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STATUS OF SIX ENDANGERED CALIFORNIA BUTTERFLIES[1/]
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by

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ABSTRACT

A survey was conducted from March-September 1977 to determine the current status of six federally endangered butterflies which reside in California. The butterflies are the San Bruno elfin (*Callophrys mossii bayensis*), Mission blue (*Plebejus icarioides missionensis*), Lotis blue (*Lycaeides argyrognomon lotis*), Smith's blue (*Shijimiaeoides enoptes smithi*), El Segundo blue (*Shijimiaeoides battoides allyni*), and Lange's metalmark (*Apodemia mormo langei*). The following aspects were investigated for each of the endangered species:

1. Survey of the site(s) currently inhabited and exploration for unknown sites;
2. Population size, density and mortality factors determined by mark-release-recapture techniques;
3. Life history investigations to determine larval foodplant(s), and,
4. Determination of factors threatening their survival.

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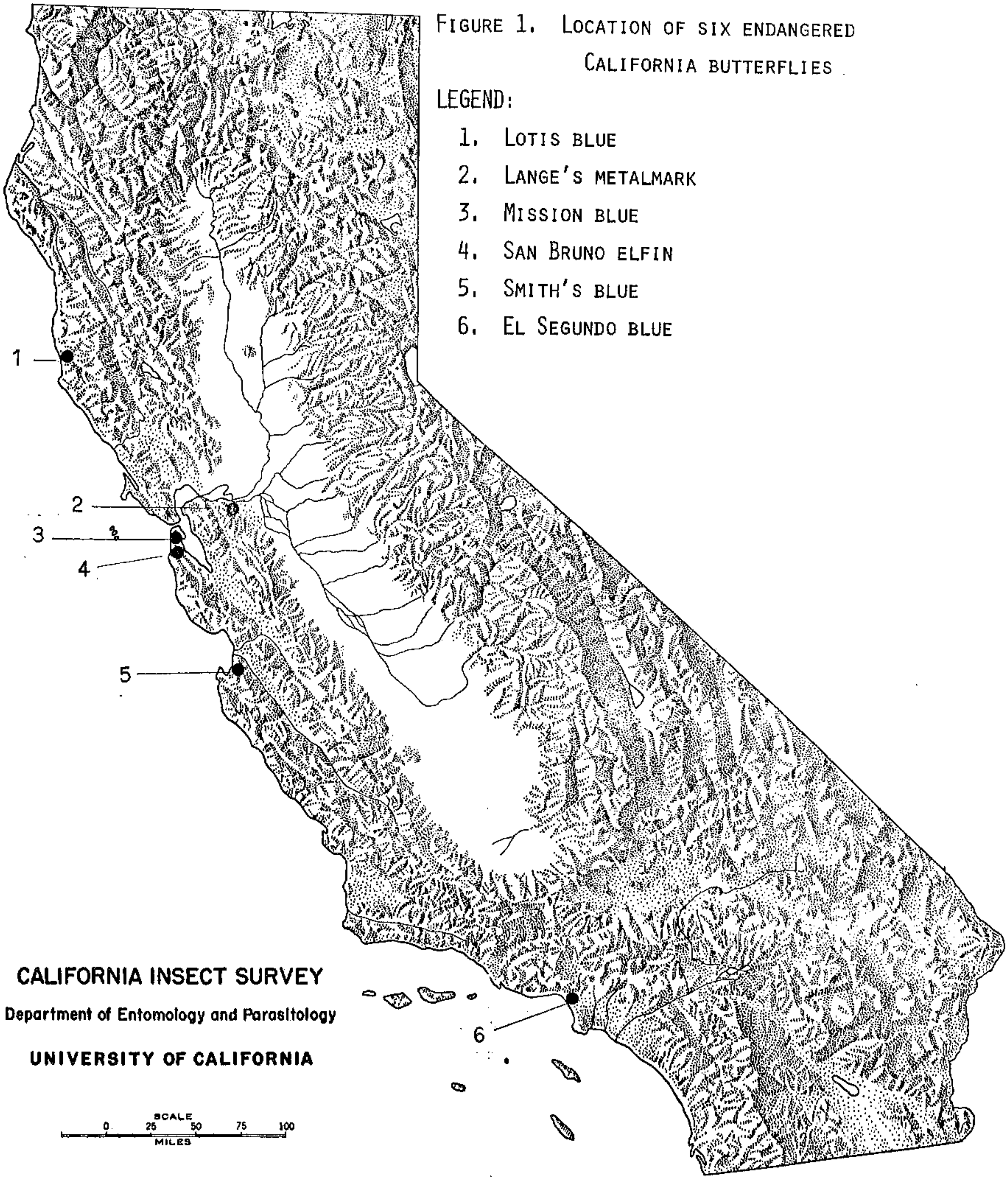
Figure 1. Location of six endangered California butterflies

LEGEND:

1. Lotis blue
2. Lange's metalmark
3. Mission blue
4. San Bruno elfin
5. Smith's blue
6. El Segundo blue



INTRODUCTION

Six California butterfly species have recently been designated as "endangered" (Federal Register Vol. 41, No. 106), in accordance with the Endangered Species Act of 1973. The butterflies are the San Bruno elfin (Callophrys mossii bayensis), Mission blue (Plebejus icarioides missionensis)[1/] Lotis blue (Lycaeides argyrognomon lotis), Smith's blue (Shijimiaeioides enoptes smithi), El Segundo blue (Shijimiaeioides battoides allyni), and Lange's metalmark (Apodemia mormo langei). Their endangered status is attributed to their confinement to vestigial habitats or ecological islands, formerly larger in distribution but now greatly reduced in size due to man-made alterations.

The critical habitat for each species was recently proposed by the U. S. Fish and Wildlife Service (Federal Register Vol. 42, No. 26). Section 7 of the Endangered Species Act of 1973 defines critical habitat as the area of land, water and air space required for the normal needs and survival of a species. These needs include space for growth, movement and behavior; food and water procurement; sites for breeding and rearing of offspring; cover or shelter; and other biological or physical requirements. Compared to mammals and birds little is known about the biologies and requirements for living space of butterflies.

Habitat alteration is the primary problem causing the extirpation of butterfly populations. Five of the six proposed critical habitats are currently threatened by developments. The autecological investigations reported herein, provide much information about the immature biologies, foodplants, nectar sources, reproductive behavior, flight ranges, parasites and predators, plus mortality and natality factors. Hopefully, this information will provide a data base for the preservation of the endangered butterflies and their habitats.

Population structure is of paramount importance in determining the genetic consequences of selection, gene flow, and stochastic processes. The parameters necessary to gain reasonable inferences about population structure are difficult to determine for natural populations. As a first step in understanding the structure and dynamics of a natural population, it is essential to know something about the population size and related parameters such as survival rate, vagility, etc., at given points in time. Mark-release-recapture techniques provide the best estimates of these important parameters.

STUDY TECHNIQUES

Marking

For four of the five species studied, each captured butterfly was marked with a unique series of coded dots allowing individual recognition of each marked animal. Marks were applied to the ventral wing surfaces with "Marks-A-Lot" felt-tipped, permanent ink pens. The marking technique of Ehrlich and Davidson (1960) was used. A maximum of 150 individuals could be marked using one color of ink. The marks were permanent as long as the wings remained intact. In the case of the fifth species, numbers were applied using "Pilot" pens.

Butterflies were netted, marked and then released immediately at the point of capture. The date, sex, quadrate, number, activity, time and physical condition of each specimen was recorded for the initial capture and all subsequent

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1/ Genus identified as Icaricia in the Federal Register Vol. 42, No. 26

recaptures. Watt's, et al. (1977), method of rating the physical condition of each individual was used: 1) freshly emerged, wings still damp; 2) wings and other cuticle dry and hard, no visible damage; 3) noticeable wear of scales from wings or body; 4) wings showing fraying or tearing in their cuticle; 5) wings with extensive scale wear and cuticle damage.

Time spent sampling each quadrate was determined by the number of individuals encountered within it. An effort was made to treat marked and nonmarked individuals equally; nonetheless there may have been some bias in pursuing obviously marked individuals.

Several marked individuals were subsequently recaptured again the same day as initially marked. These recaptures were not used in the calculations to estimate population sizes.

Some consideration must be given to the possibility of influencing an individual's chance of survival by the capture and marking process before interpreting recapture results as indicative of population behavior. The number of successive recaptures regardless of the previous captures should describe the poisson distribution for a particular sample size and mean if the probability of an insect being collected is constant. A comparison of the observed and poisson distributions for the number of successive racaptures is shown for each species. A significant deviation from the expected values may indicate a tendency for a marked individual to be recaptured more often than expected. Another alternative exists if the life expectancy over the study period changes for the majority of individuals composing the population. In this case, the probability of an insect being recaptured is not constant and depends on the date of original capture.

Population Estimates

The numbers of animals present at any one time in a population is of interest in its own right for ecological studies. It also serves as a necessary basis for other calculations important to the analysis of population structure.

Jolly's stochastic method (1965) was used to process the mark-release-recapture data. A computer program was used to carry out Jolly's calculations to estimate population size $\hat{N}_i$, survival rate $\hat{\emptyset}_i$, and recruitment rate $\hat{B}_i$, for each day, and prints these as well as Jolly's intermediate variables (e.g., the estimated number of marks at risk, $\hat{M}_i$, etc.).

Jolly's method cannot give proper $\hat{N}_i$ values for the first or last days of a study. On the first day, one has only the number of animals taken in the marking sample; on the last day, $\hat{M}_i$ is underestimated and the estimate $\hat{N}_i$ is depressed unrealistically. If the last and next-to-last days of the study are close in time, $\hat{M}_i$-1 is a reasonably good estimate of $\hat{M}_i$, especially if the population is not yet at the end of its flight season. Thus, $\hat{M}_i$-1 has been used to generate a hand-calculated N_i.

In most populations, the recapture probabilities of the two sexes are significantly different as shown by X^2 tests. The sexes were then processed separately through the Jolly's analysis. Since no parameters were shared in these processings, and since the numbers of males and females captured were independent, the $\hat{N}_i$ for both sexes could legitimately be pooled, and their variances summed to estimate the entire population at the study site.

Estimates for the numbers of males and females of each species, and the estimated standard errors are figured. The latter are sometimes very large. Undoubtedly this is due in part to low sampling intensity, i.e., the fraction of the population captured per sample (Roff, 1972) on those days when adverse weather terminated butterfly flight early. But, some of this estimate variance reflects biologically important changes in average population mobility, mark dispersal, and exchange which are themselves caused by weather and other factors.

Residence Times and Population Per Season

As an estimation of lifespan under field conditions I have used Jolly's (1965) survival estimates (ϕ). Unfortunately Jolly's recruitment and survival estimates are subject to severe fluctuation even when based on extensive data. Scott (1973) introduced a method for weighted averaging of the daily Jolly survival estimates, valid if a constant survival rate throughout the study (Type II Survivorship of Deevey, 1947) can be assumed. The validity of this assumption and the accuracy of Scott's methods can be checked by inspection of a semilogarithmic plot of recapture numbers against the period of survival of recaptures. If the entire flight season is examined with no major gaps in sampling, such a decay plot will accurately reflect the survivorship of the population sampled. Since only a portion of the flight season was studied, the data on the 6 butterflies should be biased as the longer periods of survival will be missing and thus the survival rate will be underestimated.

Thus far, I have used the term "survival" for the sake of continuity with cited references. A more accurate term is "residence" since emigration and death cannot be distinguished here as a cause of loss (Ehrlich, 1961; Jolly, 1965; Watt, *et al.*, 1977). I will refer to residence rates, plots, etc., for which I will use Jolly's survival symbol ϕ. Thus $\hat{\phi}_i$ is the estimated probability that an insect present on day i will still be alive there on day i + 1; $\hat{\phi}$ is the average residence value for the season. Ln $\hat{\phi}$ is the slope of the decay plot, and $-(\ln \hat{\phi})^{-1}$ is the mean expectation of residence (Cook, *et al.*, 1967). I use $1-\hat{\phi}$ as a loss rate for estimating total animals present in the brood, multiplied by $\sum \hat{N}_i$; when there are gaps in the $\hat{N}_i$ series, I average the four surrounding values to fill these, again following Cook, *et al.* (1967).

Since it is unlikely that all butterflies that are marked are marked immediately after emergence, or recaptured for the last time just prior to death, time in residence will tend to underestimate adult survival time. Hence, estimates of total population size obtained by this method will represent an overestimate.

An estimate of the total numbers of each sex resident in the population over the entire study period may be made by multiplying the total animal-days (the sum of the N_i values) by the day specific-loss rate. These estimates are given for each species.

One caution should be issued about the meaning of Type II survivorship. While this implies an entirely constant loss rate over a generation, and even with a large initial sample, one should not expect to find any surviving past some maximum age. What happens is that most of the population never attains maximum lifespan, due to constant loss occasioned by weather, predation, etc. But one would expect to see a decrease in recapture probability among those old animals which do approach the maximum longevity-an increasing departure from Type II survival. If the wear rating system does serve to "age" the butterflies effectively, then we should witness a decrease in recapture probability for class 4, and especially class 5 butterflies presented for each species.

Dispersal Analysis

The vagility parameters of Scott (1976) were computed for each species. These included the following: (d_i, t_i) minimum distance and time in days between i^{th} and $(i + 1)^{th}$ capture; (D, T) sum of the d's and t's respectively for each individual; (R) greatest distance between recapture points; ($V_i = d_i/t_i$) minimum speed; and ($V = D/T$) minimum overall speed. Sample sizes of D, T, R and V equal the number of individuals recaptured for each group; sample sizes for d_i, t_i and v_i equal the total number of recaptures for each group.

Movement patterns for individuals were also examined by noting the location of consecutive captures. Movement was classified as local if the captures were made in the same or adjacent quadrates. A move to another quadrate would be classified as long.

In order to determine and compare the micro-distribution of each butterfly, Morisita's Index (Morisita, 1959) was computed from the formula:

$$I_m = N\frac{\sum n_i(n_i-1)}{\sum x\ (\sum x-1)}$$

Where N equals the number of samples; n_i equals the number of individuals in the i^{th} sample, and x equals the total of individuals in all samples. Values near 1.0 indicate a random pattern, values less than 1.0 a uniform pattern, and values greater than 1.0 an aggregated pattern. Morisita's Index is relatively unaffected by differences in means and is useful in comparing different groups (Southwood, 1967).

SAN BRUNO ELFIN

Distribution

Despite its occurrence in a region where lepidopterists have collected for over a century, the San Bruno elfin (Callophrys mossii bayensis) was not discovered until 1962 (Brown 1969).

The majority of colonies of the elfin occur on San Bruno Mountain, which is located on the San Francisco Peninsula at the northern end of San Mateo County, California. It is approximately 4 miles long, 1-2 miles wide, and runs from northwest to southeast. Elevation ranges from sea level at the eastern end on San Francisco Bay, to 1314' at the peak. An excellent description of the climate, geology, and flora of this area is provided by McClintock, Knight and Fahy (1968). On San Bruno Mountain, San Bruno elfin have been collected in six localities (Figure 1). These localities are generally situated on north-facing slopes where direct sunlight is minimal, thus moisture is conserved and the larval foodplant (Sedum spathulifolium) grows in abundance.

In addition, they have been found at three other locations (Figure 2). One locality is Milagra Ridge, just north of Sharp Park Road. Two colonies reside here: one along a dirt road near the south end of the ridge, at 400-500' elevation, and the second at the northwest end of the ridge on the abandoned military base property.

These colonies are about 4 air miles southwest of San Bruno Mountain. Another colony is on the northwest flank of Montara Mountain, near the Linda Mar School in Pacifica. A third colony, discovered during this survey, is on Whiting Ridge in the San Francisco Fish and Game Preserve. All of these colonies are situated on on north-facing slopes and located in the "fog belt."

Herbaria records indicated that there were several other locations in San Mateo, San Francisco, Marin, and Contra Costa counties where the larval foodplant occurs. I visited all of these localities but could only locate one new elfin colony, as mentioned earlier.

Coastal chapparal is the dominant vegetation on these slopes. Representative vegetation includes: Rhus diversiloba, Baccharis pilularis, Anaphalis margaritacea, Eriophyllum staechadifolium, Ceanothus thyrsiflorus, Artemisia californica, Erigeron glaucus, Arctostaphylos imbricata, A. montarensis, A. pacifica, A. uva-ursi, Erysimum franciscanum, Arabis blepharophylla, Achillea millefolium, Lomatium utriculatum, Ranunculus californicus, Castilleja affinis, Diplacus aurantiacus, Heracleum maximum, and Viola adunca.

Life History

The San Bruno elfin is univoltine. Adults eclose primarily during the month of March. A survey of specimens in California entomological collections indicates that occasionally adults can be captured as early as the last week in February. Adults are rarely seen on the wing after mid-April.

Oviposition occurs throughout March and early April. The white, oblate spheroid eggs are laid on the foliage of the larval foodplant, stonecrop (Sedum spathulifolium). Field observations indicated that the eggs are laid

Figure 1. Distribution of San Bruno elfin, San Bruno Mountain

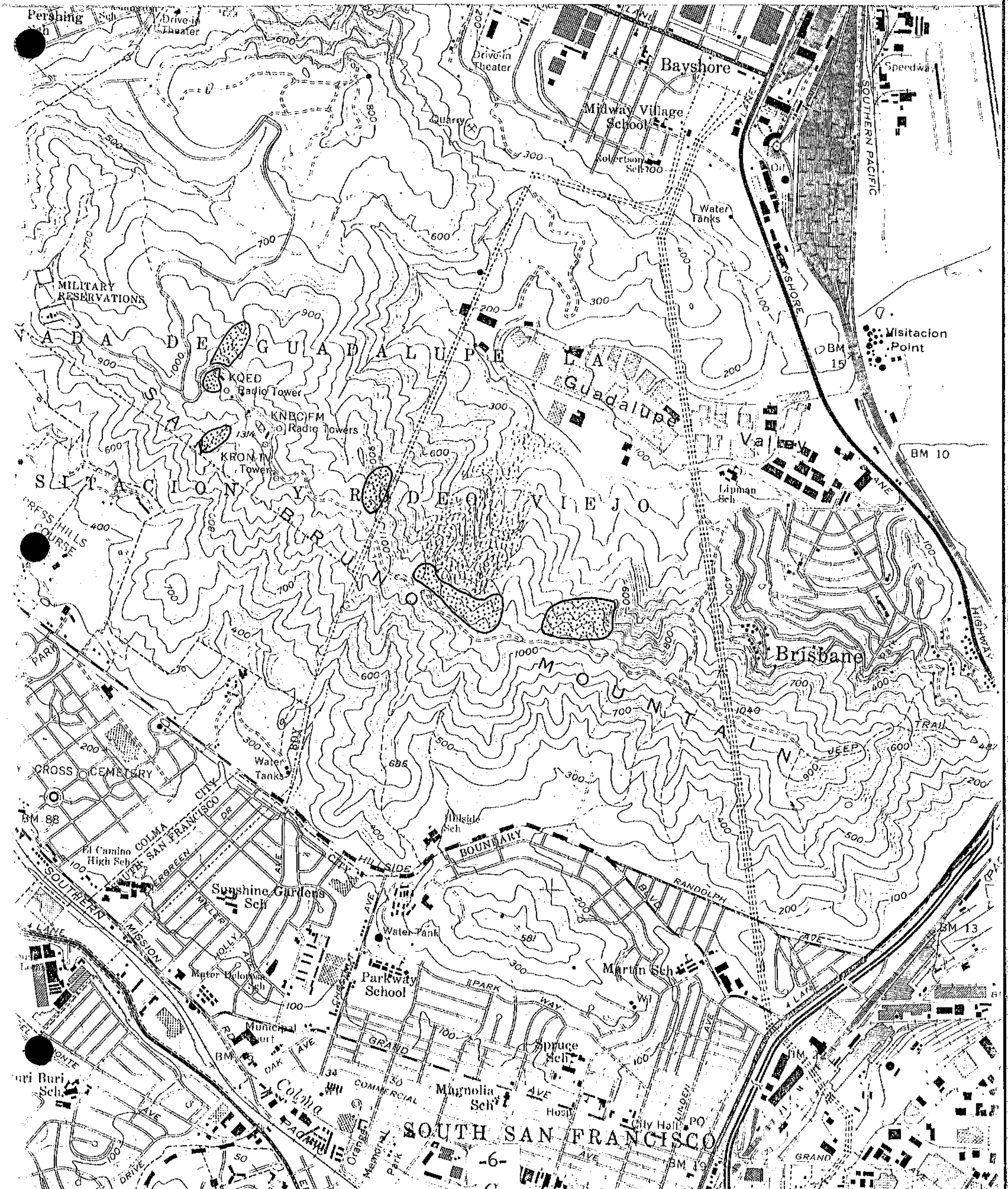
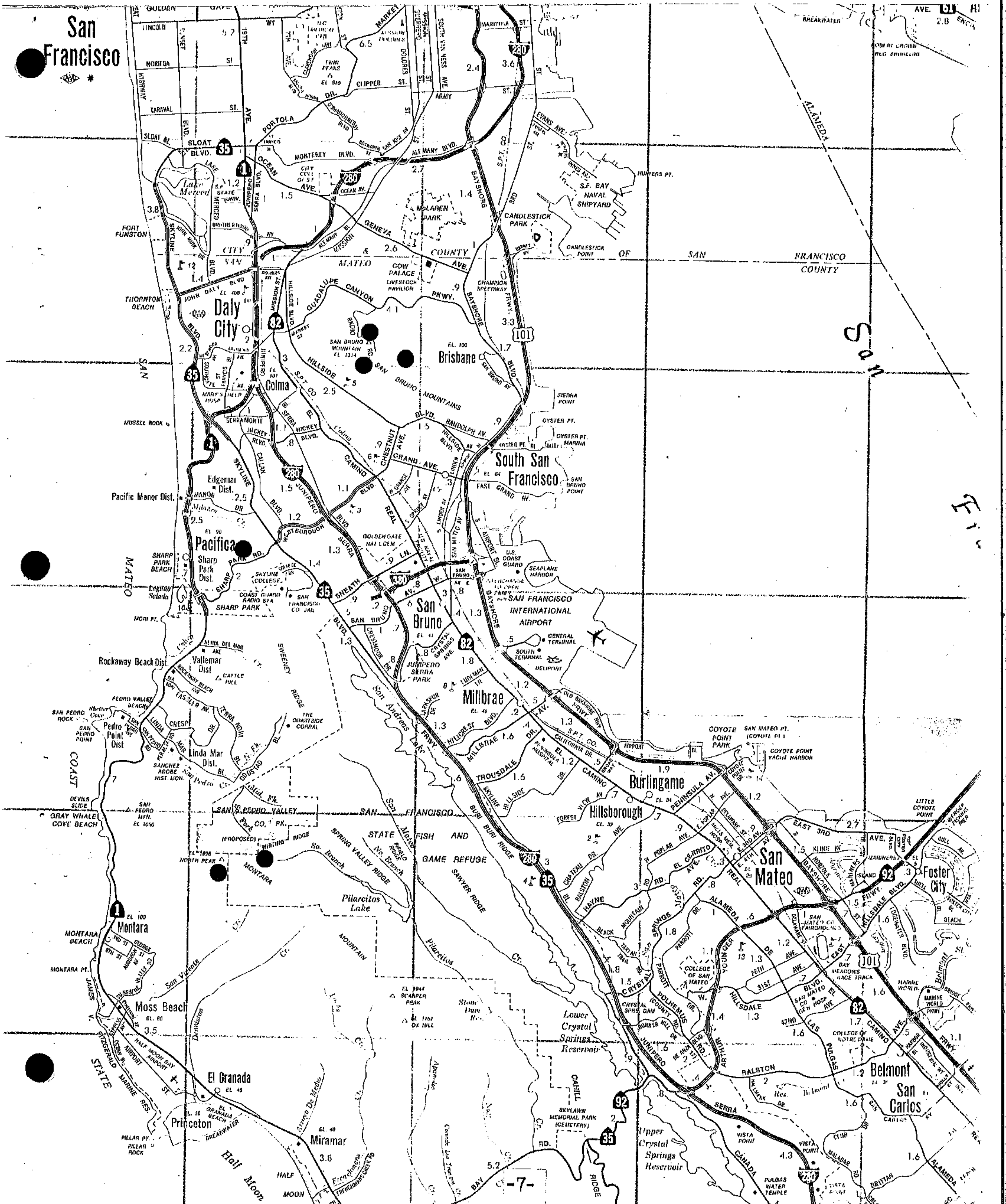


Figure 2. Distribution of San Bruno elfin, San Francisco peninsula



generally on the ventral surface of the foliage, though 17% were laid on dorsal or lateral surfaces.

Laboratory ovipositions were obtained by confining females singly in sandwich-size brown paper bags containing the larval foodplants. Cheese cloth was draped over the open end of each bag. The bags were illuminated by a 60-watt incandescent light bulb for 12-hour photoperiods. Twice daily, females were fed a 20% sucrose alfalfa honey water solution. Females were maintained in this manner until death. They were immediately fixed in Kahle's solution and later dissected to check for the presence of a normally formed spermatophore in the bursa copulatrix, indicating passage of sperm. Only pairings in which a spermatophore was present are included in this analysis. Eggs were recovered from the foodplant, sides of the bags, and cheese cloth daily, and placed loose in baby food jars. Larvae were removed as they hatched and placed on fresh stonecrop sprigs. After a week to 10 days, the remaining unhatched eggs were divided into two groups: infertile and nonviable. Nonviable eggs are those in which embryos develop, but fail to hatch. Data on egg fertility, embryo viability and percentage hatched are presented in Table 1. I follow Remington (1968) and Oliver (1972) in considering the percentage of fertile eggs as equal to the percentage hatched plus the percentage of nonviable eggs.

TABLE 1

Egg fertility, embryo viability and percentage hatched of San Bruno elfin.

Origin of Female		Number of Eggs	Fertile/ Laid	Hatched/ Fertile	Hatched/ Laid
Montara Mtn.	♀76C1	46	.91	.95	.87
	♀76C2	67	.88	.98	.87
Milagra Ridge	♀76C3	82	.98	.94	.91
	♀76C4	29	.90	1.00	.90
	♀76C5	64	1.00	1.00	1.00
San Bruno Mtn.	♀76C6	103	.95	.94	.89
	♀76C7	54	.98	.94	.93
	♀76C8	61	.91	1.00	.91
	♀76C9	47	.89	.93	.83
	♀76C10	88	.99	.97	.95
San Bruno Mtn.	♀77C1	31	.97	1.00	.97
	♀77C2	44	1.00	1.00	1.00
	♀77C3	92	.91	.96	.88
	♀77C4	59	1.00	1.00	1.00
	♀77C5	67	.97	.98	.96
	♀77C6	70	.90	.97	.87
	♀77C7	51	.98	.94	.92
	♀77C8	124	.96	.94	.90
	♀77C9	86	.97	.96	.93
	♀77C10	73	.99	.96	.95
	♀77C11	51	.85	.97	.83
	♀77C12	62	.95	.98	.94
	♀77C13	45	.88	.93	.82
	♀77C14	58	1.00	.98	.98

First and second instar larvae were reared in baby food jars on stonecrop sprigs. The larvae bore into the small succulent leaves in the center of the rosette. The larvae were voracious feeders. While feeding, they remained relatively motionless. Newly eclosed larvae were colored either red or yellow. They remained one color throughout their larval life.

By the time the third instar is reached in nature, the plants are beginning to bloom. *Sedum spathulifolium* blooms from April to June. In areas where the plant is abundant, the bright yellow flowers and red stems form a virtual carpet of color over the rocky terrain. The third instar larvae crawl up to the flowering stalks and feed to maturity on the flowers. Brown (1969b) states that the color of the mature larvae depends upon the color of that part of the foodplant on which it feeds. This hypothesis implies that the larva has the ability to change color depending upon its substrate. This is not true. The larvae possess two distinct color morphs, red and yellow, plus an intermediate light orange. Data on larval colors are presented in Table 2. If the light orange and yellow colors are lumped into one class, a 3:1 ratio of red to yellow is apparent, thus suggesting a simple allelic genetic expression of the two colors.

TABLE 2

Color ratios of San Bruno elfin larvae.

Female Rearing No.	Red	Yellow	Color Ratio
76C1	26	9	2.89:1
76C2	40	10	4.00:1
76C3	50	15	3.33:1
76C4	14	6	2.33:1
76C5	42	14	3.00:1
76C6	60	18	3.33:1
76C7	31	14	2.21:1
76C8	37	11	3.36:1
76C9	30	9	3.33:1
76C10	57	19	3.00:1
			$\bar{x}$ = 3.08:1
77C1	19	5	3.8:1
77C2	23	6	3.83:1
77C3	32	12	2.67:1
77C4	26	8	3.25:1
77C5	39	11	3.55:1
77C6	47	18	2.61:1
77C7	44	20	2.20:1
77C8	33	10	3.3:1
77C9	30	10	3.0:1
77C10	56	19	2.95:1
77C11	28	10	2.8:1
77C12	35	11	3.18:1
77C13	21	9	2.33:1
77C14	25	11	2.27:1
			$\bar{x}$ = 2.86:1

The third and fourth instar larvae are myrmecophilous. Several different ant species tend the larvae, though each species tends only one color morph of the larvae (Table 3). Table 15 presents the frequency of myrmecophilous occurrences in the field. As evidenced by laboratory rearing, the larvae are facultative myrmecophiles.

TABLE 3

Relationships of ant species and larval color morphs of San Bruno elfin.

Ant Species	Color of Larvae Tended
Formica fusca L.	Red
Lasius alienus (Forst.)	Red
Prenolepsis imparis (Say)	Red
Tapinoma sessile (Say)	Red
Formica subpolita Mayr	Red
Monomorium minimum (Buck.)	Red
Leptothorax sp.	Red
Formica integroides Em.	Yellow

The larvae possess a honeydew gland on the posterior portion of the abdomen which exudes droplets of honeydew when the larvae are "massaged" by the antennae of the ants. In this symbiotic relationship, presumably the ants protect the larvae from parasites and predators. Nevertheless, a tachinid fly, Aplomya theclarum (Scudder), is very successful at parasitizing the larvae. Table 4 details the percentages of larval parasitism by A. theclarum in field collected samples. Note the differences between the percent of parasitism in the red and yellow color morphs.

Prior to pupation, the fourth instar larvae spend about 3 days in a pre-pupal stage. They are motionless during this period and contract considerably in length. This stage occurred after the larvae crawled from the flower heads to the base of the rosettes. Pupation occurred among the loose soil and litter of the roots. Initially the pupae are pink, but they soon transform to a chocolate-brown color. The pupae range in length from 0.7 to 0.9 cm.

