OBSERVATIONS ON SANDALUS NIGER KNOCH, ITS EGG, AND FIRST INSTAR LARVA[1]

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In 1921, Dr. F. C. Craighead (Proc. Ent. Soc. Wash. 23: 44–46, 1 pl.) made an important contribution to our knowledge of the biology of *Sandalus*. Under the circumstances of his discovery of a pupa of *Sandalus niger* Knoch within the body of a cicada nymph, the parasitic nature of this beetle appears to be definitely established, and, from the larval exuvium which accompanied the pupa, the characters of the mature larva were made known. Prior to this time Dury, 1900 (Jour. Cincinnati Soc. Nat. Hist. 19: 172–173) and Manee, 1908 (Ent. News 19: 288–289) had published observations on the adult beetle. Dury's interpretation of his observations supported the idea of phytophagous habits, but the beetle's parasitic nature was not suspected at this time, and nothing further has been published since Craighead's discovery.

The writer has been fortunate in observing a brood of this beetle and has secured and hatched its eggs. In this paper the writer's observations on the adults, eggs, and first instar larvae are given, and the latter is described and figured. It is hoped that the interest of other entomologists may hereby be aroused, so that the complete life cycle may be made known. This will likely be no easy task, however, for the beetle's life cycle is probably intimately associated with that of its host cicada, whatever species that may be, and the problems that beset a study which involves a subterranean insect with a long life cycle are obvious. One of the first steps in such a study might be the correlation of appearance of broods of the beetle with broods of cicadas, or perhaps someone familiar with the habits and rearing of cicadas may be able to effect parasitism under controlled conditions.

OBSERVATIONS ON THE ADULT BEETLES

Broods.—Observations agree that this beetle occurs in numbers in localized areas, at times appearing to restrict its activities to a certain

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tree or group of trees. Dury found it associated with ash, Manee with oak, and Blatchley records it from cedar and ash. In the light of its parasitic nature, this apparent association with certain trees has no significance except as it may indicate host or oviposition preferences of the host cicada.

The localized appearance of this insect may be explained in great part by the fact that the female beetle, though winged, has not been observed to fly, so that a great majority of the eggs laid from generation to generation by a given brood are likely laid in the same small area.

In the fall of 1937, a brood of *Sandalus niger* occurred at Columbus, Ohio, on the Ohio State University campus. The beetle was already present in good numbers on September 30, when first noticed. 16 females and 50 males were taken from that date until the last day of October. All beetles except one were taken from a wooded area between the chemistry building and the high school. The single exception was a female found crawling upon the sidewalk at 41 E. Woodruff Avenue, about three blocks away. Occasional males were observed in flight on other parts of the campus, but the brood was very closely confined to this particular woods. Beetles were especially common on trees which stood apart from the others, so that their boles were exposed to the sunlight. They occurred on basswood, beech, elm, sugar maple and sycamore, and were particularly prevalent at a large basswood just behind the chemistry building, standing somewhat apart from the other trees.

This area was re-examined in the fall of 1938 and 1939 for occurrence of the beetle. No beetles were definitely observed, though on two occasions in 1938 what appeared to be a male *Sandalus* was seen in flight about the crowns of trees, but at such a height that positive identification was not possible.

Another brood was encountered October 5 and 6, 1939, by Roy W. Rings, about four miles distant from the 1937 brood, at 1158 Oakland Avenue, Grandview, Ohio. 30 females and 5 males were taken on two afternoons, between the hours of 3:00 and 4:00 P. M., on the trunks of elm and oak, in the back yard of this residence.

Flight.—Though they have not been observed to fly, females appear capable of doing so, and the specimen taken on Woodruff Avenue (October 27) may have flown there from the infestation on the campus. The males, however, are strong fliers, and they are so alert in their flight that it is almost impossible to catch one with the hand. They resemble large bees as they circle about tree trunks in search of females. As the flight of males is closely correlated with mating, further notes may be found under that heading.

