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Title BIOLOGY AND ADULT VARIABILITY IN AN OREGON POPULATION OF LEPTARCTIA CALIFORNIAE (WALKER) (LEPIDOPTERA: ARCTIIDAE)

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Leptarctia californiae (Walker) was studied on clear and semi-forested southern slopes in the Coast Range Mountains of Benton County, Oregon. The spring of 1965 had an unusually long warm period (21 days) resulting in adult emergence approximately 25 days earlier than in the cooler spring of 1966. Peak flight activity occurred between 12:00 noon and 3:00 p.m. RST. Pheromone emission by females appeared to be the mechanism of male attraction. Larval developmental time in the laboratory (65-80°F) required approximately 60 days, which was 60 per cent longer than development under field conditions. First, second, and third instar larvae fed both day and night on low growing plants while fourth and fifth instars fed nocturnally on other plant species up to 18 inches above ground level. Dorsal hind wing colors in both males and females are black on black and yellow. In addition, females also have combinations of black with yellow-orange, orange, or red.

BIOLOGY AND ADULT VARIABILITY IN AN OREGON POPULATION OF *LEPTARCTIA CALIFORNIAE* (WALKER) (LEPIDOPTERA: ARCTIIDAE)

BY

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INTRODUCTION

The phenomenon of polymorphism in plants and animals was misunderstood by early classical biologists and taxonomists. Scientific names often were applied to each polymorph. The fact that these "species" often bred with other "species" and produced offspring, both parental and non-parental in appearance, raised questions about inheritance which went unanswered until the time of modern genetics in the early Twentieth Century. Today, polymorphism is considered the result of the action of single genes or gene complexes which are maintained by some selective advantage imparted to their respective phenotypes (Thoday and Boam, 1959).

The fields of population genetics and ecological genetics have advanced rapidly using recognized polymorphs as indicators of the presence and frequency of certain genes in populations. A variety of plants and animals have served as tools in these studies on polymorphic forms, the most notable being insects in the Orders Lepidoptera and Diptera. Species of Lepidoptera (polymorphic for wing color patterns) useful in studies of ecological genetics were found to have easily recognizable polymorphs in the field often represented by a distinct genotype. Further, there was adequate accessibility and abundance of most species, and they were easily handled both in the field and in the laboratory. One of the most useful, in relation to the above, is the European arctiid moth *Panaxia dominula* (L.) which has been investigated

by Fisher and Ford (1947), Cook (1962), and Williamson (1960). Long range ecological genetic studies of this species have lead to the determination of the adaptive value of the polymorphic "medionigra" gene (Sheppard and Cook, 1962).

The western North American arctiid moth Leptarctia californiae (Walker) is also highly polymorphic. It may be a better insect than Panaxia to study ecological genetics because it occurs in an environment which is changing rapidly (undergoing successional changes toward reforestation). The resulting changes in selective pressures could lead to a more rapid and pronounced change in a population than was observed in the Cothill Population of P. dominula studied from 1939 to 1961 (Ford, 1964). Because of an inadequately known biology, the potential usefulness of L. californiae in studies of ecological genetics has remained unrecognized. It is the purpose of this thesis to investigate that biology.

Males of L. californiae possess well developed pectinate antennae and strong powers of flight which are similar attributes of moths studied by Kettlewell (1961) in sex attraction studies. In addition, the diurnal flight behavior and apparent method of males assembling to virgin females is also similar, suggesting that this insect is of potential value for use in these studies.

Mimicry studies are needed to investigate whether or not the red and yellow hind wing coloration functions aposematically with apparent distastefulness of this moth to predators. Whether other species of Lepidoptera are deriving protection as mimics because of coloration and

patterning similar to L. californiae should be determined.

Preliminary knowledge of the biology of L. californiae should be of great value in considerations of population dispersal and interchange. Because of color pattern differences which exist between populations over a distance of a few hundred miles, questions regarding the nature of genetic unity throughout its range need to be answered.

Genetic analysis should also be conducted to determine the inheritance patterns of the polymorphs and the geographical variants, each of which are apparently maintained through their respective selective advantage. It was with the hope of furthering studies on polymorphic insects that this inquiry into the biology of the species was initiated.

LITERATURE REVIEW

This section deals with the taxonomic position of L. californiae (Lepidoptera: Arctiidae) as well as specific taxonomic, biological, distributional, and historical references. The distributional references are augmented by data labels on specimens from museum collections. Some literature dealing with polymorphism, mimicry, genetics, evolution, and biology, where important, has been cited in the Introduction with additional references from these areas reviewed in the Results and Discussion section.

In 1855, Walker[1] described californiae from specimens collected in

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[1]Walker, Francis. 1855. Catalogue of the British Museum-Lepidoptera III: 625 (Reference unavailable).

California, placing the species in the genus Nemeophila Stph. The same color phase described by Walker was later described as Lithosia adnata by Boisduval (1869). Stretch (1873) described the genus Leptarctia and included Lithosia lena Boisd. (=adnata Boisd.) and Lithosia decia Boisd., and a new species dimidiata Stretch. At the end of Stretch's volume, L. lena (Boisd.) was placed in synonomy with L. californiae Walker. A check list, published by the Brooklyn Entomological Society in 1881, listed three species in the genus Leptarctia (L. decia (Boisd.), L. dimidiata Stretch, and L. lena (Boisd.)). Grote's check list, according to Coolidge (1910) mentioned californiae, placing it as a synonym of L. lena.

Butler (1881) described eight "varieties" of californiae. Later, French (1889) and Smith (1890) increased this number to eleven. Dyar (1902) recognized californiae, decia, and dimidiata as valid. Of the eleven varieties listed by French (1889) and Smith (1890) the descriptions of boisduvalii Butler, dimidiata Stretch, albifasciata French, fulvofasciata Butler, and californiae Walker fit individuals occurring together at one locality in western Oregon. The polymorphs in this population belong to one species because the polymorphs can all be progeny of a single female and interbreed freely, but proof is lacking as to the conspecificity of this population with other distant populations. Today it is widely accepted that Leptarctia is monobasic with californiae (Walker), the only species (Coolidge, 1910; French, 1889; Comstock and Dammers, 1943; McDunnough, 1938).

The early stages of L. californiae were described by French (1889). A more detailed description of the egg and first instar larva was made by Dyar (1903). Photographs of a dorsal and lateral aspect of the mature larva plus dorsal, lateral and ventral aspects of the pupa were presented without further description by Comstock and Dammers (1943).

Many of the older localities were compiled from papers by Edwards (1873), Butler (1881), French (1889), and Llewellyn-Jones (1935). Biological observations were scattered through many of the previously mentioned papers. In discussing this species from Golden, Colorado, Dyar (1903) states "... I found some larvae there on the ground or feeding on low plants." It was not indicated whether this observation was diurnal or nocturnal. Observations and discussion on the length of the various stadia were made by French (1889). Food plant records were briefly mentioned in this same paper by French (1889) and by Coolidge (1910) and Comstock and Dammers (1943), who also listed the only parasite as "...a species of Ichneumon."

Taxonomic Position

Members of the family Arctiidae ("Tiger moths") are among the more colorful of the Lepidoptera, frequently displaying various shades of red, pink, yellow, white, and black. The "furry" larvae, usually known as "wooly bears," are familiar to almost everyone.

Bourgogne (1951) divided the Arctiidae into four subfamilies: Lithosiinae, Arctiinae, Aganainae, and Nolinae. Leptarctia has been placed in the large subfamily Arctiinae, which is generally characterized by a stout, usually hairy thorax and abdomen, medium to large

size, presence of ocelli, and presence of vein 8 on the primaries (Turner, 1946). Unlike most of the other Arctiinae, L. californiae is diurnal.

Geographical Distribution

Leptarctia californiae is widely distributed throughout several of the United States and in the Province of British Columbia, Canada. The known range of this species is west of the 106th longitude to the Pacific Coast and from British Columbia south to southern California. Specimens from California, Arizona, Nevada, Oregon, Idaho, Washington, Colorado, Montana, and British Columbia have been examined during the course of this study.

Among the oldest collecting records are those of Lord Walsingham who collected in Oregon in 1871 and 1872 (Butler, 1881; Comstock and Dammers, 1943). Edwards (1873) wrote of the "Leptarctia" in the collection of Mr. Harvey of Vancouver, British Columbia. Dyar collected and reported them from Colorado (1903) and from the Kootenai District of British Columbia (1904). The oldest collection records at the Los Angeles County Museum were from Santa Cruz County, California, collected in 1901, and San Fernando, Los Angeles County, California, collected in 1914.

This species occupies a variety of habitats throughout its range. In southern California, it is found from the western coastal sand dunes of El Segundo through the foothill canyons and valleys of the San Gabriel, San Bernardino, and San Jacinto Mountains to the eastern

desert highlands of the Providence Mountains (collection of the Los Angeles County Museum, examined December, 1965). It is found primarily in semi-forested mountainous regions over most of its distribution northward and eastward from southern California. Collecting records suggest that L. californiae has been established as a permanent element of the biota over much of its range. New and potentially inhabitable environments have been provided by logging and burning of Douglas fir, Pseudotsuga menziesii (Mirb.) Franco, forests.

All western Oregon sites visited during this study were once dense forests of Douglas fir and are now reduced to scattered second growth with burned logs and stumps of past logging operations. These sites had southern exposures, steep hillsides, numerous open areas, and low-growing vegetation. Figure 1 illustrates the numerous logged or burned over regions of western Oregon prior to 1936, which are potential sites in addition to other L. californiae localities throughout the state.

Figure 1. Extent of logged-off or burnt-over timberland west of the summit of the Oregon Cascades prior to 1936. Besse (1938).

MATERIALS AND METHODS

Field Studies

Field studies were conducted primarily on an open grassy hillside near the North Fork of the Alsea River in Benton County, Oregon. During the months of March through July of 1965 and 1966, 31 daytime and four night trips were made to this locality in search of various stages of L. californiae. Additional trips were made during this time to four other localities. Observation and collection of adults were of primary interest on most field trips. Observations of caged larvae and searches for eggs, larvae and pupae in the field also were made. Various collecting procedures utilizing lightweight collecting equipment and observational techniques are discussed below.

Description of Collecting Sites

Leptarctia californiae were observed or collected in the five western Oregon localities listed below and indicated in Figure 2.

Locality I. Oregon, Benton County, North Fork Alsea River, 4.5 miles N.N.E. Alsea, open slope east of the State Fish Hatchery, R7W, T13S, Sec. 20, W.M., 500-1000 feet elevation.

Most of the field collecting and observations were made at this site during 1965 and 1966. The area is an open grassy hillside which was burned in 1850 and the remaining large Douglas fir (Pseudotsuga menziesii (Mirab.) Franco) timber was logged in the 1930's or 40's. The remaining stumps and snags are charred, indicating additional fires about twenty years ago (Meier, 1966). The hillside is "L" shaped

with one slope facing south, the other facing west. Douglas fir occurs occasionally on the south slope becoming dense along the ridge together with an abundance of iris (Iris tenax Dougl.), Bracken fern (Pteridium aquilinum (L.) Kuhn.), and grasses dominate much of the open slope. Ceanothus sanguineus Pursh, Holodiscus discolor (Pursh) Maxim., Rhus diversiloba T. & G., Cornus nuttallii Aud., and Arbutus menziesii Pursh are widespread and less common. On the west slope, these plants are more abundant and in places form impenetrable thickets with Rubus parviflorus Nutt. and Gaultheria shallon Pursh. Cornus nuttallii Aud. and Acer circinatum Pursh are most abundant in the hollow between the two slopes. Most collecting sites at Locality I (Figure 3) are on the steep hillsides pictured in Figures 4, 5, and 6.

Locality II. Oregon, Benton County, One mile east of Old Blue Mountain, R7W, T13S, Sec. 4, Center, W.M., 2450 feet elevation.

The area is a steep rocky ridge with a southern exposure in an extensive clearcut.

Locality III. Oregon Benton County, 6.5 miles S. W. Philomath, on Oregon Hwy. 34, near BM 498 and Hide Creek.

This area is marked by C. nuttallii, P. menziesii, and A. circinatum growing on an open roadside strip 15 yards wide between dense second growth timber to the north.

Locality IV. Oregon, Benton County, Price Peak, approximately 7 miles N.W. Corvallis, 1875 feet elevation.

This mountain-top clearcut is presently dominated by H. discolor, R. parviflorus, G. shallon, and grasses.

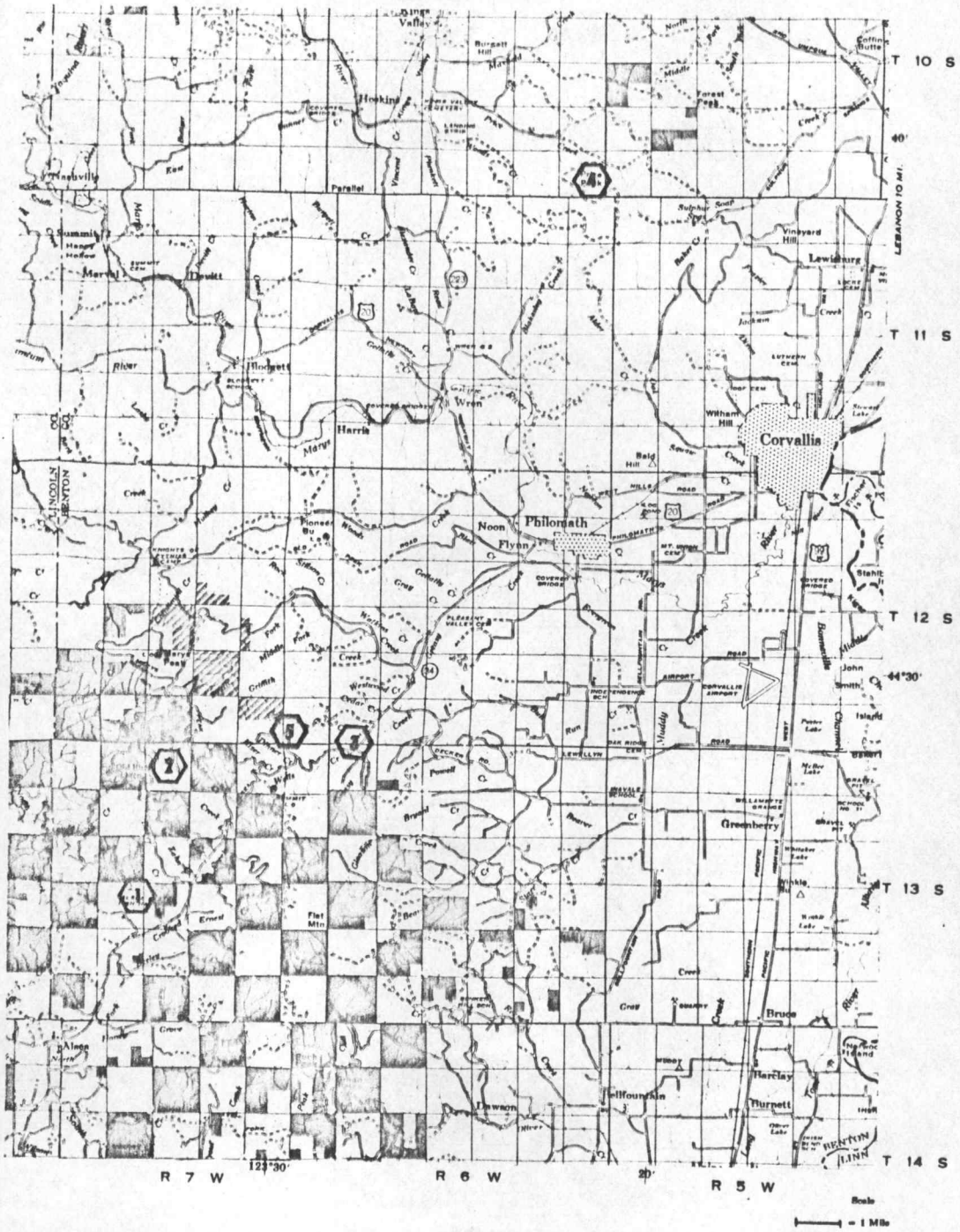

Figure 2. West central portion of the Willamette Valley and Coast Range Mountains of western Oregon. Localities in which Leptarctia californiae (Walker) were known for 1965 and 1966 are designated. Darkened areas are O & C or Public Domain lands. Reproduced from Bureau of Land Management Alsea-Rickreall Master Unit, 1960.

Locality V. Oregon, Benton County, approximately 8 miles S.W. Philomath, on State Hwy. 34 to .5 miles N. Dinner Creek crossing, R7W, T12S, Sec. 36, W.M., 1250 to 1750 feet elevation.

