WATER BEETLES IN RELATION TO PONDFISH CULTURE, WITH LIFE HISTORIES OF THOSE FOUND IN FISHPONDS AT FAIRPORT, IOWA.

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INTRODUCTION.

IMPORTANCE OF WATER BEETLES.

The beetles are far more numerous than any other order of insects and are very cosmopolitan in their distribution. Every natural pond, river, and stream is peopled with them, and if one constructs an artificial fishpond in all probability beetles will constitute its first and most permanent insect inhabitants. Pondfish culture, therefore, in order to prove successful, demands sufficient acquaintance with the water beetles to yield a workable knowledge of their economic relations to the fish. The following paper is a beginning toward such an acquaintance and endeavors to suggest lines of research that may prove both interesting and profitable to the fish-culturist.

IGNORANCE OF AMERICAN SPECIES.

Unfortunately, while our American water beetles are fairly well known to the systematist, so that they appear in museum collections and lists of species, very little is known about their life histories, their habits, and their economic importance. According to Comstock (1912), at least 300 species of carnivorous diving beetles (Dytiscidæ) occur in this country, 40 species of whirligig beetles (Gyrinidæ), and 150 species of water scavenger beetles (Hydrophilidæ). Moreover, there are 25 species of herbivorous water beetles (Haliplidæ), a family only briefly mentioned by Comstock. Out of this total of more than 500 species, which is probably far below the actual number, the habits and complete life histories of only about 20 are known. The partial development of 15 other species has been recorded, chiefly the egg cases and newly hatched larvæ of hydrophilids by Richmond (1920). This excellent paper also gave valuable keys for the identification of the egg cases, larvæ, and pupæ of the Hydrophilidæ, but nothing of the sort has been published for the other families.

Abstracts of one or two of these published life histories, which are important from the standpoint of fish culture, are included in the present paper, and in addition those of 20 other common species are presented, together with the economic relations of the entire group.

With our present meager knowledge outside of the Hydrophilidæ it is not safe to name the larvæ and pupæ of any species, even tentatively, by basing our judgment on the known fauna of the pond from which the specimens were taken, on their size, or on any likeness they may show to European forms. All but one of the species here presented has been reared from the larva to the imago, thus making its identity certain.

LAKES VERSUS FISHPONDS.

Attention should be called to one very pronounced difference between the fauna of a lake and that of an ordinary fishpond. In the former water beetles are almost entirely lacking; in the latter they are one of the most abundant groups present.

Muttkowski (1918, pp. 413, 414), in discussing the fauna of Lake Mendota, said:

> With all their manifold adaptations to an aquatic life, aquatic beetles, except for a few species, are scarce in the lake complex * * *. The Hydrobiidæ, Dytiscidæ, Hydrophilidæ (except Berosus), Donaciinæ, and Gyrinidæ, the latter despite the water-breathing larvæ, are practically absent from the lake community. The typical lake Coleoptera are the Haliplidæ in the vegetation zone and the Dryopidæ in the rocky and gravelly areas, while several species of adult Dytiscidæ are locally abundant * * *. The difference between the lake and other aquatic communities is very marked in late summer, when sheltered water, such as the lagoons in the parks and the several ponds and creeks about the lake, teem with young dytiscid larvæ of several species, while such larvæ are conspicuously absent from the lake.

Baker (1916, p. 308), in his discussion of the relations of mollusks to fish in Oneida Lake, N. Y., gave a list of the plants and animals found associated with the mollusks. There were included only two species of dytiscids, one haliplid, three gyrinids, and two hydrophilids. Of these, two species were found only in the stomach of the painted terrapin, leaving six species for the fauna of a lake 21 miles long and 5.50 miles wide.

Sherman (1913, p. 44), in summing up the habits of the Dytiscidæ, said:

> In the larger bodies of water it is very difficult to locate any beetles, and in them, whether swamps, ponds, or rivers, the beetles seem to occur only in very limited spots, which are usually separated from the main sheet of water, such as the eddies or small pools along the shore. In fact, the small water bodies are always best, and the time most favorable for collecting is when the water is low or almost dried up.

In marked contrast to this scarcity in large bodies of water is the abundance of beetles in the smaller ponds. The largest of the Fairport ponds is but a trifle more than an acre in area, and yet in the fauna of them all beetles are among the most numerous insects both in number of species and in individuals. Pond 5D, just an acre in area, yielded 39 species, while 2E, only 0.13 of an acre, contained 31 species, and 12B, less than 0.02 of an acre, contained 17 species.

METHODS.

All the different beetle larvæ that could be obtained were first studied in detail until they could be easily recognized. When the larva leaves the water in order to pupate, it either buries itself in the mud or constructs a pupal chamber, and on transforming throws off the old larval skin. As a part of this skin the chitinous covering of the head remains entire, with the antennæ and mouth parts still attached, and the species can be recognized as easily from these discarded skins as from the living larvæ.

Then a search for as many pupæ as could be found was made along the shores of the ponds, and in every instance care was taken to secure the old larval skin from the inside of the pupal chamber. In this way the larvæ and pupæ were definitely related, one to the other, and the pupæ were then kept in suitable terraria until the adult beetle emerged. On transforming from the pupa to the adult the old pupa skin is thrown off and may be obtained from the pupal chamber and used to identify the species.

One of the best methods with the larger species, when a pupal chamber is found on a pond shore, is to leave it as nearly intact as possible. By cutting around it with a knife blade a small cube of earth containing the chamber may be removed. This cube can then be kept in a terrarium until the adult beetle emerges, and the chamber will contain both the larval and pupal skins. If the chamber has been opened during the removal, it should be covered again with a pellet of mud before being placed in the terrarium. Darkness is necessary for the best success in rearing the specimens. In the case of the smaller species, and often with the larger ones, the natural pupal chamber is destroyed when the pupa is found. In such cases they will thrive equally well in an artificial chamber, made as nearly the size and shape of the original as possible, and with a removable cover, so that the development of the pupa may be watched from day to day. Frequently the pupal chamber will be found to contain a larva not yet transformed, and sometimes a larva can be obtained that has come out of the water but has not yet begun to build its pupal chamber. These can be dealt with in the same manner as the pupæ, and if placed in artifical chambers will go on with their transformation.

A convenient terrarium can be made as follows: Punch the bottom of a small cylindrical tin box full of holes and stand it upright in the center of a large iron pan. Fill the pan half full of sand around the upright box, then pour water into the latter until the sand is thoroughly wet. The cubes of earth containing natural pupal chambers and the artifical ones made in imitation of them can be placed upon the wet sand, which will keep them from drying up. By renewing the water in the central box as fast as it disappears the sand, and with it the pupal chambers, may be kept at just the right degree of moisture, which should be the same as that of the earth from which the larva or pupa was originally obtained.

Certain habits of the larvæ and adults, such as swimming and breathing, can be watched better in an aquarium in the laboratory than in their natural environment. There are other habits, however, such as feeding, deposition of the eggs, and formation of the pupal chamber, upon which reliable information can be obtained only by watching the beetles in their normal habitat. When transferred to aquaria both adults and larvæ will eat almost anything that is furnished to them. Carnivorous species usually devour animal food and herbivorous species vegetable food. If kept in confinement, however, under stress of hunger they may radically change their diet. It is probable that they are rarely compelled to do this under natural conditions. What they eat in an aquarium, therefore, is an excellent criterion of their ability to adapt themselves to circumstances and shows how far they are able to overcome adverse conditions. It may also be extremely useful in suggesting available food upon which they can be reared during experimentation, but it does not indicate their natural food preference any more than a prison menu indicates the preferences of a convict. The food of the species here given is to be understood as the result of observations made in the ponds. What they were known to eat in the laboratory is so stated and is included for the reasons just given.

Much also can be learned under artifical conditions about the methods employed by the different species in the construction of their pupal chambers; but the distance they travel from the water's edge and the kind of a location they choose can be judged only by finding the pupæ *in situ* on the shore of the pond.

The same is true of the materials used. There is no sand on the shores of any of the ponds, and of more than 100 pupal chambers of *Dineutes americanus* collected during the last three summers, every one was made of moist earth pellets. Yet when six larvæ, whose freshly made pupal chambers had been hopelessly broken, were transferred to a suitable terrarium and each constructed a new chamber, two used entirely moist sand instead of earth pellets. The methods employed with both materials were exactly the same, however.

ECOLOGY.

MODIFICATIONS OF STRUCTURE AND VESTITURE.

All beetles that live in the water show some modifications of structure and vestiture to fit them for their aquatic life. This fact was noted by Leng (1913, p. 32) in a paper on aquatic Coleoptera in the Journal of the New York Entomological Society. He added that the modifications were more noticeable in the adults than in the larvæ. These modifications serve varied and quite different uses and may be concerned with locomotion, with sex activity, with flotation, with respiration, and with sight. They can be considered most conveniently in connection with the various functions they assist.

LOCOMOTION.

The beetle larvæ can all walk, but none of them move fast enough to warrant the assertion that they run. Most of them can swim, and a few can jump; that is, they can throw the body a short distance by kicking with the legs or by suddenly flexing the posterior portion of the abdomen. The relative locomotor ability of the various larvæ is given under each species separately. In general, the dytiscid larvæ are excellent walkers and swimmers, and some of them can jump. The two species of Laccophilus are the best walkers and the most agile larvæ of all those studied, the two species of Thermonectes are the best jumpers, and the Cybister larva is the most active swimmer. The hydrophilid larvæ are fair walkers and good swimmers, but none of them so far as known can jump. The gyrinid larvæ are good walkers and excellent swimmers, while the Dineutes larvæ can jump, although not as well as the Thermonectes larvæ. The haliplid larvæ can only crawl, they can neither swim nor jump, and all their movements are extremely slow. Yet the Peltodytes larva, when ready to pupate, travels farther from the water's edge than the much larger Cybister or Hydrous larva.

Leng (1913, p. 35) made a curious statement with reference to these larvæ: "The larvæ of the Haliplidæ, Dytiscidæ, Hydrophilidæ, Gyrinidæ, and Parnidæ are purely aquatic, living wholly in the water, but not swimming." This applies only to the Parnidæ and Haliplidæ; the others can and do swim.

The adult beetles can walk, run, jump, swim, and fly with varying ability. Flying is the means of locomotion by which they travel from one body of water to another and so disseminate their species. The larger species of dytiscids and hydrophilids can cover long distances and are sometimes found at night around electric lights far removed from any water. Many instances of their capture about these lights are recorded by Sherman (1913) in his paper on "Some Habits of the Dytiscidæ." Needham in "Fresh-water Biology" (1918, p. 905) said of Hydrous: "It is attracted to electric lights in vast numbers in the spring, where it falls beneath them and flounders around in the dust of the street. * * * Another hydrophilid, which often swarms into trap lanterns set over streams, is Berosus." Yet most of the adults can be safely kept in an open aquarium. Though the gyrinids have to climb up on some support above the water before they can spread their wings for flight, yet once started, they prove to be strong fliers, for Fall (1901, p. 55) has recorded: "I have seen hundreds of *Gyrinus consobrinus* about the electric lights at Riverside (Calif.) in May."

The order of excellence in swimming and walking amongst a series of representative adult dytiscids has been determined by student classes at Lake Forest for a number of years, and, with the addition of jumping, was published in the American Naturalist (Needham and Williamson, 1907, p. 480). The general conclusion that increasing fitness for swimming accompanies increasing unfitness for walking and running seems to be well established. Incidentally it may be noted that the Gyrinidæ show this nearly as well as the Dytiscidæ. Swimming with such swiftness and agility that it is almost impossible to catch them without a net, once they are removed from the water they prove to be very poor walkers, and can not run at all.

Jumping seems to be a function peculiar to the dytiscids and gyrinids, and so far as known is not found at all among the hydrophilids and haliplids. There is another dytiscid whose jumping ability exceeds that of *Laccophilus maculosus*, the champion of the Lake Forest tournaments. This is *Thermonectes ornaticollis*, which, when captured in a net, leaps about like a small frog. Another peculiarity, not mentioned by Needham and Williamson, is that both Laccophilus and Thermonectes can jump when lying on their backs as well as when right side up. The ability to jump is evidently dependent upon the flattening of the hind legs, which brings the basal joints into one plane of action, and greatly increases their efficiency in that plane. To compensate for the lack of ability to jump, all the adult hydrophilids and haliplids are good walkers, and many of the former can run with agility.

The relative swimming ability of the dytiscid and the hydrophilid is well shown when they come to the surface for fresh air. The hydrophilid swims well but not rapidly, turns on its side as it reaches the surface, pauses an instant, and then swims back to the plants below. The dytiscid sweeps to the surface like a flash and without a sensible pause darts back again. The direction of its movement is the only indication that it has obtained a new supply of air. The actual taking of the air is too rapid to be detected, although it can be plainly seen in the hydrophilid. Miall (1895, p. 74) has noted another difference between the swimming of the hydrophilids and dytiscids. The former, together with the haliplids, use their oar legs alternately, whereas the latter move them in unison. In other words, the dytiscids gallop, but the hydrophilids and haliplids merely trot, and there is a corresponding difference in the rapidity of the resultant motion. The inability to jump on the part of these last two beetle families may be due to the fact that they can not, or at least do not, move their hind legs in unison.

To summarise, the adult dytiscids are excellent swimmers, excellent jumpers, and poor walkers, without any ability to run. The hydrophilids are good swimmers, good walkers, and good runners, but can not jump at all. The gyrinids are excellent swimmers, fair walkers, poor jumpers, and can not justly be classed as runners. The haliplids are excellent walkers and can run with considerable agility, but are very slow swimmers and can not jump.

MIGRATION FROM ONE POND TO ANOTHER.

The marked differences in the fauna of adjacent ponds and the restriction of so many species to comparatively limited areas is the more remarkable in view of the rapidity with which a new pond is populated when filled with water for the first time.

The following is taken from manuscript notes made by Geo. B. Lay during the summers of 1916 and 1917: On the morning of July 22, 1916, water was first let into two newly constructed ponds, numbered 2 and 3, series E. At 4.30 p. m. the ponds were full of water, but absolutely devoid of beetles.

After standing for 24 hours the following beetles were obtained from the two ponds, *Dineutes americanus*, *Gyrinus ventralis*, *G. limbatus*, *Hydrous triangularis*, *Tropisternus lateralis*, *Coptotomus interrogatus*, *Berosus striatus*, *Peltodytes edentulus*. On the 25th *Laccophilis maculosus* was fairly abundant, and a few *Laccophilus proximus*, *Acilius semisulcatus*, and *Haliplus triopsis* were taken. One *Hydroporus consimilis* was captured. On the 26th seven adult *Hydrous triangularis* were secured from pond 3, and 18 from pond 2. Two egg cases were found in pond 3 and one in pond 2, and in both ponds the eggs hatched a few days later. On the 27th six more adult *Hydrous triangularis* were captured in pond 2 and five in pond 3. On the 28th *Dytiscus hybridus* was taken in pond 3, and there were a few small larvæ in both ponds. These observations show how quickly any pond situated near others will become populated with adult insect life.

In 1918 pond 2E was drained July 9 and left absolutely dry until August 15, when it was refilled. During this month the bottom of the pond became hard and thoroughly baked in the hot sun, so that all insect life was destroyed. The present author examined the pond August 16, the morning after it was filled, and found the following beetles in it: *Tropisternus lateralis*, abundant; *Coptotomus* *interrogatus*, common; *Tropisternus glaber*, two specimens; *Berosus striatus*, abundant; *B. perigrinus*, one; *Philydrus ochraceus*, one; *Peltodytes edentulus*, a few; *Laccophilus maculosus*, one. Yet *Berosus striatus* and *Peltodytes edentulus* were two of the beetles that were not found in pond 9D, although they were common in 8D, next to it.

DISTRIBUTION ACCORDING TO SIZE.

Needham and Williamson, in the paper already referred to, while discussing the distribution of the Dytiscidæ in the "Gym" pond at Lake Forest, made the following statement (1907, p. 478):

> The shoreward distribution of these beetles corresponds roughly with their size; the largest are found in the deepest water, the smallest nearest shore.

On the following page this statement is somewhat modified.

> It must not be understood that there is any such definite and sharply limited zonal distribution as aquatic plants on such a sloping shore often exhibit. That is not to be expected in animals possessed of such excellent powers of locomotion. We have meant to indicate merely the favorite haunts of each species, and the general correspondence between the size of the beetle and the depth of the water.

If the beetle list be extended to include the Hydrophilidæ and Haliplidæ, the modified statement probably still holds good, but it does not apply at all to the Gyrinidæ. Moreover, it is profoundly modified by the breeding habits of the various species. During the breeding season beetles of all sizes gather indiscriminately in the shallower waters near the shore for the purpose of depositing their eggs. In June, July, and August, the months during which the present investigations have been conducted, there is practically no distribution according to size. The same sweep of the net will capture *Hydrous triangularis*, the largest beetle in the ponds, and such microscopic forms as *Laccobius agilis* and *Hydrovatus pustulatus*. Another sweep will bring up *Dytiscus hybridus* and *Bidessus lacustris*, with beetles of various intermediate sizes. *Hydrophilus obtusatus* and *Tropisternus nimbatus* are nearly always associated, and yet the former is fully twice the size of the latter. After the breeding season is over, however, the beetles probably separate more or less according to size, the same as the other denizens of the pond.

STRUCTURAL ADAPTATIONS.

FOR LOCOMOTION.

Doctor Sharp (1882) in his monograph on the Dytiscidæ called attention to certain structural modifications which help in adapting the beetles to their aquatic life. These were afterwards explained in greater detail by Needham and Williamson (1907) and may be briefly summarized as follows: The three principal adaptations that are concerned in locomotion are an increased body rigidity, a diminished resistence to the water, and an increased swimming efficiency of the hind legs. Body rigidity has been secured by compacting together the various parts of the body, thereby greatly reducing, and usually entirely eliminating, the flexibility found in land beetles. The head is immersed in the front of the thorax; the three divisions of the thorax and the abdomen segments are tightly telescoped together; the elytra are closely joined to the prothorax in front, to each other along the mid line, and to the sides of the abdomen along their lateral margins.

Diminished resistance to the water has been effected first and most notably by this very compacting together of the body parts, thereby getting rid of gaping joints, interstices, and irregularities of the surface; by the rounding and smoothing of the body contours into a boat-shaped form; by the reduction of spines, hairs, and sculpture on the body, especially on the dorsal surface; by the reversal of the antennæ, and in the Dytiscidæ and Gyrinidæ by the folding of the first two pairs of legs into concavities on the ventral surface of the thorax, and by the conspicuous flattening of the hind legs.

The increased swimming efficiency of the hind legs has been brought about by the transformation of the coxæ into large flattened plates, securely welded to the ventral surface of the metasternum, thus furnishing an exceptionally rigid supporting base; by the flattening of the remaining joints of the leg into one horizontal plane; by the shortening of the proximal and the lengthening of the distal joints; by the development of swimming fringes of long hairs along the margins of the tarsus and sometimes of the tibia, and by the reduction of the terminal claws.

FOR RESPIRATION.

Since both the larva and the adult live in water, some provision has to be made to supply them with oxygen. In discussing the various methods by which this is accomplished it will be convenient to separate the two stages.

In the adult beetles the modifications of structure for the purpose of breathing are as interesting as those concerned in locomotion. They consist in a migration of the spiracles onto the dorsal surface of the body, so that they are entirely covered by the elytra. Attention has already been called, in the compacting of the body, to the tight joints made by the elytra with the prothorax, with each other, and with the sides of the abdomen. A reservoir for air is thus formed between the elytra and the dorsal surface of the body, which when filled enables the beetle to breathe while it is beneath the water. This reservoir is supplied in various ways.

In the Dytiscidæ the posterior end of the abdomen is projected above the surface of the water and the elytra are lifted slightly, enabling the air to enter directly. According to Brocher (1911a) the beetles in this family breathe by drawing in air through the last two adbominal spiracles and expelling it through the others, particularly the anterior pair. He also found in Cybister air pockets in the muscles of the meso and meta thorax, directly connected with the anterior spiracles, but he did not think any large amount of air was stored in them.

In the Hydrophilidæ the elytra are strongly arched, thus creating a relatively large reservoir for storage of air. This is not filled directly by thrusting the posterior end of the body above the surface, as in the Dytiscidæ. On the contrary, the angle between the head and the prothorax on one side is brought to the surface and the club-shaped antenna on that side is carried outward until it comes in contact with the air above the water. It is then folded back again, carrying a bubble of air with it. Some of this air is spread over the ventral surface of the body in a thin, silvery film, and some of it finds its way to the reservoir under the elytra through a groove between the meso and pro thorax. Thus, the structural modifications for respiration in this family include the arching of the elytra, the modified antennæ, whose enlarged club-shaped terminal joints are covered with a dense coat of fine hair, the groove opening into the dorsal reservoir, and an enlargement of the meso and meta thoracic and first abdominal spiracles.

In the Haliplidæ the elytra are held firmly in place by groovings in the pleura and by knoblike structures at the outer ends of the posterior coxæ. The latter are not soldered fast to the metasternum as in the other families, but are free and project backward far enough to cover from three to five abdomen segments. The posterior end of the body is thrust out of the water, and air is admitted to the space between the broad posterior coxæ and the ventral surface of the abdomen. This air finds its way to the reservoir beneath the elytra through a groove in the pleurum at the anterior end of each coxa. The structural modifications in this family thus include the peculiarly modified posterior coxæ, the grooves leading to the dorsal reservoir, and the enlargement of the metathoracic and first abdominal spiracles.

In the Gyrinidæ the lateral or outer margin of each elytron is turned downward and a little inward and its free edge is grooved. The lateral margins of the meso and meta thorax and the anterior abdomen segments are fused and raised into a longitudinal ridge, which fits into the groove along the edge of the elytra, the two locking together like the lateral hinge on a fresh-water mussel. Opposite the junction of the meso and meta thorax is a rounded peg just inside the edge of each elytron, which fits into a socket in the thorax and holds the elytron securely in place. In Dineutes at the posterior end the under surface of each elytron and the upper surface of the abdomen segment immediately beneath it are covered with short hairs, which make a tight joint when the elytra are closed. In Gyrinus the same closing of the joint is accomplished by a transverse ridge, which runs around the posterior end of each elytron on the under surface. The air enters the dorsal reservoir through a groove just inside the posterior end of the turned-down lateral margin of each elytron. In this family, accordingly, the structural modifications for breathing consist in the interlocking margins of the elytra and the body, in the peg for fastening the two together, and in the posterior groove for the admission of air. The spiracles are all about the same size.

In the larvæ there are two methods of supplying the lateral tracheæ with air—one by direct admission above the surface of the water, the other by infiltration. For the former it is necessary that the tracheæ open externally at the posterior end of the body; that this opening be closed in some way while the larva is beneath the water; and that some provision be made for holding the larva at the surface long enough to thoroughly aerate the tracheæ. In the dytiscid larvæ the tracheæ open at the extreme posterior end of the body close to the dorsal surface. Beneath them on the ventral surface are given off a pair of cerci which are heavily fringed with setæ. The extensor muscles operating these cerci run from the base of the latter to the dorsal surface of the abdomen, around the tracheæ. They are so arranged that when the cerci are extended parallel with the body axis or nearly so the posterior openings of the tracheæ are closed by the contraction of the muscles.

