

THE BIOLOGY AND DISTRIBUTION OF
HEMILEUCA ELECTRA (SATURNIIDAE) POPULATIONS IN
THE UNITED STATES AND MEXICO, WITH
DESCRIPTIONS OF TWO NEW SUBSPECIES

PAUL M. TUSKES

3808 Sioux Avenue, San Diego, California 92117, USA

AND

STEVEN McELFRESH

Department of Entomology, University of California,
Riverside, California 92521, USA

ABSTRACT. Analysis of adult phenotypes indicates that distinctive populations of *Hemileuca electra* usually are restricted to well defined desert plant communities. This has resulted in *Hemileuca electra clio* being separated taxonomically from the Mojave Desert population and the formal recognition of unique populations from the Sonora Desert of Baja California, Mexico. We describe two populations as new subspecies, *Hemileuca electra mojavensis* and *H. electra rubra*, and discuss other populations in southern California and Mexico. The known range of *H. electra* has been extended to include southwest Utah, southern Nevada, portions of Arizona, California, and south into Baja California and Baja California Sur, Mexico. Flat-top buckwheat (*Eriogonum fasciculatum*) is the only larval hostplant in the United States, but in Mexico other hosts are used.

Additional key words: *rubra*, *mojavensis*, Lower Colorado Desert, Vizcaino Desert, Mojave Desert.

Hemileuca electra Wright is a day-flying saturniid moth that occurs over a vast area, from southwestern Utah to Baja California Sur, Mexico (Fig. 1). The nominate form was described from the California coastal chaparral plant community, but populations occur in the Mojave Desert and in three distinct subdivisions of the Sonoran Desert. Desert communities are expansive, often leading the casual observer to believe they are homogenous. However, there is a great deal of complexity in desert plant communities brought on by elevation, edaphic, and climatic factors. When populations are subject to differing natural selection in discontinuous or different habitats, unique phenotypes may develop if gene exchange is sufficiently restricted. Colonization of a new area may be accomplished by a few individuals, or a single female moth resulting in a limited initial gene pool (founder effect). With time, variability of the population may increase, but certain characteristics present in the parent population may be irrevocably lost, or selected against, resulting in unique biological or phenotypic traits. As a result, many distinctive populations may be assigned to one species, and the sum total of these populations and their attributes define the species. As presented in this paper, local populations also may experience unique biotic and abiotic conditions that result in changes in behavior, the time of egg hatch and

eclosion of adults, and hostplant preferences. Under such circumstances, the taxonomic status of a population may be difficult to assess based only on museum specimens.

It has been our observation that among North American *Hemileuca*, the more extensive their range in mosaic environments, the more likely it is for them to express a wide range of variability in all life stages. In reviewing *Hemileuca electra* populations, we found that some phenotypes are part of a cline that extends over many km, while another population exhibits such sharp discontinuity that species status was considered. The criteria we used to judge the status of *Hemileuca* species and subspecies is presented in the methods section.

The *H. electra* populations examined include: (1) nominate *H. electra* from coastal chaparral plant community of southern California, south to the area of San Quintin, Baja California, Mexico; (2) *Hemileuca electra clio* Barnes & McDunnough, a dark phenotype from the Arizona Upland plant community of Arizona; (3) the Mojave Desert population that extends across portions of southern Utah, Nevada, and California, characterized by its distinctly white forewings; (4) a Colorado Desert population extending from Riverside County, California, south into the deserts of Baja California, Mexico, characterized by its smaller size and mottled forewings; (5) a Vizcaino Desert population extending from south of El Rosario to approximately Rosarito in Baja California, Mexico, characterized by its large size and red coloration; (6) a population in Baja California Sur, Mexico, with a wide range of phenotypes, but with an overall appearance somewhat similar to that found in coastal and desert southern California populations 600 km to the north. Brown (1982) defined and described in detail the above plant communities.

METHODS

Adult specimens from each population were collected from August to November in traps baited with pheromone-emitting virgin females as described in Collins and Tuskes (1979), or netted as they approached females placed in screen cages. Quantitative characters were measured on field collected males. In order to secure additional females, larvae were collected during February and March and reared to maturity. Specimens also were borrowed from Mike Smith, Pat Savage, David Hawks, Guy Bruyey, and the Natural History Museum of Los Angeles County.

Six quantitative characters and eleven qualitative characters were scored on each adult. Quantitative characters included: (1) forewing (FW) length as measured from the apex to wing base; (2) diameter of the FW discal spot; (3) width of white FW medial patch between veins Cu1 and Cu2; (4) diameter of hindwing (HW) discal spot; (5) width of

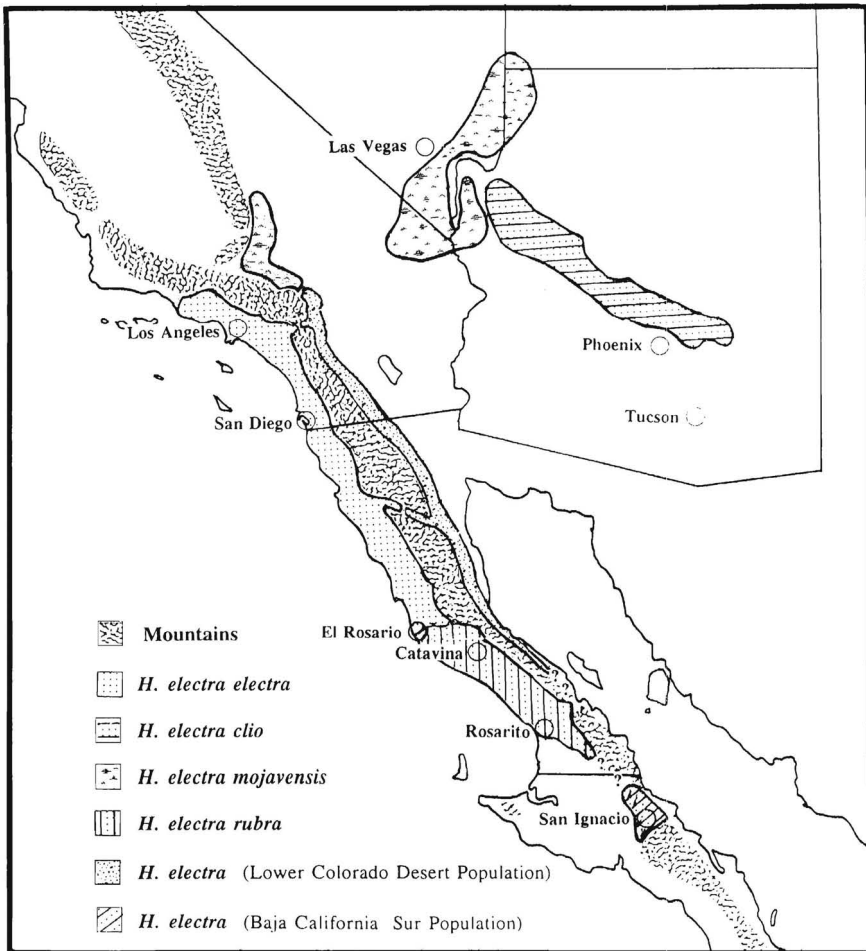


FIG. 1. Distribution of *Hemileuca electra* populations in the United States and Mexico.

black HW margin between veins m2 and m3; and (6) FW length to width ratio (higher values indicate narrower wings). Qualitative characters included: (7) black FW submarginal line touching discal spot; (8) presence of red scaling on antemedial area and/or inner FW margin or costal area; (9) color of male HW anal area (red or black); (10) color of ventral abdominal surface (black & white or black & red/pink); (11) color of the thorax (black & white or black & red); (12) color of the thoracic collar (white or red/pink); (13) transparency of wings [Wings were considered transparent if a data label could be read through the wing, translucent if the data on the label could be seen but not read,

and opaque if it could not be seen though the wing.]; (14) base of FW black and white or black only; (15) presence or absence of white marking between submarginal line and wing margin; (16) presence or absence of pupil in HW eye spot; and (17) color of the tegula (black & white or black & red).