This area was burned in 1850, logged in the 1940's and is now becoming reforested (Meier, 1966). A road extends across the area and around a flattened ridge at the 1300 foot elevation. Young P. menziesii, Tsuga heterophylla (Raf.) Sarg., and G. shallon form dense thickets on the northern banks of three small streams which flow through the cut-over area. Taxus brevifolia Nutt. and Castanopsis chrysophylla (Dougl.) A. DC. are abundant near the edge of the surrounding forest. Ceanothus velutinus Dougl. var. laevigatus T. & G., A. circinatum Pursh, and C. nuttallii Aud. are common on the roadside and scattered about the more southern exposures along with grasses and Rubus vitifolius C. & S.

The following potential sites were visited during the 1965 and 1966 adult flight season, but no L. californiae were found: 1. Road from Hwy. 34, R7W, T13S, Sec. 10 SE 1/4 eastward through Sec. 9, 10, 16, 17, and 18; 2. Clearcut area R7W, T13S, Sec. 11, NE 1/4; 3. Most of Sec. 33, R7W, T13S; 4. McDonald Forest, five miles N.W. Corvallis in meadow, R5W, T11S, Sec. 18, SE 1/4, Sec. 17, SW 1/4.

Phenology of Locality I

The record of phenology at Locality I for two contrasting climatological years is presented below. Common plant species at Locality I which show new leaves at the initiation of the adult L. californiae flight period in late March are: Iris tenax Dougl., Rubus

Figure 3. Locality I as viewed from one mile to the South on Highway 34, March 24, 1965.

Figure 4. Locality I midway up the South slope looking east, March 24, 1965.

Figure 5. Locality I, view downhill to the Southwest from midway up the South ridge, March 24, 1966. Alsea State Fish Hatchery in background. Note same tree in center as in Figure 4.

Figure 6. Locality I midway up South slope ridge looking east, May 7, 1966, at end of adult Leptarctia californiae (Walker) flight period.

vitifolius C. & S., Lotus micranthus Benth., L. aboriginus Jeps., and Cardamine sp. Additional early growth plants which also flower at this time are Dentaria tenella Pursh, Micranthus sp., Fragaria bracteata Heller, and Viola spp. The general appearance of the south slope at Locality I in March is shown in Figure 5. The brown ground litter is almost entirely composed of dead Pteridium aquilinum, I. tenax, and grasses left from the previous year. By early May, at the end of the adult flight period, P. aquilinum is two to three feet tall, I. tenax is in late bloom, and most of the other foliage is rapidly growing and lush over the entire hillside at Locality I (Figure 6).

The years of 1965 and 1966 contrasted climatologically for the spring months of March, April, and May. Daily weather conditions of these months were compiled for 1965 and 1966, and are presented in connection with adult flight records in Figures 10, 11, 12, and 13. March of 1965 was unusually sunny compared to March of 1966 in which snow was reported late in the month at lower altitudes in western Oregon. In general, March, April, and May of 1965 were wetter and warmer than average, while the same months of 1966 were dryer and cooler than average. March of 1965 deviated most aberrantly from mean values. The following quotation from the U. S. Weather Bureau Monthly Weather Review for March of 1965 documents the meterological conditions that affected the early onset of spring at Locality I in 1965.

> "Anticyclonic circulation with the blocking ridge caused extremely sunny weather over Washington and Oregon. March precipitation was only 1/4 to 1/3 of normal in those States and in western Oregon consecutive rainless days equaled the March record of 21 days." (Green, 1965; p. 394)

Figures 4 and 5, taken on March 24 of 1965 and 1966 respectively, illustrate the difference in overall plant development between the two years.

At the crest of the hillside at Locality I, air temperatures ranging from 8 to 14°C were recorded on clear days with winds from the north at approximately 10 to 25 m.p.h. At the same time, on the south slope of the hillside, air temperatures ranged from 15 to 25°C with the wind from the south at approximately 5 to 15 m.p.h. Solar heating and the resulting convection currents on the south slope at Locality I can account for the warmer daytime temperatures and uphill wind movements which were noted. Turbulent cloud formations were frequently observed directly above the hillside during prevailing southwesterly winds. Occasionally a long opening in the cloud cover was observed over a four-mile-long section of valley (North Fork, Alsea River). Locality I is at the north end of this valley section and under these conditions continues to receive sunlight directly on its south slope while most of the surrounding hills are shaded by clouds.

Field Equipment and Techniques

Collecting procedures. Locality I was mapped on March 14, 1965, by marking widely separated trees and stumps with strips of blue plastic ribbon and pacing off the distances between the marked points. Duplicate maps were carried to the field and used in conjunction with a portable tape recorder to note the sightings and adult captures.

Most field trips lasted for the entire day. Arrival of Locality I was normally around 10:30 a.m. and departure ranged between 2:00 and

5:00 p.m., depending upon the weather, adult flight period, observations, and experiments.

In an attempt to determine the nature of the population structure of L. californiae, sites of initial 1965 flight collections at Locality I and the surrounding vicinity from which collections were unknown were revisited on each field trip. Later during the flight season and all of the 1966 season, searches were made for L. californiae in these areas on the average of once every 14 days during the flight season. Searches for adults were made under favorable adult flight conditions.

Whenever possible, adult males were collected for variation studies. A nylon areal net (15-inch hoop) and small, lightly charged ethyl acetate bottles (pocket size) were employed. Male flyways were taken advantage of; specimens being netted as they passed in flight. The attempt was made to collect males with uniform intensity on each field trip although this was complicated by numerous males attracted to laboratory-reared virgin females confined in screen cages. Despite this, unbiased collecting of the various color variants was followed in an attempt to secure as many adult male L. californiae as possible. The females which were also collected by net were normally returned to the laboratory in small plastic vials and allowed to oviposit for several days following capture before they were pinned.

A small, foot-deep pit dug into the ground on a shaded portion of the ridge at Locality I acted as a field "cooler" for storage of females in plastic vials, to be used in attraction studies the following day. Recently mated pairs of L. californiae were also stored

temporarily in vials placed in this cooler until their transportation from the field.

Field equipment was simple and lightweight for portability. Among the larger items were the nylon screen cages 2.5 ft. x 5 ft. x 3 ft. high used to confine larvae from dispersion and behavior studies which along with smaller cages 6 in. x 8.5 in. x 16 in. high also served to confine virgin females for attraction studies.

Observational Techniques. During the course of this study, it was found that the value of observations made in the field was proportional to the time spent. The lower than anticipated population levels during 1965 and 1966 made it necessary to create artificial situations in the field to make certain observations. By altering conditions such as prodding larvae, confining virgin females, observations were made on some aspects of the biology which would otherwise go unrecorded.

A portable battery-operated tape recorder was taken to the field on the majority of field trips, and observations were recorded as they occurred or shortly thereafter. The transcribed tapes often exceeded two typewritten pages for each field trip. Information on various experiments, adult sightings, weather, and collecting notes were permanently recorded. In this manner many important details were easily recorded with a minimum of effort in the field.

Air temperature readings were made at various sites and times using a glass mercury thermometer (Centigrade scale). Wind direction and velocity were estimated without the aid of equipment and noted along with sky conditions on each trip to the field.

Laboratory Studies

The laboratory studies which were carried out involved various aspects of the biology which were unavailable from field studies, primarily due to the lower than expected population levels. Observations on fecundity, pattern of oviposition, and duration of ovipositional period were made from field-collected and laboratory-reared females confined to one pint paper cartons and ten dram glass vials. These females were maintained solely on water. Observations on the hatching of eggs, the mobility and defensive behavior of larvae and adults were primarily conducted in the laboratory. Deficiencies in field observations such as pupal location, emergence period of similarly overwintered pupae were filled by specimens reared through the pupal stage in the greenhouse (50 to 80°F) in 6 in. x 8.5 in. x 16 in. high screen cages on Malva sp. The resulting pupae were overwintered out of doors at Corvallis, Oregon.

A considerable number of larvae were reared in the laboratory in various containers ranging in size from one-half pint covered plastic dishes to gallon jars and on both natural and artificial foods. An artificial media (Shorey and Hale, 1965) was found to be the most useful in rearing large numbers of larvae under crowded conditions. Larvae through the first two or three instars were usually reared in one-half pint plastic cartons on artificial media and then transferred to gallon jars. Approximately 40 larvae at a time could be reared in gallon jars, containing two or three inches of shredded paper in the bottom, on the artificial media of Shorey and Hale (1965). The

artificial medium (a cake) was placed on a number 14 cork in the center of each jar to keep the diet apart from larval excrement.

Attempts at securing mating in the laboratory were conducted at a window under natural illumination both direct and indirect. Adults used in field and laboratory attraction studies were kept in eight dram vials in a refrigerator (7°C) until used.

Microsporidia (Protozoa) were found to be the principal pathogens interferring with larval rearings. Dead and living larvae from each rearing group for both 1965 and 1966 were frozen at -10°C until examination for pathogens could be made. Dr. Clarence Thompson, Insect Pathologist at the U. S. Forest Service, Forest Range and Experiment Station, 3200 Jefferson Way, Corvallis, Oregon, provided the facilities and aided in the examination of approximately 40 larvae for possible pathogens.

Adult color variation studies were made from field-collected males which were pinned, labeled, and stored awaiting further examination. Males were grouped into four classes on the basis of coloration of the dorsal secondaries. Photographs of three specimens of each class (the two extremes and the mean) were made using 35 mm Kodachrome II film and 100 watt daylight photoflood bulbs. Additional adult characters were not examined. Larvae were photographed with similar equipment from the standpoint of gross color differences between individuals from different females or those which were diseased or healthy. No attempt was made to examine setal patterns, internal morphology or any other larval character.

The number and duration of instars was determined by rearing larvae separately in paper cartons and making daily observations on ecdysis. To check the number of instars, head capsule measurements were made on a group of larvae from one egg mass using a binocular dissecting microscope with a calibrated ocular accurate to $\pm$ .02 mm.

RESULTS AND DISCUSSION

Field observations were made whenever possible in describing the biological aspects of this insect. By experimentally altering conditions, such as caging virgin females for attraction studies or prodding larvae to observe defensive behavior, an attempt was made to investigate some aspects of the biology which would otherwise go unrecorded. A record of the variation in wing color pattern of 115 field-collected adult male L. californiae is presented.

Field collections and observations were initiated at the beginning of the adult flight period in March, 1965, and terminated on July 19, 1966, three months after the flight period. Data on population fluctuations at Localities I and V during the years immediately prior to 1965 are discussed only as far as collector records permit.

Life History and Habits

The seasonal life history of L. californiae begins with the diurnal spring flight period. On the first trip to Locality I on March 13, 1965, eight males were collected, some showing enough wear to suggest they had flown considerably during the previous three to five days. The last adults of the 1965 flight season were noted on May 10, 1965. In 1966, the first adult flight was noted on April 3 (the third field trip to Locality I) when four males were collected. The last adults were seen on May 1, 1966. Considering the early spring of 1965 and the later spring of 1966, the generalized adult flight period for Locality I should begin at the end of March and end

by the middle of May of the same year.

Females were observed in the field from March 13, 1965, to April 3, 1965, and from April 5, 1966, to May 1, 1966. All captured females from the field oviposited readily, suggesting the presence of eggs throughout most of the adult flight season. Eggs laid by a field-collected female in a cage at Locality I on April 6, 1966, did not emerge until April 27, 1966, 21 days later. Eggs should be present at Locality I during most of the adult flight period and for an incubation afterward which should approximate 21 days. Thus, eggs should be present in the field from the end of March to the end of May of the same year.

Larval development is rapid up to the fifth instar, which is of long duration. Following hatching on April 27, 1966, field larvae (in cages) developed to fourth instar by June 27, 1966, 61 days later. On July 19, 1966, both fourth and fifth instar larvae were present in cages. Laboratory reared fifth instar larvae required longer time to metamorphose to pupae than from egg to fourth instar. Considering this, along with warmer temperatures and an increased developmental rate, larvae of L. californiae through the fourth instar were available from mid April into early July. Estimates of the duration of the fifth instar are derived from laboratory-reared material in conjunction with the development of a group of larvae through July 19, 1966, in the field which continued in the laboratory until their sacrifice on August 14, 1966. In the absence of naturally occurring field-collected larvae, estimates suggest the fifth instar is present through mid

September, at which time pupation likely takes place.

Pupation occurs in the litter at ground level. Pupae hibernate through the winter until the time of adult emergence in late March and early April at Locality I. The presence of freshly emerged adults through the end of April suggests that pupae are present throughout most of the adult flight period, perhaps as late as the end of April at Locality I.

Summary of Seasonal Life History of Leptarctia californiae (Walker) at Locality I.

Eggs _____

Larvae _____

Pupae _____ _____

Adults _____

Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.

Larva

All larvae discussed in this section as "field larvae" were confined to three screen cages at Locality I.

Development of Instars I-V. Larval development under field conditions (screen cages at Locality I) was rapid (86 days) up through the fifth instar, examined on July 19, 1966. The larvae came from eggs deposited in a small square screen cage (approximately 1/8 cubic foot) by a field-collected female. These larvae were sacrificed to terminate laboratory studies on August 14, 1966, after nearly a month in the laboratory, at which time they showed no signs of pupation.

Based on laboratory rearing, the fifth instar is of long duration (see Table I and II). This is in agreement with the 57-day period observed by French (1889) for fifth instar L. californiae from Truckee, California. It appears from this information that had the larvae which were reared through the fifth instar not been preserved, they would have pupated no sooner than mid September. Fifth instar larvae, reared on an artificial diet, consumed food at a rate equal to fourth instar larvae at the onset and then gradually decreased until pupation. To verify the number of instars, a record of the head capsule width was made along with a daily examination of larvae as a check. Consistent differences were noted in head capsule width between larvae from different females. Head capsule width for larvae from a female designated here as female (s)[2] and comparable instar larvae from females (g), (n), and (p) larvae are given in Table III. Larvae (s) and (p) were from laboratory-reared females and larvae (n) and (g) were from field-collected females. The differences between the first instar larvae could have resulted from inadequate parental female nutrition or genetical differences. These differences could also account for the head capsule differences between fourth instar (h), (p), and (s) larvae, but complications from nutritional differences experienced in their development could obscure this. The artificial medium described by Shorey and Hale (1965) proved very useful in rearing as many as 40 fourth and fifth instar larvae together in a single gallon jar. Larvae reared on leaves in the greenhouse during 1966 sustained over 50%

[2]The letters in parenthesis refer to the progeny of a single female. Details concerning the original female or progeny are in Appendix 1.

mortality from microsporidia. The high mortality resulting from crowding and microsporidia during 1965 rearing was virtually nonexistent during the 1966 season with the use of the artificial medium.

The first, second and third larval instars spin a mat of very sparse silk over the immediate substrate on which ecdysis takes place. The silken mat made by fourth instar larvae, if present, was not seen. Larval cast skins were not eaten, but remained free on the ground as hollow fuzzy balls open at one end. On one occasion (July 19, 1966), the cast skin of a fourth instar larva was discovered in a field cage lying on a leaf of Lotus sp. five inches above the ground. This cast skin may have remained loosely attached to the larva, becoming separated as the larva moved over the leaf. For all larval stages, moulting occurred at or near ground level beneath or between layers of litter.

Time of Activity. The first, second, and third larval instars are active diurnal and nocturnal feeders while the fourth and fifth instars are preferentially nocturnal in their feeding activity.

Field observations of caged larvae, instars one through three, were made on the days of March 24, and 27, 1966, and May 1, and 19, 1966, at Locality I. Larvae were actively feeding on both the upper and lower surfaces of leaves. In the laboratory (65-80°F) the first, second, and third larval instars which were reared in Petri dishes and paper cartons fed both day and night.

Daytime searches of the field cages for later instar larvae on May 26, and June 27, 1966, were negative. On the evening of June 27,

at 8:30 p.m. another search of the cages was negative. At 9:00 p.m., with the aid of a Coleman lantern light, larvae were found ascending stems and actively feeding on foliage. Sunset on June 27, 1966, was at 8:06 p.m. P.S.T. Under room conditions, fourth and fifth instar larvae reared in gallon jars near a window remained hidden in the bottom litter until approximately one hour following sunset, at which time they moved about the jar and began feeding. When the same larvae were held in heavy paper cartons (in darkness), they were found to be feeding or present above the bottom litter at all times. Starved fourth and fifth instar larvae moved upward to feed only briefly during daylight hours in jars.

Host Preferences. Three nylon screen cages, 2.5 ft. x 5 ft. x 3 ft. high, were placed over vegetation at Locality I to establish host preferences and assure an enclosed supply of larvae under conditions as natural as possible. In attempting to expose larvae to a variety of potential host materials, the cages were placed over plants in areas similar to those frequented by adult females. Observations of larval feeding in these cages were made from April 17, 1966, to July 19, 1966, during which time the composition of plant species in the cages changed. The caged larvae were usually found feeding on a variety of plants when observed.

