A STUDY OF THE BIOLOGY OF THE CHRYSOPIDÆ.

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There is much of biological interest to be found in the life history of the Chrysopidæ. The group is a very homogeneous one, varying little in morphology and habits. They are of wide distribution, and one or more species in all localities visited can be appropriately classed among the most common insects. Several species are somewhat rare and difficult to collect, hence, the biological data available concerning these is still somewhat fragmentary. This brief paper is a summary of a large detailed paper, the publication of which has been unavoidably delayed.* A full report of this work is now awaiting publication as a thesis for the doctorate in the memoir series of the Cornell University Experiment Station. This report will be amply illustrated.

Life Cycle.

The total life history of the Chrysopidæ requires a period of approximately 25 to 50 days. Cold weather in the late fall or early spring greatly retards growth and development. From 4 to 12 days were required for embryonic development, the eggs hatching in midsummer in four to six days after deposition. The first molt occurs in three to seven days, or, in cool weather, in 11 days after hatching. The second molt occurs at an interval of two to seven days, the majority molting three and four days after the first molt. The third instar may vary greatly in time. Sometimes it is much prolonged, especially if food is scarce. But from the second molt to spinning the cocoon, there is usually a period of 4 to 10 days, the majority requiring five or six days. The final larval molt to the pupa occurs within the cocoon 5 to 12 days after spinning. However, in

* The writer has been studying the Chrysopidæ intensively for about five years. During this time some or all of the immature stages of fifteen species have been seen. Collections and rearings have been made at Ithaca, N. Y., where this work was begun under the direction of Professor James G. Needham, of Cornell; at Dayton, Ohio; at Milwaukee, Wisconsin; at Charlottesville, Virginia, and at Manhattan, Kansas. Through the courtesy of Dr. Nathan Banks, the Fitch, Hagen and Banks' types at the Museum of Comparative Zoology, at Cambridge, Mass., were studied.

the case of overwintering generations, which remain in the cocoon as prepupæ, this molt does not occur for a period of four to eight months after spinning. The pupa emerges from the cocoon in a minimum of 10 days after pupation. The pupal molt is at once shed and a full-fledged adult appears which may oviposit after a period of three to six days.

The Eggs.

The eggs of our Chrysopidæ, as is well known, are stalked, the stalks ranging from about four to eight millimeters in length in the different species. The stalk is composed of a gelatinous substance exuded at oviposition, which hardens quickly after being drawn out into the usual form. The eggs are elongate, ellipsoidal, and light green to distinctly greenish yellow in color. *Chrysopa nigricornis* Burm. has the longest stalks of any eggs seen, and *C. quadripunctata* the shortest. The stalks apparently vary directly as the length of the abdomens in the different species. The eggs of *C. nigricornis* are deposited on the leaves of the trees, maples by preference, and are nearly always in rather closely arranged groups, with the stalks somewhat tangled or entwined. Single eggs of this species are not uncommon, however. The other species deposit their eggs in less closely arranged and often regular groups, in rows or singly. The place of oviposition, the size of the egg, the length of stalk, and the coloration serve in practically all cases to identify the eggs of the different species.

Many abnormalities occur in oviposition which have not been described. Some of our most common species which normally deposit stalked eggs, may, under certain conditions, deposit stalkless eggs, eggless stalks, stalked eggs attached to other eggs or to their stalks. Three eggs of *C. chi* were found with their stalks united into one at about midway. In the case of our common species, these can be explained as accidents occurring during oviposition.

Oviposition has been correctly described, at least in the main, by several writers. No differences of importance have been observed in the different species. No difficulty was experienced in obtaining large numbers of eggs when the adults of our most common species were confined in vials and fed daily on plant lice. Most of this work has been carried on with

C. oculata and *C. nigricornis*. Some species, on the other hand, have consistently refused to oviposit in captivity and could not be kept alive more than a few days.

In the process of hatching, an egg burster serves to cut the initial slit in the chorion. This process has been recently described by the author and the published account will soon appear.

The Larvæ.