TABLE 4

Percent of elfin larval parasitism by *Aplomya theclarum*

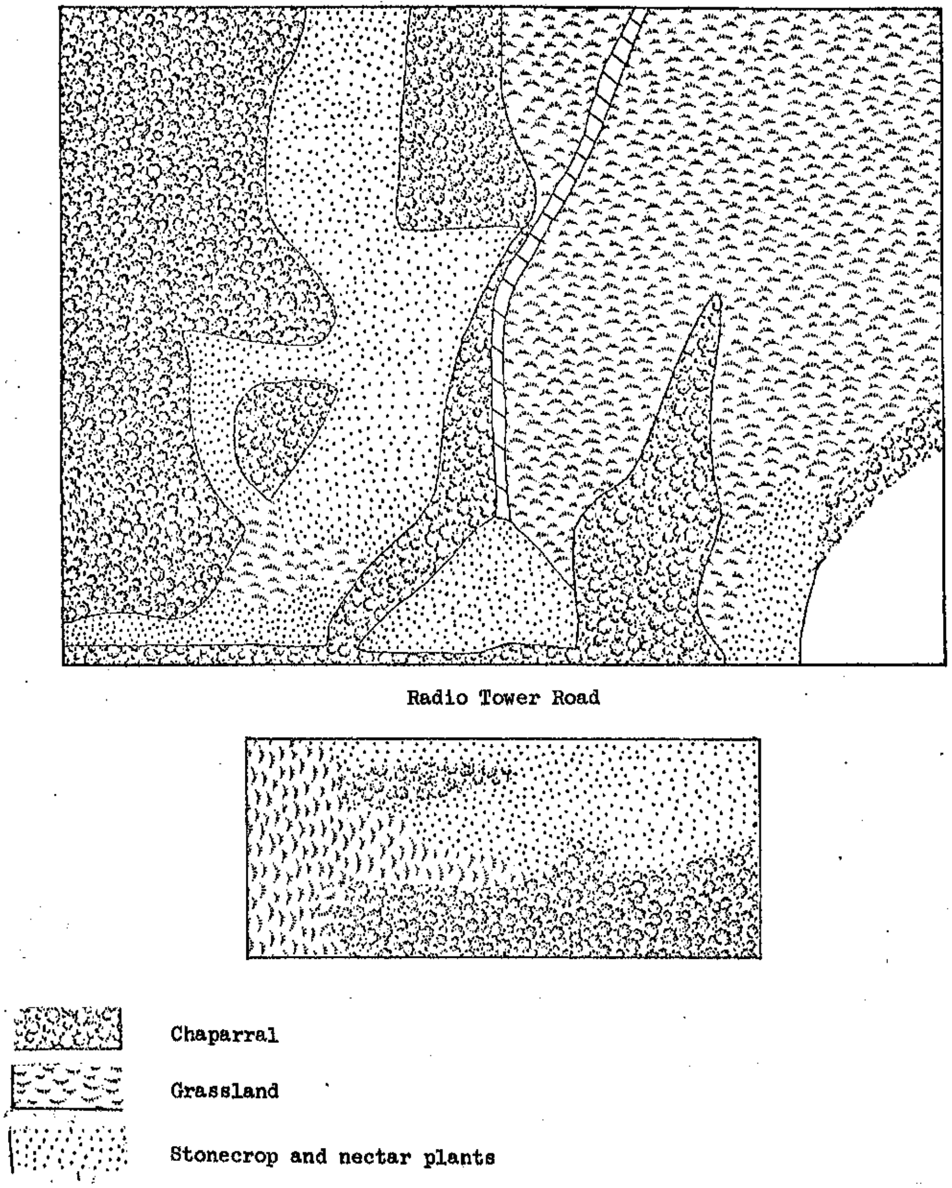
Rearing No.	No. of Red Larvae	Percent Parasitized	No. of Yellow Larvae	Percent Parasitized
76D1	24	17	7	00
76D2	59	14	16	06
76D3	34	26	4	25
76D4	17	35	1	00
76D5	62	56	12	17
76E1	60	73	18	33
76E2	19	63	7	14
76E3	33	64	13	23
76E4	39	51	14	21
76E5	44	43	9	22
76E6	12	58	16	31
76E7	21	62	2	00
	424	$\bar{x}$ = 47	192	$\bar{x}$ = 16
77D1	12	08	5	20
77D2	26	19	14	14
77D3	18	22	9	00
77D4	44	36	17	24
77D5	21	48	12	33
77D6	38	37	18	17
77E1	52	46	21	10
77E2	20	55	8	13
77E3	41	44	16	19
77E4	36	72	14	14
77E5	29	62	23	26
77E6	33	73	13	31
77E7	36	75	14	21
77E8	24	79	6	33
77E9	16	69	7	14
	446	$\bar{x}$ = 50	197	$\bar{x}$ = 19

Population Study

Study site and sampling

The study site was a steep, north-facing slope near the peak of San Bruno Mountain. Chaparral with an influx of grassland comprised the dominant vegetation. Figure 3 is a vegetational map of the site. A grid of 16 m X 16 m quadrates was laid.

Figure 3. Vegetational map of the San Bruno Mountain study site



Crocker Land Company, Brisbane, California, is the current owner of the property. San Mateo County has filed a condemnation suit against Crocker Land Company to obtain 1,250 acres for a county park. The study site colony is within the proposed county acquisition.

Marking techniques were described in the introduction.

Sampling was initiated each day at 0800 to 0900 PST and terminated at 1300 to 1430 PST.

A comparison of the observed and poisson distributions for the number of successive recaptures is shown in Table 5. A test of goodness of fit shows no significant deviation of the expected from observed values for the range of 0-4 successive recaptures. This agreement means that collecting and marking individuals did not alter their probabilities of survival.

TABLE 5

Distribution of the observed number of recaptures per number of repeats and their expected poisson values for San Bruno elfin.

Males:

Number of Recaptures	Observed (f)	Expected ($\hat{f}$)
0	93	92.09
1	37	39.23
2	10	8.36
3	1	1.19
4	0	0.13

$\bar{y} = 0.426$

Females:

Number of Recaptures	Observed (f)	Expected ($\hat{f}$)
0	76	74.17
1	26	28.56
2	5	5.50
3	2	0.71
4	0	0.07

$\bar{y} = 0.385$

Results

Aging and sex ratio

San Bruno elfin is univoltine. Generally, adult males eclose earlier in the flight season than do females. Collectors desirous of perfect specimens usually wait until a week or so after sighting the first males to obtain scale-perfect speciemns of both males and females. Also, wear damage to these butterflies' wings is believed to accumulate gradually with age after eclosion.

The data supports both beliefs (Table 6). The sex ratio does shift from a preponderance of males early in the flight season to a greater fraction of females later on. Day 7 does not conform with the general trend, though this is probably due to the occurrence of cold, wet weather for the 2 day interval between days 6 and 7. On day 7, the new individuals which were marked were mostly fresh, indicating that the inclement weather had probably caused the death of many of the individuals we handled on days 1-6. Nevertheless, the data support the belief that males eclose earlier in the flight season than do females.

TABLE 6

Sample-based sex ratios and wear ratings of males and females of adult San Bruno elfin in relation to the progress of the flight season.

Date	Day	♂:♀	Percent ♂:♀	♂ Average Wear	♀ Average Wear
14 March	1	2:0	0:	2.00	—
18 March	2	15:5	75:25	2.27	2.00
19 March	3	53:33	62:38	2.85	2.36
20 March	4	63:34	65:35	2.95	3.18
21 March	5	16:19	45:55	3.19	3.05
22 March	6	7:14	33:67	3.14	2.71
25 March	7	19:19	50:50	2.31	2.37
26 March	8	19:24	44:56	3.37	3.08

The average wing-wear rating does increase relatively smoothly throughout the period of study. Females lag behind males, as would be expected from the eclosion lag. Thus samples with a high proportion of males and a low average wear rating must indeed be younger, and those with more females and/or higher wear ratings must be older, in the course of the flight season. It follows that an individual with a high wear rating is likely to be older than one with a low rating, although some elfins fresh when first captured, were recaptured several days later with no change in wear rating over that time.

Daily numbers

Table 7 shows estimates for the number of males and females and the estimated standard errors. The large fluctuations were puzzling, since field experience indicated that the number of butterflies present in the study site increased rapidly in the early part of the flight period, remained more or less constant for a few days, then slowly declined until the insects disappeared altogether. The marked increases and decreases, as much as 2-3 times over a one day period, did not seem to coincide with my observations of the population. Some of the reasons for their apparent unreliability, however, may be found by examining the various assumptions that underlie the methods of capture-recapture analysis which are discussed by Southwood (1966). Although the Jolly method is based on more reasonable assumptions than various deterministic models, it suffers from many of their limitations.

TABLE 7

Population parameters of San Bruno elfin estimated from Jolly's stochastic model of multiple recapture data.

Males:

Day	Alpha	M	N+1.96SE	PHI+1.96SE	B+1.96SE
1	0.0000	0.00	0.0 + 0.0	2.417 + R	0.0 + 0.0
2	0.1176	4.83	41.1 + 39.0	.933 + 0.430	113.9 + 107.2
3	0.1273	19.69	154.7 + 104.8	.733 + 0.317	-.8 + 75.7
4	0.4407	49.60	112.6 + 47.4	1.441 + 1.901	109.8 + 208.8
5	0.4375	119.00	272.0 + 383.1	.430 + .744	29.8 + 148.2
6	0.3750	55.00	146.7 + 220.0	1.083 + 1.687	75.1 + 232.4
7	0.2778	65.00	234.0 + 305.2	0.0 + 0.0	0.0 + 0.0
8	0.4815	0.00	0.0 + 0.0	0.0 + 0.0	0.0 + 0.0

Females:

Day	Alpha	M	N+1.96SE	PH1+1.96SE	B+1.96SE
1	0.0000	0.00	0.0 + 0.0	2.250 + R	0.0 + 0.0
2	0.4000	4.50	11.2 + R	5.704 + R	-18.4 + 46.8
3	0.9355	42.78	45.7 + R	0.615 + 0.309	17.8 + 14.5
4	0.6000	27.56	45.9 + R	0.661 + 0.444	-9.2 + 10.0
5	1.1111	23.50	21.1 + R	0.667 + 0.619	3.9 + 5.4
6	0.8333	15.00	18.0 + R	0.650 + 0.721	29.9 + 37.5
7	0.2500	10.40	41.6 + 44.4	0.000 + 0.000	0.0 + 0.0
8	0.6667	0.00	0.0 + 0.0	0.000 + 0.000	0.0 + 0.0

Alpha = Proportion of marked animals
M = Total marked population
N = Total population
Phi = Probability of survival
B = Number of new animals joining the population

Since the study site is 3.07 hectares, the peak density of the population is very high, even in a drought year such as 1977. Upon examining the maps of the male and female movements (Figs. 4 and 5), it is obvious that the adults rarely stray from quadrates containing stonecrop. If we consider the density in only those quadrates within the study site where individuals were captured or recaptured, the peak density is extraordinarily high (Table 8).

TABLE 8

Density of San Bruno elfin at the study site.

Sex	Density of Entire Study Site	Density in Only Occupied Quadrates
Males	89.75/ha	359.00/ha
Females	41.82/ha	147.59/ha

A total of 202 males and 102 females were marked at the study site. Even though the sex ratio is apparently skewed, data from laboratory rearings have given positive evidence that the actual sex ratio is 1:1 (Table 9). This deviation from a 1:1 ratio could be caused by several reasons. Nonetheless, the most reasonable explanation is to assume that the adult sex ratio is essentially 1:1 and the observed discrepancy arises from behavioral differences between the sexes, as is frequently observed in many other species.

TABLE 9

Sex ratios of laboratory reared broods. Statistical significance determined by Chi-square test for goodness of fit to a 1:1 sex ratio (ns=nonsignificant; $.05 > p > .01$).

♀ Rearing No.	♂♂	♀♀	Sex Ratio	X^2
76C1	19	16	1.00:0.84	ns
76C2	23	27	1.00:1.17	ns
76C3	30	35	1.00:1.17	ns
76C4	12	8	1.00:0.67	ns
76C5	30	26	1.00:0.87	ns
76C6	36	42	1.00:1.17	ns
76C7	25	20	1.00:0.80	ns
76C8	24	24	1.00:1.00	ns
76C9	22	17	1.00:0.77	ns
76C10	40	36	1.00:0.90	ns
	261	251	1.00:0.96	

Male elfins perch on bushes and other substrates which on the average are higher above the ground than perches of the females. The males dart out at passing objects, whereas the females remain sedentary. Different males occupy the same perches from day-to-day. This is evidenced by the movement patterns and vagility figures for the males. Females are less vagile. Thus, there is a large turnover of males at preferred perches, resulting in a large number of males being marked. But because they occupy a given perch for only a day, and move greater distances, a smaller percentage of males are recaptured. Since females are less vagile, a higher percentage of them are recaptured. For example, of the 202 males marked, 51 (25%) were recaptured at least once; however, of 102 females marked, 34 (33%) were recaptured. Five percent of the males marked were recaptured 2 or more times, while 6% of the females were recaptured 2 or more times.

TABLE 10

Number of individuals marked, percent of individuals recaptured, and number of recaptures for individuals recaptured at least once for San Bruno elfin.

Sex	Number Marked	Percent Recaptured	Average Number of Recaptures
Male	202	25.2	1.22
Female	102	33.3	1.21

A slight lag in emergence times for females may also contribute to the sex ratio discrepancy. The first females were not observed until 4 days after the males had begun to fly. A greater proportion of the total daily catch is female toward the end of the flight season.

In a univoltine butterfly such as San Bruno elfin, the size of the potential breeding population for any one year will be the total number of individuals involved in the flight. The total number of insects caught and marked during that period will obviously represent the minimum size of the population (Brussard, et al., 1974).

Residence

Table 11 presents day-specific residence and loss rates and mean expected residence times (Cook, et al., 1967) for both sexes.

TABLE 11

Residence rates ($\hat{\phi}$), mean expected residence, loss rate and estimates of total brood number for San Bruno elfin.

Sex	$\hat{\phi}$	Mean Expected Residence (days) $-(\ln \hat{\phi})^{-1}$	Day-specific Loss Rate	$\Sigma \hat{N}i$	Estimated Total Brood Numbers
Males	0.724	3.1	0.276	999.0	275.72
Females	0.674	2.5	0.326	394.05	128.46

In most butterfly species, the female lives longer than the male. This happens because males can fulfill their function of mating rapidly, whereas the location of suitable larval foodplants and the maturation of eggs before oviposition are more time-consuming processes. Data indicate that females live longer than males. But because the males dispersed farther, their emigration would tend to lower survival rates more than females. Thus the lifespans of both males and females may be approximately equal.

Dispersal Analysis

Vagility

Males flew further, and crossed distances in slightly faster times than did females (Table 12). Among butterfly species females usually are more vagile, presumably the result of larval-foodplant-searching behavior (Scott, 1976). As evidenced by San Bruno elfin, there are some exceptions (Ehrlich, 1965; Brussard and Ehrlich, 1970). In this case, the greater vagility of the males may be due to searching for suitable perches and the investigation of other individuals which enter the "territory" of each male. Females rarely investigate other individuals when their paths cross.

TABLE 12

Vagility parameters for San Bruno elfin.

Vagility Parameter	Male	Female
Mean T (days)	2.78	2.67
Max T (days)	8.00	6.00
Mean t_i (days)	2.27	2.03
Mean R (meters)	49.2	40.2
Max R (meters)	168.0	112.0
Mean D (meters)	51.2	44.0
Max D (meters)	168.0	136.0
Mean d_i (meters)	41.74	35.38
Mean V (m/day)	27.0	26.4
Max V (m/day)	128.0	112.0
Mean v_i (m/day)	25.2	25.74

Movement patterns for individuals were also examined by noting the location of consecutive captures. Movement was classified as local if the captures were made in the same or adjacent quadrates. A move to any other quadrate would be classified as long. Local and long-distance movements for males were approximately equal (Table 13). Females made 1.5 times more local than long-distance movements. Thus, it is easy to see that the males are more vagile. Nonetheless, both sexes are very sedentary when compared to the vagility figures for other butterflies (Scott, 1975). Both Brussard, et al. (1974) and Hafernik (1976) used 70 m as the cut-off point for local and long-distance movements for Euphydryas editha (Boisduval) and Junonia coenia (Hubner) respectively. The longest movement by a San Bruno elfin was 168 m. This movement was accomplished by a male. Only 17 individuals flew over 70 m.

TABLE 13

Local versus long moves for San Bruno elfin.

Sex	Local	Percent	Long	Percent
Male	30	51	29	49
Female	24	60	16	40

Perhaps the most interesting conclusion to be drawn from the above is that movement of individuals within a colony is extremely limited. Also, it is highly unlikely that individuals are actively moving from one colony to another. Thus, the exchange of genetic information among colonies is probably very limited. The reproductive biology seems to favor rapid insemination of newly emerged females by local males followed by oviposition virtually in situ.

Dispersion

San Bruno elfin on San Bruno Mountain is restricted in its distribution to areas where Sedum spathulfolium grows. In order to determine and compare the micro-distribution of the San Bruno Mountain population, Morisita's Index was computed.

Dispersion indices were calculated for both males and females. Samples consisted of 120 quadrates, each 16 m X 16 m. The number of individuals recorded in each quadrate equaled the number of individuals captured and recaptured in that quadrate during the 12-day sampling period.

Male and female San Bruno elfin showed little difference in dispersion patterns (Figs. 4 and 5). Morisita's index (Table 14) revealed that males are slightly more aggregated than females. While the difference is slight, perhaps it can be explained as the result of different selective influences. Males can best increase their genetic contribution to the next generation by mating as often as possible. They thus select areas with the highest probability of encountering a receptive female. Females, on the other hand, once they have mated, can best increase their genetic contribution by laying as many eggs as possible. Their time is mostly spent searching for suitable oviposition sites and their dispersion is thus less contagious. But, since the foodplants are clumped (Fig. 4), females spend a comparatively long time around each clump ovipositing on several different individual plants, and thus spend less time in searching flight between clumps. This conclusion is based upon the data of female vagility parameters. This accounts for the fact that the females were captured near their foodplants and have a higher I_m.

TABLE 14

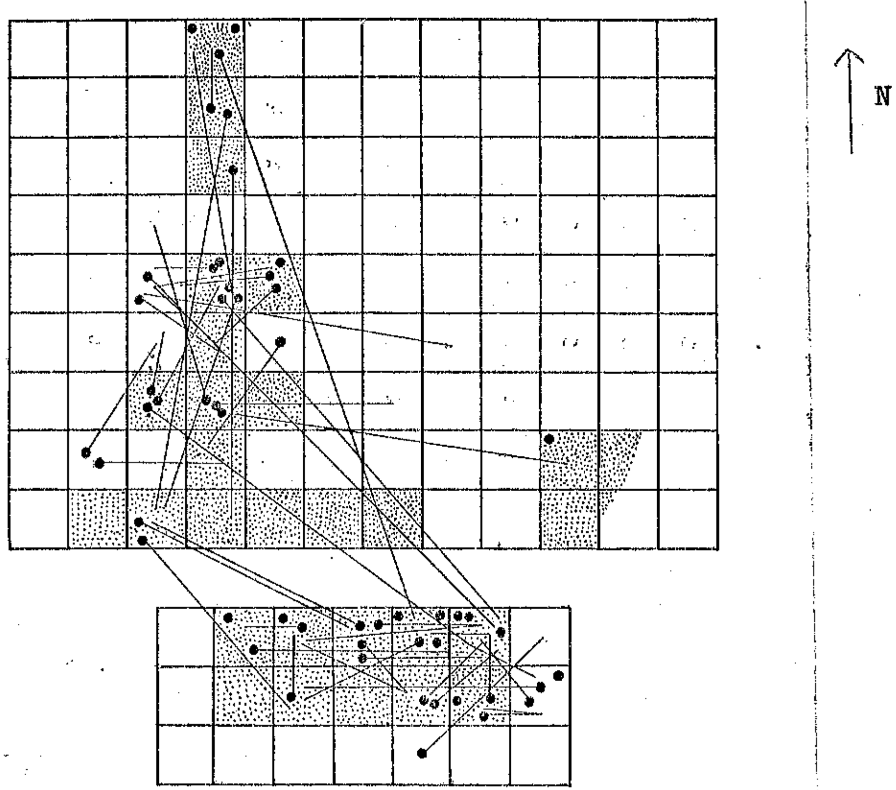
Indices of dispersion for San Bruno elfin.
All groups are significantly aggregated ($p > .001$).

Sex	I_m
Male	5.45
Female	5.12

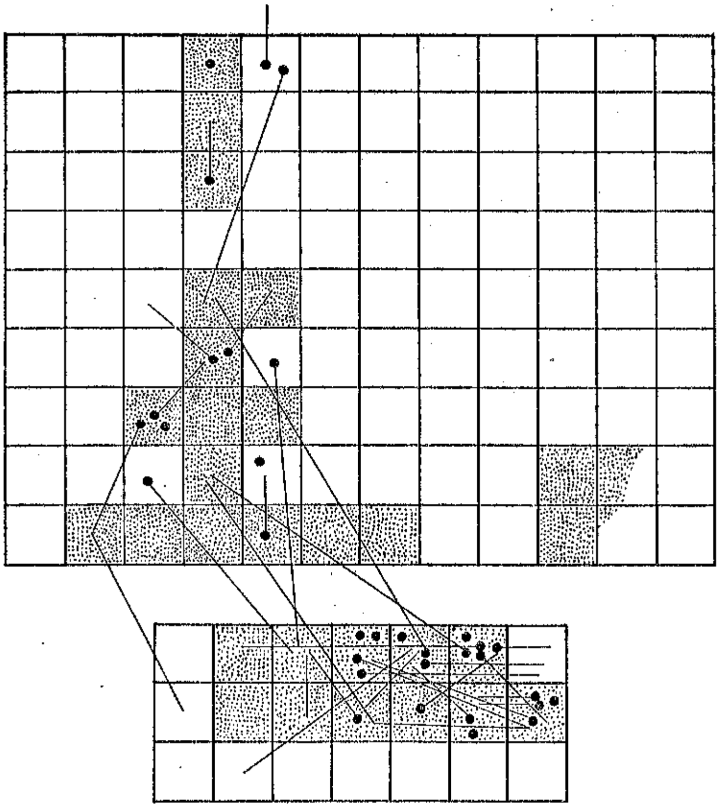
This pattern of dispersal has both advantages and disadvantages. The possibility of laying a large number of eggs in a short time is energetically efficient and no doubt produces the most eggs laid per female. It also allows a greater possibility of predation and parasitism and an increased likelihood of disease than the strategy of ovipositing on widely spaced foodplants, as

Figures 4 and 5. Movements of adult San Bruno elfin on San Bruno Mountain study site. *Sedum spathulifolium* occurs in stippled quadrates.

Male



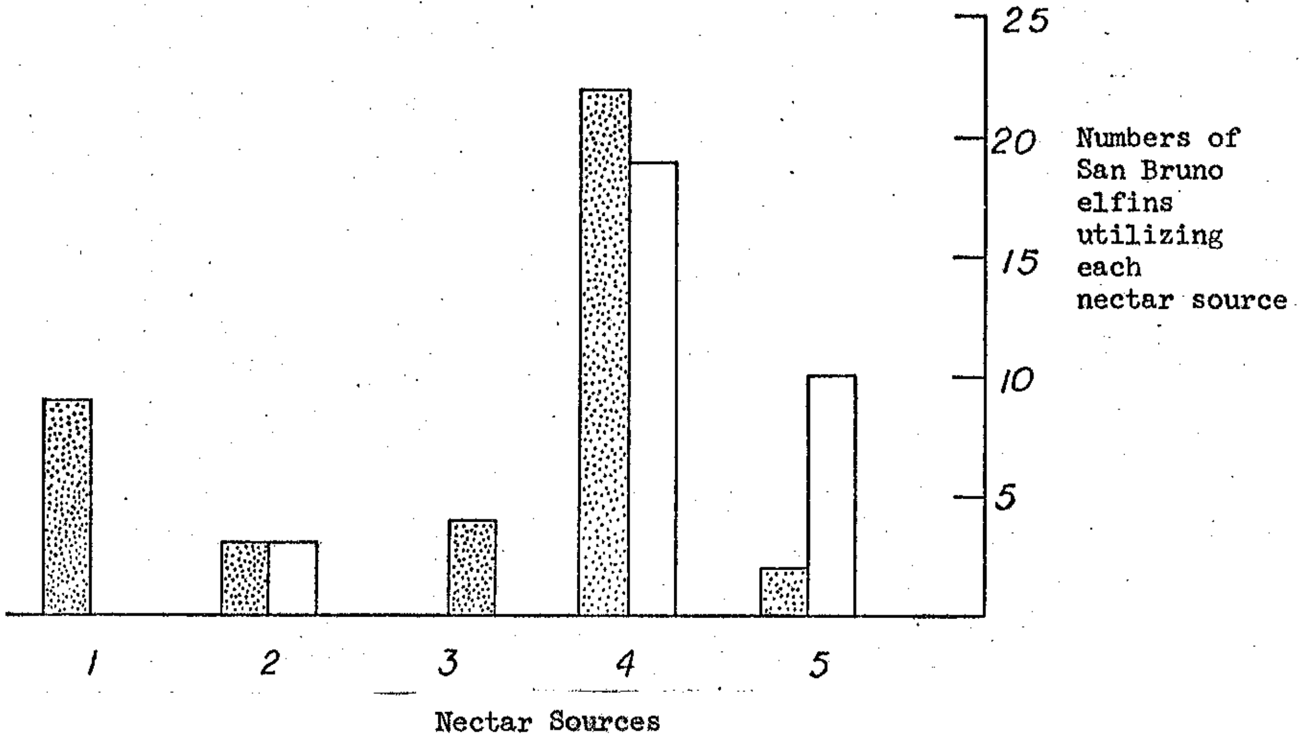
Female



does Junonia coenia (Hafernik, 1976). Unlike San Bruno elfin, no correlation was found between micro-distribution and foodplants for butterflies from subalpine Colorado (Sharp, et al., 1974). These data were primarily based upon observations on males, however, whose behavior would not be expected to be as closely tied to their foodplants. The aggregation of San Bruno elfin males and their foodplant is unique among butterflies thus studied.

Nectar sources are known to play an important role in the direction and length of movements in populations of some butterflies (Gilbert and Singer, 1973). Several species of plants were utilized as nectar sources (Fig. 6). Lomatium utriculatum (Nuttall) Coulter & Rose is the primary nectar source for both sexes. Secondary nectar sources are different depending upon the sex. The micro-distribution of nectar sources did not greatly affect micro-distribution of adults as they only visited flowers interspersed with the larval foodplants.

Figure 6. Nectar sources of San Bruno elfin, San Bruno Mountain

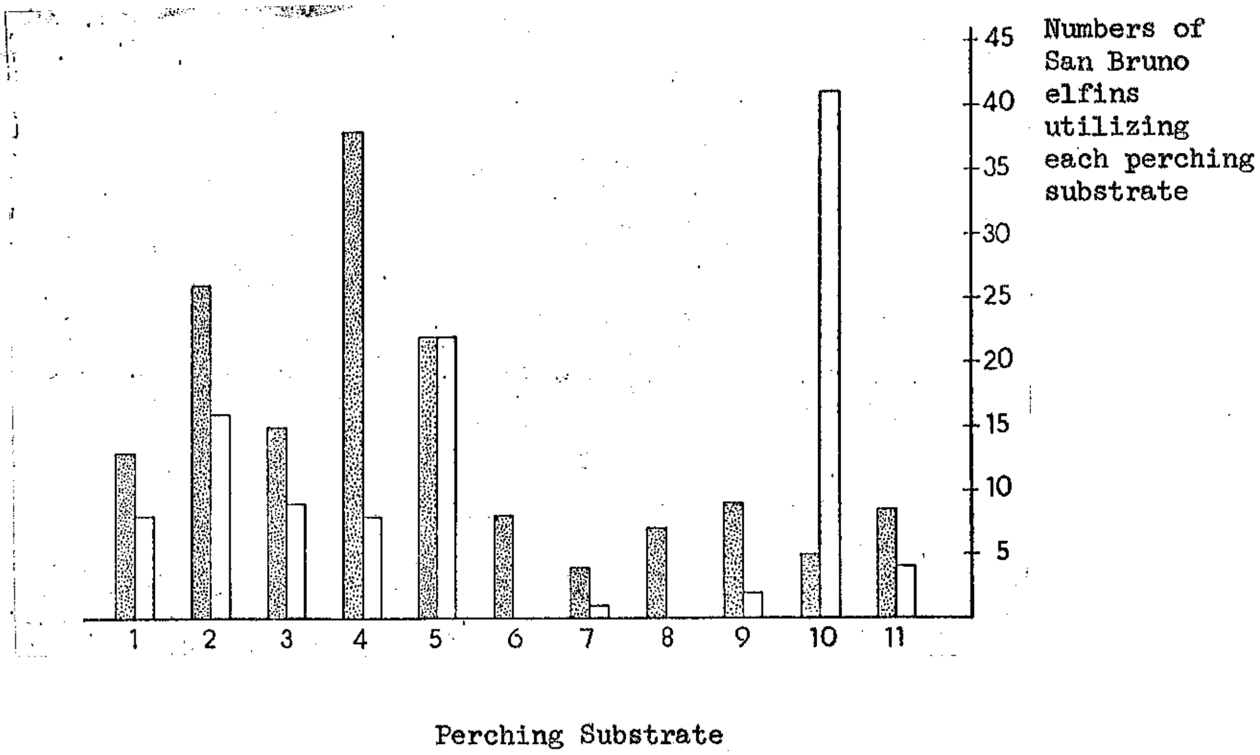


Note:
1. Achillea millefolium
2. Arabis blepharophylla
3. Erysimum franciscanum
4. Lomatium utriculatum
5. Ranunculus californicus

Open bars refer to females; stippled bars to males.

Although males and females exhibited similar highly aggregated dispersion patterns, there was little spatial overlap in their micro-distributions. This was due to sexual differences in perching site preference. Figure 7 depicts perching site preferences. These differences seem to be associated with differences in preferential perching substrate, which results in perching at different heights. Males preferred perches such as Eriophyllum and Baccharis which were 12-24" above ground, while females preferred Sedum and bare ground, which were 0-6" above ground. Presumably, the males have better vantage points at higher heights.

Figure 7. Perching substrates of San Bruno elfin, San Bruno Mountain



Note: 1. *Artemesia californica*
2. *Baccharis pilularis*
3. Bunch grass
4. *Eriophyllum staechadifolium*
5. Ground or bare rocks
6. *Lupinus variicolor*
7. *Marah fabaceus*
8. *Rhus diversiloba*
9. *Scrophularia californica*
10. *Sedum spathulifolium*
11. Miscellaneous

Open bars refer to females; stippled bars to males.

Activity

Fifteen individuals were captured 3 or more times. When the subareas of capture of these butterflies were plotted on a map, the areas enclosed by their capture points indicated that the spatial distribution of individual male elfins overlapped considerably. Likewise, the spatial distribution of female elfins also overlapped.

In order to estimate the size of the "home ranges," or the proportion of the available habitat utilized by individual males and females during their adult life, I first fixed the center of activity, or geometric center of all capture points, after the method suggested by Hayne (1949) and modified by Brussard, *et al*. (1974). The center of each 16 m x 16 m quadrate was designated as the capture point for each specimen captured in that plot. Then x and y coordinates were assigned to each plot center. Thus, the initial capture point and each subsequent recapture point received two values, according to the plot center on the coordinate grid. The means for the horizontal and vertical values were calculated, and these fixed a point, or the center of activity.

Next, I calculated the standard area of activity (SA), or the average area over which a male or female elfin would be expected to range. This was done by measuring on a map the distance in meters between the calculated center of activity and the centers of the plots in which a butterfly was captured. A standard range radius (r_s) was calculated from the formula:

$$r_s = \sqrt{\frac{\Sigma r_i^2}{N-1}}$$

where r_i is the distance in meters between the center and each recapture point and N is the number of measurements. The SA in hectares, then, is equal to: $\pi(r_s^2)/10^4$.