When possible, 20 males and 10 females from each location were scored. The quantitative data were analyzed with a One-Way ANOVA, a correlation matrix and t-test, and discriminant analysis. Discriminant analysis was applied only to males, as too few females were available for a meaningful analysis. Nominate *H. electra* was used as the reference population. Data for multiple locations within each population are presented individually in order to better characterize variation. Qualitative characters were scored and summarized as percent occurrence.

Although there is no definition of how distinctive a population must be to warrant subspecies status, we set our criteria as follows. The population must be geographically and phenotypically distinct, and genetically compatible with other populations. Ideally, the characters that define the population would represent an adaptation to a unique environment. Although this aspect is difficult to evaluate, as a principle it involves life history traits, genetic compatibility, and the environment the population occupies, and places less emphasis on what is sometimes trivial phenotypic variation.

RESULTS

Of the 17 characters used to evaluate each specimen, characters 14–17 did not contribute significantly to distinguishing populations statistically, and thus these data are not presented or discussed. Other characters (2 & 4) were not statistically significant when all locations within a range were pooled, but in some instances individual locations differed significantly; these were included because of the trends they exhibit. Table 1 presents data for nominate *H. electra*, *H. electra rubra*, the blend zone populations, and the populations in Baja California Sur, Mexico. The information is based on 248 males from 12 locations. The forewing length of *rubra* and Baja California Sur population is significantly larger than that of nominate *H. electra* ($p > 0.01$), and the black hindwing margin of *rubra* is smaller ($p > 0.05$). Differences in qualitative characters between *H. electra electra* and *H. electra rubra* are striking. Other than size, the Baja California Sur population has similarities to nominate *H. electra* and the Lower Colorado Desert population. The intermediate character of blend zone males to the north (El Rosario) and south (Rosarito) of the *H. electra rubra* populations are characterized in Table 1.

Table 2 compares data for females from various *H. electra* popula-

tions. The average forewing lengths of female *clio* and *rubra* are significantly ($p > 0.05$) larger than that of nominate *H. electra*. The white forewing medial areas of *clio* and nominate *H. electra* are smaller than those of *rubra* and *mojavensis* ($p > 0.05$). The hindwing black margins of *mojavensis* and *rubra* are narrower than in other populations ($p > 0.05$), as is the hindwing discal spot of *mojavensis*. Too few females from the Lower Colorado Desert population were available to include this population in the statistical analysis. Differences in qualitative characters also are shown. Table 3 compares data for nominate *H. electra* males with *H. electra clio*, *H. electra mojavensis*, and the Lower Colorado Desert population, and is based on 267 specimens from 12 locations. The forewing length, hindwing discal spot, and margin width of *H. electra clio* are significantly ($p > 0.05$) larger than nominate *H. electra*. Southern populations of *H. electra mojavensis* are larger than nominate *H. electra* ($p > 0.05$), but others from the northern part of the range are not. The width of the white medial forewing area is larger ($p > 0.05$) in Mojave and Lower Colorado Desert populations than in nominate *H. electra*. Populations in Arizona from east of Davis Dam towards the type locality of *H. electra clio*, exhibit a reduction in size of the white forewing medial area and a tendency toward larger hindwing margins and discal spots than *mojavensis* populations. The Lower Colorado Desert population from Riverside and San Diego counties is most similar to the Mojave Desert population, but the white forewing medial area is significantly smaller.

Discriminant analysis separated *H. electra electra*, *H. electra clio*, and *H. electra mojavensis*. Ninety-three percent of the variance was accounted for by hindwing margin width, forewing length, hindwing eye spot diameter, and width of medial white forewing area. The Lower Colorado Desert population was placed by the analysis mid-way between *H. electra electra* and *H. electra mojavensis*, with some points overlapping nominate *H. electra* and *mojavensis*.

***Hemileuca electra* Populations**

Adult *H. electra* are attractive red, black, and white day-flying moths. Since adults lack functional mouth parts and thus do not feed, they are short-lived compared to most butterflies. Comstock and Dammers (1939) described the immature stages and biology of *Hemileuca electra*. Additional biological and distributional information has been published by Tuskes (1984) and Stone and Smith (1990). All *H. electra* populations have one generation per year. Depending on the population, the adult flight period may begin as early as July or as late as September. Adults emerge in the morning and depending on the temperature, the male flight begins between 0730 and 1000 h. Although mating occurs in the

TABLE 1. Comparison of male *Hemileuca electra rubra* and Baja California populations with *H. electra electra*.

Males	FW* length	FW discal	FW white patch	HW discal	HW margin	FW/HW ratio	Discal touch	Base FW red	HW anal black	V-Abd B&W	Collar white	Thorax B&W	Sam- ple Size
<i>H. electra electra</i>													
Motte Reserve	25.0	4.5	2.6	2.7	2.3	2.3	96%	0%	87%	100%	100%	100%	30
Riverside Co., CA	0.8	0.2	0.3	0.4	0.3	<0.1							
San Pasqual	25.0	4.5	1.7	2.3	2.1	2.4	90%	0%	80%	100%	100%	100%	30
San Diego Co., CA	0.9	0.4	0.9	0.4	0.3	<0.1							
El Secorro	25.3	4.1	3.2	2.3	1.8	2.4	60%	0%	75%	100%	95%	100%	20
Baja Cal., Mexico	1.0	0.4	0.6	0.3	0.2	0.1							
<i>H. electra/rubra</i> hybrid zone													
El Rosario	25.5	3.9	2.9	2.3	1.8	2.5	47%	15%	20%	67%	7%	35%	30
Baja Cal., Mexico	0.7	0.5	0.9	0.5	0.2	0.8							
<i>H. electra rubra</i>													
Pt. Canoas	26.3	3.5	3.3	1.8	1.3	2.6	53%	100%	10%	0%	0%	10%	30
Baja Cal., Mexico	1.3	0.5	0.8	0.3	0.2	<0.1							
El Progreso	29.5	4.1	4.5	2.4	1.7	2.6	14%	100%	0%	0%	0%	0%	7
Baja Cal., Mexico	0.8	0.3	0.7	0.4	0.4	<0.1							
Catavania	29.1	3.9	4.6	2.0	1.3	2.5	0%	100%	0%	0%	0%	0%	15
Baja Cal., Mexico	1.2	0.5	1.9	0.2	0.3	0.1							
Chapala	28.7	4.3	4.2	2.5	1.4	2.6	24%	100%	0%	0%	0%	0%	20
Baja Cal., Mexico	1.1	0.3	0.5	0.2	0.3	0.1							
P. St. Rosalilita	28.1	4.1	3.6	2.1	1.6	2.5	46%	100%	0%	33%	0%	0%	12
Baja Cal., Mexico	1.0	0.8	1.0	0.3	0.2	0.9							
Baja California Sur, blend population													
10 km N Rosarito	29.0	4.1	4.2	2.1	1.5	2.6	10%	58%	0%	35%	3%	10%	20
Baja Cal., Mexico	1.0	0.3	0.6	0.3	0.3	0.1							
15 km S Rosarito	28.1	4.1	4.0	2.3	1.8	2.5	29%	21%	21%	71%	11%	36%	14
Baja Cal., Mexico	1.4	0.6	0.8	0.3	0.3	<0.1							
Baja California Sur, Mexico population													
Mesquital	27.6	4.5	3.5	2.7	2.4	2.4	60%	0%	50%	98%	95%	100%	20
Baja Cal. Sur, Mexico	1.3	0.6	1.0	0.4	0.4								

*Measurements in mm. FW = forewing, HW = hindwing, V-Abd = ventral abdominal surface, B&W = black and white. See methods for full definition of characters.

TABLE 2. Comparison of female *Hemileuca electra* from various populations.