When the larva thrusts the posterior end of the body above the surface of the water to breathe, the cerci are turned down at right angles to the body axis on top of the surface film. This is done by contracting the flexor muscles and relaxing the extensors, thereby opening the tracheæ. In the hydrophilid larvæ the tracheæ open in the bottom of a transverse groove, which is connected with the base of the cerci in such a way that it is kept closed when the cerci are extended but is opened when they are flexed. Incidentally the turning down of the cerci onto the surface film of the water supports the larva while it is breathing. The operation of the cerci in both these families has been well described and figured by Brocher (1913, Dytiscidæ, p. 125, text figs. 2 and 5) and d'Orchymont (1913, Hydrophilidæ, p. 202, text figs. 22 and 23).

An infiltration of air occurs in the haliplid and gyrinid larvæ and in exceptional genera of the Dytiscidæ (Coptotomus) and the Hydrophilidæ (Berosus). This is accomplished by the presence in the larvæ of lateral gills along the sides of the abdomen and in the haliplid larvæ by jointed spines on the dorsal and lateral surfaces of the thorax and abdomen. Branches of the lateral tracheæ run out into these gills or spines and there give off fine tracheoles, through whose thin walls the air infiltrates from the water.

FOR FLOTATION.

Formerly the film of air clinging to various parts of the bodies of adult beetles was universally regarded as designed for breathing purposes. Brocher (1914a), however, has clearly demonstrated that it is not used for that purpose but for something very different, and his idea has been accepted by Leng (1913) and others.

According to this interpretation the air film of a beetle corresponds to the air bladder of a fish and is concerned with flotation or the maintenance of equilibrium. In the Dytiscidæ the dorsal surface of the abdomen behind the elytra is covered with a heavy pubescence to which a bubble of air clings when the beetle dives. But this is an exhaled bubble and not one that is to be inhaled.

In the Hydrophilidæ the terminal joints of the antennæ, the ventral surface of the thorax, the whole of the first and varying amounts of the succeeding abdomen segments are covered with a fine pubescence, which retains a film of air when the beetle is submerged. Since the hair by entangling the air keeps the body dry, it has received the name of hydrofuge pubescence. Its real use, however, is not to keep the water away from the body, but by entangling the air to lessen the specific gravity of the beetle and thus aid it in locomotion.

In the Gyrinidæ also the ventral surface of the body is covered with short hairs, which entangle a film of air, and this aids in supporting the body upon the surface of the water. This film seems intended entirely for flotation, and none of it, as far as known, is used for respiration.

In the Haliplidæ, as in the Dytiscidæ, there is often an air bubble at the posterior end of the elytra. This must be exhaled air, however, since the air supply enters the dorsal reservoir by way of the coxal plates and the pleural grooves. The tip of the abdomen is hairy on the dorsal surface, and the pleural grooves are lined with fine hairs. These seem rather to prevent the entrance of water than to retain an air film, and the latter is not present in any of the genera. Evidently there is enough buoyancy in the air carried under the coxal plates and beneath the elytra to obviate the necessity of an air film.

FOR SEX FUNCTIONS.

Certain structural modifications that are evidently designed for sex functions are found in the males of these beetles. Amongst these is the enlargement of one or both of the anterior pairs of tarsi, which is carried much farther than in terrestrial beetles. Attention has already been called to the smooth and polished surface of the adult beetle as a help in locomotion through the water; but such a surface is very difficult to grasp and hold by any ordinary means. Accordingly, the tarsi of the males are modified in many of the genera by the dilation of the basal segments, by the formation of palettes or suckers on the ventral surfaces of these expanded segments, and by the secretion of a peculiar viscid fluid. This fluid is secreted by glands inside the tarsus and is carried by ducts to the base of the columella or stalk on which the palettes are borne. The stalk is hollow and conveys the fluid to the disk of the palette whenever the latter is pressed against any surface. The fluid spreading over the surface of the disk affords a secure attachment on any smooth surface to which the disk may be applied. The arrangement of the dilated segments and their disks will be described under the separate species.

FOR SIGHT.

Another remarkable structural modification is concerned with sight and furnishes the most distinctive characteristic of the Gyrinidæ. Their eyes are completely divided by the lateral margins of the head, leaving half of each eye on the upper surface of the head with which to look into the air and half on the lower surface with which to look into the water. They are thus admirably suited for their whirligig mode of life on the surface of the water. No such modifications are found in any of the other families of water beetles.

ENEMIES OF LARVÆ.

THE LARVA.

The larva itself is its own worst enemy. All the larger larvæ among the Dytiscidæ, Hydrophilidæ, and Gyrinidæ are cannibals, and when kept together eat one another relentlessly until only one remains. *Hydrous triangularis* spins a silken cocoon in which are deposited about 100 eggs. When these hatch, the tiny larvæ begin their warfare on one another as soon as they are born, and many of them are eaten before they ever leave the cocoon. Not even the presence of an abundance of suitable food affects their cannibalism in the slightest. The first question for settlement with them is the survival of the fittest, and as long as another of their kind is present and the two can find each other, this question demands an immediate answer. Some of the smaller species of these three families and all the haliplid larvæ are free from cannibalism. In consequence they may be safely kept together in an aquarium and their entire life history worked out in detail. This has actually been accomplished by Matheson (1912) for some of the Haliplidæ, by Needham and Williamson (1907) for Hydroporus, and by the writer for both Hydroporus and Enochrus.

On the other hand, cannibalism in so many of the species is a very serious obstacle to the attainment of their full life history. Needham and Williamson (1907) related a characteristic experience with one of these species. They tried various devices to prevent them from eating one another; they even went so far as to construct a series of small wire chambers in which individual specimens could be kept separately. The partitions between the chambers projected some distance above the surface of the water, but in the night the isolated larvæ climbed out of the water and over the tops of the partitions and ate one another just the same, leaving but a solitary victor in the morning. The present author has experimented with all but one of the species whose life history is here given and several besides. Hydroporus, Enochrus, and *Tropisternus mixtus* are the only ones outside of the Haliplidæ whose larvæ could be induced to live together in peace.

TIME OF PUPATION.

This is a critical period in the life of a larva; it must then emerge from the water and either build its pupal chamber or find a place where it can hollow out one in the mud. The danger varies with the length of time the larva remains uncovered, and in this particular those that bury in the mud have a decided advantage. The larva of Berosus, Tropisternus, Laccophilus, or Coptotomus does not travel far from the water's edge before it begins to burrow into the mud, where it is soon covered and protected. Once beneath the surface of the ground it can take as much time as necessary in fashioning its pupal chamber.

On the other hand, a larva like that of Thermonectes must gather mud into pellets and build itself a chamber, and not until the latter is fully completed is the larva safe from its enemies. It is even worse in the case of the Dineutes larva, whose pupal chamber is constructed with more care, and hence requires a much longer time for its completion. Such enemies as parasitic Hymenoptera and Diptera, Carabid beetles, and the like, have more time to locate these larvæ, and it is not unusual to find the beetle pupæ infested with the larvæ of these parasites. Then, too, there are enemies like the frogs and turtles, which sit on the bank and watch for their prey. The mud-burrowing larvæ quickly bury themselves and escape notice, but the movements of Theromonectes, Dytiscus, and Dineutes larvæ attract attention and reveal the presence of the larvæ to their enemies.

Again rapidity of movement, especially locomotion, becomes a vital factor at this critical period. Thermonectes is very agile in all its movements and quickly throws together the fragile walls that constitute its pupal chamber. This partially compensates for the attention it attracts and helps it to escape danger. Dineutes however, is slow and sluggish and does nothing with rapidity, and hence it more often becomes infested with parasites. The Berosus larva is another slow mover, and many more of them than of the agile species fall victims to the parasites.

DRAGONFLY NYMPHS.

The larger nymphs, like those of Aeschna, Anax, and Libellula, eat beetle larvæ, even including those of Hydrous and Dytiscus. The mature nymphs in June and July can easily overpower a dytiscid or a hydrophilid larva an inch or more in length, and of course any of the smaller species. The voracious Tropisternus larvæ frequently finish a long orgy of gluttony and cannibalism by passing down the throat of an Anax nymph. Five half-grown Anax nymphs were captured July 20, 1920, in pond 5D with Tropisternus larvæ in their jaws.

MITES.

As a rule, beetle larvæ are free from mites and pests of similar kinds, but several larvæ of *Cybister fimbriolatus*, captured in pond 5D in July, 1920, were each infested with a single large mite, which had fastened to their leg and was distended with blood. One such parasite could do but little harm, but if the number were increased they might easily become a menace.

HYDRA.

While examining some Spirogyra and other filamentous algæ for haliplid larvæ a considerable number of hydras were found. One of them had captured a young larva of *Laccophilus proximus* and was ingesting it. Of course, this might have happened during the handling of the material, but the fact that the larva had been paralyzed and was being eaten would show that small larvæ are subject to this peril if they once come within reach of the hydra. To this danger the slow-moving haliplid larva, which feeds upon the algæ, must be especially subject.

ANTS.

Ants of many species swarm everywhere around the margins of the ponds and are always on the alert to seize any larvæ they can overcome. Most of the larvæ are too large and active for them, but occasionally one of the smaller species gets crippled and is then quickly pulled in pieces and devoured.

TURTLES.

Small turtles are apparently fond of both larval and adult beetles. Baker (1916, pp. 231–233) reported the examination of the food contents of 15 specimens of the painted turtle (*Chrysemis picta*). Three of them had eaten beetles including both land and water species. In one 60 mm. long the wing cases of beetles formed 5 per cent of the food mass in the intestine. Another, 41 mm. long, had eaten 9 adult *Hydrovatus pustulatus* and 10 larvæ of Peltodytes, forming 40 per cent of its food. The third, 40 mm. long, had eaten 10 adult *Hydrovatus pustulatus* and 1 larva of Peltodytes, constituting 15 per cent of its food.

FROGS.

Two frogs are very common around the shores of the ponds—the leopard frog (*Rana pipiens*) and the little cricket frog (*Acris grillis*). Many specimens of both these frogs were examined and the contents of their digestive canal carefully listed. Every one with a single exception had eaten either land or water beetles, sometimes both, and while beetle larvæ constituted but a small percentage of their food there were enough to show that the frogs are dangerous enemies of the larvæ.

SNAILS.

Cooke (1895), in his "Molluscs," of the Cambridge Natural History series, noted on page 34 that Lillian's pond snail (*Lymnæa stagnalis lillianæ*) feeds on dytiscid larvæ, snails, and minnows. This fact, of course, suggests that it may also eat the larvæ of other water beetles, and that other carnivorous snails may also feed upon them.

PARASITES.

The parasites do not usually get a chance to infest the larva until it comes out of the water to pupate, and the injury that they inflict is not manifest until the pupal stage. For that reason this enemy belongs to the pupal stage and will be discussed there.

ENEMIES OF PUPÆ.

WATER.

Strangely enough the worst enemy of the pupa is undoubtedly water, although both the larva and the adult live in the water. The pupa possesses none of the structural modifications found in the larva and adult which enable them to swim and breathe while in the water, and hence it is absolutely helpless in such a medium. Furthermore, it is confined within the narrow pupal chamber, whose diameter is often less than its own length. If this pupal chamber becomes filled with water the pupa is quickly drowned, and this is also true of the larva after it has burrowed into the ground and before it has transformed into a pupa and of the beetle imago after emerging from the pupa and before leaving the pupal chamber. The devices possessed by the larva and adult for maintaining a supply of fresh air will not function within the narrow confines of the pupal chamber. There is thus often two or three days previous to pupation and two or three days after emergence as well as the entire pupal stage during which the presence of water in any amount is fatal. When the larva comes out of the pond and burrows into the ground, he stakes his very life upon the weather conditions during the next two or three weeks. If it is pleasant or with only a normal amount of rain, the chances are all in the larva's favor; but if there comes a severe storm and the pupal chamber is filled with water, either from surface drainage or from the raising of the surface of the pond, it results in the death of the larva, pupa, or imago, whichever is caught in the chamber. In digging for pupæ along the shores of the fishponds in 1920 many pupal chambers were opened that had been flooded in this manner. Four larvæ of *Hydrous triangularis*, 19 pupæ, and 2 imagos were found dead; 2 larvæ of *Tropisternus lateralis*, 8 pupæ, and 1 imago; 2 pupæ and 1 imago of *Thermonectes ornaticollis*. The absence of smaller larvæ and pupæ was probably due to the fact that they had been carried off bodily by ants. All the larger ones had been thoroughly decimated by the same scavengers and much of the softer tissues removed.

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IMPERFECT PUPATION.

In pupating the head is withdrawn from the chitinous larval covering, and the latter is left entire. In all the larvæ studied the base of the head is narrower than the central portion, and hence in order to be withdrawn successfully the base must be opened. This is usually done by a division along the dorsal mid line. If for any reason the chitin covering fails to divide, it may become impossible to withdraw the contents of the larval head, and the pupa will be malformed. Figure 94 (p. 307) represents such an occurrence in *Dineutes americanus*. One of the pupal chambers brought into the laboratory did not hatch with the others. On being opened a distorted adult beetle was found inside, with a portion of its head, including the antennæ and mouth parts, still inside the old larval covering. The rest of the beetle was perfect, but, of course, it would have died very soon, since it could not even get out of the pupal chamber, and if it had done so it could not have eaten anything.

PARASITES.

A hymenopterous parasite (*Spilocryptus incertus* Cresson) was found within a cocoon of *Dineutes americanus* by Dimmock and Knab (1904). They also gave the life history of a bombardier beetle (*Brachinus janthinipennis*) whose larva is parasitic upon the pupa of *Dineutes americanus*. Wickham (1894) was the first to find this beetle parasite inside of the pupal chamber of Dineutes, but he could not secure sufficient material to make a detailed study of the parasite. Dimmock and Knab were more fortunate and secured an abundance of material from pupal chambers found about a reservoir in Holyoke, Mass. They said (1904, p. 35): "The larva of *Brachinus*, until about ready for pupation, keeps its mouth parts most of the time imbedded in the pupa of *Dineutes*, and pupation takes place in the mud cell made by its host." Wickham (1893, p. 332) also mentioned that the parasite larva, "perhaps on account of the partial decomposition of the *Dineutes* pupa, on which it was originally feeding, consented to complete its growth on the pupa of *Tropisternus glaber*, which I killed and opened for it." Wickman also found a hymenopterous parasite (*Cyrtogaster dineutis* Ashmead) upon a Dineutes larva, an ichneumonid parasite (*Gausocentrus gyrini* Ashmead) upon two pupæ of a species of Gyrinus, and a dipterous parasite (*Phora* sp.) upon a pupa of *Tropisternus glaber*.

Attention has already been called to the fact that the mud-burrowing larvæ are better protected against these parasites than are those which construct a pupal chamber. We see from the above, however, that even the mud burrowers get caught sometimes.

THE BLACK HORSEFLY.

Both the larvæ and the pupæ of the black horsefly (*Tabanus striatus*) are common in the mud around the shores of the ponds and are frequently dug up when searching for beetle pupæ. In a single instance a larva was obtained from the shore of pond 5D, August 10, 1920, that had nearly consumed a pupa of *Tropisternus lateralis*. These larvæ have been recorded as attacking and eating the grubs of Phyllophaga and Cyclocephala. In all probability when they are as common as around these fishponds they consume many of the beetle pupæ.

ANTS.

It was noted above that the ants consumed the softer portions of the bodies of beetle larvæ, pupæ, and adults which had been drowned inside the pupal chamber. They are not content with being scavengers, however, and they frequently kill both larvæ and pupæ. Their depredations would be much more numbrous were it not for the fact that the beetle usually constructs its pupal chamber in earth too moist for the ants.

ENEMIES OF ADULTS.

TURTLES.

Mention has already been made on page 244 of certain adult beetles eaten by turtles. A medium-sized snapping turtle was caught August 7, 1920, in one of the ponds and placed in a large metallic tub. It disappeared over night but left behind excreta containing 1 adult *Hydrous triangularis*, 2 *Cybister fimbriolatus*, 1 *Dytiscus hybridus* and 1 *Tropisternus lateralis*, these beetle remains constituting fully 50 per cent of the excreta.

BIRDS.

McAtee and Beal (1912, p. 19) recorded the food of a horned grebe (*Colymbus auritus*) as containing 23.3 per cent beetles, chiefly aquatic. Two little green herons (*Butorides virescens virescens* Linn.), shot at one of the fishponds in Fairport August 10, 1918, were examined and their stomach contents listed. Among other things one had eaten an adult *Hydrous triangularis*, which formed 25 per cent of its food. The other had eaten two Donacia adults and one *Laccophilus maculosus*, which together formed 30 per cent of its food.

The shoal water ducks must also be recorded among the more important enemies of adult water beetles. In a paper by W. L. McAtee (1918) a summary was given of the items of food identified in the stomachs of three species of mallard ducks. Out of 2,398 stomachs examined Haliplidæ were found in 25, Dytiscidæ in 139, Gyrinidæ in 9, Hydrophilidæ in 99. This is a total of 272, a little more than one-ninth of the whole number. What was said with reference to the common mallard (McAtee, 1918, p. 8) may be taken as applying to all three species.

> The mallard's attention to insects is divided about equally among beetles, bugs, and dragonflies, which together constitute more than half of the insect food. The beetles include both larvæ and adults of the Haliplidæ, 20 different kinds of Dytiscidæ, both adults and larvæ, Hydrophilidæ and Gyrinidæ.

A paper by D. C. Mabbott (1920) gave the items of food of seven species of shoal water ducks. These contributed to the destruction of beetles in the following manner:

> The most common Coleoptera [in gadwall stomachs] were water scavenger beetles (Hydrophilidæ), predacious diving bettles (Dytiscidæ), ground beetles (Carabidæ), leaf beetles (Chrysomelidæ), and weevils (Rhyncophora). * * *. Of the 362 birds taken during the fall and winter months only 23 had eaten beetles, and these never amounted to more than 4 per cent of the stomach contents. Of 11 ducklings taken in July, however, all but one had eaten beetles; in three instances these amounted to 15 per cent and constituted 7.09 per cent of the food of all [p. 9].

More than two-thirds of the insects eaten by the baldpate (0.29 per cent of the whole) were beetles. These included water scavenger beetles (Hydrophilidæ), found in 8 stomachs, predacious diving beetles (Dytiscidæ), in 2, * * *, and unidentified fragments of beetles in 16 [p. 15].

Those [beetles] most commonly taken [by the green-winged teal] were predacious diving beetles (Dytiscidæ), water scavenger beetles (Hydrophilidæ), crawling water beetles (Haliplidæ), snout beetles and other weevils (Rhyncophora), and ground beetles (Carabidæ) [p. 21].

Beetles (Coleoptera) amounted to 2.62 per cent of the food of the blue-winged teal, or less than one-tenth of the total animal matter eaten. Ten species of predacious diving beetles (Dytiscidæ) were noted, five of water scavengers (Hydrophilidæ), four of crawling water beetles (Haliplidæ), * * *, and one of whirligig beetles (Gyrinidæ) [p. 27].

Over half of the insect food of the series of cinnamon teals (5.40 per cent of the whole) consisted of beetles (Coleoptera). Disregarding several unidentified fragments, only four families were represented, the predacious diving beetles (Dytiscidæ), water scavenger beetles (Hydrophilidæ), leaf beetles (Chrysomelidæ), and snout beetles (Curculionidæ) [p. 30].

Beetles (Coleoptera), amounting to 0.93 per cent of the total food of the pintail, consisted largely of three families, the predacious diving beetles (Dytiscidæ), water scavenger beetles (Hydrophilidæ), and ground beetles (Carabidæ) [p. 36].

Beetles of at least 15 families were represented in the food of the wood ducks examined. Of these the water scavenger beetles (Hydrophilidæ), predacious diving beetles (Dytiscidæ), and leaf beetles (Chrysomelidæ) were most commonly taken. * * *. Two other strictly aquatic families—the whirligig beetles (Gyrinidæ) and crawling beetles (Haliplidæ)—were well represented. * * *. Peculiar little silken cases containing eggs of water scavenger beetles, usually attached to a submerged leaf or to the body of the female beetle herself, are not infrequently found in duck stomachs [p. 47].

TOADS AND FROGS.

In discussing the natural history and utilization of frogs Wright (1920, p. 41) made the following statement:

Coleoptera, mainly ground, lamellicorn, and click beetles, and weevils constitute 27 per cent of the food of the toad, while in the animal food of the leopard frog beetles form 33 per cent of the whole, the principal groups being ground, tiger, and snout beetles. In the food of the wood frog, pickerel frog, and green frog the proportion is equally large, while in the diet of the bullfrog the beetle element is surprisingly large. No doubt water beetles of the surface enter into the food of the bullfrog more than into that of the other species of frog.

Of 10 leopard frogs (*Rana pipiens*), captured on the shores of the fish ponds at Fairport in August, 1920, 8 had eaten adult water beetles, and 1 of the other 2 had eaten land beetles. Of 15 cricket frogs (*Acris grillis*) captured at the same time, every one had eaten adult beetles, and in the diet of 8 of them some form of water beetle was included. The simple fact that beetles constitute so large a percentage of the food of the toad and the various frogs indicates that all of these batrachians probably eat water beetles whenever they get a chance.

ELECTRIC LIGHTS.

Reference has already been made under locomotion to the fact that the adult beetles while migrating from place to place are often attracted by electric lights. Although some escape this peril many fall beneath the lights into the dust and perish. This is especially true of the larger species but applies also to the smaller ones. Trap lanterns that are set for moths usually capture a considerable number of water beetles, and the nearer to the water they are set the greater the danger to the beetles.

BEETLES AS FISH EATERS.

The food of the various larvæ and adults will be given under the separate species, and it will be sufficient here to make a few general statements. On the whole, the larvæ of the Dytiscidæ, Hydrophilidæ, and Gyrinidæ are carnivorous, while those of the Haliplidæ are strictly vegetarian. Of the adults the Dytiscidæ and Gyrinidæ eat animal food, whereas the Hydrophilidæ and Haliplidæ eat vegetable food of various kinds. Neither the plant-eaters nor the animal-eaters are strictly confined to their own kind of diet, however. Under stress of hunger or when for any reason the natural food supply fails they both show great ability to change their diet. Some species probably combine the two kinds under normal conditions. The thing that concerns us most in connection with their food is the fact that some of them eat small fish, and this is worthy of careful consideration. In considering this problem it will be convenient to separate the larvæ and adults and discuss them separately.

In searching for the food of the larvæ no information can be obtained from an examination of the contents of the stomach and intestine if the larva belongs to the Dytiscidæ, the Gyrinidæ, or the Haliplidæ. In these three families the larval mandibles are either grooved or pierced for the passage of fluids only. Hence, the fluid contents of the food are all that is swallowed, and obviously they furnish nothing that could identify the species of plant or animal from which they came.

The hydrophilid larva, on the contrary, chews up its prey and swallows the solids as well as the liquids. Instead of being pierced or grooved its mandibles are toothed on the inner margins to fit them for chewing. Accordingly, in this family we can obtain the very best information by an examination of the contents of the stomach and intestine. This has already been done with the larvæ of *Hydrous triangularis*, and fish remains were found in the stomachs of 12 out of 50 larvæ examined (Wilson, 1923). In the present investigation the stomach contents of 50 larvæ of two species of Tropisternus have been examined, but no fish remains were found in any of them. The larvæ of Berosus are too small to yield much that is of value from such examinations. For these small hydrophilids and for all the larvæ in the other families actual observation is the only source of information in reference to the food. The problem of beetle larvæ as fish eaters, therefore, narrows down to answers to the following questions: What kinds of beetle larvæ have been seen eating fish and under what conditions? What kinds are likely to eat fish either under normal conditions or from stress of hunger? Of the Dytiscidæ the larvæ of various species of Dytiscus and Cybister have been observed eating fish even when an abundance of other food was available. By reason of their voracity these larvæ are commonly called water tigers. Kellogg, in his American Insects (1908, p. 257), said of the Dytiscidæ:

> Both larvæ and adults are fierce and voracious, and the larger species attack and kill small fish. In the middle States these beetles actually do much damage in carp-ponds.