Chrysopid larvæ are generally described as spindle shaped. They are thysanuriform, exhibiting at the same time a quite primitive type with some remarkable specializations. Among the latter are the anal silk glands and the sucking mouth-parts. The maxillæ and mandibles are greatly prolonged forward, forming the so-called sickle-shaped jaws. The two halves are mechanically fastened together by means of a flange on the outer edge of the maxillæ working in a groove in the mandibles. A tube extends between them to the pharynx. The mandibles are quite pointed and the whole is well suited to puncturing the bodies of insects. The juices are taken up by suction effected by a heavy pharangeal musculature and by short muscles within the maxillæ which by their contraction dilate the tube leading to the pharynx.

The three parts of the thorax are each divided into two parts or subsegments. The anterior subsegment of each is much smaller than the posterior one. The posterior subsegment in all but the first and last two or three segments bears a pair of more or less prominent lateral tubercles which are beset in the third and last instar with 12–20 strong setæ. The abdomen in all species seen has ten segments. Considerable difference of opinion has arisen concerning this point. The first segment, which is short and without the lateral lobes, has been overlooked by some. It is distinctly marked by the first pair of abdominal spiracles. The last two segments are tubular and partially invaginated within themselves. The terminal segment is applied to the substratum in walking. A clear, gelatinous fluid, secreted by anal glands, gives the larva security in climbing smooth surfaces. It is well known that the larvæ of this family void no excrement. The mid intestine is closed at its posterior end. The hind intestine is quite small, in cross section appearing no larger than a malpighian tubule. The excrement is

stored in a large bean-shaped mass in the mid-intestine, and is voided by the adult immediately following the pupal molt to the adult.

The food of the larvæ is predominantly aphids. They exhibit little choice between the different species of aphids, though some are more suitable for feeding them in rearings than others. Other small or soft bodied insects, as Jassids, Capsids, Coccids, small Diptera, and many kinds of insect eggs have been used in rearing work.

The classification and identification of the larvæ of the various species is no more difficult nor complicated than the identification of adults. Most published descriptions of larvæ are inadequate for naming or placing them in a key. The black spots on the dorsum of the head serve to divide the larvæ into three groups, which in the main are most closely related as adults. The first group has two longitudinal and converging spots on the head as in the case of the following species of the genus Chrysopa; *plorabunda*, *rufilabris*, and *interrupta*. *C. bimaculata* has two narrow, black bands on the head, but they extend cross-wise and the larva is a trash carrier. The next group has three black triangular spots on the dorsum of the head. This is characteristic of *C. oculata*, (which includes the two nominal species *albicornis* and *chlorophana*, which the writer places in synonomy with *oculata* on the basis of rearings), *C. chi*, (including also the nominal species *ypsilon* also placed in synonomy with *chi*), and *C. nigricornis*. The next group have four long, narrow bands on the dorsum of the head, a short inner pair, and a longer outer pair arising at the bases of the antennæ and extending to the anterior border of the prothorax. This group contains the trash carriers, *Chrysopa lineaticornis*, *lateralis*, an unidentified species now being reared at Manhattan (thought to be *cockerelli*) and *quadripunctata*. In connection with the latter species, observations at Charlottesville, Virginia, clearly showed this species to be a transition in the trash carrying habit between the true trash carriers and the naked larvæ. Specimens were found with considerable debris on their backs, but it was not definitely arranged into a neat packet. There are more short, minute setæ on the dorsum than in the naked larvæ proper, which suggest the hooked dorsal setæ of the trash carriers.

To identify larvæ to species, the following features have been found useful in addition to the dorsal head spots; first, the general coloration of the larva, including the color, shade of color, whether solid or spotted, the markings either side of the dorsal vessel, the markings in the lateral border, and the color of the jaws and legs; and second, the size and shape of the lateral tubercles, the color and comparative size of the setæ on the same, the comparative length of the stalks of the lateral tubercles and the coloration of the same. The presence of lateral tubercles on the first abdominal segment is useful, especially in the case of *nigricornis*, which possesses them. Furthermore, if the larva carries a distinct packet, identification is simplified, for there are only a few species known to be trash carriers.

