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A BIOSYSTEMATIC STUDY OF TWO SPECIES OF CALLOPHRYS (CALLOPHRYS) IN CALIFORNIA (LYCAENIDAE)

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INTRODUCTION

The genus *Callophrys* Billberg is represented in North America by six subgenera separable on the basis of male genitalia (Clench, 1961). These subgenera are *Xamia* (one species), *Sandia* (one species), *Incisalia* (eight species), *Mitoura* (seven species), *Cyanophrys* (one species) and the nominal subgenus *Callophrys* (six species).[1] The six species included in the nominal subgenus are characterized by green on the undersides of the wings, with or without presence of white maculations.

Callophrys (*C.*) *affinis* (Edwards) has a light green color usually without any maculations. This species ranges from northern Utah and Wyoming to Washington and British Columbia, and according to Clench the life history is still unknown. Two subspecies *C. a. affinis* (Edw.) and *C. a. washingtonia* Clench currently are recognized, separable on the basis of scale color dorsally and ventrally (Tilden, 1963).

A related species, *C. sheridani* (Carpenter), is characterized by a solid line of white on the ventral surface of the hindwings. There are three subspecies, *C. s. sheridani* (Carpenter), *C. s. neoperplexa* (Barnes & Benjamin), and *C. s. newcomeri* Clench, separable by the pattern and degree of development of the macular band (Tilden, 1963). The latter two are confined mostly to Washington and Oregon away from the immediate coast, whereas the nominal subspecies occurs in the Rocky Mountain states.

A third species, *C. apama* (Edw.) has two subspecies, *C. a. apama* (Edw.) and *C. a. homoperplexa* Barnes & Benjamin, the latter characterized by the absence of a macular band. The nominal subspecies is characterized by the maculations on the undersides of the hindwings tinged with black rather than the dominant white seen in other species in the subgenus.

Callophrys comstocki Henne, a recently described species, occurs in semi-arid to arid habitats from northern Inyo County in California south to the Providence Mountains of San Bernardino County. *C. comstocki* appears to be closely related to *C. apama*, but lacks the tricolored fulvous band found on the undersides of *C. apama* (Henne, 1940).

The present study concerns two species found in California, *C. dumetorum* (Boisduval) and *C. viridis* (Edwards). The former was previously considered to include two subspecies, *C. d. dumetorum* (Bdv.) and *C. d. perplexa* Barnes &

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1 A recently described population from the higher elevations of the Sierra Nevada has been named *C. lemberti* by Tilden (1963), but not enough evidence concerning life history and distribution is known to confirm its specific status and relationships.

Benjamin, occurring from British Columbia to Baja California Norte, with *perplexa* said to be confined to San Diego and Los Angeles counties, and adjacent portions of Baja California. The ventral sides of the hindwings of this species are a light green with a variable number of white maculations.

A third entity was recently described from the Pacific Northwest as *C. d. oregonensis*, based on restriction of the gray scales to the Cu_2 vein on the undersides of the forewings as well as on comparative notes on this entity's biology (Gorelick, 1970).

The last species, *C. viridis* (Edw.) which also has a variable number of white maculations, is known only from San Mateo County to Mendocino County, California, along the immediate coast. The deep yellow to blue-green tinge separates *C. viridis* superficially from *C. sheridani* and *C. dumetorum*.

Barnes & Benjamin (1923), Clench (1944) and Tilden (1963) in characterizing differences between species in the subgenus *Callophrys*, included morphological features such as scale color (wing fringes, forewing costa below, shade of green below, labial palpi, facial hairs, and dorsal ground color) and shape or angle of forewing and hindwing margins. After examining a large series of specimens of the two so-called species, *Callophrys dumetorum* (Bdv.) and *Callophrys viridis* (Edw.), the present author found no evidence which seemed conclusive or sufficient to warrant separation of the two as species. These characters vary considerably even within a single population.

Populations of the two were found to be allopatric, indicating that interbreeding probably does not occur. In the absence of evidence of interbreeding, biological characteristics such as differences in female ovipositional substrate and differences in courtship and mating are characteristics which were examined in an attempt to confirm or refute a specific level of differentiation between the two. Comparisons of larval morphology, host specificity, and development time were also used to help determine whether the two are to be considered subspecies or species.

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HISTORICAL REVIEW

Linnaeus, in 1758, proposed the genus *Papilio* which included a diversity of butterflies. A single hairstreak characterized by the complete green undersides of the wings was named *Papilio rubi*. The name *Callophrys* was originally propounded by Billberg (1820) to include three groups of lycaenids based on possession of three tails, two tails and one tail. In the group characterized by one tail only *P. rubi* was recorded. *P. rubi* was selected as the type of the genus *Callophrys* by Scudder in 1875 although the more encompassing generic name *Thecla* remained in general usage until 1914.

Boisduval (1852) described *Thecla dumetorum* which he believed to be a local race of the European species.

W. H. Edwards (1862) described *Thecla viridis*, characterized by the uniform deep green wing undersides and by white antennae.

Barnes & Benjamin (1923), after examining a small series of *Callophrys dumetorum* from the San Diego area, named the southern California race *perplexa* on the basis of complete or almost complete absence of white maculations on the undersides. They also believed *Callophrys viridis* to be conspecific with the typical northern California race of *Callophrys dumetorum*, rendering *C. viridis* a synonym of *C. dumetorum*.

Comstock (1927: plate 50) pictured a male and female of *C. viridis* from San Francisco which he labeled "*C. dumetorum*", but *C. dumetorum*, in reality, does not occur in San Francisco.

Clench (1944) revised the genus *Callophrys* and cited *C. viridis* as a species. San Francisco was named as the type locality and a neotype was designated.

Ziegler (1960), in his revision of the Lycaenidae based on male and female genitalia, combined *Mitoura* Scudder, *Sandia* Clench and Ehrlich, and *Callophrys* Billberg under the latter, making each a subgenus.

Tilden (1963) discussed many diagnostic characters useful in separating the members of the subgenus *Callophrys*, emphasizing scale patterns and wing shapes.

Gorelick (1970) described *Callophrys dumetorum oregonensis* from the Pacific Northwest based on scale patterns and biological data.

METHODS AND MATERIALS

The study was divided into four stages, the first being the examination of 782 museum specimens (both species). Diagnostic characters were sought other than those having to do with scale patterns in order to separate not only *C. dumetorum* from *C. viridis* but also *C. d. dumetorum* from *C. d. perplexa*. Dissections of male and female genitalia from both species were done using the technique outlined in Ehrlich and Ehrlich (1961), these specimens being chosen from many different localities for possible variation between populations.

The second stage dealt with obtaining specimens (included in the study) from many lepidopterists to clarify the geographic range of these species. Weekend trips were taken during the late spring months of 1967 to extend the range of *C. viridis*.

The third dealt with the selection of several localities in the San Francisco Bay area where ecological and behavioral data for the two species could be obtained and compared during the spring of 1967. Study sites were the following:

Callophrys viridis:

1. San Bruno Mountains, near Daly City, San Mateo Co.
2. 9 mi. NE of Pt. Reyes lighthouse, Marin Co.
3. Del Puerto Canyon, 22 mi. W. Patterson, Stanislaus Co.

Callophrys dumetorum:

1. San Gabriel Canyon, near Azusa, Los Angeles Co.
2. Sand dunes, 1 1/2 mi. E. of Antioch, Contra Costa Co.
3. Brannan Id. State Park, Sacramento Co.

Observations of *C. dumetorum* were also made at Dictionary Hill (San Diego Co.) by Oakley Shields (via correspondence). Specific localities within each study site were chosen for capturing, marking and releasing adults in order to study individual behavior.

The San Bruno Mountains population was observed from February 10 to May 20, whereas Antioch and Brannan Island were visited from April 4 to May 30. Observations were made at the Pt. Reyes study site between April 30 and June 3, and Del Puerto Canyon was only visited twice, in late March and in mid-May. Field observations were made two or three times each week at all but the latter two localities.

Adults of both species occurred at specific hilltop localities in the San Bruno Mountains (*C. viridis*) and Brannan Island (*C. dumetorum*). Marks were made with a black felt pen on the green scales on the wing undersides while the specimen was held within the net. The marks were made so that the specimen could be determined as to date of marking. To avoid loss of individuals immediately after marking, they were held in the net until docile and then released. Marking was done all day for one day at each of the above localities and all recaptured specimens taken throughout the study were recorded as to date and time of day taken. No secondary marking or re-releasing of the recaptured specimens was conducted.

Adults were observed in the lab on several plants including the natural host plants but no courtship, mating or oviposition occurred in the lab.

