (Menominee) in northeastern Wisconsin (Opler, 1995). Despite the similarity of their habitat type (pine-oak barrens and openings), these two taxa have never been found in the same locality in the Midwest (Opler, 1998). Thus, populations appear identifiable based on range, habitat (flora), and typical phenotypes based on multiple individuals. Authoritative identification of a single individual — especially one deviating from the typical phenotype or lacking data on locality, habitat, and plant association — would have to rely on dissection (Opler, 1998).

Factors Related to Detection

All three taxa tolerated some habitat degradation, based on their choices for nectar visits and the vegetative characteristics of occupied sites. Nonetheless, northern and Karner blues were localized in distribution, where they sometimes reached relatively high densities, while the melissa blue occurred in more vegetation types but generally lower densities. This was the pattern in our study sites, which represented the range of habitats occupied by northern and Karner blues much better than for melissa blue.

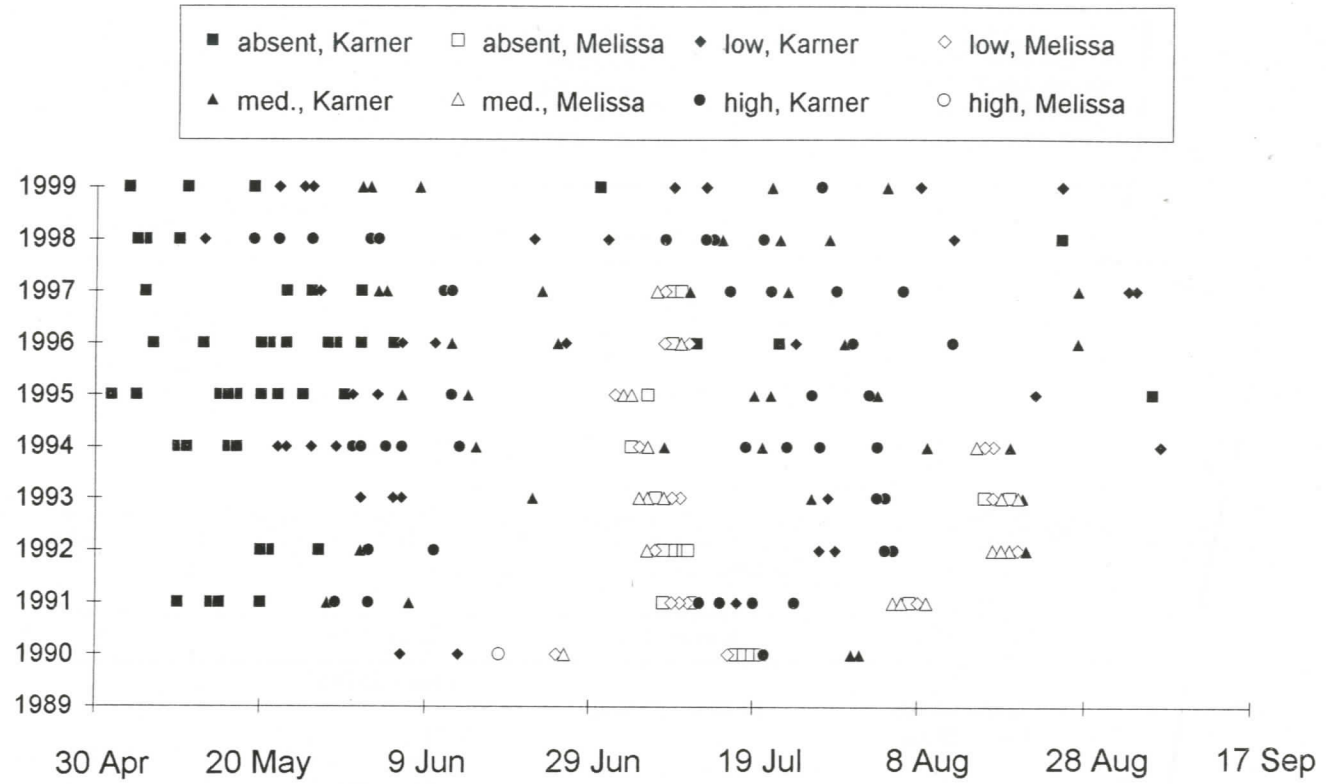


Fig. 1. Relative densities (absent, low, medium, and high) of Karner and melissa blues by date, if >10 minutes of survey effort or any individuals seen that day. Since the range of relative densities varied greatly between these two taxa, the categories were scaled somewhat differently between taxa (see Methods), so that comparable timings in the flight period might be identified.

Relative density (i.e., detectability) of both Karner and melissa blues increased, to varying degrees, with increasing temperature and later hours during the survey day, but decreased with increasing wind speed. They showed no correlation to percentage of sunshine and crepuscularity (Table 3). Survey conditions were similar for both taxa except it was somewhat sunnier for Karner blues and windier for melissa blues. Thus, these two closely related taxa showed similar responses to weather and daily timing.