When stationed at the U. S. Fish Hatchery in Homer, Minn., H. L. Canfield had occasion late in August, 1913, to draw down one of the ponds containing small-mouthed black bass fingerlings from 2 to 2½ inches in length. As soon as they felt the pond begin to lower the fingerlings swarmed to the surface near the outlet. At the same time numbers of these water tigers appeared and attacked the fish from all sides. The dytiscid larva seized the fish by its throat and plunged its powerful mandibles into the flesh near the heart. After sucking the blood a moment it dropped the fish and attacked another, until the destruction became enormous. Similar attacks have been witnessed in the fishponds at Fairport, Iowa, but the number of fish killed was much less, owing to the smaller number of dytiscid larvæ present.

On May 18, 1916, 4,500 fry of *Ictiobus cyprinella*, the common buffalofish, were placed in pond 14B, from which all the larger fish had been previously removed. From the time these fry were placed in the pond repeated search for them failed to reveal their presence. On July 12 the pond was drawn, but no buffalo fry were found. Many dytiscid larvæ, however, appeared, and it was felt that they, with other enemies, might have contributed to the disappearance of the fish fry. No positive proof of this could be obtained, and since the dytiscid larva does not chew its prey but merely sucks its juices, it would seem as if there should have been some of the dead fry floating in the pond if the dytiscid larvæ were really responsible for their disappearance.

One of these attacks of a water tiger upon a small fish has been made the subject of a movie film. While this particular attack was undoubtedly staged for effect, it does reveal the voracity and tigerlike nature of the larva. There is no objection to artificial conditions when the reality has been repeatedly observed under perfectly natural conditions. Fortunately the larvæ of other dytiscid genera are too small to function as enemies of fish. None of them, so far as known, have been reported as attacking young fish, and it is probable that ordinarily they are satisfied with other food.

Of the Hydrophilidæ the larvæ of various species of the genus Hydrous have been captured while eating fish both in Europe and in America. The following is another instance to be added to a list that is already rather long. Ten thousand small fry of the buffalofish (*Ictiobus cyprinella*) were placed in pond 3E, June 1, 1918. During the month many Hydrous larvæ appeared in the pond and the buffalo fry began to disappear. By watching the pond closely the beetle larvæ were actually captured while eating fish on July 3. The pond was then drained and the fry removed and about 150 full-grown Hydrous larvæ were picked up, while many more larvæ and pupæ were obtained from pupal chambers around the pond shores. In this instance, therefore, it was actually proved that the beetle larvæ were responsible for the disappearance of some of the fish. Of the remaining genera of the Hydrophilidæ, Hydrophilus is about the only one whose larvæ would be large enough to become a menace to small fish. It has not been reported as actually seen committing this depredation, but it might do so under stress of hunger.

Of the Gyrinidæ the larvæ of *Dineutes americanus* have been seen eating small fish. In the early summer of 1916 the channel catfish (*Ictalurus punctatus*) in pond 9D for the first time spawned and hatched a brood of young. During the subsequent lowering of the pond in order to secure and remove these fry, George Lay observed large numbers of Dineutes larvæ attacking the young fish. Several would mob together and seize the fish from different sides, and they kept up the attack until the fish succumbed. Of course, when the pond was lowered all its animal fauna was crowded together into a limited space, and the relations of the various species to one another became somewhat abnormal. If these larvæ attack fish under such conditions, they might repeat the performance at another time, especially if their food supply became scarce. So far as known no other gyrinid larva has ever been reported as attacking fish.

The haliplid larvæ are all strict vegetarians and are so small and inactive that they do not catch any living animal, much less attack small fish.

To summarize, therefore, the larvæ of Dytiscus, Cybister, and Hydrous are known to eat small fish as a part of their regular diet. The larvæ of Dineutes have been observed killing fish fry under somewhat abnormal conditions and might do the same thing whenever they had a chance. The larvæ of Acilius and Hydrophilus are large enough to overpower very small fish fry, but thus far there is no positive proof that they actually do this. The other beetle larvæ are too small to be reckoned as a menace to fish culture.

With reference to the attacks made by adult beetles upon fish the testimony is much less satisfactory. Von Mentzschefahl in 1778–79 mentioned two species of adult water beetles (Dytiscidæ) that attacked the perch in a pond in Silesia. Similar destruction of young fishes by adult water beetles was noted by Elles in 1830, by Dale in 1832, by Riley in 1885, and by Dimmock in 1886.

Elles wrote as follows (1830, pp. 148–149):

I observe that one of your correspondents notices the probability of ponds in elevated situations being stocked with fish through the agency of the water beetle. If this active and voracious little creature were really useful in that way, it might in some measure atone for its other mischievous propensities; for I do not know a more destructive little insect to fish themselves, besides devouring the spawn. A neighbor of mine lost several hundred of the fry of the gold and silver fish by this little pest; and, to leave no doubt about the matter, he caught one and placed it in a large basin of water, to which he shortly after added a little fish. The beetle immediately made a dead set at the fish, which completely paralyzed the poor little animal, for it was soon after seized near the tail by the beetle without making any effort to escape, and never left until it was a perfect skeleton similar to numbers, that he had previously found.

Elles gave no hint as to the genus and species of this beetle, although the query was made by a correspondent in Volume IV of the same magazine, and Elles's attention was called to it by Dale on page 668 of Volume V.

Riley stated (1885, p. 311):

The large water insect which attacks and kills young carp is evidently some species of Cybister or Dytiscus of the coleopterous family Dytiscidæ.

Dimmock's testimony was quite different; he said (1886, p. 357):

I have seen a dead rat in a small pond surrounded by a great swarm of these beetles (Dytiscidæ) and they prefer such food to living food.

Garman said (1890, p. 163):

Both adults and young (Dytiscidæ) lead a predatory life, attacking and devouring whatever they can master. They do not hesitate to attack animals many times larger than themselves and are very destructive in fishponds to young fishes. They are in turn eaten by the larger fishes.

The writer (Wilson, 1923) has recorded the killing of a young buffalofish in an aquarium at Fairport, Iowa, by a female *Hydrous triangularis* just after she had completed spinning an egg case.

None of these accounts are very convincing. If the neighbor mentioned by Elles had actually seen a beetle killing his goldfish fry, there was no need of further proof. If he had not, the placing of the two together in a basin of water with the resultant death of the fish certainly did not furnish such proof. There are large water bugs belonging to the family Belostomidæ which are just as likely to kill young carp as are the two beetle genera mentioned by Riley. Garman's statement is a general one without the citation of anything to prove its validity. The writer, in his record above cited, called attention to the fact that the conditions under which the killing of the buffalofish occurred were artificial and abnormal. Consequently, while it is highly probable that these large beetles do sometimes kill small fish, we have to admit in all fairness that their guilt has not yet been legally established. It is also worthy of record that while Cybister and Dytiscus and Hydrous are common in nearly all the fishponds at Fairport, no one has ever seen an adult beetle attacking one of the fish fry.

FISH AS BEETLE EATERS.

Having ascertained how many and what species of beetle larvæ and adults prey upon fish fry, we may turn about and inquire what kinds of fish ordinarily eat beetle food. Our inquiry now is much more easily answered, since it does not involve any watching of the fish. We have simply to examine the contents of the fish's digestive canal to obtain exact information both as to the quality and the quantity of food consumed. Moreover, the beetles eaten are more readily recognized than almost any other kind of food. The hard chitin covering of the head of the beetle larva, together with the antennæ and mouth parts, remain sufficiently intact to be readily recognized. For the adults the entire beetle is sometimes practically uninjured and may even make a respectable specimen after a temporary sojourn inside a fish's stomach. In case it is mutilated, there is always enough of the hard chitin parts to render identification easy and certain.

EVIDENCE FROM FISH BAIT.

So far as known neither the beetle larvæ nor the adults are used anywhere in the United States as fish bait, but there is apparently no reason why they would not make excellent bait. The larva of the horned Corydalis or dobsonfly (*Corydalis cornuta*) is known to fishermen everywhere as the dobson, crawler, and a variety of other names and is much prized as fish bait, especially for black bass.

The larva of *Hydrous triangularis* closely resembles the dobson in size and general appearance, and it is greedily eaten by bass whenever offered to them. Large-mouthed black bass are used in many of the experiments at Fairport, and there are some of them in the tanks most of the time. Hydrous larvæ of all sizes up to full development have been fed to these fish during the summer. They have always eaten the larvæ with great avidity, and if they were hungry it sometimes seemed as if the larva did not fairly strike the surface of the water before it was snapped up. It is not probable that a bass thus greedy could distinguish between a dobson and a Hydrous larva when placed on a fishhook as bait. Accordingly, it seems probable that the beetle larva would make fully as successful bait as the dobson.

EVIDENCE FROM FISH STOMACHS.

The data in the five tables in this section on the beetle food found in the stomach contents of food and game fishes examined by scientific men in various localities present ample evidence that beetle larvæ and adults constitute an important item of fish food.

Food of the fishes of Illinois, by S. A. Forbes.

Kind of fish.	Terrestrial beetles, adults.	Terrestrial beetles, larvæ.	Undetermined aquatic adults.	Undetermined aquatic larvæ.	Hydrophilidæ, adults.	Hydrophilidæ, larvæ.	Dytiscidæ, adults.	Dytiscidæ, larvæ.	Gyrinidæ, adults.	Gyrinidæ, larvæ.	Haliplidæ, adults.	Chrysomelidæ, adults.
Abramis chrysoleucas, roach or bream	+				+		+					
Ambloplites rupestris, red-eye	+	+			+		+					
Ameiurus nebulosus, common bullhead	+						+	+	+			
Ameiurus nebulosus marmoratus, marbled bullhead	+				+	+						
Aphredoderus sayanus, pirate perch				+								
Aplodinotos grunniens, sheepshead or croaker					+					+		
Argyrosomus artedi, cisco	+											
Catostomus nigricans, hog molly, stone roller	+			+								
Chænobryttus gulosus, warmouth bass	+											
Dorosoma cepedianum, gizzard shad	+											
Eupomotis gibbosus, common pumpkin seed	+				+							
Eupomotis heros, southern pumpkin seed					+		+				+	
Fundulus diaphanus, Menona top minnow	+				+							
Fundulus notatus, common top minnow	+				+	+						
Hybopsis kentuckiensis, river chub	+											
Hyodon tergisus, toothed herring	+		+		+		+					
Ictalurus punctatus, channel cat	+				+	+	+	+				
Ictiobus bubalis, small-mouthed buffalofish	+				+	+						
Ictiobus cyprinella, red-mouthed buffalofish	+	+		+								
Ictiobus urus, mongrel buffalo fish	+	+										
Lepomis cyanellus, green sunfish	+				+		+					
Lepomis megalotis, long-eared sunfish	+									+		+
Lepomis pallidus, bluegill	+	+			+	+	+	+	+	+		+
Micropterus dolomieu, small-mouthed black bass		+				+		+				
Moxostoma aureolum, common red horse					+	+				+		
Moxostoma macrolepidotum, large-scaled red horse	+					+				+		
Notropis atherinoides, silverside shiner	+											+
Notropis cornutus, common shiner	+									+		
Notropsis hudsonius, spot-tailed minnow	+											
Notropis whipplii, silver-fin shiner	+	+										
Placopharynx duquesnei, pavement-toothed red horse		+				+						
Polyodon spathula, spoonbill cat	+						+	+				
Pomoxis annularis, crappie		+						+		+		
Roccus chrysops, white bass		+										
Schilbeodes gyrinus, tadpole cat				+								
Semotilus atromaculatus, horned dace	+				+						+	+

These records by Forbes (1888) are very valuable, since they include so many of our food and game fish, and it is to be regretted that they do not contain more data on the size of the fish and the relative proportions of the various beetle foods. The larvæ and adults of terrestrial beetles have been included, because the fish that will eat them will probably not refuse aquatic forms when available. This is abundantly shown by the fact that two-thirds of the fishes enumerated in this list have eaten both terrestrial and aquatic beetles. Among the aquatic forms the Hydrophilidæ serve as food more often than any of the other families, possibly because they are more numerous.

Of the fishes included the bluegill is the most omnivorous, eating everything on the menu except the Haliplidæ. However, if the terrestrial beetles were separated into families corresponding with the aquatic forms, the toothed herring would have to stand first, since it seems to eat anything and everything that comes its way.

Forbes himself offered the following comment upon his list (1888, p. 484):

Larvæ of aquatic beetles, notwithstanding the abundance of some of the forms, occurred in only insignificant ratios, but were taken by 56 specimens, belonging to 19 of the species—more frequently by the sunfishes than by any other group. The kinds most commonly captured were larvæ of the Gyrinidæ and Hydrophilidæ, whereas the adult surface beetles themselves (Gyrinus, Dineutes, etc.)—whose zigzag-darting swarms no one can have failed to notice—were not once encountered in my studies.

He was at fault, however, in this last statement, since he noted, on page 519 (1888), that a common bullhead (*Ameiurus nebulosus*) had eaten gyrinid adults.

Food of the shore fishes of certain Wisconsin lakes, by A. S. Pearse.

[Figures in the food columns are percentages by volume, the entire food being 100.]

Kind of fish.	Number of fish examined.	Average length of fish, millimeters.	Gyrinidæ, adults.	Gyrinidæ, larvæ.	Haliplidæ, adults.	Haliplidæ, larvæ.	Dytiscidæ, adults.	Dytiscidæ, larvæ.	Hydrophilidæ, adults.	Hydrophilidæ, larvæ.	Undetermined beetles.
Abramis crysoleucas, golden shiner	3	122.6					1				
Ambloplites rupestris, redeye	5	77			2.6		2		3.4		
Ameiurus melas, black bullhead	1	274		6				2			
Ameiurus nebulosus, common bullhead	33	36	0.5								
Catostomus commersonii, common sucker	3	51.8					2.3				
Cyprinus carpio, German carp	4	20		2.5				2.5			
	18	31.8				0.1	2.5			0.3	
	18	29.5			1.5						
Etheostoma Iowæ, Iowa darter	4	48.5		11.2						9	
Fundulus diaphanus menona, top minnow	49	35.4									0.6
	10	38									6
Lepomis incisor, bluegill	2	116				2.5					
	10	54.8				.3					
	10	45.4				.2					
	3	69.6				.6					
Micropterus salmoides, large-mouthed black bass	3	30.6						5			
Perca flavescens, yellow perch	10	156					.3				
Pomoxis sparoides, black crappie	1	200									28
Salmo irideus, rainbow trout	1	126			3						
Salvelinus fontinalis, brook trout	18	103				.2	1.1	2.3			
Schilbeodes gyrimus, tadpole cat	9	42.6									33.2
Umbra limi, mud minnow	9	51.1			.2						
	10	49.3			2.5						
	14	20.6									3.5

The relative amounts of beetle food given in this table seem at first sight so small as to be hardly worth considering, but such is by no means the case. The total number of fishes examined by Dr. Pearse (1918) was 1,576. In the general summary of foods eaten by these fishes the largest single item was that of insects, 36.30 per cent, nearly twice the size of its nearest rival, the Entomostraca. The insects contributing the most food were the Diptera, those second in order were the

Ephemerida, and the Odonata and Coleoptera were tied for third place. Pearse divided the fish foods into nine classes, the first four of which in the order of their importance were: (1) Insect larvæ, oligochaetes, and leeches. (2) Entomostraca. (3) Fishes and frogs. (4) Insect pupæ and adults. In the present instance the larvæ and adults are combined in one table, while the pupæ, transforming out of water, are never eaten by fish. This beetle food, therefore, belongs partly to the class considered of greatest importance and partly to the class placed fourth in the list.

Pearse's table may well supplement the preceding one, since it includes several kinds of fish not mentioned by Forbes and also adds new items to the diet of other species. Of greatest interest is the inclusion of the German carp, of which 40 young specimens, varying from 15 to 64 mm., were examined. These had eaten freely of gyrinid larvæ, haliplid adults and larvæ, dytiscid adults and larvæ, and hydrophilid larvæ, the sum total forming an amount of food surpassed only by the Diptera and Entomostraca. Pearse said (1918, p. 258):

> The German carp during its first few weeks after hatching from the egg feeds largely on entomostracans and rotifers; after that it turns more to insect larvæ.

And of this insect food the beetles are second in importance.

It is also worthy of note that three young suckers, averaging 2 inches in length, had consumed enough dytiscid adults to form a respectable percentage of their total food. The little Iowa darter subsists almost entirely upon amphipods and insect larvæ, and among the latter the beetles are second only to the Diptera.

The only family of aquatic beetles not found in the food of the bluegill as given by Forbes was the Haliplidæ. All of the 25 specimens of bluegill examined by Pearse contained haliplid larvæ, the larger fish containing the greater amount.

The large-mouthed black bass, the yellow perch, the black crappie, the golden shiner, and the mud minnow did not appear in Forbes's list.

Food of trout, by Chancey Juday.

Kind of trout.	Locality.	Number examined.	Length in centimeters.	Number eating Coleoptera.	Average percentage of Coleopterous food.[1]
Salmo sebago	Twin Lakes	19	20-70	4	73
Salmo stomias	do	64	10-20	25	42.7
Salmo irideus shasta	do	106	15-45	37	22.2
Salvelinus fontinalis	do	29	2.5-5	1	5
	do	126	10-33	43	15.7
Salmo whitei	Kaweah River	12	14-20	6	30
	Soda Creek	6	11-18	2	12.5
	Little Kern River	41	12-20	38	15
Salmo roosevelti	Volcano Creek	18	12-28	12	2

[1] The total food is considered 100 per cent.

It should be noted first of all that Doctor Juday (1907) made no distinction between aquatic and terrestrial beetles, nor between adult and larval forms. In all probability terrestrial species formed a large proportion of the total amount. This is especially true of the trout captured in running water. To judge from the long list of terrestrial beetles recorded by Forbes, many of whose fish were taken in rivers and streams, it would seem reasonable to infer that in the trout recorded by Juday from rivers and creeks much of the beetle food was terrestrial. This, however, does not in any way affect the conclusions that follow, since the trout that captured and swallowed a terrestrial species would do the same to an aquatic species, if the opportunity offered. Beetle systemy will not, to any appreciable extent, affect a trout's appetite.

Of the 421 trout examined by Doctor Juday 40 per cent had eaten beetles, and in their stomachs the beetles formed on an average one-quarter of the total food. Such a percentage is large enough to constitute an important factor in the food supply of these fish. It will be noted that a larger number of individuals taken in running water had eaten beetle food, the percentage reaching as high as 92.68 in the Little Kern Rivér. On the contrary the relative amount of beetles in the total food was greatest in the trout from the quiet waters of the Twin Lakes, reaching an average of 73 per cent in the four landlocked salmon. Again the smaller fry, from 2.5 to 5 cm. in length, consumed practically no beetles, whereas the medium-sized fish, from 10 to 40 cm. in length, consumed the greatest amount.

The largest landlocked salmon was 70 cm. in length and the smallest one 20 cm., and although no data were given as to the length of the four that had eaten beetles, we may infer from the other statistics in the table that they were among the smaller rather than the larger ones. Beetles, therefore, do not become a factor in the food of trout until the fish have reached a length of 7.5 cm. (3 inches). The fingerlings then begin to eat them freely, and during the period of growth from 10 to 30 cm. beetles form an important part of the total food.

For trout above 30 cm. in length other fish become a more and more important item of food until they practically supplant everything else. Of the 64 greenback trout (*Salmo stomias*) only four had partaken of fish; none of the small brook trout had touched them, and only two of the 126 large brook trout and none of the trout from the creeks and rivers had eaten fish. On the other hand, seven of the landlocked salmon, presumably the larger ones, had eaten nothing but fish, that item constituting 100 per cent of their food.

The percentages given for each species in this table were obtained by dividing the sum of the per cents of the different food items by the number of stomachs containing food. Of the 12 food items of the landlocked salmon, fish was the only one that surpassed beetles. In the greenback trout, also with 12 food items, Crustacea and beetles were the two largest, the former 0.22 per cent larger than the latter. In the rainbow trout, with 17 food items, beetles were the third in abundance, being surpassed by fish and vegetable débris. In the large brook trout, with 16 food items, beetles were surpassed only by vegetable débris and Hymenopetra. For the small brook trout beetles formed the smallest of the 10 food items.

Food of Louisiana fish, by H. E. Schradieck.

[Figures in the last five columns are percentages, the total food being 100.]

Kind of fish.	Number of fish examined.	Extremes in length of fish, millimeters.	Number of fish containing beetle food.	Length in millimeters of fish containing beetle food.	Terrestrial beetles, adults.	Hydrophilid beetles, adults.	Hydrophilid beetles, larvæ.	Dytiscid beetles, adults.	Haliplid beetles, adults.
Chænobryttus gulosus, warmouth bass	16	25, 115	1	45		65			
			2	103		50			
Gambusia, affinis, viviparous top minnow	31	13, 32	1	13	85				
Lepomis cyanellus, green sunfish	86	26, 73	1	41			25		
			2	50		10			
			3	50	15				
			4	50		40			
			5	54	1				
			6	60		10			
			7	60			20		
			8	60	2				
			9	70				45	
Lepomis megalotis, long-eared sunfish	17	50, 100	1	38		30			30
			2	90			10		
			3	90			15		
			4	92			10		
Lepomis miniatus, scarlet sunfish	14	70, 120	1	85				10	
			2	94		10			
			3	100		10			
			4	100		20			
			5	110		25			
Lepomis symmetricus, symmetrical sunfish	1	60	1	60		10			
Pomoxis sparoides, calico bass	32	45, 70	1	70					8

The data for this table of the food of Louisiana fish were taken from manuscript notes by H. E. Schradieck on file in the office at the U. S. Fisheries Biological Laboratory at Fairport, Iowa.

None of these fish that ate beetle food were under 40 mm. in length, with the exception of the single top minnow and one long-eared sunfish. The former is easily accounted for by the fact that it feeds at the surface, and the beetles it had eaten were land species that had fallen into the water and were floating on the surface. The sunfish were so near 40 mm. in length that it does not constitute a real exception.

The adult hydrophilid beetles furnished the most attractive food, probably because they were more numerous in the localities from which the fish were obtained. If we include the larvæ with the adults, the Hydrophilidæ served as food for 16 out of the 23 fish that ate beetles, or more than 75 per cent. In the next table, the data for which were taken also from manuscript notes by H. E. Schradieck on file in the office of the U. S. Fisheries Biological Laboratory at Fairport, Iowa, this order is reversed and the Dytiscidæ have twice the percentage of the Hydrophilidæ.

Food of fish in fishponds at Fairport, Iowa, by H. E. Schradieck.

[In the last five columns the figures are percentages, the entire food 100.]

