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OBSERVATIONS ON THE LIFE-HISTORY OF *CALEPHELIS BOREALIS*. PART II.

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DEVELOPMENT IN CAPITIVITY

Larvae raised indoors were observed under different conditions. Those raised by SMALLEY were placed in small, individual bottles or one-half ounce vials with tight caps or corks, and fresh leaves of the foodplants were added at the least sign of wilt. In this environment all but one of the 178 larvae which SMALLY has raised over a period of several years have emerged as imagoes in the fall, from late August to early November, of their larval year. The one exception acted as if it were going to hibernate but died in early November. The first brood raised indoors by the author in large bottles with cloth covers emerged in November of the larval year. Therefore, it was decided that some should be raised under conditions which would approximate the humidity and temperature variations experienced by larvae in their natural environment. The larvae were placed on leaves of *Senecio obovatus* plants growing in glass bowls in their original soil and mulch. The bowls were enclosed in a screen cage and left on a north-west windowsill where the window was left open continuously. When the larvae went down to dead leaves in the fall and remained there to hibernate, the cage and enclosed bowls were moved to a completely enclosed woodshed and left there until April. Four of the larvae successfully raised in this way hibernated in the larval stage, but two of them suddenly began to increase in rate of growth after the first week of September, pupated on October 3 and 4 and both emerged on October 30.

The larval stages and measurements for the caged larvae were much the same as those outlined by DOS PASSOS. The larvae which were raised in bottles grew very much faster. The size of imagoes, however, was smaller for SMALLEY'S "bottle"-raised larvae, which never attained the dimensions of those in nature. The larvae which hibernated did so in the sixth instar. In spring they molted twice before pupating.

There were a number of interesting observations concerning the larvae which were confined in cages. On one occasion a Neuropterous larva was discovered in the act of devouring a *C. borealis* larva. The Neuropteran must have been imported from the woodland with the *Senecio* plants. It was de-

stroyed by the author before it could prove how avid was its appetite. The larvae passed the first four molts rather consistently, but the sixth and seventh were variable both with the larvae which hibernated and those which did not hibernate. Usually the larvae raised in captivity did not wander far when they began to descend to positions under dead leaves. Twice they were observed crawling around the edge of the bowl and twice they were seen moving across several leaves before settling on one. Once, however, on November 2 a larva crawled over the edge of the bowl which had been temporarily set on a window sill outside its cage, proceeded halfway across the sill a distance of eighteen inches, and assumed a resting position on the vertical edge of the sill where it was sheltered from the direct wind coming in the open window. When it was replaced in the bowl it crawled to the underside of a *Senecio* leaf which was nearly touching the ground. On October 22 the first larva went down to earth and crawled into a curled, dead leaf beneath a *Senecio* plant, where it remained for over a week. Then it moved a short distance to another leaf, but the following day moved back to its first position again. The other three larvae also began wandering by the first of November. After descending to the ground, two of them ascended to plant leaves again for only a few hours, and then one crawled to a dead leaf on the ground and the other to a plant leaf touching the ground. There was no visible sign that any had eaten of the food plant since the first of November, and the one had not eaten since the 22nd of October. On November 5 the last one went down to hibernate, apparently into a crevice beneath the plant or between earth and side of bowl.

During ecdysis *C. borealis* larvae in captivity usually passed through an inactive period of two stages exemplified externally by a very white color phase evidently caused by evacuating the alimentary tract and by a dark color phase just preceding the molt. The duration of time spent in these stages was variable both with the larvae in nature and in captivity. For the complete process of ecdysis usually three days were required, roughly two in the white stage and one in the dark. However, with the indoor larvae there were records of a total of only two days and on one occasion only one day, and once the white stage was not even noted. From the chance records of the larvae *in situ* and the complete records of larvae in captivity, it appears that the exuviae are usually only partially eaten or left intact in the first two molts and the last two, while the exuviae are usually eaten completely in the intervening molts. There are records of larvae eating exuviae in the second molt, however; and in the molt before the pupal molt the larvae ate most of the exuviae. In the third molt none of the larvae consumed their exuviae although two "nibbled' at them, and none of the larvae ate their exuviae at the time of their first post-hibernation molt.

A most remarkable observation resulted from an acccident. On April 8 the captive larvae were removed from the shed where they had been kept during hibernation. Examination revealed that three larvae had survived the winter months; a lifeless one was found intact. They were placed on a roofless porch in the sunshine. On the 9th and 10th there was a torrential rain, and during the absence of the author the larvae had been forgotten. Great was the disappointment, therefore, when the mistake was discovered on the 11th, and the bowl which contained the larvae was found to be flooded.