Table IV lists those plants found in the cages which larvae fed upon frequently or occasionally along with those suspected of being fed upon and those apparently never fed upon. Synthyris reniformis (Dougl.) Benth. and Cardamine sp. were available to caged larvae up through

TABLE I. DURATION OF LARVAL INSTARS OF LEPTARCTIA CALIFORNIAE (WALKER) LABORATORY REARED AT ROOM TEMPERATURE (65-80°F).

Instar	Larval Group[1]	Number	Host Material	Stadia Time in Days for 50% ecdysis[3]
First Instar	(e)	35	Malva sp.	7.00 ± .50
First Instar	(k)	4	Malva sp.	5.50 ± .25
Second Instar	(k)	4	Malva sp.	7.50 ± .25
Third Instar	(k)	4	Malva sp.	5.50 ± .25
Fourth Instar	(k)	2	Malva sp.	6.50 ± 1.00 (died before pupation)
Fifth Instar	(o)	5	Artificial Diet[2]	41 ± 4

[1]Each letter refers to the progeny of a single female. Details concerning the original female or the progeny are in Appendix 1.

[2]Composition of artificial diet, Shorey and Hale (1965).

[3]The ± range includes the variation in stadia length between all individuals of a given group plus any estimation of the point of 50% ecdysis to the next instar when observations were made at least twice daily.

TABLE II. DURATION OF THE LARVAL STAGE OF *LEPTARCTIA CALIFORNIAE* (WALKER) REARED IN THE LABORATORY AND THE GREENHOUSE.

Interval From	To	Larval Group[1]	Number	Host Material	Time in Days to Point of 50% Pupation[3]
First Instar Larva	to Pupa	(m)	20	*Malva sp.* in screen cage in laboratory (Temp. range: 65-80°F)	58 ± 5
First Instar Larva	to Pupa	(p)	100	Artificial diet in carton in laboratory (Temp. range: 65-80°F)[2]	65 ± 10
First Instar Larva	to Pupa	(g)	30	*Malva sp.* in laboratory, April 12, 1965, to May 23, 1965, when transferred to greenhouse. (Temp. range: 50-80°F)	85 ± 10

[1]Each letter refers to the progeny of a single female. Details concerning the original female or the progeny are in Appendix 1.

[2]Composition of artificial diet, Shorey and Hale (1965).

[3]The ± range covers the approximate period between the first and last pupa formed.

TABLE III. HEAD CAPSULE WIDTH OF LARVAE (INSTAR I-V) OF LEPTARCTIA CALIFORNIAE (WALKER)

Larval Instar	Larval Group*	Number	Range of Head Capsule Width in mm.	Mean Head Capsule Width in mm.
I	(s)	3	0.53	0.53
I	(g)	2	0.35	0.35
II	(s)	10	0.79-0.94	0.87
III	(s)	12	1.23-1.76	1.47
IV	(n)	10	1.76-2.11	1.94
IV	(p)	10	2.15-2.46	2.32
IV	(s)	10	2.20-2.55	2.38
V	(s)	10	2.55-2.90	2.76

*Each letter refers to the progeny of a single female. Details concerning the original female or the progeny are in Appendix 1.

May until the plants died or ceased growing. Rubus vitifolius and Iris tenax then became the favored foliage in the cages.

The following plants were accepted by larvae as host material in the laboratory:

Viola sp.
Malva spp.
Cirsium arvense (L.) Scop.
Trifolium repens L.
Salix sp.
Rubus spp.
Taraxacum officinale Weber
Rumex occidentalis Wats.
Verbascum thapsus L.
Plantago lanceolata L.
Plantago major L.

Larvae showed no apparent reluctance to feed on different host material at various times during their development, and as seen from the field studies discussed earlier, are likely to feed on a variety of available hosts.

Location on Plants. After hatching from the egg, larvae in field cages were seen crawling over dry litter and stems on the ground. The first instar skeletonized and chewed through the lower surfaces of leaves of Synthyris reniformis, Rubus vitifolius and Cardamine sp. near their point of release. Synthyris and Cardamine are typical of many plants with primary growth of low basal leaves just above the ground or litter surface. The undersides of the leaves of Gaultheria shallon (four to six inches above the litter) were fed on for the ten days immediately following larval hatching from eggs placed at the base of the plant. Aside from this, all first through third instar larvae observed in the field cages were found on leaves no more than two inches above the dry ground litter.

Caged fourth instar larvae were seen feeding up to 18 inches above the ground on the long leaves of iris on the night of June 27, 1966.

They ascended the iris blades and fed from the underside. One larva, while on the top surface of an Oxalis suksdorfii Trel. leaf, was seen feeding on overhanging Lotus sp. about six inches off the ground. Caged fifth instar larvae fed on the edges of leaves of Gaultheria shallon from the underside on the night of July 19, 1966, and during that day one larva was discovered in the litter at the base of an iris plant.

Field cage observations on fourth and fifth instar larvae are in agreement with notes of nocturnal feeding of L. californiae from Arizona by McFarland (1962), but attempts to collect the larvae in the manner outlined by him at Locality I failed. Searching and sweeping the plants in a variety of areas at Locality I and the adjacent woods on June 28, 1965 (10: p.m. to 1:00 a.m.); July 1, 1965, (9:15 p.m. to 11:00 p.m.); and June 27, 1966, (8:45 p.m. to 10:45 p.m.) along with taking six berlese samples, each four square feet, of plants and topsoil on the hillside on May 10, 1965, and two hours of sifting plants, duff, litter, and loose topsoil in areas frequented by females and with plants showing probable larval feeding on May 26, 1966, failed to reveal any larvae.

Larval Dispersion. Larvae of L. californiae show no tendency toward gregariousness. Newly hatched first instar larvae tend to move away from their egg mass in all directions. The common daytime clustering of fourth and fifth instar larvae in the darker corners of a rearing cage is an apparent light avoidance reaction, and the occasional occurrence of more than one larva feeding on the same leaf

TABLE IV. HOST PREFERENCE OF LEPTARCTIA CALIFORNIAE (WALKER) DETERMINED BY FEEDING ASSOCIATION OF CAGED LARVAE.

Feeding Rate/ Plants in Cages	Time Interval at Recorded Feeding Rate
Frequently Fed Upon[1]	
Synthyris reniformis (Dougl.) Benth.	April 17, to April 27, 1966
Cardamine sp.	April 27, to May 1, 1966
Rubus vitifolius C. & S.	April 27, to May 19, 1966
Iris tenax Dougl.	June 27, 1966
Gaultheria shallon Pursh	April 17, to April 27, 1966, July 19, 1966
Occasionally Fed Upon[2]	
Fragaria bracteata Hel.	April 27, to May 1, 1966
Cirsium sp.	May 1, 1966
Lotus aboriginus Jeps.	June 27, 1966
Grass (Gramineae)	June 27, 1966-(near vegetat-
Collomia heterophylla Hook.	May 26, 1966 ive peak of
Lotus micranthus Benth.	June 27, development) and July 19, 1966
Probably Fed Upon[3]	
Hypericum perforatum L.	May 26, 1966
Symphoricarpos mollis Nutt.	May 26, 1966 and July 19, 1966
Rhus diversiloba T. & G.	May 19, 1966
Never Fed Upon	
Juncus sp.	
Lilium columbianum Hans.	
Arenaria sp.	
Pteridium aquilinum (L.) Kuhn.	
Polystichium munitum (Kaulf.) Presl	
Oxalis suksdorfii Trel.	
Galium tricorne Stokes	
Galium aparine L.	
Hypochaeris radicata L.	
Rosa pisocarpa Gray.	
Achillea millefolium L.	

[1]50 per cent or more of the larvae actively feeding on these plants at time cages were searched, noticeable damage to plant leaves as a result of feeding.

[2]Less than 50 per cent actively feeding on plants at time cages searched, minimum feeding evidence.

[3]Nature of leave damage suggestive of feeding activity.

in field cages was considered a result of crowding. Inside uniform rearing containers (round paper cartons), larvae appeared randomly scattered about the bottom and sides.

A test of larval dispersal, made by releasing 79 first instar larvae in the center of a nylon screen cage 2.5 ft. x 5 ft. x 3 ft. high, placed over natural vegetation at Locality I on April 17, 1966, produced the following results. On the seventh day following release, only seven larvae were found, the farthest being ten inches from the point of release. On the tenth day after release only four larvae were found, the farthest being 24 inches away. No specific direction was taken by the larvae. Movement was through a mat of litter at least two inches thick on the cage bottom. No tests were made on the dispersal of the later larval instars other than the general observations on mobility.

Mobility. Later instar larvae move more rapidly in avoiding harassment than the younger first, second, and third instar larvae.

First instar larvae are the most immobile, remaining inactive and rolled up for several minutes after being disturbed. The possibility of this reaction being a protective mechanism in the first instar is discussed in the next section. Second and third instar larvae do not drop and run from their feeding sites as readily as do later instars. In the laboratory, the fourth and fifth instars often erupted into a frenzied burst of activity when disturbed. They would drop to the ground, twist themselves upright, and crowd beneath the nearest object. When the fifth instar larvae were placed on a smooth table

top and prodded from behind, they ran in a rapid undulating manner, flailing their terminal brush of hairs against the table surface as they moved along. During these sudden bursts, larvae would travel five to ten inches in three to five seconds. The heavier lateral hairs appeared to aid the general forward motion of older larvae by contacting the substrate and providing support when the prolegs were momentarily retracted. The dense hairs on the larva were helpful in pushing into and through the small spaces often used for larval concealment. By tightening and relaxing their verrucae (the abundant sharp spines thereon performing a similar holding function to the caterpillar's prolegs), larvae could alternately hold against their surrounding confinement and push or draw themselves forward with force and speed greater than that possible using prolegs alone. Larvae required a "u" turn in order to reverse direction when in the confinement of narrow cracks and tight places. The larval habit of wedging into small areas led to frequent larval escape through holes and cracks of laboratory rearing cages. When moving about undisturbed, all instars appeared to travel at about the same speed in proportion to their size. Fourth instar larvae were observed under field conditions, ascending and descending nearly vertical iris blades at the rate of approximately one inch every two or three seconds on the night of June 27, 1966. Compared with several other genera of Arctiidae reared by the author (Arctia, Arachnis, Izia, Halysidota, and Platyprepia), the larval movements of L. californiae were the most rapid.

Defensive and Protective Mechanisms. Many facets of the biology

of this species may be considered protective or defensive reactions for larval survival. The first three larval instars fed diurnally but protectively on the underside of leaves close to the ground whereas the last two instars, although found feeding well above the ground, fed nocturnally. The quick evasive movements and the hirsute body of fifth instar larvae are better developed than the earlier instars suggesting greater protective adaptations for the longer duration of this instar.

When first instar larvae are disturbed, they curl up to form a ball, and remain rolled for several minutes. When a larva begins to curl, a few long fine hairs as long as the larva itself on each of the six rows of verruca lift the larva off the substrate. These long hairs project outward in all directions and enable the tightly curled first instar larva to roll or drop through ground litter or to be blown about the ground. Urticating hairs are absent on first instar larvae.

The later larval instars are not easily blown about, but are able to roll up. Larvae show an increased number of urticating hairs with each successive instar. Fourth and fifth instar larvae roll into a ball when roughly handled or pushed along a surface, but when touched lightly they generally remain elongate, stiffening somewhat as they retract their head, bringing forward dorsal hairs to complete their dense, hairy armor. Presenting a mixture of longer fine hairs through open tufts of stiff urticating hairs, the larvae are well fitted for defense against small mammals or reptiles. My own experience with a

few loose urticating hairs being inadvertently rubbed onto my arm resulted in quarter inch welts which burned and itched severely.

Perhaps the most interesting larval behavior involved the use of a 1/2-inch long cluster of hairs present on the terminal segments of fourth and fifth instar larvae. This cluster is especially well developed on the fifth instar, usually taking the form of an upcurving brush. I found that, by holding this brush between my fingers, the larva would walk away effortlessly, leaving the entire terminal brush behind. No ill effects were observed by the loss of this terminal brush, which was often missing from larvae reared in crowded moist containers. The hairs became stuck and were left behind or were chewed off by the other larvae. Although untested, this phenomenon may act as a protective mechanism for the later instars.

Fifth instar larvae often raise their last three segments bearing the terminal brush when touched or prodded (Figure 7). This movement is sudden and repeated, resulting in the brush being thrust as far forward as the head with a twitching, jabbing motion. Similar lateral movements are made in response to prodding the larva from the side. This behavior is similar to the "stinging" gestures made by adult male Mecoptera and Dermaptera when disturbed, and probably represents a similar defensive gesture on the part of the larva. With repeated prodding, larvae fail to react as dramatically, and often remain motionless. This additional disturbance occasionally caused larvae to regurgitate and lash their head sideways. They would rapidly defecate three to four pellets of excrement and continue to excrete liquid

Figure 7. Defensive response of fifth instar Leptarctia californiae (Walker) larvae to applied pressure.

matter against the substrate with each successive disturbance. In this latter response to harassment, the reaction of L. californiae larvae is similar to many other lepidopterous larvae.

Pupa

This section deals with the general site of pupation, appearance of the cocoon, and records of the pupal stage under various conditions.

Location. Since pupae were not discovered in the field during the course of this study, general observations on pupation have come from laboratory studies. The site of pupation was the lower and darker areas in the various rearing containers used, often beneath debris and in contact with the soil surface. Figure 8 illustrates pupae and

prepupae taken with shredded toweling anddetached from the bottom of a gallon jar, and shows the loose nature of the cocoon in its surroundings. Figure 9 depicts a pupa enclosed in a complete cocoon which was carefully separated from the surrounding material. The loose cocoon surrounding the pupa is formed of larval silk and hair, mixed during construction. Sand particles, leaves, and objects in the immediate vicinity of the pupating larva are also attached to the cocoon with larval silk. When the cocoon is complete, it is difficult to remove major particles attached to the cocoon without ripping it. The cocoon provides a possible rain shield, but it is not strong enough to protect the pupa from being physically crushed.

Duration and Hibernation. The pupa of L. californiae is a hibernating stage which normally requires a cold period to complete development. The duration of the pupal stage in western Oregon is six to seven months, lasting from approximately mid September of one year to late March of the next.

Prolongation of warm dry conditions into late October under greenhouse conditions (50-80°F) resulted in high pupal mortality. Approximately 100 laboratory- and greenhouse-reared larvae ((e), (g), (i), (h))[3] pupated in late June, 1965, and were maintained in the greenhouse (50-80°F) until October 26, 1965, at which time they were transferred to the laboratory (65-80°F). Dissections on approximately 15 of these

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[3]The letters in parenthesis refer to the progeny of a single female. Details concerning the original female or progeny are in Appendix 1.

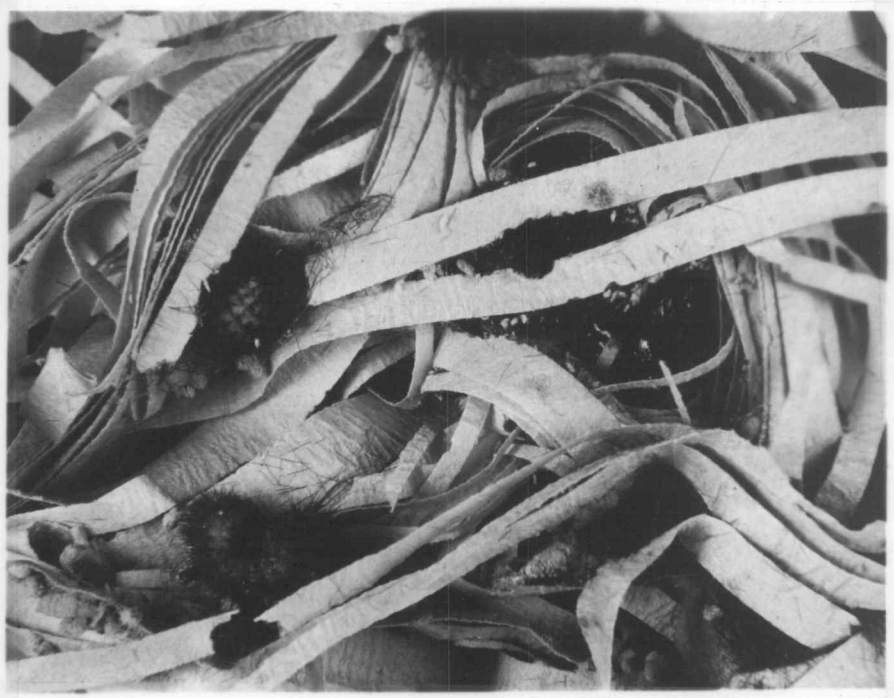

Figure 8. Prepupae and pupae of Leptarctia californiae (Walker) in shredded paper toweling from bottom of rearing jar. Note the loose cocoons and broken larval hairs.