The fourth stage included the lab rearing of larvae of both species on a series of related and unrelated plants to determine relative specificities and also to note the rate of development on each. The experimental host plants used were:

1. *Lupinus arboreus* Sims. (Leguminosae)
2. *Vicia* sp. (Leguminosae)
3. *Lotus scoparius* Ottley (Leguminosae)
4. *Trifolium obtusiflorum* Hook. (Leguminosae)
5. *Cytisus monpessulanus* L. (Leguminosae)
6. *Eriophyllum staechadifolium* Lag. (Compositae)

7. *Gnaphalium* sp. (Compositae)
8. *Achillea lanulosa* Nutt. (Compositae)
9. *Amsinckia intermedia* F.& M. (Boraginaceae)
10. *Eriogonum fasciculatum* Benth. (Polygonaceae)
11. *Eriogonum latifolium latifolium* Sm. (Polygonaceae)

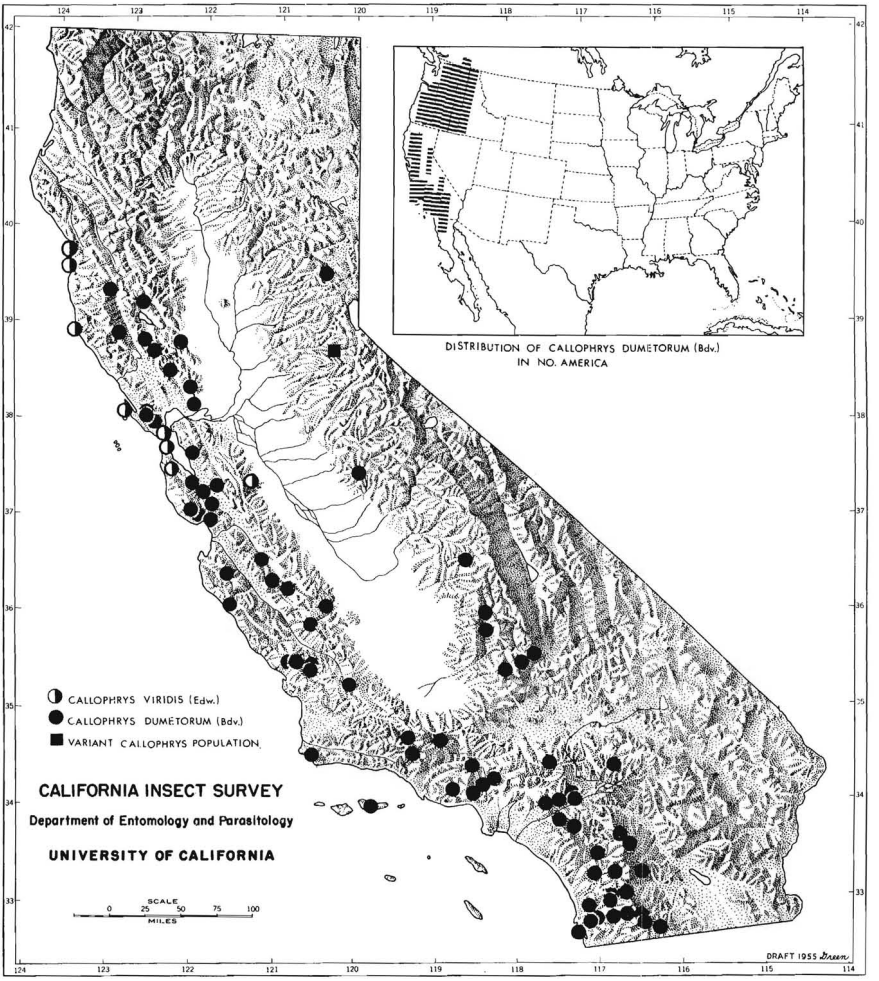
Eggs of *C. dumetorum* were obtained at the Antioch and Brannan Island study sites by taking large numbers of *Lotus scoparius* buds from the field to the lab for microscopic examination. *C. viridis* eggs were taken from the leaves of *Eriogonum latifolium latifolium* at Pt. Reyes.

Glass vials were used, one individual per vial, to rear larvae of both species. Each vial was labeled according to date of egg hatching and arranged by locality in a rack for daily observations. Larval development during the 1967 season was not recorded in detail, but successive instars were accurately recorded in the 1968 lab data using head capsules as an instar number indicator. One or two leaves and several flowers, were placed in each vial with the egg or larva and replaced every other day when desiccation or wilting occurred. Records were kept of the larval acceptance of each plant, especially the time taken to feed, the manner and/or duration of feeding, and of larval refusal to feed. The rate of development on each plant was used as an index for feeding success as well as host acceptance. Lab temperatures during the rearings (1967 and 1968) ranged from 72° to 76° F.

Developing larvae were examined under 45x for distinguishing characteristics and an ocular micrometer was utilized at 32x for larval head capsule measurements. Life history photographs were taken (Figures 1-14) and comparative morphology of the immatures were diagrammed (Figures 15-21B). Larvae were fixed in KAAD for 20 minutes and preserved in 95% ethyl alcohol. Many of these larvae, along with all marked and recaptured specimens have been deposited in the California Insect Survey collection at the University of California, Berkeley.

GEOGRAPHIC AND ECOLOGICAL DISTRIBUTION

Callophrys dumetorum (Bdv.) occupies a wide distribution extending from British Columbia to Baja California Norte, eastward to the eastern edge of the Sierra Nevada in California. Sierra Nevada populations show broad ecological tolerance, occurring as high as 5000'. *Callophrys viridis* (Edw.) is found along the immediate coast in California from the San Bruno Mountains in San Mateo County to Juan Creek, near Westport, Mendocino County (see map 1). Efforts to find this species along the coast in Oregon and the northernmost boundaries of Humboldt County failed. Neither *C. dumetorum* nor *C. viridis* occur in Lower Sonoran areas.



MAP 1 - Distribution of *Callophrys dumetorum* and *C. viridis* in California.

Flight Periods

Populations of *C. dumetorum* fly early in February in southern California whereas adults in San Francisco Bay area populations are not seen until mid-March. At Kusshi Creek, Yakima County, Washington, flight does not occur until May (Newcomer, 1965). The *C. viridis* population studied in the San Bruno Mountains reached a peak flight period on March 7, 1967 whereas the *C. viridis* population found along the sand dunes at Pt. Reyes on the coast in Marin County did not reach a peak flight period until May 14, 1967.

Host Associations

Eriogonum latifolium latifolium Sm., the observed foodplant of *C. viridis* (Brown and Opler, 1967) is only known from the coast of California and Oregon, whereas *C. dumetorum* females have been observed ovipositing on species of *Syrmatium*, *Hosackia*, *Lotus* and *Eriogonum* in southern California (Coolidge, 1924). Newcomer (1965) lists *C. dumetorum* foodplants in Washington as *Eriogonum heracleoides*, *E. compositum* and *E. elatum*. The hostplant of a variant population found at China Flat Campground in the Sierra Nevada is probably *Eriogonum wrightii* Torr. ssp. *trachygonum* (Torr.) Stokes whereas the foodplant of the Del Puerto Canyon population, on the basis of three *Callophrys* eggs found on a single stand in March, 1968, is *Eriogonum latifolium* Sm. ssp. *auriculatum* (Benth.) Stokes.

COMPARATIVE MORPHOLOGY

Evaluation of characters: Callophrys dumetorum and C. viridis

Genital dissections were carried out using specimens taken in two localities for each species. No differences were discovered between the males of *C. viridis* and those of *C. dumetorum*. The male gnathos and valvae appeared to have the same length and the same degree of sclerotization. The females of both species, too, had no structural differences. Careful examinations of sternites VIII, IX and X yielded no differences in size or shape. The signum was examined for possible differences but the amount of sclerotization was great in worn specimens while barely present in fresh ones, evidently a function of age. Male and female genitalia of *C. lemberti* Tilden and *C. comstocki* Henne were also examined but showed no apparent structural differences from one another. Therefore these structures do not provide the answer in determining the validity of species.

Androconial scales from the scent pouches of the males of both species were removed with a minute probe and placed on a slide for examination under 100x. No apparent differences were seen. Labial palpi from both males and females of both species also manifested no structural or scale differences. Of the fourteen characters mentioned by Tilden (1963)

for separating the members of the subgenus, ten were insufficient after examination of 150 specimens of both species. Such a character, for example, is the number of white maculations present on the undersides of the wings mentioned by Barnes & Benjamin (1923), Clench (1944), and Tilden (1963) as a good diagnostic character. But according to Ford (1945), individuals within a single population vary in the number of maculations present and do so even in the European species.

Examination of 596 specimens of *C. dumetorum* and 186 of *C. viridis* (total of 782 specimens) yielded the following characters useful in separating the two species:

1. Females of *C. viridis* are a uniform olive-gray on the dorsal surface, as are the males (fig. 7), varying to a mild olive-brown suffusion in some specimens. *C. dumetorum* females are dark gray-brown with a variable amount of yellow-brown suffusion within a single population as well as throughout the entire flight range (figs. 8, 9).

2. The color of the ventral surface of the wings appears to be a soft or dull yellow-green, varying to olive-green in almost all California populations of *C. dumetorum* (figs. 10-12). *C. viridis*, on the other hand, has deep yellow to blue-green undersides varying only with occasional mild yellow-green individuals within a single population as well as throughout the entire range (figs. 13, 14).

3. The antennae, when viewed dorsally, are black and white in *C. dumetorum* whereas fresh *C. viridis* specimens have all white-scaled antennae.

4. In most California populations of *C. dumetorum*, the green scales on the ventral surfaces of the forewings medially never exceed the Cu_1 vein whereas *C. viridis* populations examined almost always have green scales reaching the Cu_1 or Cu_2 vein of the forewings.

Characters 1 and 2 are evidently the most efficient way to separate *C. viridis* from *C. dumetorum*. The third characteristic is useful only when the specimens being compared are fresh. *C. viridis* antennae tend to lose the white annular scales after a few days of flight, making them appear similar to those of *C. dumetorum*.

Of 68 randomly selected *C. dumetorum* specimens (both male and female) examined from all over California, 4 (5.8%) had the medial green scales on the forewing undersides between the costal and radial veins, 17 (25.0%) had green scales extension restricted to the M_1 vein, 32 (47.1%) had green scales reaching the M_2, 12 (17.6%) had green scales reaching the M_3 and 3 (4.4%) showed green scales reaching the Cu_1.

On the other hand, 75 examined *C. viridis* specimens from Pt. Reyes and the San Bruno Mountains showed 5 (6.6%) with green scales restricted to the M_3, 68 (90.1%) with green scales reaching Cu_1 and 2 (3.3%) with green reaching Cu_2.

Evaluation of characters: Callophrys dumetorum perplexa

Other questions raised concern the validity of *Callophrys dumetorum perplexa*, the atypical race found in southern California. Barnes & Benjamin (1923) recognized this race as a valid one occurring in Los Angeles and San Diego counties southward into Baja California Norte and distinguishable from typical *C. dumetorum* by "the complete or almost complete absence of white markings on the undersides".