Females	FW* length	FW discal	FW white patch	HW discal	HW margin	FW/HW ratio
<i>H. electra electra</i>	29.6	4.6	1.7	2.8	3.1	2.2
	1.3	0.5	0.8	0.3	0.4	<0.1
<i>H. electra rubra</i>	33.0	4.5	5.5	2.4	2.4	2.3
	1.1	0.2	1.3	0.2	0.5	<0.1
<i>H. electra mojavenensis</i>	30.5	4.1	6.6	1.9	2.3	2.2
	1.3	0.5	1.9	0.3	0.7	<0.1
Lower Colorado Desert population	31.5	4.4	4.2	2.2	3.4	2.2
	1.6	0.3	1.2	0.4	0.6	<0.1
<i>H. electra clio</i>	31.9	5.3	1.4	4.0	3.5	2.2
	1.3	0.8	1.7	0.7	0.5	<0.1

	Discal touch	Base FW red	V-Abd B&W	Collar white	Thorax B&W	Sample size
<i>H. electra electra</i>	80%	0%	100%	100%	100%	12
<i>H. electra rubra</i>	20%	100%	0%	0%	0%	5
<i>H. electra mojavenensis</i>	0%	60%	100%	100%	0%	13
Lower Colorado Desert population	100%	0%	100%	33%	33%	3
<i>H. electra clio</i>	80%	0%	100%	100%	10%	9

* Measurements in mm. FW = forewing, HW = hindwing, V-Abd = ventral abdominal surface, B&W = black and white. See methods for full definition of characters.

morning, we observed females ovipositing from the afternoon to at least early evening; females have been collected occasionally at lights. The eggs are laid in rings or clusters that hatch between December and March. The early instar larvae are black and feed gregariously, while late instar larvae feed singly; the spines of these larvae are urticating. Pupation occurs in the soil or under surface debris; the pupal stage may last up to three years.

Hemileuca electra electra (Figs 2 & 16) inhabits the coastal chaparral plant communities of southern California (San Diego, Orange, Los Angeles, western Riverside, and southwestern San Bernardino counties) to just south of San Quintin, Baja California, Mexico (Fig. 1). Populations are found from sea level to approximately 1000 m. As a result, the mountain ranges that separate the chaparral and desert communities (San Gabriel, San Bernardino, San Jacinto, and Laguna mountains) define the northern and eastern limits of the population. A great deal of habitat has been lost to development, from the Los Angeles basin south to Laguna Beach, and we do not know the status of *H. electra* in this portion of its range. The only hostplant utilized by the

larvae is flat top buckwheat (*Eriogonum fasciculatum* Benth.; Polygonaceae). Females are similar to males in appearance but are larger, have more rounded and more densely scaled wings, and lack the black scaling on the anal portion of the hindwing that is common among males (Figs. 2 & 16). Table 1 characterizes males from three locations, and Table 2 characterizes females from southern California.

The flight season extends from July to December, with most records from mid-September and early October. During August and September we frequently observe flight activity during the morning and afternoon, with few or no males active during the hottest part of the day. As the days shorten and cool (October–December), flight continues throughout the day.

The average number of eggs per ring is 49 (standard deviation (SD) of 15.2, n=76 rings), with an average individual egg weight of 1.7 mg (SD 0.7 mg). The gray-green eggs hatch between late December and early March. The mature fifth instar larva has a brown ground color and three lateral cream to light yellow lines that extend nearly the length of the larva. Pupation occurs during April and May.

Hemileuca electra clio Barnes & McDunnough (Figs. 3–5 & 19–21) was described in a brief fashion from specimens collected at Kingman, Mohave Co., Arizona. Ferguson (1971) illustrated the lectotype and syntype and expressed concern regarding the lack of material and status of this subspecies. The melanic tendencies of *H. electra clio* were discussed by Ferguson, but a non-melanic topotype similar to the phenotype found in the Mojave Desert of California was illustrated, suggesting a variable population. As a result, a wide variety of phenotypes came to be called *H. electra clio*. Adults were characterized as being larger than nominate *H. electra*, and generally thought to have either predominately white or black forewings.

Collecting efforts during the past 20 years by Guy Bruyey, David Hawks, Mike Smith, Pat Savage, and the authors, resulted in a better understanding of the distribution and biology of this population. The type locality is at the western edge of this subspecies' range and borders the blend zone with the Mojave Desert population of *H. electra* (Fig. 1). Of 26 males collected at the type locality by Pat Savage, 20 were melanic or had melanic tendencies, and only 6 had clear white markings on the forewing. Since the name *clio* already was associated with the slightly melanic syntype and melanic tendencies have been mentioned in the literature, we applied the name *clio* to melanic populations from Kingman east to at least Pinal and Gila counties, Arizona. Most specimens are very dark; it is common for 40–60% of the hindwing and 70–100% of the dorsal forewing to be black. Females are characterized in Table 2 and males in Table 3.

TABLE 3. Comparison of male *Hemileuca electra clio* and *H. electra mojavensis* populations with *H. electra electra*.

Males	FW* length	FW discal	FW white patch	HW discal	HW margin	FW/HW ratio	Discal touch	Base FW red	HW anal black	V-Abd B&W	Collar white	Thorax B&W	Sample size
<i>H. electra electra</i>													
Motte Reserve	25.0	4.5	2.6	2.7	2.3	2.3	96%	0%	87%	100%	100%	100%	30
Riverside Co., CA	0.8	0.2	0.3	0.4	0.3	<0.1							
San Pasqual	25.0	4.5	1.7	2.3	2.1	2.4	90%	0%	80%	100%	100%	100%	30
San Diego Co., CA	0.9	0.4	0.9	0.4	0.3	<0.1							
Lower Colorado Desert population													
Mt. View/Springs	26.8	4.6	4.5	2.0	2.1	2.4	30%	0%	3%	100%	100%	93%	30
San Diego Co., CA	0.8	0.7	0.8	0.4	0.4	<0.1							
White Water Canyon	26.0	4.3	4.6	2.4	2.0	2.3	40%	0%	0%	100%	100%	30%	15
Riverside Co., CA	1.0	0.4	0.7	0.2	0.2	0.1							
E. Ensenada	26.4	4.5	3.9	2.5	2.2	2.5	21%	0%	0%	0%	93%	100%	15
Baja Cal., Mexico	1.2	0.5	1.0	0.3	0.3	0.1							
<i>H. electra mojavensis</i>													
LA & SB counties, CA	27.4	4.5	6.4	2.0	1.6	2.3	0%	30%	0%	100%	94%	90%	30
	1.0	0.4	1.0	0.3	0.2	<0.1							
Washington Co., UT	25.1	3.7	6.7	1.8	1.4	2.3	0%	100%	0%	100%	100%	70%	10
	1.3	0.3	0.7	0.1	0.1	0.1							
Newberry Mts.	25.9	4.0	4.7	2.2	1.7	2.3	10%	60%	0%	100%	60%	30%	15
Clark Co., NV	0.8	0.5	0.9	0.2	0.2	0.1							
E. Davis Dam	26.3	4.2	3.9	2.3	1.9	2.3	20%	40%	0%	100%	50%	50%	20
Mohave Co., AZ	0.8	0.4	0.6	0.3	0.3	0.1							
Hualapai Mts.	26.6	4.5	2.7	3.2	2.3	2.3	50%	40%	0%	100%	80%	60%	12
Mohave Co., AZ	0.8	0.5	1.1	0.3	0.2	0.1							
<i>H. electra clio</i>													
Kingman	27.0	4.3	3.0	2.9	2.3	2.4	50%	10%	0%	90%	80%	40%	30
Mohave Co., AZ	1.0	0.4	1.1	0.3	0.4	<0.1							
Superior	28.2	5.2	1.8	3.5	3.0	2.3	76%	10%	0%	100%	60%	13%	30
Pinal Co., AZ	0.7	0.5	1.3	0.4	0.4	<0.1							

* Measurements in mm. FW = forewing, HW = hindwing, V-Abd = ventral abdominal surface, B&W = black and white. See methods for full definition of characters.