Mating.—On October 12, 1937, the writer secured 2 females and 33 males in less than half an hour, during the noon hour, and several other females could have been taken. The day was warm and the sky slightly hazy, and it was to be noted that the males were not as active as they were on bright, clear days, for several were caught in flight by the hand. The locality was re-visited at 3:30 P. M., by which time the sky had clouded over. The males had practically disappeared, a careful search disclosing only two, one still in copulation, the other the prey of a pentatomid nymph. Of the three females found at this hour, two were ovipositing and the other mating.

Whether mating or ovipositing, the females occur on the trunks of trees, particularly large, isolated trees with boles exposed to the sun. They usually are within reach of the ground, but occur anywhere from the ground level to a height of 12 or 15 feet. On favorable days the males appear in abundance, and are found flying from tree to tree, or circling about the trunks in search of the female. Mating pairs were observed a number of times, but detailed notes on the act of copulation are lacking. It appears at best a lengthy process, and perhaps occurs repeatedly. Other males may be attracted by a mating female, and on one occasion two males were about a mating pair so closely that all four of these large beetles were pinned by the mouth of a cyanide tube seven-eighths inch in diameter. On one occasion a male was observed to alight upon a trunk several feet above a mating pair and slowly run about with its antennae extended, elytra raised and hind wings fanning the air, in its search for the female.

Males were found in abundance and mating only on three days, September 30, October 1, and October 12. Rings captured 5 males and 30 females between the hours of 3:00 and 4:00 P. M. This is just the inverse of the sex ratio of the specimens collected by myself, and with regard to my observations on October 12, it is likely that he would have found the males very numerous if he had collected earlier in the afternoon.

Mating appears to take place only under certain optimum conditions of temperature and light, and possibly humidity and the hour of the day are important. At any rate, the males are abundant and actively searching for their mates at noon or early afternoon of warm, bright, sunny autumn days. Later in the afternoon of the same days the females may still be found, but the males have practically all disappeared.

A table is given, showing the weather conditions for the days that the beetle was found.

Oviposition.—Females not mating were usually ovipositing in the crevices of the bark, anywhere from the ground level to higher than one can reach. There is a possibility that eggs may also be laid in the ground, but oviposition upon the trunks was so commonly observed that this is considered to be the normal habit. Captured females readily laid eggs in the crevices between the cork and the wall of the perforated celluloid vial in which they were kept. The ovipositor can be extended farther than the length of the body, and with whip-like and undulating movements it explores the crevices. Eggs are extruded by pulsating movements of the ovipositor, one at a time in tiny crevices, and four or five at once in larger ones.

Longevity.—This insect appears in the fall of the year; the brood observed by the writer being first seen September 30, but undoubtedly the insects had emerged prior to this date. After a period of unfavorable weather from October 13 to 25, the insect was quite scarce, 6 females and 2 males being taken or seen between October 26 and 31. The life span of any individual, particularly the females, may be expected to last a major portion of this period, though individuals confined in the laboratory did not live more than several days. The beetles have not been observed to feed, and, from Mr. Ring's examination of the alimentary tract, it is highly improbable that they do so.

Weather conditions and activity of the beetle.—Meteorological data for the days the beetle was observed have been supplied by the Columbus weather bureau. Caution must be used in applying such data, as they were taken from the top of the post office building, and will vary somewhat from conditions where the beetle was found. The information is for the hours ending at 1, 2, 3 and 4:00 P. M. The sunshine data covers the duration of sunshine, not the intensity, and the figures are expressed in hours and tenths of hours, i. e., .5 would indicate that the sun shone for 30 minutes of the hour in question.