Sixty two specimens of *C. d. perplexa* were examined from the vicinity of the type locality (San Diego), 53 of which were males. These males included 6 individuals with no white maculations on the wing undersides (11.3%), 8 with 1 (15.1%), 36 with 2 (67.8%) and 3 specimens having 3 (5.8%).

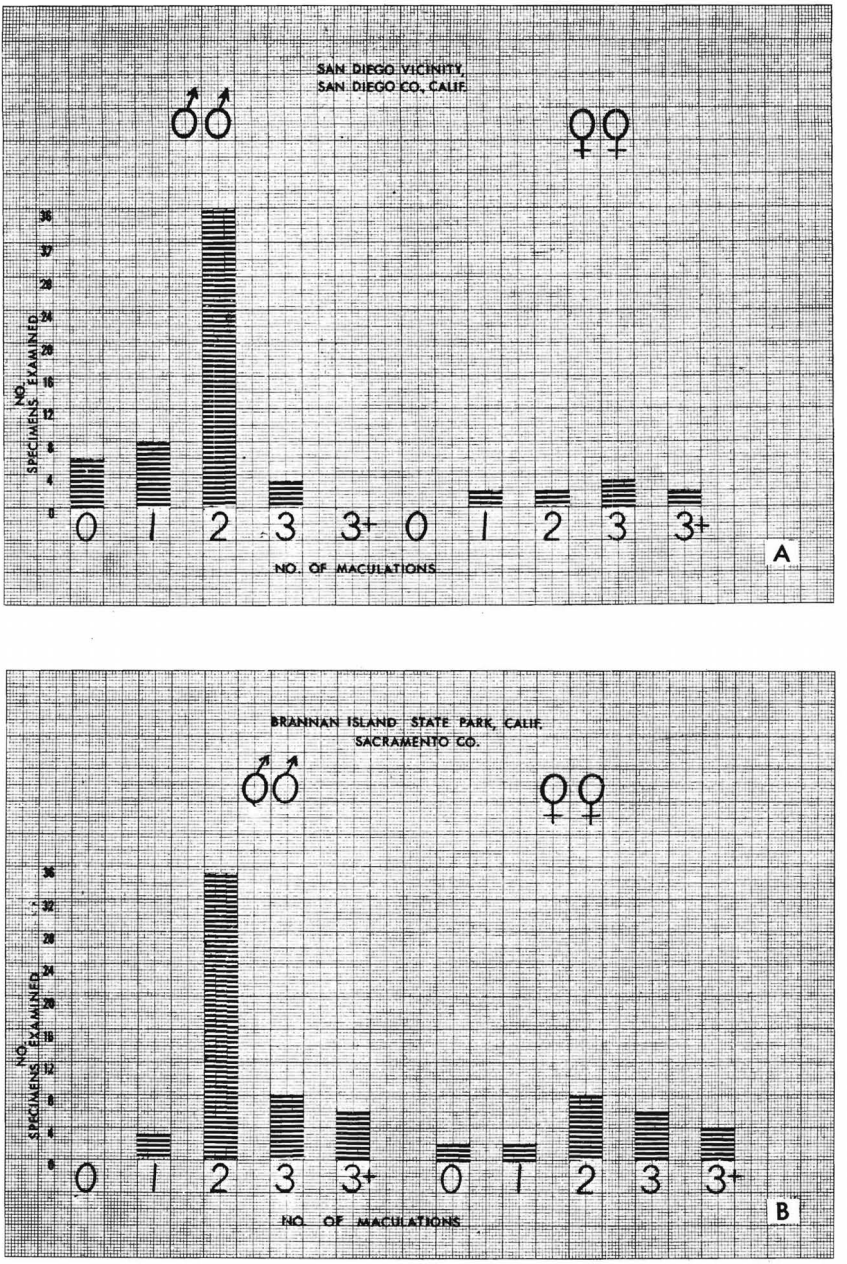
Of the 9 females examined none lacked any maculations, 2 had only 1 (22.2%), 2 had 2(22.2%), and 3 showed 3(33.4%). The remaining 2 females had more than 3 (22.2%) (see graph 1A).

In comparison, a series of 51 males of *C. dumetorum* examined from Brannan Island State Park, Sacramento County, varied from none without any maculations, 3 with 1 (5.9%), 35 with 2 (68.6%), 8 with 3 (15.7%), and 5 with more than 3 (9.8%).

Females of the above population also varied considerably. Of the 21 specimens examined, 2 had no maculations (9.5%), 2 had 1 (9.5%), 8 had 2 (38.1%), 6 had 3 (28.6%), and 3 showed more than 3 (14.3%) (see graph 1B).

The results of the above comparisons suggest that northern California populations are characterized by more spots but not significantly enough to warrant subspecific recognition. Because the males (and most females) of both populations compared showed that the two-spot condition was most prevalent, clinal variation was not assumed to be the case. These maculations, although variable in number, never vary in scale pattern. All are white outwardly and black inwardly.

The invasion of the brown scales on the undersides of the forewings almost to the costa, thus restricting the green scales to the costal margin area, is a character which is supposed to be typical of *C. d. perplexa*. No differences could be found, however, concerning the restrictions of green scales in any of the *C. dumetorum* examined throughout its entire range in California.



GRAPH 1 - A comparison of maculation percentages between two California populations of *Callophrys dumetorum*: A,- Southern California population. B - Northern California population.

The color of the scales composing the fringes of the wings was used as a character by Barnes & Benjamin (1923) separating the *perplexa* form from the typical form of *C. dumetorum*. These fringes were dark and becoming white outwardly, seen in typical *C. dumetorum* as well as in *C. d. perplexa*. This, too, is a variable trait of no significance.

Lastly, Clench (1944) asserted that *C. d. perplexa* is characterized by the "presence of fulvous edging (light brown or dull yellow) on the costa of the forewings ventrally". This is a characteristic also seen in the northern California specimens of *C. dumetorum*.

After review of 554 specimens relative to the above four characters attributed to *Callophrys dumetorum perplexa*, this writer concludes that they do not validate a distinct southern California subspecies because of their presence in the phenotypes of northern California populations as well. Because of the population variation factor present in California, no nomenclatorial distinction is required.

The chief enigma encountered during this study was the discovery of two populations of *Callophrys* (s. str.) that were not clearly either *C. dumetorum* or *C. viridis*. A female *Callophrys* examined from China Flats Campground, El Dorado County, appears to be *C. viridis* although populations representing the *C. viridis* phenotype are not otherwise known to occur in the Sierra Nevada. A second interesting population was found in Del Puerto Canyon in western Stanislaus County. Here individuals match the original description of *C. viridis* with the exception of the black annular scales present on the antennae which fit *C. dumetorum*. In several specimens from Del Puerto Canyon, the green scales were restricted to the area above the subcostal veins as seen in *C. dumetorum*. Since these characters were seen even in fresh specimens, the question must be raised as to whether *C. dumetorum* and *C. viridis* interbreed. Field work throughout the Bay Area where the two come closest together while remaining allopatric indicate that they do not.

In summary, the failure of good evidence of interbreeding suggests the two are reproductively isolated species, and the failure of comparative morphology to reveal reliable criteria for separation of the two indicates other means of confirming their distinctness must be sought. Biological characteristics are therefore examined in this study.

GENERAL BIOLOGY

Most of the species in the subgenus *Callophrys* are single brooded, fly only during the spring and feed on a fairly wide range of hostplants. Females of the Palearctic species *Callophrys rubi* (L.) oviposit on rock-rose (Cistaceae), purging buckthorn (Rhamnaceae), gorse, broom, Dyer's greenweed (Leguminosae), bramble (Rosaceae, dogwood (Cornaceae)

and whortleberry (Ericaceae) (Ford, 1945). Most Nearctic species use members of the buckwheat genus *Eriogonum*, with *C. dumetorum* also using the leaves and buds of legumes such as *Lotus* (some genera recorded in older literature as foodplants for *C. dumetorum*, i.e., *Lotus*, *Hosackia* and *Syrmatium*, recently have been included in the genus *Lotus* (Munz, 1963)). Larvae feed on the leaves and flowers and appear to derive protection from predators due to their cryptic coloration. Pupation occurs in inconspicuous places at the base of the hostplant (Comstock, 1927).

General adult activity is influenced by weather conditions. Clouds blocking the sun, temperatures below 55° F, wind and rain prevent flight activity. During cold weather, adults lean or flatten themselves against leaves, rocks and other flat surfaces. Presumably this is a thermoregulatory mechanism through increased area for insulation (Clench, 1966). On warmer, sunny days flight activity is seen all day.

BIOLOGY OF CALLOPHRYS DUMETORUM

The biology of *C. dumetorum* was studied at four localities, the first being San Gabriel Canyon (near Azusa), Los Angeles County, an area characterized by many chaparral species, including *Eriogonum fasciculatum* and *Lotus scoparius*. The second locality was Dictionary Hill, San Diego County, where observations were made by Oakley Shields in early March for several weeks. The third locality, 1 1/2 miles east of Antioch in Contra Costa County, is characterized by a river delta sand dune flora. The last locality, Brannan Island State Park in Sacramento County is also typified by a sand dune flora. Observations were made on seven days between April 8 and May 11 at the latter two localities.

Adult Behavior

Callophrys dumetorum adults, flying not more than three or four feet above the ground, alighted repeatedly on both *Lotus scoparius* and *Eriogonum fasciculatum* in San Gabriel Canyon. At Antioch, however, females circled specific stands of *Lotus* and landed frequently, ignoring the numerous stands of *Eriogonum latifolium* ssp. present. This lack of interest in *E. latifolium* by *C. dumetorum* females was seen throughout the 1967 flight season and indicates that this plant is probably not used as a host. "Aggressive" behavior was displayed by many males, especially when another butterly species entered the area. The possibility, however, that these flights were merely an attempt to elicit female response should not be ruled out. Not infrequently two *C. dumetorum* males perched within one or two inches of one another and numerous "scuffle flights" or mutual response reactions (whereby males compete for a given territory while in flight) occurred, those individuals involved revolving around one another up to 20 feet in the air, returning to separate leaves

on the same plant or to different plants. Such behavior has been seen in many butterly species and is discussed in detail by Shields (1968).