Chrysopid larvæ can be readily separated from the larvæ of the Hemerobiidæ, which they resemble closely by the following differences. Hemerobiid larvæ are generally more slender, the first subsegment of the prothorax being especially longer than in the Chrysopidæ, as is also the case with the last two segments of the abdomen. When the larvæ walk rapidly the end segments of the abdomen are lifted and carried horizontally, while the head sways from side to side with a rapid jerky motion. The prominent trumpet-shaped pulvillus which occurs on all species of Chrysopidæ seen by the writer or figured in texts is absent in the Hemerobiidæ. The lateral tubercles are also absent in the Hemerobiidæ. The dorsal and lateral setæ of the latter are very short and inconspicuous, except on the last few abdominal segments. The jaws are heavier and more nearly straight than in the Chrysopidæ. In most species they come to a point rather abruptly. No known species of Hemerobiidæ are trash carriers.

It is frequently said that Chrysopid larvæ cover themselves with the skins of their victims. In the experience of the writer, this habit is confined to a few species of trash carriers which regularly construct a neat hemispherical packet of aphid skins, insect molts or parts of insect's bodies, spider's webs, plant fibers, lichens, and other similar materials.

The writer has seen four species of trash carriers. *C. lineaticornis*, *C. bimaculata*, *C. lateralis*, and a species in Kansas now being reared. *Allochrysa parvula* Banks and *Leucochrysa floridana* Banks are in all probability trash carriers, judging

from the cocoons of these species seen at the Museum of Comparative Zoology, Cambridge, Mass. All three instars have these packets, which are constructed anew after each molt. The morphology of the larvæ is considerably modified and specialized for carrying the packet. The abdomen is much shorter, but broader and thicker than in the naked larvæ, causing it to be arched conspicuously from the first to about the seventh segment. The lateral abdominal tubercles are rather small, fleshy lobes without clearly defined stalks and the setæ are likewise short. The dorsal setæ are present and fairly prominent. In the Kansas species there has been observed one to three rows of microscopic hooked setæ on each abdominal segment from one to six, inclusive. There are six in the shortest rows and about thirty in the longest rows. The tips are bent downwards and serve to hold the packet in place. It has been usually stated that there is a gelatinous substance on the setæ holding the debris in place. The writer has not found such a secretion, but would explain the firm security of the packet on the dorsum as due to these hooked setæ, assisted by the larger dorsal and lateral setæ. The thoracic tubercles have stalks much longer than is the case in the naked larvæ, and the setæ on the first two pairs extend outward in a fan-shaped manner, turning upward at the tips. This provides an even and firm support for the anterior rim of the packet. All four of the packet bearers seen are somber gray larvæ, with little of a color pattern. All but *C. bimaculata* have the two pairs of dorsal head bands and in the last instar have posterior spots which suggest a third pair.

The first instar of all Chrysopid larvæ can be distinguished by the presence of two large setæ on each lateral tubercle except the mesothoracic and metathoracic tubercles, which bear three each. The dorsal head spot in the first instar of *C. chi*, *C. oculata*, and the varieties of each, breaks up into three spots in the third instar. In *C. nigricornis* there are three spots of the same pattern as in the preceding on the dorsum of the head in all instars.

The Pupa.

Grown larvæ normally spin silken cocoons in which to transform. The silk is produced by modified malpighian tubules and is spun through the anus. Some larvæ fail to spin a cocoon, a

few apparently making no effort to spin. If the larvæ are disturbed while spinning, they frequently fail to spin further or many spin a mat of silk upon which to transform. Larvæ have repeatedly passed through the pupal stage outside of a cocoon and one specimen wintered without this protection. The cocoons are usually placed near the feeding habitat, i. e., the tree inhabiting species, spin their cocoons on the under side of leaves or under bark. In the case of *C. oculata* it is believed that they generally spin their cocoons just under the loose earth on the ground. Cocoons of this species are not often found on plants in the field. The trash carriers use their packet as a kind of foundation or starting point for their cocoon. It adheres to one side of the finished cocoon.