	Temperature (Fahrenheit)				Sunshine (duration)				Wind Velocity (miles per hour)				Relative Humidity	
Hour (P. M.)	1	2	3	4	1	2	3	4	1	2	3	4	Noon	7:30
(1937)														
Sept. 30	77	80	81	80	1.0	1.0	1.0	1.0	9	9	9	9	42	37
Oct. 1	82	84	85	84	1.0	1.0	1.0	1.0	3	5	5	6	45	42
Oct. 2	77	80	81	79	.0	.3	.2	.1	4	5	5	7	42	76
Oct. 4	69	72	71	70	.0	.4	.0	.0	7	9	11	8	81	83
Oct. 12	71	72	71	58	1.0	1.0	.8	.0	21	24	24	21	41	85
Oct. 26	62	63	61	60	.8	1.0	1.0	1.0	16	21	19	17	47	75
Oct. 27	47	46	46	47	.0	.0	.0	.0	17	19	21	19	82	67
Oct. 29	63	67	70	70	1.0	1.0	1.0	1.0	17	19	19	19	43	49
Oct. 31	54	55	56	57	1.0	1.0	1.0	1.0	9	9	6	7	45	47
(1938)														
Oct. 8	70	73	75	75	1.0	1.0	1.0	1.0	15	18	17	16	41	49
Oct. 9	68	69	71	72	1.0	1.0	1.0	1.0	8	9	9	8	50	40
(1939)														
Oct. 5	77	77	77	78	1.0	1.0	.7	.9	23	23	20	21	41	58
Oct. 6	80	80	81	82	1.0	1.0	1.0	1.0	13	16	14	14	24	42

Abundance of males in flight was observed by the writer on September 30, October 1, and October 12. A single male was observed in flight at 3:00 P. M., October 29, and what appeared to be male *Sandalus* were observed in flight October 8 and 9, 1938, the exact hour not being recorded. As the table shows, these were all sunny days, with temperature approximately 70 degrees or above.

Rings made his collection of the beetle between 3:00 and 4:00 P. M., October 5 and 6, 1939. He reports that they were mating and on the wing at this time.

Males taken when not in flight are as follows: one male resting on a tree trunk near the ground, October 26, 2:30 P. M.; one male crawling in the grass at the base of a tree, October 2, about noon; two males labelled October 4. There are no notes regarding the latter specimens, and the circumstances of their capture are not recalled. They may be erroneously labelled.

Females were observed mating and ovipositing on September 30 and October 1 and 12. Additional data are as follows: one ovipositing on a tree trunk and one in the grass at its base, October 2, about noon;

3 ovipositing, October 26, 2:30 P. M. (this was the first favorable day after a long period of unfavorable weather); one crawling upon the sidewalk, October 27; one upon a tree trunk at arm's reach at 3:00 P. M., October 29; one ovipositing, 1:30 to 2:30 P. M., October 31.

OBSERVATIONS ON THE EGGS

Mr. Rings counted 16,864 eggs in a particularly large and gravid female, and there is a possibility that this specimen had already been ovipositing prior to its capture. These eggs, necessarily minute, are remarkable, not only by the numbers that are produced, but because the time required for hatching requires that the winter is passed as eggs in crevices of the bark of tree trunks, a situation poorly if at all protected from temperature and humidity extremes and fluctuations, desiccating winds, or soaking rains.

The eggs laid by captive females were all stored for a time in a 4-degree C. temperature cabinet, either immediately after deposition or after being held for a month at room temperature and humidity. Some eggs stored at this temperature immediately after deposition were transferred to room temperature and 75% humidity about three weeks later. After about two months incubation, the eggs started to hatch.

A great quantity of eggs, deposited October 12 to 14, was kept, part in a corked, part in an uncorked vial, in a drawer of my desk in room 309, Botany and Zoology Building. The relative humidity of this room is estimated to vary between 15% and 35%. Both sets of eggs appeared plump and viable on November 12, at which time they were transferred to 4° C. On April 25, 1938, eggs from the corked vial were examined. Of 381 eggs, 17 were not viable at this time, having turned a brownish-yellow color, in contrast to the pearly white appearance of the others. From this vial of eggs and on this date, six lots of 50 eggs each were established to incubate at room temperature and relative humidities of 100%, 75%, 70%, 31%, 30%, and 10%.

Hatching was best at 75% and 70% humidity, and these two lots will be considered together. When examined May 15th none had hatched, but the ends were clearing. This transparency at the ends develops prior to hatching. By May 24, six eggs had hatched; May 31, 13 more; when the project was disbanded June 9th, 39 of the hundred eggs had hatched, 37 were still viable, and 24 were dead.