At Brannan Island 10 males and 9 females were marked and released at 10:00 A.M. on April 13, but of the 104 females and 42 males taken between April 13 and May 2, only 1 marked male was recaptured.

In March 1967, Oakley Shields marked individuals of *C. dumetorum* for 18 days to determine whether males attempt to occupy specific territories. The markings occurred on Dictionary Hill in San Diego County, an area characterized by an abundance of *Brassica nigra*. Of 20 males marked, 7 (35%) were recaptured as follows: 2 after 1 day, 1 after 4 days, 1 after 5 days, 1 after 8 days, 1 after 9 days, and 1 after 18 days. The worn male taken after 18 days was not in excellent condition when marked, giving some indication of the longevity of individuals of this species.

Courtship behavior, observed several times at Brannan Island during the 1967 season, commenced as early as 10:15 A.M. (PST) when an individual male approached a female in flight for several seconds, "forcing" the female to alight. The female, facing the shrub, perched motionless while the male perched on a leaf behind the one occupied by the female and vigorously vibrated its wings. It then moved in a clockwise direction 180° until facing outward in the opposite direction. The entire courtship process lasted no longer than 15 seconds.

As a summary to both Shields' and the present author's observations, mating occurred on the summit in a given territory assumed by a single male. The territories assumed by males of *C. dumetorum* during these observations (as shown by the marking study results) seemed to shift around when many males were present.

Mating behavior was witnessed at 12:30 P.M. (PST) at Brannan Island on April 18, 1967 when one pair was observed for 30 minutes. The female faced the interior of the shrub (*Lupinus arboreus*) with the antennae oriented upwards whereas the male faced the opposite direction, antennae pointing downward. Later, another pair was observed *in copulo* on *Lupinus* from 10:56 A.M. to 11:45 A.M. In April, 1968 a single mating pair was observed displaying the above posture as late as 3:00 P.M. on *Lotus scoparius*. After several observed matings, lab dissections of four females (two of which had been observed mating) were carried out. The two mated females yielded two concentrically-deposited spermataphores in the mouth of the bursa copulatrix indicating that many females mate at least twice.

Oviposition was seen at 10:00 A.M. on May 5, 1967 when a female, perched on a *Lotus* bud, inserted its abdomen well into the bud and deposited a single green egg 90 seconds after

insertion. After turning 180° to face the interior of the same bush, the butterfly flew to another apical bud and oviposited another egg after only 30 seconds. Rapid wing rubbing ensued, followed by antennal vibration. Only when the antennae touched another bud or leaf surface did the female move onto another part of the plant. The female inspected many buds and leaves before attempting to oviposit and flew off if a satisfactory substrate was not found. At no time did a female *C. dumetorum* at Brannan Island attempt to oviposit on *Eriogonum latifolium* ssp. No eggs or larvae were collected from *Eriogonum fasciculatum* in San Gabriel Canyon thus failing to support Coolidge's claim that females accept the latter as a suitable host. Since *E. fasciculatum* is often found in association with *Lotus scoparius* throughout the California coast ranges, *Eriogonum* should not be ruled out as a foodplant for some populations.

Life History

The eggs, approximately 0.4 mm in diameter, are ovoid, finely reticulated, green, and are deposited singly on the host plant (figs 1, 15). Eggs were collected from apical buds of *Lotus scoparius* at Antioch and Brannan Island and kept at room temperature. Emerging larvae were placed on experimental foodplants, and the results of these rearings are presented in Tables 1 and 2.

Morphological changes in each instar in the Brannan Island population corresponded closely to the descriptions given by Coolidge (1924). He showed *Callophrys dumetorum* to have four larval instars, verified by measurement of the head capsule widths of each larva examined. This technique has been found to be useful; there is apparently no overlap of head capsule width between instars in *C. dumetorum* and *C. viridis* larvae. This may be true of most lycaenids since it was also reported by Lawrence and Downey (1967) in larvae of a plebejine lycaenid, *Everes comyntas* Godart.

The following measurements were made on a total of 23 *C. dumetorum* larvae reared and preserved during 1967 and 1968.

	Head Capsule Width (mm)	Body Length (mm)
I instar: (N=7)	0.15-0.25 (avg. 0.20)	0.92-1.54 (avg. 1.17)
II instar: (N=1)	0.40	3.20
III instar: (N=4)	0.70-0.92 (avg. 0.80)	4.80-9.10 (avg. 7.59)
IV instar: (N=11)	1.23 (avg. 1.23)	11.8-15.5 (avg. 14.8)

TABLE 1 - HOST PLANT ACCEPTANCE AND DEVELOPMENT OF FOURTEEN CALLOPHRYS DUMETORUM LARVAE (1967)

HOSTPLANT	Hostplant locality	Egg	1st instar	2nd instar	3rd instar	4th instar	Color changes	Pupa
Lotus scoparius buds and leaves	Brannan Is. State Pk.	IV-8	IV-13	?	?	V-8	Pink on V-10	Light green to dark brown in 2 hours V-15
Lotus scoparius leaves	"	IV-13	IV-17	IV-20	IV-23	?	Pink on V-10	V-14
Lotus scoparius leaves	"	IV-13	IV-17	IV-20	IV-23	?	Pink on V-10	V-14
Lotus scoparius leaves	"	IV-13	IV-15	?	?	Moved to *E. latifolium* flrs. V-5	Pink on V-5	V-12
Lotus scoparius leaves	"	IV-13	IV-14	IV-17	IV-23	IV-26	Pink on V-6	V-12
Trifolium obtusiflorum flowers	San Bruno Mountains	IV-20 Refr. until IV-25	IV-28	IV-30	V-9	V-14	Pink on V-26	V-29

Eriogonum latifolium latifolium flowers	San Bruno Mountains	IV-20 Refr. until IV-25	IV-28	V-1	?	V-21	Pink on V-28	V-29
Eriogonum fasciculatum leaves	Del Puerto Canyon	IV-20 Refr. until IV-25	IV-28	IV-30	V-15	?		V-26
Lupinus arboreus leaves	Brannan Is. State Park	IV-20 Refr. until IV-25	IV-27 (Died IV-29)*					
Eriophyllum staechadifolium buds and leaves	San Bruno Mountains	IV-20 Refr. until IV-25	IV-27 (Died IV-30)*					
Vicia sp. leaves and flowers	"	IV-25	IV-29 (Died)*					
Cytisus monspessulanus leaves	"	IV-25	IV-27 (Died)*					
Gnaphalium leaves	"	IV-27	IV-30	(Died V-6)				
Amsinckia intermedia, Achillea lanulosa leaves	"	IV-20 Refr.	IV-28 (Died V-1)*					

* No attempt to feed

TABLE 2 - DEVELOPMENT OF CALLOPHRYS DUMETORUM LARVAE ON LOTUS SCOPARIUS LEAVES (1968)[1]

Egg	1st instar	2nd instar	3rd instar	4th instar	Color changes	Pupa
IV-7	IV-7	IV-11	IV-16	IV-21	Pink IV-26	IV-30
IV-7	IV-8	IV-11	IV-16	IV-21	Pink IV-26	IV-30
IV-7	IV-8	IV-12	IV-19?	IV-25	Pink IV-29	V-3
IV-7	IV-8	IV-11	IV-21	IV-25	Pink IV-29	V-3

1 Eggs collected April 7, 1968, at Brannan Island State Park, Sacramento County, California on *Lotus scoparius*.

Measurement of the molted head capsule widths at the end of each instar yielded the following ranges:

I instar: 0.15-0.38 mm
II instar: 0.39-0.68 mm
III instar: 0.69-1.10 mm
IV instar: 1.11-1.23 mm

The mature 4th instar larvae of *C. dumetorum* are uniform light yellow-green with subdorsal and lateral white stripes, turning pink just before pupation (figs. 2, 16). Triordinal crotchets arranged in a mesoseries are present on the prolegs (figs. 18A, B) and the crotchets (fig. 18A) are interrupted at the middle by a spatulate lobe, stated by Fracker (1915) to be typical of lycaenid larvae in general. The body, covered by numerous secondary setae, has uniformly rounded segmentation throughout the entire length. The head capsule is heavily sclerotized from the first to the third instars but only the ventral portion of the adfrontal sutures (above antennae) and the ocellar area remain heavily sclerotized in the fourth instar(fig. 17).

Upon hatching, first instar larvae began to skeletonize terminal leaves of *Lotus scoparius*; the second instars did the same. The larvae moved down the stem when the upper leaves died or became completely skeletonized. Mature larvae defoliated the lower branchlets rather than skeletonizing leaves. Larval feeding in general occurred throughout the morning hours in all instars, somewhat actively in the afternoon, tapering off to almost no feeding at all by early evening. Resting larvae positioned themselves on the stem or on the tops of the leaves. Coolidge (1924) stated that the de-

velopment time from egg to pupa in a southern California population was 32 days with larvae feeding on *Hosackia (Lotus)*. Rearing results from the Brannan Island population indicated a 30 to 35 day span on *Lotus*. Although feeding occurred successfully on the flowers of *Trifolium obtusiflorum* and *Eriogonum latifolium latifolium*, development from egg to pupa took as long as 39 days. Feeding on *Eriogonum fasciculatum* leaves resulted in one *C. dumetorum* larva reaching the pupa stage in 36 days.

Unfortunately, a search for field larvae failed and all life history work was carried out in the lab. Thus no parasitism was encountered during the course of the larval rearings and only one mature larva was lost due to bacterial disease.

The pupae (figs. 3, 20, 21B) are a uniform dark or brown-black with the surface texture of the wing pads excessively sculptured, almost forming rows, in contrast to the dorsal surface. A total of 26 were measured, with the length ranging 8.6-10.0 mm (avg. = 9.27mm).