In this study, Karner and melissa blues occurred in similar latitudinal ranges and shared fairly similar first observation dates of the season (Table 4). However, these blues did not show consistent seasonal correspondence in sex ratio and relative position (shape of the curve) during the seasonal development of their flight periods. Both taxa are considered bivoltine in the Midwest (Royer, 1988; Marrone, 1994; Glassberg, 1999). But the flight span is quite long (Table 4), particularly for melissa blue, which suggests the possibility of another partial or full generation per year (note, in Fig. 2, that we never surveyed in the melissa blue's spring adult flight). The overall male bias of sexed individuals for the three taxa in this study (Table 1, Fig. 2) is consistent with observations of other polyommatine species (e.g., Pollard and Yates, 1993:114-115; Vojnits and Ács, 1995). The melissa blue's lack of pronounced peaks in density and relatively little change in the male-biased sex ratio suggest that its generations might overlap more than the Karner blue's, although our survey dates for melissa blue were too few to be conclusive.

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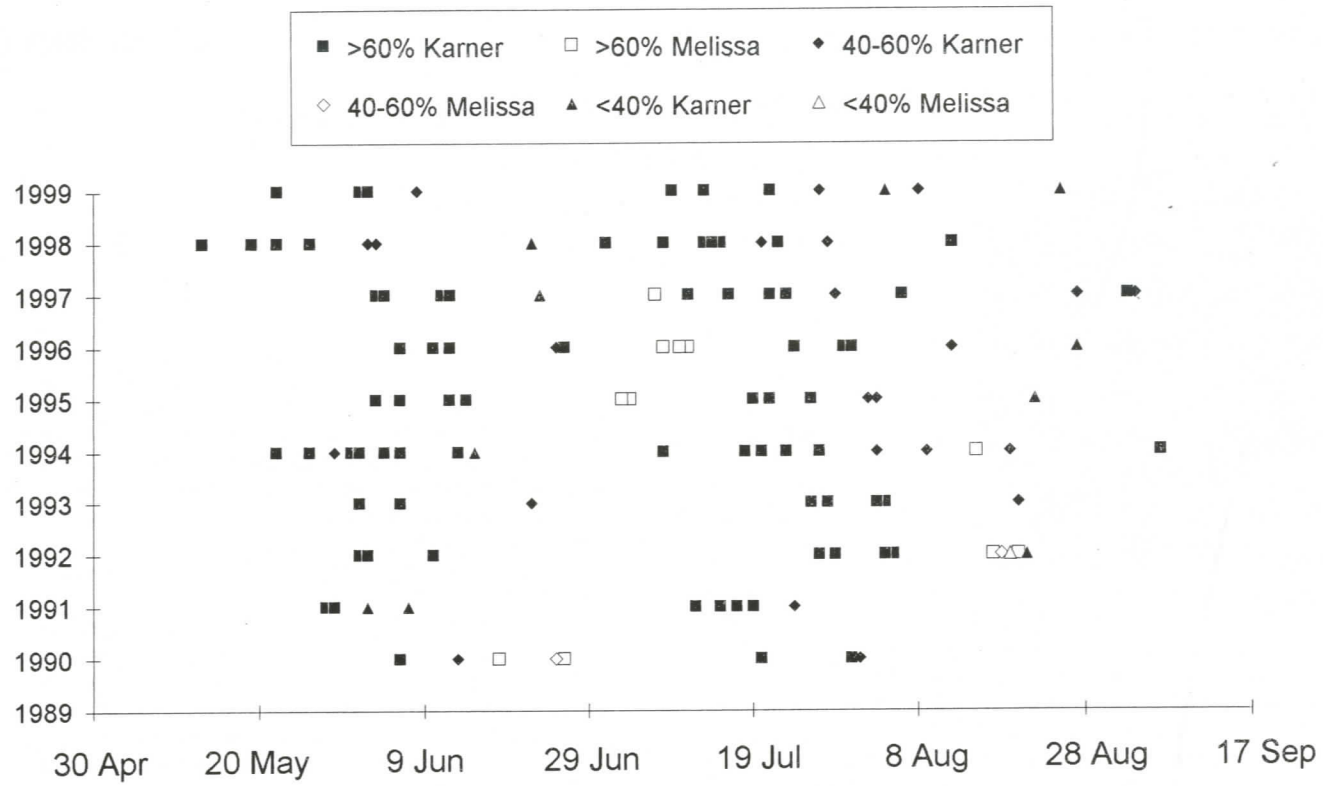

Fig. 2. Sex ratio (percent males of sexed individuals) of Karner and melissa blues by date, if >1 individual sexed that day.

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