At 100% humidity a fungus developed, and the results were not good. By May 31st two larvae had hatched. On June 9th, 12 eggs were still viable in appearance, but it was impossible to distinguish, among the others, how many had hatched or been killed by fungus.

At 30% and 31% humidities no eggs hatched. By May 15 a number showed an indentation on one side, due to desiccation, and on May 24 all were indented. On June 9, nine eggs from the two lots looked like they might still be viable, the others were all badly shriveled.

The eggs at 10% humidity were all indented May 15th, mostly badly shriveled May 24th, and about half were dry by June 9th.

To summarize hatching where the only definite records are available: eggs deposited October 13 and 14, 1937, were kept until November 12, or for 29 to 30 days, in a corked vial at room temperature. They were then transferred to a 4° C. temperature cabinet and held until April 25, 1938, or for 170 days. They were then incubated at room temperature and 70% to 75% relative humidity. Hatching was first observed May 24th, 29 days later, and was still in progress June 9th, 45 days later. This gives a total incubation period at room temperature of from 58 to 74 days and over.

The relative humidity in the 4° C. temperature cabinet was 75%. Eggs held in this cabinet until January, 1939, failed to hatch.

OBSERVATIONS ON THE FIRST INSTAR LARVAE

Larvae hatched and kept and 75% relative humidity in the laboratory usually lived not longer than two days. They resemble minute elaterid larvae in body form and activity. At any rate, they are not extremely active, like the first instar larvae of many other insect parasites whose eggs are laid at random and whose first instar larvae must seek out the host. The larvae are not cannibalistic, and pay no attention to each other when closely confined.

The amazing fact is that any of these very small, moderately active and short-lived larvae should survive to find a host nymph. Even if their progress down the tree trunk were aided by dropping to the ground, or being blown to some distance therefrom by the wind, they are still ill-adapted by their legs or mandibles for burrowing through the soil. They may, however, be able to work their way between most soil particles because of their minute size, or follow crevices or dead root paths in the soil, and the environment of the soil atmosphere may favor longer life. Could it be possible that the ultimate host, the cicada nymph, is not the initial source of food?

DESCRIPTION OF THE EGG

The egg is minute, cylindrical, rounded at both ends, .65 mm. long and .14 mm. in diameter, with shell thin but tough, unsculptured. It is pearly white, becoming transparent at both ends prior to hatching.

DESCRIPTION OF THE FIRST INSTAR LARVAE

Body (figs. A and B).—1.06 mm. long, .14 mm. wide (specimen mounted in balsam). Elongate, sparsely setose as illustrated, white. The head is slightly narrower that the body, which is subequal in width until the 8th abdominal segment, thence tapering caudally. Body segments perceptibly decreasing in length from the prothorax to the 1st abdominal segment, thence gradually decreasing or subequal in length to the 8th abdominal segment, 9th abdominal segment as long as the 1st abdominal and 10th and last segment shorter, terminating in a 4-lobed, retractile anal process. A poorly defined sclerite, extending from the anterior margin of the prosternum to the base of the coxae, is present on the prosternum; if similar sclerites exist on the meso- and metasterna they are very poorly defined. Abdominal segments 1 to 9 each with a pair of stout cuticular spines at the anterior third or fourth, near the mid-dorsal line. A seta arises from immediately behind each spine (fig. M).

Head (figs. C and D) longer than broad, widest just before the base, bluntly rounded anteriorly. The ventral mouthparts occupy the entire under side of the head. The nasale is not differentiated and epicranial suture not evident, so that no sutures are visible on the upper surface. What appear to be a pair of ocelli are situated, one behind the other, on each side of the head, midway between the insertion of the antennae and base of head. They appear as red-pigmented spots which are often irregular in outline, or even dispersed.