BIOLOGY OF CALLOPHRYS VIRIDIS

Observations on *C. viridis* (reported as "*Thecla dumetorum*") were made in the western part of San Francisco by Williams (1910) who first determined the larval hostplant to be *Eriogonum latifolium latifolium*. In June, 1963 J. A. Powell (*in litt.*) collected *C. viridis* larvae in the San Bruno Mountains in flower heads of *E. l. latifolium* and noted that their pale color with pinkish markings blended quite well with the flowers. Adults emerged in February and March the following season. Further observations on *C. viridis*, emphasizing oviposition behavior, were made by Brown and Opler (1967) in the San Bruno Mountains.

C. viridis was studied extensively during the present investigation at two localities in central California. The first is the San Bruno Mountains near Daly City, San Mateo County. This study site, located about 4 miles from the Pacific Ocean, is characterized by steep rocky slopes with dense, diverse coastal chaparral including an abundance of *E. l. latifolium*. No *Lotus scoparius* was seen here. Observations were made on 14 days between March 2 and May 12, 1967.

The second study site, nine miles northeast of the Point Reyes lighthouse, Marin County, consists of beach sand dunes and associated flora, including *E. l. latifolium*. Like the San Bruno Mountains, no *Lotus scoparius* was found. Cold weather with low clouds and fog was prevalent during the early morning hours (before 11:00 A.M. PST) but most days warmed up considerably by noon when most activity was observed. Observations were made on five days between April 30 and May 28, 1967.

Adult Behavior

As in the case of most *Callophrys* species, *C. viridis* activity is greatly influenced by weather. Flight habits and sunning behavior are similar to those seen in *C. dumetorum*. Observations during the 1967 season were made with difficulty at the San Bruno Mountains study site due to wind and long periods of rain.

The courtship pattern exhibited by *C. viridis* is like that of *C. dumetorum*; a female entering a given male territory was courted by one or more males while in flight. But unlike *C. dumetorum*, males of *C. viridis* in the San Bruno Mountains (due to their lesser numbers) were able to maintain a specific territory with a minimum of shifting around. Two females and two males were marked in late March, 1967, and two males were recaptured on the same plants five days later.

Courtship, mating and oviposition behavior of *Callophrys viridis* was observed at Pt. Reyes. The first two behavioral mechanisms were found to be similar to that observed in *C. dumetorum* at Brannan Island State Park. Oviposition was witnessed on May 14, 1967, at Pt. Reyes at 10:00 A.M.; a single female landed on many stands of *Eriogonum*, tapping several leaves on each with the antennae. Finally, after twenty minutes of flying from plant to plant, the female alighted on an *Eriogonum* leaf; and, after touching the underside of the leaf with the antennae, bent the abdomen underneath and deposited a single green egg near the apical end of the leaf after an estimated 15 seconds. The pilose mat on the leaf underside made it almost impossible to perceive the egg (photo 4).

Host selection by *Callophrys viridis* females was limited at both localities to *Eriogonum latifolium* . This may be due in part to the absence of suitable leguminous plants such as *Lotus scoparius*. *Vicia* sp. occurs at the San Bruno Mountains site, but was found to be unacceptable to *C. viridis* larvae in the lab (see Table 3).

John Emmel (*in litt.*) observed a female *C. viridis* oviposit on *Lotus scoparius* at 11:30 A.M. (PST) in the Sunset Heights district of San Francisco, April 27, 1968. The egg was laid within the apical bud as observed during my study of *C. dumetorum* females. The Sunset Heights locality is characterized by an abundance of *E. latifolium latifolium*, and Emmel reared larvae taken from both plants between June 3 and June 10, 1968 at this site (west of the U.C. Medical Center). According to Emmel, the San Francisco Presidio dunes north of the Veteran's Administration Hospital support both *Lotus* and *Eriogonum* and both are accepted by *C. viridis* females.

No *Eriogonum* in the Pt. Reyes vicinity was yet in bloom while the females were ovipositing. Oviposition on stands

of *E. l. latifolium* which have reached the bloom stage, however, has been recorded by Brown and Opler (1967) in the San Bruno Mountains. In this case the female walked slowly up and down the inflorescence stalk of the hostplant before depositing the egg on a leaf underside. It appears that no matter where the egg is deposited the females of both species of *Callophrys* display numerous inspection flights before the hostplant is chosen.

Life History

The eggs are identical in size, shape and color to those of *Callophrys dumetorum* but on *Eriogonum* are deposited singly on the undersides of leaves near the base of the plant (fig. 4). Both eggs and larvae were collected from the leaves of *E. l. latifolium* at Pt. Reyes in May of 1967 and 1968 and young larvae were offered the same series of plants used to test host specificity in *C. dumetorum*. The results are incomplete, however, due to disease and parasitism encountered during the rearings. The larvae in many cases died before pupation. The results of the 1967 and 1968 rearings are given in Tables 3 and 4.

Body lengths and head capsule widths were measured in 38 *C. viridis* larvae as follows:

	Head Capsule Width (mm)	Body Length (mm)
I instar: (N=10)	0.31-0.38 (Avg. 0.34)	1.4-2.9 (Avg. 2.25)
II instar: (N=11)	0.40-0.62 (Avg. 0.57)	3.7-5.5 (Avg. 5.1)
III instar: (N=7)	0.69-0.99 (Avg. 0.83)	4.9-9.5 (Avg. 7.0)
IV instar: (N=10)	1.15-1.30 (Avg. 1.25)	9.8-16.0 (Avg. 12.8)

Measurements of the molted head capsule widths yielded the same ranges found for *C. dumetorum* larvae, with possible exception of the upper limit of the IV instar head capsule width.

The first instar larvae examined were light green with setation much like that described by Coolidge (1924) for *C. dumetorum*. Red spots appeared along the subdorsal ridges during the late third instar and remained in the mature fourth instar, corresponding to the description given by Williams (1910). Mature larvae were variable in color; some were light yellow-green with a small amount of pink varying slightly to red, whereas others, even within a single population were whitish marked predominantly with red (figs. 5, 19). Unlike the uniformly rounded segmentation in *C. dumetorum*, larvae of *C. viridis* have pronounced dorsolateral and segmental ridges. The setation, crotchet arrangement and head cap-

TABLE 3 - HOST PLANT ACCEPTANCE AND DEVELOPMENT OF FOURTEEN CALLOPHRYS VIRIDIS LARVAE (1967)

HOSTPLANT	Hostplant locality	Egg	1st instar	2nd instar	3rd instar	4th instar	Pupa
Lotus scoparius leaves	Brannan Is. State Park			V-28	VI-1 (Died: VI-2) parasitized		
Lotus scoparius leaves	"			V-28	VI-1 (Died: VI-2) parasitized		
Lotus crassifolius leaves	Juan Creek Mendocino Co.			V-28	Died: VI-15		
Eriogonum latifolium latifolium leaves	San Bruno Mountains	V-28	VI-8 (Died VI-10)				
Eriogonum latifolium latifolium leaves	"	V-28		V-7 (Died parasitized)			
Trifolium obtusiflorum flowers	"			V-28 (Died: VI-3)*			
Trifolium obtusiflorum flowers	"			V-28 (Died: VI-3)*			
Eriogonum fasciculatum leaves	Del Puerto Canyon			VI-8 (Died: VI-10)			

Eriogonum fasciculatum leaves	Del Puerto Canyon	V-28	VI-9 (Died: VI-15)	
Eriogonum latifolium latifolium	San Bruno	V-28	VI-3	VI-8 (Died: parasitized)
Eriogonum latifolium latifolium flowers	"	V-28	VI-3	VI-9 (Died: VI-10)
Lupinus arboreus leaves		V-28 (Died: V-30)*		
Eriophyllum staechadifolium leaves		V-28 (Died: VI-1)*		
Vicia sp. leaves; *Cytisus monspessulanus* leaves		V-28 (Died: VI-1)*		

*No attempt to feed

sule morphology are identical to those in *C. dumetorum*. The distance between the lateral adfrontal sutures proximal to the clypeus (widest point) were identical for mature larvae of both species (avg. 0.70 mm).

An undescribed species of *Apanteles* (Hymenoptera: Braconidae) was recovered from one second, two third and one fourth instar larvae during the 1967 rearings. Thompson (1944) recorded no parasite record for any species of Nearctic *Callophrys*, but several ichneumonid and tachinid species are known to parasitize *C. rubi* in Europe.

Pupae were examined from Pt. Reyes and the San Bruno Mountains and their lengths are: (N=14) 8.2-9.7 mm (avg. 9.2 mm).

These pupae, unlike those of *C. dumetorum* described above, are brown with a mottled appearance owing to interspersed pale areas, particularly on the wing covers. Both species exhibited finely sculptured ridges, but these appear less pronounced on the lighter colored pupa of *C. viridis* (figs. 6, 21a).

RESULTS AND CONCLUSIONS

Laboratory and field study during the spring of 1967 and 1968 on *Callophrys viridis* and *C. dumetorum* produced interesting similarities between the two. Host selection (based on host availability) in the field proved to be of little use in separation of the two species, while larval characteristics provided the most valuable diagnostic information. The results of the study are summarized as follows:

1. Laboratory inspection of 63 San Diego County *Callophrys dumetorum* specimens showed that the four characters used most frequently to define the so-called subspecies *C. d. perplexa* were found to be present in northern California populations in varying proportions. The degree of difference does not appear to warrant treatment of *C. d. perplexa* as a valid subspecies.

2. The percent difference in green scaling on the wing undersides between *C. viridis* and *C. dumetorum* is consistent enough to distinguish between them; ground color on the female uppersides and the quality of green color on the undersides are also useful in separating the two entities.

3. At no place in the respective distributions of the two species has interbreeding been found to occur, although allopatric San Francisco Bay area populations of both species fly during the same months.