The main facts concerning the spinning of the cocoon have been noted by several writers, but some interesting details have been overlooked. The larva first forms a framework by attaching the viscid silk thread to whatever supports are near. It requires an hour or more to complete the foundation, depending on how much time has been wasted seeking places to attach the thread. The larva shifts its position frequently so that the cocoon soon assumes a spherical shape. The spinning pattern during the formation of the greater part of the cocoon is a rather constant triangular design. The larva shifts each time a little to one side of a true circle, so that the wall of the cocoon is of approximately uniform thickness throughout. As the larva turns in its cramped quarters, the dorsal and lateral setæ are broken off and are spun into the cocoon structure. The triangles of the spinning pattern grow smaller and the movements of the larva become slower. The final spinning appears to be a general plastering over of the inner wall of the cocoon. This is effected by a copious silk secretion being spread by the last segment of the abdomen. The cocoons are completed in most cases in about 24 hours, some requiring a little more time, a few finish in less time.

Especial effort was made to observe the manner of emergence from the cocoon, but with only partial success. It is believed that the circular lid through which the pupa emerges, tears in that peculiar manner as the result of the spinning pattern, and that it is torn by internal pressure exerted by the pupa. The writer is not positive whether the large pupal mandibles assist in starting the tearing at emergence; in his opinion it is possible

that they may assist but probably not necessary. It has been observed in the more transparent cocoons of *rufilabris* and *plorabunda* that the pupæ within the cocoons are capable of shifting their positions very easily and rapidly.

Just before emergence, the pupal coloration and characters can be seen rather clearly in most cocoons. The pupal disc is the old larval molt and immediately before emergence is quite black. The golden or brownish eyes of the pupæ can be seen, while the general color of the cocoon changes from the pearly gray or white of the newly spun silk to yellowish in *quadripunctata* to a distinct green in *harrisii*.

The Adult.

The chief points of importance in connection with the adult which it is desired to describe here are the length of life, number of eggs laid, food, and ecological distribution. It is usually stated that the adults are short lived. Some of the less common species could not be kept alive in captivity longer than a few days to a week at the most, but, of the commoner species, two females of *C. oculata* lived 42 and 34 days, depositing 617 and 470 eggs, respectively. Dissections showed that neither had deposited their full quota of eggs. These are records in both cases. Adults of *C. plorabunda* have been be kept alive over winter. *C. rufilabris* and *C. harrisii* were also kept alive from late September until the latter part of December. Overwintering specimens can be distinguished from normal specimens by the brownish color which replaces the green, a change brought about comparable, it is thought, to the discoloration in autumn leaves.

Some confusion exists concerning the feeding habits of adults. Specimens of *oculata*, *rufilabris*, *nigricornis*, *plorabunda*, *chi*, and *quadripunctata* were kept alive for relatively long periods by daily feedings with aphids or weak sugar solution, and water. Our common species feed upon aphids, without doubt, and other small, soft bodied creatures. It is believed that the adults feed upon approximately the same species of aphids as the larvæ of the same species. This explains why adults go to aphid infested plants to oviposit rather than the doctrine of parental solicitude for the young. Adults of *lineaticornis*, *harrisii*, *cockerelli*, *Meleoma signoretti*, and other less common species could not be kept alive very

long on common aphids. It was thought that their particular kinds of food were not supplied, rather than that they took no food. It is therefore held that the economic importance of this family is much greater than has been usually stated.

Fairly definite habitats were observed in the species studied. *C. oculata* and varieties are the most common and most widely distributed garden and field types. *C. plorabunda* is here our most abundant field species. *C. nigricornis*, *C. rufilabris*, *C. harrisii* and *C. lineaticornis* are tree forms. *C. harrisii* is especially partial to pine, while *lineatricornis* and *quadripunctata* seem to prefer oaks. *C. nigricornis* and *rufilabris* are found on a variety of trees, but maples probably predominate. Adults can best be collected by beating the bushes with a long stick and then catching the adults with a net as they fly out into the open.