Hemileuca electra clio is restricted to Arizona and occurs in the Arizona Upland plant community as defined by Brown (1982). It has been collected in Mohave, Yavapai, Maricopa, Gila, and Pinal counties (Fig. 1). Nearly all specimens exhibit melanic tendencies, and many have little or no white markings on the forewing. With the exception of the red on the basal part of the hindwing, some *clio* superficially resemble *Hemileuca juno* (Packard). Most specimens have been collected from mid-September to mid-October. The significance of the dark adult phenotype is unknown; it may allow better thermoregulation during the fall and/or may help the adult blend into the rocky surroundings.

The larval hostplant is flat-top buckwheat. The eggs are larger (avg. 2.7 mg., SD 0.2) and are laid in smaller clusters (avg. 31 eggs, SD 7.2, n=10 rings) than those of *H. electra electra*. Mature larvae often have darker dorsal scoli, and the intersegmental area is usually black; among nominate *H. electra* the intersegmental area is often a brick red, and dorsal scoli are black and yellow.

***Hemileuca electra mojavensis* Tuskes & McElfresh,
new subspecies**

(Figs. 8–10 & 17–18)

Holotype: Male (Fig. 10). HEAD: Eyes brown. Frontal, vertex and clypeal scales red. Antennae plumose, black and bipectinate. THORAX: Dorsally clothed with elongated black, red, and white scales. Thoracic color white and light pink. Legs black and red. ABDOMEN: Dorsal surface red, with tuft of red scales at tip. Ventral surface black, intersegmental area white, causing a banded pattern. FOREWING: Length from apex to base, 29 mm. Costa, antemedial area, and outer margin black. Black discal spot with white pupil. Medial area with white scales. Ventral surface with red and black costal and antemedial areas. Pattern similar to dorsal surface but with red scales present in antemedial area. HINDWING: Length 21 mm. Ground color red. Anal margin with long red scales, outer margins black. Discal spot solid and black. Ventral surface similar to dorsal surface.

Allotype: Female (Fig. 22). HEAD: Eyes brown. Frontal, vertex and clypeal scales red. Antennae bipectinate, reddish-brown. THORAX: Dorsally clothed with elongated red scales, tegula white. Legs black and red. ABDOMEN: Dorsal surface red. Ventral surface black, intersegmental area white, causing a banded pattern. FOREWING: Length from apex to base, 31 mm. Costa and outer margin black. Antemedial area black, white, and pink. Black discal spot with white pupil. Medial area with white scales. Ventral surface of FW with costa, outer margin, and discal spot black, remainder of wing red. HINDWING: Anal margin with long red scales, outer margins black. HW discal spot solid and black. Ventral surface of HW similar to dorsal surface.

Types: **Holotype.** Male, 1.5 km west of Phelan, San Bernardino Co., California, 28 Sept. 1973, P. Tuskes. **Allotype.** Female, 1.5 km N. of Barnwell, New York Mts., San Bernardino Co., California, 26 Sept. 1981, P. Tuskes. **Paratypes.** California, San Bernardino Co., 3 males, same data as holotype; 48 males, 11 females, N. base of Ord Mt., E. of Hesperia, 23–26 Sept. 1989, G. Bruyey, D. Hawks, & S. McElfresh, 10 males, same location, 26 Sept. 1994, S. McElfresh & P. Tuskes; 3 males Coxey Rd., S. of Apple Valley, 3 Oct. 1987, M. Smith. Nevada, Clark Co., 1 female, Hwy 161, 5 km. W. Jean, 5 Sept. 1987, M. Smith; 4 males, Newberry Mts., nr X-Mass Tree Pass, 29 Sept. 1987, P. Savage. Utah, Washington Co., 5 males, Hwy 91, nr Shivwits, 20 Sept. 1987, P. Savage, 1 male,

same location, eclosed 5 Aug. 1987, M. Smith. The holotype, allotype, and paratypes are deposited in the collection of the Natural History Museum of Los Angeles County.

Etymology. This distinctive population is named based on its distribution in the Mojave Desert of the southwestern United States. In California, the Spanish spelling of Mojave has been retained, while in Arizona, Mohave County has an English spelling. Since most of the Mojave Desert is in California, as is the type locality for this subspecies, we also use the Spanish spelling.

Paratype variation. The antemedial area of either sex may be solid black, or black with one or on occasion two white patches. In a small percentage of the population, the black scaling of the antemedial area may extend to the discal spot. The thoracic collar varies from white to pink. Average forewing length: males 27.4; females 30.5 mm.

Diagnosis. Adults of *H. electra mojavensis* are characterized by the extensive white medial forewing which clearly isolates the discal spot from the black margin and extends as a solid band from near the apex to the inner wing margin. On the hindwing, the black margin is narrower than that of the nominate form, and the anal area of the wing has no black scaling. Further, *mojavensis* is larger than nominate *H. electra*, exhibits little sexual dimorphism other than size, and the wings are heavily scaled and not translucent. It is distinguished from *H. electra clio* by its predominately white forewing, orange hindwing, and narrow black hindwing margin. Melanic tendencies are often associated with *clio* and the hindwing is red and black (Figs. 3–5 & 19–21). Tables 2 & 3 summarize many additional differences between *mojavensis*, *clio*, and nominate *H. electra*.

Distribution. *Hemileuca electra mojavensis* occurs primarily in the moderate elevations of the Mojave deserts of California, Arizona, Nevada, and Utah (Fig. 1). Utah, Washington Co., Hwy 91, near Shivwits at Apex Mine Rd. Nevada, Clark County, Hwy 161, 5 km NNW of Jean; Railroad Pass, SE of Henderson; Spring Mts., Calico Basin; and X-mass Tree Pass, Newberry Mts. Arizona, Mohave Co., Hwy 68, 10.7 miles east of Davis Dam, Black Mts. California records are so numerous that only geographic areas are given: San Bernardino Co., Hackberry Mts., New York Mts., Providence Mts., Ord Mt., Granite Mts., Lucerne Valley, Morongo Valley, Apple Valley, and Pioneertown; Los Angeles Co., Phelan, Pearblossom, and Little Rock. Kern Co., Red Rock Canyon off Hwy 14.

Discussion. The habitat of *H. electra mojavensis* differs from that of *H. electra clio*, in that the Mojave Desert usually lacks summer rains and is hotter and drier than the Arizona Uplands plant community of *H. electra clio*. The averaged combined winter and summer temperature for the Mojave is 20.2°C, followed by the Lower Colorado at