4. The number of individuals marked and released for each species was too small to be of statistical significance, but the number of recaptures along with observations of male

TABLE 4 - OBSERVATIONS ON THE DEVELOPMENT OF CALLOPHRYS VIRIDIS LARVAE (1968)

HOSTPLANT	Hostplant locality	Egg	1st instar	2nd instar	3rd instar	4th instar	Color changes	Pupa
Eriogonum latifolium latifolium leaves	Pt. Reyes	V-10	V-11	V-15	V-23 (Died)			
Eriogonum latifolium latifolium leaves	"		V-10	V-14 (Parasitized)				
Eriogonum latifolium latifolium leaves	"		V-10	V-14 (Parasitized)				
Eriogonum latifolium latifolium leaves	"	V-10	V-14	V-29? (Died)				
Eriogonum latifolium latifolium leaves	"		V-10	V-14	V-23 (Died)			
Lotus scoparius leaves	Brannan Is. State Park			V-23	VI-10	VI-17	VI-19 (pink)	VI-23
Lotus scoparius leaves	"			V-23	VI-10	VI-17	VI-19 (pink)	VI-23

concentration points indicate that courtship behavior for both species is identical. Territories, while sustained by individual males for short times, shift around from day to day when numerical density is high, but appear to be maintained over several day periods in sparse colonies.

5. Aerial courtship and reverse male-female orientation on the host and non-hostplant substrates were seen to occur at least twice by individuals of both species.

6. Mating was observed twice during the morning hours in both species; courtship behavior and oviposition also were witnessed in morning and not commonly during afternoon. Undisturbed males and females of both species remain *in copulo* for at least 30 minutes.

7. Females of *C. dumetorum* select *Lotus scoparius* for oviposition even when *Eriogonum latifolium* is present; while *C. viridis* females select *Lotus* and/or *Eriogonum* when both are present in the same locality. Females of both species spend much time examining and probing the substrate before egg deposition, evidently in relation to the structural quality of the hostplant.

8. In the laboratory, larvae of *C. dumetorum* fed successfully on *Lotus scoparius*, *Eriogonum latifolium*, *E. fasciculatum* and *Trifolium obtusiflorum*; *C. viridis* larvae fed successfully on the first three but failed to accept *Trifolium*.

9. Larvae of both *C. dumetorum* and *C. viridis* matured more rapidly on *Lotus scoparius* than on any other host.

10. Immatures provided the best morphological characters for the separation of these two species. Most noteworthy are the characters given in Table 5.

As stated by Clench (1963), *Callophrys* is an interesting subgenus because of the difficulty in discriminating between the species comprising it. The results of the present study indicate that the morphology of the larvae lend strongest evidence for confirmation of species integrity in *C. dumetorum* and *C. viridis*. It appears that *C. viridis* is not conspecific with *C. dumetorum* as believed by many earlier workers, but rather a species which is ecologically allopatric. Females' host acceptance, especially the preference for *Lotus scoparius* by both species, indicates that the two are closely related. It is possible that *C. viridis* is a more specialized offshoot of *C. dumetorum* as suggested by the more restricted distribution and acceptable host substrates (as seen in the laboratory). But as Clench (1963) asserted, it is also possible to think of *C. viridis* as conspecific with *Callophrys sheridani* (Carpenter) and because relatively little has been recorded on the biology of the latter species, this hypothesis remains to be tested. Further work of a biological nature is needed to clarify confusing issues plaguing this subgenus.

TABLE 5 - CRITERIA USED TO SEPARATE THE IMMATURE STAGES OF CALLOPHRYS DUMETORUM AND CALLOPHRYS VIRIDIS

STAGE	CONDITION	
	C. dumetorum	*C. viridis*
MATURE LARVA:		
a. Subdorsal white stripes	present	absent
b. Subdorsal ridges with red spots	absent	present
c. Ground color	green to yel-ow green	yellow-green to whitish
d. Subdorsal and segmental ridges	absent	present
PUPA		
Color	dark brown-black	light brown, mottled paler
Wing pad sculpturing	pronounced	weak

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APPENDIX

MATERIALS STUDIED

Callophrys viridis

Arranged alphabetically, 106 males and 80 females as follows:

CALIFORNIA. Marin Co.: Point Reyes, 2M, 3F, IV-8-51 (C.D. MacNeill), 2M, III-30-56 (W.R. Bauer), 2F, V-16-58 (J. Powell); Point Reyes, 9 mi. NE lighthouse, 4M, 1F, VI-18-66 (R.S. Wielgus), 3F, IV-30-67, 2M, 8F, V-7-67, 7M, 12F, V-14-67 (all G.A. Gorelick). Mendocino Co.: Fort Bragg, 18.6 mi. N, 2M, VI-12-67 (G.A. Gorelick); Juan Creek, betw. Rockport and Westport on Hwy.1M, 4F, VI-9-67 (G.A. Gorelick); Point Arena, 2M, 1F, VI-12-67 (G.A. Gorelick). San Francisco Co.: Lone Mountain, San Francisco, 2M, 5F, III-6-17-1910 (F.X. Williams); Presidio, San Francisco 1M, 1F, IV-5-26 (no collector), 1M, 1F, IV-18-29 (no collector), 1M, IV-10-38 (L.I. Hewes); San Francisco, 1M, V-28-05 (F.X. Williams), 1M, IV-22-16 (K. Coolidge), 2M, IV-26-16 (K. Coolidge), 3M, IV-22-31 (A. Kusche), 2M, 1F, IV-19-34, 3M, 1F, IV-27-34, 6M, 1F, V-8-34, 1M, 2F, V-13-34 (all W. Hovanitz); Twin Peaks, San Francisco, 1F, IV-4-60 (N. LaDue), 5M, 3F, IV-2-60 (R. Stanford), 2M, 1F, LV-13-61 (P.A. Opler). San Mateo Co.: San Bruno Mountains, 4M, II-28-61, 4M, III-10-61, 2M, 3F, III-17-61 (J. Powell), 2M, III-28-61 (N. LaDue), 1F, V-5-61 (J. Powell), 1F, III-9-62 (J. Powell), 1M, 3F, III-31-62 (J.W. Tilden), 9M, 8F, Iv-6-7-62 (J. Powell) 3M, IV-10-62 (J. Chemsak, J. Powell), 2M, 2F, II-26-28-63 (J. Powell), 1M, IV-28-63 (R.L. Langston), 2F, VI-4-63, emerged II-24-64, III-16-64 (reared from *E. latifolium latifolium*) (J. Powell, #63F8), 1F, III-17-66 (A.J. Slater), 4M, III-19-66 (P.A. Opler), 9M, 1F, III-25-66 (P.A. Opler, 1F, IV-13-66 (J. Powell), 5M, 2F, IV-16-66 (P.A. Opler), 4M, 1F, IV-24-66 (R.S. Wielgus), 2M, III-2-67 (G.A. Gorelick), 2M, III-7-67, 1M, 1F, III-22-67 (G.A. Gorelick).

Variant populations: El Dorado Co.: China Flat Campgrounds, 5 mi. S of Kyburz, 1F,VI-5-61 (N. LaDue). Stanislaus Co.: Del Puerto Canyon, 22 mi. W of Patterson, 2M, III-5-63 (R.L. Langston, J. Powell), 1M, 1F, II-22-64 (R.L. Langston, J. Powell, 1M, 1F, IV-6-49, *in copulo* (V.M. Stern) (Adobe Creek); 1F, III-24-67 (G.A. Gorelick), 1M, IV-9-67 (P.A. Opler).

Callophrys dumetorum

Arranged alphabetically, 270 males and 242 females as follows:

BAJA CALIFORNIA. Baja California Norte: Tajo Branch of Cantillas Canyon, Sierra Juarez, 1M, III-23-67 (J. Powell).