The SA's for males ranged from 0.0-8.17 ha with a mean of 2.31 ha. Female SA's ranged from 0.12-2.11 with a mean of 0.87 ha. Thus, each male and female utilizes a very small portion of the area which potentially can be occupied by the population.

Perching sites were distributed throughout the larval and adult feeding areas, but several "preferred" sites were noted. These were particularly common near adult feeding areas.

The perching sites resemble leks of other animals. True leks consist of areas used for communal male displays and mating, and are removed from feeding areas (Wilson, 1975). Communal displays are thought to increase the volume and attractiveness of the male signal, thereby increasing the attraction of females. Leks are often associated with features of the habitat that allow easy orientation such as open spaces, prominent high or low places, or other distinctive locations. In addition, males of lek-forming species often establish territories within the lek.

Males do not show either individual or communal display behavior. Instead they are rather inconspicuous when perching because their wings are kept closed over their back. Any attraction of females to the perching site must result primarily from orientation to specific features of the habitat. This is no doubt the case for butterflies which have mating arenas on hilltops (Shields, 1967; Scott, 1968). In the case of the San Bruno elfin, the cue may be an interface between low and tall vegetation, which is a common characteristic of perching sites throughout its range. The separation of mating and feeding areas often results from selection to reduce predation pressure (Wilson, 1975; Spieth, 1968). But predation pressure seems an unlikely explanation for the evolution of San Bruno elfin perching behavior. If anything, the aggregation of males in perching areas coupled with their conspicuous investigatory behavior, in which they fly out at potential predators as well as mates, should increase predation of males.

Maintenance of perching sites provides an efficient means for encountering males. Restriction of mating to localized portions of the habitat reduces the time between eclosion and mating for females, thereby increasing their fecundity. It also increases the probability of encountering a receptive female for males.

The investigative flights of San Bruno elfin males led Emmel and Ferris (1972) to classify elfins as "pugnacious" and to infer that they were defending a territory. My studies indicate that they are not territorial in the narrow sense of the term. Males do not establish and defend fixed territories, rather they select perches within favorable areas. They maintain an investigative space of 5-8m^2 about them. This space shifts as they change perches. Certain perching sites are obviously best as different males will occupy the same site, often the same branch, on different days.

Although permanent territories are not established, the maintenance of an individual, shifting investigative space does fall within the broad concept of territoriality presented by Wilson (1975).

Males will investigate other males which enter their "territory." Male-male encounters are characterized by vertical flights that leave both participants near the place of original contact. Male-female encounters are briefly vertical, then horizontal with the male chasing the female.

Threats To Survival

As long as the habitat of the San Bruno elfin is not destroyed, the butterfly should be able to survive. Unfortunately, a large portion of the already minuscule gene pool of the elfin is threatened with extirpation.

Presently, a large portion of San Bruno Mountain is planned for development as a San Mateo County Park. Much of the remainder of the land would become homesites and commercial developments. Even though an environmental impact report was prepared (Davis, et al., 1975), no attempt was made to survey and analyze the invertebrate fauna. As a result, the developments have been proposed without consideration for the habitat destruction and other deleterious effects upon the elfin.

The environmental impact report (EIR) master-plan was approved by the San Mateo County Board of Supervisors on March 8, 1977. Currently, they are awaiting cost estimates on plans A and B (the EIR estimated costs only for plan C), before deciding upon which plan of development to pursue. If either plan C or B is approved, elfin colonies will succumb to picnic sites, new trails, road widening, and the location of a nature museum. The planting of trees in some ravines could shade-out the stonecrop in a few canyons.

There is an active quarry below one of the larger elfin colonies. At this time it poses no threat to the elfin, but future expansion of the quarry could destroy elfin habitat.

Much of the mountain burns annually during the dry summer and fall months. In recent years, an average of 49 fires annually have occurred (Arnold, in prep.). Most of the chaparral plants in the elfin habitat are characterized by their ability to regenerate after fire.

The military base on Milagra Ridge is abandoned, but I have not been able to learn of any future plans for the land. The Montara Mountain colony would be threatened by the proposed rerouting of Calif. Hwy. 1. The colony at the San Francisco Fish and Game Preserve is protected from habitat destruction by man.

Essential Habitat

The critical habitat as proposed by the U. S. Fish and Wildlife Service is largely in error (Federal Register, 1977). The area supporting most of the elfin colonies is north of the ridge line, not south (Fig. 1). Figure 8 shows the location of these colonies relative to existing and proposed developments. The land where the elfin colonies occur on San Bruno Mountain is owned by Crocker Land Company of Brisbane, California.

Although the best colonies of the elfin occur on San Bruno Mountain, the critical habitat proposal should also include the other colonies. The Whiting Ridge land is owned by the city and county of San Francisco, as this land is part of their watershed. The Montara Mountain land is owned by Deane & Deane, Inc. Milagra Ridge is owned by the U. S. Coast Guard. Location of these colonies are shown in Figure 2.

Management Recommendations

To ensure the survival of the San Bruno elfin, the following conditions are necessary:

1. *Sedum spathulifolium* must be present, consisting of approximately 25-50% of the total ground cover in an area no smaller than 12 ha (the size of the smallest known elfin colony.

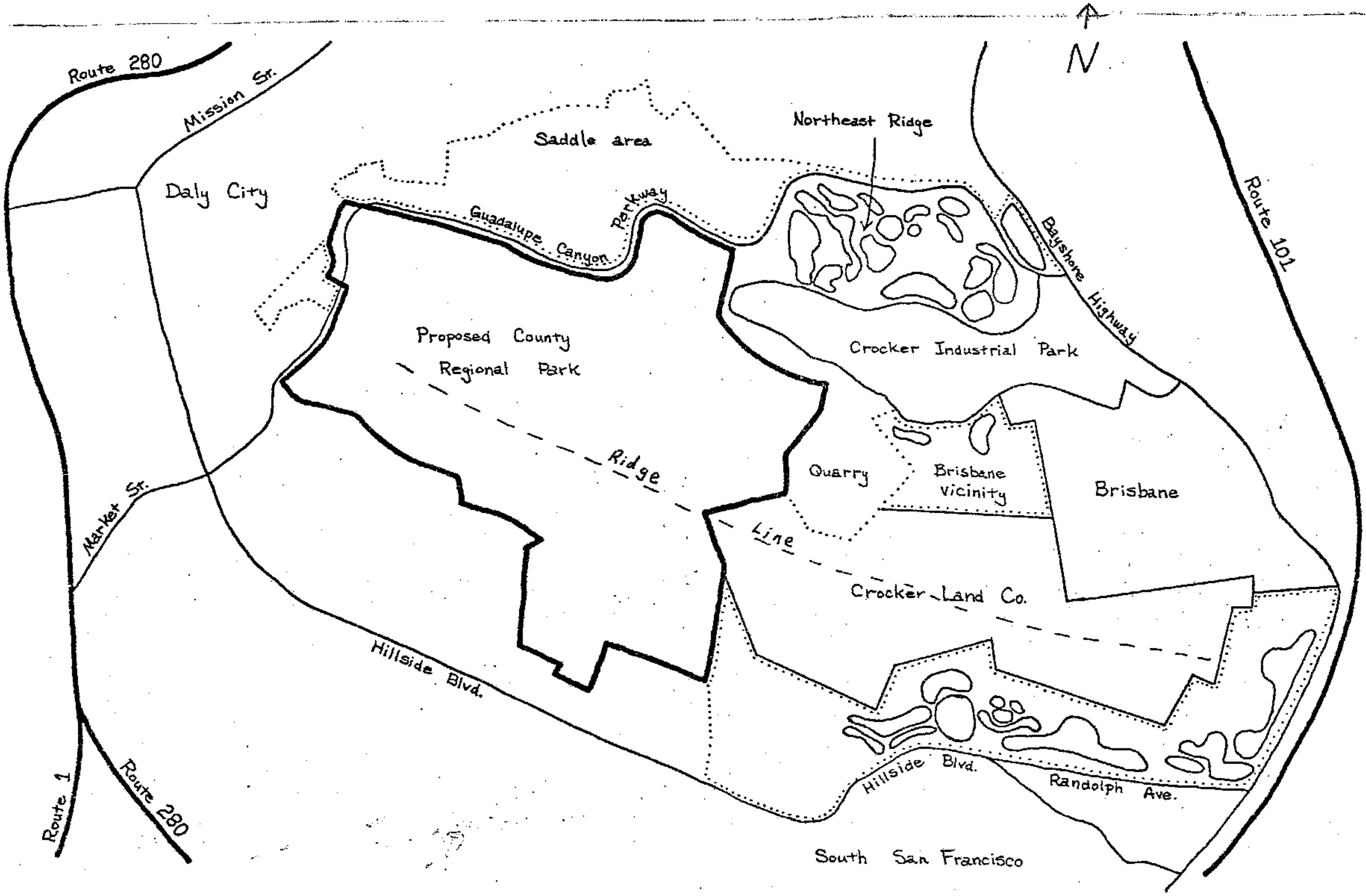
2. Perching sites for adult males, especially *Eriophyllum staechadifolium*, are necessary and must be intersperced among the larval and adult foodplants.

3. Controlled disturbances are necessary to allow for colonization of stonecrop. Controlled burning is probably helpful to keep the woody vegetation from shading-out the stonecrop. Also, small landslides or road widening open new areas for colonization by stonecrop. Some of the best stands of stonecrop on San Bruno Mountain are along roads and trails and rocky outcrops.

4. If San Mateo County develops San Bruno Mountain as a public park, trampling at the colony sites should be minimized. Trampling could destroy much of the stonecrop biomass and many of the nectar sources.

5. Care should be taken not to introduce any weeds or ice plant-like competitors which could out-compete the native vegetation at each colony site.

Figure 8. Map of San Bruno Mountain showing location of existing and proposed development.



MISSION BLUE

Distribution

Plebejus (=Icaricia) icarioides (Boisduval) occupies the greater portion of the continent of North America west of the central Great Plains region. Within this area, the majority of populations are found in the Canadian and Transition life zones. Populations are found from sea level to over 10,000 feet elevation. The various infraspecific populations of this species are further restricted to the distribution of the plant genus Lupinus upon which the larvae feed.

Like the San Bruno elfin, the majority of colonies for the Mission blue (Plebejus icarioides missionensis) occur on San Bruno Mountain (refer to the distribution section of San Bruno elfin for more information on San Bruno Mountain). Eight colonies exist here occurring on sites ranging from 700-1200 feet elevation (Fig. 1). Two lie within the fog belt and 6 inhabit areas beyond the fog belt. Another colony can be found at Twin Peaks (Fig. 2) in San Francisco (also within the fog belt). Little suitable habitat remains on Twin Peaks, thus the area supports only a small population of the blue. This colony is approximately 4 air miles north of San Bruno Mountain and ranges from 800-900 feet elevation.

A local lepidopterist, Robert L. Langston, reported a colony at Ft. Baker in Marin County (Fig. 2) However, in three trips to this site, we failed to turn up any Mission blue and no preserved specimens could be located to verify the existence of this colony.

The Mission blue utilizes several species of lupine as larval foodplants. Herbaria records revealed several other locations in San Mateo, San Francisco and Marin counties where these species grew. I visited all of these localities, but could not locate any new Mission blue colonies.

Grassland with occasional influx of coastal chaparral is the dominant vegetation at the habitat sites. Table 1 lists representative species at the study sites.

Table 1

Representative vegetation at Mission blue study site
on San Bruno Mountain.

Pteridium aguilinum
Amsinkia intermedia
Stellaria media
Achillea millefolium
Anaphalis margaritacea
Baccharis pilularis
Carduus pycnocephalus
Centaurea calcitrapa
Chrysopsis villosa
  var. bolanderi
Cirsium vulgare
Gnaphalium californicum
Matricaria matricarioides
Solidago californica
S. spathulata

Convolvulus subacaulis
Arabis glabra
Brassica geniculata
Rhaphanus sativus
Sisymbrium officinale
Phacelia californica
Lupinus nanus
L. variicolor
L. bicolor
Sidalcea malvaeflora
Camissonia ovata
Plantago lanceolata
Eriogonum latifolium
Rumex acetosella
Ranunculus californicus

Baeria chrysostoma
Potentilla glandulosa
Foeniculum vulgare
Viola pedunculata
Aira caryophyllea
Avena barbata
Elymus glaucus
Hordeum leporinum
Lolium multiflorum
Sisyrinchium bellum
Allium triquetrum
A. dichlamydeum
Brodiaea laxa
B. pulchella
Sanicula arctopoides

Figure 1. Distribution of Mission blue, San Bruno Mountain

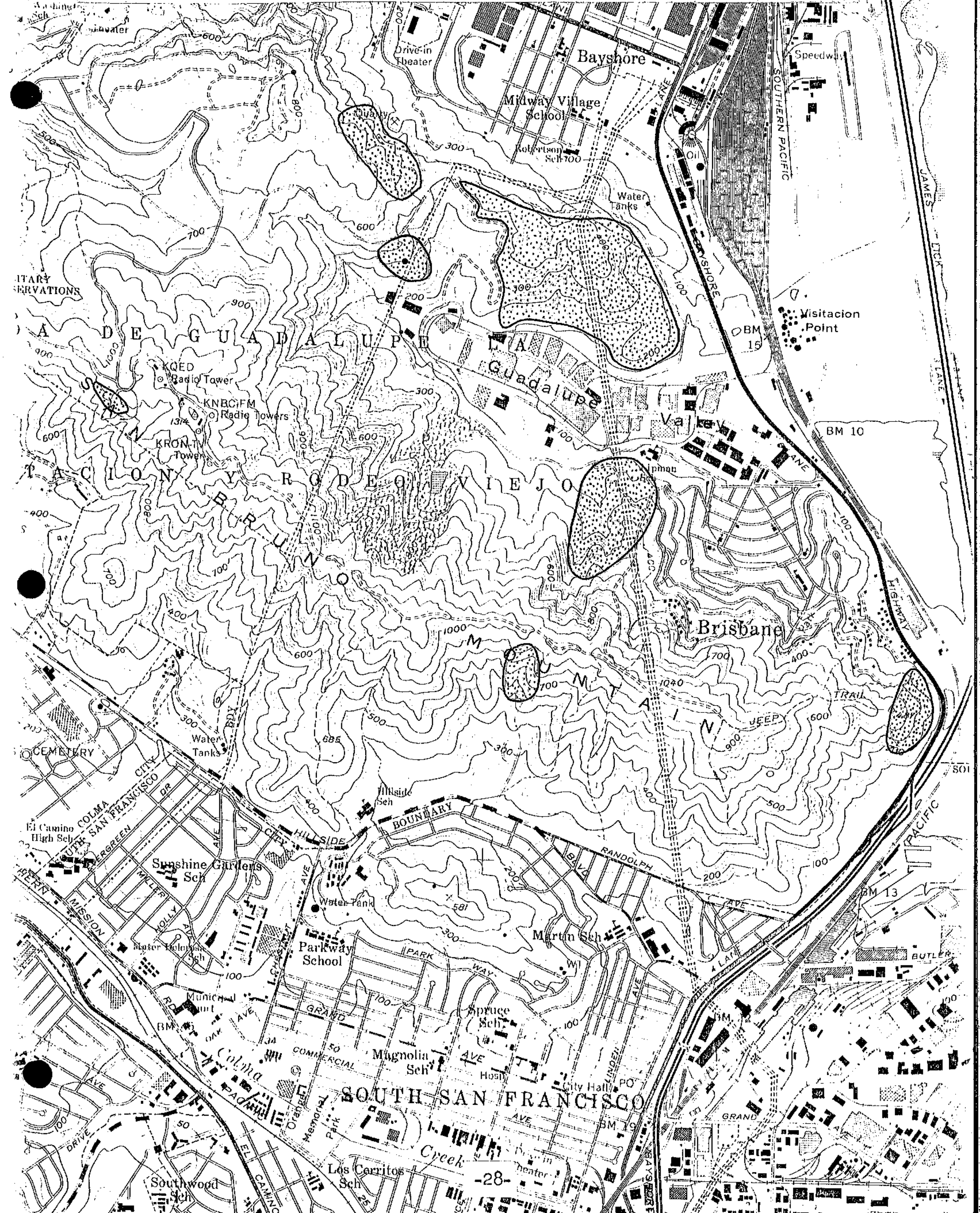
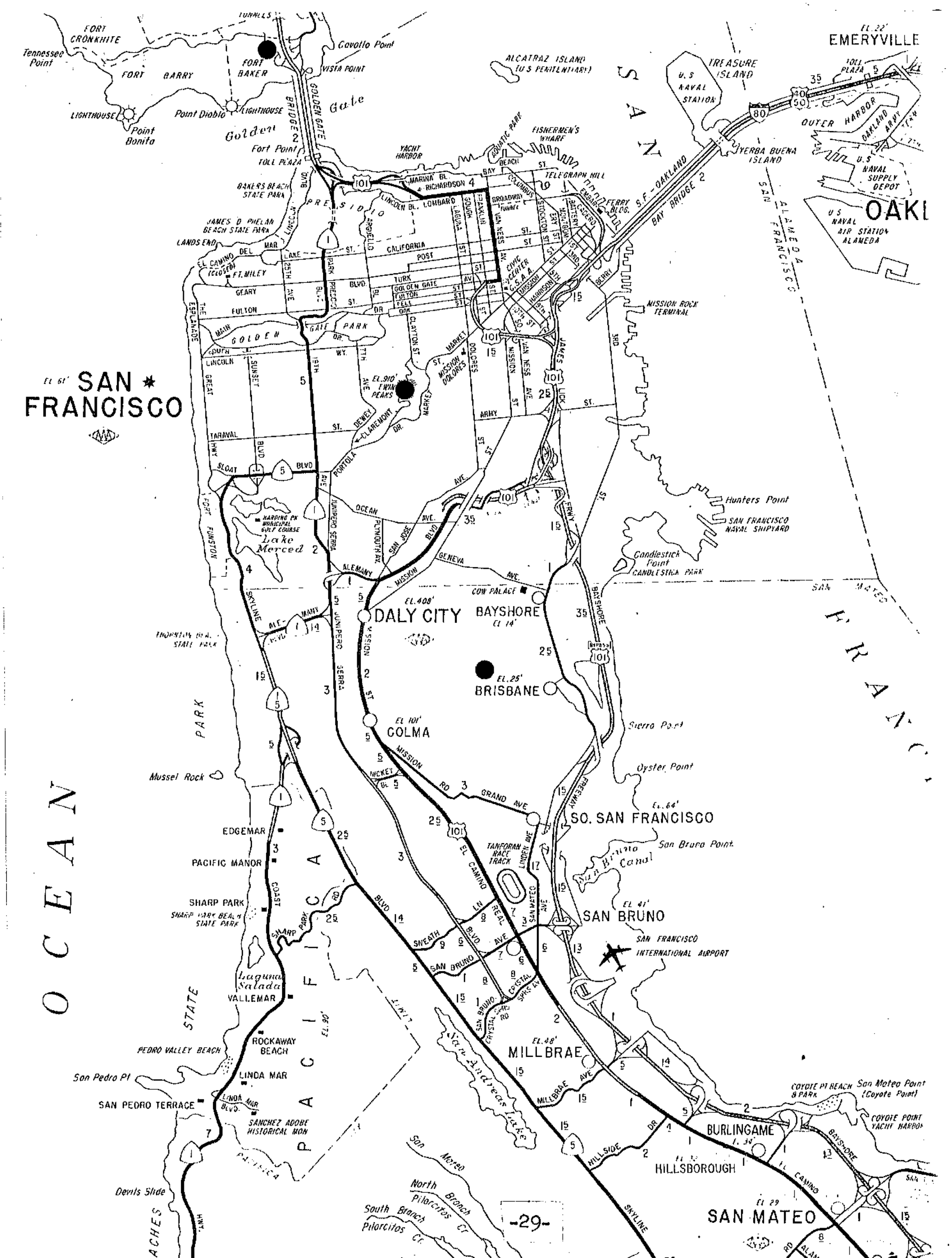


Figure 2. Distribution of Mission blue, San Francisco Peninsula and Marin County



Life History

This taxon is univoltine. Adults emerge in late March to mid-April in fog-belt populations, and late April to early May in colonies beyond the fog-belt. The peak of the population numbers is reached about 4 weeks after the earliest date of eclosion. Downey (1957) states that this peak coincides roughly with the time of seed formation by the foodplant, but my observations did not confirm this.

Oviposition occurs throughout the adult flight period. They are deposited singly on leaves, stems, flowers and seed pods of the host lupine. On San Bruno Mountain, Lupinus albifrons, L. formosus, and L. variicolor are utilized. Occasionally several eggs will be deposited on a single whorl of leaves. Most of the eggs are laid on new growth, particularly leaflets. Eggs were found on both the dorsal and ventral surfaces of the leaflets. Egg density varied between colonies and is probably dependent upon the density of adult females and suitable lupines.

One parasitic Hymenoptera was reared from Mission blue eggs. The percent of parasitized field collected eggs varied from 12-49% (Table 2). An unidentified Encyrtid was the primary parasite. Additionally, Downey (1957) has reared 2 other parasitic Hymenoptera from the eggs of P. icarioides (Trichogramma minutum Riley and Telenomus sp.). Thus, parasitism is a highly significant population density limiting factor in the San Brunos.

Table 2

Percent of Mission blue egg parasitism by Hymenoptera

Rearing No.	No. of Eggs	Percent Parasitized
77E16	12	17
77E21	29	48
77E22	7	43
77E23	27	33
77E26	43	49
77E27	48	42
77E28	35	43
77E30	56	45
77E31	44	43
77F5	87	46
77F6	21	09
77F7	14	29

Under field conditions, eggs hatch in 6-10 days (Table 3). At 70°F and 70% relative humidity, they hatch in 4-6 days. Normally, there are 4 larval instars. The second stage larva begins an obligate diapause. This likely happens in the soil or among the duff at the base of the lupine plants, although diapausing larvae have been found on the leaves, stems, and caudex of the foodplant. Diapause is initiated about 3 weeks after eclosion. The larvae remain quiescent throughout the summer, fall and winter. Although collected at different dates, larvae from the various colonies when reared at the same temperature and humidity, molted and began diapause after the same lapse of time (i.e., 3 weeks).

Table 3

Egg fertility, embryo viability
and percentage hatched of Mission blue.

Female Rearing No.	Number of Eggs	Fertile/ Laid	Hatched/ Fertile	Hatched/ Laid
76D19	22	.91	.95	.86
76E3	41	.95	.92	.88
76E4	16	1.00	1.00	1.00
76E7	24	.96	1.00	.96
76E10	33	.91	.90	.82
77E13	29	1.00	1.00	1.00
77E15	47	.98	.98	.96
77E17	42	.98	1.00	.98
77E18	34	.88	.97	.85
77E19	18	.78	1.00	.78
77E20	56	.91	.98	.89
77E24	26	1.00	1.00	1.00
77E25	31	.94	.97	.90
77F4	6	.83	1.00	.83

Emergence from diapause was quite random, even in sibling larvae. In sibling larvae, reared under the same laboratory conditions, I observed differences as great as one month in the time of first post-diapause feeding. Downey (1957) observed differences of up to two months. Inasmuch as post-diapause larvae can complete their development to adults in 4-5 weeks, it is possible to have adults and second instar larvae (in diapause) in the same locality, both of which originated from the same egg clutch the previous year. This also explains why newly emerged adults can be taken in an area throughout a period of two months.

Mature and penultimate instar larvae can be found on the caudex of lupines. Occasionally they can be found on the branches or flowering stalks, although they are usually concealed by the stem sheath. Mission blue larvae are tended by ants, primarily by Prenolepis imparis (Say) (Table 4). Presumably, the ants are attracted either by secretions from a gland on the 10th segment, or by a pair of eversible sacs on the 11th segment. Newcomer (1911) presented a drawing of this sac. Currently, I am preparing the structures for histological examination.

Table 4

Frequency of myrmecophilous Mission blue larvae in the field.

Rearing Lot No.	No. of Larvae	Percent Myrmecophilous
77D23	14	29
77D29	3	67
77E6	19	63
77E11	11	45
77E14	8	75

Larvae are often discovered on the foodplant by the presence of the more conspicuous ants, especially Prenolepis imparis (Say), which tend them. On Twin Peaks, Downey (1962) found larvae tended by Formica lasioides Em. Nothing could be determined about this myrmecophilous relationship after the last instar larvae pupate. Downey (1957) suggests that the larvae pupate in the ground, possibly in ant nests. Many of my laboratory reared individuals pupated on the larval foodplant, although most were near the base of the lupine. Mature larvae of several other Lycaenidae are carried to ant nests where they subsequently pupate (Balduf, 1939). I dug up several ant nests at the base of lupine plants but could not locate any evidence of Mission blue. As evidenced by successful laboratory rearings, the Mission blue is a facultative myrmecophile (Balduf, 1939).

Larval parasites included an unidentified Tachinid fly and an unidentified Braconid wasp (Table 5).

Table 5

Percent of Mission blue larvae parasitized

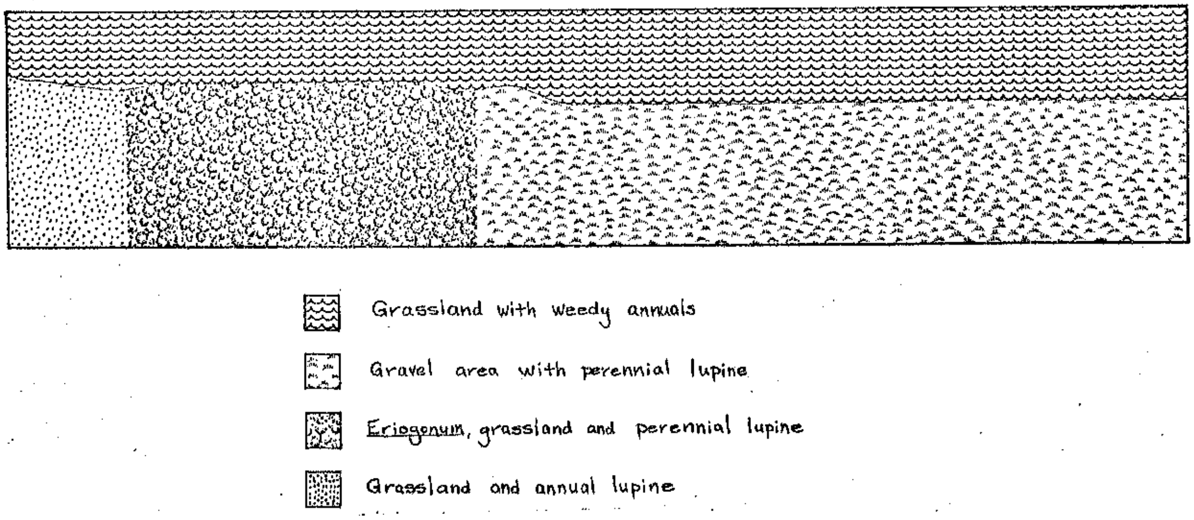
Rearing Lot No.	No. of Larvae	Percent Parasitized
77D23	14	14
77D29	3	00
77E6	19	21
77E11	11	27
77E14	8	13

Population Study

Study site and sampling

A north-facing road cut, plus a portion of adjacent grassland comprised the study site. It was located on the northeast ridge of San Bruno Mountain. Grassland was the dominant vegetation. Table 1 is a list of plants identified from the study site. Figure 3 is a vegetational map of the site. Visitation Associates own the property.

Figure 3. Vegetational map of Mission blue study site, San Bruno Mountain



A grid of 16 m X 16 m quadrates was laid.

Each captured butterfly was marked with a unique number. Numbers were applied to the ventral surfaces of the wings using "Pilot" felt-tipped, permanent ink pens. Data was taken in the manner described for the San Bruno elfin.

Sampling was initiated each day between 0830 to 0930 PDT and terminated at 1430 to 1600 PDT.

The probability of collecting a Mission blue was compared with a Poisson distribution for the number of successive recaptures. A comparison of the observed and Poisson distributions for the number of successive recaptures is shown in Table 6. A test of goodness of fit show no significant deviation of the expected from the observed values for the range of 0-4 successive recaptures. This agreement means that collecting and marking individuals did not alter their probabilities of survival.

Table 6

Distribution of the observed number of recaptures per number of repeats and their expected Poisson values for Mission blue (pooled values for males and females).

Number of Recaptures	Observed (f)	Expected $(\hat{f})$
0	109	110.13
1	58	58.30
2	19	15.43
3	1	2.72
4	0	0.36

$\bar{y} = 0.5294$

Results

Aging and sex ratio

Plebejus icarioides missionensis is univoltine. The data presented in Table 7 reveal that male adults generally eclose earlier in the flight season than do females. Also, wear damage to the wings of this taxon accumulates gradually with age after eclosion. The sex ratio shifts from a preponderance of males early in the flight season to a greater fraction of females later on. The average wear values for both sexes increases relatively smoothly throughout the study. Females lag slightly behind males, as would be expected from the eclosion lag.

Table 7

Sample-based sex ratios and wear ratings of males and females of adult Mission blue in relation to the progress of the flight season.

Date	Day	♂:♀	Percent ♂:♀	♂ Average Wear	♀ Average Wear
V-20	1	6:1	86: 14	2.17	2.00
V-23	2	17:4	81: 19	2.29	1.75
V-25	3	17:7	71: 29	2.59	2.29
V-27	4	9:7	56: 44	3.11	2.57
V-28	5	13:9	59: 41	3.38	2.89
V-29	6	12:7	63: 37	3.83	3.57
V-30	7	13:17	43: 57	2.85	2.59
VI-1	8	8:12	40: 60	3.50	3.33
VI-3	9	6:15	29: 71	4.33	4.00
VI-6	10	2:4	33: 67	4.50	4.25
VI-7	11	0:1	0: 100	--	5.00

Daily Numbers

A total of 103 males and 84 females were marked at the study site. Data from laboratory rearings indicates that the sex ratio is actually 1:1 (Table 8). The proportion of marked animals, the total marked population, daily population estimates, the probability of survival, and the numbers of new animals joining the population for males and females is presented in Table 9.

Table 8

Sex ratios of laboratory reared Mission blue broods. Statistical significance determined by Chi-square test for goodness of fit to a 1:1 sex ratio (ns=nonsignificant; $.05 > p > .01$).

♀ Rearing No.	♂♂	♀♀	Sex Ratio	X^2
76D19	3	3	1.00:1.00	ns
76E3	8	6	1.00:0.75	ns
76E4	5	6	1.00:1.20	ns
76E7	10	7	1.00:0.70	ns
76E10	11	10	1.00:0.91	ns
	37	32	1.00:0.86	ns

Table 9

Population parameters of Mission blue estimated from Jolly's stochastic model of multiple recapture data.

