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MIGRATORY ACTIVITY IN VANESSA CARDUI (NYMPHALIDAE) DURING 1992 IN WESTERN NORTH AMERICA, WITH SPECIAL REFERENCE TO EASTERN CALIFORNIA

Additional key words: migration, population dynamics, weather, Owens Valley.

Migrations of Vanessa cardui (L.) were unusually large in southwestern North America during 1991–1992, the largest since 1968 and 1973, providing a rare opportunity to study the complex mass behavior and population dynamics of this species (cf. Woodbury et al. 1942, Abbott 1951). Here we summarize 1992 records for the region and present observations made by one of us (DG) in Inyo County, California. The methods follow those outlined in Giuliani and Shields (1995). Migration rates here (no./5min/15m) are arbitrarily classified as light (1–29), small-scale (30–49), medium-scale (50–99) and large scale (>99). Vanessa cardui, like the monarch (Danaus plexippus L.), has a southward return migration during the summer and fall (Emmel & Wobus 1966, Shapiro 1980, Myers 1985, Nelson 1985, Giuliani & Shields 1995).

Small numbers of migrating V. cardui were reported during February and March 1992 in California, including: NW at Hemet (29 February, 12–22 March), NNW in San Diego County (9–10 March), NW–WNW near Bakersfield (111 March), NNE–WNW in Inyo County (15–17 March), and WSW in Ventura County (19 March) (pers. obs.; J. F. Emmel, in litt.; McKown 1993). A light migration was seen between Barstow and Yucca Valley on 26 March (McKown 1993). Many northward migrators were seen near San Diego (27–30 March) (R. Larson, pers. comm.), and there were several newspaper accounts of V. cardui plastering windshields during late March in the southern San Joaquin Valley.

One of us (DG) toured SE California and extreme W Arizona during 19–28 March to monitor V. *cardui* activities. Sightings increased southward from only a few non-migrators at NW San Bernardino County to a large-scale migration at Mecca, Riverside County; light to small-scale flights occurred in Imperial County and SW Arizona. Directions observed varied from NNE to W with most flights headed NNW–NW.

On 28 March, R. E. Wells (in litt.) observed V. cardui in Baja California from Catavina to 5 km N Los Angeles Bay cutoff, where thousands of larvae were feeding on Malva L. (Malvaceae) with pupae utilizing the spines of young cardon cacti. Migration flights to the NNW were noted from Los Angeles Bay cutoff to 40 km SE Guerrero Negro. At San Lucas Cove during 28 March-6 April, adults flew NW–NNW, including 11 km offshore. On 9 April a large NNW–NW migration (3–30/km and over 300/min counted while driving) was seen in the vicinity of Guerrero Negro to ca. 65 km SE of there. Near Rosarito, up to 93/km were counted and numbers increased near Punta Prieta on 9 April to an estimated 620+ km, with larvae evident on the highway.

Vanessa cardui significantly expanded its range northward during April. In Little Chino Valley (Yavapai County, Arizona), fresh adults migrated NW on 6-7 April in uniformly large numbers over at least a 16 km front; the main flight period lasted for 5 h each day (L. Muehlbach, in litt.). Migrations near Phoenix were completed by 10 April, with heavy NE movement in NE Arizona and NW New Mexico during 15–20 April even under cold, cloudy and snowy conditions; large sedentary populations were present during late April and early May in the North Rim, the Flagstaff area, and in the White Mountains (K. Roever, in litt.). A large flight passed through Denver, Colorado in an ENE-NE direction during 26 April-5 May (Scott 1992). Large numbers flew in the Los Angeles area in early April (M. & S. Foster, in litt.) and on 13 April in the western Mojave Desert (R. Larson, pers. comm.). There were nearly daily migrations in Inyo County throughout April, some large-scale in size, and migrations first appeared in Mariposa County after 5 April. Many migrating V. cardui were present by mid April in the Davis-Sacramento-Reno area, as well as in Salem, Oregon (R. Wescott, in lift.). On 27 April, large numbers flew SW in Owyhee County, Idaho (McKown 1992), and many faded migrators reached extreme SW British Columbia on 25-28 April (C. Guppy and R.P. Nelson, in litt.). From May to August, V. cardui became widespread in the United States and southern Canada (cf. Mc-Kown 1993, Swengel & Opler 1993).