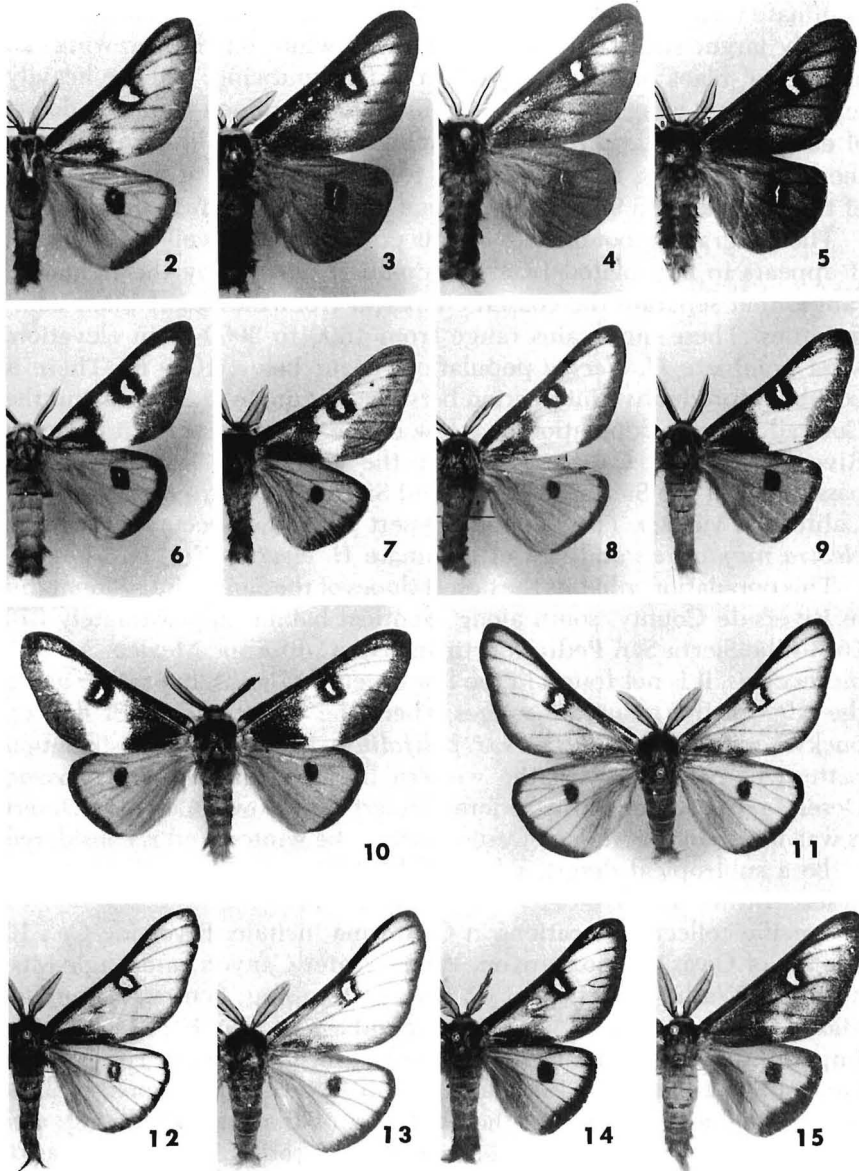
18.2°C, and the Arizona Upland at 17.7°C. The light forewing coloration may be important in thermoregulation. Other Mojave Desert *Hemileuca* have primarily white fore- and hindwings. On the eastern edge of its range there is a narrow transitional band between the Mojave Desert and the Arizona Upland plant communities where intermediate *H. electra* phenotypes occur. The best known area is between Oatman and Kingman in Mohave County, Arizona, a distance of about 45 km. Kingman (the type locality of *clio*) is on the eastern edge of the blend zone, thus, it is not surprising that topotypes exhibit a wide range of phenotypes that contributed to earlier confusion.

Nearly all adult records are from mid-September to late October. We have collected adults as early as 0800 h and as late as 1730 h. Females are more likely to be found flying in the afternoon and on occasion have been collected at lights. The adults typically fly within 2 m of the ground.

The clusters of eggs contain an average of 16 (SD 3.2, n=11 rings) large gray eggs. The larvae of *mojavensis* feed on *Eriogonum fasciculatum* var. *polifolium* (Watson). On occasion we have found larvae on *E. wrightii* Torr., but have not observed them feeding. Early instar larvae are found in late February or early March, and pupation occurs in April. Mature larvae tend to have a dark gray-black ground color, the intersegmental area is black, and the three lateral abdominal lines are nearly white. Thus, *mojavensis* larvae look quite similar to those of *H. electra clio*. There are five larval instars. The adult phenotype remains consistent regardless of where field collected eggs or larvae are reared.

A cross between a coastal San Diego female *H. electra electra* and a male *H. electra mojavensis* produced F₁ males similar to *mojavensis*, but larger and with more black on the forewing. The F₁ females were very large, and although the forewing was similar in markings to that of *mojavensis*, all were melanic. One female was very melanic and appeared to lack ova (Tuskes 1984). A second batch of larvae produced an F₁ generation that were similar to *mojavensis*. Tuskes (1984) provided biological information and a distribution map for this subspecies, but at the time it was not distinguished from *H. electra clio*. He also identified the Lower Colorado Desert *electra* population as related to, but different from, what herein is described as *H. electra mojavensis*.

Western Lower Colorado Desert population (Figs. 6–7 & 17–18). Based on discriminant analysis, this population was separate from, but has similarities with, both nominate *H. electra* and *H. electra mojavensis*. Although distinctive, it was not named because additional field work in Mexico would be required to understand its relationship to the population in Baja California Sur, the Vizcaino population, and the



FIGS. 2-15. Male *Hemileuca electra*. 2. Nominate *H. electra*, San Diego, Co. CA. 3.-5. *H. electra clio*, Pinal and Gila Co., AZ. 6. & 7. Lower Colorado Desert population, San Diego and Imperial Co., CA. 8. & 9. *H. electra mojavensis* paratypes, San Bernardino Co., CA. 10. *H. electra mojavensis*, holotype, San Bernardino Co., CA. 11. *H. electra rubra* holotype, Catavina, Baja CA, Mexico. 12. *H. electra rubra* paratypes, nr Chapala, Baja CA, Mexico. 13. *H. electra rubra* paratypes, nr El Progreso, Baja CA, Mexico. 14. & 15. Baja California Sur population, nr Mezquital, Mexico.

nominate form. This population differs from nominate *H. electra* in its slightly larger size, the presence of more white on the forewing, an absence of black on the anal portion of the hindwing, and the heavily scaled opaque wings (Table 3). Of 46 males examined from the desert of east San Diego and Imperial counties, and Baja California, Mexico, the black forewing margin extends to the discal spot or within 1 mm of the discal spot in 94%, and only one male was similar to *mojavensis*.

The geographic boundaries of this population are well-defined, and it appears to be isolated from nominate *H. electra* by the mountain ranges that separate the coastal chaparral from the desert plant communities. These mountains range from 1500 to 3000 m in elevation. Most nominate *H. electra* populations occur below 1000 m. There is possible reproductive interaction between nominate *H. electra* and the Colorado Desert population in a few of the lower passes that occur in Riverside County, California, and in the Valle de la Trinidad area, a pass between the Sierra de Juarez and Sierra San Pedro Martir of Baja California, Mexico. The Colorado Desert population occurs south of *H. electra mojavensis* and east of nominate *H. electra* (Fig. 1).

This population inhabits the desert slopes of the San Jacinto Mountains in Riverside County, south along identical habitat approximately 270 km to the Sierra San Pedro Martir in Baja California, Mexico. As with *mojavensis*, it is not found in the low desert flat lands, but rather along the edge of the mountain ranges where the desert variety of flat-top buckwheat, *E. fasciculatum* var. *polifolium*, is found. This distribution pattern corresponds with the western limits of the Lower Colorado Desert, a subdivision of the Sonoran Desert. The Lower Colorado Desert is warmer than the Mojave Desert during the winter, and is considered to be a subtropical desert, whereas the Mojave is a warm temperate desert (Brown 1982).

Specific collecting locations in California include: Riverside Co., 10 km SW of Oasis, Chino Canyon, White Water Canyon, and Eagle Mts. near Big Wash. San Diego Co., Scissors Crossing, Sentenac Canyon, Mason Valley, Desert View Tower, Jacumba, and 5 km E. of Manzanita. Imperial Co., Mountain Springs. Baja California, Mexico, Hwy 3, 150 km, and 130 km E. of Ensenada. At 55 km east of Ensenada, black scaling begins to appear on the anal area of the male hindwing, and the black hindwing margin becomes wider; both are characters associated with nominate *H. electra*.

The ova of this population are light beige and slightly larger than those of nominate coastal *H. electra*. The average number of eggs per cluster is 19 (SD 3.2, n=14 rings). Plants of *E. fasciculatum* var. *polifolium* are generally much smaller than coastal *E. fasciculatum* var. *fasciculatum*, and often not as dense. Fewer ova per cluster may be

an adaptation to the smaller hostplant. A large number of gregarious larvae on a small plant may preclude any from surviving. The eggs and larvae are similar in appearance to those of *mojavensis*.