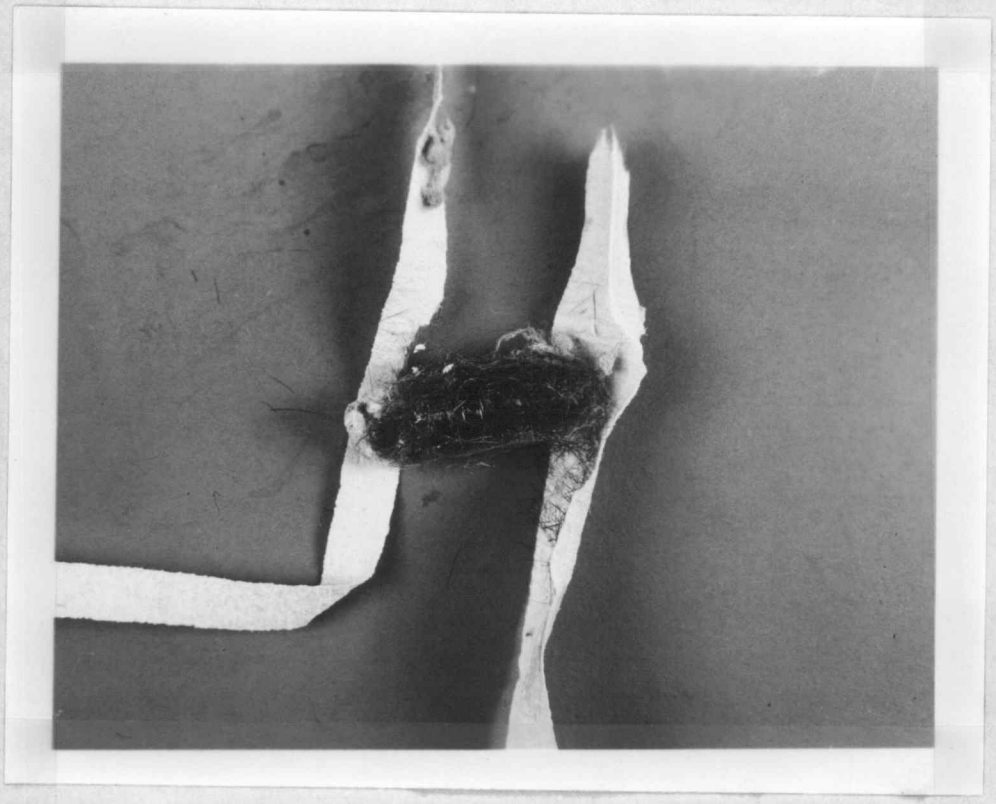

Figure 9. Pupa and cocoon of Leptarctia californiae (Walker) cleared almost entirely of paper to which it was attached.

pupae made on February 1, 1966, revealed that a majority were dead and dried and no adult structures were discernable in them. The only exception was a single deformed adult male which had emerged prior to February 1. On February 22, 1966, the remaining pupae were transferred to the out of doors at Corvallis, Oregon, under conditions of minimum average temperatures in the mid 50's (Zimmerman, 1965). During the first week in April they were brought into the laboratory where less than 20 per cent emergence took place.

An overwintering period, approximating that in nature, was given to eight laboratory-reared pupae (m) by placing them out of doors at Corvallis, Oregon, following pupation in June of 1965. On March 10, 1966, all eight appeared to be alive when they were brought into the laboratory, with seven emerging between March 18, and 21, 1966; the eighth died.

The overwintering period was extended for seven additional (m) pupae. On March 10, 1966, these were taken from out of doors and placed in a refrigerator at 44 ± 3°F for continued "overwintering". On July 15, 1966, the pupae were found to be dead, but they contained fully formed adult structures. If pupal development is most rapid just prior to adult emergence, the preformed or nearly preformed imago inside the pupae case was unable to tolerate this extended cold period. In the field, these pupae must be able to tolerate several days of cold spring weather and still remain in an advanced state of development in order toemerge rapidly and fly as one of the first Lepidoptera in the spring.

Adult

This section deals primarily with field observations on adult behavior at Locality I. Notes on laboratory behavior are given to supplement field observations and aid in any considerations of large scale rearing.

Emergence. The following section deals with the manner in which adults emerge in the spring under laboratory and field conditions, the length of the natural emergence period, and the relative numbers of adults present throughout the field season.

Under laboratory conditions (65-80°F), the emergence time of the two groups of pupae on separate years was quite similar. In 1965, pupae (c) were placed on moist sand in a six-inch plastic pot with clear plastic sides and a solid lid. In 1966, pupae (m) were placed on dry sand in a similar "pupa pot". The tabulated emergence data in Table V indicate that most adults emerged before mid day, perhaps during the late night or early morning hours, although the exact time of emergence was determined for only a few individuals. It is interesting to note that under the more uniform and warmer temperature conditions of the laboratory a daily average pattern prevailed. From these data, it cannot be assumed that emergence occurs before mid day under field conditions, but it seems reasonable to expect that females emerge just before or during the mid day flight period. These females would stand a better chance of being mated and ovipositing rather than falling prey to natural enemies while waiting for the next favorable daytime weather and male flight period.

TABLE V. EMERGENCE OF LEPTARCTIA CALIFORNIAE (WALKER) UNDER LABORATORY CONDITIONS (65-80°F) FOLLOWING PUPAL OVERWINTERING OUT OF DOORS IN CORVALLIS, OREGON.

Pupal Group and Date Brought Into Laboratory[4]	Emergence Dates	Number and Sex	Time of Emergence
(c) March 23, 1965	March 29, 1965	4 females	three before 12:00 p.m., one after 12:00 p.m.
	March 30, 1965	4 females 1 male	all before 12:00 p.m.
	March 31, 1965	5 females 1 male	all before 12:00 p.m.
	April 1, 1965	2 females 1 male	all before 12:00 p.m.
(m) March 10, 1966	March 18, 1966	2 males	10:00 a.m. 6:00 p.m.
	March 19, 1966	none	
	March 20, 1966	2 females 2 males	before 1:00 p.m.
	March 21, 1966	4 females	one before 8:00 a.m., three not noted

It was not revealed whether one sex emerged before the other. Using Figures 10, 11, 12, and 13 to follow, it appears that females emerge throughout most of the male flight period.

[4]The letters in parentheses refer to the progeny of a single female. Details concerning the original female or progeny are in Appendix 1.

The sex ratio of males to females did not differ from a one to one ratio for approximately 100 reared adults from seven different females from Locality I and V.

For the years of 1965 and 1966, the weather conditions which prevailed at Locality I were quite diverse. Generally, the spring of 1965 was sunny and warmer than 1966, especially the month of March. During March of 1966, snow fell and much of the rest of the season was cooler and drier (Green, 1965). Daily observations of the weather from Corvallis, Oregon, were kept for these two years. Whenever field trips were taken to Locality I (approximately 17 miles away from Corvallis), the weather was recorded directly. These records are summarized along the bottom of Figures 10, 11, 12, and 13 for the 1965 and 1966 adult flight period. The weather records reflect general weather changes and illustrate the marked contrasts between March, 1965, and March, 1966.

The first field trip to Locality I (March 13, 1965) was late for the initial emergence period by as much as a week judging from the condition of specimens which were flying at the time (Table VI). Therefore, an estimated time of first emergence of adults for 1965 was set at March 8. In contrast, field trips taken on March 22, 24, and 26 of 1966 revealed no adults. The first adults were collected on the fourth field trip (April 3, 1966). These adults emerged almost one month later in 1966 than in 1965. A record of observed adult L. californiae at Locality I is presented to illustrate the general abundance of individuals in the field through these two contrasting flight seasons.

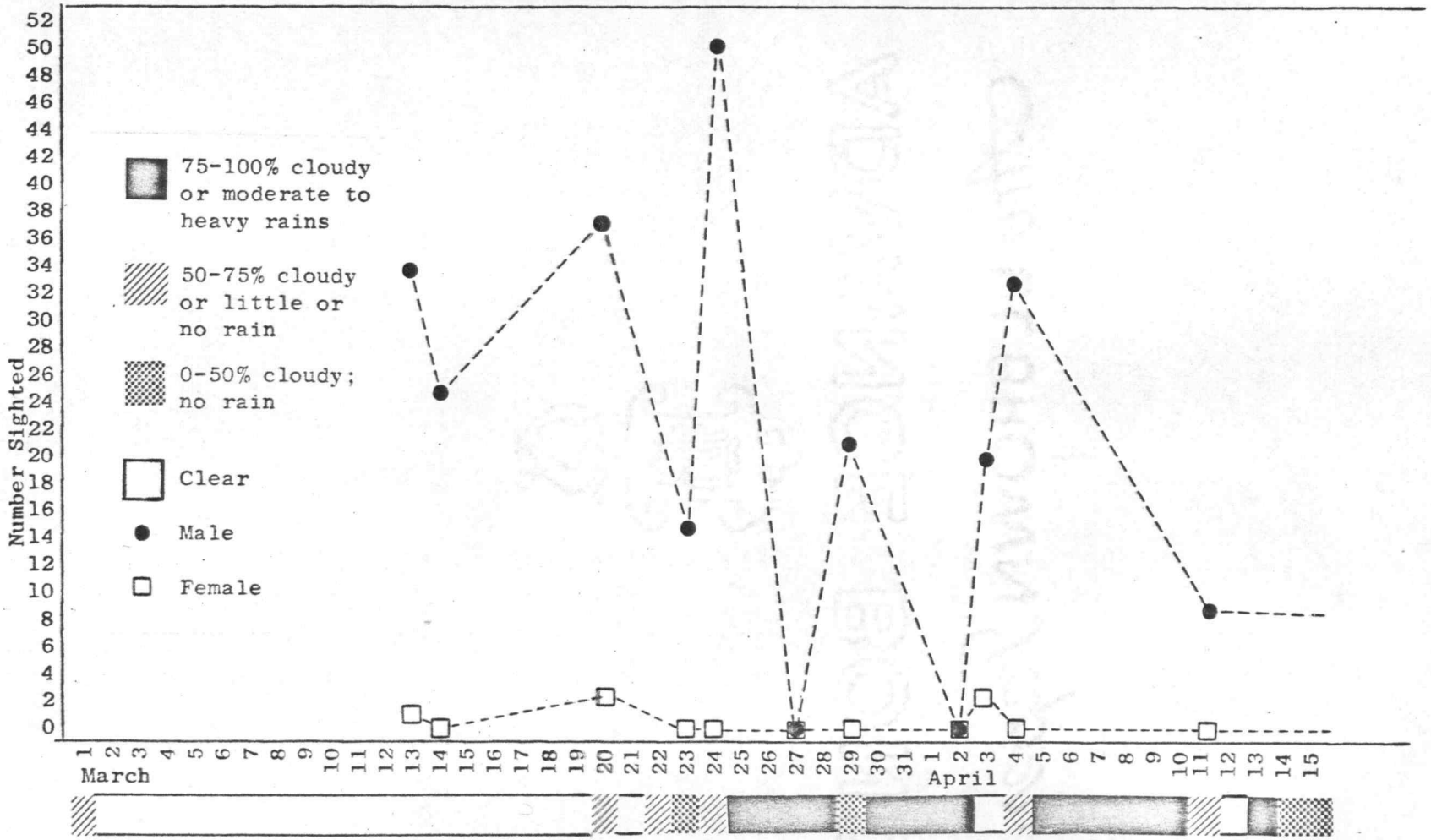

Figure 10. Sighted Leptarctia californiae (Walker) at North Fork of the Alsea River, Oregon, Locality 1, with General Weather Conditions of March through Mid April for 1965.

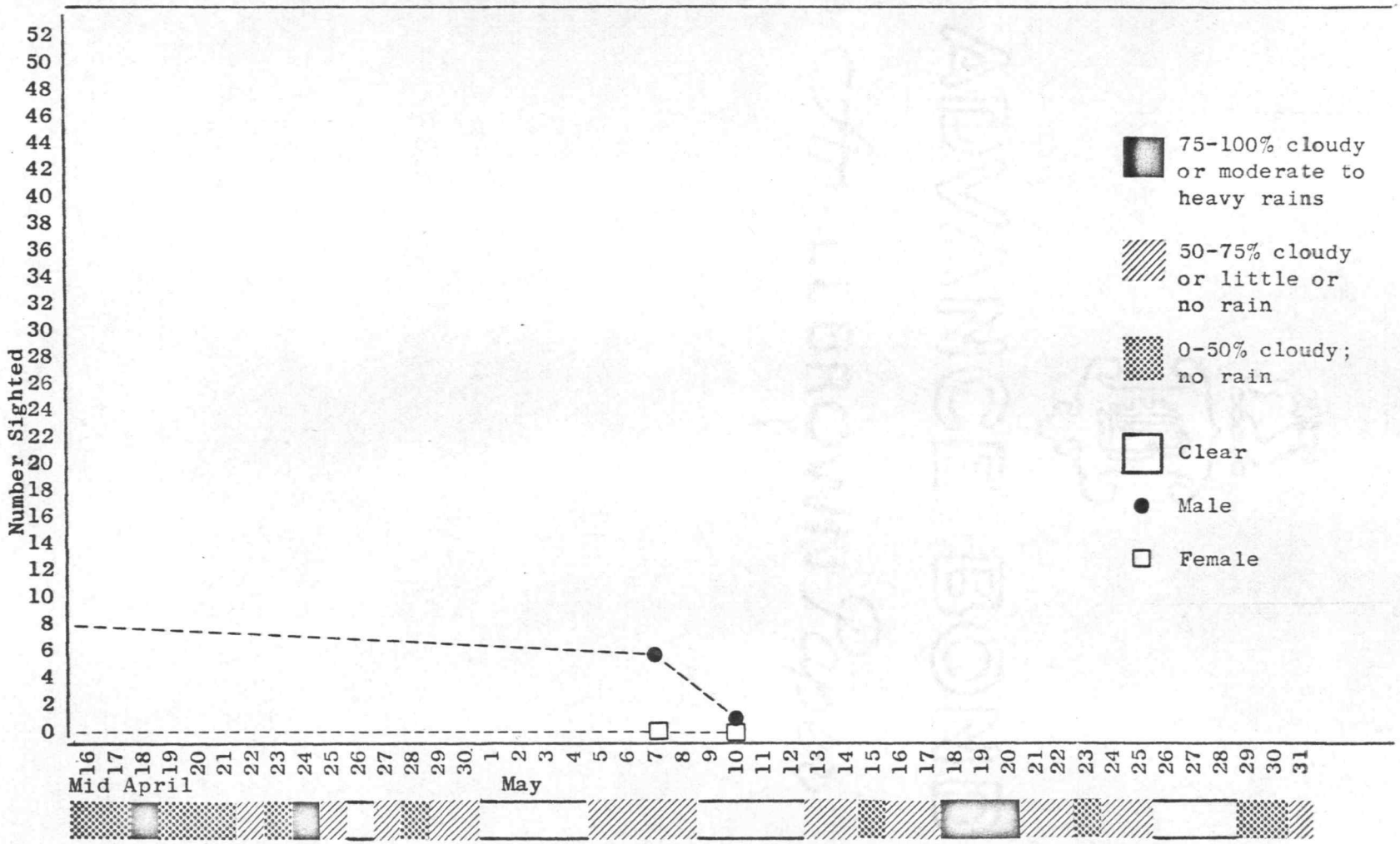

Figure 11. Sighted Leptarctia californiae (Walker) at North Fork of the Alsea River, Oregon, Locality 1, with General Weather Conditions of Mid April through May for 1965.