Inyo County observations. The first *V. cardui* appeared 3–17 March at Big Pine and displayed no apparent migratory behavior, as 3–6/day nectared on the blossoms of apricot trees. Light to large-scale migrations were seen 4–25 April at various Inyo County locations, with no migrations during 26–30 April. Beginning in May, flights became more complex as NW migrators intermingled with locally emerging adults that also flew northward. Occasional migrators appeared 1–3 May as local emergence began, soon producing densities comparable to those of April. Light to large-scale migrations were observed 4–17 May, with a lull on the 13th. Few were seen during 18–21 May, but numbers increased in the following week (including two large-scale flights). Subsequently, few migrated on the Owens Valley floor, though light migrations continued at higher elevations in Inyo County until early October.

Table 1 summarizes the numbers and directions taken by migration flights through Owens Valley during the spring of 1992. These flights reached maximum densities in mid-April and largely represent an influx from the SE, from the direction of the Sonoran Desert region of SE California, S Arizona and NW Mexico. Table 2 summarizes the large densities achieved by some of the migratory flights in the Inyo County region during April and May 1992.

The final large-scale migration of *V. cardui* in Inyo County occurred on 25 May at 1980–2315 m in the Inyo Mountains, with up to 152/5 min/15 m flying N–NE in the late morning. Migration rates were low below 2990 m 26–31 May, with almost no migrators at Big Pine after 1 June. Occasional migrators were observed at higher elevations through June, with small numbers also on flowers.

Fig. 1 shows the shift in migratory flight directions during the summer. Southward migration began in early July, overlapping with residual NW movement, and continued into October. These southward flights consisted of small numbers (<1/5 min/15 m) primarily at

Date	Maximum #/5 min/15 m	Primary Geographic Directions	
March 17	1	NW–WNW	
April 1	2	NNW-NW	
April 3	2	NW-WNW	
April 4	9	N–W	
April 5	59	variable (E–N–SW)	
April 7	30	NW-SW	
April 8	62	N-NW	
April 10	228	NW-W	
April 14	19	NNE-NW	
April 15	81	NNW-WNW	
April 16	265	WNW-WSW	
April 21	179	NW	
April 22	83	NW-WNW	
April 23	50	NNW-WNW	

TABLE 1. Spring migrations of *Vanessa cardui* through Owens Valley, Inyo County, California in 1992.

high elevations (less than 20% of the observations were below 3000 m). Only one migration of 1992 showed a clearcut change of direction with time of day. On 5 April at Big Pine, 0800–1200 h, under clear skies and no wind, a medium-scale migration initially heading NW altered its direction counter-clockwise at a steady rate of 27°/h until heading SW as the sun moved clockwise across the sky.

In Saline Valley at 480 m on 16 and 26 November, occasional individuals were seen in flight and on *Baccharis* flowers. No adults were seen in Saline Valley on 23–27 December under mostly sunny conditions with no wind (in some years a few have been seen there throughout the winter). Elsewhere, a few nectaring adults were observed 20–21 September in the Providence and Dead Mountains, San Bernardino County, and several adults were seen on *Lantana* flowers at Hemet in November (J. F. Emmel, in litt.). On a trip to Baja California Norte in late November-early December, R. E. Wells (in litt.) observed only one adult at Miller's Landing.