Kind of fish.	Fish-pond from which taken.	Number of fish examined.	Extreme lengths of fish examined, millimeters.	Length of fish eating beetles, millimeters.	Unidentified beetles, débris.	Hydrophilid beetles, adults.	Hydrophilid beetles, larvæ.	Dytiscid beetles, larvæ.	Haliplid beetles, adults.
Eupomotis gibbosus, common sunfish	16B	173	10	14	10	...	...	...	...
			45	20	8	...	...	...	...
				26	22	...	...	...	...
Ictalurus punctatus, channel catfish	4E	10	85	98	...	...	3	...	46
			108	108	...	5	...	...	...
	1E	3	93	93	...	...	...	12	...
			110	98	...	...	3	...	...
				110	97	...	...	...	...
Ictiobus bubalis, small-mouthed buffalofish	4D	40	13	...	...	...	...	...	...
			25	...	...	...	...	...	...
	16B	38	11	...	...	...	...	...	...
			24	...	...	...	...	...	...
	5D	3	90	135	...	...	50	...	...
			135	...	...	...	...	...	...
	7D	8	57	76	...	...	...	6	...
			80	...	...	...	...	...	...
Lepomis pallidus, bluegill	2D	103	20	41	...	...	25	25	...
			74	44	...	...	5	5	...
				45	...	...	25	25	...
				45	...	...	30	30	...
				48	...	...	5	...	...
				52	...	...	45	45	...
				54	...	20	...	...	...
				55	...	...	...	...	15
				56	...	...	15	10	...
				62	...	20	...	...	...
	8D	136	11	50	...	...	15	10	...
			56	...	...	...	...	...	...
Micropterus salmoides, large-mouthed black bass	2D	22	43	45	...	...	10	8	...
			80	...	...	...	...	...	...
	3D	89	12	22	...	...	...	20	...
			45	24	...	...	...	25	12
				24	...	...	...	5	...
				24	...	12	...	...	...
				28	...	...	...	15	...
				28	...	...	...	15	...
				35	...	...	...	35	...
				37	...	...	...	50	...
				39	...	...	...	30	...
				41	...	...	...	55	...
				41	...	...	...	70	...
				42	...	...	...	50	...
				42	...	...	...	7	...
				42	...	...	...	20	...
				45	...	...	...	...	20

This table is of considerable interest for several reasons in spite of the fact that it contains but five different kinds of fish. In the first place, these fish are widely distributed and represent 10 different ponds, whose contents of animal and vegetable life are very diverse. In consequence the record has a broader significance than it would otherwise possess. Again, three of these fish—the common sunfish, the channel catfish, and the small-mouthed buffalofish—appear only in Forbes's record, where there were no data as to the size of the fish or the amount of food. A fourth, the large-mouthed black bass, appears only in Pearse's record. where the amount of beetles consumed was insignificant.

The present record supplies these missing details and, so far as the bass is concerned, entirely changes the diet statistics. Of the small-mouthed buffalofish the examination of two lots from separate ponds, totaling 78 fish, none of which ate any beetle food, have been included for the sake of the contrast in size. The largest of these fry was only 25 mm. in length. Both of the ponds from which they were taken contained an abundance of beetle adults and larvæ of many species, and the fact that the buffalofish fry ate none of them shows that at this early stage they prefer other food. The two that did eat beetle larvæ were much larger fish, and in one of them hydrophilid larvæ constituted half the entire food, although there were 13 other food items.

Of the 89 bass examined from pond 3D, 16 were less than 20 mm. and 20 were between 20 and 25 mm. in length. The smallest bass that ate any beetle larvæ was 22 mm. long, and the largest percentage of beetle food was found in those from 35 to 45 mm. in length. A bass, then, begins to eat beetle larvæ as it approaches 25 mm. in length and increases the amount of this food up to at least 50 mm. in length. Above that we have no records, but probably beetles continue in the diet somewhat longer, for some of the larvæ are of good size. Eventually, of course, the bass becomes almost exclusively a fish-eater. The preference for dytiscid larvæ in these bass was very marked, although there were nearly as many species of hydrophilids in the pond, and at least four of them were abundant and one (*Tropisternus lateralis*) a prolific breeder.

In the case of the bluegills also fully one-third (37) of those from pond 2D were under 40 mm. in length and nearly two-thirds (90) of those from pond 8D. The bluegill does not eat beetle larvæ until it reaches a length of 40 mm., or twice the length of the bass; but, on the other hand, it never becomes a fish eater like the bass and probably continues to take at least some beetle food as long as it lives.

In support of this an interesting observation was made by Mr. Lay in the summer of 1916. Pond 1D contained that year 26 adult bluegills and 4,258 young fish 2 to 3 years old. Noting that this was the only pond upon which no gyrinids were to be seen, Mr. Lay, as an experiment, caught and liberated on the pond at different times during the summer numbers of *Dineutes americanus* adults. In every instance these were immediately eaten by the bluegills, who kept this pond clear of gyrinid adults all summer. That this was a matter of choice, or was due to the fact that the beetles attracted attention through their movements, seems evident, because the other kinds of food in the pond were very varied and abundant, insect larvæ, pupæ, and nymphs, Crustacea, mollusks, and a rich assortment of vegetation. Pond 2D, which is separated from 1D by a narrow bank of earth only 15 feet in width, contained that summer bluegill fry and yearlings, which were eating freely of beetle adults and larvæ, but they did not keep that pond free from gyrinids. Most fish do not eat gyrinid adults, perhaps on account of the peculiar fluid which they exude when captured, which has a disagreeable odor; but neither that nor anything else deterred these bluegills in pond 1D. It will be noted, furthermore, from the table that the bluegills are impartial in their choice of beetle food. Pond 2D contained about an equal number of dytiscids and hydrophilids, and their larvæ were about equally divided in the fish food.

The beetle food of the small sunfish from pond 16B was unidentified and might well have contained the remains of terrestrial species. The pond, however, contained six dytiscid and eight hydrophilid species, most of which were breeding freely.

GENERAL SUMMARY AND SUGGESTIONS.

1. The larvæ of three beetle genera—Dytiscus, Cybister, and Hydrous—are positively known to destroy small fish under normal conditions. Ordinarily they are kept in check by their enemies and do not become a serious menace to fish culture, but sometimes under specially favorable conditions they breed in sufficient numbers to kill the newly hatched fish fry about as fast as they appear. The adults of these genera have also been known to kill young fish under somewhat abnormal conditions, but even then they are much less destructive than the larvæ. Adult beetles belonging to each of these genera are present in most of the Fairport fishponds but have never been observed attacking fish fry, although they have had repeated opportunities.

The larva of another genus—the whirligig beetle Dineutes—has been known to kill fish fry under abnormal conditions. The larva of the scavenger beetle Hydrophilus has been suspected of being capable of committing similar depredations, but there is as yet no actual proof. All the evidence at hand seems to indicate that both these larvæ are usually perfectly harmless. There has never been even a suspicion against the adults of either genus. These are the only beetle genera capable of injuring fish fry; all the others are too small. Consequently, the problem is reduced practically to guarding against these genera; the others are negligible.

2. On the other hand, beetle larvæ and adults are eaten freely by the young of nearly all our food and game fishes after the latter have reached a length of 25 to 40 mm. As the fish increase in size they eat the larvæ of the five genera mentioned above, even after these larvæ have become full grown. Many fishes continue to eat beetle food as long as they live. All beetle larvæ that live in the water, therefore, and the adults of the numerous smaller species constitute a very important item of fish food.

3. It is only young fish of the year that are seriously menaced by these beetles. Fish a year old have acquired sufficient ability to escape the attacks of the beetles and in their turn have begun to eat freely of beetle larvæ and adults. Hence, beetles can do very little harm in a pond that is stocked with fish a year old or over; on the contrary they contribute materially to the available food supply. Such a pond, therefore, will not require watching as far as the beetles are concerned. If the fish are breeding and young fry appear, however, then the pond must be guarded to prevent the dangerous beetle species from becoming too numerous or too ravenous.

4. In case any of the beetles here mentioned should become obnoxious in a breeding pond there are two possible methods of dealing with them. Either they may be gotten rid of or the fish fry may be removed to another pond, and thus be freed from them. The former would seem to be the easier method, but there are strong objections to it and many obstacles that are hard to overcome. In the first place, it is very hard to weed out the larger dangerous species and leave the smaller harmless ones. Any means used to exterminate one species will operate also against all the others. There will thus be destroyed a considerable amount of excellent fish food which might otherwise have been utilized. There are only three beetle species, one for each of the three genera, Dytiscus, Cybister, and Hydrous, in the Fairport fishponds that are really dangerous, while there are 50

others that are eminently desirable. Even if it were possible to eliminate these three species they are themselves good food for older fish and are as freely eaten as any of the other species, so that it would seem to be poor economy to kill them off.

Again any attempt to eliminate the obnoxious beetles must employ mechanical means since chemicals are out of the question. This being true it will be found difficult to get rid of the beetles without sacrificing the other kinds of insect larvæ which can not consistently be spared since they furnish the very food upon which the young fish most depend.

Trap lanterns set at night around the shores of the fishpond will capture many of the adult beetles. The larger species are the ones most accustomed to flying at night and they are easily attracted by a bright light. If this mode of attack is started by the middle or last of May, before the beetles begin to breed, and is consistently followed, it will destroy large numbers of the very species that are most obnoxious. However, this is a preventive measure, to be applied beforehand, and not a cure after the infection has appeared. It is tedious, involves considerable expense, and has no effect upon the larvæ but only upon the adults. What the fish-culturist really wants is a remedy that may be applied with sufficient celerity to save the remainder of the hatch when once the beetles have begun their ravages, since ordinarily there is no necessity for preventive measures.

The use of a dip net in the shallow waters around the shores of the pond, pushing the net towards the the shore and to the very water's edge, will capture many of the larger larvæ and adults. If persistently followed, it will materially reduce the numbers of the obnoxious species and might check their ravages sufficiently; but it is a slow and very laborious method at the best and does not appeal to the average fish-culturist as possessing the requisite celerity.

The only method of removing the beetles quickly and thoroughly is by draining the fishpond. If the fry can be kept an hour or two in a large tank after the pond has been nearly drained, the draining may then be fully completed. The large beetle larvæ and adults thus become conspicuous, traveling around in search of water, and practically every one of them may be captured. Witness the draining of one of the Fairport fishponds as related on page 250. The fish may then be returned with safety to the pond as it is refilled. This method has certain disadvantages noted below, and it will also be necessary after the larvæ have been destroyed to make sure that a second brood does not appear. There may be many pupæ in chambers around the edge of the pond which would emerge as adults if left alone. They may be destroyed by raising the pond level 8 to 12 inches, keeping it up for half a day and then lowering it again. If this were done once a week during the summer, it would mean that no beetle larvæ could develop into the adult stage, since they would all be drowned while in the pupal chamber (see p. 245). Such universal destruction is not at all desirable, but it indicates the effectiveness of the remedy. Any of these methods of getting rid of the beetles is only to be used in emergencies as a sort of last resort. The second method mentioned above, that of removing the fish fry to another pond, is much to be preferred and is worthy of separate discussion.

5. If a second pond is available, transferring the fry to it will effectively rid them of their enemies. The original pond can then be stocked with larger fish that will

use the beetles for food. Of course, in making such a transference care must be taken that the same species of beetles are not present in the second pond. This will almost never happen, however, even when the two ponds are close together and to all appearances the conditions are the same. During the summer of 1920 the only fishpond at Fairport in which any Cybister larvæ were found was pond 5D. Adults were found in several adjacent ponds but no larvæ. Similarly, Hydrous larvæ were confined to ponds 3E, 4E, and 14B, and nothing but straggling individuals appeared elsewhere. Dytiscus adults were fairly common in ponds 2, 3, 4, and 8, in series D, and in 16B, but not a single larva was captured during the entire summer in any pond. The larvæ of *Thermonectes ornaticollis* were confined to pond 12B, and none were found in any other pond, although the adults were common enough. In 1921 the large dytiscid larvæ described on page 284, which were probably those of *Acilius semisulcatus*, were found only in pond 7D; none could be found in ponds 5, 6, or 8, all of which are very close to pond 7. The buffalofish fry taken out of pond 3E (see p. 250) in July, 1918, were carried only a short distance to another pond in the same series, but there they were entirely free from attacks of beetle larvæ. Such a transference of the fish fry, therefore, is the simplest, the most reasonable, the quickest and the most effective method of freeing them from the attacks of beetles. It must be borne in mind, however, that in draining a pond either for the destruction of the obnoxious beetles or for the transference of the fish fry these latter are always subject to increased depredation by the beetles during the operation. The lowering of the water brings the larvæ and fish fry together in a steadily diminishing area. The beetles are almost certain to take advantage of this opportunity and kill many of the fry; but the danger is only temporary, and as it can not be avoided it must be accepted as one of the means necessary to the ultimate deliverance of the fish from their enemies. As in all warfare some sacrifice is necessary in order to secure final victory.

6. There is also another method that merits at least some attention, namely, the wintering out of a breeding pond. If a pond is drained in the fall and left dry through the winter, all the insect larvæ it contains, including any beetle larvæ that might possibly remain, will be destroyed. The adults will migrate elsewhere or will be killed, and in the spring the pond will be clean and free from all obnoxious pests. If a pond were persistently infested with any insect enemies of young fish, it might be advisable to winter it out. The chances of reinfection during the following year will thereby be greatly diminished, and in the majority of cases it will remain free from the pests for several years. Here again, however, it must be remembered that such a procedure gets rid of all the insect fauna, the beneficial as well as the harmful. Consequently, there will not be as much fish food the following year, and the fry will be compelled to depend upon whatever happens to get into the pond unless they are fed artificially. If the latter method be adopted, or if the pond be filled with water pumped from a river or lake, there will probably be plenty of food for the fry. In such cases the wintering out of a fishpond is one of the most effective methods that can be adopted for getting rid of obnoxious insects. On the contrary, if the pond be fed from springs, some provision must be made for a food supply the following year.

BEETLE DISTRIBUTION IN FAIRPORT FISHPONDS.

The first of the two following tables shows how the beetles were distributed in the various ponds at Fairport, Iowa; the second shows how they were distributed according to beetle families.

Beetle distribution in the Fairport (Iowa) fishponds.

[a, abundant; c, common; f, few in number; r, rare. *See text, p. 264.]

Beetle species.	Pond number and series.																				
	12 B	13 B	14 B	15 B	16 B	1 D	2 D	3 D	4 D	5 D	6 D	7 D	8 D	9 D	1 E	2 E	3 E	4 E	1 F	2 F	3 F
Haliplidæ:																					
Haliplus borealis*	....	....	....	....	....	r	f	a	c	f	c	c	c	c	....	c	....	....	....	....	....
Haliplus punctatus	....	....	....	....	....	....	....	....	....	....	....	r	r	r	....	....	....	....	....	....	....
Haliplus ruficollis	r	r	r	r	r	f	c	a	c	r	....	r	f	f	r	r	r	r	r	r	....
Haliplus triopsis*	....	....	....	....	....	....	....	....	....	r	....	....	....	....	....	r	r	r	....	....	....
Peltodytes edentulus	r	f	c	f	c	c	c	c	c	c	....	c	c	....	c	c	c	c	f	r	r
Dytiscidæ:																					
Acilius semisulcatus	....	....	....	....	....	....	....	a	....	r	....	a	a	....	c	c	c	c	....	....	....
Agabus gagates	....	....	....	....	r	....	r	....	a	r	....	r	f	....	....	r	....	....	....	....	r
Bidessus flavicollis	....	....	....	....	....	r	r	r	r	f	....	r	r	f	....	....	....	....	....	r	....
Bidessus fuscatus*	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	r	....	....	....	....	....
Bidessus lacustris	....	....	a	a	....	....	f	r	....	....	....	r	....	....	r	r	r	r	....	....	....
Coelambus acaroides	r	....	....	....	....	....	r	....	....	r	....	....	....	....	....	r	r	....	....	....	....
Coptotomus interrogatus	....	....	r	....	c	r	c	c	c	c	....	c	c	c	c	c	c	c	r	a	a
Cybister fimbriolatus	....	r	r	....	....	r	a	r	r	a	....	r	r	....	....	f	r	a	....	....	....
Dytiscus hybridus	....	....	....	....	....	....	....	....	....	f	....	....	....	....	....	....	f	....	....	....	....
Dytiscus verticalis	....	....	a	....	c	....	c	c	c	f	....	r	c	....	a	c	c	c	....	r	r
Graphoderes fascicollis	....	....	....	....	....	....	....	....	....	r	....	....	....	....	....	f	....	....	....	....	....
Graphoderes liberus	....	....	....	....	....	....	....	....	....	r	....	....	....	....	....	....	....	....	....	....	....
Hydrocanthus iricolor	....	....	....	....	....	....	....	....	....	r	....	r	r	....	....	....	....	....	....	....	....
Hydroporus consimillis	r	....	....	....	c	r	r	....	....	c	....	....	....	....	....	r	....	....	....	....	....
Hydroporus niger*	....	....	....	....	....	r	r	r	r	r	....	r	r	....	....	....	....	....	....	r	....
Hydrovatus pustulatus	....	....	....	....	....	r	r	f	r	f	....	....	....	....	....	....	....	....	....	....	....
Ilybius biguttulus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	r	....	r	....	....	....
Laccophilus maculosus	a	c	a	f	a	a	a	a	a	a	....	a	a	c	a	a	a	a	c	a	a
Laccophilus proximus	f	....	....	....	....	....	a	a	a	a	....	a	a	....	a	a	a	a	c	c	....
Laccophilus undatus*	....	....	....	....	....	....	r	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Thermonectes basilaris	r	....	....	....	....	....	....	....	....	r	....	....	f	....	....	r	r	r	....	....	....
Thermonectes ornaticollis*	a	....	....	....	....	....	....	....	....	r	....	....	r	....	r	c	r	c	....	....	....
Gyrinidæ:																					
Dineutes americanus	a	a	c	c	a	....	a	a	a	a	a	a	a	a	a	a	a	a	c	c	c
Gyrinus analis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	r	r	r
Gyrinus limbatus	....	....	....	....	....	....	r	c	c	r	....	r	r	....	....	a	r	r	....	r	....
Gyrinus minutus*	....	....	....	....	....	....	....	....	c	....	....	....	....	....	....	....	....	....	....	....	....
Gyrinus ventralis	....	c	....	....	....	....	r	c	c	r	....	r	r	....	....	a	r	r	c	....	....
Hydrophilidæ:																					
Berosus pantherinus*	....	....	....	....	....	....	....	....	r	r	....	f	....	....	....	r	r	....	....	r	....
Berosus perigrinus	r	....	....	....	....	....	r	....	....	....	....	....	....	....	....	r	r	....	....	....	....
Berosus striatus	....	....	r	r	a	r	a	a	a	a	....	a	a	....	a	a	r	....	....	a	f
Creniphilus despectus*	....	....	....	....	....	....	....	....	....	r	....	....	....	r	....	....	r	....	....	....	....
Creniphilus digestus	....	....	....	....	....	....	r	....	r	r	....	....	....	....	....	....	....	....	....	....	....
Creniphilus subcupreus	....	....	....	....	....	....	r	r	r	r	....	r	r	....	....	....	....	....	....	....	....
Enochrus diffusus	r	f	a	f	r	f	a	a	a	a	r	a	....	f	....	r	r	r	f	r	r
Enochrus hamiltoni*	....	....	....	....	....	....	r	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Enochrus nebulosus	c	c	r	....	....	....	c	r	f	....	c	....	....	....	....	r	r	....	....	....	....
Enochrus ochraceus	....	....	....	....	a	....	f	a	a	a	a	....	....	....	....	....	....	....	....	....	....
Enochrus perplexus	....	....	....	....	....	....	....	r	r	r	r	....	....	....	....	....	....	....	....	....	....
Helophorus lacustris	....	....	....	....	r	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Helophorus lineatus*	....	....	....	....	....	....	r	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hydrochus squamifer	....	....	....	....	....	....	r	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hydrophilus obtusatus	a	....	....	....	....	....	....	....	c	r	....	r	r	....	r	a	c	r	....	....	....
Hydrous triangularis	c	f	r	r	r	c	c	c	c	c	....	c	c	....	c	a	c	c	r	a	c
Laccobius agilis*	....	....	....	....	r	....	....	....	....	r	....	....	....	....	....	....	....	....	....	....	....
Tropisternus glaber	a	r	....	r	c	c	c	c	c	c	....	c	c	c	c	c	c	c	c	c	c
Tropisternus lateralis	a	a	r	a	a	a	a	a	a	a	....	a	a	c	c	a	a	a	c	c	c
Tropisternus mixtus*	c	....	....	....	....	....	....	....	....	f	....	r	r	....	....	....	....	....	....	....	....
Donaciidæ: Donacia æqualis	....	....	....	....	c	c	c	c	c	c	....	c	c	c	c	c	c	c	....	....	....

Distribution in the Fairport (Iowa) fishponds according to beetle families.

Pond number and series.	Halliplidæ.	Dytiscidæ.	Gyrinidæ.	Hydrophilidæ.	Total.	Pond number and series.	Halliplidæ.	Dytiscidæ.	Gyrinidæ.	Hydrophilidæ.	Total.
12B	2	6	1	8	17	7D	4	12	3	9	28
13B	2	2	2	5	11	8D	4	12	3	7	26
14B	2	5	1	5	13	9D	3	3	1	4	11
15B	2	2	1	5	10	1E	2	7	1	5	15
16B	2	5	1	8	16	2E	4	15	3	9	31
1D	3	7	0	5	15	3E	3	11	3	10	27
2D	3	13	3	13	32	4E	3	10	3	5	21
3D	3	10	3	9	25	1F	2	3	3	4	12
4D	3	9	4	12	28	2F	2	6	3	6	17
5D	4	18	3	14	39	3F	1	4	2	5	12
6D	1	0	1	4	6						

SOURCE OF MATERIAL.

In the summer of 1916 Geo. B. Lay collected and identified the various insect forms found in the Fairport fishponds, and in 1917 Dr. R. A. Muttkowski checked the species thus obtained and, with Mr. Lay, completed their identification. Both made out reports of their work, containing in addition to the check list some notes on the habits of certain of the insects in relation to fish breeding. The writer has used their check list in its entirety as the basis of the one here presented, chiefly because it was prepared during the same years that Mr. Schradieck was listing the food of the fish and Dr. Emmeline Moore was studying the plant fauna of the ponds. For this reason the beetle list, the plant list, and the fish-food list exactly supplement one another. The first shows the kinds of beetles found in the ponds from which the fish were taken, the second explains the relative abundance of the beetles in the different ponds on the basis of their plant environment, and the third indicates the choice the fish made of the beetles that were available.

Every species in this beetle list has been verified by the present author during the years 1918, 1919, and 1920, and to it have been added other species that either escaped capture in 1916 and 1917 or have appeared more recently in the pond fauna. These additions are indicated by a star (*) following the species name and include only two forms that are anything more than occasional interlopers, namely, *Haliplus borealis* and *Thermonectes ornaticollis*.

INFLUENCE OF ENVIRONMENT.