Males:

Day	Alpha	M	N + 1.96 SE	PHI + 1.96 SE	B + 1.96 SE
1	0.0000	0.00	0.0 + 0.0	.848 + .543	0.0 + 0.0
2	.1176	5.09	43.3 + 50.0	.787 + .368	16.5 + 48.8
3	.3125	15.82	50.6 + 36.7	.739 + .301	-17.6 + 24.4
4	1.0000	20.57	20.6 + 9.4	.929 + .380	8.5 + 7.7
5	.6923	19.11	27.6 + 13.2	.793 + .321	2.5 + 8.4
6	.7500	18.33	24.4 + 11.1	1.594 + 1.196	16.3 + 25.6
7	.6154	34.00	55.2 + 47.5	.415 + .376	3.0 + 15.4
8	.6250	16.20	25.9 + 18.8	.833 + .576	2.4 + 15.5
9	.6667	16.00	24.0 + 18.7	.667 + .377	-13.0 + 8.1
10	4.0000	12.00	3.0 + R	0.000 + 0.000	0.0 + 0.0
11	2.0000	0.00	0.0 + 0.0	0.000 + 0.000	0.0 + 0.0

Females:

Day	Alpha	M	N + 1.96 SE	PHI + 1.96 SE	B + 1.96 SE
1	0.0000	0.00	0.0 + 0.0	2.000 + R	0.0 + 0.0
2	.5000	4.00	8.0 + R	1.500 + 1.230	15.0 + 31.4
3	.3333	9.00	27.0 + 34.8	.589 + .573	2.8 + 21.9
4	.4286	8.25	19.2 + 16.8	.833 + .657	11.2 + 24.5
5	.3750	10.20	27.2 + 26.2	1.327 + 1.551	-5.2 + 32.7
6	.6667	21.50	32.2 + 38.9	.678 + .927	71.5 +109.4
7	.1765	16.60	94.1 +122.0	.458 + .396	-4.5 + 52.5
8	.3636	14.00	38.5 + 35.6	.773 + .588	-.8 + 23.3
9	.5714	17.00	29.7 + 22.7	.500 + .498	-3.4 + 6.8
10	1.0000	12.00	12.0 + 11.4	0.000 + 0.000	0.0 + 0.0
11	3.0000	0.00	0.0 + 0.0	0.000 + 0.000	0.0 + 0.0

Alpha = proportion of marked animals
M = total marked population
N = total population
Phi = probability of survival
B = number of new animals joining the population

There are no large fluctuations in the estimates as were noted for the San Bruno elfin. This is probably due to several reasons: 1) Jolly's method is most reliable if a large proportion of the population is captured and marked; 2) comparison of the alpha values for San Bruno elfin and Mission blue reveals that a larger portion of the Mission blue population has been marked; and 3) the variance in the estimated size of the population decreases as the proportion of recaptures increases. A higher percentage of Mission blue were recaptured than San Bruno elfin because Mission blue congregate on hilltops. This results in a greater percentage of San Bruno elfin never being seen after initial capture. Jolly's method thus assumes that these individuals have emigrated or died. This assumed "emigration" causes large fluctuations in the proportion of recaptures from day to day, causing concordant variation in the estimated size of the population. The other factor which removed the fluctuations from the Mission blue results is the fact that its entire flight season was sampled.

The study site is 2.04 ha (5.06 acres). Thus the peak population density is high (Table 10). Upon examining the maps of the male and female movements, it is obvious that the adults will stray from quadrates containing only lupine in order to nectar and locate mates. Nonetheless, males were found in only 46 of the quadrates, and females in only 29 quadrates. If we consider the density in only those quadrates within the study site where individuals were captured or recaptured, the peak density is very high (Table 10).

Table 10

Density of Mission blue at the study site.

Sex	Density of Entire Study Site	Density in Only Occupied Quadrates
Males	18.77/ha	32.64/ha
Females	16.59/ha	45.76/ha

The observed deviation from the 1:1 sex_ratio is probably due to behavioral differences between the sexes. Both sexes are primarily "patrollers," i.e., they tend to fly throughout the habitat looking for mates and suitable oviposition sites rather than "perching" as do the San Bruno elfins. The patrolling occurs only during the morning and early afternoon. After about 1400 PST, the adults tend to perch more than patrol. A smaller percentage of females were recaptured, only 31% vs. 41% of the marked males subsequently being recaptured (Table 11).

Table 11

Number of individuals marked, percent of individuals recaptured, and number of recaptures for individuals recaptured at least once for the Mission blue.

Sex	Number of Individuals	Percent Recaptured	Average Number of Recaptures
Male	105	41	1.23
Female	84	31	1.18

Both sexes are equally vagile, but females tend to move about in areas different from those of the males. Females fly from lupine to lupine looking for suitable oviposition sites. Also, they nectar on plants which are near the larval foodplants. Males, tend to hill-top and nectar on the plants at the top of the hill. Thus, it is easier to recapture males since they tend to congregate at the tops of hills, while females tend to be more dispersed looking for suitable oviposition sites. A slight lag in emergence times for females may also contribute to the sex ratio discrepancy. Females were more abundant than males only after 10 days into the study.

Residence

Table 12 presents day-specific residence and loss rates, plus mean expected residence times for both sexes.

Females live about 1 day longer than males. Since this study was done throughout the entire flight season, these lifespan estimates are probably accurate.

Table 12

Residence rates ($\hat{\phi}$), mean expected residence, loss rate and estimates of total brood number for Mission blue.

Sex	$\hat{\phi}$	Mean Expected Residence (days) $-(\ln \hat{\phi})^{-1}$	Day-specific Loss Rate	$\Sigma \hat{N}i$	Estimated Total Brood Numbers
Males	0.860	6.63	0.140	274.6	38.44
Females	0.882	7.96	0.118	287.9	33.97

Dispersal Analysis

Vagility

Males flew slightly faster and farther than females. Both sexes are patrollers thus it is not surprising that their vagility figures (Table 13) would be nearly equal.

Table 13

Vagility parameters for Mission blue

Vagility parameter	Male	Female
Mean T (days)	2.67	2.68
Max T (days)	6.0	5.0
Mean t_i (days)	1.96	2.27
Mean R (meters)	32.25	32.57
Max R (meters	112.0	104.0
Mean D (meters)	38.36	37.86
Max D (meters)	132.0	124.0
Mean d_i (meters)	28.13	32.12
Mean V (m/day)	15.01	14.07
Max V (m/day)	56.0	57.0
Mean v_i (m/day)	18.26	15.88

Local versus long-distance movements for males and females were approximately equal (Table 14). Both sexes are very sedentary when compared to vagility figures for other butterfly species. Only 7 individuals moved more than 70 m. The longest movement was 112 m by a male.

Table 14

Local versus long moves for Mission blue

Sex	Local	Percent	Long	Percent
Males	40	51.9	37	48.1
Females	18	54.5	15	45.5

Thus, the movement of individuals within a colony is limited. Based upon the vagility data and the distances between colonies, it is unlikely that individuals are actively moving from one colony to another.

Dispersion

The distribution of the Mission blue on San Bruno Mountain is primarily restricted to areas where either Lupinus albifrons, L. variicolor, or L. formosus grow. In order to determine the microdistribution of San Bruno Mountain Mission blue, Morisita's Index was computed.

Dispersion indices were calculated for both males and females. Samples consisted of 80 quadrates, each 16 m X 16 m. The number of individuals recorded in each quadrate equaled the number of individuals captured or recaptured in that quadrate during the 19-day sampling period.

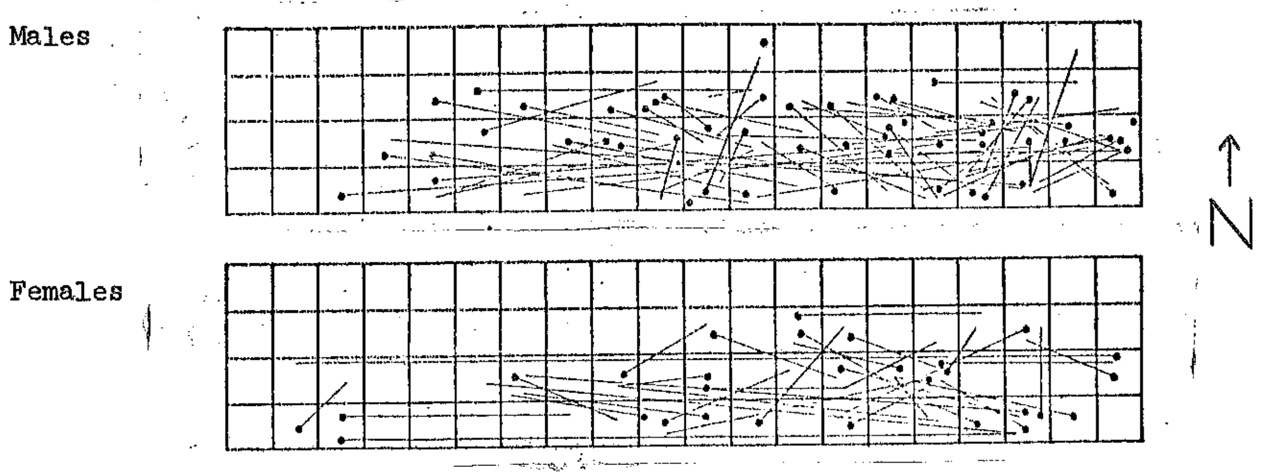
While Morisita's Index revealed that males and females are equally aggregated (Table 15), the movement maps (Fig. 4) reveal some intersexual aggregational differences. Females tend to not stray very far from their lupine larval foodplant. Nonetheless, they move around a great deal within the boundaries of the lupine looking for oviposition sites. On the other hand, several males moved outside the boundaries of the lupine to obtain nectar or to locate mates. Mission blue males exhibit a phenomenon known as "hilltopping." While the hills they ascend are only 30-60 m higher than the rest of their habitat, hilltopping is an obvious activity in both sexes.

Table 15

Indices of dispersion for Mission blue
All groups are significantly aggregated. ($p > .001$).

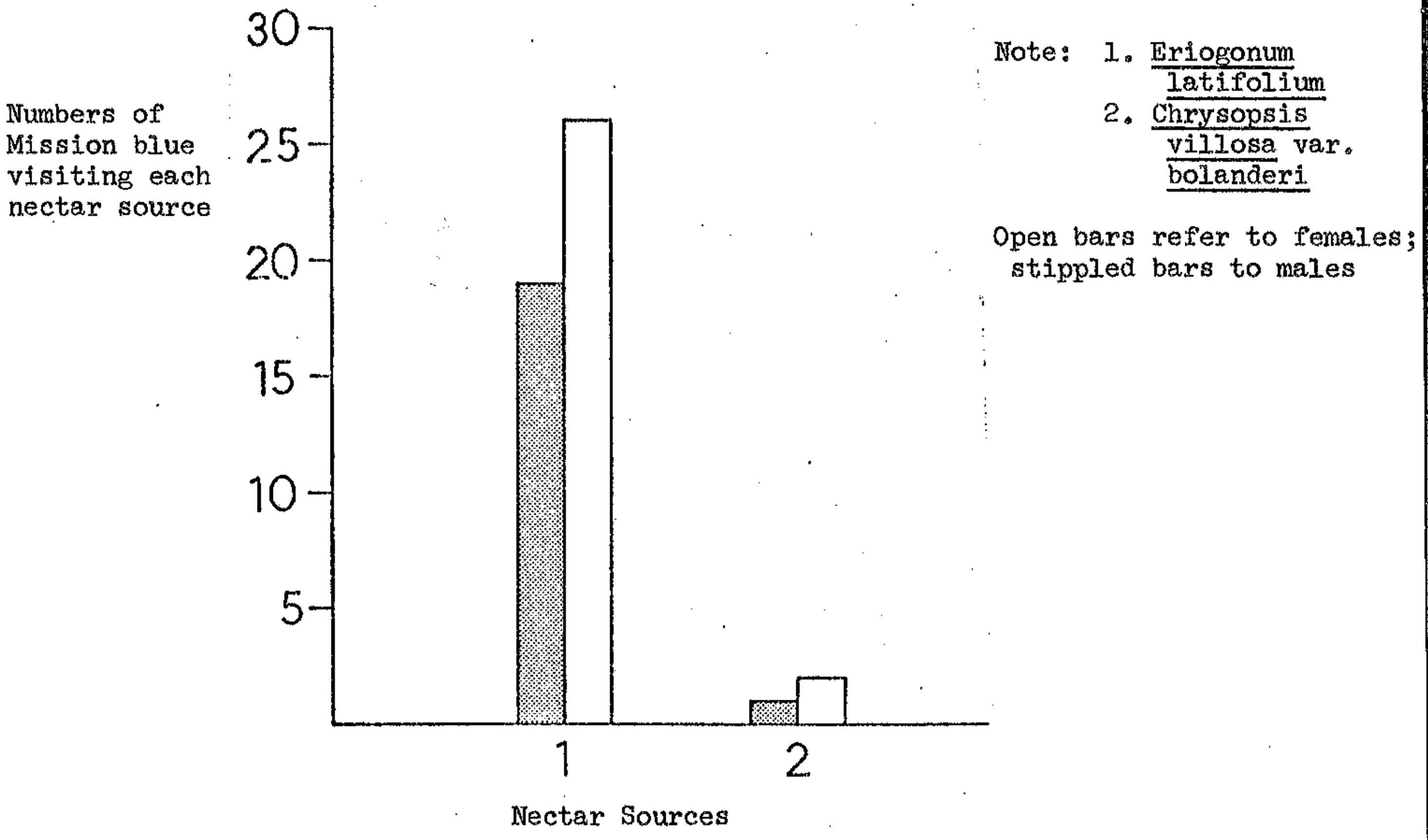
Sex	I_m
Male	3.15
Female	3.11

Figures 4 and 5. Movements of adult Mission blue, San Bruno Mountain study sites



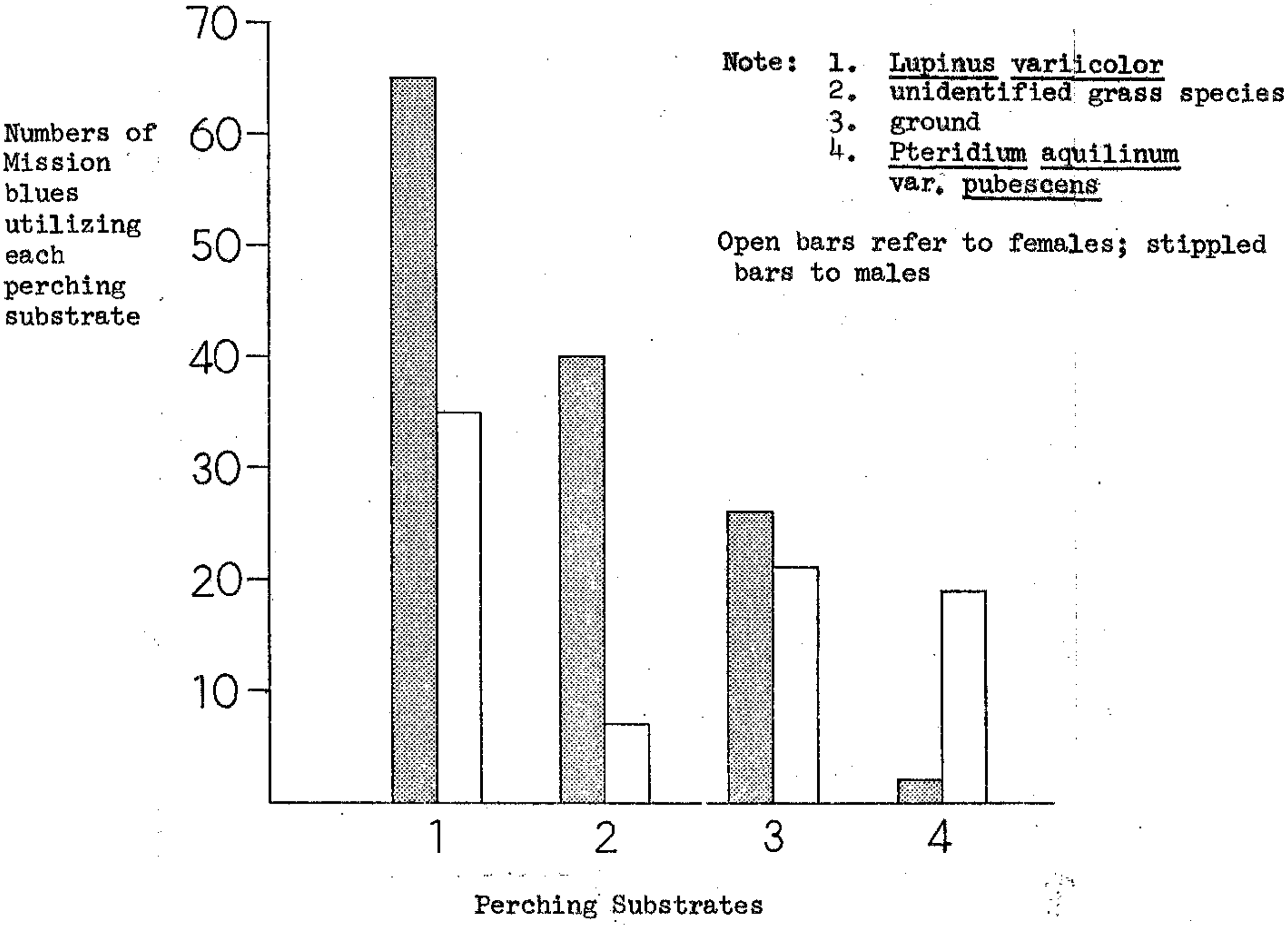
Nectar sources are known to play an important role in the direction and length of movements in populations of some butterflies. Two plant species were utilized as nectar sources (Fig. 6). Buckwheat is the primary nectar source for both sexes. While it appears that the micro-distribution of nectar sources affected the micro-distribution of males, this is misleading due to the hilltopping behavior of adult males (see section on patrolling areas and rudimentary territoriality).

Figure 6. Nectar sources of Mission blue, San Bruno Mountain



Although males and females possess similar dispersion values, there was little spatial overlap in their microdistributions. This was due to differences in the patrolling "beat" of each sex, rather than perching site preferences as were found in the San Bruno elfin. Perching sites are essentially the same for both sexes of the Mission blue (Fig. 7).

Figure 7. Perching substrates of Mission blue, San Bruno Mountain



Behavior

The standard areas of activity for males ranged from 0.20 to 1.05 with a mean of 0.51 ha. Female standard areas of activity ranged from 0.39 to 1.05 ha, with a mean of 0.61 ha. Since there is approximately 1.18 ha of suitable habitat for males, these data indicate that the average male utilizes about 43% of the area which potentially can be occupied by all males. Females were found in 0.74 ha of the habitat, thus the average female utilizes about 83% of the total area which potentially can be occupied by all females. These data point out that females move throughout most of their potential area in their search for suitable oviposition sites, whereas males tend to congregate on the hilltop waiting for a mate.

Hilltopping is a wide spread phenomenon in butterflies and insects. Males and virgin or multiple-mating females seek a topographic summit where they congregate for the purpose of mate location. This theory suggests that males, which emerge a few days earlier than females, visually orient and fly to the hilltops. When females emerge, they orient and fly to the hilltops where mating ensues, after which the females leave to lay their eggs. Presumably if the female meets a male before she arrives at a hilltop, mating ensues and she would not visit the hilltop. This theory is supported by observations of mating pairs on hilltops, a high percentage of virgin females of hilltopping species on hilltops, and an experiment in which virgin female Papilio zelicaon Lucas flew to hilltops (Shields, 1967; Scott, 1968).

I was able to observe mate location and subsequent copulation in 13 pairs of Mission blue. Eleven of the 13 matings were initiated on the summit. All of the females were fresh (2.0 of the wear rating scheme), which would suggest that they were virgins. Of all the females handled in this study (both captured and recaptured individuals), 33% were netted on the summit. The average wear ratio of these females was 2.25. The average wear ratio of females occupying the lower quadrates was 2.78. Forty-four percent of all males were handled on the summit. Their average wear ratio was 3.07. The average wear ratio of males patrolling the lower quadrates was 2.56. Thus, younger females are mating on the summit while older females are ovipositing. Also, older males are mating on the summit while younger males make their way to the hilltop.

Once the summit is reached, a hilltopping male initiates patrolling behavior. Individual marked males were observed to patrol throughout a narrow area of the summit. This area was adjacent to the upper most patches of lupine. Hilltopping usually occurs in species whose larval foodplants are not near the summit (Shields, 1967; Scott, 1968). In this case the larval foodplant not only grows near the summit, but also has a few scattered clumps on the summit. Nectar sources were scattered throughout this narrow belt, and males frequently paused from their patrolling to nectar. Females upon reaching the summit usually patrolled until they located a nectar source or one of a few small clumps of lupine. Usually, a male would quickly notice the female and courtship flight would begin. Frequently the courting pair would fly horizontal to the ground, thus moving downslope and out of the mating arena. Presumably this prevents other males from interfering with courtship and the act of copulation.

Hilltopping can be effective only for low density species such as the Mission blue, because: 1) at high densities on hilltops interference between males prevents mating with females, and 2) the number and area of hilltops is limited (Scott, 1968).

Both Scott (1968) and Shields (1967) note that hilltopping species are generally large, fast-flying, solitary species with more widely scattered and less abundant foodplants than nonhilltopping species, which tend to be small, weak-flying colonial species with common or clumped foodplants. The vegetational composition of the grassland on San Bruno Mountain has been altered in recent years by introduced grasses and forbs. Only a few places on the mountain possess the original grassland vegetation. In these areas, Mission blue is a solitary species with widely scattered foodplants. Today it inhabits the banks along road cuts where lupines have invaded and form the dominant ground cover. Thus, the adults are probably more dense yet they still hilltop to locate mates. My observation of 2 matings being initiated below the hilltop may be due to the increased density of the population which results in more frequent intersexual encounters below the summit. It will be interesting to see if the Mission blue continues to use hilltopping as a mate locating mechanism as its populations become more dense.

Alexander (1961) enumerated two phenomena which are associated with territorial animals: 1) a tendency to stay in restricted areas, or repeated return visits to specific areas, or both; and 2) aggressive behavior displayed toward intruding individuals. The hilltopping behavior of Mission blue certainly satisfies the first criterion. Also, males are pugnacious on hilltops. Characteristically, aggressiveness of territorial male insects can be divided into 4 parts: 1) investigative flight toward intruders into the male's "territory," followed by 2) chase of the intruder, or 3) intraspecific flight, or 4) a return to the perch area (Lin, 1963; MacNeill, 1964). Mission blue are patrollers rather than perchers, thus they fly throughout a portion of the summit, known as their "beat," and are aggressive towards intruders.

Although they do not establish permanent, defended territories, hilltopping does fall within the broad concept of territoriality presented by Wilson (1975).

Threats to Survival

Five of the seven Mission blue colonies are threatened by condominium and commercial developments by Visitacion Associates (VA), which owns 1,244 acres on San Bruno Mountain (Fig. 8). Nearly 18,000 people would eventually live at the current colony sites if VA realizes its plan (Fig. 9). Development plans have largely been approved by the various local governmental agencies. Thus, the Mission blue will likely lose the overwhelming majority of its habitat. Even though it has successfully invaded a few road-cuts, the destruction of most of its native grassland habitat could be an insurmountable blow to the survival of the Mission blue on San Bruno Mountain.

Housing developments have severely reduced the size of the remaining Mission blue habitat on Twin Peaks (Fig.10). Fortunately, most of the remaining suitable and potential habitat on and surrounding Twin Peaks is owned by the city and county of San Francisco. A notable exception is a large parcel nearly bordering on the northern peak which the city has zoned for apartments. Construction has already begun at this site.

Essential Habitat

The critical habitat proposal for the Mission blue on San Bruno Mountain is accurate, but with discovery of a Mission blue colony in the Saddle area the critical habitat designation should be expanded to include this area (Fig. 9). The inclusion of the entire mountain as critical habitat is necessary because of the invasion by the lupines of road-cuts and the potential extension of Mission blue into newly created habitat.

The critical habitat proposal for the Twin Peaks colony is much larger than the area which can potentially be occupied by the Mission blue (Fig.10). Since this excess area is composed of concrete and buildings, I suggest that the area of critical habitat be reduced to the undeveloped property owned by the city and county of San Francisco as shown in Figure 10 as Mission blue habitat. With proper management by the city, the Mission blue should be able to adequately increase its numbers here to ensure its survival.

Figure 8. San Bruno Mountain land ownership

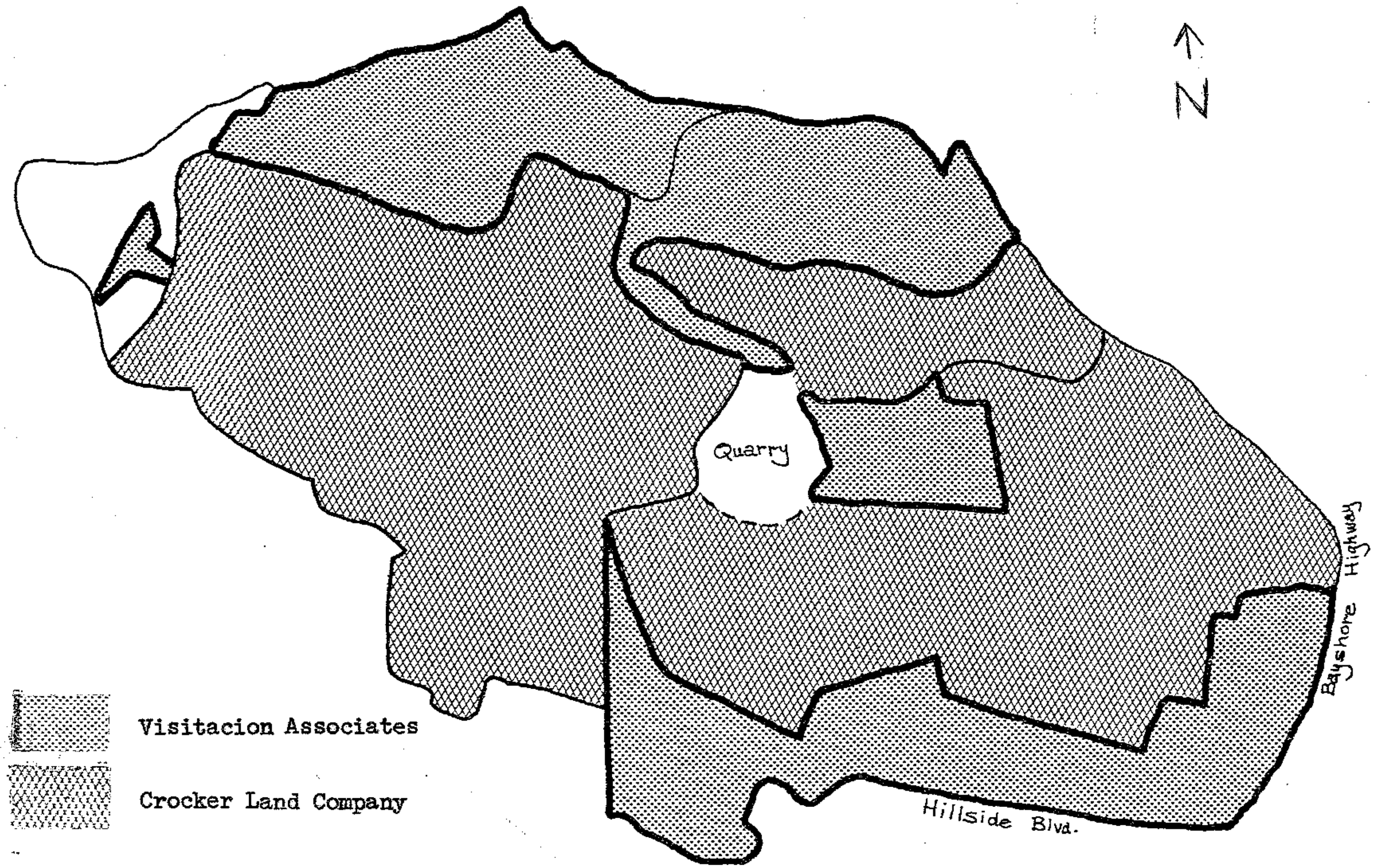
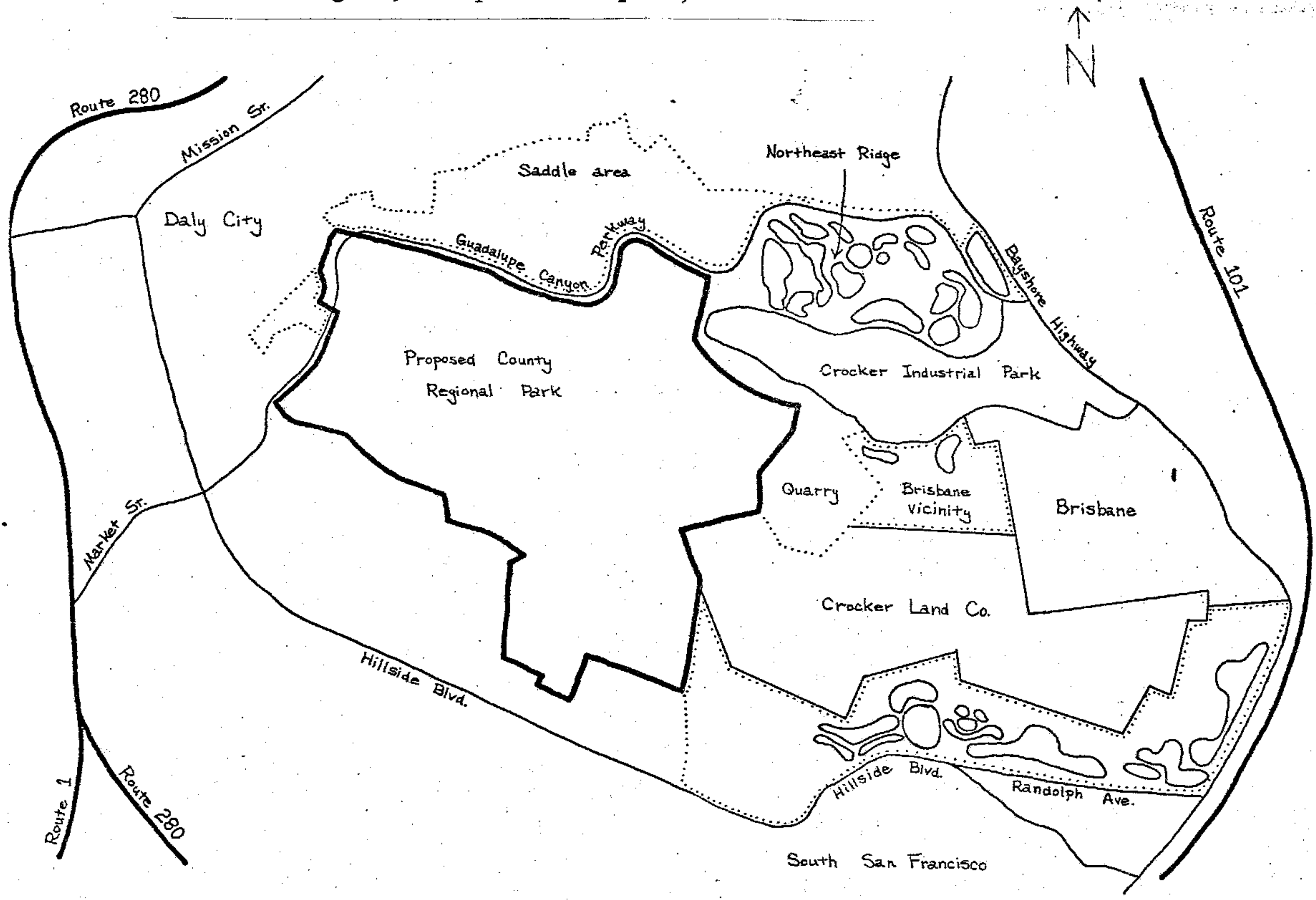


Figure 9. Proposed development, San Bruno Mountain



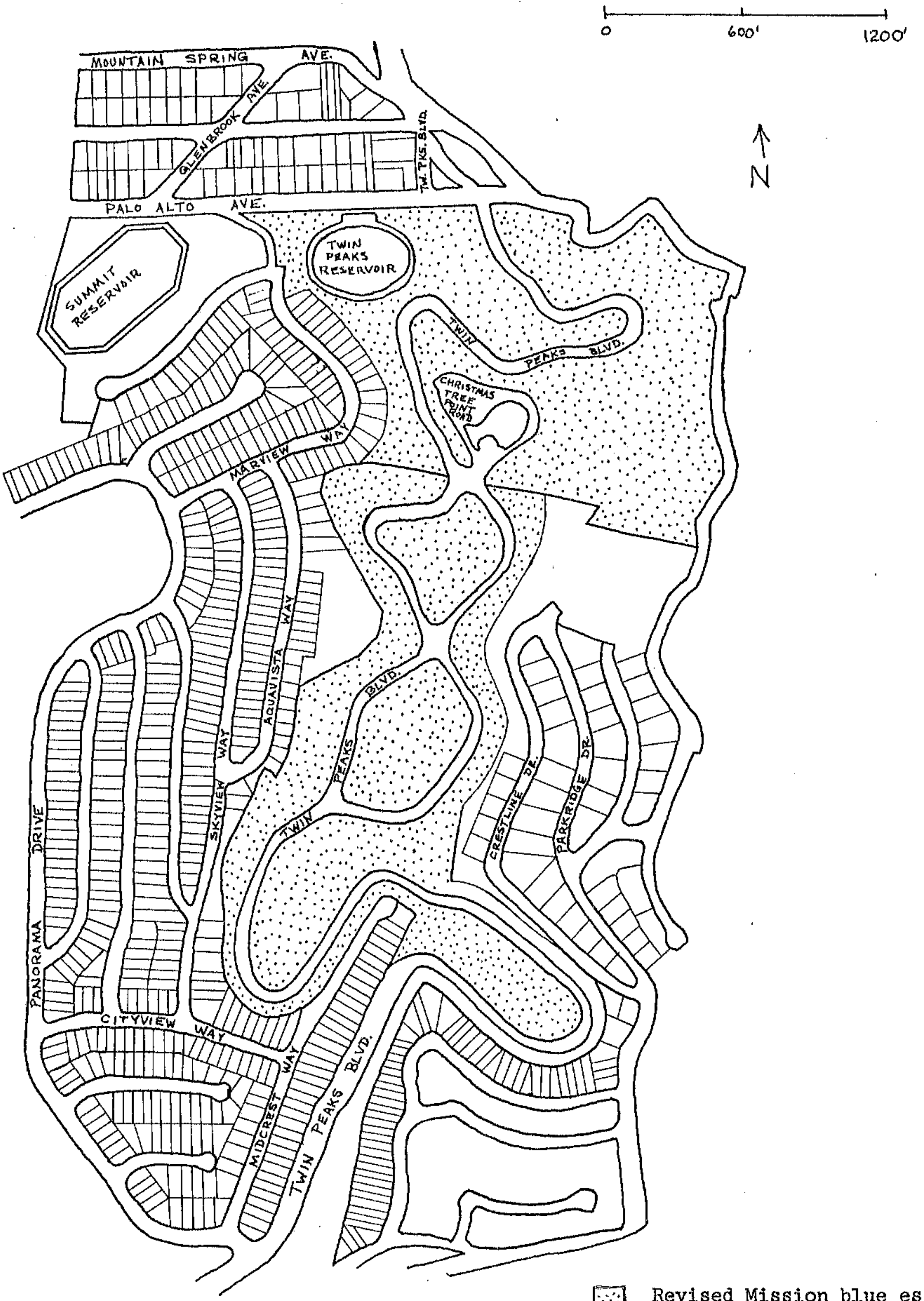


Figure 10. Location of essential habitat for Mission blue on Twin Peaks

▨ Revised Mission blue essential habitat proposal

Management Recommendations

To ensure the survival of the Mission blue, the following conditions are necessary:

1. The areas on San Bruno Mountain supporting Mission blue colonies should be acquired for public ownership.

2. Lupinus variicolor, L. formosus, or L. albifrons be maintained in these areas. Lupines compose 10-60% of the total ground cover in existing colony sites.