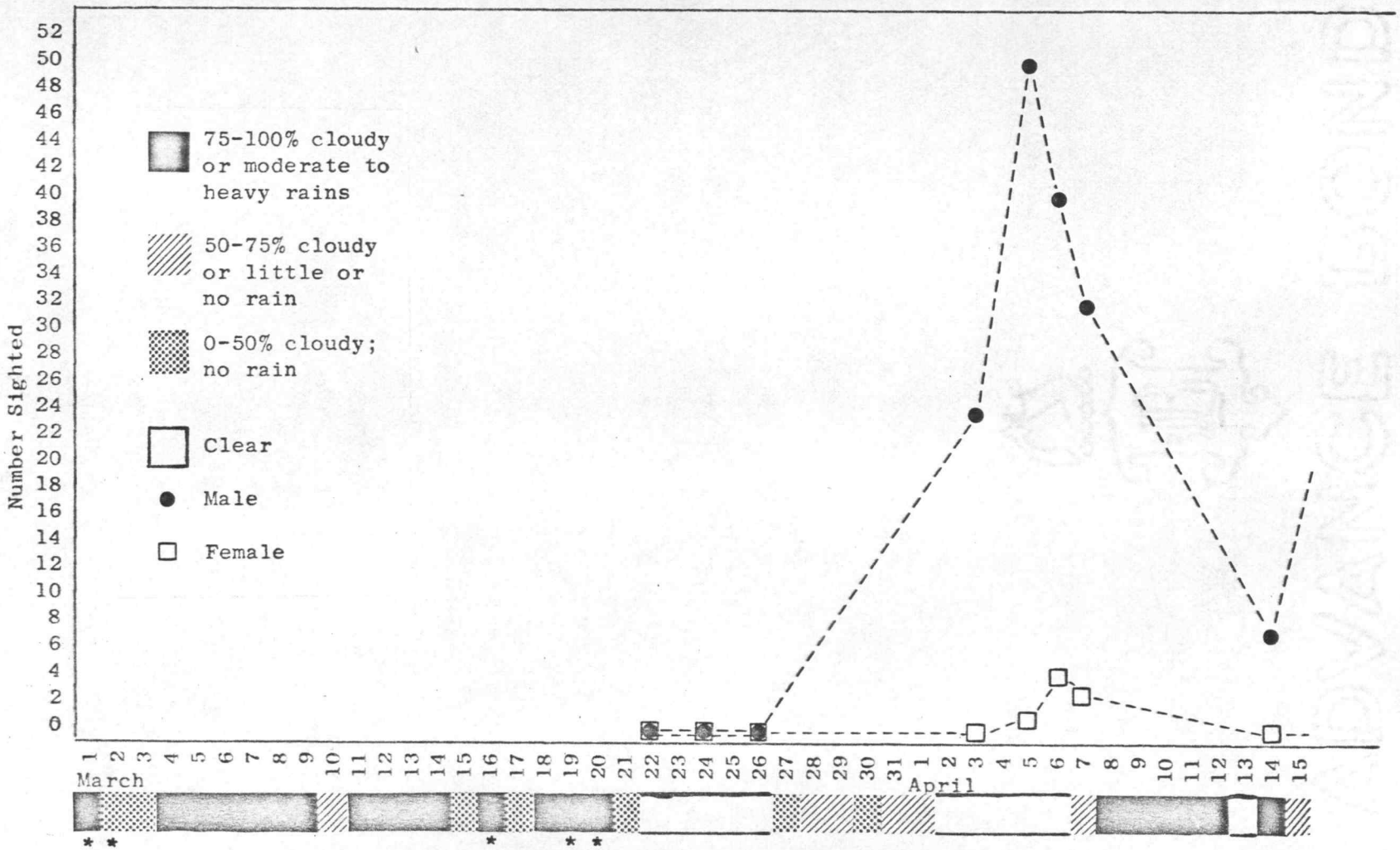

Figure 12. Sighted Leptarctia californiae (Walker) at North Fork of the Alsea River, Oregon, Locality 1, with General Weather Conditions of March through Mid April for 1966.

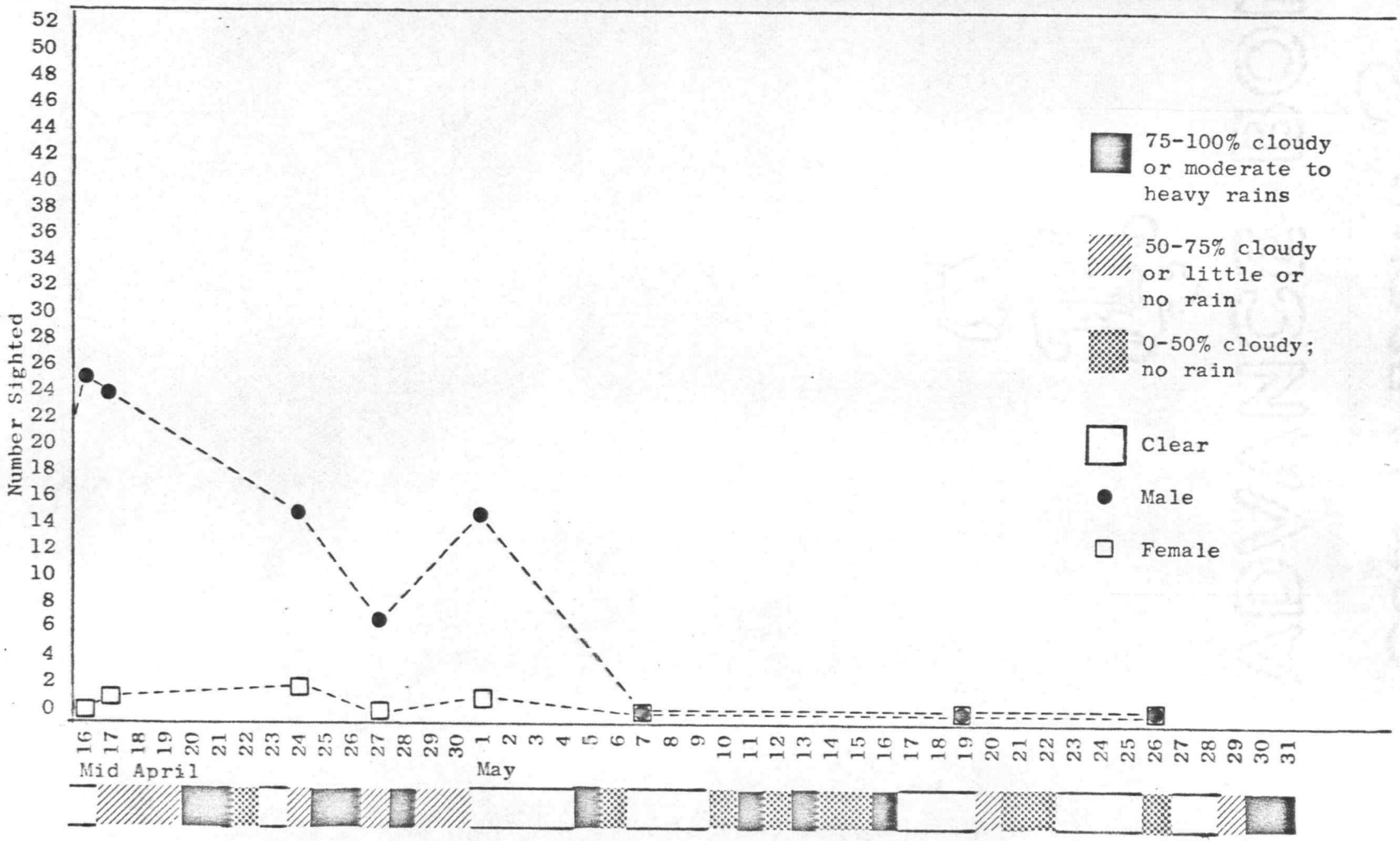

Figure 13. Sighted Leptarctia californiae (Walker) at North Fork of the Alsea River, Oregon, Locality 1, with General Weather Conditions of Mid April through May for 1966.

Under field conditions, adult emergence at Locality I began during mid March and continued to the beginning of May. This emergence period was determined by examining male L. californiae collected from Locality I for 1965 and 1966 for freshness of condition. It was assumed that the freshest specimens were the most recently emerged individuals which, after one flight period, would show indications of wear (loss of scales, scratches, and color fading, especially on thorax) as a result of their rapid flight. Table VI illustrates the relative condition of males for the 1965 and 1966 flight seasons. Although capture, mark, release, and recapture methods would have been more conclusive, it appeared that after about one week of flight, individuals in poor condition were present in the population. A life span of between two and three weeks was estimated for adult males.

Initiation and Cessation of Flight. Adults fly under a variety of weather conditions. Females appeared to fly during the male flight period but in rather low numbers for the 1965 and 1966 flight seasons. Because of this, the following discussion will involve only males. The following data is drawn from a series of 29 field trips taken to Locality I during the 1965 and 1966 L. californiae flight seasons. All air temperature readings quoted were taken in the shade, two feet off the ground and all time expressed was Pacific Standard Time.

On days which clouds were absent or did not persist much beyond 10:00 a.m., the first male flight was initiated sometime between 12:15 p.m. and 1:00 p.m. The earliest observed male flight occurred at 11:00 a.m. At flight initiation, the air temperature ranged between

TABLE VI. RELATIVE CONDITION OF CAPTURED MALE LEPTARCTIA CALIFORNIAE (WALKER) FOR 1965 AND 1966 ADULT FLIGHT SEASONS.

Date	Number of Field Trips Taken During Interval Resulting in Captures		Number Captured		Condition of males (in per cent of total capture) for six-day interval*					
					Excellent		Good		Poor	
	1965	1966	1965	1966	1965	1966	1965	1966	1965	1966
March 10-15	2	0	9	0	44	-	33	-	23	-
March 16-21	1	0	4	0	75	-	-	-	25	-
March 22-27	2	0	15	0	53	-	47	-	-	-
March 28-Apr. 2	1	0	3	0	-	-	33	-	66	-
April 3-8	2	4	9	53	11	50	33	50	56	-
April 9-14	1	1	5	4	40	75	40	-	20	25
April 19-20	0	2	0	5	-	-	-	60	-	40
April 21-26	0	1	0	3	-	33	-	33	-	33
April 27-May 1	0	2	0	4	-	25	-	-	-	75
May 2-7	1	0	1	0	-	-	-	-	100	-

* Excellent = Bright colors; near perfect condition; resembling reared specimen.
Good = Slight fading of colors; small scratches on wings; few wing tears.
Poor = Colors faded; thoracic abdominal, and wing scales and hairs missing; wing tears.

14 and 17°C with fluctuations of two degrees apparently resulting from gusty uphill winds and intermittant cloud cover. When the air temperature dropped to 12°C or below, adult flight ceased. This occurred commonly during the flight period when local cloud cover blocked the sun. On cool windy days with intermittant cloud cover, adults ceased flight activity almost immediately as clouds blocked the sun and resumed flight just as quickly with the passing of the clouds. The lowest air temperature recorded while males were in flight was 12.5°C under intermittant cloud cover. Maximum air temperature on completely cloudy days was usually 8 ± 3°C. Full sunlight did not appear to be a necessary requirement for flight. Males have been observed flying during cloudy periods and on one occasion (April 14, 1966), they were flying on a totally cloudy day during a fine drizzle. This flight occurred while the temperature was near 15°C. This was an unusual situation for spring weather, and points to temperature as the primary limitation for adult flight.

On a clear or partly cloudy day, there appeared to be a general increase in the number of males in flight between 1:30 and 2:15 p.m. Males suddenly seemed more numerous; a situation which often lasted only about 15 or 20 minutes. During this time, air temperatures were maximum for the day, ranging between 15 and 25°C with the higher temperature occurring during late April and May. Males ceased flight between 3:00 and 4:00 p.m. and were observed flying slowly into poison oak bushes, dry grass, or dead bracken fern, finally coming to rest on stems a few inches above the ground. They pass at least the first two

or three hours of their post-flight period in such places. Adult males can be disturbed into flight from the base of poison oak bushes during the preflight period or cool weather by sharply striking the branches of the bush. The disturbed males appeared able to fly only short distances (10 to 20 yards), often landing on ground litter. Normally these males were quite easy to approach and capture.

Flight. The first part of this section will discuss length, habits, and general pattern of individual male and female flight at Locality I. The second section will describe the flight patterns and range of the entire population for 1965 and 1966 flight seasons.

Diurnal flight of male and female L. californiae differ in the length of time spent in flight. Males seem to be constantly on the wing, flying so intensely and rapidly they rarely remained in one place long enough to be noticed by the casual observer.

Males follow no apparent localized flight territory. Their flight speed is approximately 10 to 15 miles per hour with wing strokes rapid enough to give the illusion of a blur as they fly. There is no soaring or gliding habit. The flight of some individual males observed was unidirectional, with apparent disregard to slope or wind. Others were seen flying the margins of the open areas, often doubling back over the same area. While standing on the slope of the hill at Locality I (Figure 5), it was easy to get in line with straight flying males and capture them as they approached. Under these conditions it was apparent that male L. californiae have a well developed visual sense. Males darted to the side and flew around as they approached in

response to sudden movements. Occasionally under these circumstances males would reverse flight direction or gain altitude and fly over. In contrast, some females flew a short distance, being in flight less than a minute. One female was observed flying slowly over an area of about 30 square yards, landing on the taller stems and twigs of both dead and live plants. This female stopped for ten to twenty seconds between short flights of a minute or less. Most other females have been observed in more rapid flight, approximating that of males. Males usually fly out of sight, whereas a good many of the female flights terminate with the individual descending rapidly to bare ground, or flying into tall stems and twigs. Deviations in altitude are much less frequent, with most male flight occurring between one and two feet above the existing ground cover. The ground cover at the beginning of the flight period in March is a plant "mat" (dead stems and leaves from previous year's growth) less than 12 inches tall. As the season progressed, bracken fern (P. aquilinum), Iris (I. tenax), and grasses formed ground cover of uniform height, as much as two and one half feet above the ground. Males maintain the same one to two foot clearance over the various ground covers throughout the flight season. When flying through an area of close spaced five to ten foot tall trees and shrubs, few males would fly above the trees and shrubs, with the majority winding through the open areas. When faced with a single obstacle such as a Douglas fir tree, males tended to fly around it. When in flight toward a dense stand of young Douglas fir (approximately 15 feet or more in height), males often reversed direction toward the

more open areas or flew parallel to the boundary of the trees. On a few occasions males closely pursued flew over trees in the 15 to 20 foot range in areas nearly surrounded by dense stands of trees. In general, males strongly favored the open areas at Locality I. Male landings were observed in late afternoon (3:00 to 4:15 p.m.) on bare stems of poison oak and dead bracken fern stalks. At no time were males observed to stop for nectar or to feed upon anything in the field. Males confined in the laboratory would readily accept water. Under field conditions, water was available to the adults in the form of rain, dew, plant gutation, puddles, and streams. At Locality V a female flew down to a water puddle on the road, and appeared to take in water from the moist sandy edge.

Females follow no apparent localized flight territory, but have been found more numerous in certain areas of Locality I (see Figure 14). Their flight is generally slower, with less rapid wing strokes and a more laborious type of flight. All females observed in the field at Locality I were in open unforested areas as were the males. When pursued uphill, some females flew into the young Douglas fir trees on the ridge of Locality I, seemingly taking advantage of the uphill wind currents. In many cases, females appeared unable to successfully fly into the uphill wind drafts (approximately 10 to 15 miles per hour) and were blown into low growing plants. Observations of other females revealed that some could fly nearly as fast as males, and were able to fly into oncoming air currents. Females collected at Locality I and V, which exhibited the slower and weaker type of flight, were fresher

(younger) and in better condition than the faster fliers. These fresher females oviposited on the average about 200 more eggs than the faster flying females. Oviposition, resulting in weight loss, may be a prerequisite to more rapid female flight.

Observations on flight patterns and range of the areas with high numbers of adult L. californiae were found to be the middle and upper parts of steep south facing slopes. At Locality I the east-west running arm of the "L" shaped hillside was the area where most adults were observed. Males generally flew in a pattern oblique or parallel to the ridge of this part of the hillside. Winds were primarily up hill. Males flew between Douglas fir trees (10 to 20 feet high) and over the open slopes indicated in Figure 14.

The range of the population at Locality I for 1965 and 1966 extends from the south and southwest base of the open hillside to the crest of the "L" shaped ridge. The open slope abruptly becomes a large truncated open hilltop extending northeast 300 yards or more from the center of the hill crest. L. californiae have never been seen on this hilltop even while many were in flight on slopes a few yards to the southwest. Figure 14 also charts the combined data for the range of L. californiae at Locality I for 1965 and 1966 since population numbers and range were similar for both years.