Dr. Muttkowski called attention in his report to the remarkable difference in both the quantity and the quality of the population of the various ponds. This is the more noteworthy because of the contiguity of the ponds. Those in the same series are separated from one another by narrow banks of earth, 12 to 15 feet in width, and pond 4E is separated from pond 5D by a similar narrow bank. Pond 6D is very small and is used as a natural aquarium in which to keep the large bass to prevent them from eating other fish. They are so hungry most of the time that they keep the pond cleared of all animal food throughout the summer. This accounts for the meagerness of its insect fauna, and it can not be fairly considered in comparison with the others. Ponds 1 and 2D are contiguous, are about the same size and depth, and are surrounded with the same vegetation. They were

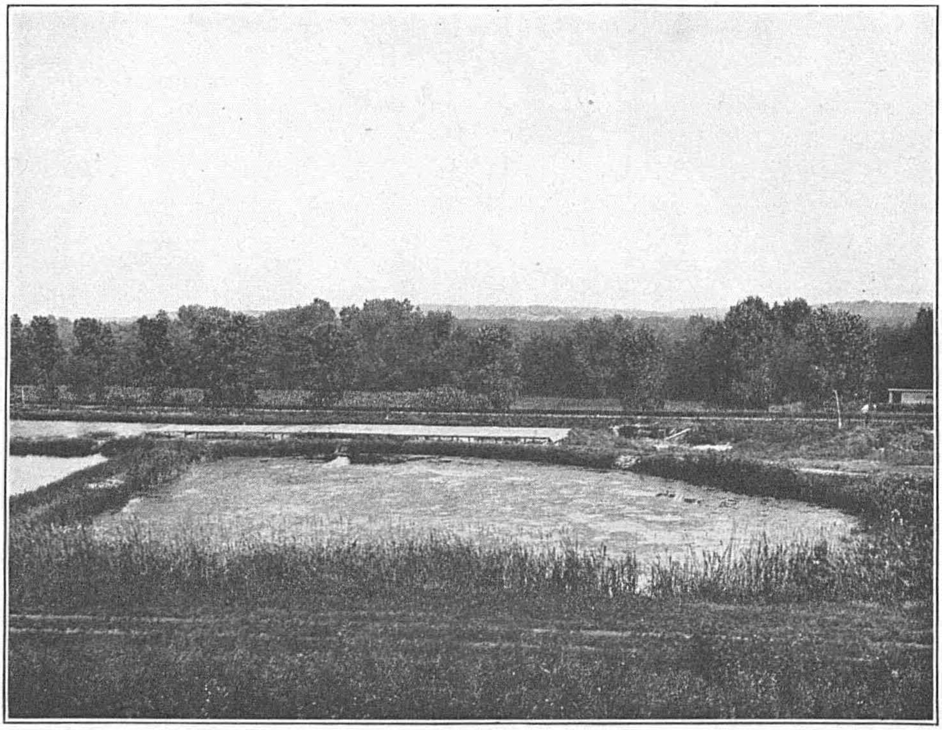


FIG. 6.—Pond 1D covered with blanket algæ and containing very few beetles in 1920 and 1921.

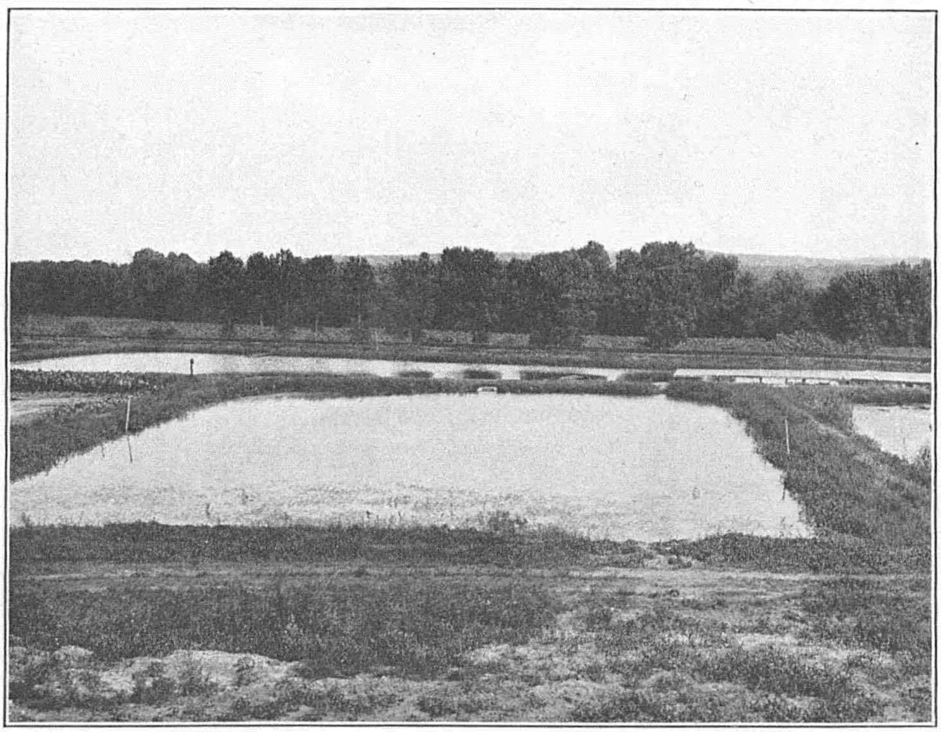


FIG. 7.—Pond 2D free from blanket algæ and containing over 30 species of beetles in great abundance.

also treated alike the previous year; that is both were wintered full and not dry. Yet pond 2 contained more than twice as many beetle species as pond 1, and while in the former seven species were abundant and eight were common, in the latter only two were abundant and four common, and all six were small species and mostly vegetable eaters.

A partial explanation of such a radical difference may be found in the statement of Dr. Moore (1920, p. 11), which was as follows:

Physiologically, however, they are more or less distinct because of the dissimilar character of the vegetation in them. Pond 1D has been richly stocked with floating algæ, which at times have covered the surface. Few of the larger-rooted aquatics are present. Pond 2D has no algal mats or blankets, but fully one-tenth of the surface area has been covered by the large-rooted aquatic *Potamogeton illinoensis*, interspersed in places with the nonrooted Ceratophyllum, or hornwort.

These two ponds furnish such striking differences in their beetle fauna that they have been photographed as illustrations of the presence and absence of floating algæ and are shown in Figures 6 and 7 as they appeared in 1921. In pond 1D (fig. 6) the algal blanket described by Dr. Moore has persisted from year to year and has covered practically the entire surface. As a result the beetle fauna of 1916 has steadily declined in numbers and variety until in 1921 there were only straggling specimens left, outside of the haliplids. The dytiscids were reduced to the minute species of Bidessus and Hydroporus, and the hydrophilids to those of Berosus and Philydrus. One of the species that was abundant in 1916 (*Laccophilus maculosus*) had entirely disappeared, and the other (*Tropisternus lateralis*) was reduced to a minimum and would have to be classed as rare.

In contrast with this the photograph of pond 2D (fig. 7) shows no algæ but a limited area of Potamogeton. This also has persisted from year to year and has increased in extent until in 1921 it covered about a third of the entire surface. The beetle fauna has steadily increased in number and variety, particularly of the dytiscids and hydrophilids. The seven species that were abundant in 1916 have remained so, and five of the eight species that were then common have become abundant.

A similar result has been observed to follow the presence of duckweed on the surface of a pond. The little pond, 13B, only 25 feet square, was fairly swarming with hydrophilid beetles in 1919. The latter part of that summer, however, it developed a blanket of duckweed which remained through 1920 and 1921. In consequence every beetle species except the haliplids disappeared. We may reasonably conclude, therefore, that the presence of a blanket of any sort that covers the entire surface of a pond is extremely unfavorable to beetle development. The diving beetles require open water in order to obtain their air supply, and even the scavenger beetles are seriously hindered by such a blanket in securing sufficient oxygen. The gyrinids are, of course, absolutely banished, since there is no water surface left upon which to perform their whirligig movements. The little haliplids are the only ones that can successfully compete with such restrictions.

Ponds 8 and 9, D, are also contiguous, are practically the same size and depth, and are surrounded with identical vegetation. Pond 8D, however, contained more than twice as many beetles as 9D, and whereas in the former six species were abundant and seven common, in the latter only one was abundant and six common. Here, again, we must seek an explanation in the physiological differences of the two ponds, due to the dissimilar character of the vegetation. Pond 9D contained an abundance of the blue-green alga (*Aphanizomenon flos-aquæ*). Dr. Moore stated (1920, p. 12) that when first called to her attention "It was so abundant that the water appeared blue-green and oily." Multiplication continued to take place with great rapidity "until the maximum was reached in the interval of July 24 to 30, when the algæ could be rolled up from the bottom like mush." The beetles seem to have been as much prejudiced against mush under foot as they were against an algal blanket overhead.

In series E pond 2 was manured in 1918 and pond 3 in 1919. As a result they proved very attractive to the beetles, and pond 2 had the highest number of dytiscid species and the largest aggregate of hydrophilid individuals of all the ponds examined. It is significant that these two ponds in 1920 were covered with a heavy blanket of Hydrodictyon, which greatly reduced their beetle fauna both in numbers and variety. The dytiscids and gyrinids practically all removed to other ponds, leaving only the haliplids and a few hydrophilids. Furthermore, in 1920 and 1921 the blue-green algæ in pond 9D almost disappeared, and as a result the beetle fauna noticeably increased. The influence of the algæ, therefore, is only temporary, and once they are removed the beetle fauna quickly recovers.

RESTRICTION OF SPECIES.

Species are often restricted to one or two ponds and are not found in any of the others. In the table here presented 8 species are confined to a single pond and 10 others are found in only 2 or 3 ponds, usually contiguous in the same series. This is a third of the entire number, and there are also some of the others whose distribution is far more limited than the table would seem to indicate.

In contrast with these there are certain other species that may be classed as cosmopolitan, for the Haliplidæ (*Peltodytes edentulus*), for the Dytiscidæ (*Laccophilus maculosus*), for the Gyrinidæ (*Dineutes americanus*), and for the Hydrophilidæ (*Tropisternus lateralis* and *T. glaber*) are found in all the ponds except one or two. *Hydrous triangularis* is also reported from every pond except two, but it can not be included with these others because it is restricted in its breeding and the larvæ rarely appear in more than a single pond during any one season.

In 1920 *Thermonectes ornaticollis* was present and breeding in large numbers in pond 12B but was found only rarely in any of the other ponds. Two specimens of this species were all that were obtained in 1916—one in pond 8D and one in pond 1E. Similarly, *Thermonectes basilaris* was confined to pond 5D in 1919, to pond 8D in 1920, and to pond 7D in 1921. *Cybister fimbriolatus*, although the adults have been found in a dozen ponds, including some of every series, has never been known to breed anywhere except in 5D, with the exception of a single pupa found on the shore of 13B in the summer of 1921. In general, ponds 2, 3, 4, 5, and 7, D, and 2 and 3, E, are the richest both in variety of beetle species and in numbers of individuals, while the B series of ponds are the poorest.

RELATIVE IMPORTANCE OF SPECIES.

In these tables the Haliplidæ are represented by 5 species, the Dytiscidæ by 22, the Chrysomelidæ by 1, the Gyrinidæ by 5, and the Hydrophilidæ by 20, a total of 53 species. Many of these, however, as just stated, are so rare or occur in such small numbers that they do not enter at all into the ecology of the fishponds. Once listed as having been found and identified with reasonable certainty, they may be conveniently dropped from further consideration without affecting at all the ultimate results. Such a procedure reduces the number of species that really deserve consideration so much that they can be intelligently and profitably discussed within the limits of a single paper. On this basis there will be left 2 haliplids, 11 dytiscids, 2 gyrinids, and 10 hydrophilids, a total of 25 species out of the 53 enumerated. With these, mention should be made of the chrysomelid (*Donacia aequalis*), both the adults and larvæ of which are common in nearly all the ponds. The adults are only semiaquatic and are found upon the leaves and stems of pond lilies, arrowhead, pickerel weed, reeds, and sedges, while the larvæ live upon the outside of the submerged roots of these plants. Both larvæ and adults are eaten freely by fish.

SYSTEMATIC DESCRIPTIONS OF FAIRPORT SPECIES.

The part that follows is as much for the ordinary fish-culturist as that which has preceded. Having convicted three of the prisoners brought before the bar, justice demands that their likenesses and individual descriptions, as well as their criminal records, be published, so that they may be recognized whenever they attempt any nefarious work. The fish breeder, if he desires success, ought to be able to tell these offenders at sight and so guard against their depredations. The easiest method of doing this is to become familiar with their pictures and habits. With this object in view, photographs of an adult Cybister, an adult Dytiscus, and an adult Hydrous are here presented (figs. 1, 2, and 3, frontispiece). These are the only genera whose adults kill fish fry, and the photographs will constitute a sort of rogue's gallery for the fish-culturist. There is no necessity of determining the particular species. Any beetle that lives beneath the water in a fishpond and comes to the surface to breathe is a water beetle, and if it resembles any of these figures in size and shape it may safely be condemned and destroyed.

A fully developed larva of any of these three genera can be told by its size, but younger stages are not as readily identified. The best means of recognition is the head, and for that reason there will be found on the following pages an enlarged figure of the head of each larva described. These give enough detail for identification, because the individual characters remain practically the same throughout the life of the larva. The half-grown or quarter-grown larva may be recognized in this way with nearly as much certainty as after it becomes fully matured.

It is not, of course, intended that the average fish breeder should become a systematic entomologist; that is not necessary. He may be fortunate enough never to have occasion to identify any of these beetles either as larvæ or as adults. Should such a necessity arise, however, the figures here given will afford a quick and ready means of recognition. Unfortunately, none of these larvæ or adults have a common name except the larvæ of Cybister and Dytiscus, which are called "water tigers" indiscriminately; but it is not a difficult task to learn the three generic names, and there is no need of distinguishing species among the larvæ any more than among the adults. Use the photographs and figures of larval heads, therefore, for identification and the text for habits and food.

The descriptions of the larvæ and pupæ have been made as scientifically accurate as possible, in order that they may serve as a contribution to economic entomology. As was stated in the introduction, our knowledge of the life histories of the North American water beetles is still deplorably limited. It is hoped that the present paper will contribute a little to that desirable knowledge.

The keys that follow include the larvæ and pupæ of those genera found in the Fairport ponds. Richmond (1920, p. 83) gave more detailed keys of the larvæ and pupæ of the Hydrophilidæ and also one of the egg cases. His keys contained 22 genera of the single family included, and may be used to supplement those here given.

KEY FOR IDENTIFICATION OF LARVÆ.

1. Tarsi with two claws, mandibles suctorial.....2
1. Tarsi with only a single claw, mandibles manducatory.....3
    2. Abdomen with slender lateral filaments, which serve as tracheal gills, its apex armed with four prehensile hooks.....GYRINIDÆ.....4
    2. Abdomen with neither filaments (except Coptotomus) nor hooks; larvæ elongate, slender and agile.....DYTISCIDÆ.....5
3. Eyes in groups of five; larvæ vegetable eaters.....HALIPLIDÆ....16
3. Eyes in groups of six; larvæ carnivorous.....HYDROPHILIDÆ....17
    4. Lateral filaments of abdomen all plumose; mandibles with fine teeth on the inner margin.....GYRINUS.
    4. First two pairs of lateral filaments not plumose in mature larva; mandibles without teeth on the inner margin.....DINEUTES.
5. Abdomen with slender lateral filaments which serve as tracheal gills; cerci long, slender, and densely plumose.....COPTOTOMUS.
5. No lateral filaments on the abdomen; cerci shorter and less plumose.....6
    6. Mandibles attached diagonally to ventral surface of head and shutting up against the tip of the proboscis, visible both dorsally and ventrally.....7
    6. Mandibles attached beneath the frontal margin of the head, toothed on their inner margin, not visible dorsally.....8
    6. Mandibles attached to the anterior margin of the head and shutting past each other like a pair of shears, visible dorsally and ventrally.....9
7. Proboscis broad, with a notch on either lateral margin; labial palps two-jointed, seven times as long as the labium.....HYDROPORUS.
7. Proboscis narrow, club-shaped, not notched; labial palps three-jointed and not longer than the labium itself.....HYPHYDRUS.
    8. Mandibles slender, narrowly sulcate at the tip, simple; third joint of antennæ more than twice as long as the fourth.....HYDROCANTHUS.
    8. Mandibles stout, bifid at the tip; third joint of antennæ no longer than fourth..CANTHYDRUS.
9. Maxillæ filiform, eight- to ten-jointed, not enlarged at the base.....10
9. Maxillæ only five or six jointed, distinctly enlarged at the base, with a well defined four-jointed palp.....11
    10. Larger, 50 to 75 mm. long; antennæ 7-jointed; frontal margin of head evenly rounded; cerci long and densely plumose.....DYTISCUS.
    10. Larger, 50 to 75 mm. long; antennæ 9-jointed; frontal margin of head very uneven; no cerci.....CYBISTER.
    10. Smaller, 20 to 25 mm. long; antennæ 7-jointed; cerci long with scattered hairs only. HYDATICUS.

11. Prothorax two or three times as long as wide; cerci short and naked; labium with a large ligula; stipes of maxilla as long as the palp........12
11. Prothorax a little longer than wide; cerci half the length of the abdomen and densely plumose; labium without a ligula........LACCOPHILUS.
11. Prothorax considerably wider than long; cerci long and plumose; labium without a ligula; maxillary palp much longer than stipes........13
    12. Ligula tipped with two long, jointed spines........THERMONECTES.
    12. Ligula without terminal spines........ACILIUS.
13. Larger, 15 to 20 mm.; cerci densely plumose........14
13. Smaller, 8 to 12 mm.; cerci with scattered hairs only........15
    14. Maxillary stipes slender, with concave sides, armed on the inner margin with a long seta and a single spine........COLYMBETES.
    14. Maxillary stipes stout, with convex sides, armed on the inner margin with two or three spines and a row of setæ........RHANTUS.
15. Maxillary stipes armed on the inner margin with two long curved claws and many small spines and setæ........ILYBIUS.
15. Maxillary stipes armed on the inner margin with small spines and setæ only; no curved claws. AGABUS.
    16. Body segments with filiform tracheal appendages as long as the body itself; tip of abdomen bluntly rounded........PELTODYTES.
    16. Body segments with short triangular appendages; tip of abdomen acuminate, ending in two filiform, jointed setæ........HALIPLUS.
17. Epicranial suture wholly lacking; each mandible with a terminal seta, a simple lobe or lacinia mobilis, and an inner tooth........HYDROCHOUS.
17. Epicranial suture present; mandibles without a terminal seta or a lacinia mobilis, but with one or more inner teeth........18
    18. Abdomen with seven pairs of long lateral filaments, which serve as tracheal gills; mandibles with two or three teeth........19
    18. Tracheal gills reduced to mere tubercles or wanting; mandibles with only one or two teeth.....20
19. Second joint of antenna with finger appendage outside of the terminal joints; no stigmatic atrium at tip of abdomen........BEROSUS.
19. No finger appendage on antenna; ninth and tenth abdominal segments forming a stigmatic atrium........HYDROPHILUS.
    20. Second joint of antenna with finger appendage outside of the terminal joint; mandibles not grooved internally; femora without a fringe of swimming hairs........21
    20. No finger appendage on the antenna; mandibles definitely grooved internally; femora with a fringe of long swimming hairs........22
21. Labium without a ligula; tarsus as long as the tibia........LACCOBIUS.
21. Labium with a ligula, which is longer than the basal joints of the palpi; tarsus much shorter than the tibia........PHILYDRUS.
    22. Mandibles each with a single inner tooth; ligula not as long as the basal joints of the palps. HYDROUS.
    22. Mandibles each with two or more inner teeth; ligula distinctly longer than the basal joints of the palps........TROPISTERNUS.

KEY FOR IDENTIFICATION OF PUPÆ.

1. Tibiæ of first two pairs of legs folded tightly against the femora and the two inclined forward at an angle of 45° with the body axis; knees projecting strongly and armed with spines; antennæ folded across the eyes; no posterior cerci........HALIPLIDÆ.......2
1. Femora at right angles to the body axis, tibiæ not folded against them; knees neither projecting nor armed with spines; antennæ not crossing the eyes; a pair of stout posterior cerci, jointed or bifid; styli long and jointed, with an enlarged basal portion........HYDROPHILIDÆ.....3
1. Femora at right angles to body axis, tibiæ not folded against them; first pair of knees projecting but not armed with spines; each compound eye divided into a dorsal and ventral half, separated somewhat; no posterior cerci; styli in the form of short bristles, not jointed..........GYRINIDÆ.....8

1. Femora at right angles to body axis, first pair of tibiæ folded against them, but not the other two pairs; knees neither projecting nor armed; posterior cerci in the form of stout spines, not jointed nor bifid; styli in the form of short spines, also not jointed........................DYTISCIDÆ.....9
   2. Styli in the form of long, curved, linear spines, not jointed; wings folded tightly against the body and smooth..PELTODYTES.
   2. Styli in the form of short triangular spines; wings loosely held against the body and very rough..HALIPLUS.
3. Styli on dorsal surface of abdomen in transverse rows of four on each segment; spiracles partly concealed by lateral tubercles.. 4
3. Styli on dorsal surface of abdomen in transverse rows of six on each segment; spiracles not concealed, no tubercles.. 7
   4. Two supraorbital styli over each eye; basal portion of pronotal styli not annulate; no metasternal spine; cerci long, slender, moniliform.. 5
   4. One supraorbital stylus over each eye or none; metasternal spine prominent; basal portion of pronotal styli multiannulate; cerci short, stout, and bluntly bifid at the tip.............. 6
5. 24 pronotal styli; no inner spur on mesotibia; tarsi all tipped with stout spines; eighth abdominal segment with a pair of dorsal appendages resembling cerci...................LACCOBIUS.
5. 26 pronotal styli; inner spur on mesotibia prominent; no spines at tips of tarsi; no appendages on eighth abdominal segment..BEROSUS.
   6. Larger, 25 to 30 mm. long; one supraorbital stylus; posterior cerci superficially annulate and bifid..HYDROUS.
   6. Smaller, 12 mm. long or less; no supraorbital stylus; cerci not annulate, but bifid and acute. TROPISTERNUS.
7. Larger, 13 mm. long or more; 32 pronotal styli; eighth abdominal segment with two small dorsal tubercles, each tipped with a stylus; cerci bifid and acuminate..............HYDROPHILUS.
7. Smaller, 8 mm. long or less; 24 pronotal styli; no dorsal tubercles on the eighth abdominal segment, but with a pair of styli; cerci not bifid but long and linear......................PHILYDRUS.
   8. Larger, 10 mm. long or more; bristles arranged as in Figures 92 and 93 (p. 307); labrum prominent and well defined..DINEUTES.
   8. Smaller, 6 mm. long or less; bristles not definitely arranged; labrum less prominent. GYRINUS.
9. Posterior margins of first six or seven abdominal segments raised into prominent transverse ridges dorsally; cerci short, stout, and straight..10
9. Dorsal surface of abdomen smooth, without transverse ridges; cerci long, narrow, and crooked, or club-shaped..13
   10. Eighth abdominal segment much narrower than the seventh; metatibial spur large and prominent..11
   10. Eighth abdominal segment nearly as wide as the seventh; metatibial spur scarcely visible..12
11. Larger, 30 mm. long or more; styli in the form of stiff bristles; cerci simple and acute. CYBISTER.
11. Smaller, 15 mm. long or less; styli with a stout basal portion and a slender terminal seta; cerci bifid and blunt..THERMONECTES.
   12. Larger, 10 mm. long or more; styli with a short enlarged basal portion; anterior margin of pronotum three-quarters as wide as the posterior..............................ILYBIUS.
   12. Smaller, 6 mm. long or less; styli with a short enlarged basal portion; anterior margin of pronotum only one-third as wide as the posterior..............................AGABUS.
   12. Smaller, 4 to 5 mm. long; styli in the form of stiff bristles, without enlarged basal portion; anterior margin of pronotum three-quarters as wide as posterior...........LACCOBIUS.
13. Anterior margin of pronotum much narrower than posterior; styli in the form of slender bristles, without enlarged basal portion..14
13. Anterior margin of pronotum nearly as wide as posterior; styli with a short enlarged basal portion and a long terminal seta..15
   14. Larger, 35 to 40 mm. long; pronotum with two raised processes on the anterior margin; cerci club-shaped and densely plumose..DYTISCUS.