Date	Locality	Elev (m)	Time (h)	#/5 min/15 m	Primary Directions
April 10	Lone Pine	1130	0830 - 0845	206-228	NW–W
April 16	8 km E Big Pine	1435	0920 - 0955	124 - 265	WNW-WSW
April 16	Deep Springs Valley	1615	1300	128	SW-SE
April 17	Gilbert Summit	1890	1245	135	SE (some NW)
April 17	Gilbert Summit	1980	1400 - 1425	116 - 139	WNW
					(some SSE)
April 20	N end Eureka Valley	1260	0645 - 0700	266 - 351	NW
April 20	E of Big Pine	1830	1500	845	NW-WNW
April 21	White Mountains	2805	0815	104 - 105	NNE-NNW
April 21	White Mountains	2650	0845	427	N-NW
April 21	Big Pine	1220	1145	179	NW
May 6	Crater Mountain	1830	0900 - 1100	>295	Ν
May 10	Bridgeport, Mono Co	1970	0800	100	WNW-WSW
May 12	White Mountains	2195	0745 - 0803	100 - 329	ENE-NNE
May 17	N end Death Valley	1495	0830 - 0840	130 - 131	SE-ENE
May 24	Inyo Mountains	2315	0945 - 1125	122 - 281	NNE-NW
May 25	Inyo Mountains	2135	1115	152	NE-N

TABLE 2. Inyo County, California large-scale migrations of Vanessa cardui, 1992.



FIG. 1. Stacked bar chart showing change in flight direction from north to south of *Vanessa cardui* migrations above 2745 m in Inyo County, California. Black = May 12 to June 10, 1992; white = July 3–19, 1992. All directions are geographic: east = 0, north = 90, west = 180, south = 270. Vertical axis shows number of individuals observed within each 10-degree interval.

Mariposa County observations. *V. cardui* were first seen in Mariposa County migrating NNW–NW, on 6–8 April near Mariposa, with a medium-scale migration flying NW on 9 April (1530–1645 h). On 19 April, NW migrating reached rates of 35–65/5 min/ 15 m at 1035–1205 h, decreasing to occasional migrators on 20 April. A few dozen nectared at blossoms of *Brodiaea* Sm. (Amaryllidaceae) as well as yard *Buddleja* L. (Buddlejaceae) and apples. At Mariposa migration ceased whenever cloud cover appeared.

At 1100 m at Jerseydale, V. cardui migrations did not appear until 21 April when a large-scale migration of worn individuals flew NNW at about 1400–1500 h. On 3–4 May occasional migrators occurred, along with resident V. cardui, that oviposited on lupines, Rumex L. (Polygonaceae), and other annuals. On 4 May at 1430 h, a small-scale migration of mostly fresh individuals flew NNE–NNW; flight was mainly to the NNE at 1530–1615 h with numbers decreasing by 1645 h, and ceasing at 1743 h (occasional individuals flew in the opposite direction at 1726 and 1734 h). On 5 May at Jerseydale, migration began at 0755 h in partly cloudy weather, with very few migrating at 0900–1000 h under overcast skies, with many nectaring on Chamaebatia foliolosa Benth. (Rosaceae). Only a few adults were seen after late May: on 9 June, 4 July, 25 July, and 11–13 October. On 11 June 10–15% of the meadow thistles (Cirsium) had larval web-nests with dried frass of all sizes, but only four medium to large larvae were located (two alive, two dead). No larvae were found on lupines or other plants despite the earlier large migration numbers.

At Jerseydale, six migrators were captured on 5 May and were placed at one location in the grass at the end of the day. These remained torpid overnight and began activity on 6 May between 0640–0800 h by first rapidly vibrating their closed wings for about 2–5 minutes; four of the six then flew in a complete circle before heading off erratically in a flight direction before usually landing again, while two others took off immediately without a circle flight. The weather was overcast with dilute sunshine and calm conditions. Possibly the circling flight was performed for initial sun-orientation during overcast weather. In late April 1941 at 0650 h, six migrators that spent the night on a lawn flew up, circled around, and flew off to the NW (Abbott 1950:166).

Migration times. No migrators were seen before sunrise. In Imperial County, as the sun was rising on 24 March at 0600 h, *V. cardui* adults were easily disturbed from the ground, with the first migrators observed at 0623 h; they appeared to first warm up on the ground at dawn, then went to flowers, then migrated. On 20 April in Inyo County, a single migrator was observed at 0555 h and another at 0600 h; at 0645 h a large-scale NW migration abruptly appeared. Atop a 2315 m ridge in the Inyo Mountains on 24 May, counts were made of a large migration from 0500 to 1800 h. The first migrators were seen at 0545 h and the last at 1735 h. The rate during successive 2-hour times from 0700 h was 14, 75, 235, 52, 10; an estimated 517,000/km passed through the area on that day.