3. Nectar sources, especially Eriogonum latifoluum and Chrysopsis villosa var. bolanderi be maintained and intersperced among the clumps of lupine.

4. Habitat manipulation such as controlled clearing and controlled burning be done to encourage lupine growth. In addition, controlled burning is very effective at reducing the influx of weedy annuals.

LOTIS BLUE

Distribution

Lycaeides argyrognomon (Bergstrasser) is circumpolar in its distribution and was described from the Old World. Lotis blue (Lycaeides argyrognomon lotis) is one of 11 subspecies in North America.

It is known primarily from only one locality, a sphagnum bog under a Pacific Gas and Electric powerline near Mendocino, California (Fig. 1). This bog is owned by Mr. Jack Helfer of Mendocino. Through Mr. Helfer, I learned of two other localities where Lotis blue was sighted. During April, May and June, I made five visits to these localities but could not find a single specimen. The bog had no standing water in it. Mr. Helfer and others told me that the water table had dropped from its normal depth of 100 feet below ground level to 400 feet in less than one year.

Herbarium records for the suspected larval foodplants revealed several other localities in Mendocino and Sonoma counties where the plants grew. I checked each of these localities. Most were near or in the famed Pygmy Forest, although one was as far away as Point Arena. No suitable bogs with the assemblage of characteristic bog plants, such as sphagnum, Drossera sp. and Cornus sp., of the type locality were located.

Study of this species will have to wait until next year when the adults fly in May and June.

Threats to Survival

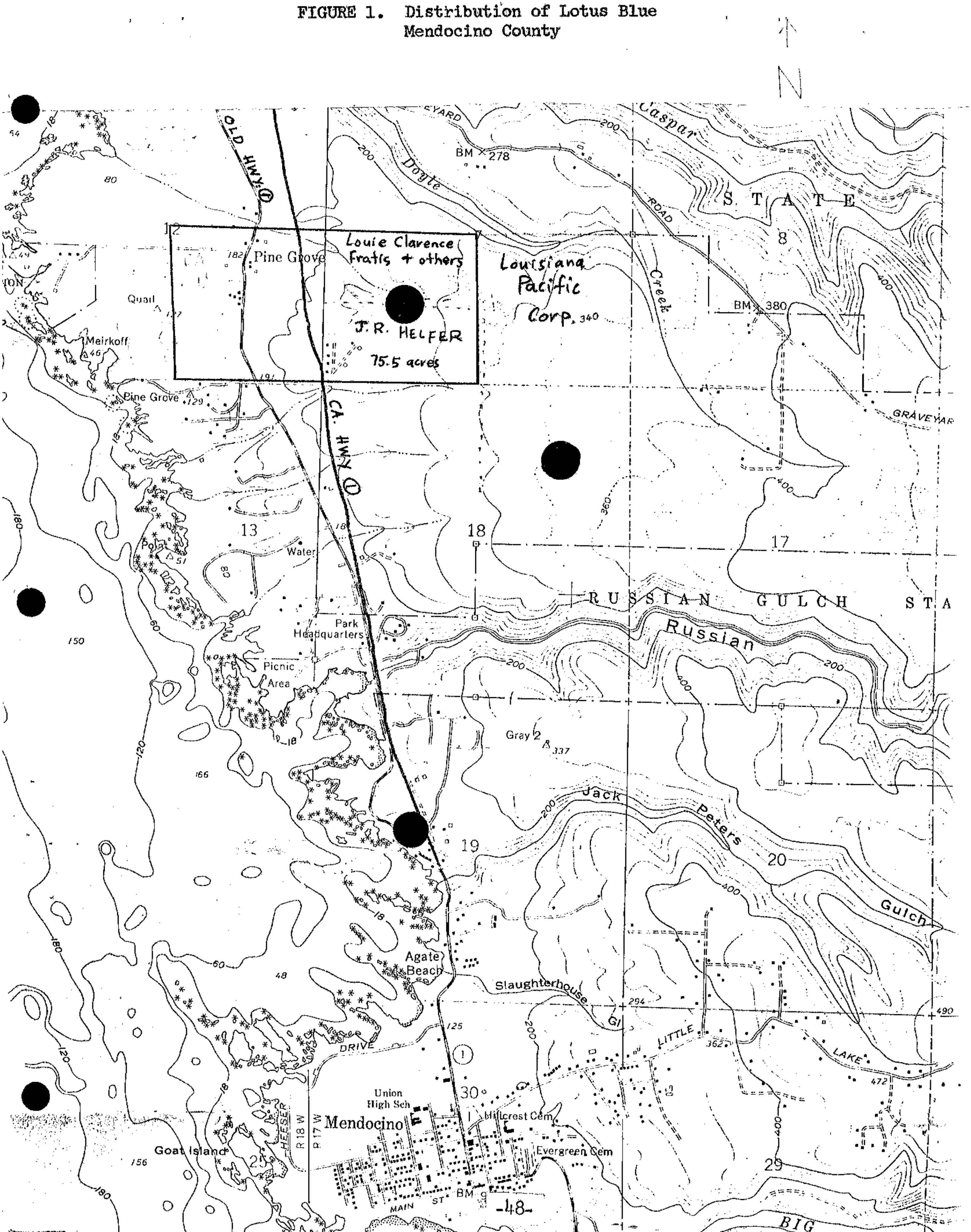
The most immediate threat to the survival of this taxon is the drought which has drastically lowered the Mendocino water table. Undoubtedly this phenomenon has occurred in the past, but we have no knowledge of how the Lotüs blue has responded to the droughts of the past.

The fact that this property is not in public ownership poses a threat to the continued survival of this species. One of the neighboring land owners is a lumber company, which has been buying a great deal of land in this area. As long as the Pacific Gas and Electric powerline and right-of-way require minimum maintenance, they will pose no threat to the Lotis blue. Drainage of the bog would threaten the survival of this species.

Essential Habitat

Until the Lotis blue can be studied in the same manner as the other five endangered butterflies, I suggest that the critical habitat be delineated as it was originally proposed. Even though this is a much larger area than that in which it normally occurs, I believe that the aforementioned threats to survival dictate the need for a large area of critical habitat.

FIGURE 1. Distribution of Lotus Blue
Mendocino County



Management Recommendations

At this point in time, my only recommendation is to acquire the land upon which this species occurs. Perhaps an agreement with Pacific Gas and Electric and Jack Helfer can be made such that the State in cooperation with these parties can manage the habitat.

SMITH'S BLUE

Distribution

Mattoni (1954) described Smith's blue (*Shijimiaeiodes enoptes smithi*) from a series near California State Highway 1. All known colonies of Smith's blue are confined to Monterey County, mostly along the immediate coast. The southern most colony is located near Lucia (Langston, 1963), while the northern most colony is at a Department of Fish and Game Ecological Reserve just south of the mouth of the Salinas River. Other colonies include Marina Beach dunes; Seaside dunes (almost entirely extirpated); Monterey "sand hills"; Paraiso Springs; Burns Creek at Highway 1; Lucia, 3 and 4 miles southeast; 4 miles north of Point Gorda; two large colonies, plus a couple of smaller ones on the Fort Ord Military Reservation near Highway 1; and, Vasquez Knob, 3 miles west of Carmel Valley Village (Fig. 1).

Herbaria records indicated that there were several other localities both north and south of Monterey County where the larval foodplants, *Eriogonum latifolium* and *E. parvifolium* occur. Because of widespread occurrence, I visited only a few of these localities but could turn up no new colonies.

Coastal sand dune strand is the dominant vegetation at colonies bordering on the coast. Chaparral-woodland is dominant at the Vasquez Knob colony. Table 1 lists representative plant species found at the Fort Ord colonies.

Table 1

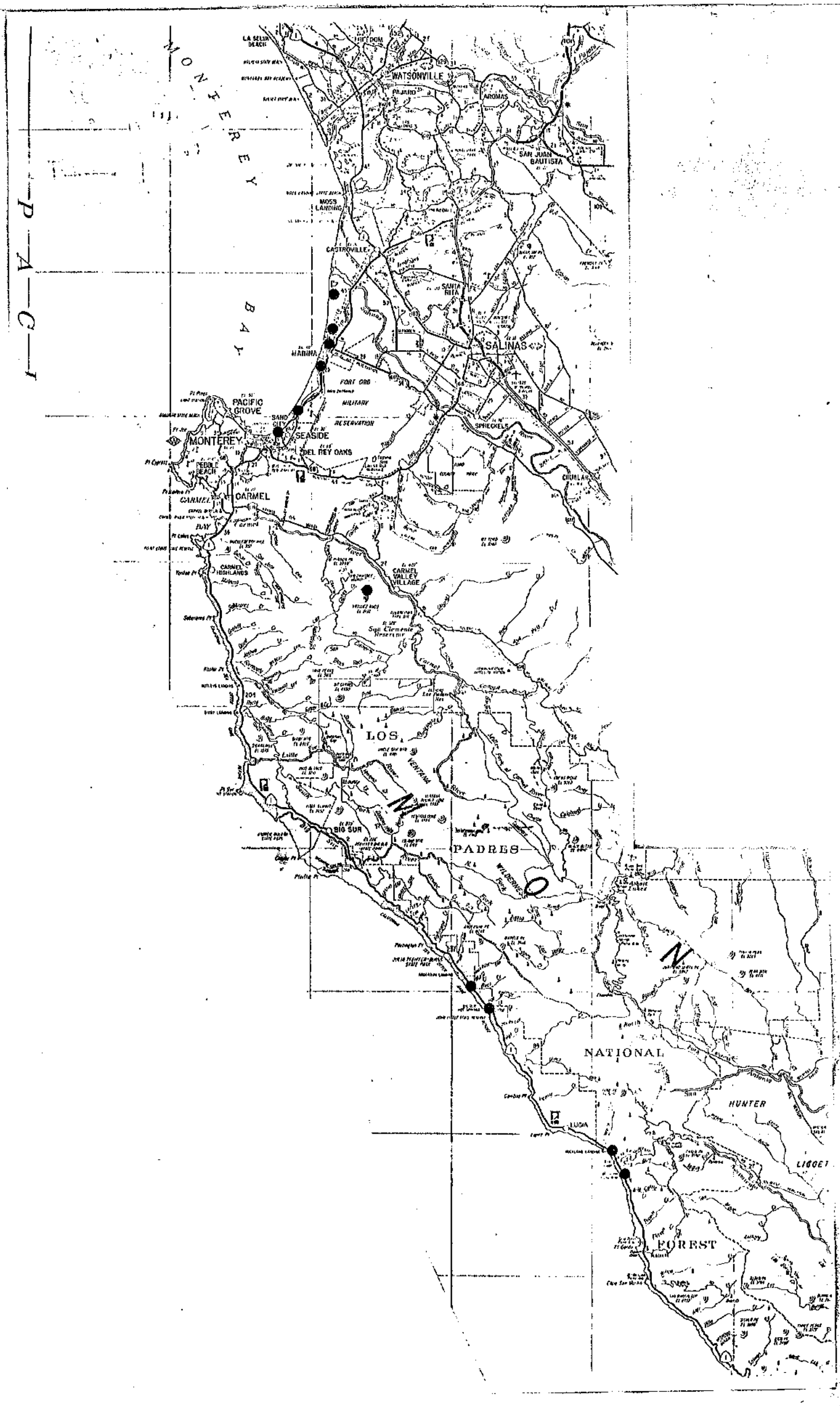
Representative vegetation at Smith's blue study site.

Abronia latifolia
A. umbellata
Ambrosia chamissonis
Ammophila arenaria
Artemesia pycnocephala
Cakile maritima
Castilleja latifolia
Chorizanthe pungens
Cirsium occidentale
Convolvulus soldanella
Corethrogyne leucophylla
Croton californica
Dudleya caespitosa
Elymus mollis
Eriogonum latifolium
E. parvifolium
Eriophyllum staechadifolium
Erysimum ammophilum
Eschscholtzia maritima
Haplopappus ericoides
Lathyrus littoralis
Lotus heermanii
Lupinus albifrons
L. arboreus
L. chamissonis
Mesembryanthemum chilensis
M. chilensis x *M. edulis*
M. edulis
Oenothera cheiranthifolia
Orthocarpus purpureus var. *pallidus*
Poa douglasii

Life History

Smith's blue is univoltine. Females will oviposit on either of two plants, *Eriogonum latifolium* and *E. parvifolium*. *E. latifolium* is herbaceous and leafy only at its base while *E. parvifolium* is a shrub. Both buckwheats are flowering

Figure 1. Distribution of Smith's blue, Monterey County



from mid-June through early August, when the adults are flying. Adult emergence is closely synchronized with the peak blooming period of the host plants: eggs are laid shortly after copulation. In the field, females oviposit on or in the flower heads. The eggs are usually laid singly on sepals of the newly opened flowers or on the late bud stage. Eggs are less frequently found on the white petals or a short distance down the pedicel. Each oviposition occurs only after much abdominal probing, walking over the flowers, and "dancing" in the flower heads. In the laboratory, females oviposited only on fresh flower heads. Ovipositions were obtained in the same manner as described for the San Bruno elfin (Table 2).

Table 2

Egg fertility, embryo viability and percentage hatched of Smith's blue.

♀ Rearing No.	Number of Eggs	Fertile/ Laid	Hatched/ Fertile	Hatched/ Laid
77G1	17	1.00	1.00	1.00
77G2	25	.88	1.00	.88
77G3	63	.94	.93	.84
77G4	55	.98	1.00	.98
77G5	36	.94	1.00	.94
77G6	32	1.00	1.00	1.00
77G8	41	.98	.98	.95
77G9	18	1.00	.94	.94
77G10	21	.86	.94	.81
77G14	17	1.00	.94	.94
77G15	47	.94	.98	.89
77G16	54	1.00	.96	.96
77G17	5	1.00	1.00	1.00
77G18	39	.90	.97	.87
77G22	26	.81	1.00	.81
77G23	67	.92	.98	.91
77G25	35	.94	.91	.86
77G28	13	.62	.88	.54
77G32	7	.43	1.00	.43
77G33	22	.82	.89	.73

Females fly from plant to plant, or flower head to flower head in a rapid, erratic manner. They continue this activity nearly all day, pausing only to nectar and occassionally rest.

Under field conditions, the larvae emerge in four to eight days. They immediately begin feeding on the flower parts. Larvae are present from early July to late August. Because of the long period of oviposition, plus some probable microclimatic variations, the larval development tends to become staggered within a colony. Along the shoreline, development tends to be slowed because of the cooler temperatures. But a few hundred meters inland, the temperatures are usually a few degrees warmer and development is more rapid. Also, at the warmer spots, buckwheat flower heads wither sooner than those along the cooler shoreline. On 23 July, first, second, and third instar larvae were collected at the study site. On 18 August, mostly third, fourth, and fifth instar larvae were collected at the study site, while first and second instars were found along the shore. On 27 August, no larvae were found at the study site, while third, fourth, and fifth instars were collected along the shoreline. The larvae of all five instars feed only on the flower heads. By 18 August when most of the mature larvae were found, many of the buckwheat flower heads were well into the seed stage. Mature larvae are yellowish to pinkish-brown. Until the penultimate instar, they are largely concealed by the flower head in which they feed. The third, fourth and fifth instars are myrmecophilous (Table 3), but the ants are not yet identified. Larvae are often located by the presence of the more conspicuous ants as the coloration of the mature larvae blend nicely with that of a slightly withered flower head. The larvae are heavily parasitized by a tachinid fly, whose identity is not yet known. Nearly 42 percent of the larvae were parasitized (Table 4).

Table 3

Frequency of myrmecophilous Smith's blue larvae in the field.

Number of Larvae	Percent Myrmecophilous
177	29.38

Table 4

Percent of Smith's blue larval parasitism by an unidentified Tachinid.

Rearing No.	No. of Larvae	Percent Parasitized
77G34	28	28.57
77G35	61	40.98
77H28	77	67.53
77H29	45	22.22
77H37	48	50.00
	259	$\bar{x}$ = 41.86

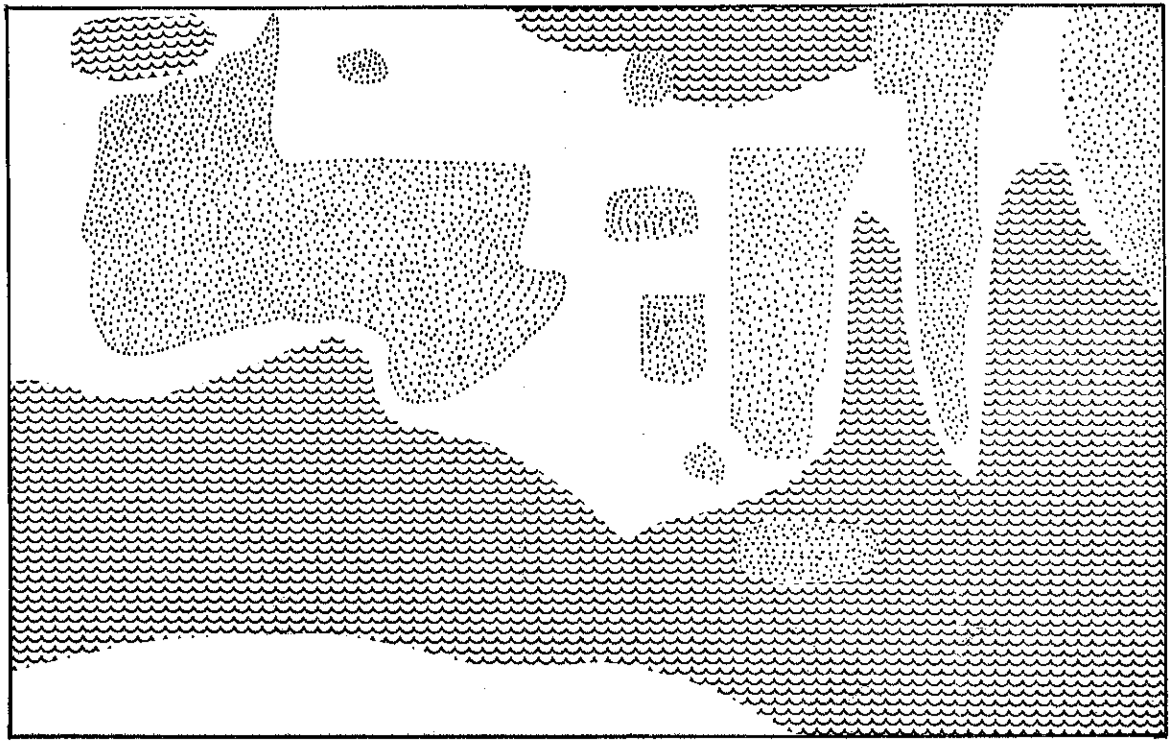
Pupation generally occurs from mid-August to early September. A few pupae were found in buckwheat flower heads. The majority of larvae reared in the laboratory on potted plants pupated in the sand or at the base of the buckwheat among the duff.

Population Study

Study site and sampling

A gently sloping north-facing dune, dominated by coastal strand was the study site. It was located near the northern boundary of the Fort Ord Military Reservation and near the Pacific Ocean. The site of this colony formerly served as a grenade tossing practice field. Figure 2 is a vegetational map of the site. The U. S. Army owns the property.

Figure 2. Vegetational map of Fort Ord,study site



Methods

Marking techniques were as described in the introduction.

Sampling was initiated each day at 0730 to 0900 PST and terminated at 1400-1600 PST.

The probability of collecting a Smith's blue was compared with a poisson distribution for the number of successive recaptures. A comparison of the observed and poisson distributions for the number of successive recaptures is shown in Table 5. A test of goodness of fit shows no significant deviation of observed from the expected values for the range of 0-4 successive recaptures. This agreement means that collecting and marking individuals did not alter their probabilities of survival.

Table 5

Distribution of the observed number of recaptures per number of repeats and their expected poisson values for Smith's blue.

Number of Recaptures	Observed (f)	Expected ($\hat{f}$)
0	663	659.25
1	221	226.78
2	40	39.01
3	5	4.47
4	1	0.38

$\bar{y} = 0.344$

Results

Aging and sex ratio

The data presented in Table 6 reveal that male adults generally eclose five to six days earlier than do females. Also, wear damage to the wings accumlated gradually with age after eclosion. The sex ratio shifts from a preponderance of males early in the flight season to a greater fraction of females later on. The average wear values for both sexes increases relatively smoothly through the study. Females lag slightly behind males, as would be expected from the eclosion lag.

Daily Numbers

A total of 551 males and 379 females were marked at the study site in a 12 day period. Data from Shields (1975) indicates that the actual sex ratio is 1:1. My rearing material is in the pupal stage and will not emerge until next summer.

The proportion of marked animals, the total marked population, daily population estimates, probability of survival, and the numbers of new animals joining the population for both sexes is presented in Table 7. The fluctuations in the daily estimates were puzzling, since field experience indicated that the number of butterflies present in the study site increased rapidly in the early part of the flight period, remained more or less constant for a few days, and then slowly declined until the butterflies disappeared altogether. The fluctuations resulted from the fact that I thought I was studying a discrete colony, when in fact I was studying a subpopulation of a larger colony.

Table 6

Sample-based sex ratios, and wear ratings of males and females, of adult Smith's blue in relation to the progress of the flight season.

Date	Day	♂:♀	Percent ♂:♀	♂ Average Wear	♀ Average Wear
VII-7	1	92:26	78: 22	2.27	2.24
VII-8	2	110:41	73: 27	2.48	2.39
VII-9	3	119:66	64: 36	2.71	2.53
VII-10	4	71:51	58: 42	2.98	2.84
VII-12	5	41:42	49: 51	3.33	3.06
VII-13	6	29:35	45: 55	3.68	3.29
VII-14	7	19:22	46: 54	3.71	3.58
VII-15	8	43:35	55: 45	2.87	2.98
VII-16	9	24:29	45: 55	3.24	3.37
VII-17	10	3:25	11: 89	3.86	3.55
VII-18	11	0: 7	0: 00	—	3.66

Since the study site is 1.84 ha, the peak density of the population is high. Upon examining the map of the male and female movements (Figs. 3 and 4), it is obvious that the adults rarely stray from the quadrates containing Eriogonum. Both males and females were found in 23 quadrates. If we consider the density in only the quadrates within the study site where individuals were captured or recaptured, the peak density is very high (Table 8).

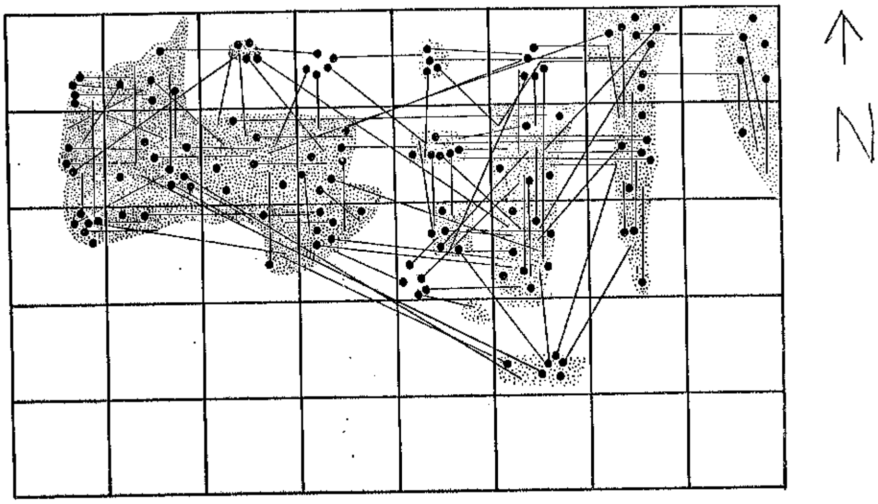
The observed deviation from the 1:1 sex ratio is probably due to behavioral differences between the sexes. Both sexes are perchers, although each will readily move from one plant to another. The preferred perching substrate and nectar source of both sexes are buckwheat flower heads (Figs. 5 and 6). While one male often occupies the same perch from day to day, females tend to move around more. This is evidenced by the movement patterns and vagility figures for both sexes.

Because they occupy a given perch for only a day, and move greater distances, a smaller percentage of females are recaptured. Since males are less vagile, a higher percentage are recaptured. For example, of the 551 males marked, 171 were recaptured (31 percent) at least once; however, of 379 females marked, 96 were recaptured (25 percent) at least once (Table 9).

The lag in emergence times for females also contributes to the sex ratio discrepancy. Females did not compose the majority of the catch until six days into the study.

Figures 3 and 4. Movements of adult Smith's blue, Fort Ord study site
Stippling refers to buckwheat distribution.