14. Smaller, 17 mm. long or less; anterior margin of pronotum smooth; cerci crooked, tapering, sparsely setose..COLYMBETES.
15. Body densely covered with setæ; cerci also setose; metatibial spine short and hardly discernible. HYDROPORUS.
15. Body with few setæ; cerci naked; metatibial spine long and very prominent; five supraorbital styli above each eye..COPTOTOMUS.

Genus PELTODYTES Régimbart.

Peltodytes (Régimbart, 1878, p. 450).
Cnemidotus (Erichson, 1832, p. 48).

A genus of small beetles, both the larvæ and adults of which feed exclusively upon algæ. They are yellowish or reddish with black spots on the elytra, which vary in number, size, and arrangement in the different species. They may be distinguished from the other haliplids by the terminal joint of the labial palps, which is longer than any of the preceding joints, and by the coxæ of the hind legs, which cover all but the last segment of the abdomen. The genus is represented in the Fairport fishponds by a single species.

Peltodytes edentulus (Leconte). Figures 8 and 9.

Cnemidotus edentulus (Leconte, 1863, p. 21).
Peltodytes edentulus (Matheson, 1912, pp. 174 and 186; fig. B, text; pl. 10, figs. 2, 5, 6, 9; pl. 13, figs. 20, 21, 23, 25–27, 29–31; pl. 14, figs. 33–35).
Peltodytes edentulus (Roberts, 1913, p. 122).

The eggs.—The eggs are fastened individually to filaments of Nitella or Chara. The average time required for hatching is about two weeks.

Habits of the larva.—The natural history of the Haliplidæ has been admirably worked out by Robert Matheson and was published in 1912. The complete life history of the above species was also secured by the writer, and it confirms the statements published by Matheson, except in regard to the duration of the prepupal and pupal periods. This larva can only crawl about slowly over the algæ, trailing its long spines. It can not run or swim at all, but it is a most persistent crawler and, when hunting for a place to pupate, travels a longer distance from the water's edge than any other larva studied, except that of the gyrinid (*Dineutes americanus*).

It is the only larva that constantly refused to pupate in an artificial mud cell. It always persisted in crawling out and making its own pupal chamber somewhere else. In spite of its porcupine coat of bristles it can burrow readily into mud considerably hardened. It feeds entirely upon filamentous algæ, such as Spirogyra and Mougeotia, and the structure of its mouth parts and legs is peculiarly adapted to this sort of food. It breathes through tracheoles in the long jointed spines, and thus has no need to come to the surface for air. It has no visible spiracles.

Description of the larva.—General form an elongated cone 6 mm. in length, the thorax and the first four abdomen segments about the same diameter, the last five abdomen segments tapered to a blunt point. The head is considerably narrower than the thorax, somewhat depressed, turned downward almost at right angles to the thorax, and tapered anteriorly. The prothorax is armed with six dorsal jointed spines, nearly as long as the body. Four of these are close to the anterior margin, two lateral and two dorsal, and have enlarged bases; the other two are dorsal and farther back. The meso and meta thorax and the first seven abdomen segments each have a transverse row of four spines, two lateral and two dorsal. The last two abdomen segments have only two dorsal spines apiece, each 4.5 mm. in length, and no lateral ones.

The number of joints in these spines varies from 11 in the posterior dorsal pair of the prothorax to about 18 in the meso and meta thorax. The basal joint is rather long, the next two or three are very short, and the remainder are of varying lengths. These 46 spines give the larva very much the appearance of a porcupine with abnormally developed quills (fig. 8).

The antennæ are four-jointed with a terminal spine, the last segment consisting of two fused pieces placed side by side. The mandibles are short and wide with rounded ends; the sharp tip is on the inner

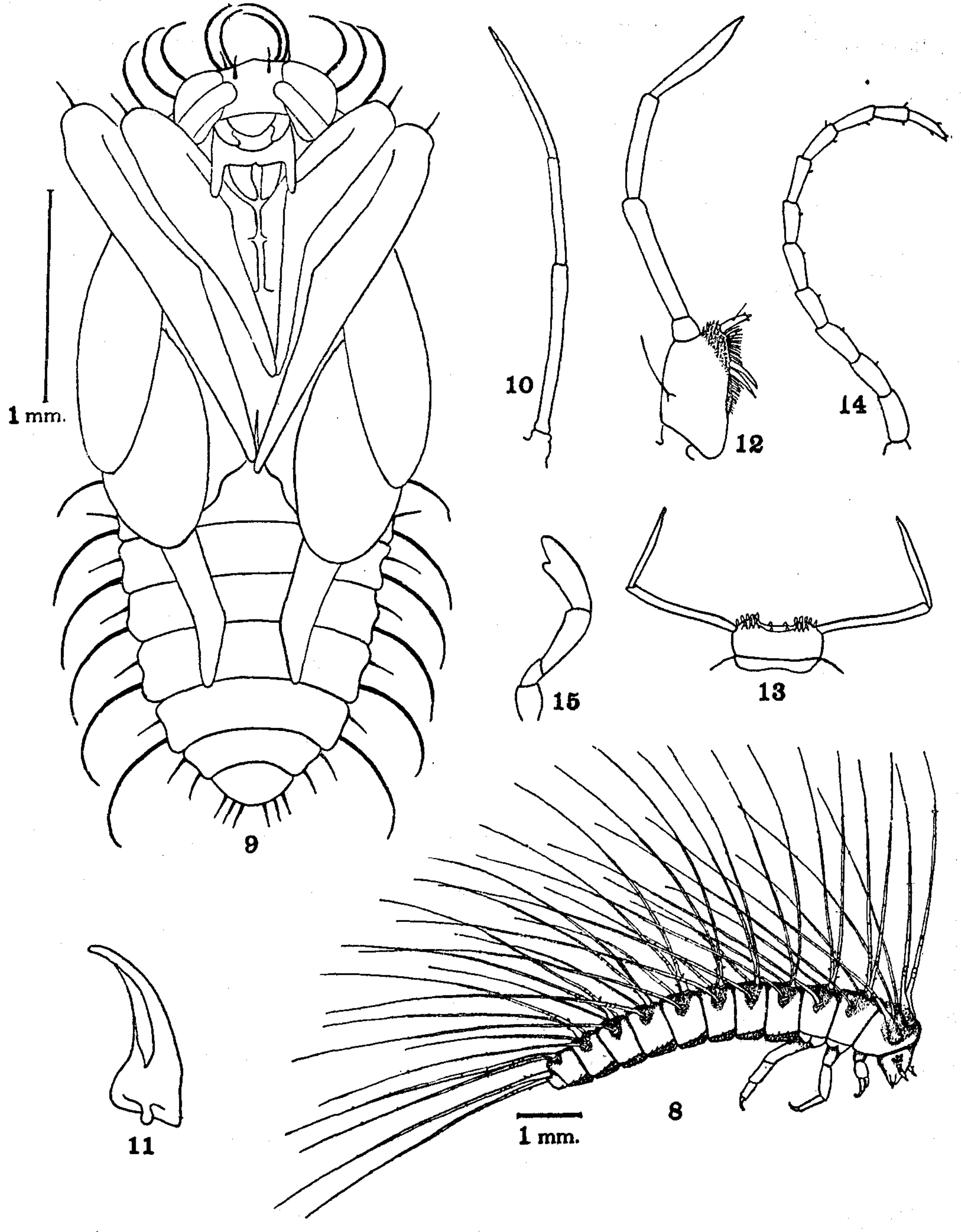


FIG. 8.—Larva of *Peltodytes edentulus*, side view, showing the linear, tracheated, and jointed spines on each segment of the thorax and abdomen. FIG. 9.—Ventral view of the pupa of *Peltodytes edentulus*. FIG. 10.—Antenna of larva of *Coptotomus interrogatus*. FIG. 11.—Mandible. FIG. 12.—Maxilla, ventral view. FIG. 13.—Labium, ventral view. FIG. 14.—Antenna of adult beetle. FIG. 15.—Labial palp of adult beetle, side view.

margin and not at the apparent end of the appendage; it is also hollow and communicates with a tube that opens into the mouth. Each maxilla is made up of a smaller basal segment and a larger second segment, which has a two-jointed palpus on its tip and a chitinous projection covered with setæ at its inner distal corner. The labial palps are one-jointed.

In the first legs the penultimate segment is prolonged at the inner distal corner, and the projection is toothed along the margin that faces the last joint, against which it shuts, forming a sort of chela. There is but a single terminal claw, with a short basal spine.

Pupation.—From 20 to 25 days after hatching the larva is ready to pupate. It crawls a long distance from the water's edge and forms its pupal chamber in rather dry mud. Into this it pushes for half an inch or more and there hollows out a spherical chamber about 5 mm. in diameter. It remains inside of this chamber from four to six days before transforming. The jointed spines are all discarded with the larval skin; of course many of them get broken during the formation of the pupal chamber, especially the long, narrow ends where the tracheoles are located. It would seem, therefore, as if the spiracles must begin to function before the transformation takes place. They become visible during this prepupal period, and with the disappearance of the tracheolar spines they assume their proper functions.

Description of the pupa.—General form an elongated oval, 3.5 mm. long and 1.75 mm. wide. It is white or sometimes cream-colored, with a decided yellowish tinge, the eyes black or dark brown. The most striking feature is the position of the two front pairs of legs. In these the tibiæ and tarsi are in a straight line and are folded tightly against the femur. The three are then turned forward until they stand at an angle of 45° with the body axis, the knees projecting a considerable distance on either side of the head. The anterior margins of the front legs touch the eyes, and the antennæ are carried diagonally across the anterior half of the eyes. Each knee of these two anterior pairs is armed with a stout spine; the head has two short spines between the eyes and one posterior to each eye; the pronotum has 10 long, curved, simple styli on its dorsal surface, and a short jointed one on either side of the posterior margin close to the mid line. The meso and meta thorax have four short dorsal spines, two on each segment. Each of the first six abdomen segments has on its dorsal surface four long styli, two lateral and two dorsal, and between the latter a short spine on either side of the mid line. The seventh segment has four shorter styli and the last segment has six.

The pupa lies on its back more than any of the other pupæ studied, but also rests upon its ventral surface, with the body arched strongly upward, like the other pupæ. When in this position, it is supported on the spines at the knees of the first two pairs of legs and the styli on the last abdomen segment. Of 16 pupæ reared to the adult stage, 12 remained in the pupa stage 12 days and four transformed at the end of the tenth day (fig. 9, p. 272).

Habits of the adult.—The adults swim slowly and with considerable effort, moving the legs alternately as in walking. The tibiæ of the first and second pairs of legs and the tarsi of all three pairs have long fringes of swimming hairs. In marked contrast to their labored swimming they walk and run on land with great agility, but can not, or at least do not, jump at all. They fly readily from pond to pond, but apparently can not cover very long distances. They live among the plants in shallow water and are not found in the open parts of the ponds. As far as observed they feed entirely upon Chara and Nitella.

Description of the adult.—General form elongate-ovate, quite strongly convex; color pale straw-yellow with black markings; length 3.5 to 4 mm. Head with a large crescentic black spot between the eyes, punctate except in front of the black spot; eyes nearly circular in outline. Pronotum with a pair of basal black spots, rather sparsely punctate. Legs pale yellow except the femora of the third pair, which are dark brown ringed with yellow at their distal ends. Posterior coxæ reaching the last segment of the abdomen, punctate. Elytra each with 10 rows of punctures and a partial row between the third and fourth rows, and with seven or eight black spots more or less confluent.

Genus HALIPLUS Latreille.

Haliplus (Latreille, 1802, p. 77).

Another genus of small beetles, which, both in the larval and adult stages, feed exclusively upon algæ. They, too, like the members of the preceding genus, are yellowish or reddish in color with black spots on the elytra. They may be distinguished from other haliplids by the fact that the terminal joint of the labial palps is much shorter than the preceding joint, while the coxæ of the hind legs cover only the first three segments of the abdomen and the fourth tarsal segment is much shorter than the first.

Haliplus ruficollis (DeGeer).

Dytiscus ruficollis (DeGeer, 1774, p. 204; pl. 16, fig. 9).
Haliplus immaculicollis (Harris, 1828, p. 164).
Haliplus ruficollis (Schiødte, 1864, p. 161; pl. 8, figs. 1-12).
Haliplus ruficollis (Matheson, 1912, p. 169 and 186; fig. C, text; pl. 13, figs. 22 and 24; pl. 14, figs. 32 and 36).

The eggs.—The female cuts a hole with her mandibles in the side of a filament of Nitella and deposits several eggs within the algal cell, which hatch within 10 or 12 days.

Habits of the larva.—This larva also crawls about slowly over the algæ and can not run or swim. It feeds exclusively upon algæ, and for this purpose seizes the algal filament in its modified fore legs and passes it backward until it finds a broken end. It then punctures the wall of the filament with its mandibles and sucks out the fluid contents through the mandibular tubes. This larva has no tracheolated spines for breathing, but spiracles are present on the last two thoracic and the first seven abdominal segments. Aeration is apparently accomplished in some way through these.

Description of the larva.—Body very long and slender, made up of a head, three thoracic segments, and 10 abdominal segments. Head short, depressed, narrower than the thorax. The three thoracic and the first six abdominal segments about the same width, the seventh and eighth segments slightly narrowed, the ninth half the width of the eighth, and the tenth less than half the width of the ninth. This last segment is much prolonged and ends in two long spines, which are not jointed; the spines end in long setæ. The first seven abdominal segments are each armed with two dorsal plates, the eighth and ninth with a single plate, all closely set with short spines.

The antennæ are four-jointed, the last joint made up of two longitudinal parts side by side, the outer one terminated by a short spine. The mandibles are short and highly chitinized; each ends in a curved hollow point or tip, which opens on its inner margin into a tube that runs to the base of the mandible and there opens into the mouth. The maxillæ approach those of the adult much more closely than in any other beetle here described. The cardo is distinct and pyriform, the stipes very broad with a row of setæ along the outer margin and two large spines at the inner distal corner. At the outer distal corner is borne the palpifer and the three-jointed palp, the two basal joints of which are equal and half the length of the terminal one, each with a seta on the outer margin. Along the terminal margin is borne the galea, which is broad, bluntly rounded and well armed with setæ and spines. The labium is narrow and elongate and is tipped with a row of long spines; the palps are two-jointed, the terminal joint considerably longer than the basal, and both joints unarmed.

The front legs are transformed from locomotor into grasping organs for the purpose of seizing and handling the algal filaments upon which the larva feeds. In these legs the penultimate segment has a process on the inner distal corner which extends outward beside the last segment and reaches the tip of the latter. This process carries a spine on either side and two spines at the tip, between which the terminal claw of the last joint shuts down. The process and the last joint together form a sort of chela, guarded by the spines and the terminal claw, and form an admirable organ for handling filamentous algæ.

Pupation.—Matheson (1912) found the eggs of this species and reared the larvæ up to the point where they began to enter the soil for pupation, but unfortunately was compelled to give up the work before any larva actually transformed. Schiødte (1864) described in detail the larva of this beetle but said nothing about the pupa, and it remains still unknown. We may safely say, however, that pupation takes place within an earthen chamber formed by the larva in much the same way as that of the Peltodytes larva.

Description of the pupa.—The pupa of this species is unknown, but Schiødte obtained the pupa of *Haliplus variegatus*, and from it we may obtain a good idea of the pupæ of the genus. It showed the same turning forward of the two front pairs of legs, with the knees projecting on either side of the head, but they are not armed with spines in Schiødte's figure. In place of the long curved styli on the pronotum of Peltodytes we find two short triangular spines at each anterior corner and two others on either side of the mid line, with a row of four along the posterior margin. The mesonotum and metanotum each

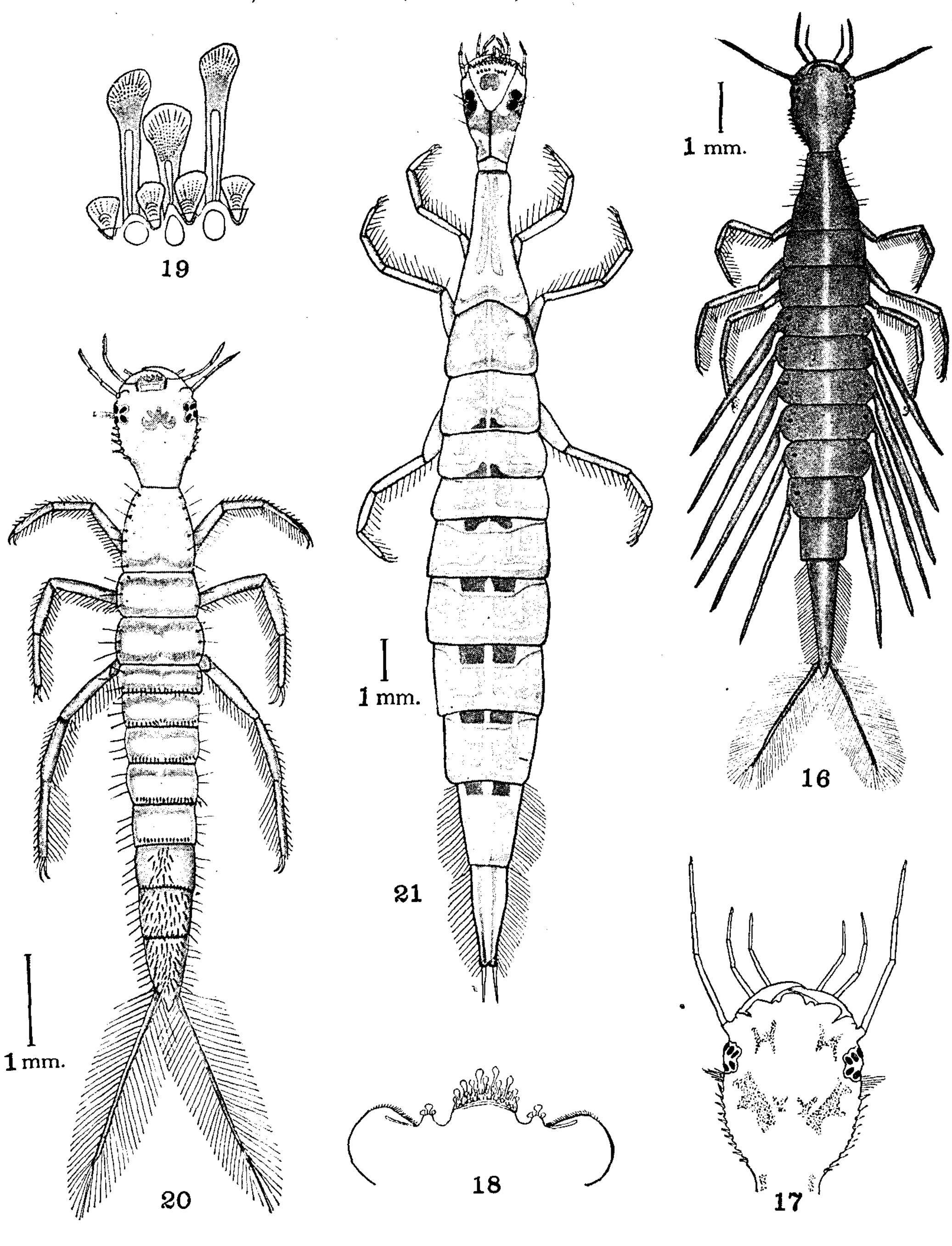


FIG. 16.—Larva of *Coptotomus interrogatus*, dorsal view. FIG. 17.—Head of same enlarged, showing color pattern. FIG. 18.—Anterior margin of head. FIG. 19.—Portion of same, highly magnified. FIG. 20.—Larva of *Laccophilus maculosus*, dorsal. FIG. 21.—Larva of *Acilius semisulcatus*, dorsal.

carry six similar spines; the first seven abdominal segments each have four spines; the last segment is unarmed. In addition to these dorsal spines the lateral margins of the first seven abdominal segments are prolonged into spines, which extend outward on the anterior segments and gradually turn backward on the posterior segments. The knoblike prolongations of the posterior coxæ and the corresponding indentations of the elytra and wings appear plainly.

The adult beetle.—General outline oval, the wider end anterior; body strongly convex. Total length, 2.5 to 3 mm.; greatest width, 1.5 mm. The head and thorax pale yellow, with a small depression on either side of the thorax near the base. Elytra also yellow, each with five black spots, all rounded, the two median ones more or less fused. The eyes are smaller and not as convex as in other species.

These beetles swim very poorly, although their hind legs are armed with fringes of long swimming setæ; but on the land they walk very well and can run with considerable agility, lifting their body high above the ground on their long hind legs. Like other haliplids they secure their supply of fresh air by means of the posterior coxal plates and lateral grooves in the pleura. They feed exclusively upon filamentous algæ.

This species has been found in every one of the fishponds except 6D and 3F, but was abundant only in the single pond 3D. Both the larvæ and the adults furnish excellent fish food and are themselves too small to menace young fish.

Genus COPTOTOMUS Say.

Coptotomus (Say, 1834, p. 443).

A genus of medium-sized oval dytiscids having the terminal joint of both labial and maxillary palps somewhat compressed laterally and notched at the tip. The prosternum has an elevated carina and its process is much swollen along the middle. The claws of the tarsi are equal or nearly so, are pressed closely together and appear like a single claw. There is but a single species found in the Fairport ponds, whose life history follows.

Coptotomus interrogatus (Fabricius). Figures 10–19, 22.

Dytiscus interrogatus (Fabricius, 1801, p. 267).
Coptotomus interrogatus (Say, 1834, p. 443).

Eggs.—Deposited singly in the stems of various water plants with no preference for any one kind. The eggs hatch in six to eight days.

Habits of the larva.—This larva swims well, using mainly the fringe of hairs on the lateral margins of the ninth segment and the much denser fringe on the sides of the cerci, propelling itself by a vertical undulatory movement. The legs assist materially, their length compensating for the scanty fringe of swimming hairs they possess. While swimming, the lateral gills are trailed inertly along the sides of the body.

Breathing through these gills the larva does not need to come to the surface for an air supply and remains continually beneath the water, crawling about over the vegetation. It eats in true dytiscid style, sucking the juices of its victims through its mandibles. It seems to prefer small damselfly and mayfly nymphs, with an occasional chironomid or beetle larva. In an aquarium it feeds greedily upon Laccophilus larvæ and also eats others of its own kind smaller than itself. It is thus cannibalistic, although the notes of Needham and Williamson (1907, p. 486) do not apply, because the larvæ they obtained were not those of this species, notwithstanding that the figure they gave has been published as authentic several times.

Description of the larva.—General form spindle-shaped, narrowed anteriorly and posteriorly. Total length, 12 to 14 mm.; cerci, 2 mm. additional. Greatest width, at the first abdomen segment, 2 to 2.5 mm.

Head contracted posteriorly to half its anterior width; prothorax one-fourth longer than wide, contracted anteriorly into a long neck, a little wider than the posterior portion of the head. First six abdominal segments diminishing regularly in width backwards, each with a pair of long and slender tracheal gills. Seventh segment reduced abruptly to three-fifths the width of the sixth segment; eighth segment elongate, narrow, tapering to a rounded point, with lateral fringes of long hairs; cerci filiform, as long as the eighth segment and densely fringed with long hairs. General color light brownish yellow, a little darker on the dorsal surface; eyes black.