***Hemileuca electra rubra* McElfresh & Tuskes, new subspecies**

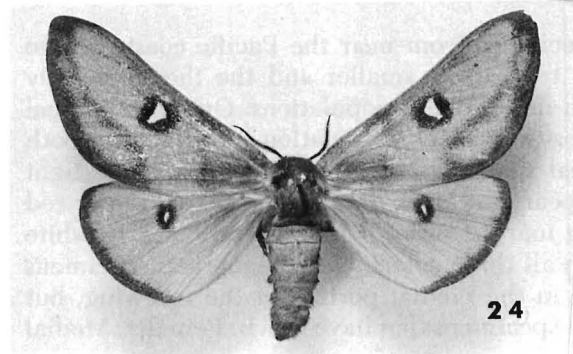
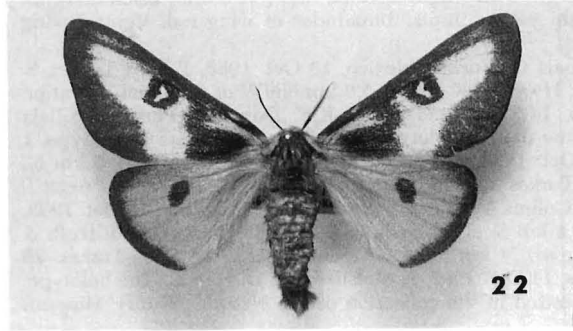
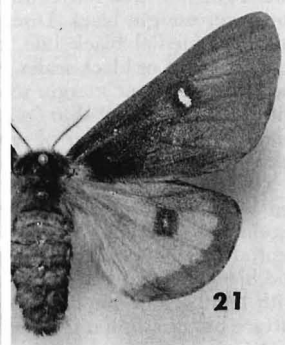
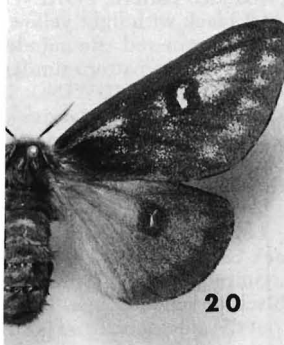
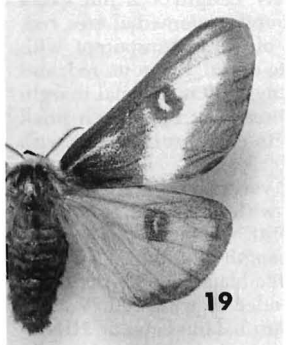
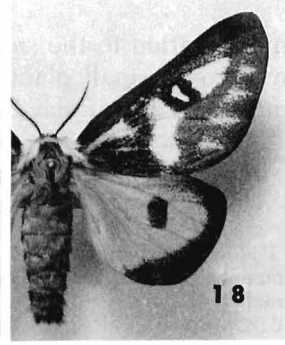
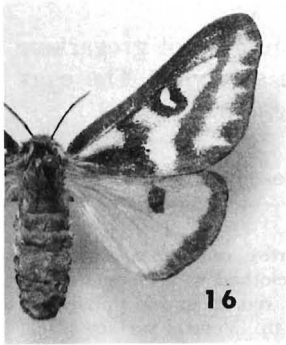
(Figs. 11–13 & 24–25)

Holotype: Male (Fig. 11). HEAD: Eyes brown. Frontal, vertex, and clypeal scales red. Antennae plumose, bipectinate, black. THORAX: Dorsally clothed with elongated red scales, tegula red with some black scaling. Thoracic collar red. Legs red and black. ABDOMEN: Dorsal surface red, with tuft of red scales at tip. Ventral surface black, intersegmental area red, causing a banded pattern. FOREWING: Length 30.2 mm. Costa and outer margin black. Discal spot black with light yellow pupil. Antemedial area red, faint antemedial black line. Inner margin red. Remainder of wing transparent with occasional red or black scales. Ventral surface pattern similar to dorsal, but costa red, and red scales on inner margin more prevalent. HINDWING: Length 20 mm. Anal margin with long red scales, thin (<1.5 mm) black outer margins. Discal spot black with small white pupil. Remainder of wing transparent. Ventral similar to dorsal surface but with sparse red scaling more noticeable.

Allotype: Female (Fig. 24). HEAD: Eyes brown. Frontal, vertex, and clypeal scales red. Antennae bipectinate, red. THORAX: Dorsally clothed with elongated red scales; tegula red. Thoracic collar red. Legs red and black. ABDOMEN: Dorsal surface red, ventral surface with red and black banding. FOREWING: Length 33.5 mm. Costa red and black. Margin black, submargin red, curved postmedial line black. Discal spot black with light yellow pupil. Faint black antemedial line. Remainder of wing red. Ventral surface pattern similar to dorsal, but the antemedial and postmarginal lines absent. HINDWING: Length 25 mm. Anal margin with long red scales, thin (<1.5 mm) black margins. Discal spot black with small light yellow pupil. Remainder of wing red. Ventral wing surface similar to dorsal.

Types. Holotype: Catavina, Baja California, Mexico, 13 Oct. 1988, P. & A. Tuskes, S. McElfresh, M. Collins. **Allotype:** Hwy 1 (PK 169.3), 5.3 km NNW of Catavina, elevation 607 m, Baja California, Mexico, 14 Sept. 1984, J.P. & K.E. Donahue. **Paratypes:** Baja California, Mexico. 10 males, same data as holotype. 2 females, same data as allotype. 1 male, 7 km N. El Progreso, 8 Oct. 1988, Tuskes. 4 males, 5 females (reared), 5 km N. El Progreso, Sept./Oct. 1989, Tuskes. 2 males, 1 female, 4 km W. of Punta Prieta, 9 Oct. 1988, Tuskes, McElfresh & Collins. 12 males, 3 km E. Santa Rosalillita, 13 Oct. 1988, Tuskes & McElfresh. 10 males, 4 km S. of Chapala, 9 Oct. 1988, Tuskes, McElfresh & Collins. 3 males, 6 females (reared), 4 km S. of Chapala, 8–23 Oct. 1989, Tuskes. 25 males, 10 km NE. Puerto Canoas, 11 Oct. 1987, S. McElfresh & D. Hawks. The holotype, allotype, and paratypes are deposited in the collection of the Natural History Museum of Los Angeles County.

Paratype variation. Specimens from near the Pacific coast (Puerto Canoas, Santa Rosalillita) tend to be smaller and the thorax slightly darker than material from more inland populations. On an individual basis, the width and intensity of black maculation is variable in both sexes. The hindwing discal spot does not always have a white/light yellow pupil, but may appear as a black dot. Males: Tegula red or red and black. Inner forewing margin varies from red and black to white and black, or may contain all three colors. Newly emerged specimens have sparse white scaling in the medial portion of the forewing, but scales are less noticeable in specimens that have flown. Females: Medial



forewing area red or pink; one of seven wild females has white scaling in the medial area. On the forewing, black may extend from the margin to the postmedial line eliminating the red submarginal area; the black may be slightly reduced resulting in isolated red wedges between these two lines; or as in the allotype these two lines may be clearly separated by a red submarginal area.

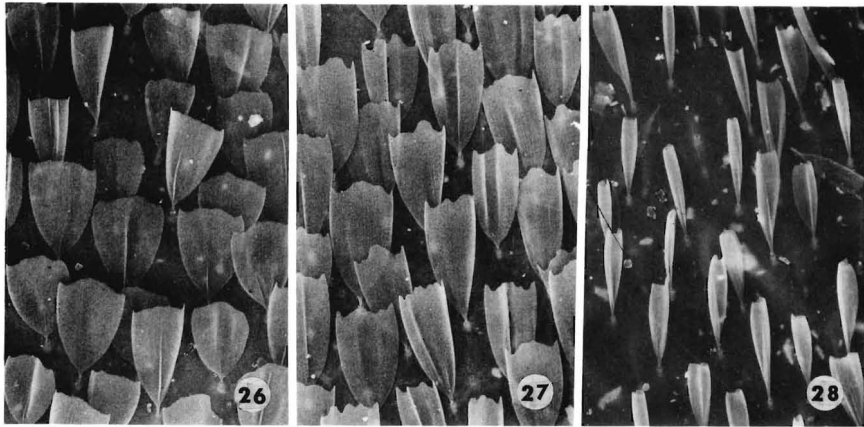
Diagnosis. A comparison of characters between *rubra* and nominate *H. electra* is summarized in Tables 1 and 2. In addition to those already mentioned, other important diagnostic characters of *rubra* males are: the thorax, collar and usually the tegula are predominately red; the ventral abdominal surface is pink and/or red; the black hindwing marginal band is narrow and the anal area of the wing is free of prominent black scales. Females: the forewing is opaque and the dorsal surface is usually pink/red, and black, the antemedial area is usually red. Only 1 of 7 wild females had a white forewing medial area. The thorax and frequently the tegula are red. Among both sexes of nominate *H. electra*, the forewing, thorax, tegula, and ventral abdominal surface is black and white, while the thoracic collar is white (Tables 1 & 2).