After a search two of the larvae were found under submerged leaves; they were limp and apparently lifeless. The bowl was drained and the "lifeless" larvae placed on top of dead leaves and replaced in the shelter. It was most fortunate that the larvae were not discarded immediately, because on the afternoon of April 26 the bowl and its contents were again examined, and three larvae were up on one of the plants, one on a stem and the other two on leaves. Of the two on leaves, one was on the underside halfway between midvein and the margin and the other on top of the leaf. The two "dead" larvae had survived the flood, and the lost third one had reappeared. The larvae had eaten three spots about 2 mm. in diameter on the underside of a fresh *Senecio* leaf; they were slightly changed in color and measured 6 mm.

At the time of pupation both the natural and captive larvae displayed great sensitivity to any disturbance. One of the captive larvae had voided in preparation for the molt on September 27 and had taken up a position on a mat of silk on the lid of the cage when the lid was opened for periodic examination. At this intrusion the larva moved to the other end of the box lid and assumed a position similar to the first position. On the next day the cage lid was lifted very carefully for inspection, but the larva immediately moved to the other end of the box lid and assumed a position similar to the first position. On the next day the cage lid was lifted very carefully for inspection, but the larva immediately moved to a third place on the cage lid. Again the lid was lifted carefully several times as a test. On the 29th this larva then moved off the lid, went back to a leaf of *Senecio* and took up a position between the midvein and margin. Since the time when it had taken the third position on the lid it was much shrunken. It pupated on October 3 in the early morning. The behavior of this larva corresponds with that of the two natural larvae disturbed after voidance prior to pupation, as described above. The period of time required by this larva to consummate pupation was seven days. A second larva voided and began to seek a location in which to pupate on the 29th; it pupated on October 2 in the afternoon, a lapse of only four days. These intervals correspond closely with the records of the two larvae in natural environment, one of which required six days and the other nine days to effect pupation. A record was kept of the coloring of the pupa of one of the *C. borealis* larvae which hibernated. The larva transformed into a pupa at 11:00 AM. By 1:00 PM the dorsal chrysalid spots were barely discernible under the still soft, greenish-white pupal case. At 3:00 PM the spots were fairly clear and the chrysalis noticeably harder. By 6:00 PM dorsal and lateral spots were clear. Close observation of the pupa just prior to transformation into the imago disclosed the following sequence of color changes: the eye cases became rich brown and the tail region darkened slightly; next the dark brown spread to the wing cases and shortly thereafter to the whole head and in a band to the posterior extremity; and finally the actual color of the wings showed through the pupal case preceding emergence of the imago. In the first group of pupae the author observed, this color sequence required three or four days, a day for each stage. Only two days were required by other broods. The duration of time spent in the pupal stage varied from 12 days for the larvae which hibernated to 27 and 28 days for the two which developed comletely without hibernating. The one brought home from the natural

habitat after hibernating spent 13 days in the pupal state. The first brood the author raised in 1938 passed 16 to 24 days in the pupal stage.

While the egg has been described, the color changes of the developing egg have not received attention in the papers cited. During the course of development the egg changed from a pale lavender, to purple, then to a claret, and finally to a deeper shade of red. A day to two days before hatching the eggs became a waxy white. SMALLEY also noted that immediately on hatching the larvae have a claret tinge which becomes a greenish-gray as soon as they begin to eat.

The maximum length attained by a captive larva raised by the author was 17mm. x 4mm.; the others were 10 to 13mm. at maximum. The largest natural larva measured 15 mm. before it disappeared to pupate. The sizes of both groups of larvae at the time of hibernation were the same for both maximum and average. The color of the natural larvae, however, was more amber in later instars than that of the captives.

Generally the development of the author's captive larvae closely paralleled that of the natural larvae. The fact that three of the indoor larvae had not assumed hibernating positions until five to six days later than the natural ones might have been because the indoor larvae were in a more sheltered environment despite one open window.

In still other ways than have already been mentioned SMALLEY'S "bottle"-raised larvae differed from the other two groups. One year when a close record of observations was kept it was found that thirteen larvae pupated in the seventh instar after six molts, but four extended into the eighth instar after seven molts. One other larva molted a sixth time and then three days later molted again. With twenty larvae the average was six days for each of the first three instars; the average for the fourth was eight days; for the fifth instar nine and one-half days; for the sixth ten and one-half days if it pupated in that instar but only seven days if it didn't. The seventh averaged fifteen days for the four which extended into that instar. SMALLEY never observed larvae eating exuviae. He took the skins for study after a day passed, and by that time his larvae were eating leaves. However, six exuviae could not be found for larvae which should have molted; these had probably been eaten.