Head one-half longer than wide, strongly flattened, widest through the bases of the antennæ, which are attached near the anterior corners behind the bases of the mandibles. Sides of the head behind the eyes contracted in a uniform curve to a short neck at the posterior margin. Behind each group of eyes on the lateral margin is a tuft of silky hairs, and the curve from there to the neck is thickly set with short spines, nine or ten in number. At the center of the anterior margin on the dorsal surface is a short rounded rostrum, about one-quarter as wide as the head itself. The frontal border of this rostrum has a fringe made up of two rows of rigid flattened processes similar to those on the larva of *Laccophilus maculosus*. In the present larva, however, the difference in the lengths of the processes of the two rows is much greater, and in the ventral row of longer processes there are two lengths alternating with each other. The rostrum is strongly arched dorsally and is flanked on either side by a small projection tipped with three similar processes.

The antennæ are attached to the lateral margins behind the bases of the mandibles, are filiform and four-jointed, the terminal joint minute. The mandibles are slender, bluntly pointed, and grooved on the inner margin nearly to the base, which has a small tooth at its center on the dorsal surface. The maxillæ have a short and narrow cylindrical cardo and a much wider stipes, whose tip is covered with short spines and whose inner margin is set with a dense fringe of short hairs, in the midst of which are two long curved spines or claws. The galea is a short fingerlike process tipped with a single seta; the palpifer is short, but the palp is long, filiform and three-jointed, the joints about the same length. The labium is short and twice as wide as long, its terminal margin armed with short, blunt, cylindrical processes. The labial palps are long and slender and two-jointed, the basal joint considerably longer and stouter than the terminal, though both are almost filiform. The ligula is wanting.

The legs are long and slender, with a fringe of short hairs. Each tracheal gill of the abdomen contains a minute central tracheole, which is given off from the lateral trachea and is unbranched. From its dorsal wall a short tube leads to the spiracle in the same segment, which is inoperative during the larval stage. In the first segment the distance from the lateral trachea to the base of the spiracle tube is considerable, but this distance diminishes in each successive segment and becomes very short in the sixth segment. The spiracles on the seventh segment are ventral to the tracheæ and are not visible in dorsal view.

The general color of the fully matured larva is yellow with a light tinge of brown. On the dorsal surface of the head are two dark-brown spots, shaped together like the letter H, one on either side just in front of the eyes. Behind each group of eyes is an irregular spot extending backward and inward toward the mid line. The mandibles are brown, darker toward the tip; the center of the first joint of the antennæ is slightly darker in color, while the center of the second joint is almost black; the ends of both joints are white. There is a dark-brown spot on either side of the neck at the base of the head, a ring of brown around each joint of the legs, and a narrow band at the base of the cerci, with a wider one at their tips. On the dorsal surface of each segment of the thorax and abdomen is a pair of sclerites faintly marked in brown; on the eighth and ninth segments these are fused and extend around the segment as in the Laccophilus larva.

Pupation.—When fully grown, the larva crawls out on the land and burrows into the earth from three-quarters of an inch to an inch and a half below the surface. Here it hollows out a pupal chamber 10 to 12 mm. in diameter, and after resting from 24 to 48 hours it pupates. As soon as it comes out of the water its spiracles begin to function and its lateral gills dry up and shrivel. Usually by the time pupation begins most of them are broken off, and the larval skins found inside of the pupal chambers seldom have more than one or two of them left still attached.

Description of the pupa.—General form ovate, not much widened anteriorly, rather bluntly rounded posteriorly. Total length, 6.75 mm.; cerci, 2 mm. additional. Greatest width, at the second abdominal segment, 3 mm. Color brownish-white except the eyes, which are black.

The head is sunken deeply in the prothorax and has a row of five small styli in front of, and another row of six behind each eye on the top of the head. The anterior and lateral margins of the pronotum are densely fringed with similar styli, and there are about eight along the posterior margin at each corner. The mesothorax and metathorax each have a group of five styli on either side of the mid line, and another group of three at the base of each elytron and wing. Each of the first seven abdominal segments has a group of from three to five styli on either side of the mid line and another group of two or three behind each spiracle. The eighth segment has two on either side of the mid line and one on each lateral margin.

At the posterior end of the abdomen are the pupal cerci, which are very slender, 2 mm. in length and only one-seventh as wide at the base.

The antennæ extend obliquely outward and backward beneath the first and second legs; the maxillæ extend to about the center of the second legs; the labial palpi are longer, reaching the posterior margin of the second legs.

The femora of the first two pairs of legs are at right angles to the body axis, and the tibiæ and tarsi extend obliquely inward and backward to meet on the mid line. The third legs are similarly arranged, except that the femora are pulled so far forward as to become diagonal to the body axis.

There are large branches on the third legs for the spines at the distal ends of the tibiæ.

The pupa is not very active in the pupal chamber and spends much of the time lying on its side. However, the normal position seems to be with the dorsal side uppermost and the body strongly arched. Of 10 pupæ reared to the adult stage 7 emerged 4 days after pupation, 2 five days after, and 1 six days after.

Habits of the adult.—The adult beetle swims rapidly and with considerable agility, the tarsi of the hind legs being especially well armed with swimming setæ. When captured in the net, it proves to be a good jumper, but can not equal Laccophilus and Thermonectes. On the land it can not lift its body clear of the ground, and hence flounders around rather helplessly. The only food that any of the adults were seen to eat was the nymphs of damselflies, but it is almost certain that their diet is not confined to these.

Description of the adult.—General shape an elongated oval, broadest anteriorly, the dorsal surface subconvex; total length 7 mm., width 4 mm.

The head, thorax, and entire under surface of the body are reddish-brown, the reddish tinge rather brighter in the male. The vertex of the head is black, and the prothorax has a narrow black line across the base and apex. The apical line stops on either side at about the center of the eye and does not reach the lateral margin. The basal line is only half the width of the thorax and is slightly enlarged at either end. The elytra are dark brown with numerous very small pale yellow markings. The basal portion of the elytra in the female is not as shiny as in the male and is sculptured with short and indistinct striæ.

The antennæ are 11-jointed, joints about equal; the mandibles have a rounded tooth on the dorsal surface of the inner margin near the tip and a fringe of short bristles behind the tooth. In the maxillæ the palps are four-jointed and subclavate, the terminal joint distinctly notched at the tip. The labial palps are also notched at the tip, but the notch can be seen only in side view. The prosternum is keeled along the mid line and the process it gives off is swollen through the center.

In the male the first three joints of the tarsus in the two anterior pairs of legs are slightly dilated and furnished with a dense fringe of stiff hairs along the lateral margins, each hair tipped with a minute disk. The ventral surfaces of these joints are covered with scattered disks, somewhat larger, each at the tip of a long stalk whose diameter equals that of the disk. On the sides of the stalks and around the margins of the disks are a few minute hairs. The tarsal claws are equal and so tightly appressed laterally that they often appear as one; those on the front feet are long and emarginate at the base. The hind legs are well developed, the femora with small laminæ at the apex and the tarsi lobed externally.

Genus CYBISTER Curtis.

Cybister (Curtis, 1827, p. 151).

This is a genus of large beetles considered the highest and most completely developed of the dytiscids. Both the adults and the larvæ are voracious and will destroy young fish whenever opportunity offers. They have broad and powerful hind legs and are strong swimmers; the hind claws are very unequal, the inner one being obsolete or wholly wanting. In the males the front tarsi are strongly dilated and bear four rows of disks.

Cybister fimbriolatus Say. Figures 23–33, 51.

Cybister fimbriolatus (Say, 1825, p. 91).
Cybister fimbriolatus (Sharp, 1882, p. 715).
Cybister fimbriolatus (Dugès, 1885, p. 26; pl. 2).

Eggs.—Deposited singly in slits made in the stems of rushes, cat-tails, arrowhead, etc. The eggs hatch in six to eight days.

Habits of the larva.—These larvæ are excellent swimmers; the legs are not very heavily fringed with swimming hairs, but their length compensates for this. There is also an excellent swimming fringe along the lateral margins of the last two abdominal segments. Ordinarily they use their legs in moving through the water, but when alarmed or wishing to move more rapidly they wriggle the whole body. By lashing the abdomen up and down they can dart with considerable rapidity.

When coming to the surface to breathe, their body is inclined with the head upward, but on reaching the surface they assume a horizontal position instead of completely reversing the body like the hydrophilids. Sometimes they assume this horizontal position quite a distance below the surface and then float slowly upward. At the surface the base of the head and the prothorax as well as the last abdominal segment rest in the surface film, while the center of the body is arched downward. When out of the water, the larva crawls along slowly, dragging its abdomen, but it can jump vigorously by lashing with the last two abdominal segments.

The larva eats tadpoles of the leopard frog, nymphs of mayflies and dragonflies, and the larvæ of other water beetles, even those of Dytiscus and Hydrous. This is one of the three genera whose larvæ eat fish, and when full-grown the larva is so large and powerful that it has no difficulty in killing fish of considerable size. They are also cannibals, and whenever two come together they fight until one or the other gains the victory. The winner then sucks the juices from the body of his unfortunate competitor, leaving nothing but the tough skin. Such skins are often found in the ponds during the summer and may be recognized by the rents made at intervals where the sharp mandibles of the victor pierced them.

If several larvæ are put in the same jar on a collecting trip, the chances are that only one will be alive on reaching the laboratory, and this is just as true when the jar contains numerous smaller and weaker larvæ of other kinds as when it contains only the dytiscids. This chronic cannibalism is the salvation of the other denizens of the pond, since it furnishes a very efficient means of reducing the number of Cybister larvæ.

Description of the larva.—General form elongate and spindle-shaped (fig. 51, opp. p. 291), tapering both anteriorly and posteriorly. A full-grown larva is 75 mm. long and 7.5 mm. wide through the second and third abdominal segments.

The head is contracted posteriorly to half its anterior width, forming a short neck. The thorax widens posteriorly, the hind margin being more than twice the width of the front margin. The abdomen is made up of eight segments, the first five about the same width, the last three strongly tapered, and the last two with wide lateral fringes. The lateral margins of the first six abdominal segments, and to a lesser degree those of the mesothorax and metathorax, project as a rounded longitudinal ridge. The base of this ridge forms a well-defined groove on the dorsal and ventral surfaces of the second, third, fourth, and fifth abdominal segments, with traces on the other segments.

The head, the thorax, and the legs are reddish-yellow, inclined to orange on the dorsal surface and flecked with brown pigment. The abdomen is brown on the dorsal surface, yellow along the lateral ridges and on the ventral surface, and brown in the ventral grooves bordering the lateral ridges.

The head is widest across the anterior border, which is emarginate and very irregular, with a long and narrow conical process on the mid line, a shorter and wider one on either side of it, and rounded lateral corners. Each of the three processes is tipped with a dense fringe of hairs, and there is a tuft of hairs inside each lateral corner. The lateral margins of the head are fringed with scattered and very unequal hairs.

The antennæ are filiform and nine-jointed, the relative lengths of the joints being 32, 44, 15, 14, 12, 13, 13, 17, 4; the second, third, and fourth joints bear one or two setæ each. The mandibles are sickle-shaped, perforated near the tip, the perforation opening into a tube that extends along the inner margin of the mandible and opens at the base on the dorsal surface. The inner margin of the mandible has a fringe of short, stiff, blunt spines along its center, leaving the base and tip smooth. At the distal end of this fringe the entire surface of the mandible is covered with long hairs. At the base of the mandible on the ventral surface is a flattened, knoblike process, which fits into a socket in the chitinous covering of the head.

The maxillæ (fig. 26) are reduced to a single filiform ramus of 10 joints; the basal joint carries three setæ, the second joint one, the fourth and fifth joints tufts of small setæ near their tips, and the seventh and ninth joints one seta each. At the base of the appendage on the ventrolateral surface is a small process bearing a tuft of setæ. The labium is small and its anterior margin is deeply emarginate, bearing

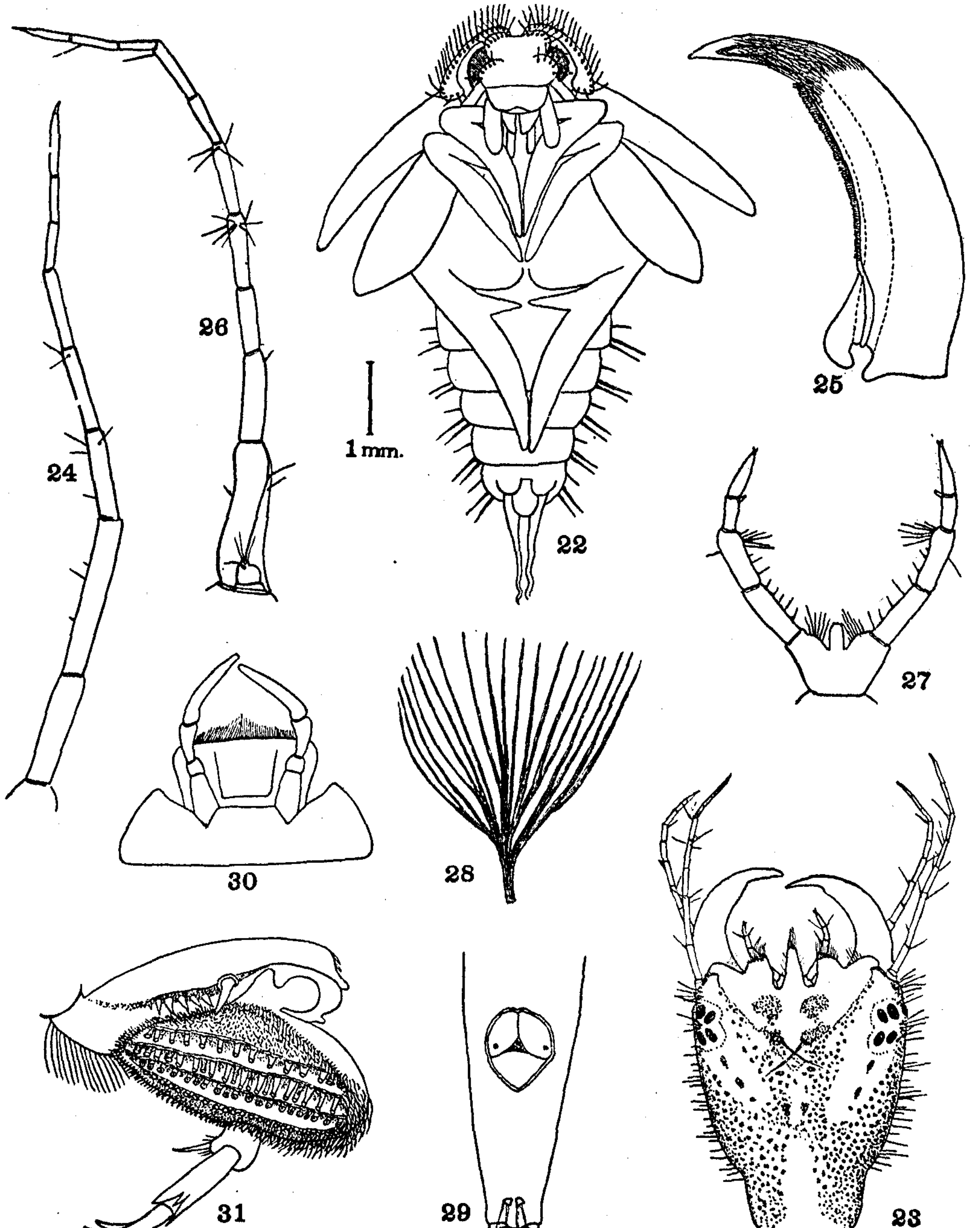


FIG. 22.—Ventral view of pupa of *Coptotomus interrogatus*. FIG. 23.—Dorsal view of head of larva of *Cybister fimbriolatus*. FIG. 24.—Antenna. FIG. 25.—Dorsal view of right mandible. FIG. 26.—Maxilla. FIG. 27.—Labium. FIG. 28.—Plumose hair from prothorax. FIG. 29.—Posterior end of abdomen. FIG. 30.—Labium of adult beetle. FIG. 31.—Foreleg of male, showing enlarged tarsal joints and sucking disks.

in the center a short and narrow ligula, with a tuft of setæ on either side (fig. 27). Each palp is four-jointed, the second joint with a tuft of setæ on the inner margin at the distal end, the terminal joint tipped with two tiny sensory processes.

The sclerite of the prothorax extends around the lateral margins and onto the ventral surface as far as the base of the legs; the sclerite of the mesothorax stops at the lateral margins; and the sclerite of the metathorax stops at the base of the lateral ridge. These three sclerites do not quite reach the posterior margins of their respective segments. The sclerites of the first six abdominal segments are very short and narrow, covering less than a fifth of the length and about half the width of each segment. The sclerites of the last two segments are entire, covering the lateral and ventral as well as the dorsal surfaces. Each sclerite of the first six abdominal pairs has two longitudinal dark stripes, and the brown of the dorsal surface of each segment is deepest along the lateral margins. The last segment ends in two tracheal tubes which project slightly. Just in front of the tip on the ventral surface is a pair of tiny triangular processes, each bearing two long setæ (fig. 29). The anus opens on the ventral surface about a quarter of the length of the segment in front of its tip. The sides of the thorax and the lateral ridges along the first six abdominal segments are clothed with short, scattered hairs of unequal length. On the dorsal surface of the lateral ridges near the anterior margin of each of the first six abdominal segments and on the sides of the meso and meta thorax are the spiracles. Behind the spiracles, near the longitudinal center of each segment, is a brown pigment spot. From the center of each of these spots, from a corresponding position on the prothorax and from each of a row of tiny spots across the dorsal surface near the anterior margin of the prothorax projects a plumose hair (fig. 28). The base of each of these hairs is a single thick trunk, which is divided and subdivided dichotomously until there are from 12 to 20 resultant branches.

Pupation.—A larva was found on the bank of pond 5D July 24, about 2 feet from the water's edge. It was hunting for a place to pupate and so was brought into the laboratory and placed in an artificial pupal chamber, whose size was proportioned to that of the larva. At first it stretched itself at full length upon the floor of this chamber, bending its head downward at right angles to the thorax and burying its mandibles for their entire length in the mud. It remained in this position for a week, scarcely moving at all, and then some water was put in the bottom of the jar and allowed to soak up through the floor of the chamber. Apparently this was what it was waiting for, since just as soon as the mud became soft enough it built a new pupal chamber inside of the artificial one. Although the larva was 75 mm. in length this new chamber was only 35 mm. long, 30 mm. wide, and 25 mm. high, outside measure. It was made of mud pellets half the size of a pea, which were cut out by the mandibles, rolled into form between the mandibles and labium, and then pressed into place, one against another.

Inside of this chamber the larva rested upon its back and folded its body in exactly the same manner as the Thermonectes larva, the posterior portion of the abdomen being turned forward above the anterior portion, and the head and thorax turned backward above the two. It remained in this position until August 8 before pupating, when the skin split along the dorsal mid line from the base of the head to the posterior margin of the sixth abdominal segment. The contents of the larval head and of the last two abdominal segments were withdrawn *in toto*, and the skin was then flattened back against the inside of the wall of the chamber. The adult beetle emerged August 22.

Another larva was obtained from a loosely constructed chamber close to the water's edge. This chamber also was made of mud pellets, but fragments of leaves and small sticks were mixed with them and the walls were so fragile that they could not be removed to the laboratory. Accordingly the larva was placed in an artificial chamber, which was made much smaller, profiting by previous experience. It was evidently still too large, however, for the larva constructed a new and smaller one inside of it, in which it pupated August 6, and the adult beetle emerged August 19.

Description of the pupa.—On first emerging from the split larval skin the pupa is creamy white in color, and its skin is shiny like the wings of a teneral dragonfly. Its total length is 35 mm. and the greatest width 13 mm. The only pigment visible is a lavender band around the anterior margin of each compound eye, and just behind this the six larval eye spots, which are black. Five of these spots are arranged in a row close to the posterior margin of the lavender band; the sixth one is a little farther back, between the second and third spots of the row. The first (dorsal) spot in the row and the sixth one are elongated at right angles to the longitudinal axis of the head, the others are circular.

At this stage the pupa is at least one-half longer and narrower than subsequently, and its first act is to stretch itself vigorously. The abdomen is arched upward until it becomes nearly a half circle, and the two ends of the pupa thrust the discarded larval skin against the walls of the pupal chamber. The hind legs are but a trifle longer than the first and second pairs, and the tarsi of all three pairs are deeply cleft. The legs, antennæ, and mouth parts stretch with the rest of the body and quickly assume their normal proportions, and the clefts at the tips of the tarsi gradually fill out and disappear. The abdomen shortens and widens, and the compound eyes become entirely pigmented. By the third day the pupa turns over and rests upon the dense bristles at the anterior margin of the prothorax and upon the posterior spines, the body being arched strongly upward.

The general shape of the pupa at this stage is that of an elongated ovoid, just twice as long as wide, considerably narrowed, and rather pointed anteriorly. The front margin of the prothorax projects over the base of the head and is armed with a dense row of short and stiff bristles, and there is another row, much less dense, along the hind margin. On the mid line of the dorsal surface, near the anterior margin of the prothorax, and at the center of the mesothorax and metathorax are small areas covered with bristles. Each of the first six abdominal segments is raised into a dorsal ridge near its posterior margin, the ridges being highest on the third and fourth segments and diminishing both anteriorly and posteriorly. Each ridge carries a single row of bristles. The ventral surface of the seventh segment is covered with a hard, smooth plate, armed with scattered short bristles. At the posterior end of the body are two stout curved spines; the lateral margins of each abdominal segment and the ventral surface are armed with scattered short setæ (fig. 33, p. 283).

The antennæ are twisted around beneath the femora of the first legs; the labial palps reach nearly to the posterior margin of the bases of the second legs. The legs are short and rather stout and are bent in such a manner that their tips meet on the mid line; the tip of each leg in all three pairs is emarginate. The wings are also very short, hardly reaching the fourth abdominal segment.

The color of the pupa is white, tinged with light brown on the back, the eyes brown, the bristles reddish. In later development the head and prothorax and the last two abdomen segments become reddish brown, while the elytra are tinged with dark brown, almost black. The spiracles are on the dorsal surface and close to the anterior margin of each segment, the anterior ones slightly larger than the posterior.

Habits of the adult.—In this genus is shown the highest development of those modifications which are adapted to swimming and diving, and as a result the beetle displays great rapidity and agility when in the water. On being removed to the land, however, it makes only a poor attempt at walking and can not run at all or jump.

In breathing Brocher (1911a) claims to have discovered that the last pair of spiracles are the only ones that possess an apparatus for filtering the air. Furthermore, and of greater importance, the last two pairs of spiracles are provided with a special tubular trachea, which extends forward to the metathorax. Hence, he concludes that inhalation takes place through the last pair of spiracles, exhalation through the other abdominal spiracles.

The adult beetles have been accused along with Dytiscus and Hydrous of catching and eating small fish, but the testimony against Cybister seems mostly derived from analogy. Although this species is abundant in at least three of the fishponds they have never been known to attack a fish either in the ponds or in aquaria in the laboratory. They have been seen eating dragonfly and mayfly nymphs, together with those of Corixa, Notonecta, and Benacus.

Description of the adult.—The newly emerged adult is a beautiful yellowish white without any pigment except in the legs, which are reddish, and the black eyes. General shape obovate with the posterior end pointed. Color brown with a decided greenish tinge; a broad yellow band along the margins of the thorax and elytra; the front of the head, the two front pairs of legs, and spots on the ventral surface at the sides of segments three to six of the abdomen are also yellow. The thorax and elytra of the female are covered with impressed lines of varying length and not parallel, even anastomosing in places. The thorax and elytra of the male are smooth and shining.