Distribution. This subspecies occurs only in the northwest section of the Vizcaino Desert, a subdivision of the Sonoran Desert habitat of Baja California, Mexico. The distribution is from just north of El Progreso, south to Rosario, a distance of 220 km, and from the Pacific coast east to the edge of the arid central gulf habitat (Fig. 1). The Vizcaino subdivision is characterized by a unique plant community associated with arid conditions. The average precipitation of 27 stations is 9.9 cm/yr, with a range of 4.8 to 15 cm/yr (Brown 1982). Some of the unique vegetation includes elephant tree or torote (*Bursera microphylla* A. Gray; Burseraceae), elephant tree or copalquin (*Pachycormus discolor* (Benth.); Anacardiaceae), cardon (*Pachycereus pringlei* (S. Wats.); Cactaceae), and boojum or cirio (*Idria columnaris* Kell.; Fouquieriaceae).

Discussion. The most distinctive and largest specimens of *H. electra rubra* come from the central peninsular area between El Progreso and Chapala. Males from these locations have nearly transparent forewings with a slight reddish cast. The forewing averages 13% longer than that

←

FIGS. 16–25. Female *Hemileuca electra*. **16.** Nominate *electra*, San Diego, Co. CA. **17. & 18.** Lower Colorado Desert population, San Diego and Imperial Co., CA. **19.–21.** *H. electra clio*, Pinal and Gila Co., AZ. **22.** *H. electra mojavensis*, allotype, New York Mts., San Bernardino Co., CA. **23.** *H. electra mojavensis* paratypes, San Bernardino Co., CA. **24.** *H. electra rubra* allotype, nr Catavina, Baja CA, Mexico. **25.** *H. electra rubra* paratypes, nr Chapala, Baja CA, Mexico. [With the exception of female *H. electra mojavensis*, most populations have white or red scaling between the forewing postmedial line and wing margin. Although there is individual variation, females of *H. electra mojavensis*, and *H. electra rubra* have narrower black hindwing margins.]



FIGS. 26–28. Electron micrographs of male *H. electra* medial dorsal forewing. 26. *H. electra clio*. 27. *H. electra electra*. 28. *H. electra rubra*.

of nominate *H. electra*, but some individuals are as much as 30% larger. The relative difference in size is about the same as the difference between *H. hera* (Harr.) and *H. hera magnifica* (Rotger). Specimens from near the Pacific Ocean tend to be smaller and have some black on the thorax, but the wings are still quite transparent.

Electron micrographs of male forewings show that the scales of *rubra* are less dense and more curled than those of *H. electra electra* (Figs. 26–28). Differences in scale density and the laterally curled, somewhat conical shape are the primary reasons for the transparent appearance of the wings. The loss of scales with age contributes to the appearance, but it is not the primary cause as reared specimens which have not flown still exhibit this character.

Females of *rubra* express phenotypic variation related to environmental conditions experienced during the larval and pupal stages. Fourth and fifth instar larvae collected in Baja that emerged in the fall produce the striking red/orange to pink wild phenotype. In captivity, pupae that hold over and emerge the following year produced females with a great deal of black smudging on the pink forewing. When reared from ova or as field collected 1st and 2nd instar larvae, the females had a reddish antemedial area and red along the inner forewing margin, but the remainder of the forewing was black and light pink or white. The forewings of these females are similar to those from the Lower Colorado Desert population but differ by the presence of the red to red-orange ground color. Rearing conditions only affected the forewing pigments of females and had no influence on other *rubra* characters.

The phenotype of the male does not appear to be influenced by rearing conditions.

Well-defined transitional populations have been identified at both the northern and southern boundaries. The northern transitional population is a step cline that occurs primarily from El Rosario south approximately 25 km. At El Progreso, 50 km south of El Rosario, the phenotype is that of *rubra*. Specimens from the blend zone differ from nominate *H. electra*, exhibiting decreases in the size of the fore- and hindwing discal spot, the hindwing margin, and black scaling on the hindwing anal area. There are corresponding increases in wing length, width of the white forewing medial area, frequency of red thoracic collar, and transparency of the wings (Table 1). We have only three females from this area and all have pink/red forewings. This blend zone corresponds with the transitional area between the California Coastal Chaparral and Sonoran Desert plant communities (Fig. 1). Males from 32 to 50 km west of Bahia de Los Angeles have sparse black scaling on the anal area of the hindwing, but otherwise are typical for *rubra*.

South of El Rosarito specimens exhibit transitional characters found in the more southern population. About 50% of these specimens have sparse black scaling on the anal area of the hindwing, increased black scaling on the thorax, red or white thoracic collars, and less transparent wings. All of these characters are found commonly in the Baja California Sur *H. electra* populations. Material from the northern and southern transitional populations was not included in the paratype series.

Hybrid crosses between nominate *H. electra* from San Diego and *H. electra rubra* from El Progreso and Lake Chapala provide further evidence for the genetic divergence of this population. During 1988 and 1989 six crosses were made with the following results. Over 97% of the eggs hatched, and if the female was from San Diego the ova hatched in January or February; if the female was from Mexico the ova hatched in December. All larvae developed rapidly with little mortality. In the prepupal stage, mortality exceeded 85%. Of those that pupated, over 30% were deformed and died during the summer. Of the normal pupae, approximately half failed to emerge and died after 2 years. Only 5–6% emerged as adults. Some males and most females had wing deformities on the left side, and only 2 of 6 females had eggs in their abdomen. As a control, nominate *H. electra* and *H. electra rubra* colonies from El Progreso and Lake Chapala were reared at the same time. These had approximately 90% survival with no notable deformities among the adults. Last instar larvae collected from the hybrid zone produced 3 females; 2 had wing deformities and none contained eggs. Thus, both laboratory hybrid females and those from

the hybrid zone display deformities and had significantly reduced fecundity.

Crosses between female nominate *H. electra* and male *rubra* resulted in F_1 females that were similar to nominate *H. electra*, but half had red collars. The F_1 males, likewise, were similar to *rubra*, but the wings were not as transparent. When the reciprocal cross was made, the F_1 females were more similar in appearance to *rubra*. The males had red thoracic collars, but the hindwing had distinctive black scaling in the anal area, a character common to nominate *H. electra* males. A comparison of these findings with the intermediate population near El Rosario, Mexico, suggests a great deal of similarity. The narrow hybrid zone may be maintained by the close proximity of contrasting selective forces found in the California coastal chaparral and Sonoran Desert, and the degree of genetic incompatibility between these two populations. The rapidity by which one phenotype and biological pattern is replaced by another, and its close association to floral shifts is striking.

The apparent lack of genetic compatibility with nominate *H. electra*, the utilization of additional hostplants, and the unique adult morphology and phenotype are strong arguments that *rubra* is a distinct species. We have described it as a subspecies because the relationship between *rubra* and the Lower Colorado and Baja California Sur populations in Mexico require further study to determine the extent of their compatibility.

First instar larvae have been collected from December through mid February. The large number of 4th and 5th instar larvae observed in early-February 1988 (perhaps 70%) suggests that most eggs hatched in December, which is earlier than nominate *H. electra*. Although we have found prepupal larvae in early February, most larvae pupate during March. Larvae from late emerging eggs pupate in April.

South of Lake Chapala mature larvae usually are found during the day at the base of the main stem, or on the ground under flat-top buckwheat. Feeding patterns suggest that some mature larvae wander from plant to plant, even when the host is not depleted, perhaps to avoid parasitoids. By searching for fresh frass on the ground under the hostplant it was easy to locate mature larvae.