CALIFORNIA. Alameda Co.: Berkeley Hills, 1400', NE Oak-

land, 1M, IV-17-62, 1M, IV-15-64 (J. Powell); Oakland, NE, 1M, III-9-30 (G. Heid), 1M, V-1-37, 2F, IV-9-38 (C.W. Anderson). Contra Costa Co.: Antioch, 4F, III-18-57 (P.A. Opler); Antioch, 1 mi. E. 1M, III-19-60 (R. Stanford); Antioch, 1.5 mi. E, (Little Corral) 1M, IV-19-60 (P.A. Opler), 6M, 2F, IV-20-67 (G.A. Gorelick; Mt. Diablo, 1M, IV-9-61 (P.A. Opler). Fresno Co.: Coalinga, 23 mi. W, 1F, V-6-63 (R.L. Langston); Huntington Lake, 1M, V-22-36 (L. Martin). Kern Co.: Havilah, 3000', 2 mi. N, 1M, IV-28-64 (J. Powell); Walker Pass, 1 mi. W, 1M, IV-26-64 (J. Doyen); Weldon, 16 mi. S, 7M, IV-26-64 (R.L. Langston, J. Powell). Lake Co.: Bear Creek, 3 mi. E, 2F, VI-24-67 (P.A. Opler); Middletown, 2500', 4 mi. WNW, 1F V-15-58 (O.E. Sette); Whispering Pines, 3 mi. SE, 1M, IV-4-62 (R.L. Langston). Los Angeles Co.: Altadena, 1M, III-7-26 (J.A. Comstock); Azusa, 2M, IV-3-45 (C.I. Smith); Bob's Gab, nr. Littlerock, 2M, IV-2-54, 1F, IV-7-55, 2M, 2F, IV-9-60 (P.A. Opler), 2M, IV-2-66 (R. Stanford); Cobal Creek Canyon, 2M, III-19-60 (K. Hughes); Desert Springs, 1M, V-5-56 (J. Powell), 1F, V-7-63 (R.L. Langston); Fish Canyon, 2M, III-7-37 (no collector); Glendale, 3M, 1F, III-26-44 (D.L. Bauer); Griffith Park, 1M, IV-10-21 (J.A. Comstock), 2M, IV-14-60 (G.A. Gorelick); Mint Canyon, 1M, IV-16-23 (J.A. Comstock); Pasadena, 1200', 2F, IV-15-11 (F. Grinnell, Jr.): San Gabriel Canyon, 1M, III-1-25 (J.A. Comstock), 2M, III-17-61 (K. Hughes), 2M, 3F, III-20-67 (G.A. Gorelick); San Rafael Hills, 1M, II-13-41, 2M, III-9-41 (D.L. Bauer). Marin Co.: Alpine Lake, 1M, IV-25-58, 1M, IV-17-61 (J. Powell); Carson Ridge, 1M, IV-16-61 (J. Powell); Lake Lagunitas, 1F, V-2-59 (C.A. Toschi). Mariposa Co.: Bear Valley, 2 mi. N on Hwy 49, 1M, 3F, IV-15-61 (P.A. Opler). Mendocino Co.: Fort Bragg, 27 mi. E, nr. Willits, 5M, 1F, VI-9-67 (G.A. Gorelick). Monterey Co.: Hastings Reservation, nr. Jamesburg, 3M, 1F, V-3-58 (J. Powell); Partington Canyon, 1M, 1F, IV-21-51 (P.A. Opler); Stone Canyon, 1M, 1F, IV-21-19 (E.P. VanDuzee). Napa Co. Angwin, 1M, 2F, IV-19-45 (D.L. Bauer). Plumas Co.: Dixie Game Refuge, 5800', 2M, V-17-64 (D.L. Bauer). Riverside Co.: Hemet Lake, 1M, 1F, IV-28-49 (C.D. MacNeill); La Sierra College (campus), 1F, III-12-39 (D.L. Bauer); Lake Mathews, south shore, 2M, III-19-67 (J. Lane); Nightingale, 1M, IV-28-49 (C.D. MacNeill); Perris, 4M, III-4-53 (T.M. Blackman); Sage, 5 mi. S, 2M, IV-16-65 (J. Powell, D. Veirs). Sacramento Co.: Brannan Island State Park, 50M, 150F, IV-7-to V-7-67 (G.A. Gorelick). San Benito Co.: Bitterwater, 5 mi. S, 1M III-30-59 (C.W. O'Brien); Hollister, 24 mi. SE, 1M, 3F, IV-7-62 (O.E. Sette); Paicines, 5 mi. SW (Lime Kiln Rd.), 7M, 2F, III-24-66 (A.J. Slater, J. Powell, R.L. Langston); Pinnacles Nat'l. Monument, 7 mi. W of Jct., 1M, IV-9-66 (P.A. Opler). San Bernardino Co.: Desert Spring, 1 mi. E, 1M, 3F, IV-7-65 (R.L. Langston); Fontana, 8 mi. n (Lytle Creek), 1F, IV-14-65 (C.A. Toschi); Highland, NE (City Creek), 1F, IV-17-65 (G. Buckingham); Lucerne Valley, 5 mi. SW, 4M, 1F, IV-14-64, 3M, IV-15-65 (R.L. Langston); Redlands, 1M, III-15-31 (C.M. Dammers); Upland, 1M, IV-9-57, 1F, IV-28-57 (T.M. Blackman). San Diego Co.: Alpine, 4M, III-31-61 (R.L. Langston); Alpine, 5 mi. E, 1M, 1F, III-31-61 (J. Powell); Anza-Borrego Desert State Park, 1000 Palms Canyon, 1M, III-4-34 (J. Creel-

man); Banner, 3 mi. E (Two Mile Hill), 2M, 1F, III-23-41, 1M, III-22-42, 1M, 1F, IV-8-44, 1M, III-13-57, 1M, III-13-59, 1M, III-11-61 (F. Thorne); Banner, 7 mi. SE (Box Canyon), 2M, III-17-53 (F. Thorne); 1F, III-23-53 (J. Powell). Descanso Ranger Station, 1M, III-31-61 (R.L. Langston); El Cajon, 1M, III-16-35 (C.M. Brown); El Cajon, 2.5 mi. SE (800'), 3M, III-29-52, 1M, III-7-53, 2M, III-15-53 (F. Thorne); Jacumba, 3 mi. W, 1M, III-25-60 (R. Stanford), 2M, III-21-64 (F. Thorne), 3M, III-22-66 (O. Shields); Lakeside, 2 mi. NE, 2M, III-29-61, 2M, 1F, III-13-63 (J. Powell); La Posta Creek (Hwy. 80), 2M, IV-13-63 (F. Thorne); Mission Gorge, 9M, 1F, II-27-52, 2M, III-6-52, 3M, III-21-52, 3M, II-9-53, 3M, II-12-53, 2M, II-14-53 (J. Powell), 1F, III-23-60 (R. Stanford); Mount Laguna Jct., 1 mi. N, 4F, III-26-61 (R.L. Langston, E.E. Lindquist); Mount Laguna Jct., 3 mi. N (Scove Canyon), 2M, III-27-61 (R.L. Langston); Point Loma, 1M, II-12-34, 1M, II-12-35, 1M, II-17-35 (F. Thorne); Ramona, 9.5 mi. NNE (Black Mountain, 4000'), 1M, V-9-65 (O. Shields); San Diego, 1F, III-4-33, 1M, III-18-33, 1F, II-12-35 (F. Thorne); Warner's Hot Springs, 1M, IV-5-50, 2M, III-23-51 (J. Powell). San Vicente Reservoir, 1M, III-19-49 (J. Powell); Scissor's Crossing, 1 mi. W, 1M, III-28-53 (J. Powell), 2M, IV-3-60 (K. Hughes). San Luis Obispo Co.: Atascadero, 4 mi. W, 1F, V-2-62 (J. Powell); Pozo, 6 mi. NE (Black Mountain, 3300'-3600'), 1M, 1F, V-1-62 (C.A. Toschi, R.L. Langston); Pozo, 12 mi. NE (La Panza Camp), 1M, 2F, IV-29-62 (R.L. Langston, J. Powell); Simmler, 1M, III-20-40 (J.W. Tilden, G.S. Mansfield). Santa Barbara Co.: Jalama Beach, 3M, 7F, IV-22-66 (R.L. Langston, J. Powell, A.J. Slater); Sta. Cruz Is., Prisoner's Harbor, 2F, IV-29-66 (R.L. Langston; Sta. Cruz Is., Upper Central Valley, 6F, IV-26-66 (R.L. Langston, J. Powell). Santa Clara Co.: Alum Rock Park, 1M, II-12-64 (R.L. Langston), 2M, IV-21-66 (P.A. Opler), 1M, II-30-67 (G.A. Gorelick); Capitancillos Lake, 1M, III-14-64 (P.A. Opler); New Almaden, 1M, IV-17-64 (P.A. Opler); Palo Alto, 2M, 30 (W. Hovanitz); San Jose, 3M, 1F, V-6-17 (K. Coolidge). Santa Cruz Co.: Boulder Creek, 6 mi. E, 5F, V-17-64 (P.A. Opler); Mt. Ben Lomond, 2M, V-16-65 (P.A. Opler); Santa Cruz Mtns., 2M, V-15-33, 2M, III-14-36, IV-5-36 (J.W. Tilden), 1M, V-1901 (J.G. Grundel), 1M, IV-6-31 (no collector). Sierra Co.: Sattley, 1 mi. W, 1F, VL-17-67 (G.A. Gorelick). Solano Co.: Green Valley, 1M, IV-8-53 (A. Telford). Tulare Co.: Fairview, 9 mi. S, 3M, 1F, IV-27-64 (W. Turner, J. Powell, P. Rude); Johnsondale, 2 mi. E, 1M, IV-27-64 (J. Powell); Sequoia National Park, 2M, 1F, IV-16-30, 1M, V-16-30 (L.I. Hewes). Ventura Co.: Gorman, 5 mi. S, Hungry Valley, 1M, IV-10-60 (G.I. Stage); New Cuyama, 1F, III-28-57 (R.P. Allen); Sespe Canyon, 1F, IV-13-37 (G. Heid). Yolo Co.: Rumsey, 2 mi. NW, 9M, 5F, IV-12-62 (J. Chemsak, J. Powell).

EXPLANATION OF FIGURES

Fig. 1 - Eggs of *Callophrys dumetorum* on *Lotus scoparius* bud, Brannan Is. St. Pk., Sacramento Co. (G.A. Gorelick)

Fig. 2 - *C. dumetorum* larvae and pupa (same data as above)

Fig. 3 - *C. dumetorum* pupae (ventral, dorsal views), Pope Creek, Napa Co. (J. Emmel)

Fig. 4 - Egg of *Callophrys viridis* on *Eriogonum latifolium latifolium* leaf underside, Pt. Reyes, Marin Co. (G.A. Gorelick)

Fig. 5 - *C. viridis* larvae feeding on *Lotus scoparius*

Fig. 6 - *C. viridis* pupae (ventral, dorsal views), San Bruno Mountains, San Mateo Co. (J. Emmel)