Antennae (figs. G and H) are located at the sides of head, just behind and above the base of the mandibles. Each consists of a button-shaped base from which arise three appendages or processes. The largest is median, consisting of a basal sclerome and a nipple-shaped, apparently flexible tip. A slender, somewhat shorter and slightly bowed appendage terminating in a seta arises slightly above and in front of the former. The third is a slender spine situated dorsal to the first.

Mandible (fig. J) nearly the form of an equilateral triangle, its base slightly longer than the sides. Inner edge without teeth or molar structure, straight, becoming strongly rounded toward base. Outer edge bearing two setae near base, a broad, transverse notch near apex. Basal margin straight, without evident condyle for articulation, though the mandible is movable. The mandible is one-third as thick, dorso-ventrally as broad at base, and the dorsal face more heavily chitinized than the ventral.

Ventral mouthparts (figs. D, E and F) partially fused, forming a large, rounded plate, trilobed anteriorly, which occupies the entire lower surface of the head. Gular region absent. Mentum and sub-mentum fused to form a somewhat pear-shaped median portion of the plate, defined by lateral sutures extending caudally nearly to the base. The free distal portion may have a limited dorso-ventral movement, and near its tip arise the labial palpi. Each of the latter consists of a single, slightly tapering segment, twice as long as wide at base, cylin-

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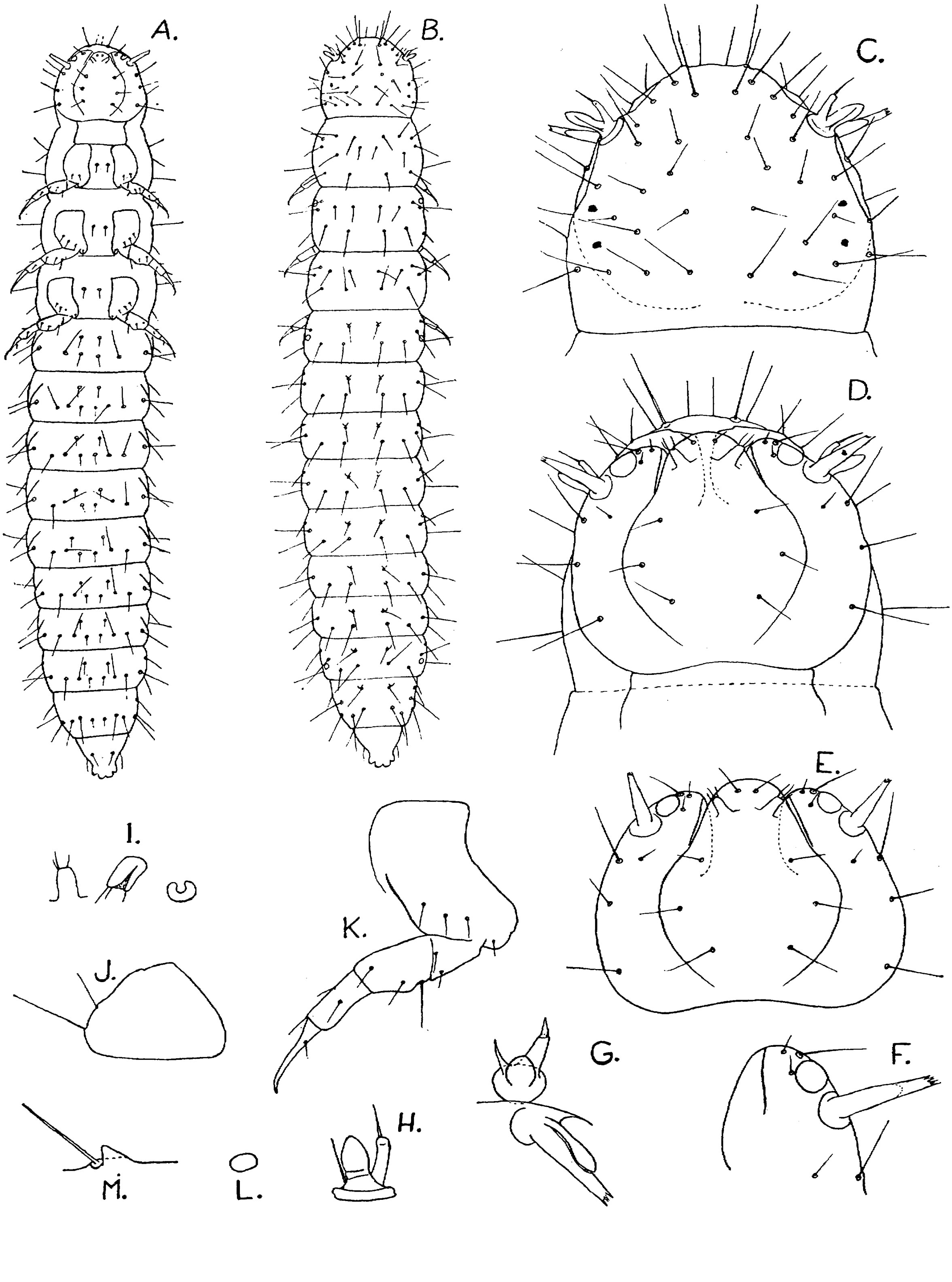
EXPLANATION OF PLATE I