The only known larval hostplant for nominate *H. electra* is flat-top buckwheat. But observations in Baja California indicate that other host plants are also utilized by *rubra*. In 1982, McElfresh and Bruyera found 30 mature larvae near Catavina feeding on tamarisk (*Tamarix* sp.; Tamaricaceae), an imported desert tree. In the fall of 1987, hundreds of males were observed near Punta de los Canoas, and in early-February of 1988, a mature larva was found about 42 km west of Bahia de Los

Angeles. The fact that no *Eriogonum* could be found at either location suggests other host plants must be utilized.

While camping west of Punta Prieta during February 1988, we found second through last instar larvae commonly feeding on flat-top buckwheat and boojum tree, and two hatched egg rings were located on stems at the base of boojum. In addition, perhaps two dozen mature larvae were feeding on *Pachycormus discolor*, and one on ocotillo (*Fouquieria splendens* Engelm.; Fouquieriaceae). In October 1988, six egg rings were found on boojum 3 km north of El Progreso. All rings were on the south side of the plant and within 1.5 m of the ground. A search of the buckwheat at this same location did not reveal additional egg rings. Though mature larvae tend to wander and appear to be oligophagus, it does not mean that either ocotillo or elephant tree are suitable hosts for early instar larvae. Often, early instar larvae do not survive on alternate plants that support mature larvae (Tuskes 1984).

The eggs of *rubra* are beige and average 2 mg each, while those of nominate *H. electra* are gray-green and weigh slightly less. Egg rings deposited on boojum averaged 104 eggs (SD 6.4, n=6 rings), nearly three times more eggs per ring than the same species deposits on buckwheat (avg 44, SD 4.5, n=6 rings). Boojum trees represent a massive vertical but dispersed larval resource when compared to the more frequent and horizontally dispersed buckwheat. The increase in eggs per ring minimizes the number of oviposition flights a female must make. The shift in the number of eggs per ring may be induced by hostplant chemistry detected by the female during oviposition. Mature larvae of *rubra* have a blackish ground color, the lateral lines tend to be white, and the intersegmental areas are black to dark brown. As might be expected, larvae from the blend zone have intermediate phenotypes.

Based on topography, it is likely that an *H. electra* population occurs in the low coastal mountains southwest of Scammon's Lagoon. Ralph Wells (pers. comm.) observed *H. electra* larvae on Cedros Island located northwest of Scammon's Lagoon, but was not able to rear them.

Baja California Sur, Mexico population (Figs. 14–15). From the area of San Ignacio, Baja California Sur, to just east of Mezquital, there is a population that superficially resembles material from the Lower Colorado Desert population and nominate *H. electra*. Most, but not all, have a white thoracic collar and black thorax with no reddish tendencies. The wings are black and white but translucent instead of opaque. Specimens are larger than nominate *H. electra*, but have black scaling on the anal hindwing area in 50% of the males. Black scaling on the anal portion of the hindwing is a character usually found only in nominate *H. electra*. Further, a few specimens have nearly melanic fore-

wings (only a trace on the hindwing), not unlike *H. electra clio*. This extensive variation is found in our small series of 24 males.

The habitat of this population is best described as scrub thorn which receives summer rains. Neither boojum nor flat-top buckwheat is present, although elephant tree and ocotillo are common. We have not found a larva or identified the most probable larval hostplant for this population. The population may extend further south, but possibly only on the Pacific Ocean side of the mountains. Extensive collecting with caged females and traps from Santa Rosalia to the mountains southwest of Loreto in 1990 and 1991 failed to produce adults.

To the north, a narrow blend zone between this population and *rubra* occurs south of Rosarito. In 1991 we collected at El Arco, in the mountains between Rosarito and San Ignacio, but did not find adults. We believe moths are present, but the quality of the dirt road did not allow us to go beyond El Arco, even with 4-wheel drive vehicles.

CONCLUSION

Hemileuca electra electra and *H. electra rubra* occur on the Pacific Ocean side of the coastal mountains, in relatively continuous habitat. *Hemileuca electra clio*, *H. electra mojavensis*, and the Lower Colorado Desert populations often occur in isolated habitat, and as might be expected, exhibit greater phenotypic variation. The extensive phenotypic and life history variation probably represents adaptations to the environment, making it difficult to speculate on the origin and ancestral phenotype of this species. Based on adult maculation, male genitalia, and larval morphology, *H. electra* is most closely related to *H. juno*. *Hemileuca juno* occurs in southern Arizona, New Mexico, extreme western Texas, and adjacent portions of Sonora, Mexico, where the larvae feed on woody legumes. Of the various *H. electra* populations, adult *H. electra clio* most closely resemble those of *H. juno*. Whether this similarity is the result of close ancestral relationships or convergence is not known.

Although larvae of all populations in the United States feed on flat-top buckwheat, populations in Baja California, Mexico, are polyphagous. The southernmost population also exhibits phenotypic characters found in nearly all other *H. electra* populations. We considered the possibility that the *electra-juno* ancestor evolved in mainland Mexico and possibly dispersed by island-hopping across the gulf during more favorable times, and became what we now recognize as *H. electra*. Polyphagous feeding behavior is often interpreted as ancestral, and the occurrence of *H. electra* on Cedros Island suggests island-hopping is possible for this species. This scenario is not supported, based on the

biogeographic pattern of other saturniids that have colonized the peninsula of Baja California (e.g., *Eupackardia*, *Rothschildia*, *Hyalophora*, *Agapema*, *Saturnia*, *Sphingicampa*, and other *Hemileuca*), and its morphological relationship to *Hemileuca* outside of the *H. tricolor* complex. The southern population of *H. electra* may be one of the most recent, and not yet well-adapted to an environment that includes dependable summer rains and a new array of hostplants.

Hemileuca electra has spread successfully throughout desert plant communities because of its genetic flexibility and adaptability. *Hemileuca electra* has adapted to the various plant communities with subtle changes in seasonal and daily flight patterns, and unique adult phenotype. The number of eggs per cluster varies depending upon the larval hostplant and population, and the eggs of desert populations are larger and lighter in coloration which may allow them to reflect solar energy and reduce water loss. The utilization of new larval hostplants in Mexico requires a change in the selection of oviposition sites, the actual process of oviposition, and of course the ability to identify the hostplant. Larval feeding behavior must change to minimize predation and parasitization, and optimize thermoregulation on a hostplant such as boojum. The variability within the populations that define *H. electra* has contributed to its success in the harsh desert and semi-desert environment from Utah to Mexico.

ACKNOWLEDGMENTS

Some collecting records and specimens for examination were provided by Pat Savage, Mike Smith, David Hawks, and Guy Bruyca. Mike Collins and Ann Tuskes accompanied us on numerous collecting trips. We thank Ann Tuskes, Mike Collins, Mike Smith, and Jim Tuttle for reading and commenting on various drafts of the manuscript.

LITERATURE CITED

- BROWN, D. E. 1982. Biotic communities of the Southwestern United States and Mexico. *Desert Plants* 4(1-4):1-342.
- COLLINS, M. M. & P. M. TUSKES. 1979. Reproductive isolation in sympatric species of dayflying moths (*Hemileuca*: Saturniidae). *Evolution* 33:728-733.
- COMSTOCK, J. A. & C. M. DAMMERS. 1939. Studies in the metamorphoses of six California moths. *Bull. South. Calif. Acad. Sci.* 37:105-128
- FERGUSON, D. C. 1971. The moths of American north of Mexico. Fascicle 20.a. Bombycoidea. Claxsey, London. 154 pp.
- STONE, S. E. & M. J. SMITH. 1990. Buckmoths (Lepidoptera: Saturniidae: *Hemileuca*) in relation to southwestern vegetation and foodplants. *Desert Plants* 10(1):13-30.
- TUSKES, P. M. 1984. The biology and distribution of California Hemileucinae (Saturniidae). *J. Lepid. Soc.* 38:281-309.

Received for publication 21 August 1994; revised and accepted 2 November 1994.