Males



Females

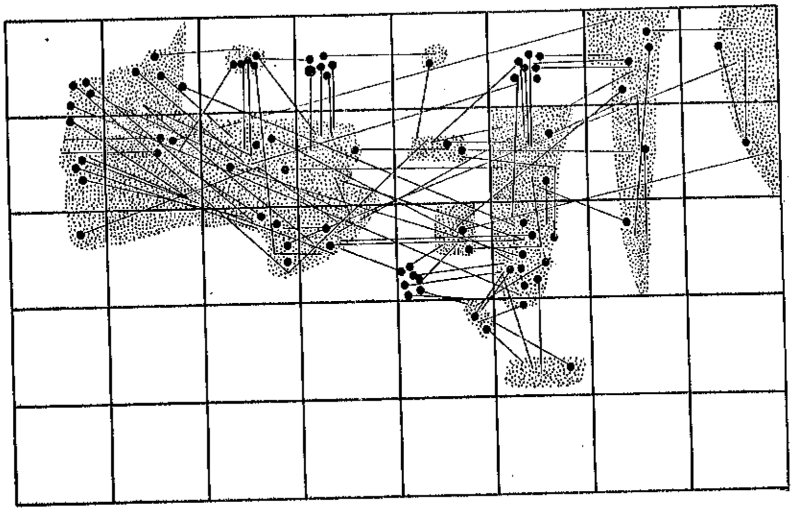
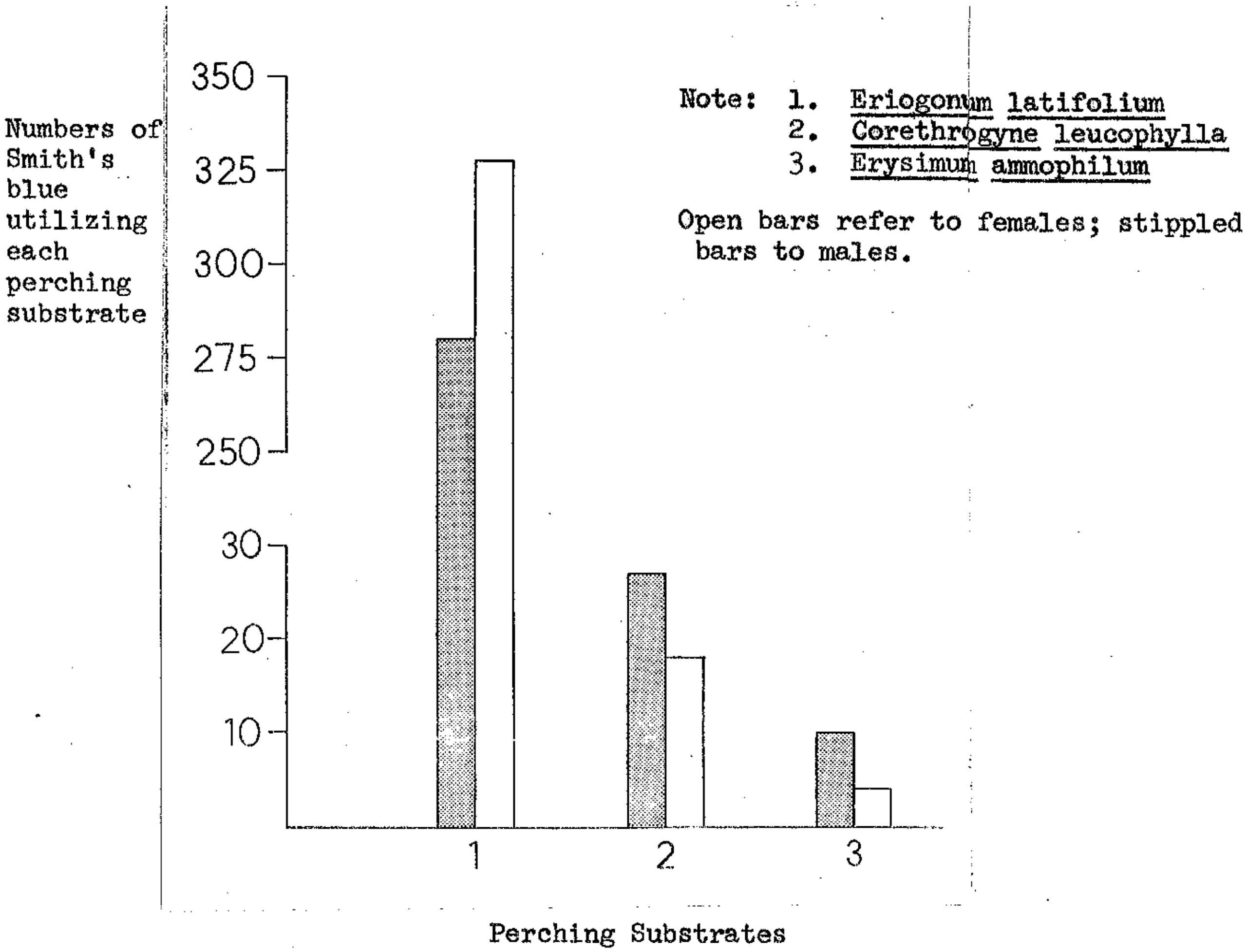


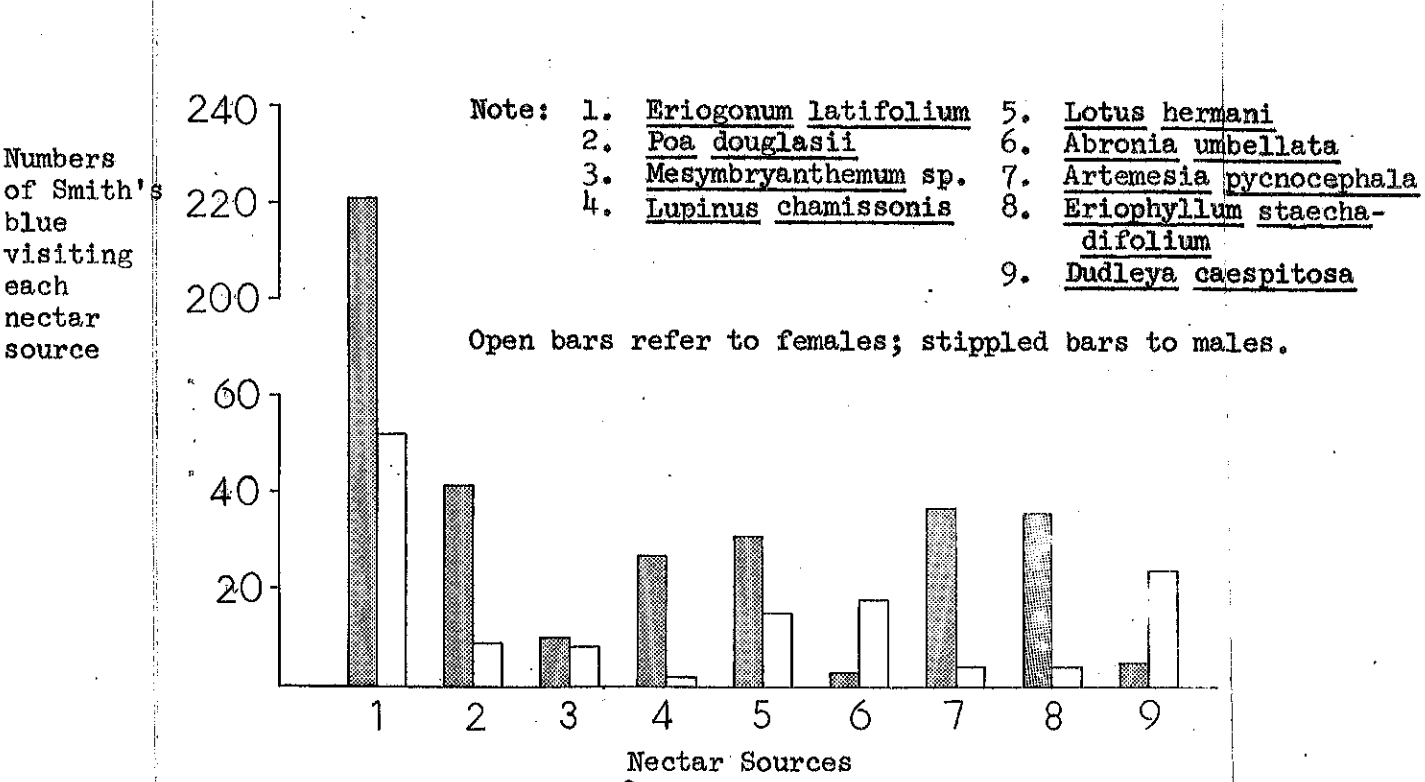
Figure 5. Perching substrates of Smith's blue, Fort Ord study site



Note: 1. *Eriogonum latifolium*
2. *Corethrogyne leucophylla*
3. *Erysimum ammophilum*

Open bars refer to females; stippled bars to males.

Figure 6. Nectar sources of Smith's blue



Note: 1. *Eriogonum latifolium*
2. *Poa douglasii*
3. *Mesymbryanthemum* sp.
4. *Lupinus chamissonis*
5. *Lotus hermani*
6. *Abronia umbellata*
7. *Artemesia pycnocephala*
8. *Eriophyllum staechadifolium*
9. *Dudleya caespitosa*

Open bars refer to females; stippled bars to males.

Table 7

Population parameters of Smith's blue estimated from Jolly's stochastic model of multiple recapture data.

Males:

Day	Alpha	M	N + 1.96 SE	PHI + 1.96 SE	B + 1.96 SE
1	0.0000	0.00	0.0 + 0.0	.757 + .328	0.0 + 0.0
2	.1296	72.67	560.6 + 340.3	.696 + .302	200.5 + 287.4
3	.1983	117.38	592.0 + 299.5	.424 + .167	-17.7 + 114.0
4	.3857	90.39	234.4 + 93.8	.699 + .283	14.4 + 64.9
5	.5250	93.89	178.8 + 79.3	.798 + .398	-38.1 + 43.8
6	.8621	90.91	105.5 + 49.4	.790 + .558	-4.2 + 13.2
7	.9474	75.00	79.2 + 50.1	.724 + .574	135.2 + 108.7
8	.2857	55.00	192.5 + 131.6	.628 + .471	-28.9 + 66.6
9	.5833	54.00	92.6 + 67.9	.273 + .199	-21.3 + 11.0
10	4.3333	17.50	4.0 + 2.4	0.000 + 0.000	0.0 + 0.0
11	2.0000	0.00	0.0 + 0.0	0.000 + 0.000	0.0 + 0.0

Females:

Day	Alpha	M	N + 1.96 SE	PHI + 1.96 SE	B + 1.96 SE
1	0.0000	0.00	0.0 + 0.0	.431 + .458	0.0 + 0.0
2	.0750	11.20	149.3 + 200.8	.697 + .527	255.2 + 331.0
3	.0952	34.29	360.0 + 354.5	.492 + .305	79.1 + 206.5
4	.1800	46.40	257.8 + 193.9	.661 + .376	121.0 + 204.9
5	.2000	58.40	292.0 + 218.7	.871 + .538	-60.6 + 172.6
6	.4118	80.50	195.5 + 128.2	.624 + .459	-15.4 + 59.2
7	.5909	63.29	107.1 + 73.1	.838 + .673	116.2 + 124.4
8	.2941	60.56	205.9 + 160.5	.795 + .690	32.8 + 126.6
9	.3448	68.00	197.2 + 173.8	.529 + .526	0.3 + 67.0
10	.4400	46.00	104.5 + 92.6	0.000 + 0.000	0.0 + 0.0
11	1.7143	0.00	0.0 + 0.0	0.000 + 0.000	0.0 + 0.0

Alpha = proportion of marked animals
M = total marked population
N = total population
Phi = probability of survival
B = number of new animals joining the population

Table 8

Density of Smith's blue at the study site.

Sex	Density of Entire Study Site	Density in Only Occupied Quadrates
Males	287.10/ha	897.18/ha
Females	343.38/ha	1073.06/ha

Table 9

Number of individuals marked, percent of individuals recaptured and number of recaptures for individuals recaptured at least once for Smith's blue.

Sex	Number of Individuals	Percent Recaptured	Average Number of Recaptures
Male	551	31.03	1.18
Female	379	25.07	1.22

Residence

Table 10 presents day-specific residence and loss rates, plus mean expected residence times for both sexes.

Table 10

Residence rates ($\hat{\phi}$), mean expected residence, loss rate, and estimates of total brood number for Smith's blue.

Sex	$\hat{\phi}$	Mean Expected Residence (days) $-(\ln \hat{\phi})^{-1}$	Day-specific Loss Rate	$\Sigma \hat{N}i$	Estimated Total Brood Numbers
Males	0.741	3.33	0.259	2039.6	528.26
Females	0.662	2.42	0.338	1869.3	631.82

Males live on the average about one day longer than females. Even though this study was conducted throughout the flight span of this species, the low recapture values for each sex has resulted in the calculation of a lower lifespan value than probably occurs. The value for the males is more nearly accurate than that for the females.

Dispersal Analysis

Vagility

Females flew farther and in faster times than did males (Table 11). This is not surprising as males tend to perch more than females. The greater vagility of the of the females is due to search behavior for larval foodplants.

Table 11

Vagility parameters for Smith's blue.

Vagility Parameter	Male	Female
Mean T (days)	2.03	2.17
Max T (days)	7.00	8.00
Mean t_i (days)	1.68	1.78
Mean R (meters)	25.18	34.42
Max R (meters)	111.00	120.00
Mean D (meters)	26.45	38.42
Max D (meters)	111.00	120.00
Mean d_i (meters)	21.96	31.55
Mean V (m/day)	15.87	21.75
Max V (m/day)	111.00	120.00
Mean v_i (m/day)	18.09	26.16

The majority of movements for both species are local, although a higher percentage of females made long movements (Table 12). Only 16 individuals, six males (3.5 percent of the male recaptures) and 10 females (10.4 percent of the female recaptives) moved over 70 m. Several other clumps of buckwheat were within 70 m of the study site, thus intercolony movement is possible.

Table 12

Local versus long moves for Smith's blue.

Sex	Local	Percent	Long	Percent
Male	147	86	24	14
Female	69	72	27	28

Dispersion

Smith's blue is restricted in its distribution along the Monterey coast where E. latifolium or E. parvifolium grows. In order to determine its microdistribution at Fort Ord, Morisita's Index was computed.

Dispersion indices were calculated for both males and females. Samples consisted of 40 quadrates, each 24 m x 24 m. The number of individuals recorded in each quadrate equaled the number of individuals captured and recaptured in that quadrate during the 12-day sampling period.

Males and females exhibit little difference in dispersion patterns. Morisita's Index (Table 13) revealed that males are slightly more aggregated than females. While the difference is slight, perhaps it can be explained as the result of different selective influences. Males can best increase their genetic contribution to the next generation by mating as frequently as possible. Because females rarely stray from the buckwheat flower heads, the males select areas with the highest probability of encountering a receptive female thus they perch on the flowers. Females, on the other hand, once they have mated, can best increase their genetic contribution by laying as many eggs as possible. Even though this plant is widespread throughout the study site, the high density of males on the flowers forces the females to patrol to search for suitable oviposition sites. Thus their dispersion is more diffuse.

Table 13

Indices of dispersion for Smith's blue.
All groups are significantly aggregated ($p > .001$).

Sex	I_m
Male	2.96
Female	2.23

Since both sexes also utilize buckwheat as a primary nectar source, they rarely stray far from it. The major exception is for evening roosts which occur in grassy areas near buckwheat. Presumably, these areas are warmer, because of their proximity to the ground, and are also shielded from the coastal winds. Nonetheless, many Smith's blue roost on the buckwheat. No sexual preferences for roosting sites could be determined.

Activity

The Standard Area of Activity for males ranged from 0.36 to 2.49 with a mean of 0.83 ha. Females Standard Area of Activity ranged from 0.40 to 3.25 with a mean of 1.25 ha. There is approximately 1.44 ha of suitable habitat for both sexes. These data indicate that the average male utilizes about 58 percent of the area which can potentially be occupied by all males. The average female utilizes about 87 percent of the total area. These data exemplify the fact that females move throughout most of their potential area in search of suitable oviposition sites, whereas males tend to perch on buckwheat flowers.

This species does not exhibit territorial behavior as did the aforementioned species. Mate location happens due to the congregation or high density of adults constantly near buckwheat. Since both sexes spend most of their entire lives on this plant, there is no need for territoriality. Thus mate location is possible with random flight by both sexes. Frequent intersexual encounters were observed on the foodplant and 42 *in copulo* pairs were noted. Copulation occurs on flowers.

Evening roosts were frequently adjacent to buckwheat but on grass stems and only a few inches above the ground. Adults were very inconspicuous in their roosting sites. Nonetheless, several spider predators captured adults. Two spiders, *Clubiona* sp. and *Theridion* sp. were most frequently observed.

Threats to Survival

Because of its numerous colonies, several of which are already in preserves, I see little threat to the survival of this taxon. Colonies at the Department of Fish and Game Ecological Reserve, Fort Ord, Point Lobos, Big Sur, and on a new reserve near Lucia offer an abundance of habitat for Smith's blue. Several of the other colonies occur on bluffs along the ocean or in steep canyons inland and are thus inaccessible to developers. I expect that at least a few more colonies of this taxon remain to be discovered. Thus, it is doubtful whether this species deserves endangered status. I recommend that it be reclassified as threatened.

Despite the fact that there are numerous colonies, management plans need to be devised to ensure their survival. For example, the Fort Ord colony is being encroached upon by ice plant.

Essential Habitat

While the critical habitat proposal of U.S. Fish and Wildlife Service does not include all the known colonies of Smith's blue, it does include the remnants of the best sand dunes along the Monterey coast. These are also the areas most likely to be developed in the near future. Possibly, the other colonies should be included in a new critical habitat proposal, but since this species is already protected on several reserves and its in inaccessible areas elsewhere, I see no need to expand the proposed critical habitat.

Management Recommendations

To ensure the survival of Smith's blue, the following conditions are necessary:

1. The invasive and allelopathic ice plant, which in many dune areas forms the dominant vegetation, be removed. This species is choking out the larval foodplants of Smith's blue, especially at Fort Ord and the Marina dunes. Also, it has stabilized many of the dunes and thus does not allow the sand to shift and thus open up new sites for seedling establishment by buckwheat.
2. European beach grass (*Ammophila arenaria*), which has stabilized the dunes and out-competed the buckwheat planted, be controlled.
3. Native dune plants be planted to reestablish vegetation in the areas currently occupied by ice plant and European beach grass.
4. Controlled burning be done in managing the flora of the Smith's blue sites.
5. Use of off-road vehicles in the reserves be controlled or prohibited.

EL SEGUNDO BLUE

Distribution

Like the San Bruno elfin, the El Segundo blue (*Shijimiaeoides battoides allyni*) occurs in a region where lepidopterists have collected for many years, yet this taxon was not discovered until recently. Shields (1975) described it as a new subspecies. This taxon now survives on small remnants of the once expansive El Segundo Dunes in Los Angeles County. The dunes originally covered about 36 square miles from what is now the Los Angeles International Airport to San Pedro, California. Museum records reveal that El Segundo blue could be found in El Segundo, Palos Verdes Peninsula, Redondo Beach and North Manhattan Beach.

Today, only two colonies exist: one at Los Angeles International Airport, and the other on two acres owned by Chevron in El Segundo (Fig. 1).

Additionally, there is one small colony of a *S. battoides* population on the Palos Verdes Peninsula. But Lycaenid expert, Dr. R. H. T. Mattooni, believes that this population is not *S. b. allyni*. Along the coastal bluffs from Malaga Cove (Palos Verdes Estates) to Point Fermin (San Pedro), occur widely scattered clumps of the larval buckwheat foodplants--*Eriogonum parvifolium* and *E. fasciculatum*. Most of these clumps are inaccessible due to the steepness of the bluffs. Those that could be checked did not yield any El Segundo blue specimens. All of these areas are located in the coastal fog belt of Los Angeles County.

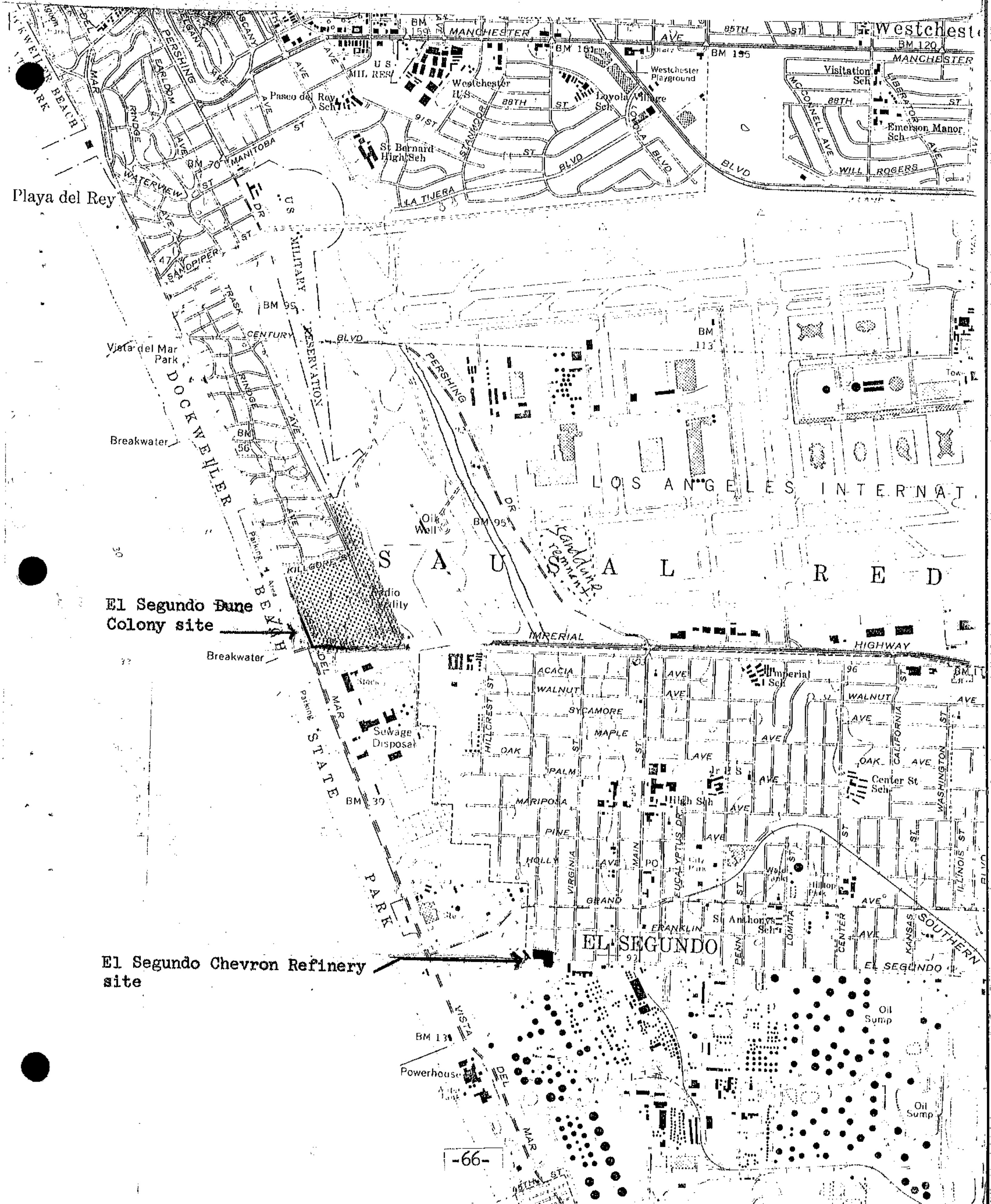
Coastal strand is the dominant vegetation on the dunes where El Segundo blue occurs. Representative vegetation is listed in Table 1.

Table 1

Representative vegetation at El Segundo blue colonies.

Abronia umbellata variabilis
Artemisia californica
Avena fatua
Baccharis pilularis
Brickellia californica
Brodiaea pulchella
Bromus mollis
Cakile edentula
Chaenactis glabriscula
Convolvulus cyclostegius
Croton californicus
Datura meteloides
Descurainia pinnata
Dudleya caespitosa
D. pulverulenta
Eriogonum cinereum
E. fasciculatum
E. parvifolium
Erysimum suffrutescens
Eschscholtzia californica
Foeniculum vulgare
Franseria chamissonis
F. c. bipinnatisecta
Gnaphalium leucocephalum
Haplopappus ericoides
Helianthus annuus
Lepidium densiflorum
Lotus micranthus
L. scoparius
Lupinus bicolor
L. longifolius
Malacothrix saxatilis
Mesembryanthemum crystallinum
Oenothera cheiranthifolia
Phacelia ramosissimum
Raphanus sativus
Rhus integrifolia
Salsola kali var. *tenuiflora*
Stephanomeria virgata
Tillaea erecta

Figure 1. Distribution of El Segundo blue colony in Los Angeles County, California



El Segundo ~~Dune~~ Colony site

El Segundo Chevron Refinery site

Life History

The El Segundo blue is univoltine. Adults fly from mid-July to late August. Females will oviposit on either Eriogonum parvifolium or E. fasciculatum. Adult emergence is synchronized with the peak blooming period of buckwheat flowers. Females initiate oviposition behavior shortly after copulation. Eggs are laid throughout the life of the female. The eggs are usually laid singly on sepals of the newly opened flower or on the late bud stage (Table 2).

Table 2

Egg fertility, embryo viability and percentage hatched of El Segundo blue.

♀ Rearing No.	Number of Eggs	Fertile/ Laid	Hatched/ Fertile	Hatched/ Laid
77H1	22	1.00	1.00	1.00
77H2	15	.93	1.00	.93
77H3	45	.98	.95	.93
77H4	28	.93	1.00	.93
77H5	37	.92	.97	.89
77H6	56	.91	.98	.89
77H8	51	.94	.98	.92
77H9	44	1.00	1.00	1.00
77H10	39	.97	.97	.95
77H14	47	.94	.95	.89
77H15	48	.96	.96	.92
77H16	19	1.00	1.00	1.00
77H17	22	1.00	1.00	1.00
77H22	30	.90	.93	.83
77H23	4	.50	1.00	.50
77H24	18	.83	.93	.78

Females fly from flower to flower in a rapid, erratic manner. This activity is continued nearly all day, pausing only to nectar and occasionally rest. Each oviposition occurs only after much abdominal probing, walking over the flowers, and "dancing" on the flower heads. In the laboratory, females oviposited only on fresh flower heads.

Under field conditions, larvae emerge in four to eight days. They immediately begin feeding on flower parts. Larvae are present from late-July to mid-September. Because of the staggered adult emergence, and probable microclimatic variations, larval developments in a colony is asynchronous. Nonetheless, larvae take approximately one month to mature.

There are five instars. The later instar larvae are myrmecophilous (Table 3). Iridomyrmex humilis (Andre) is the most frequently encountered tending ant, but there are at least two other species which also tend El Segundo blue larvae. Since the larvae bore into the flower heads of the buckwheat, the tending ants are usually more conspicuous than the larvae.

Table 3

Frequency of myrmecophilous El Segundo blue larvae in the field.

Number of Larvae	Percent Myrmecophilous
129	38.28

Pupation generally occurs at the base of the buckwheat in the debris and sand. A few pupae were located near the base at leaf axiles, and covered by the leaf. Larvae reared on potted plants in the laboratory pupated at the base of the buckwheat.

Two unidentified tachinids and one Braconid are larval parasites.

Population Study

Study site and sampling

A two acre parcel of coastal strand at the Chevron refinery in El Segundo served as the study site. The site has many native dune plants, plus several introduced species, most notably, ice plant. Figure 2 is a vegetational map of the site.

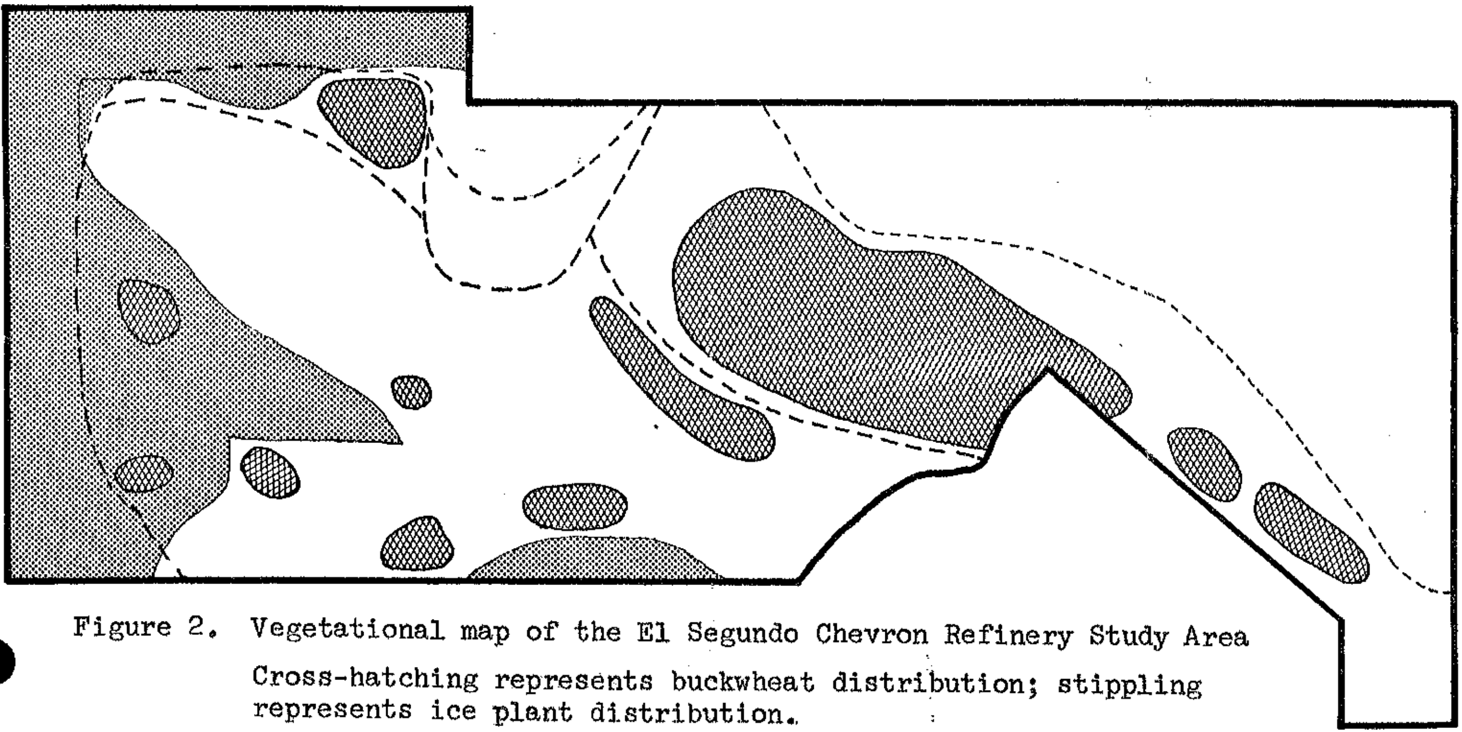


Figure 2. Vegetational map of the El Segundo Chevron Refinery Study Area

Cross-hatching represents buckwheat distribution; stippling represents ice plant distribution.

Marking techniques were as described in the introduction.

Sampling was initiated each day at 0730 to 1000 PST and terminated at 1400 to 1600 PST.

The probability of collecting the El Segundo blue was compared with a poisson distribution for the number of successive recaptures. A comparison of the observed and poisson distributions for the number of successive recaptures is shown in Table 4. A test of goodness of fit shows no significant deviation of observed from the expected values for the range of 0 to 3 successive recaptures. The inclusion of the total range of 0 to 6 does, however, introduce a significant deviation of observed from poisson values due to the very low expected frequencies of the latter. The 26 individuals which cause the significant deviation may indicate a tendency for a marked individual to be recaptured more often than expected. I find this difficult to believe, considering that the majority of individuals were not affected by marking. Another alternative exists if the life expectancy over the study period changes for the majority of individuals composing the population. Comparison of survival-rates (Table 5) shows that such a change in life expectancy did occur.

Table 4

Distribution of the observed number of recaptures per number of repeats and their expected poisson values for the El Segundo blue.

Number of Recaptures	Observed (f)	Expected ($\hat{f}$)
0	227	195.36
1	188	201.22
2	65	103.63
3	41	35.58
4	17	9.16
5	7	1.89
6	2	0.32

$\bar{y} = 1.03$

Another factor may be the extremely low vagility parameters. Due to the small size of the habitat, selection has undoubtedly favored those individuals which do not move very far. Males, in particular, move on the average, extremely short distances. Many never move from the same plant or clump upon which they were originally marked. Thus selection for sessile individuals may well be responsible for the high observed successive recapture values.

Table 5

Population parameters of the El Segundo blue estimated from Jolly's stochastic model of multiple recapture data.

Males:

Date	Day	Alpha	M	N + 1.96 SE	PHI + 1.96 SE	B + 1.96 SE
VIII-8	1	0.0000	0.00	0.0 + 0.0	.701 + .195	0.0 + 0.0
VIII-9	2	.1111	56.06	504.5 + 247.8	.746 + .159	-150.3 + 181.3
VIII-10	3	.5574	126.92	227.7 + 64.2	.682 + .140	-50.4 + 32.0
VIII-11	4	1.0000	106.39	106.4 + 24.0	1.132 + .275	-67.2 + R
VIII-12	5	2.2353	121.58	54.4 + 21.2	1.084 + .816	-45.7 + 25.4
VIII-13	6	8.2500	109.00	13.2 + 24.6	.500 + .490	-3.3 + R
VIII-14	7	12.0000	40.00	3.3 + 12.6	.944 + .106	-.1 + R
VIII-15	8	5.5000	17.00	3.1 + 12.0	0.000 + 0.000	0.0 + 0.0
VIII-16	9	3.5000	0.00	0.0 + 0.0	0.000 + 0.000	0.0 + 0.0

Females:

Date	Day	Alpha	M	N + 1.96 SE	PHI + 1.96 SE	B + 1.96 SE
VIII-8	1	0.0000	0.00	0.0 + 0.0	1.122 + .603	0.0 + 0.0
VIII-9	2	.0625	19.07	305.1 + 423.1	.740 + .326	-2.7 + 328.5
VIII-10	3	.1628	36.33	223.2 + 156.6	.736 + .238	26.4 + 136.0
VIII-11	4	.2821	53.96	191.3 + 98.1	.858 + .246	-68.7 + 79.6
VIII-12	5	.7391	71.17	96.3 + 33.9	.920 + .309	-25.3 + 18.2
VIII-13	6	1.1176	72.83	65.2 + 21.6	.772 + .257	-15.5 + R
VIII-14	7	1.5714	54.67	34.8 + 12.4	1.179 + .390	.8 + R
VIII-15	8	1.3158	55.00	41.8 + 18.9	0.000 + 0.000	0.0 + 0.0
VIII-16	9	2.8889	0.00	0.0 + 0.0	0.000 + 0.000	0.0 + 0.0

Results

Aging and sex ratio

The data presented in Table 6 reveal that the eclosion of males peaks a few days earlier than females. Also wear damage to the wings accumulates gradually with age after eclosion. The sex ratio shifts from a preponderance of males early in the flight season to a greater fraction of females later on. The average wear values for both sexes increases smoothly throughout the study. Females lag slightly behind males, as would be expected from the eclosion lag.