Cessation of daily migrations was determined in only a few instances. On 5 April a medium-scale migration at Big Pine continued until about 1705 h. On 9 April in the Owens Valley, occasional V. cardui were still migrating well after sunlight (until 1845 h) had left the tops of the surrounding mountains; four more were observed close together in flight against the moonlit clouds after 1900 h (D. Constans, pers. comm.). A medium-scale migration on 16 April ceased flying between 1725–1735 h. On 9 and 19 April at Mariposa, migration ceased at 1727–1730 h. On 9 May at Reno, Nevada, occasional migrators were last seen about 1800 h.

Wind effects. On 22 April near Bishop a migration flew mainly NW during calm conditions, many 3–6 m high and a few up to 30 m high. Later, when strong gusty winds from the N were present, they all flew within 0.6 m of the ground, rising higher whenever the winds abated. Other reports have noted *V. cardui* migrations flying low to the ground against stiff or near gale-force winds (cf. Woodbury et al. 1942:172, Giuliani 1977).

At 0900–1100 h on 6 May at an 1830 m summit south of Big Pine a large-scale migration flew N off the top under a light S wind. Most were initially 1 m above the ground but continued flying horizontally or slightly upward as they poured over the summit, instead of descending down slope. Similar behavior in migrating *V. cardui* over hill and mountain summits has been reported elsewhere (cf. Wright 1906:37, Shields 1967: 112). On 23 May, atop a 2315 m ridge SE of Big Pine during a medium-scale migration with winds from the ESE–SSE, adults flew mainly NNE–NW up slope and continued upwards at the angle of the slope after passing the crest.

When flying in a strong crosswind, individuals are often oriented to as much as 45° away from the observed direction of motion (toward wind direction).

High fliers. Although most migrations stayed within 5 m of the ground, some high altitude flight was observed. On 23 March at Coachella, Riverside County, at 1200 h, a small-scale migration proceeding NW–WNW flew 1.2 m to over 30 m high during warm, cloudy, breezy conditions. High-fliers proceeded in the same directions as those lower down. Flight numbers fluctuated dramatically, probably caused by the cooler cloud shadows encountered along their route. On 5 May near Big Pine, 0900–1100 h, under heavily clouded conditions, a light migration went N–NW; on four different occasions, individuals flying at under 2 m high climbed at a constant 20–40° angle until out of sight, while occasional migrators were seen fluttering or drifting at 15 m to over 30 m high.

On 16–17 April at the SE base of a steep 700 m high ridge east of Big Pine, a large NW migration occurred under both heavy cloud cover and mostly blue sky conditions, extending up to at least 300 m above the ground. Numbers observed by binocular reached as much as 600/min: many appeared to be drifting, hardly fluttering their wings, as though allowing themselves to be carried NW by the wind. Some of these drifters were spinning slowly (like drifting leaves) with no attempt to maintain a constant orientation. On the summit of this ridge, migrators came over the top no more than 15 m high. A similar case was noted on 24 May atop a 2315 m ridge SE of Big Pine when drifters were seen to over 100 m high at 1715 h under a cloud shadow; they did not move their wings and often were rotated about so that they faced many different directions (including opposite to the direction of movement). High flying in *V. cardui* appears to differ from that observed in mir grating *D. plexippus* (see Gibo 1986, Gibo & Pallett 1979) i.e., directed ascending flight vs. gliding in circles in rising air currents, although both exhibit some passive drift-gliding in tail winds aloft.

Interactions. Occasional interactions by individual *V. cardui* on the ground toward migrators were observed. Seen most frequently in late afternoon or dusk and occasionally in the early morning, individuals would rise from the ground to follow or interact with a migrator and then return to the same spot. On 25 March in San Bernardino County, walking at dusk caused adults to rise from the ground, including an occasional pair that flew up close together and then settled back down to the ground together.

Pairs were often present in a migration, usually as one individual flying directly behind another. Seen from March through May, primarily during late afternoon or morning hours, they constituted as much as 10% of the total numbers in flight (over 50% on one occasion). The sex(es) of such pairs could not be determined, however.