SMALLEY noted that after the larvae were large enough to eat the whole leaf their feces were forcibly expelled as minute, hard pellets which travelled several inches through the air. He found that moist excreta were voided only in preparation for pupation and then in only a few instances. In the last instar the larvae spit forth a greenish liquid when disturbed besides the usual raising of the extremities.

In these specimens the pupa measured 3 to 4 mm. wide and 9 mm. to 11mm. long. The larvae averaged sixteen to seventeen days in the pupal stage. The time from the coloration of the eyes of pupae until emergence of the imago was invariably six days in his experience. Of 18 which emerged one year, 11 were males and 7 females; but in other years the sexes were more evenly balanced. His males and females emerged intermittently throughout the season whereas in the field males precede females by at least a week.

In no instance were the larvae of *C. borealis* found to be gregarious. Several times both in captivity and in the natural state two larvae were seen on one leaf, but soon thereafter one moved to a different leaf.

DISCUSSION

The greatest enigma encountered in the study of *Calephelis borealis* was the complete development without hibernation of two of the larvae raised in cages under conditions which closely approximated those experienced by the insect in its natural state, especially since the larvae which did hibernate behaved so nearly like the larvae observed in their natural environment. Previously, the author and SMALLEY had believed that "bottle"-grown larvae matured without hibernation because they were provided with fresh and succulent leaves and/or constant conditions of temperature and humidity, but the behavior of the above two larvae erased any easy explanation of causes for their sudden increase in rate of growth and maturation while others raised along with them developed normally. The determining threshold must be very narrow.

The factors which cause the local distribution of *C. borealis* and limit its abundance are also a matter for conjecture. The species seems to be prolific in that a number of gravid females are seen each year, and SMALLEY has obtained as many as 90 eggs from one female. The females oviposit readily when subjected to direct hot rays of the sun or heat lamps. The larvae appear to be very tough, especially tolerant of moisture, relatively free of enemies. Although in captivity a lacewing larva devoured a *C. borealis* no evidence of any predation was observed in nature. It's foodplant is widely distributed and hardy. The severity of the winter did not seem to affect the larvae under observation in their natural habitat, and the winter was exceedingly harsh for this comparatively mild area. Perhaps one factor might be a narrowed tolerance for alternate freezing and thawing to which it would be exposed in more normal winters in this latitude.

SUMMARY

1. The activity of larvae of *C. borealis* appeared to be affected largely by temperature since their descent to the mulch and ascent to the foodplants generally correlated with rise and fall of temperature, although two individuals remained up on foodplants ten days longer than the others. Captive larvae hibernated five to six days later than natural larvae; and kept in an unheated but sheltered place, became active in spring about nine days earlier.

2. For temporary shelter and for hibernation *C. borealis* larvae descended to the underside of dead leaves on the ground from 4 inches to perhaps 3 feet, but definitely to as much as 24 inches, distant from its individual food plant. On occasion they may enter crevices in the earth to hibernate. They remained in place until early April when they began to move about, but evidence indicated that they did not become active enough to eat until May 5. The larvae were not gregarious.

3. In nature the larvae pupated on the underside of dead leaves laying down a mat of silk into which was fastened a cremaster and girdle of silk to hold them in place.

4. Careful inspection of their habitat gave every indication that larvae in nature invariably hibernate in the larval stage, probably in the sixth instar, never in the pupal nor adult stages.

5. Larvae raised in closed bottles or vials where temperature and humidity conditions remain almost constant usually developed into imagoes without hibernation. There was only one exception out of a total of 178 larvae which matured. Larvae raised in this manner developed much more rapidly, emerging the latter part of August and early September, whereas larvae raised in containers with open tops emerged the last of October and early November. Records also indicated that larvae raised in closed containers usually molted only six times prior to pupation (passed through only seven instars), while the others molted seven times (had eight instars).

6. The behavior of *C. borealis* throughout its life history was characterized by inactivity. Larvae responded to disturbance by elevating anterior and posterior extremities, a motion which was usually not violent enough to throw them off the surface on which they were resting; actually this response was relatively slow. Imagoes usually alighted and spread their wings on the upper surface of a roosting spot where they remained for long periods of time. However, at least fourteen instances were noted when imagoes were found on the underside of foliage. Females moved slowly and paused for long intervals when ovipositing in nature.

7. The habitat of *C. borealis* was rough hillside grown over with saplings and especially poison ivy and honeysuckle at a distance of 15 to 40 feet above the level of streams.

8. Captive larvae which hibernated closely approximated natural larvae throughout their life history.

9. Two larvae which were subjected to two days' torrential rain and which were under a submerged leaf, limp and apparently lifeless when found, revived and completed their development, demonstrating a high moisture toleration.

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