Daily numbers

A total of 327 males and 220 females were marked at the study site in a nine day period. While the sex ratio is skewed, I am confident that it is actually 1:1. My rearing material is in the pupal stage and will not emerge until next summer.

The proportion of marked animals, the total marked population, daily population estimates, probability of survival, and the numbers of new animals joining the population for both sexes is presented in Table 5.

Table 6

Sample-based sex ratios, and wear ratings of males and females, of adult El Segundo blue in relation to the progress of the flight season.

Date	Day	♂:♀	Percent ♂:♀	♂ Average Wear	♀ Average Wear
VIII-8	1	80:17	82: 18	2.47	1.88
VIII-9	2	128:32	80: 20	2.72	2.19
VIII-10	3	63:44	59: 41	3.16	2.32
VIII-11	4	31:40	44: 56	3.42	2.80
VIII-12	5	17:25	40: 60	3.71	3.20
VIII-13	6	4:17	19: 81	4.00	3.47
VIII-14	7	2:14	13: 87	4.50	3.57
VIII-15	8	2:22	08: 92	4.00	3.75
VIII-16	9	0: 9	0: 00	--	4.22

Since the entire habitat of this isolated colony was able to be effectively sampled day after day, a large proportion of the population was marked (see alpha values in Table 5). Also, a high percentage of marked individuals were recaptured, thus no major fluctuations in the daily estimates occur.

The study site is 0.83 ha. Thus the peak population density is high. Examination of the male and female movement maps (Figs. 3 and 4) reveal that the adults are found in only those quadrates containing buckwheat. If we consider the density in only those quadrates within the study site where individuals were captured or recaptured, the peak density is very high (Table 7).

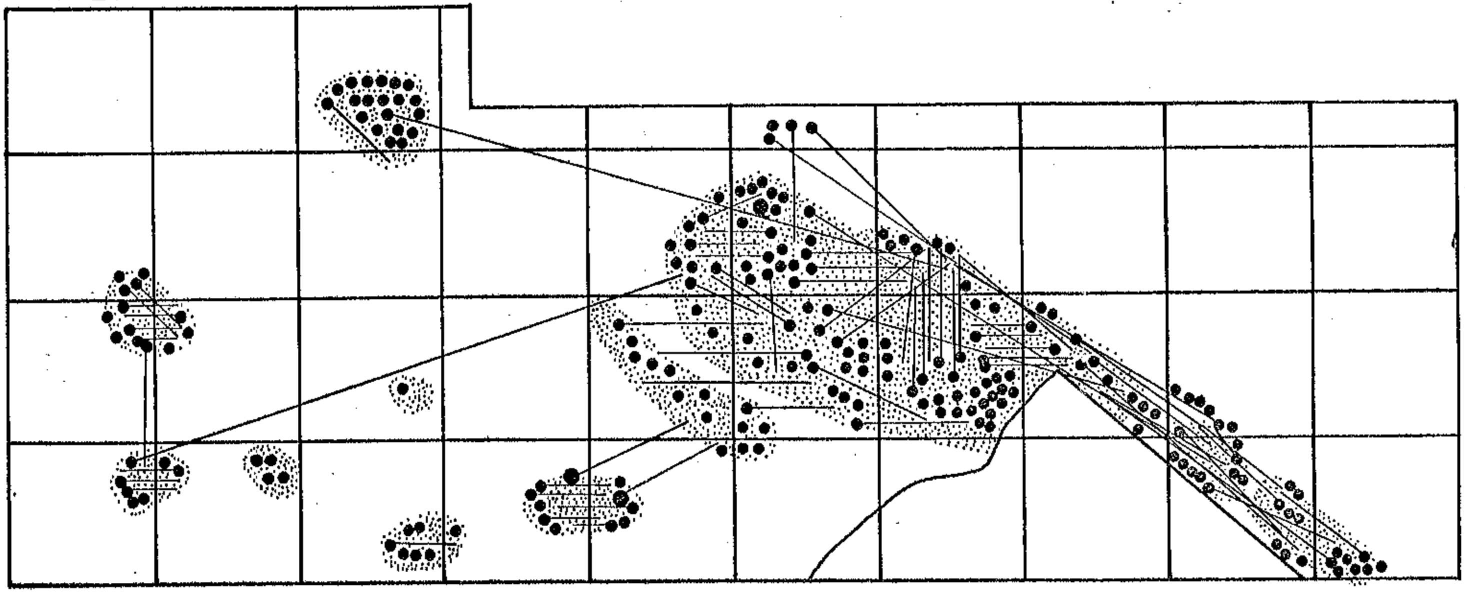
Table 7

Density of the El Segundo blue at the study site.

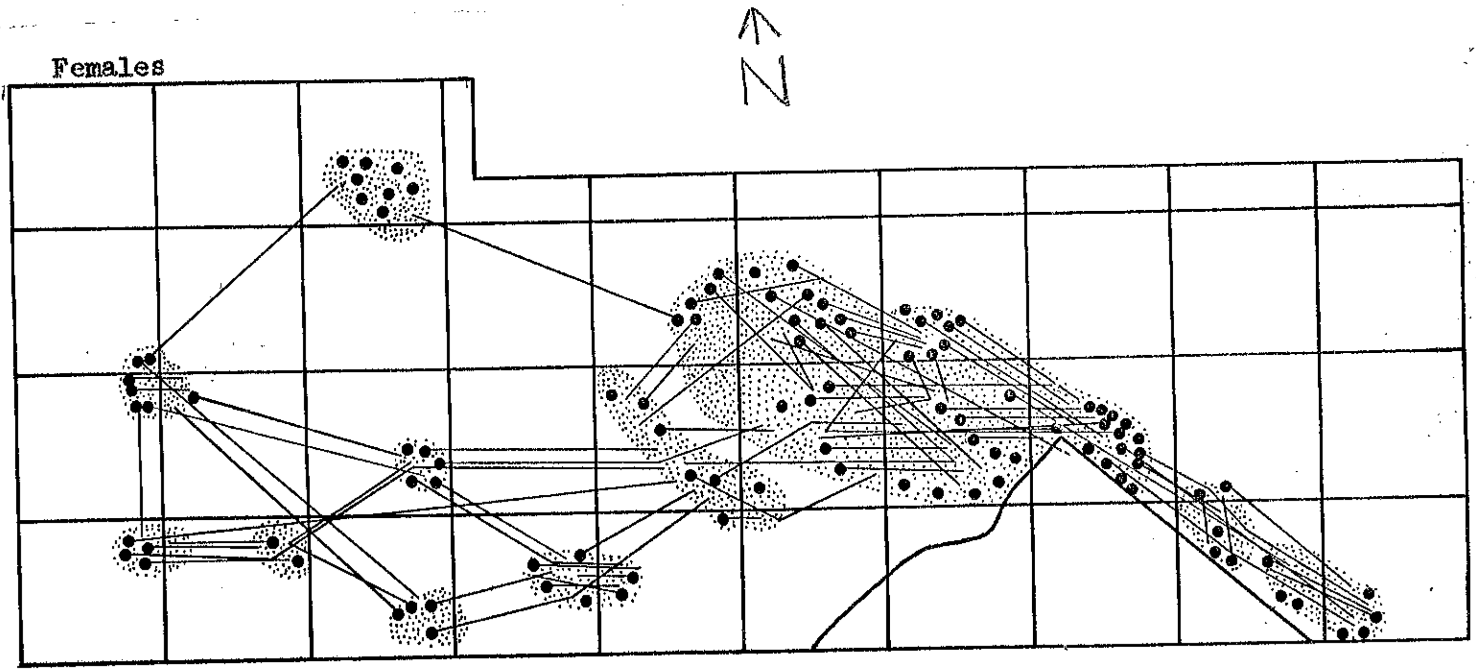
Sex	Density of Entire Study Site	Density in Only Occupied Quadrates
Male	390.09/ha	578.48/ha
Female	340.57/ha	505.04/ha

Figures 3 and 4. Movements of adult El Segundo blue, El Segundo study site
Stippling represents the distribution of buckwheat at the study site

Males



Females



The observed deviation from the 1:1 sex ratio is probably due to behavioral differences between the sexes. Both sexes are perchers, although females will patrol from flower to flower more readily than males. The preferred perching substrate and nectar source of both sexes are the buckwheat flowers (Figs. 5 and 6). While each male often occupies the same perch from day to day, females tend to move around more. This is evidenced by the movement patterns and vagility figures for both sexes. Even though many more males than females were marked, 58 percent of the males and 59 percent of the females were recaptured (Table 8). Since both sexes move only short distances and the suitable habitat is very small, the parity of these figures is not unreasonable.

Table 8

Number of individuals marked, percent of individuals recaptured, and number of recaptures for individuals recaptured at least once for the El Segundo blue.

Sex	Number Marked	Percent Recaptured	Average Number of Recaptures
Male	327	58	1.46
Female	220	59	1.47

The lag in emergence times for females also contributes to the sex ratio discrepancy. Females did not compose the majority of the catch until four days into the study.

Residence

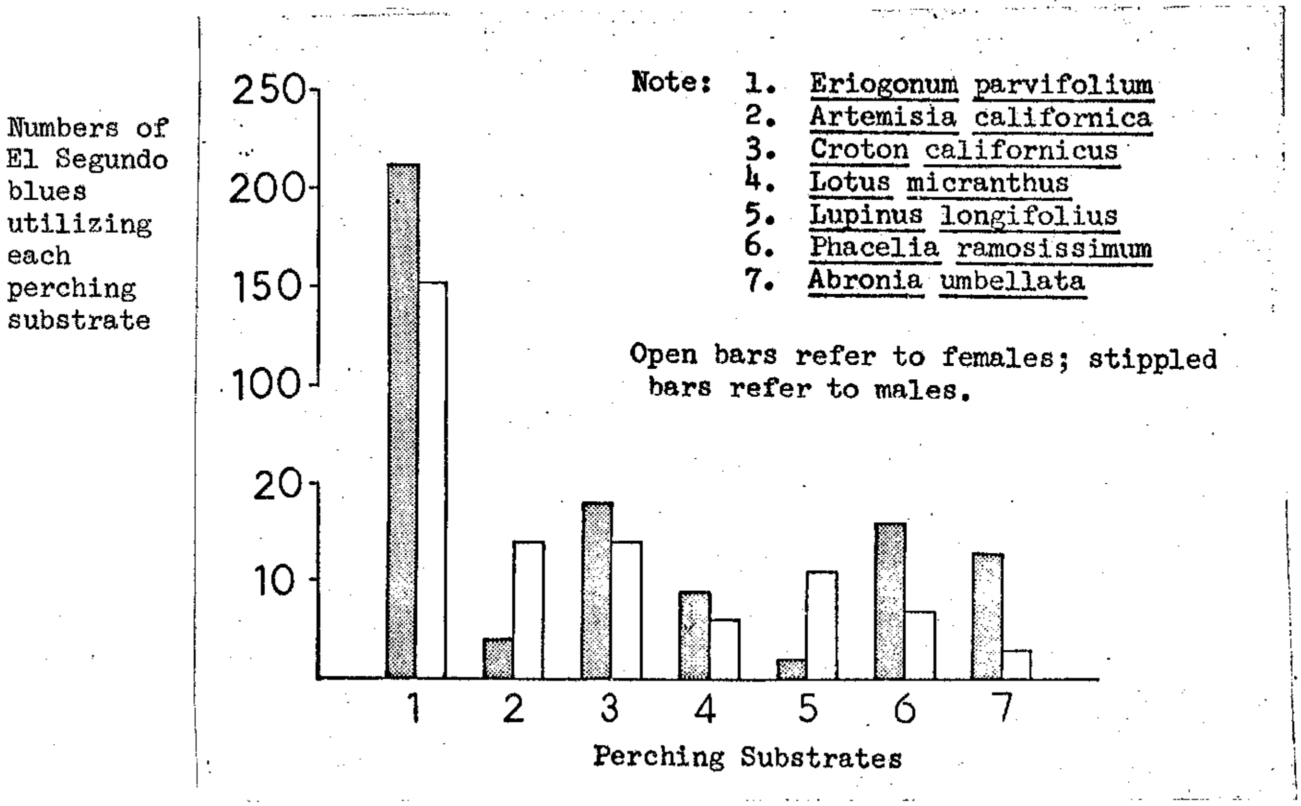
Table 9 presents day-specific residence, loss rates, mean expected residence times, and estimated total brood numbers for both sexes.

Table 9

Residence rates ($\hat{\phi}$), mean expected residence, loss rate, and estimates of total brood number for the El Segundo blue.

Sex	$\hat{\phi}$	Mean Expected Residence (days) $-(\ln \hat{\phi})^{-1}$	Day-specific Loss Rate	$\sum \hat{N}_i$	Estimated Total Brood Numbers
Male	0.643	2.27	0.357	912.6	325.80
Female	0.703	2.84	0.297	957.7	284.44

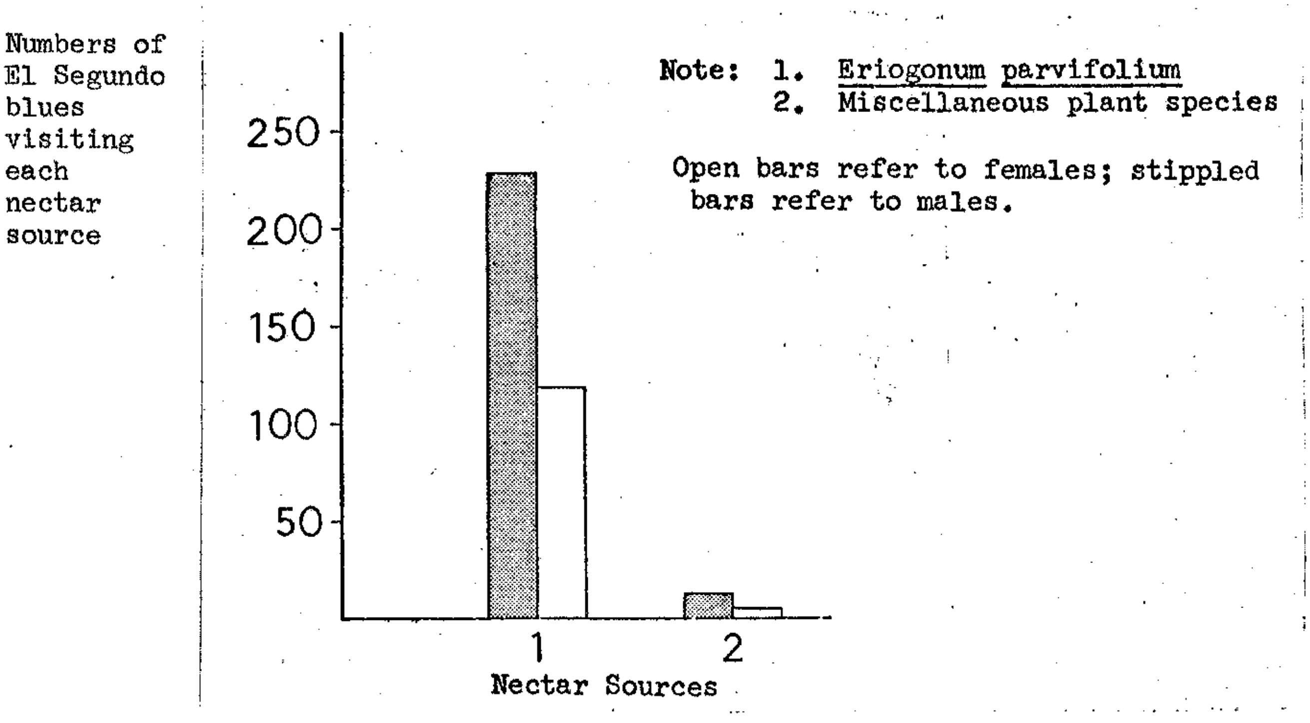
Figure 5. Perching substrates of El Segundo blue



Note:
1. Eriogonum parvifolium
2. Artemisia californica
3. Croton californicus
4. Lotus micranthus
5. Lupinus longifolius
6. Phacelia ramosissimum
7. Abronia umbellata

Open bars refer to females; stippled bars refer to males.

Figure 6. Nectar sources of El Segundo blue



Note:
1. Eriogonum parvifolium
2. Miscellaneous plant species

Open bars refer to females; stippled bars refer to males.

The females live about one day longer than males. Since this study was not done throughout the entire flight period, these estimates are probably slightly low.

Dispersal Analysis

Vagility

Females flew farther and in faster times than did males (Table 10). This is not surprising as males tend to perch more than females. The greater vagility of the females is due to searching for suitable oviposition sites.

Table 10

Vagility parameters for the El Segundo blue.

Vagility Parameter	Male	Female
Mean T (days)	2.24	1.97
Max T (days)	7.00	6.00
Mean t_i (days)	1.96	1.60
Mean R (meters)	5.21	10.36
Max R (meters)	60.00	60.00
Mean D (meters)	5.78	11.67
Max D (meters)	48.00	62.00
Mean d_i (meters)	4.85	9.47
Mean V (m/day)	2.65	5.71
Max V (m/day)	16.00	34.00
Mean v_i (m/day)	2.90	6.45

The majority of movements for both sexes are local, although a slightly higher percentage of females made long movements (Table 11). No individual moved over 70 m. The longest movement, which was accomplished by a few individuals, was 60 m. The next longest movement was 48 m. Because this colony is extremely isolated and surrounded by no suitable habitat, it appears natural selection has reduced the occurrence of long flights by El Segundo blue. Any individuals which fly beyond the boundaries of the colony are lost.

Dispersion

The distribution of the El Segundo blue is restricted to a few clumps of buckwheat. Morisita's Index was computed to determine its micro-distribution.

Dispersion indices were calculated for both males and females. Samples consisted of 40 quadrates, each 16 m x 16 m. The number of individuals recorded in each quadrate equaled the number of individuals captured or recaptured in that quadrate during the sampling period.

Table 11

Local versus long moves for the El Segundo blue.

Sex	Local	Percent	Long	Percent
Male	174	91	17	9
Female	112	87	17	13

Morisita's Index (Table 12) revealed that males are more aggregated than females. Both sexes rarely stray from the buckwheat, thus similar dispersion values are to be expected. Since males are less vagile, their frequency of movement from clump to clump of buckwheat is low, thus resulting in their micro-distribution being more aggregated. Females move around more searching for oviposition sites, as evidenced by the movement maps and vagility parameters. Thus, their greater amount of movement between clumps of buckwheat makes their dispersion more diffuse and results in their lower dispersion value.

Table 12

Indices of dispersion for the El Segundo blue.
All groups are significantly aggregated ($p > .001$).

Sex	Im
Male	4.34
Female	3.99

Since both sexes also utilize buckwheat as their primary nectar source, they rarely stray from it. The major exception is for evening roosts which occur in grassy areas near the buckwheat. Presumably, these areas are warmer during the foggy nights, because of their proximity to the ground, and are also shielded from the coastal winds. More females were found in these roosting areas. Males tend to roost on buckwheat

Behavior

The Standard Area of Activity for males ranged from 0.0 to 0.35, with a mean of 0.21 ha. Female Standard Area of Activity ranged from 0.0 to 1.31, with a mean of 0.31 ha. There is approximately 0.64 ha of suitable habitat for both sexes. These data indicate that the average male utilizes about 34 percent of the area which can potentially be occupied. The average female utilizes about 49 percent of the total area. These data exemplify the fact that females are more vagile and patrol more than males.

Like its congeneric relative, Smith's blue, El Segundo blue does not exhibit territorial behavior. Mate location happens due to the congregation or high density of adults constantly near buckwheat. Since both sexes spend most of their entire lives on the buckwheat, there is no need for territorial behavior to aid in mate location. Thus mate location is possible with random flight by both sexes. Frequent intersexual encounters were observed on the foodplant and 19 *in copulo* pairs were noted. Copulation occurs on the buckwheat flowers.

Evening roosts were frequently adjacent to buckwheat but on grass stems and only a few inches above the ground. Adults were very inconspicuous in their roosting sites.

Threats to Survival

Habitat destruction is the greatest threat to the survival of the El Segundo blue. While the Chevron refinery colony is fenced off, and Chevron employees are cognizant of the El Segundo blue's presence, a habitat management plan needs to be devised to ensure the survival of this species on their property. The most obvious problem is the encroaching ice plant and several annual weedy grasses and plants. Also, habitat manipulation is needed to open up new sites for seedling buckwheat. Most of the buckwheat now occupying the site appear to be senescing and may die out if new areas for propagation are not opened up.

The Los Angeles International Airport plans to develop a golf course and other recreational facilities on the "residential" area they have cleared. They are apparently willing to set aside the southern 40 acres of their property as a reserve for the El Segundo blue. Unfortunately, this does not protect an extension of this colony which I recently discovered (Fig. 7). It would be ideal if the development plans could be altered to include this area as part of the reserve. Also, a management plan needs to be designed such that if the golf course is constructed, water runoff and other maintenance procedures for the golf course will not alter the habitat of the adjacent butterfly colonies. Scientifically, this site is a very interesting one because the El Segundo blue population is utilizing two different species of buckwheats for larval foodplants.

A more immediate problem is the ice plant and other weedy plants. These need to be controlled in some manner compatible with the survival of buckwheat. This will also open up new areas of substrate for buckwheat seedling establishment.

The population on the Palos Verdes Peninsula needs to be studied by a competent taxonomist to determine if it is *S. b. allyni*. If it is El Segundo blue, a more thorough search of the bluffs should be initiated to determine its exact distribution. Most of these sites should be protected from habitat alteration because of their precipitous slopes.

Essential Habitat

The proposed critical habitat published in the Federal Register (Vol. 42, No. 26) includes both areas where El Segundo blue is known to exist. If the Palos Verdes Peninsula population turns out to be S. b. allyni, then the critical habitat will need to include this site.

The problem of most immediate concern is whether the proposed critical habitat at Los Angeles International Airport is too large. Airport officials believed that the El Segundo blue occurred only on the 40 acres south of Kilgore Street, and bounded by Vista Del Mar, Imperial and Pershing Drive on the west, south and east respectively. My investigations revealed that it also inhabits the narrow belt of land bounded by Trask Avenue, World Way, Pershing Drive and Kilgore Street (Fig. 7).

At first glance, this most recently discovered area appears to be largely undisturbed due to its steep slope. A 1965 aerial photo shows that homes were located just east of Trask Avenue and above the steep slope. A few Eriogonum parvifolium plants have since recolonized the area formerly occupied by homes. On and at the base of the long steep slope are many specimens of E. parvifolium and E. fasciculatum both of which are being utilized as foodplants by the El Segundo blue. The butterflies were frequently encountered in this area.

Most of the 200 acres north of Kilgore were severely altered due to the housing development. While some native plants have reestablished themselves on this 200 acres, buckwheats are still restricted only to the narrow strip mentioned earlier and the 40 acres south of Kilgore. Presumably, buckwheat would eventually become reestablished.

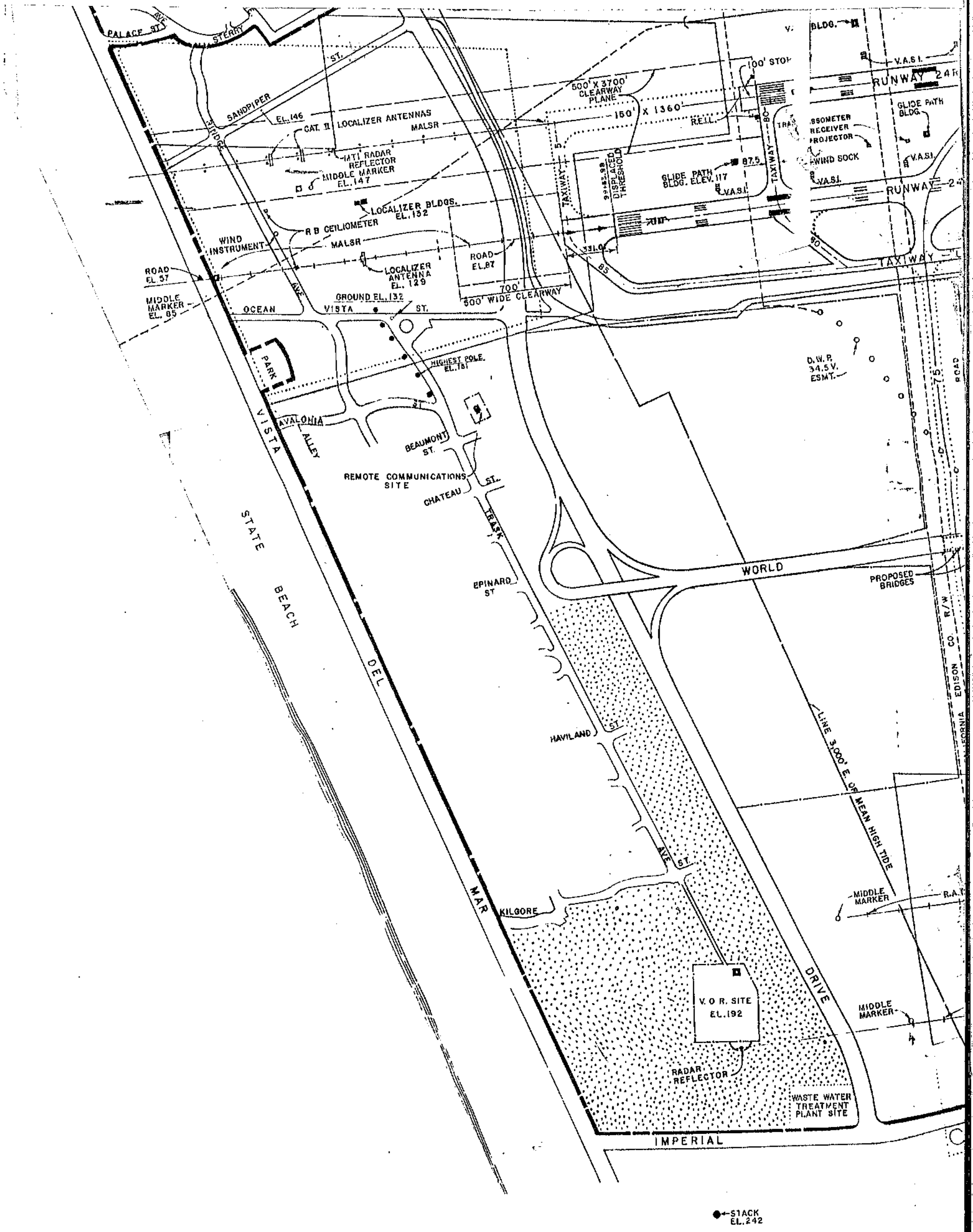
I am very reluctant to see the northern 200 acres developed because of the possibility that the dunes might eventually revert to its native state and thus provide a larger area for the El Segundo blue. Nonetheless, airport officials have noted that they are willing to set aside a reserve (south of Kilgore Street) of 40 acres for the butterfly. The reserve should now be expanded to include the recently discovered extension of this colony. If with further study it can be determined that the development and management of the recreational facilities will not adversely affect the microecosystem of the butterfly, then the area of critical habitat could be reduced to the acreage of the reserve only.

Management Recommendations

To ensure the survival of the El Segundo blue, it is recommended that:

1. Colony sites already preserved under private ownership be managed to ensure survival of the butterfly. Several plants, notably ice plant and other noxious and annual weeds, have infiltrated both sites. These need to be controlled as they are encroaching on buckwheat.
2. Habitat enhancement through planting of buckwheat and other native dune plants be done.
3. All vehicular and increased foot traffic be prohibited from these sites.
4. Habitat manipulation be done to ensure the continued survival of the unstable sand habitats and their associated native flora and fauna.

Figure 7. Habitat occupied by El Segundo blue, (stippled area), Los Angeles International Airport



LANGE'S METALMARK

Distribution

Apodemia mormo (Felder and Felder) is a widespread and locally common Riodinid in the western United States. It occurs in a variety of habitats and ranges from sea level to 9000 feet elevation. The various infraspecific populations are associated with six species of buckwheat; thus their distribution is restricted to that of the larval foodplants.

Today, Lange's metalmark (Apodemia mormo langei) occurs at two remnant sand dune sites near Antioch, Contra Costa County, California (Fig. 1): at the eastern end of the Stamm-Star Theatre property; and along the river-edge bluff of the Little Corral-Sardis-Pacific Gas and Electric (P.G. & E.) land (Fig. 2). In addition, the larval foodplant, Eriogonum latifolium auriculatum, is scattered along the waterfront of the Kaiser Gypsum property and also occurs in good numbers on the Imperial West Chemical Company, Inc. property. Figure 2 shows the distributions of buckwheat and Contra Costa wallflower (Erysimum capitatum angustatum) and Antioch Dunes evening primrose (Oenothera deltoides howellii). These latter two plants are proposed for endangered status (Fed. Reg., Vol. 42, No. 1).

Herbaria records for the larval foodplant revealed that in other areas it grows on rocky substrates rather than the sandy soil found at Antioch. A search of the neighboring coastal areas of the San Joaquin River did not turn up any new colonies. The islands in the San Joaquin River and delta region should be thoroughly searched for the occurrence of Lange's metalmark. Aerial photographs did not show any suitable habitat.

Life History

This species is univoltine. Adults emerge in early August and fly until mid to late September. The peak in population numbers is reached two to three weeks after the earliest date of eclosion.

Oviposition occurs throughout the adult flight period. The gray eggs are laid on the less pubescent surfaces of the withered foliage on the lower half of the larval foodplant. They are deposited in clusters of two to four, and less frequently singly. Single eggs are more commonly found at the junction of the leaf petiole and stem, concealed by the sheath of the petiole.

The larvae do not eclose until the following summer. The first instar larvae diapause within the eggs. Probably either in May or June, the larvae begin to feed on the foliage and stems of the foodplant. They are nocturnal feeders.

I presume that pupation occurs in the duff at the base of the foodplant, but this has not been confirmed. Further investigation is necessary to thoroughly understand the life history of this species.