Courtship. Several courtships involving V. cardui were seen late in the day during

mid-April in Inyo County, though no actual matings were observed. On 11 April at 1615 h in strong winds, a pair descended to the ground and the male approached the female; the female avoided the male's approaches, crawled into the base of a shrub, and the male perched on a twig 1.5 cm above her. On 17 April, after 1600 h, one pair landed in a shrub and each time the male approached, the female fluttered a few cm away. After the fourth try the male flew out and landed on the ground 1 m away. The female then immediately came out from inside the shrub and flew, sweeping low over the male, and the male rose and followed. Brown & Alcock (1990) reported four V. cardui pairs courting at 1605–1650 h on a central Arizona hilltop; two mating pairs of V. cardui are recorded for 1800 h (Shields 1967, Brown & Alcock 1990); and two matings of the closely related V. kershawi (McCoy) occurred at 1730 h in Australia (Alcock & Gwynne 1988).

Puddling. On 27 April, mostly very worn adults were fairly numerous on moist soil beside a creek. On 17 May in the Inyo Mountains during a large migration that progressed NNE, many were imbibing at muddy soils created by an irrigation ditch (D. Howell, pers. comm.). Similarly, during a heavy migration in late May 1941 near Price, Utah, large numbers congregated around roadside puddles (Knowlton 1954). Puddling behavior is known to replenish sodium and water loss in male butterflies (Adler & Pearson 1982).

Nectaring. V. cardui utilized many native desert flowers as nectar sources. In approximate descending order of preference among the most readily used species were: Prunus andersonii Gray (Rosaceae), Dalea fremontii Torr. (Fabaceae), Salix L. (Salicaceae), Amsinckia tessellata Gray (Boraginaceae), Encelia virginensis A. Nels. (Asteraceae), Tetradymia DC. (Asteraceae), and Stanleya elata Jones (Brassicaceae). In the Owens Valley on 13 April an estimated 6000 adults were observed nectaring on a patch of *P. andersonii* 6 m in radius, and at Keeler on 10 April many thousands from a migration nectared on the numerous introduced Tamarix L. (Tamaricaceae) trees that were in full bloom.

Oviposition, dwarf adults and hostplants. The large migrations of early April produced many eggs throughout Inyo County, primarily on the abundant *Amsinckia*. During 15–17 April, *Amsinckia* plants were found with up to 21 eggs per leaf along with small numbers of first instar larvae. By 19–21 April, many sites had more young larvae than ova. Small to dwarfed adult *V. cardui* were common in May 1992, likely the result of their annual foodplants, such as *Amsinckia* and *Cryptantha*, drying out earlier than usual (i.e., in contrast, migrating adults in Inyo County during April and after May were mostly normal and large sized). At most sites in the Owens Valley, *Amsinckia* germinated during December 1991 and had already advanced to the blooming stage by the time migrators arrived and oviposited in early April. By late April, the plants had mostly dried out and larvae were in instars 1–3 (few larvae or pupae could be found by 7 May). Millions of larvae likely perished there during late April due to the desiccation of the *Amsinckia* fields.

On 18 April in the Chemehuevi Mountains, San Bernardino County, V. cardui larvae were abundant on *Plantago insularis* Eastw. (Plantaginaceae) with others on *Amsinckia* and *Cryptantha*, with fresh to worn adults common that were about 50% dwarfed (J. F. Emmel, in litt.). On 3–4 May, Emmel noted many nectaring adults near Amboy and in the Providence Mountains, San Bernardino County (also about 50% dwarfed). On 4 May at Jerseydale, Mariposa County, the junior author observed many small to dwarfed adults in a small-scale migration heading NNE in the late afternoon, most appearing fresh. Many adults of medium-small to dwarf size occurred in Inyo County from about 6–30 May. Dwarfs were common in Iron and Washington Counties, Utah, on 22–23 May, with a statewide dwarf population present in Colorado in late May (McKown 1993).