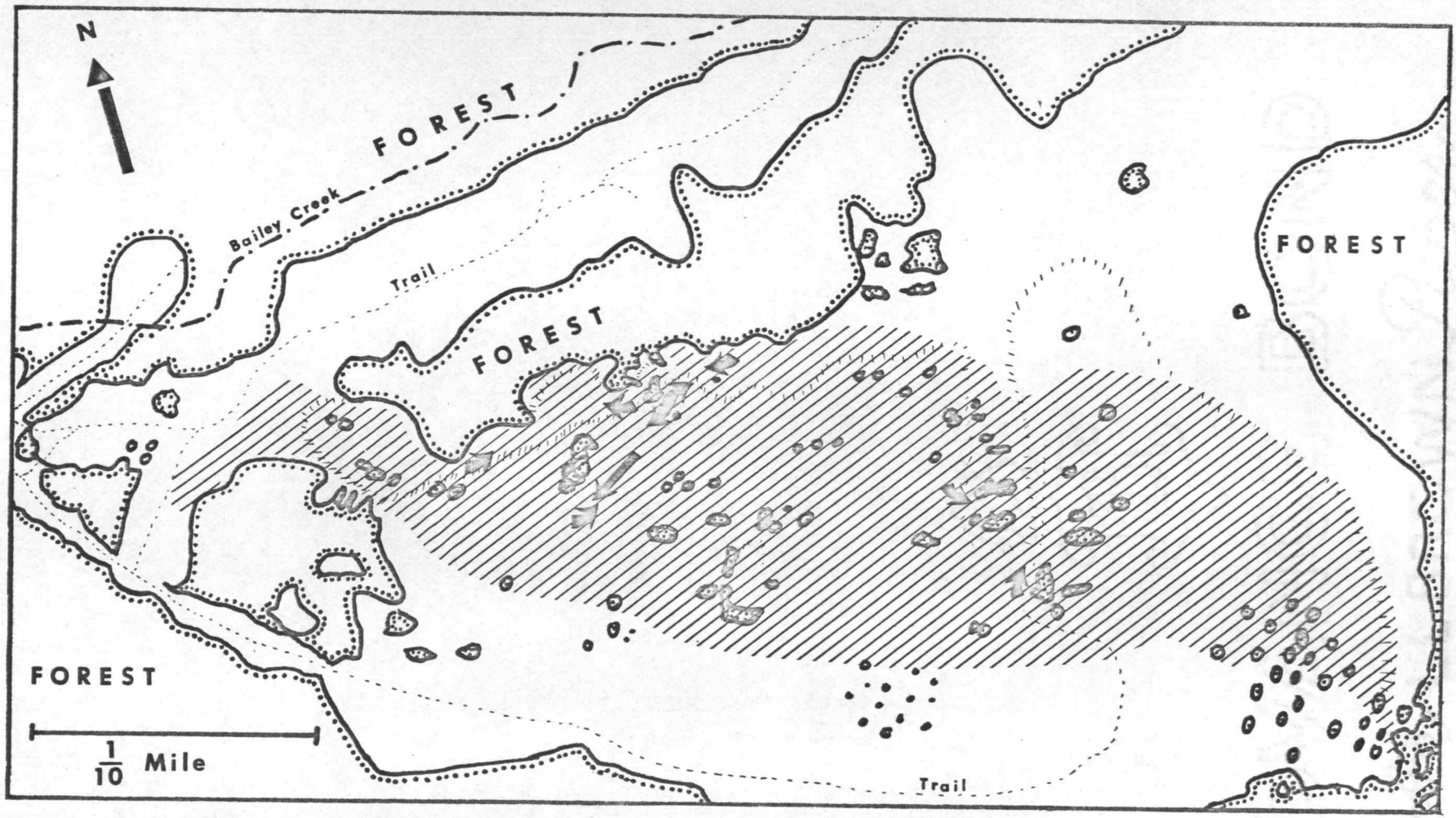

Figure 14. Map of Locality I (State Fish Hatchery, North Fork of the Alsea River). Map center is the top of a rounded ridge with an open slope on the south side. Lined areas represent the observed flight range of male Leptarctia californiae (Walker) for combined 1965 and 1966 flight seasons. Arrows denote general direction of flight in areas where the moth was abundant.

Defensive and Protective Mechanisms. When adult L. californiae are roughly poked or prodded, they hold their head downward, antennae forward, and raise their patagia (a two-parted collar) forward exposing the paired cervical glands beneath. A bead of amber liquid is secreted from each gland. An acrid odor, similar to the defensive odor described by Rothschild (1961) is apparent. Repulsive odors are common among the Arctiidae (Rothschild, 1961). Lane (1957) reported that the prothoracic-cervical glands of the arctiid moth Phragmatobia fuliginosa L. are revealed as the moth points its antennae forward and raises its "red crest" when it is disturbed.

The conspicuous red, yellow, and orange hind wing colors in L. californiae may function to warn and deter certain important predators. Of 115 males collected at Locality I and V, only one adult appeared to be damaged in a manner suggesting an unsuccessful attempt at predation. This is remarkably low compared with many other diurnal Lepidoptera and suggests that L. californiae may derive such protection.

Identification of L. californiae was somewhat difficult during the first few field trips made in 1965 and 1966 for there were several other diurnal Lepidoptera flying in the field which resemble it in coloration. Some moths (Geometridae: Epirrhoe plebeculata Gr., Xystrota rubromarginata Pack., and Brephos infans Moesch.; Noctuidae: Synedoida edwardsi Behr., Synedoida sp.; Pyralidae: Pyrausta sp.) are occasionally confused with the colored forms of L. californiae, while one other moth plus a butterfly (Noctuidae: Euclidina ardita Franc.; Hesperiidae: Thanaos sp.) look quite like the black forms of L.

californiae. All but E. plebeculata, a high flying species found near the forest margins, appeared on the open slope at Locality I.

The forewings of adults are faintly sooty spotted and lined on black, resembling very closely the lower stems and branches of poison oak. Whether such a resemblance is of any real protective value against natural enemies remains to be demonstrated.

Certain Arctiidae are known to generate ultrasonic signals with metathoracic tymbal organs (Blest et. al., 1963). L. californiae have well developed metathoracic tymbals which could function in ultrasonic signal generation or reception necessary for adult detection, protection, courtship, or navigation.

Mating Behavior. One of the most striking behavioral aspects of adult L. californiae is the ability of flying males to locate females that are inconspicuously at rest in low vegetation. Observations suggest that both visual and chemical stimuli are involved in this location ability.

The males which were attracted to caged virgin females[5] appeared to pass into a zone directly downwind from the female before attraction took place. Males would change their flight direction in favor of heading toward the caged female after entering this zone. This zone downwind from a female appears critical to a male's ability to find

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[5]Laboratory-reared virgin females from zero to 15 days old were held under refrigeration (7°C) until placed in screen cages (approximately 1/8 cubic foot) and used in the field.

that female. Figure 15 diagrams the relative size and proportion of this critical zone of attraction. A male entering from 1 (see Figure 15) reacts to the zone by abruptly flying towards the female. A male entering the zone from a direction similar to 2 in Figure 15 appeared to continue toward the female often flying straighter and faster than before.

Males approaching the female from direction 3 (Figure 15) reversed direction several yards within the zone, passing the female by initially. Males passing one or two yards downwind from the caged virgin female showed no attraction toward the female, provided that the female was in a low cage one foot high or less. Females located in taller cages (two to four feet) created a zone of attraction which extended all the way to the cage.

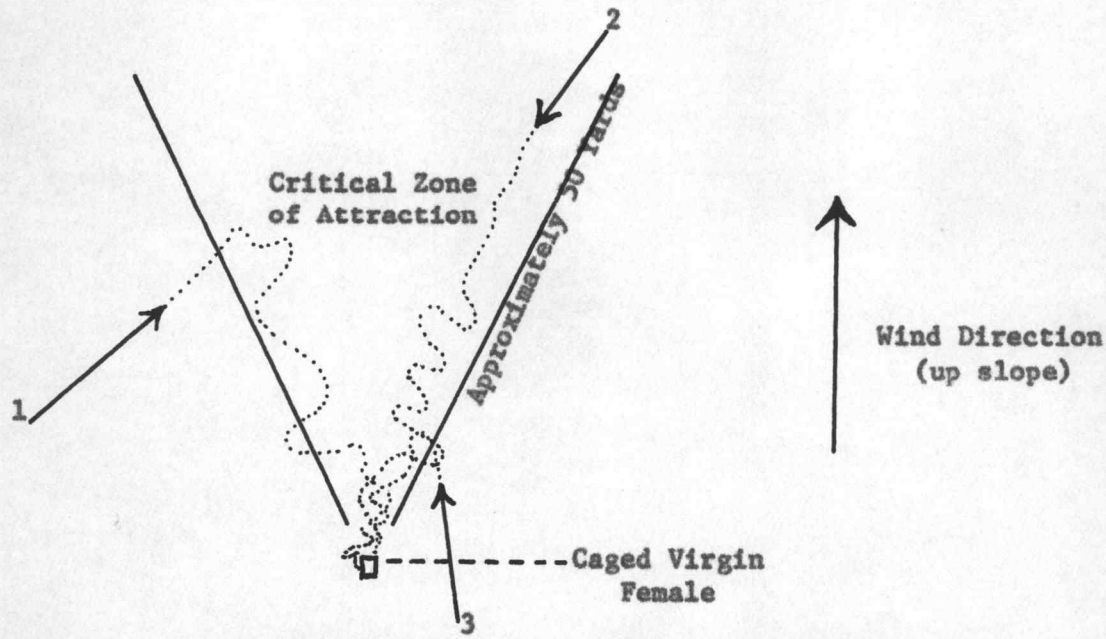

Figure 15. The critical zone of attraction produced by female Leptarctia californiae (Walker) and the nature of the male response.

Males entering the zone of attraction would fly erratically switching back and forth in flight as they approached the females. At the cages, males continued to fly back and forth a foot or so downwind from the female, often driving into the wind, passing the cage and then returning to the downwind area.

When cages were left open, free males would readily enter and attempt to mate with the virgin females inside. Normally the females remained near their point of release, on the bottom or sides of the field cages, their forewings overlapping slightly in coverage of their hind wings.

When prevented from reaching caged females, the males usually continued fluttering back and forth in an area about two or three feet downwind from the female.

Most males which were netted and placed inside cages showed no further interest toward virgin females, and flew frantically to the well-lighted top corners of the cage. Similar behavior was noted for males released in the laboratory and laboratory-reared males brought to the field. Efforts to condition males for several hours in solitary cages prior to the introduction of virgin females were ineffective in improving the male response to these females. The only exceptions to this occurred when females were persistently held in front of males as they were walking and flying up the most sunlit side of a cage. This method resulted in two matings out of approximately 30 attempts, but required several hours of work.

When free males, attracted to a caged virgin female, were net captured and placed in the cage with the virgin female, there appeared to be no further attraction of additional free males to the cage. Under these circumstances the males were quite active, often accidentally flying into the female, causing her to drop. Occasionally the female would react to the disturbance of the confined males by also flying toward the lighted side of the cage with the males. More commonly, after being disturbed she would move only a short distance and quickly resume a resting position.

When field females, which had previously mated, were captured and placed in screen cages in areas of maximum male flight, no males were attracted. Mating pairs or recently mated females confined under similar conditions were also unattractive to males.

The mating sequence between a naturally occurring pair was observed only once during this study. A female was observed flying in a low straight manner against uphill drafts, finally coming to rest on a quarter-inch thick poison oak twig about 18 inches off the ground. Four minutes later a male which had been traversing the hill passed about 20 yards uphill from the female, turned, and flew toward her. At a distance of ten feet he began to switch back and forth erratically but continued to move toward her. He flew back and forth for two or three seconds, crossing downwind from her several times. Just prior to landing, the female lifted her wings slightly, and with a weak flutter, exposed the colored hind portions. The male, only inches away, flew in and grasped the female and the stem from one side. He

immediately pushed the tip of his abdomen beneath her hind wing and they clasped genitalia. (In many cage matings the male would "nose" under the female's wing from the side or pry the wing up with his abdomen to obtain access to her terminalia.) The male then side-stepped around until the pair (wing tips overlapping) were facing in opposite directions. The pair remained in this position from 2:45 p.m. (the time of mating) until 4:00 p.m. (the time of departing from the field) and were left there overnight contemplating a resumption of observations early the next day. A return to this spot the next morning at 7:15 a.m. revealed the pair separated some time during the night. The male was on ground litter directly below the twig on which mating had occurred, and the female was five inches off the ground on a second poison oak twig, eight inches away from the male. Both specimens were in excellent condition and judged to be approximately one day old. The air temperature near the female had risen from 7°C at 7:15 a.m. to 14°C by 11:00 a.m. and 16°C by 11:30 a.m. At approximately 11:00 a.m. the female was accidentally dislodged when the branch was examined for eggs she may have deposited. Between 11:30 a.m. and 12:00 noon, she preened her antennae once and shifted positions twice, eventually coming to rest in full sunlight. At 12:05 p.m. an uphill gust of wind caused a branch to strike against the one upon which she was resting. With this disturbance she quickly flew uphill with the wind and out of sight.

Kettlewell (1963) discussed several factors common to moths which possess large pectinate antennae. He stated that in general moths

which are active during the coldest months and fly in hot sunshine against convection currents have probably the largest antennae in the world. These large antennae have been suggested to function as pheromone chemoreceptors in male gypsy moths (Wilson, 1963), Biston betularia L., and others (Kettlewell, 1961). Male L. californiae also possess well developed pectinate antennae and fly during the early season under sunny, drafty conditions, suggesting a similar mechanism of pheromone attraction. The data and observations presented so far in this section are consistent in every respect with those of Kettlewell (1961) and fit the theoretical model for pheromone attraction discussed by Wilson (1963).

The duration of copulation of three pairs obtained from field males mated with laboratory-reared females lasted from mid afternoon to about 10:00 p.m. that evening. Six additional pairs (similar to the above) in copula when leaving the laboratory (6:00 p.m.) were found to have separated by 8:00 a.m. the next morning, whether they were held in a dark refrigerator (7°C) or in the laboratory. In the field, adults in copula made no attempt to fly and were easily transferred to vials, in which they were transported from the field. Remington (1963) found that copulation in Cisseps fulvicollis (Ctenuchidae) lasts two to five hours with pair separation by morning. These results are similar to L. californiae and suggest that at least one other diurnal moth behaves in this manner.

Oviposition. Oviposition generally occurs the day after mating, with the majority of eggs being deposited in a week or less. Females

averaged 50 to 100 eggs per day under laboratory conditions (65-80°F).

When confined to plastic containers or paper cartons, females generally favored the sides or top for oviposition. A field-collected female placed in a low wood frame screen cage oviposited on the underside of the horizontal inner framework of the cage about eight inches above ground level.

Between 12:00 noon and 2:00 p.m. the female had oviposited four egg masses of 31, 18, 20, and 5 eggs respectively. At 4:00 p.m. two additional egg masses, each with 39 eggs, were present. This female was taken to the laboratory, given water, and kept in a paper carton for 11 days, resulting in 213 additional eggs.

Most egg masses were composed of ten to forty closely placed eggs roughly forming a circle. Figure 16 illustrates a mass of eggs (82), the result of two different ovipositional efforts. The time interval, sequence, and pattern of oviposition of a single egg mass is given in Table VII.

The highest number of eggs recorded were 366 from a field-collected female. Four laboratory-reared females that mated with field males oviposited 200 to 350 eggs each.

The morphology of whole egg masses revealed whether eggs would hatch or dry up. Eggs which later developed into larvae were generally oviposited in roundish, close masses discretely separated from other masses. Eggs which later shriveled and dried up, possibly from lack of fertilization, were oviposited loosely and either singly or in groups of only two to six at a time. A pattern of oviposition in

examples where only the first few eggs hatched was similar to this, except that many of the small bunches of eggs were in rows.

Egg

Eggs of L. californiae appear perfectly round and pearly cream in color (Figure 16). They are well attached to their substrate by a substance secreted during oviposition which does not appear to be affected by moisture.

Incubation Period. Under laboratory conditions (65-80°F), the duration of the incubation period ranged from six to seven days (mean 6.5 ± .5 days) for seven egg masses ((e), (i), (k), (p), and (q))[6] from five different females. Under field conditions, eggs (on the ground in small plastic vial caps) placed in a field cage on the south slope and a cage on the ridge top (Locality I) required an incubation period of 18 to 21 days respectively. The eggs were oviposited by the same female on April 6, 1966, at 2:00 p.m. in another field cage at Locality I and were transferred to the above mentioned two cages on that day.

Hatching. Two days prior to hatching, the eggs became muddy pink in color. One day before hatching the eggs developed a deep purple black color. Occasionally there was a yellowish egg among these dark egg masses. It was not determined whether these lighter eggs hatched with the others or were eaten as the remainder of the mass

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[6]See Appendix 1 for details concerning original female and progeny.