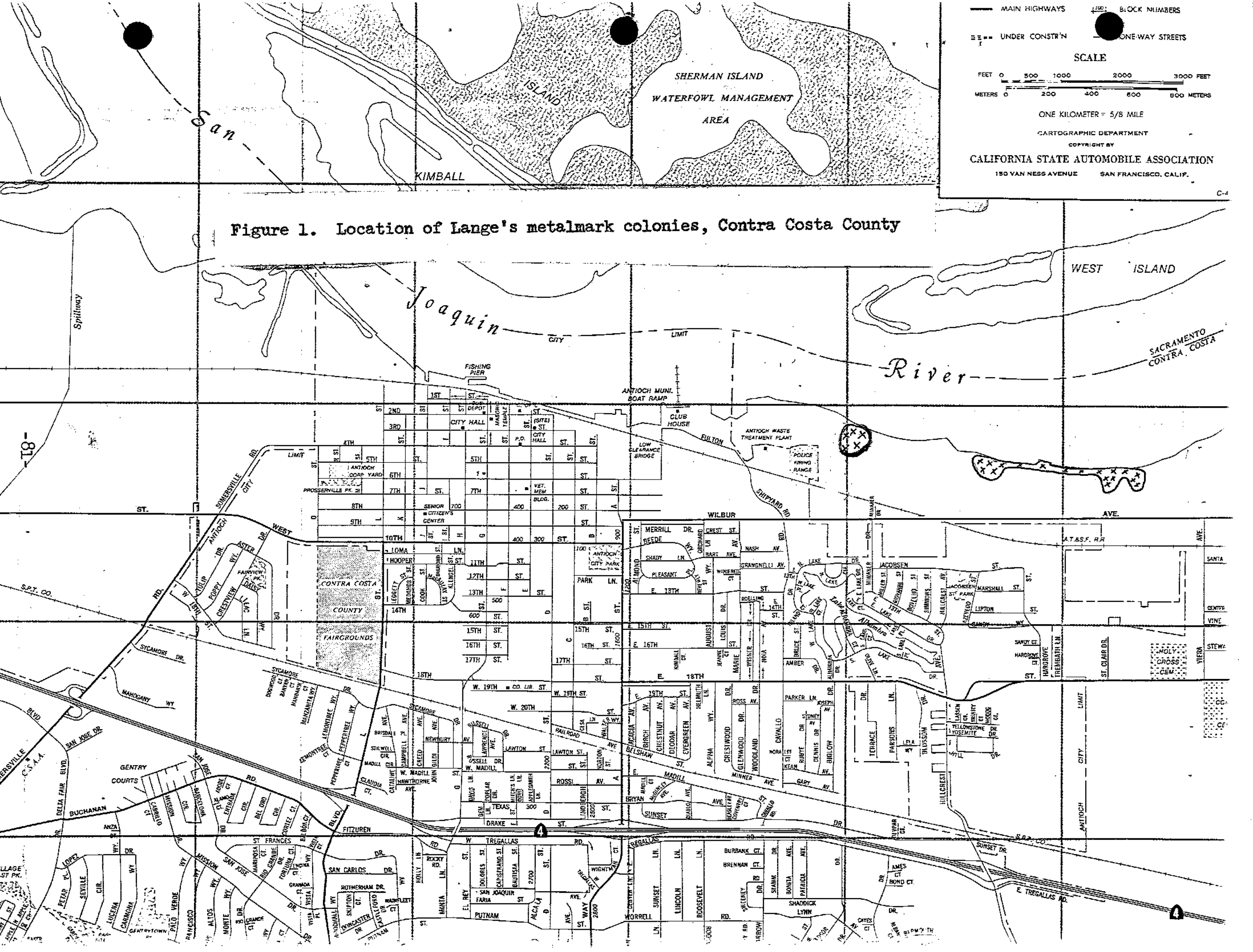
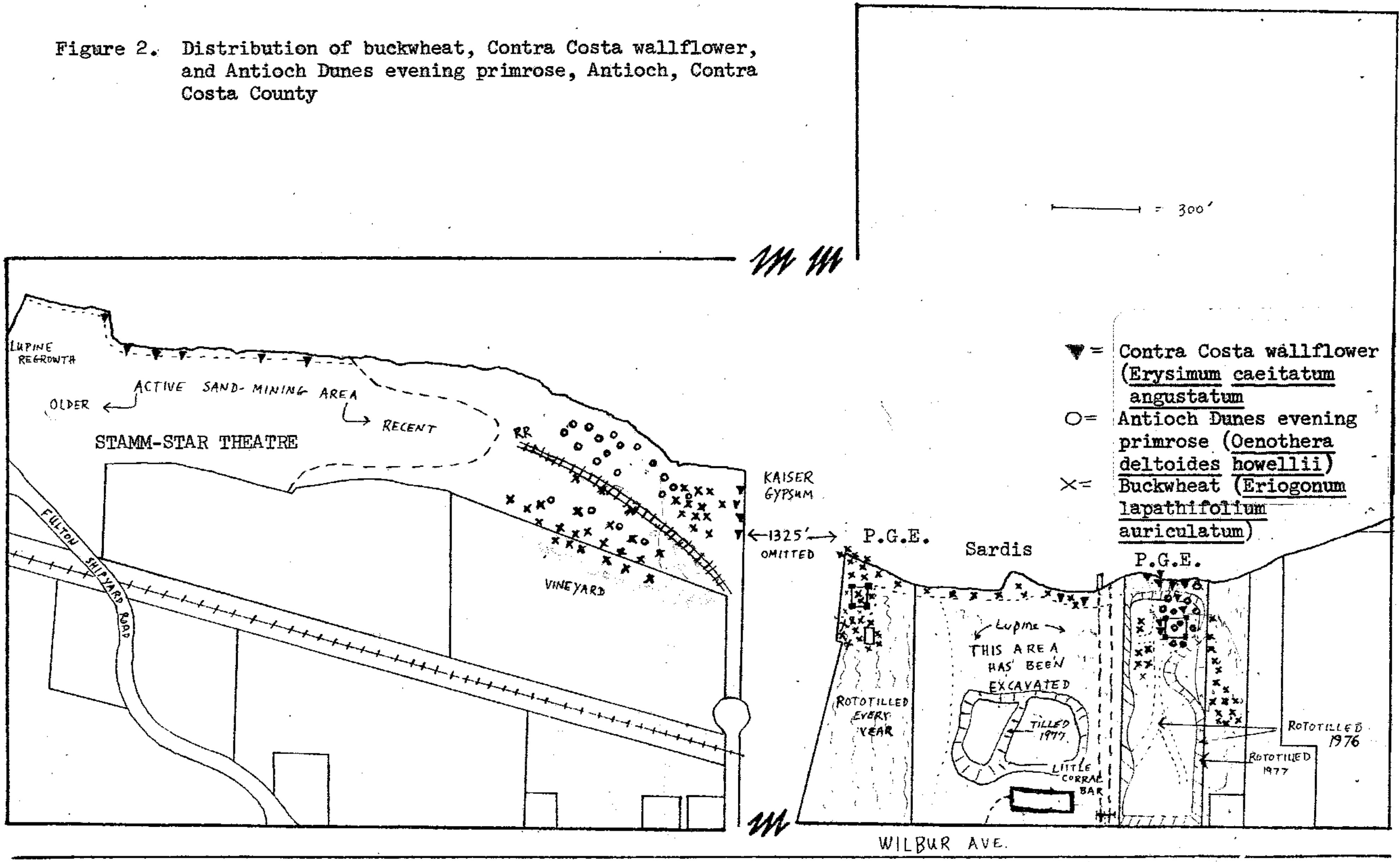


Figure 1. Location of Lange's metalmark colonies, Contra Costa County

Figure 2. Distribution of buckwheat, Contra Costa wallflower, and Antioch Dunes evening primrose, Antioch, Contra Costa County



Population Study

Study site and sampling

The Little Corral site (i.e., the two Pacific Gas and Electric parcels plus the Sardis property) comprised the study site. A mixture of native sand dune plants and introduced weeds composed the dominant vegetation (Table 1). Figure 2 is a vegetational map of the site.

Table 1

Representative vegetation at Lange's metalmark colonies.

- *Artemisia* sp.
- *Aster* sp.
- *Baccharis pilularis*
- *Brassica major*
- *Chenopodium* sp.
- *Clarkia unguiculata*
- *Croton californicus*
- *Datura meteloides*
- *Eriogonum latifolium* var. *auriculatum*
- *Erodium cicutarum*
- *Erysimum capitatum* var. *angustatum*
- *Eschscholtzia californica*
- *Foeniculum vulgare*
- *Gilia* sp.
- *Grindelia camporum*
- *Gutierrezia californica*
- *Heliotropium curassivicum* *oculatum*
- *Hemizonia* sp.
- *Heteromeles arbutifolia*
- *Heterotheca grandiflora*
- *Lotus formosissimus*
- *L. purshianus*
- *L. scoparius*
- *Lupinus albifrons*
- *Marrubium vulgare*
- *Mesembryanthemum edule*
- *Nicotiana glauca*
- *Oenothera deltoides howellii*
- *Quercus agrifolia*
- *Robinia pseudo-acacia*
- *Salix lasiolepsis*
- *Sambucus mexicana*
- *Senecio donglasii*
- *Solanum* sp.
- *Vitis vinifera*

Marking techniques were as described in the introduction.

Sampling was initiated each day at 0900 to 1100 PDT and terminated at 1530 to 1730 PDT.

A comparison of the observed and poisson distributions for the number of successive recaptures is shown in Table 2. A test of goodness of fit shows no significant deviation of the expected from the observed values for the range of 0 to 4 successive recaptures. This agreement means that collecting and marking individuals did not alter their probabilities of survival.

Table 2

Distribution of the observed number of recaptures per number of repeats and their expected poisson values for the Lange's metalmark.

Number of Recaptures	Observed (f)	Expected ($\hat{f}$)
0	91	97.35
1	59	47.76
2	8	11.71
3	1	1.92
4	0	0.23

$\bar{y} = 0.4905$

Results

Aging and sex ratio

Lange's metalmark is univoltine. Males generally eclose earlier than females. The data presented in Table 3 do not agree with this, but the marking program was not initiated until the peak of the male flight period had past. Wear damage accumulates gradually with age after eclosion. Because marking was initiated rather late in the flight season, males were already quite worn, and thus assumed to be several days old. The wear damage of females lags slightly behind that of the males, as would be expected from the eclosion lag.

Table 3

Sample-based sex ratios and wear ratings of males and females of adult Lange's metalmark in relation to the progress of the flight season.

Date	Day	♂:♀	Percent ♂:♀	♂ Average Wear	♀ Average Wear
VIII-31	1	16:15	52: 48	3.19	2.13
IX-1	2	14:21	40: 60	3.43	2.52
IX-2	3	13:19	41: 59	3.15	2.26
IX-3	4	5:20	20: 80	3.60	2.80
IX-4	5	3: 6	33: 67	3.67	2.67
IX-6	6	3:13	19: 81	4.00	2.54
IX-7	7	0: 2	00: 00	--	5.00
IX-8	8	3: 6	33: 67	2.67	3.00

Daily numbers

A total of 57 males and 102 females were marked at the study site. My rearing material is presently in diapause, but I am confident that the actual sex ratio is 1:1. The proportion of marked animals, the total marked population, daily population estimates, the probability of survival, and the numbers of new animals joining the population for both sexes is presented in Table 4. Table 5 indicates the percent of individuals recaptured.

Table 4

Population parameters of the Lange's metalmark estimated from Jolly's stochastic model of multiple recapture data.

Males:

Date	Day	Alpha	M	N + 1.96 SE	PHI + 1.96 SE	B + 1.96 SE
VIII-31	1	0.0000	0.00	0.0 + 0.0	1.142 + 1.063	0.0 + 0.0
IX-1	2	.2143	22.60	105.5 + 128.7	.565 + .473	-24.8 + 63.2
IX-2	3	.5455	19.00	34.8 + 25.6	.750 + .705	-13.7 + 16.0
IX-3	4	1.4000	19.50	13.9 + 11.8	.429 + .525	1.5 + R
IX-4	5	1.0000	7.50	7.5 + 6.4	.667 + .700	2.5 + 4.9
IX-6	6	.6667	5.00	7.5 + 7.9	.667 + .533	-1.0 + 3.4
IX-7	7	1.0000	4.00	4.0 + 3.1	0.000 + 0.000	0.0 + 0.0
IX-8	8	.6667	0.00	0.0 + 0.0	0.000 + 0.000	0.0 + 0.0

Females:

Date	Day	Alpha	M	N + 1.96 SE	PHI + 1.96 SE	B + 1.96 SE
VIII-31	1	0.0000	0.00	0.0 + 0.0	.827 + .508	0.0 + 0.0
IX-1	2	.1905	12.40	65.1 + 60.3	.558 + .268	12.9 + 42.3
IX-2	3	.3333	16.40	49.2 + 33.2	.967 + .290	-9.4 + 30.3
IX-3	4	.7000	29.38	42.0 + 16.2	1.272 + 1.163	-30.9 + 27.8
IX-4	5	2.0000	45.00	22.5 + 18.8	.636 + .824	53.9 + 62.5
IX-6	6	.3636	24.80	68.2 + 70.3	.385 + .264	-20.5 + 20.4
IX-7	7	2.0000	13.00	6.5 + R	0.000 + 0.000	0.0 + 0.0
IX-8	8	1.8333	0.00	0.0 + 0.0	0.000 + 0.000	0.0 + 0.0

Table 5

Number of individuals marked, percent of individuals recaptured, and number of recaptures for individuals recaptured at least once for Lange's metalmark

Sex	Number Marked	Percent Recaptured	Average Number of Recaptures
Male	57	36	1.14
Female	102	48	1.10

No large fluctuations in the daily estimates were noted. This is probably due to the fact that a high proportion of the population was marked (see the alpha values in Table 4).

The study site is 1.86 ha. Thus the peak population density is low (Table 5). Examination of the male and female movement maps (Figs. 3 and 4) reveal that the adults are found only in those quadrates containing buckwheat. If we consider the density in only those quadrates within the study site where individuals were captured or recaptured, the peak density is higher (Table 6).

Figures 3 and 4. Lange's metalmark study area showing movements of males and females.

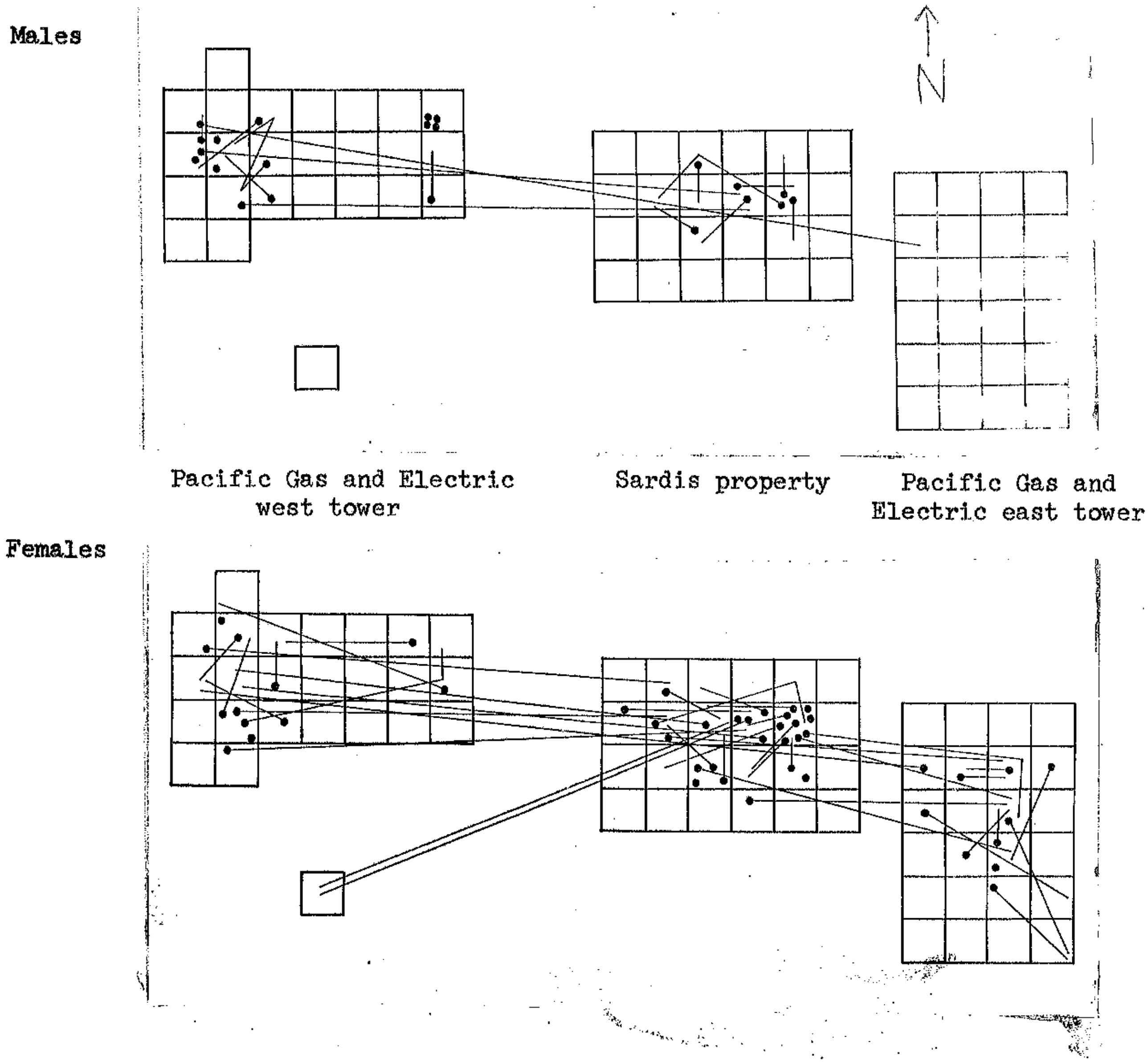


Table 6

Density of Lange's metalmark at the study site.

Sex	Density of Entire Study Site	Density in Only Occupied Quadrates
Males	26.40/ha	101.42/ha
Females	14.99/ha	28.79/ha

The observed deviation from the 1:1 sex ratio is probably due to the timing of the study. In mid-August, males were observed to be common at the study site. Unfortunately, because the marking program was not initiated until late August, females were the more prevalent sex. The fact that females were the primary sex studied should not detract from the usefulness of the data for management purposes.

Both sexes are perchers, although each sex is capable of long-distance movement between observed perching activity. The preferred perching substrate and nectar source of both sexes are buckwheat flowers (Figs. 5 and 6).

Residence

Table 7 presents day-specific residence and loss rates, plus mean expected residence times for both sexes.

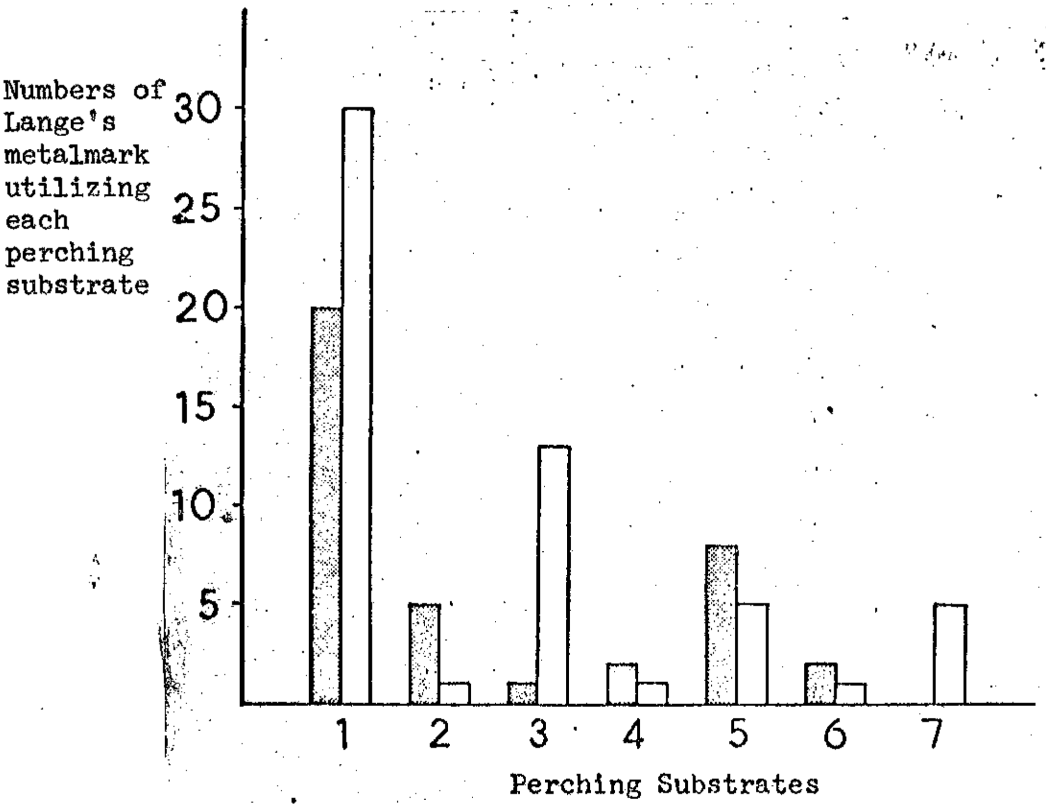
Table 7

Residence rates ($\hat{\phi}$), mean expected residence, loss rate, and estimates of total brood numbers for Lange's metalmark.

Sex	$\hat{\phi}$	Mean Expected Residence (days) $-(\ln \hat{\phi})^{-1}$	Day-specific Loss Rate	$\Sigma \hat{N}i$	Estimated Total Brood Numbers
Males	0.7152	2.98	0.2848	173.2	49.33
Females	0.8895	8.50	0.1105	253.5	28.01

According to the life-span estimates, females live several days longer than males. Since males were not sampled throughout their entire flight season, the life-span estimate for males is very low. Male life-span probably closely approximates that of the females.

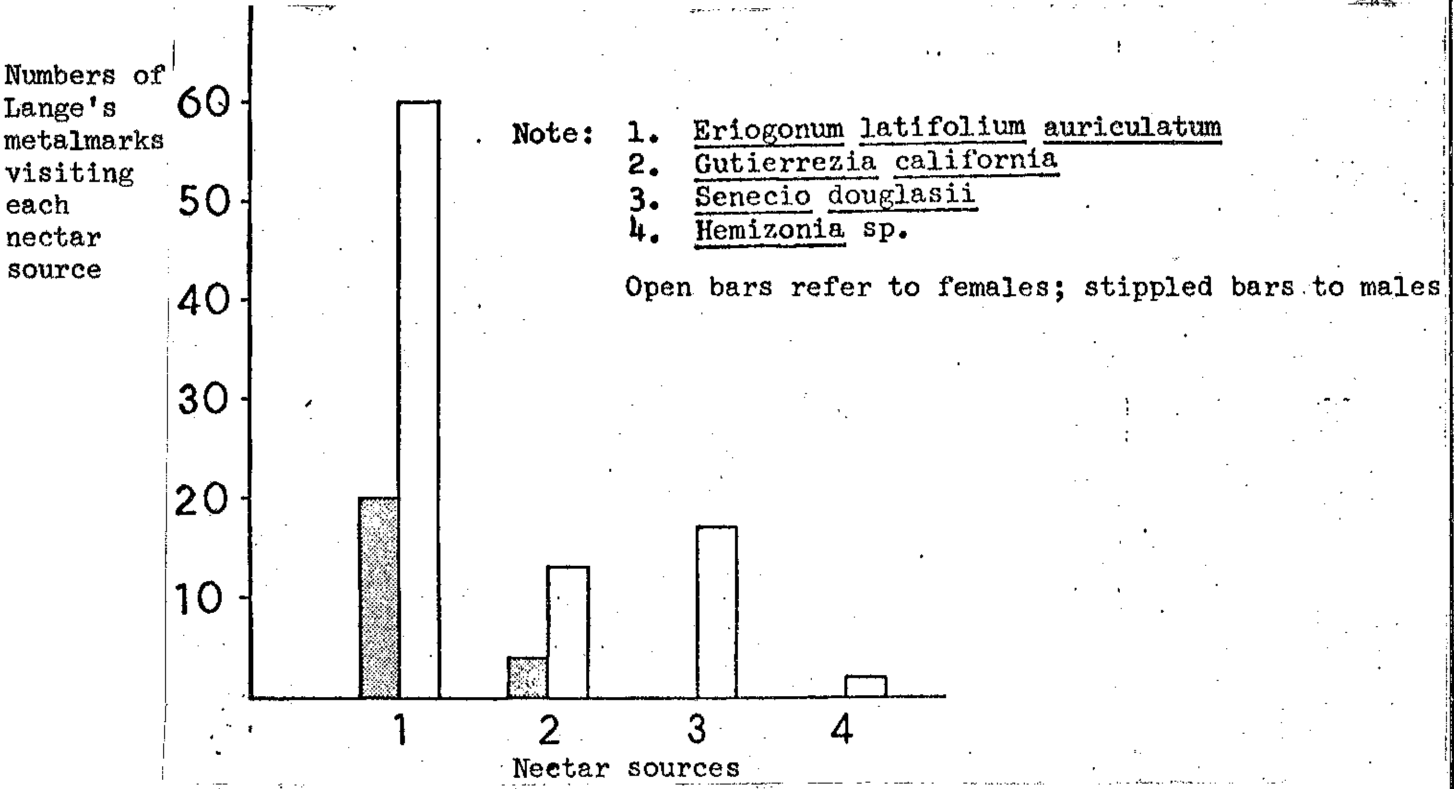
Figure 5. Perching substrates of Lange's metalmark



Note:
1. Eriogonum latifolium auriculatum
2. Mesembryanthenum edule
3. Lupinus albifrons
4. Lotus scoparius
5. Dead grass
6. Ground
7. Miscellaneous substrate

Open bars refer to females; stippled bars to males

Figure 6. Nectar sources of Lange's metalmark



Note:
1. Eriogonum latifolium auriculatum
2. Gutierrezia california
3. Senecio douglasii
4. Hemizonia sp.

Open bars refer to females; stippled bars to males

Dispersal Analysis

Vagility

Females flew farther and in faster times than did males (Table 8). This is not surprising since field observations revealed that males tended to perch more than females. The greater vagility of the females is due to searching for suitable oviposition sites.

The vast majority of male movements are local, although females are just as likely to make long movements as they are local ones (Table 9). Only two males moved over 29 m. These individuals, which may have been windblown, moved 232 and 340 m respectively. One female moved 402 m. Several other females moved between 208 and 265 m. Thus the Lange's metalmark possesses the ability to disperse lengthy distances. This is significant as these figures plus the movement maps indicate that individuals can move from colony to colony. Also, this is important for the reestablishment of destroyed or weakened colonies, such as the one at the east Pacific Gas and Electric tower where a fire in 1976 destroyed most of the immatures.

Table 8

Vagility parameters for Lange's metalmark.

Vagility Parameter	Female	Male
Mean T (days)	1.96	1.71
Max T (days)	6.00	6.00
Mean t_i (days)	1.78	1.50
Mean R (meters)	81.00	37.77
Max R (meters)	402.00	340.00
Mean D (meters)	86.49	39.91
Max D (meters)	402.00	340.00
Mean d_i (meters)	78.48	34.95
Mean V (m/day)	47.71	27.48
Max V (m/day)	402.00	232.00
Mean v_i (m/day)	50.40	26.05

Dispersion

The distribution of Lange's metalmark is restricted to a few clumps of buckwheat. Morisita's Index was computed to determine its micro-distribution.

Dispersion indices were calculated for both males and females. Samples consisted of 73 quadrates, each 16 m x 16 m. The number of individuals recorded in each quadrate equaled the number of individuals captured or recaptured in that quadrate during the sampling period.

Morisita's Index (Table 10) revealed that males are considerably more aggregated than females. Neither sex strays very far from the buckwheat. Since males are less vagile, their frequency of movement from clump to clump of buckwheat is low, thus resulting in their micro-distribution being more aggregated. Females move around more searching for oviposition sites, as evidenced by the movement maps and vagility parameters. Thus, their greater amount of movement between clumps of buckwheat makes their dispersion more diffuse and results in their lower dispersion value.

Table 9

Local versus long moves for Lange's metalmark.

Sex	Local	Percent	Long	Percent
Male	19	76	6	24
Female	24	49	25	51

Table 10

Indices of dispersion for Lange's metalmark.
All groups are significantly aggregated ($p > .001$).

Sex	Im
Male	4.29
Female	2.56

Both sexes utilize buckwheat as their primary nectar source and perching substrate. Thus they rarely stray very far from it. Females visit a greater variety of secondary nectar sources, so this coupled with their oviposition searching behavior may be responsible for their larger vagility parameters.

Activity

The Standard Area of Activity for males ranged from 0.0 to 0.90, with a mean of 0.69 ha. Female Standard Area of Activity ranged from 0.20 to 2.68, with a mean of 1.19 ha. These data indicate that the average male utilizes about 37 percent of the area which can potentially be occupied. The average female utilizes about 64 percent of the total area. These data exemplify the fact that females are more vagile and move greater distances than males.

Lange's metalmark does not exhibit territorial behavior. Since both sexes spend most of their lives on or very near the buckwheat, there is no need for territorial behavior to aid in mate location. Thus, mate location happens due to random movements of each sex from one buckwheat bush to another.

Threats to Survival

Habitat destruction is the greatest threat to the survival of Lange's metalmark. Sand mining and the fire district's annual rototilling decrease the amount of suitable habitat. If these activities are not curtailed immediately, Lange's metalmark and the other unique biotic attributes of the Antioch Dunes are doomed to extinction. Additionally, the rototilling has also encouraged the influx of many annual "weedy" species.

Local officials would like to turn the dunes into a waterfront park. Unfortunately, this activity would not be compatible with a management plan to ensure the survival of the unique fauna and flora. Increased foot or vehicular traffic on the site would be detrimental to the biota.

Another threat is the lack of a reservoir of moving sand which is an essential part of the dynamic ecology of these dunes. Moving sand opens areas for the establishment of seedlings. For example, preservation of the Metalmark colony at the east end of the Stamm property without the open sand reservoir at the west end of the property would not ensure the survival of Lange's metalmark.

Essential Habitat

While the proposed critical habitat encompasses an area considerably larger than that currently occupied by Lange's metalmark, I believe that most of this excess buffer is vital to ensure the Metalmark's survival. As mentioned earlier, the buffer zone provides a source of sand which winds can shift. Without this activity, seedlings of native sand dune plants are not able to establish themselves. Eventually, established plants would senesce and die out. As they disappeared, so would the fauna associated with them.

Buckwheat is distributed disjunctly near the waterfront along a 4000 foot stretch of land owned by Stamm-Star Theatre, Kaiser Gypsum, Pacific Gas and Electric, Sardis-Little Corral, and the Imperial West Chemical Company. Both the Contra Costa wallflower and Antioch Dunes evening primrose grow beyond this 4000 foot stretch of buckwheat, so I believe that no changes should be made in the critical habitat as is was originally proposed.

Management Recommendations

To ensure the survival of the Lange's metalmark, it is recommended that:

1. Efforts be focused on preservation of the northern parcels of the Little Corral and Pacific Gas and Electric properties as critical habitat for the metalmark butterfly.
2. A management plan be immediately implemented on these properties to: (1) restrict rototilling; (2) restrict human and vehicular access; and (3) manage the habitat for the enhancement of buckwheat, Contra Costa wallflower and Antioch Dunes evening primrose.
3. Acquisition of the Stamm-Star Theatre land be initiated. Although the best remaining fragments of the unstable dune community lie on the eastern part of this property (10-15 acres), this is due to the constant source of secondary deposit sand from the excavation areas to the west. Industrial development of the remainder of the property would leave only a narrow corridor of natural land ultimately resulting in stabilization by winds and decline in existing native flora and fauna.

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