V. cardui larvae were found in 1992 on the following hostplants that are additions to those reported for 1991 (Giuliani & Shields 1995): Boraginaceae: Cryptantha angustifolia (Torr.) Greene, C. circumscissa (H. & A.) Jtn., C. gracilis Osterh.; Fabaceae: Lupinus concinnus var. orcuttii (Wats) C.P. Sm., L. flavoculatus Heller, L. inyoensis Heller, L. magnificus Jones, L. pusillus var. intermontanus (Heller) C.P. Sm. A number of new hostplants were also recorded for the northern Central Valley of California in 1992 (Witham 1991).

Crawling larvae. On 24 April at 670 m at the NW edge of Panamint Valley, V. cardui larvae were abundant in an area where Amsinckia and Cryptantha plants were heavily eaten and desiccating. Many were crawling in straight lines on the ground in the morning, in roughly the same densities regardless of substrate and topography. Crawl speed averaged 1–2 m/min at densities up to 10/min over a 1 m line; two larvae crawled, respectively, 11 and 18 m in 10 min and neither deviated more than 5° from a straight line. Though all possible crawl directions could be found, about 80% were going ENE–NNE and 20% WSW–SW with only a few in other directions. Larval measurements indicated that 2nd–5th instars were involved in crawling (see Hammad & Raafat 1972) while many 4th and 5th instars remained on plants. While crawling, larvae often paused at plants they encountered, investigated the leaves, and fed for varying lengths of time if it was a hostplant. If it was not a host, they continued crawling in their fixed directions. By 1000 h, with rising ground temperatures, crawlers developed a strong tendency to leave their linear paths and head toward large objects (such as the observer), and most larvae soon ascended into *Cryptantha* and *Amsinckia* plants. However, many 3rd or 4th instars at this time were feeding on the leaves of *Mentzelia*, a plant they do not normally eat.

Predators and parasites. In mid-April along the highway between Big Pine and Bishop, Inyo County, crows picked up dead and injured *V. cardui* adults that had been hit by cars (one had several in its beak). On 5 May at Big Pine, three english sparrows were pulling larvae off *Amsinckia* plants and eating them. On 24 April, black harvester ants were seen carrying off small, living larvae. On 5 May near Big Pine, over a dozen of a large unidentified wasp were searching *Amsinckia* plants and attacking any larvae they found. On 16 May at Owens Lake, a yellow-green crab spider, on a flower matching its color, had captured an adult (D. Constans, in litt.). On 2 July at 2745 m in the White Mountains, 11 small pupal cases of a wasp were found near where small larvae had been, in hidden and webbed locations between overlapping leaves of *Cirsium drummondii* T. & G. (Compositae).

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DANCING WITH FIRE: ECOSYSTEM DYNAMICS, MANAGEMENT, AND THE KARNER BLUE (LYCAEIDES MELISSA SAMUELIS NABOKOV) (LYCAENIDAE)

Additional key words: conservation, endangered species, metapopulation dynamics, sand and oak barrens, savanna, prescribed burning.

The recent listing of the Karner Blue Butterfly (*Lycaeides melissa samuelis* Nabokov) as an endangered species (Clough 1992) has increased interest in managing and restoring populations of this charismatic invertebrate. The Karner Blue and other lepidopteran species are rapidly becoming symbols for restoring and conserving the barrens/savanna ecosystems that occur on well drained sand deposits in the Great Lakes Region and New England. The dynamic processes that produced unique botanical communities also produced a highly specialized community of invertebrates are often closely linked to a few key ecological resources, such as specific soil types, edaphic conditions and/or individual host-plant species or genera (Panzer et al. 1995).

The importance of oak barrens/savanna habitats to invertebrates is well illustrated by the Lepidoptera. In Ohio, the only midwestern state with a completed state-wide survey of all Lepidoptera species, the Oak Openings, Ohio's only oak barrens/savanna community, supports the largest assemblage of imperiled butterflies and moths in the state. For example, five species of imperiled butterflies and 17 species of owlet moths (Noctuidae) occur in the Oak Openings, representing approximately 4% and 3% respectively, of the resident species in Ohio (Shuey et al 1987a, 1987b, Metzler & Lucas 1990, Iftner et al. 1992, Rings et al. 1992). The maintenance of this ecosystem is vital for the preservation of lepidopteran