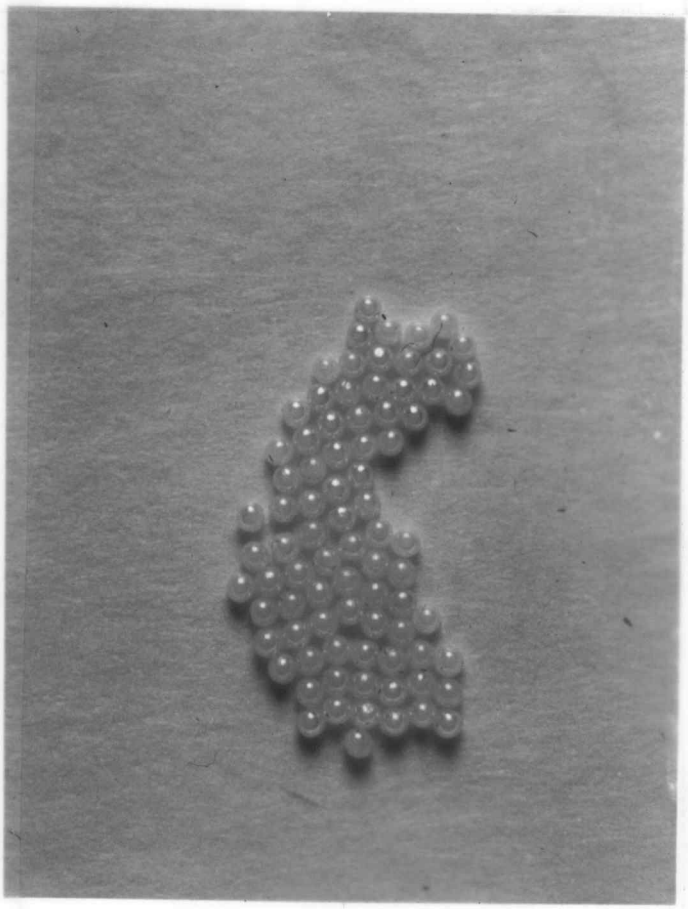
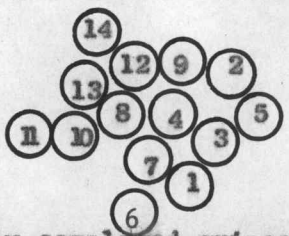


Figure 16. Two contiguous egg masses of Leptarctia californiae (Walker).

TABLE VII. TIME, SEQUENCE, AND PATTERN OF OVIPOSITION BY A SINGLE LEPTARCTIA CALIFORNIAE (WALKER) FEMALE[1] IN THE LABORATORY[2].

Egg Number	Time Since Last Egg Deposited Minutes:Seconds
1	about ten minutes
2	1:10
3	2:15
4	:50
5	:40
6	1:10
7	1:45
8	3:25
9	1:05
10	6:15
11	3:55
12	1:40
13	2:50
14	5:50
	Σ 32:50 minutes

SEQUENCE AND PATTERN



[1]Female had previously completed oviposition of 39 eggs, and drank about one drop of water prior to climbing up the vertical outside of a paper carton and ovipositing the first egg of this sequence at 2:17:40 p.m. Pacific Daylight Time.

[2]The sequence took place at a desk in the laboratory (26.5°C) under artificial and indirect natural illumination.

synchronously hatched.

Larvae normally eat about one third of their own egg shell after hatching. After about 12 hours, when food was not provided, a few young larvae began feeding on nearby whole eggs after exhausting most of their own egg shells.

Population Size

Leptarctia californiae appear to have been quite numerous in 1963 judging from records of a field trip by E. J. Dornfeld and A. N. McFarland to Locality V (May 17, 1963) in which several dozen females were seen resting on grasses along the roadside (Dornfeld, 1966). In contrast to this, during 1965 and 1966 I saw only two females in five days of collecting at Locality V.

The population size for Locality I and V for 1965 and 1966 appeared to be about the same. At Locality I, 46 males were captured out of an estimated 251 sighted for 1965, while 69 out of 239 were recorded for 1966. At Locality V, eight males were captured out of 20 sighted in 1965, while in 1966, 27 out of 49 were collected. About the same number of trips were made to Locality I and V in 1965 and in 1966.

The possibility of overlooking a synchronous adult emergence at Locality I and V seems remote in view of the young males continuously appearing in the population throughout most of the flight season.

Natural Enemies

Parasites

Comstock and Dammers (1943; p. 68) give the only record of a L. californiae parasite, referring to it as "a species of Ichneumon" without making any further comment. At present, no egg, larval, pupal, or adult parasite has been discovered under laboratory or field conditions.

Predators

Two larval predators were discovered during this study, but their value as control agents under natural conditions is questionable. The first was a larva of Chrysopa sp. (Neuroptera: Chrysopidae) which was inadvertently transferred, along with leaves of Rubus sp., to a petri dish containing third instar larvae. One L. californiae larva was found to have a chrysopid larva attached to its hind portion, apparently having fed quite successfully judging from the reduction in size of the moth larva to one half normal size. The second predator noted was an adult tiger beetle, Omus audouini Rche. (Coleoptera: Cicindelidae), which was found in an upturned vial on April 24, 1966. The vial had been left in the cage seven days earlier and contained 45 newly-hatched larvae and ten eggs. The larvae and eggs were probably destroyed as evidenced by powdered remains on the vial bottom and dried material on the wall of the vial. The beetle had to climb stems to get to the opening of the vial, two inches off the ground. Omus were seen in or near the field cages on about half of the field trips made to Locality

I and were found in most of the ground, plant, and litter samples made in search of larvae. The presence of Omus and other potential predators such as small rodents, snakes, and lizards on the hillside needs to be investigated in terms of their effect on larval and pupal populations.

Predators of L. californiae were either highly successful in each attempt at predation, or made almost no attempt at it. Out of 150 adult males collected at Locality I and V during 1965 and 1966, only one specimen was damaged in a manner suggesting an unsuccessful attempt at predation. This specimen suffered wing damage by having three quarters of the left secondaries and a portion of the posterior edge of the primaries torn off along a straight cut. This moth probably sustained this close cropping of the secondaries while in flight, as the primaries normally completely cover the secondaries while the moth is in a typical resting position. Neat tears in the secondaries are found on many specimens and are considered here only the result of adults flying into grasses. These tears were used earlier in the adult section as a crude indicator of age since eclosion from the pupa.

Disease

The only disease of L. californiae discovered during this study was a microsporidian which accounted for high larval mortality in the greenhouse and in laboratory cultures. Larvae reared from eggs procured from field-collected females were not found to be infected with microsporidia, suggesting the possible acquisition of this disease

and its maintenance in the greenhouse and laboratory or both.

The general symptoms were darkening, reduction in size, and loss of activity. Martignoni (1964) discussed a biochemical anomaly caused by a microsporidian disease which results in increased ommochrome pigment and integument darkening in Locusta. This same effect may be responsible for a darkening in larval color discussed in the next section. Dead larvae found in rearing containers were often completely filled with spores. By the time death occurred, larvae had shortened (their prolegs extending backward) and turned deep brown in color. The use of artificial diet (Shorey and Hale, 1965) for larval rearing during 1966 correlated with low mortality from microsporidian disease. Table VIII comprises the disease data taken for 1965 and 1966. The greenhouse rearing techniques appeared to increase the chances for disease in comparison with laboratory rearing on the artificial diet by Shorey and Hale (1965). Larval mortality of 50 to 75 per cent was experienced in greenhouse cultures in 1965 and 1966 compared to none in the laboratory on the artificial diet in 1966.

Record of Variation

A discussion of larval variation and a record of adult polymorphs is briefly presented here in an introductory manner to future studies.

Earlier in this study it appeared that certain groups of larvae were considerably darker in cuticle color than others. Photographs were taken of the larvae to find whether or not differences could be correlated with one of the adult polymorphs.

TABLE VIII. OCCURRENCE OF MICROSPORIDIAN DISEASE IN LARVAE OF LEPTARCTIA CALIFORNIAE (WALKER)

Larval Source[2]	Year	Presence or absence of disease[1]				Total Larvae Examined
		Laboratory		Greenhouse	Field	
		Leaves Malva sp.	Artificial Diet[3]			
(e)	1965			±		5
(g)	1965	-				7
(i)	1965	+		±		23
(k)	1965	±		+		3
(m)	1965	-				3
(o)	1966		-			4
(p)	1966		-	+		4
(s)	1966		-			2

[1] + = diseased
± = some with, some without disease
- = not diseased

[2] See Appendix 1.

[3] Composition of artificial diet, Shorey and Hale (1965).

An examination of over 50 photographs of fifth instar larvae (e), (g), (i), (k), and (m) revealed no noticeable differences between individuals or groups that could not be explained in terms of color fading prior to pupation or general darkening due to a heavy infection of microsporidia. The yellow-orange mid dorsal stripe common to fifth instar larvae was hardly visible from the dark surrounding cuticle of microsporidia-infected larvae.

Other differences may exist to substantiate the statement by Comstock and Dammers (1943) that their breeding experiments gave them reason to conclude that the larvae were more variable than previous accounts indicated, but possibilities of other larval variation were not investigated.

Early in this study, it was intended that a large number of adult L. californiae would be collected in the field and reared in the laboratory to gain a better understanding of the genetics responsible for the polymorphism they exhibit. Unfortunately, only four females and 115 males were collected at Locality I during 1965 and 1966 combined.

Hopefully, any documentation of the relative proportion of polymorphs will, at some future date, be useful in evaluating the effect of rapid ecological changes now taking place at Locality I on this polymorphism.

The males and females from Localities I through V appeared similar in color and pattern. Dorsal hind wing colors are either black, or yellow and black in males and females. Additional hind wing colors in

females are orange with yellow, orange, and red.

For purposes of description, the polymorphs have been divided into four types. Figures 17, 18, 19, and 20 illustrate the two extremes (top and bottom) and the mean (center) for each of the four types. Table IX summarizes the relative proportion of each of the four polymorph types at Locality I.

TABLE IX. RELATIVE PER CENT OF FOUR MALE POLYMORPHS[1] OF LEPTARCTIA CALIFORNIAE (WALKER) FOR 1965 AND 1966 AT NORTH FORK OF ALSEA RIVER[2], BENTON COUNTY, OREGON.

Year	Number of Specimens	Type I	Type II	Type III	Type IV
1965	46	17.4%	30.4%	19.6%	32.6%
1966	49	11.5%	42.1%	18.8%	27.6%
Total	115	13.9%	37.4%	19.1%	29.6%

[1]See Figures 17, 18, 19, and 20.

[2]Locality I.

Black males (Type IV) with a broad band of white on the primaries (Figure 20 bottom) were quite rare. For 1965 and 1966 one of these was present in the 115 collected at Locality I and from Locality V one out of 35. Five out of 15 (g)[6] adults (three males, two females) also displayed this wide band on the forewings, a characteristic which was

[6]Details concerning the progeny and original female are in Appendix 1.

not observed in other groups of reared adults. Females with yellow or yellow and orange on their secondaries about equaled field females with red secondaries. The possibility that yellow might be dominant or incompletely dominant over red wing color requires further crosses of known parentage.

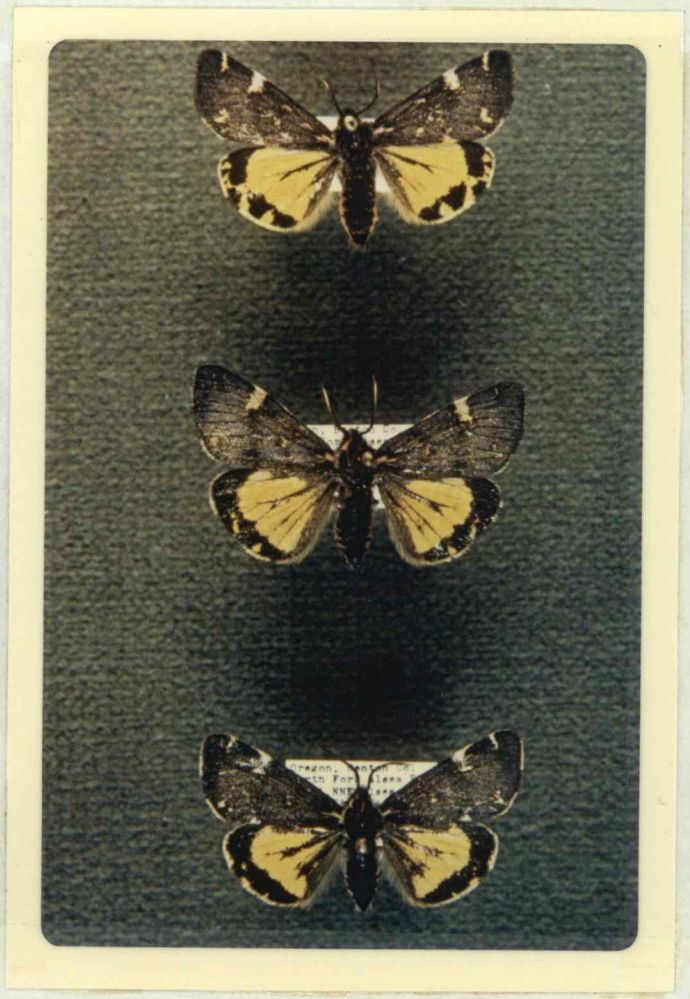


Figure 17. Type I male morph of Leptarctia californiae (Walker) from the North Fork of the Alsea River, Benton County, Oregon (Locality I).

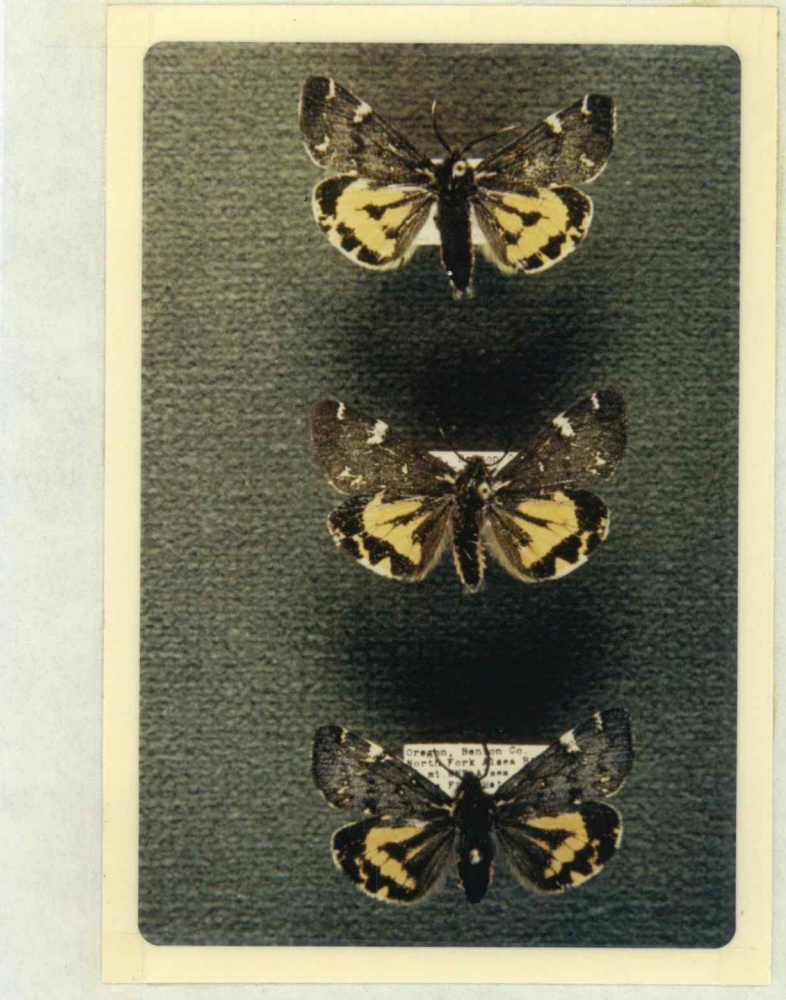


Figure 18. Type II male morph of Leptarctia californiae (Walker) from the North Fork of the Alsea River, Benton County, Oregon (Locality I).