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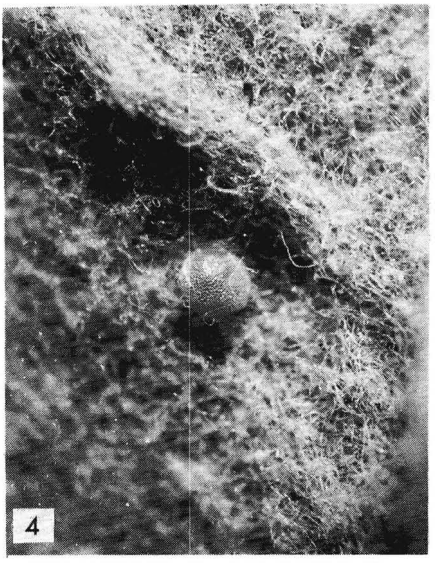
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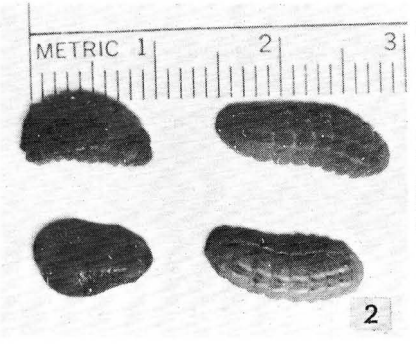
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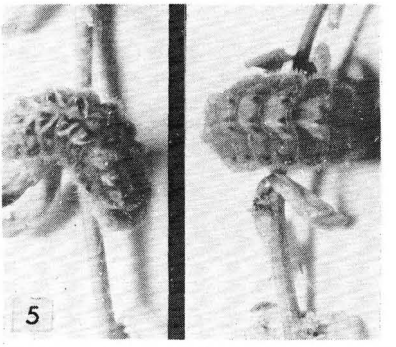
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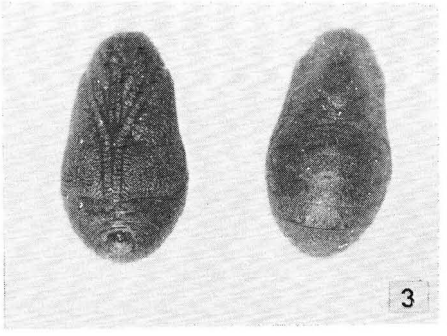
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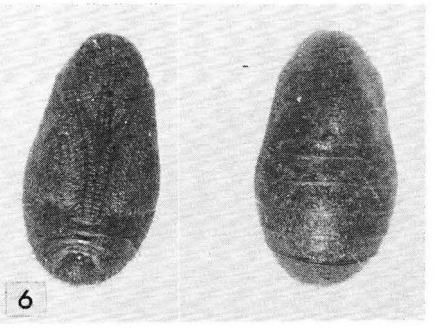
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EXPLANATION OF FIGURES

Fig. 7 - *Callophrys viridis*, dorsal view, Marin Co. (G.A. Gorelick)

Fig. 8 - *C. dumetorum*, dorsal view, Sacramento Co. (G. A. Gorelick)

Fig. 9 - *C. dumetorum*, same data as Fig. 8

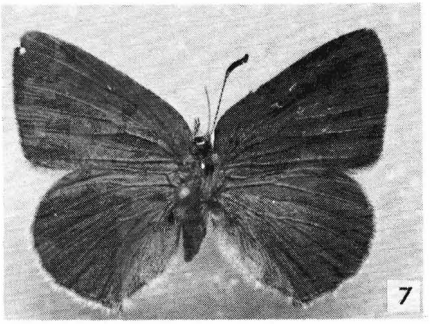
Fig. 10 - *C. dumetorum*, ventral view, Sacramento Co. (G.A. Gorelick)

Fig. 11 - *C. dumetorum*, same data as Fig. 10

Fig. 12 - *C. dumetorum*, ventral view, San Diego Co. (J. Powell)

Fig. 13 - *C. viridis*, ventral view, Marin Co. (G.A. Gorelick)

Fig. 14 - *C. viridis*, same data as Fig. 13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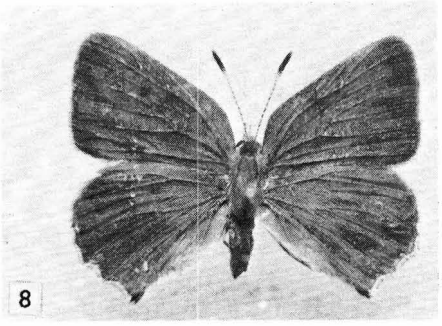
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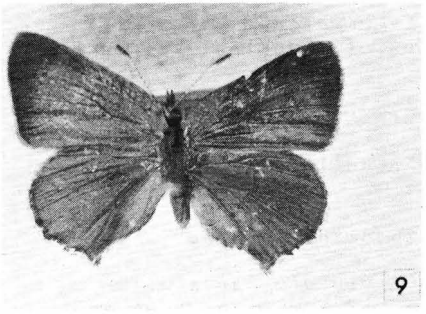
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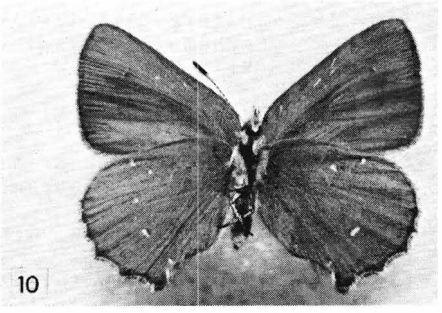
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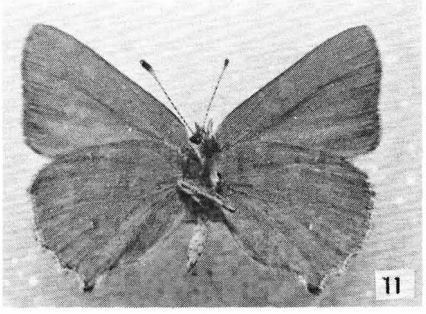
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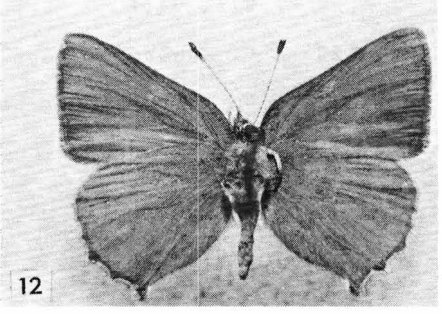
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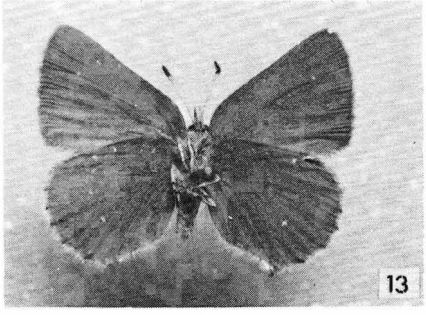
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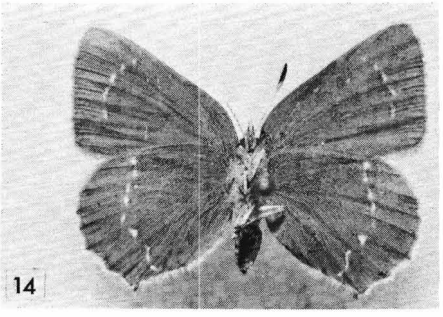
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EXPLANATION OF FIGURES

Fig. 15 - *Callophrys dumetorum* egg

Fig. 16 - Mature, 4th instar *C. dumetorum* larva with schematic dorsal view of abdominal segments VII, VIII

Fig. 17 - Head capsule of mature *C. dumetorum* larva

Fig. 18A - Lateral view of 4th abdominal proleg showing crotchet arrangement

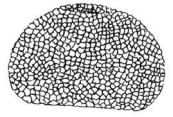
Fig. 18B - Medial view of 4th abdominal proleg

Fig. 19 - Mature, 4th instar *C. viridis* larva with schematic dorsal view of abdominal segments VII, VIII

Fig. 20 - *C. dumetorum* pupa, dorsal view

Fig. 21A - *C. viridis* wing pad sculpturing (ventral view)

Fig. 21B - *C. dumetorum* wing pad sculpturing (ventral view)



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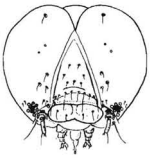

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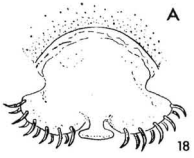

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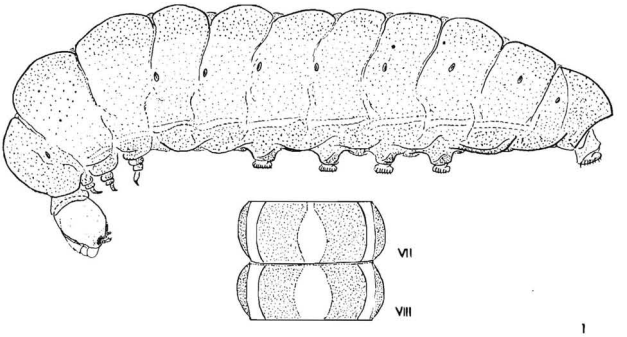

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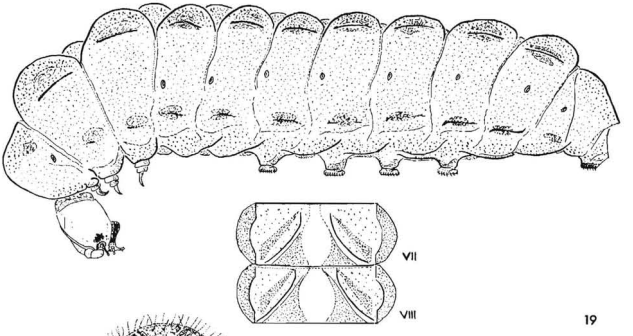

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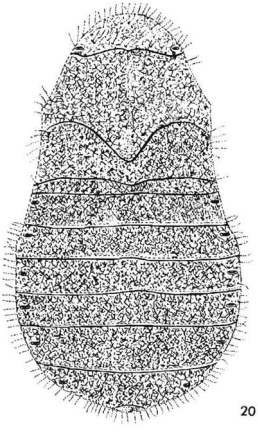

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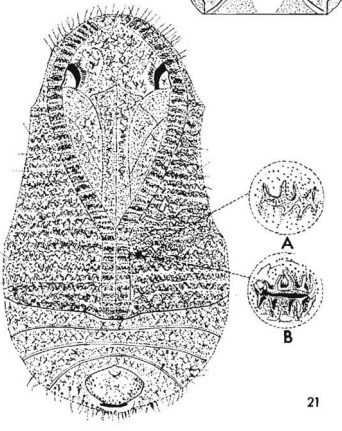

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