All figures were drawn by aid of a camera lucida and reduced between 4 and 5 diameters in reproduction. A and B are ×120; C, D, E and K, ×400; F to J, L and M, ×600.

Slides from which drawings are made are deposited in the U. S. National Museum

A. Larva ventral view
B. Larva, dorsal view.
C. Head, dorsal view
D. Head, ventral view
E. Ventral mouthparts.
F. Maxillary mala, ventral view.
G. Antenna and maxillary palpus, as seen in lateral view of head.
H. Antenna, ventral view.
I. Labial palpus. Left to right, ventral view, dorsal view showing groove, and sectional view near tip.
J. Right mandible, ventral view.
K. Metathoracic leg, ventral view.
L. Spiracle.
M. Dorsal abdominal spine, with seta arising from behind its base.


A.
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drical, with a furrow deepening apically on its dorsal side, and three setae at its apex.

There are no sutures on the maxilla, and it must be quite incapable of lateral movement. Only the distal third, or mala, is defined by its inner margin (fig. E), and is deeply ridged most of its length on its ventral surface, near the inner margin, for reception of the distal, free portion of the labium. The maxillary palpus arises from an oval area near the middle of its lateral margin, and anterior to it is another oval area, distinguishable from the rest of the maxilla only by its periphery.

The maxillary palpus (figs. F and G) is 4 times as long as wide, widest at base and tapering apically, its apex obliquely truncate. The exact nature of the apex is not distinguishable; it seems beset with short setae. An appendage three-fourths the length of the palpus arises near to and above its base and lies closely appressed to its outer surface, which appears to be somewhat excavated for its reception. The latter is club-shaped, with a slender basal portion which is best observed in lateral view (fig. G).

The ventral mouthparts are sparsely setose, as shown in fig. E.

Spiracles (figs. L and B) are oval, simple. Three pair located on the tergites, close to the lateral margin, of the mesothorax and abdominal segments 1 and 8. The former is at the anterior fourth of the segment, the latter two just behind the middle.

Legs (fig. K) 5-segmented, terminating in a single, slender claw, curved apically.

SUMMARY

The present paper contributes several details to our knowledge of the life history and habits of *Sandalus niger* Knoch, namely, description and figures of the first instar larva, and rather extensive notes on the adults and eggs. Previous to this time briefer observations on the adults were published by Dury, 1900, and Manee, 1908, and Craighead's (1920) discovery of a parasitized cicada nymph is indicative of its parasitic nature, and has made known the characters of the last instar larva.

The complete life cycle of this remarkable insect is far from understood, and one would do well to distinguish fact from fancy in this contribution. However, with our present knowledge it is probable that *Sandalus* has a hypermetabolic life cycle as complicated as that of the Meloidae or Rhipiphoridae. The first instar larva differs radically from the last instar larva in nearly every detail, and Dr. Anderson indicates that it is unusual, among the coleoptera, to find abdominal spiracles on the first and eighth segments only.