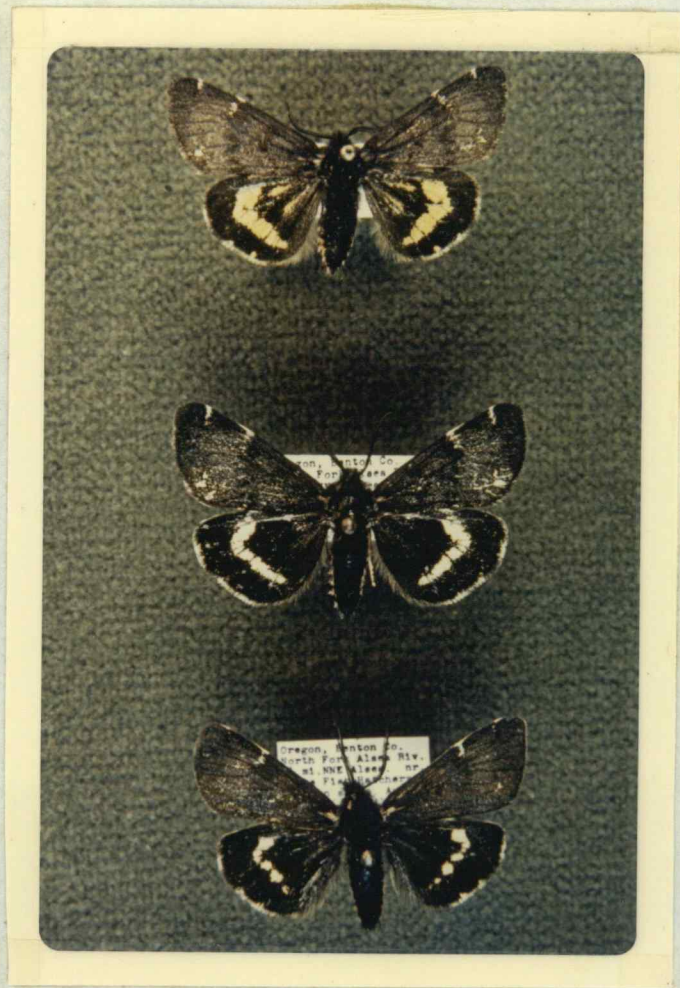


Figure 19. Type III male morph of Leptarctia californiae (Walker) from the North Fork of the Alsea River, Benton County, Oregon (Locality I).

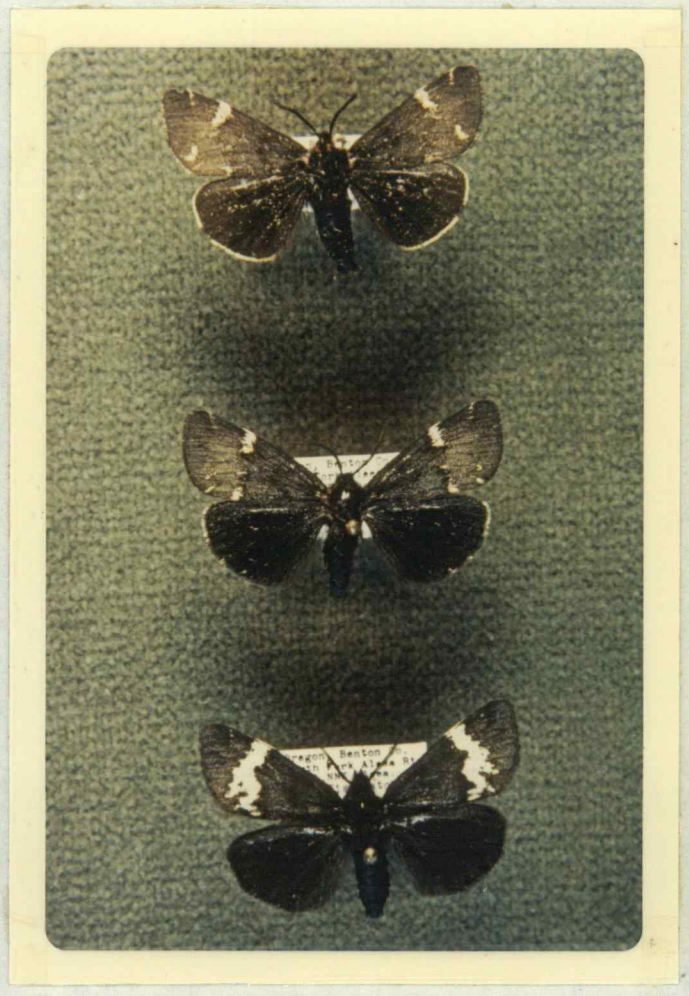


Figure 20. Type IV male morph of Leptarctia californiae (Walker) from the North Fork of the Alsea River, Benton County, Oregon (Locality I). White marked forewings occurred only with this type of hind wing color morph.

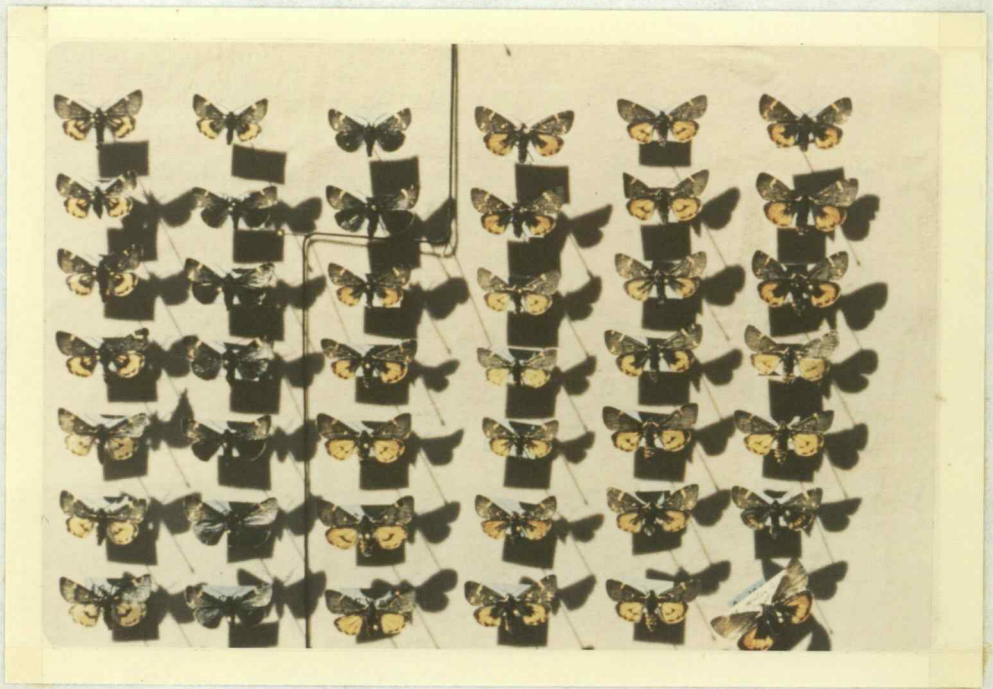


Figure 21. Male (left of line) and female (right of line) progeny reared from a single female (lower right corner) collected near Alsea Mountain, Benton County, Oregon (Locality V). The extent, but not necessarily the proportion, of variation in hind wing color and pattern is pictured.

SUMMARY AND CONCLUSIONS

L. californiae was studied on the south and west facing slopes of an open hillside (elevation 500 to 1000 feet). Spotty natural reforestation of Douglas fir has occurred since the area was logged and burned over 20 to 30 years ago.

The emergence of adult moths is apparently dependent upon meterological conditions. The 1965 mid March emergence was during an extended warm dry period (21 days) while the 1966 April emergence followed a cool wet March.

Eggs procured from captive females hatched in the field within 21 days. Larval development through the fourth instar averaged 80 days. Laboratory-reared individuals developed 60 per cent faster. The duration of the fifth instar under laboratory conditions was 41 days. By inference, in nature this stadium would be expected to average 66 days in duration.

Feeding behavior of captive larvae varied with the developmental stage. First, second, and third instar larvae fed diurnally at ground level while fourth and fifth instars were nocturnal and fed 12 to 18 inches above ground level.

The differences in the vegetational strata available through the season resulted in larvae which were feeding higher up on the foliage, since they had to utilize different species of plants for food. It is interesting to note that fifth instar larvae have the greatest development of urticating hairs plus a terminal brush of long soft

hairs which is brought forward by raising the end of the abdomen in response to disturbance.

Peak male flight activity occurs between 12:00 and 3:00 p.m. P.S.T. on sunny days. Frequently temporary cloud cover, when accompanied by a drop in temperature (near or below 12.5°C), abruptly curtailed flight activity.

Greatest adult flight activity was found on south slopes and open areas in the surrounding forest where air temperatures were five to ten degrees warmer. No flight occurred on nearby ridges and north slopes even though they were well illuminated. Such areas were in direct line with prevailing north and east winds, and temperatures that were apparently below the minimum flight requirements prevailed.

The existence of a female chemical attractant is postulated from observations made on male reactions to caged virgin females.

Four classes of male color morphs as pictured in Figures 17, 18, 19, and 20 account for 13.9, 37.4, 19.1, and 29.6 per cent respectively of the 115 specimens collected in 1965 and 1966. Colored males have yellow hind wings; those of females are yellow, orange, yellow orange, or red. These colors may have an aposematic function such as found in other Arctiidae.

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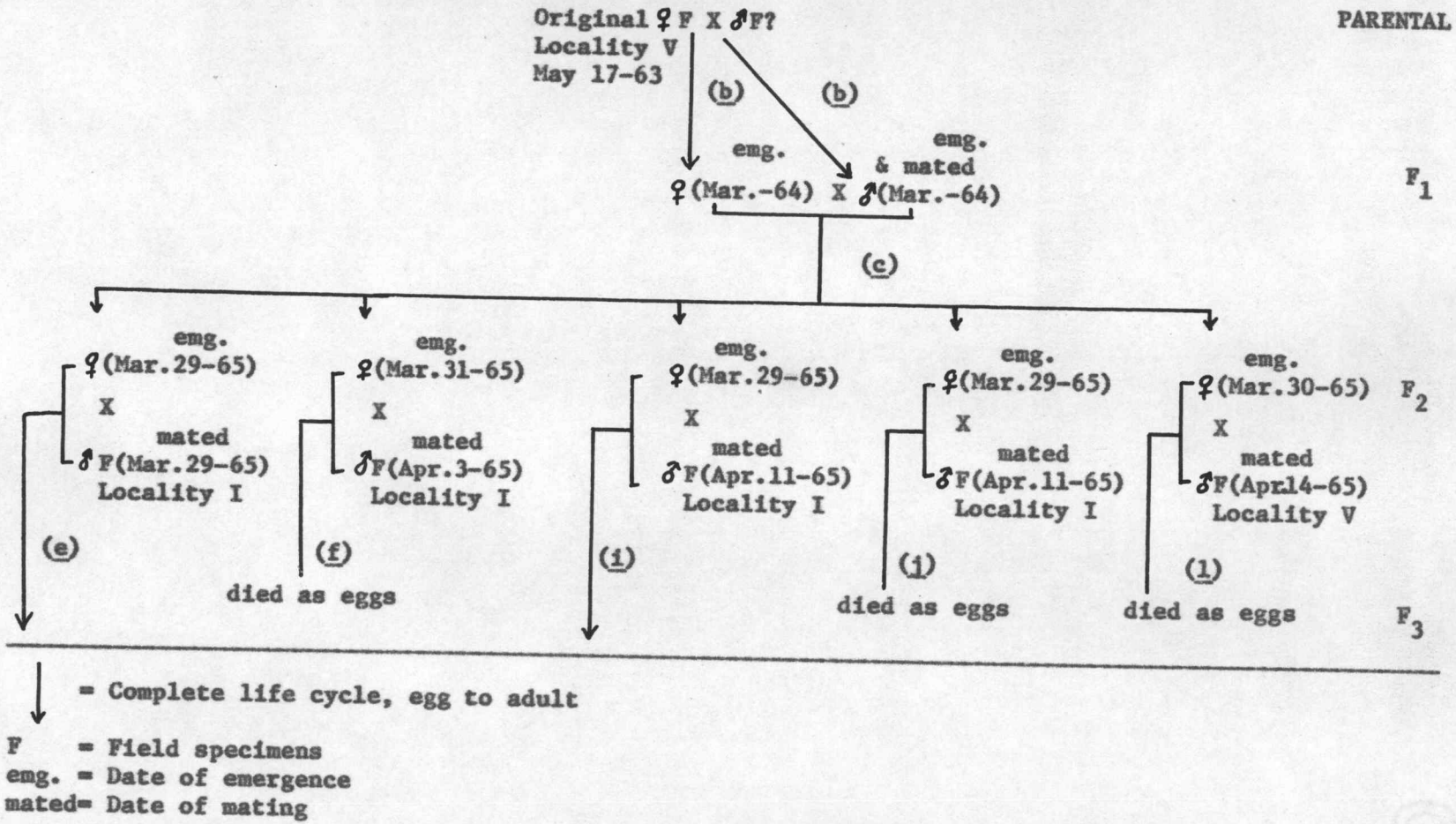
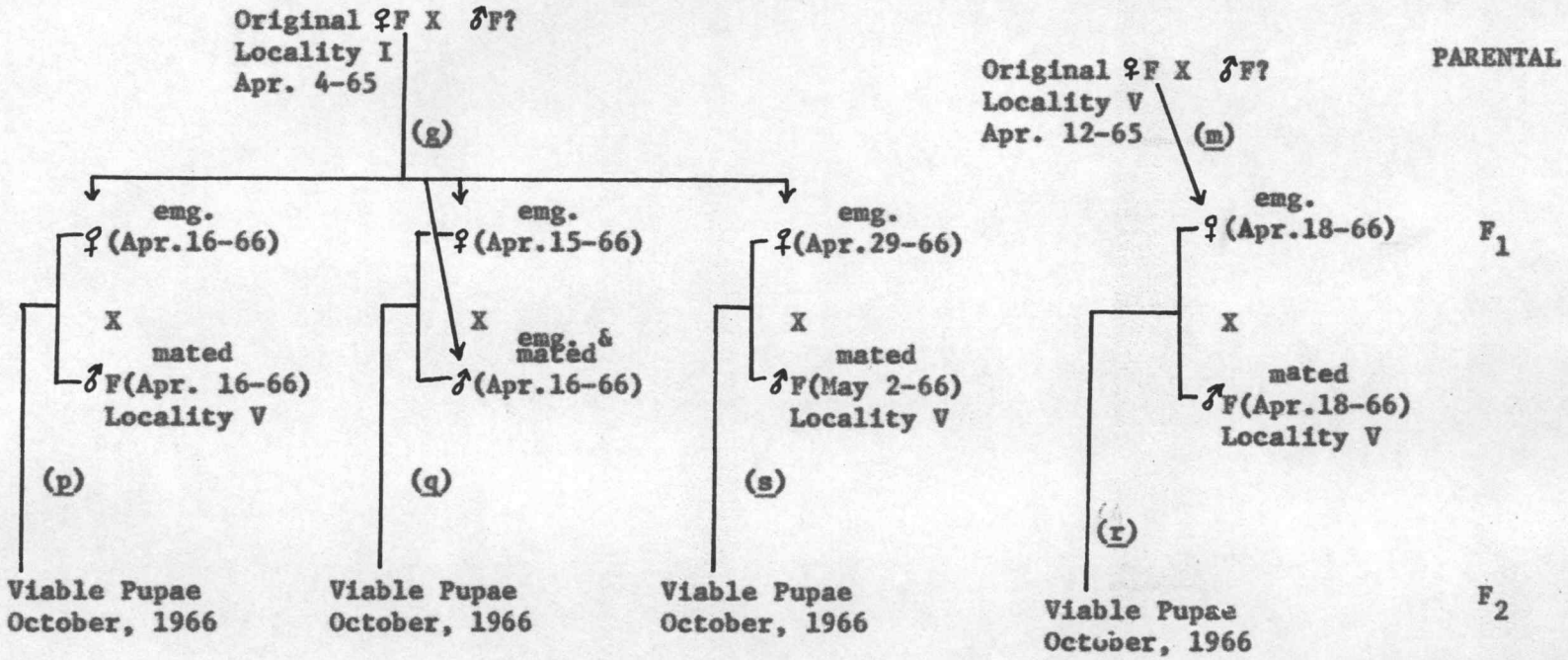
APPENDIX


Original ♀F X ♂F?
Locality V
May 17-63
PARENTAL
(b)
(b)
emg.
emg. & mated
♀(Mar.-64) X ♂(Mar.-64)
F1
(c)
emg.
♀(Mar.29-65)
X
mated
♂F(Mar.29-65)
Locality I
(e)
emg.
♀(Mar.31-65)
X
mated
♂F(Apr.3-65)
Locality I
(f)
died as eggs
emg.
♀(Mar.29-65)
X
mated
♂F(Apr.11-65)
Locality I
(i)
emg.
♀(Mar.29-65)
X
mated
♂F(Apr.11-65)
Locality I
(j)
died as eggs
emg.
♀(Mar.30-65)
X
mated
♂F(Apr.14-65)
Locality V
(l)
died as eggs
F2
F3
= Complete life cycle, egg to adult
F = Field specimens
emg. = Date of emergence
mated= Date of mating



Two females from Locality V (captured on April 12, 1965, and April 5, 1966) gave rise to egg masses designated as (k) and (o) respectively. One female from Locality I (captured on April 6, 1966) gave rise to egg mass designated (n). Representatives from egg masses (n) and (o) are now overwintering as pupae. Representatives from egg mass (k) transformed into adults but were not bred further.