The front tarsi of the males are attached at an angle to the tibiæ and point backward toward the body. The first three segments of the tarsus are enlarged into a disk, which together with the tibia forms a triangle, whose apex is proximal and base distal. In dorsal view the tarsus is apparently joined to the base of the tibia instead of its tip. On the bottom of the disk are four transverse rows of small, equalsized cupules on long stalks. The basal segment has two rows, one of 15 cupules across the center of the segment and another of 20 cupules along the distal margin. The proximal half of the basal joint is covered with fine hairs. The second segment has a single row of 21 cupules, and the third segment a single row of 20 cupules, both along the distal margins. There is also a band of short hairs on the ventral surface of the basal joint of the tarsus of the second legs and three or four coarse folds at the apex of the hind coxæ.

Wickham has given a short description (1893, p. 324) of the male tarsus of this species with a figure (pl. 5, fig. 2). He also described and figured the male tarsus of *Cybister explanatus* from California (pl. 6, fig. 4), and described without a figure that of *Cybister tripunctatus*, an African species. The obsolete claw of the hind tarsus of the female varies much in size. In one specimen it could scarcely be detected; in another it was nearly a third as long as the large claw.

In all the other beetles raised from larvæ the adult emerged perfectly formed, except in one instance. Of the *Cybister* adults, however, 75 per cent were malformed in some particular. A front leg was lacking in one, a hind leg in another, some of the mouth parts in a third, a fourth had a wry neck, and so on. Whether this is true also of those that emerge under natural conditions could not be determined.

Genus DYTISCUS Linnaeus.

Dytiscus (Linnaeus, 1758, p. 411).

This is another genus of large beetle, of which both the larvæ and the adults kill and eat young fish. These beetles are dark, olive-brown in color, with a dull yellow stripe along the sides of the thorax and elytra; the front and hind margins of the thorax are also usually yellow. The claws are equal in both sexes, and in the males the basal joints of the front tarsi are broadly dilated and armed with sucking disks of different sizes.

Dytiscus verticalis Say. Figures 34–38.

Dytiscus verticalis (Say, 1825, p. 92).

Eggs.—No direct observations have been made with reference to the eggs of this species, but they are probably deposited singly in incisions made by the female with her ovipositor in the stems of water plants in a manner similar to that followed by the female of *Dytiscus marginalis.*

Habits of the larva.—The material for this species consists of three adults, one of which was taken from a pupal chamber, a larval skin from the same chamber, and two larvæ nearly full-grown. This larva, like that of Cybister, swims more by means of the fringe along the lateral margins of the last two abdominal segments than by its legs. The latter are poorly fringed with swimming setæ, but make up for it in their length. When swimming slowly, the legs are used alone, but in rapid locomotion the whole body contributes. This larva also can jump to a considerable distance by sudden flexure of the last two abdominal segments, and it can do this on land as well as in the water. According to Brocher (1913, p. 125) when the Dytiscus larva breathes it may either stand upon some sort of vegetation and reach upward, thrusting the tip of its abdomen above the surface of the water, or, releasing its hold on the vegetation, it may float slowly upward, the abdomen preceding, until the tip of the latter reaches the surface; or, when the specific gravity of the body is greater than that of water, it may swim with its head directed upward and on reaching the surface turn parallel to the latter and thrust its abdomen above the surface. In all three cases the cerci are turned down against the surface film, this action both opening the posterior spiracles and supporting the larva while it breathes.

With reference to food we find the following statements, which were made not of this particular species but of the genus in general. Evermann and Clark (1920, Vol. I, p. 639) stated that the larvæ of Dytiscus attack the tadpoles of the leopard frog and devour them. Dytiscus larvæ were found by Needham and Williamson (1907, p. 485) in the "Gym" pond on the campus at Lake Forest, Ill., feeding upon Corethra pupæ. Wright (1920, p. 42) stated: "The water beetles, especially their larvæ (water tigers) and dragonfly nymphs also take their heavy toll of tadpole lives." Miall (1895, p. 47) made the statement: "Almost all kinds of aquatic animals, snails, worms, insects, tadpoles, and fishes are devoured by the insatiable Dytiscus larvæ." Garman (1890, p. 163) testified: "Both adults and young lead a predatory life, attacking and devouring whatever they can master. They do not hesitate to attack animals many times larger than themselves and are very destructive in fishponds to young fishes. They are in turn eaten by the larger fishes."

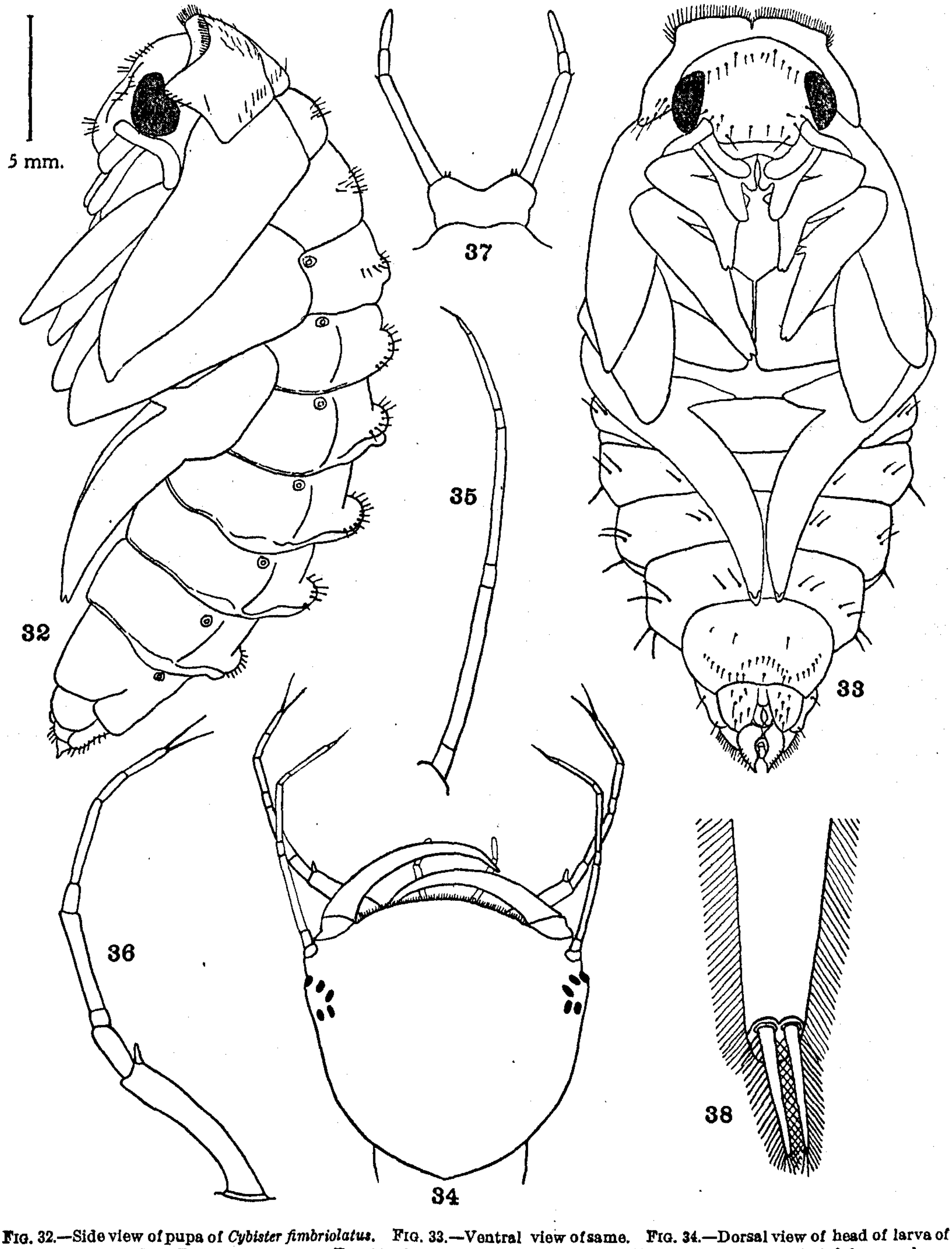


FIG. 32.—Side view of pupa of *Cybister fimbriolatus*. FIG. 33.—Ventral view of same. FIG. 34.—Dorsal view of head of larva of *Dytiscus verticalis*. FIG. 35.—Antenna. FIG. 36.—Maxilla. FIG. 37.—Labium. FIG. 38.—Posterior end of abdomen, showing cerci.

They are also cannibals like the Cybister larvæ, and whenever two come together they fight until one or the other gains the victory, and the winner then sucks the body of his vanquished foe.

Description of the larva.—General form a flattened spindle 70 mm. in length, tapering both anteriorly and posteriorly, widest through the mesothorax and metathorax, 7 mm. Each of the three thoracic and the first six abdominal segments has a pair of dorsal sclerites which meet at the center and cover nearly the whole dorsal surface. Head (fig. 34) wider than long, considerably flattened, its anterior margin evenly rounded and fringed with short spines. Antennæ filiform, the second, fourth, and sixth joints several times the length of the first, third, and fifth, the terminal joint but little more than a spine. Mandibles similar to those of Cybister, with a basal process on the ventral surface, but without a fringe of bristles along the inner margin. Maxillæ (fig. 36) uniramose, eight-jointed, the first, fourth, and sixth joints longer than the others; the basal joint stout, somewhat curved, with a rudimentary process on the inner margin at the distal end. Labium (fig. 37) wider than long, deeply emarginate anteriorly; labial palps three-jointed, the basal joint longer than the other two; ligula wanting; inside the base of each palp are two short and stout spines. Legs long and fringed with short hairs.

Last two joints of the abdomen much narrowed and heavily fringed with stout swimming setæ. Terminal joint with two long cerci on the ventral surface near the distal end, which are about half the length of the joint and are also heavily fringed with setæ. These are chiefly used to suspend the larva from the surface film of the water when it is breathing. Color a dark olive-brown, deepest on either side of the mid line, along which extends a much lighter stripe.

Pupation.—After the larva is fully developed it leaves the water and breathes now through the thoracic and abdominal spiracles, which have opened for use. We are told that the Dytiscus larva makes a rough cell in the earth along the pond shore or on the bank of a stream, but we are not informed whether this pupal chamber is simply hollowed out in the soft earth or is made of mud pellets like that of Cybister. Theoretically, the latter seems much the more probable, and the chamber from which the larval skin and newly emerged adult were taken was made of pellets.

Description of the pupa.—So far as known the pupa of this species has never been seen except by Wickham (1894), and he has not given us any description of it. We can only give the characters of Dytiscus pupæ in general. The prothorax projects over the head, hiding a portion of the eyes. The elytra and wings are short and reach only to the third or fourth abdomen segment. The hind legs are also short and do not reach beyond the seventh segment. Each of the first six abdomen segments is raised into a ridge on its dorsal surface near the posterior margin, but these ridges are much less prominent than those on the Cybister pupa. In the figure of a European species published by Miall (1895) from Schiødte the dorsal surface is nearly flat and there are no perceptible ridges. At the posterior end of the abdomen are two cerci, which are oblong and project for a considerable distance. In the European species they are fringed with setæ, but in an American species figured by Kellogg (1908) they are without setæ.

Miall (1895) said that the pupal stage in summer lasts only a fortnight or so, but Kellogg (1908) said that it lasts three weeks. Fortunately we have a statement with reference to the present species. Wickham (1895a, p. 71) said in the Canadian Entomologist:

> The length of time spent in this latter pupa stage must vary greatly in different broods and with the various species, but it was found to be 10 or 11 days in the case of *Dytiscus verticalis*, of which a larva, taken at Bayfield, Wis., pupated July 18, the beetle appearing on the 28th.

Habits of the adult.—The long hind legs are admirably adapted for swimming, though they are not as powerful as in Cybister; but they are not suited for walking, and the beetle flounders about clumsily on the land. It flies well and is frequently captured at night around trap lanterns. With reference to its food, two of the quotations already given under the habits of the larva apply also to the adult. In addition, Cooke in his "Molluscs" (1895, p. 59) cited the case of a Dytiscus in an aquarium that killed and devoured seven *Lymnaea stagnalis* in one afternoon. These beetles also ate *Lymnaea peregra*, but seemed to prefer *stagnalis*.

This beetle was abundant in two of the ponds and common in eight of the others; yet only two larvæ were found in three seasons of work on the water beetles, and in spite of the abundance of the adult beetles not one of them has ever been seen attacking young fish either in the fishponds or in aquaria.

Description of the adult.—Like Cybister the adult when it first emerges is soft and pale in color, the only pigment appearing in the legs and eyes. Several days elapse before it hardens and assumes the dark, olive-brown color of the fully matured adult. The shape is regularly oval, with the posterior margin evenly rounded and not pointed as in Cybister; length 35 mm., width 20 mm.

The clypeus is separated from the head by a distinct suture, the thorax is not margined, and the claws are equal in both sexes. The elytra are smooth and do not show the numerous short impressed lines found in the Cybister female. Near the posterior end of each is a narrow and oblique subapical crossbar of yellow. The abdominal segments are uniformly black, and there are no yellow spots along the lateral margins.

In the male the enlarged tarsus of the front legs is nearly circular in outline and the sucking disks on its ventral surface vary greatly in size. Near the base are two which are very much enlarged, their combined diameters almost equaling the width of the swollen basal joint of the tarsus. The other disks are smaller and rather irregularly arranged.

Genus HYDROPORUS Clairville.

Hydroporus (Clairville, 1806, p. 182).

A genus of small species, all very similar to one another and hence difficult to distinguish. The adults are oval in form and dark brown in color; they swim well and when taken out of the water can jump quite a distance. The larvæ are spindle-shaped and may be recognized by the fact that the head is much narrowed in front of the antennæ and the clypeus is prolonged into a sort of rostrum whose anterior margin is armed with rows of wide laminæ. The mandibles also are set at an angle and shut up against the lower surface of the rostrum instead of shutting past each other.

Hydroporus niger Say. Figures 79–83.

Hydroporus niger (Say, 1825, p. 102).

Eggs.—Nothing is known of how or where the eggs are laid or of the length of time that elapses before they hatch. In the species whose larvæ have been described by Schiødte and Meinert nothing was said about the eggs.

Habits of the larva.—The larvæ live among the Mougeotia and other filamentous algæ, over which they crawl almost ceaselessly. They swim very slowly, because their legs are short and have no swimming fringes but only a few scattered setæ. When out of the water they can walk quite rapidly, but can not run or jump. The larva has no lateral gills and does not come to the surface for its supply of oxygen, but is enabled in some way to obtain it from the water. It feeds upon the larvæ commonly found among the algæ, such as Chironomus, Epiphragma, Odontomyia, Corethra, Probezzia, and Palpomyia. They do not appear to be cannibals and can be kept together in confinement without eating one another, as was noted by Needham and Williamson (1907).

Description of the larva.—General form spindle-shaped, narrowed only a little anteriorly, very much posteriorly; length 7 mm., width 1.6 mm. Body made up of a head, three thoracic and eight abdominal segments, widest through the mesothorax and metathorax, whose diameter is about one-fifth of the body length, exclusive of the posterior cerci. The thorax and first six abdominal segments are covered dorsally with chitin sclerites; those of the last two segments cover the lateral and ventral surfaces as well as the dorsal.

Color light brown on the dorsal surface, the head and the last two segments of the abdomen yellow; a broad Y-shaped brown mark on the head, following the sutures; antennæ, mouth parts, legs, and entire ventral surface white, tinged with brown on the thorax. Each sclerite covers the whole dorsal surface of its segment and is armed with setæ along its lateral margins and a transverse row across its posterior margin. The sclerites of the sixth and seventh segments are prolonged into small papillæ at their posterior corners. The lateral areas of the head and the rostrum are also covered with setæ.

Head ovate, one-half longer than wide, the clypeus prolonged into a broad and bluntly rounded rostrum, extending far in front of the antennæ. The top of the head and the rostrum are strongly convex, and the tip of the rostrum is curved over ventrally. On this turned-down anterior margin is borne the characteristic dytiscid fringe of this genus. In the present species it consists of three rows of flattened lamellæ; those in the terminal row are large and broadly ovate, in the second row much smaller and narrlowy obovate, and in the third row triangular with all three margins concave. The sides of the rostrum are indented about one-third of the distance from the tip to the base, and the broader basal portion is fringed with setæ along its lateral margins and several transverse rows across the top. The epicranial suture is about one-fourth the length of the head, and each fronto-antennal suture is curved like the letter S, joining the lateral margin of the rostrum in front of the antennæ.

The prothorax is one-half wider than long, the mesothorax three times, and the metathorax four times as wide as long. The abdominal segments decrease regularly in width and the last one takes the form of a triangle with a bluntly rounded tip, its length more than three times its width. To its center on the ventral surface are hinged the cerci close together on the median line. Each is two-jointed, slender, tapering, and about one-third as long as the body.

The antennæ are four-jointed, the second and third joints the same length and much longer than the first and fourth. The mandibles are curved and deeply grooved along the inner margin. They are attached not to the corners of the frontal margin as usual, but to the ventral surface of the head posterior to the bases of the antennæ, and their bases are not visible in dorsal view. Furthermore, they are attached at an angle, so that instead of shutting past each other like a pair of scissor blades they shut in diagonally, their tips just meeting against the ventral surface of the rostrum inside the fringe. Each maxilla consists of a stout basal joint armed with three large setæ on its ventral surface and a three-jointed palp, whose second joint is three-fourths as long as the first, and the third half the length of the second and tipped with two minute setæ. The labium is wider than long, the palpiger heavily armed with stout setæ on its ventral surface; there is no ligula. The labial palps are two-jointed, the terminal joint a little shorter and more slender than the basal and tipped with two tiny setæ. These palps are nearly as long as the maxillæ and are sparingly armed with setæ. The tarsal claws are alike, very long, slender and acuminate.

Pupation.—The species reared by Needham and Williamson (1907) pupated without making any chamber, while another species (*septentrionalis*) found by Matheson (1914) in the Salmon River near Truro, Nova Scotia, constructed a pupal chamber out of pellets of sand under flat rocks on the river bank.

Description of the pupa.—None of the larvæ of the present species could be induced to pupate, and we have to be satisfied with a general description applying to the genus as a whole. The pupa is white in color, except the eyes, which are pigmented. The head is withdrawn into the prothorax and is well provided with short and strong styli. The anterior margin of the pronotum is also armed with a row of short styli, and others are scattered over the dorsal surface of all the thoracic segments. In the abdomen the posterior margin of each segment is raised into a transverse ridge, which is armed with a row of styli. The abdomen ends in a pair of large and long spines or cerci, which help to support the pupa inside the chamber. Matheson (1914) said that the species he studied rested upon its back in the pupal chamber, but the row of stout styli along the front of the pronotum and the strong cerci would indicate that they are used to support the pupa at least a part of the time. If this be true, then it rests also upon its ventral surface with the body arched strongly upward like the other pupæ.

Habits of the adult.—The hind legs are rather weak, but are heavily fringed with swimming setæ, so that the beetle moves through the water quite rapidly and shows considerable agility. On the land it is not as clumsy as many of the dytiscids but walks farily well and can jump a short distance. These beetles are rather difficult to watch, because they stay among the filaments of the algæ most of the time. The only thing they were seen to eat was Chironomus pupæ.

Description of the adult.—General form an elongate oval, slightly narrowed posteriorly; width considerably more than half the length; length 4 mm., width 2.5 mm. The dorsal surface is uniformly black, with the head and legs reddish-brown; antennæ dark brown, the base lighter in color. Thorax and elytra finely and evenly punctured and covered with scattered soft hairs. Both the adults and the larvæ of these beetles furnish excellent fish food.

Genus LACCOPHILUS Leach.

Laccophilus (Leach, 1817, p. 69).

These are small but very active beetles whose bodies are considerably depressed and usually spotted in color. The hind legs are well developed, and they are strong swimmers in consequence. In the male the tarsi of the two front pairs of legs are dilated and covered on the ventral surface with spongy hairs. There are also rows of fine ridges on the plates of the hind coxæ, which form a stridulating organ when rubbed by the hind femora. Two species are common in the Fairport fishponds and a third is found rarely.

Laccophilus maculosus Say. Figures 20, 39, 41, 43, 44, 46, 48, 50.

Laccophilus maculosus (Say, 1825, p. 100).

Eggs.—No eggs of this species were obtained, but it is probable that they are inserted singly by the female in the stems of water plants after the manner of other dytiscids.

Habits of the larva.—The larvæ are excellent swimmers, and when out of the water are much the most agile of any larvæ here described. The swimming fringes are well developed on all the legs and carry the larva through the water without any movement of the body itself. The resultant motion is rapid and exceptionally uniform, the abdomen and cerci being used for steering purposes only. When out of the water, the body is considerably shortened by the telescoping of the segments, the abdomen is lifted well above the surface of the ground on the long legs and inclined slightly upward, and the larva walks with great rapidity or even runs and can turn and dodge with agility.

Kept in an aquarium with plenty of water plants the larvæ are quiet and do not show their cannibalistic tendencies at once. They crawl about over the plants very slowly, feeling about with each foot before putting it forward and keeping the abdomen elevated at an angle of 45°. They breathe by raising the tip of the abdomen to the surface of the water while still standing on the plants, at the same time inclining the cerci ventrally until they rest upon the surface film. The two posterior spiracles are opened in a manner similar to that in the Dytiscus larva. Having filled the air tubes, this larva can remain an hour or more beneath the surface. In clear water they are obliged to swim to the surface in order to breathe. In doing this the head is kept upward until close to the surface, then the tail is elevated in a broad curve and an effort is made to throw the cerci out horizontally on top of the surface film. Often several efforts are made before this is accomplished, but once successful the body is dropped into a vertical position and hangs supported by the cerci. When the breathing is completed, the cerci are elevated and the larva sinks beneath the water.

If put in a dish of clear water, some of them betray cannibalistic tendencies by forthwith attacking the others, and the one first grasped by the other's jaws gives up without a struggle, even when his head is left free so that he could fight if he would. The victor then swims about sucking the juices of his victim until they are all extracted, the empty skin being finally thrown away.

In the ponds these larvæ frequent the open water between the rush stems but do not take kindly to Hydrodictyon or similar blanket algæ. They do, however, crawl about among the Spirogyra and Mougeotia and feed on the larvæ usually found there—Corethra, Ceratopogon, Dixa, etc.—and occasionally they eat a larva of Peltodytes, Haliplus, or Hydroporus, which are found in the same localities.

Description of the larva.—General form spindle-shaped, 7 to 9 mm. long, the body being widest through the metathorax where it is 1 to 1.5 mm. broad, and tapering slightly forward and backward (fig. 20, opp. p. 275). The head is comparatively large, widest through the eyes, where it is the same width as the thorax, and contracted posteriorly to less than half that width. The lateral margins behind the eyes are armed with a row of five or six short and stout spines on either side. The prothorax is a trifle longer than wide, the anterior margin half the width of the posterior, the sides strongly convex. The mesothorax and metathorax each increase slightly in width, while the abdomen segments diminish regularly, the last one being rather abruptly contracted posteriorly at the base of the cerci (fig. 20).

The sclerite of the prothorax extends laterally nearly to the bases of the first legs; those of the mesothorax and metathorax and the first five abdominal segments do not reach the lateral margins; that of the sixth abdominal segment extends onto the ventral surface, covering three-quarters of the entire circumference, and those of the seventh and eighth segments extend around the body, covering the entire surface, dorsal, lateral, and ventral.

The abdominal segments are capable of considerable telescoping, and when the larva is taken out of the water, or when it crawls out of its own accord, the body is much shortened by the pushing of the anterior end of each segment into the posterior end of the segment in front of it. In preservatives also the body of the larva is usually telescoped in the same manner, but occasionally it remains extended.

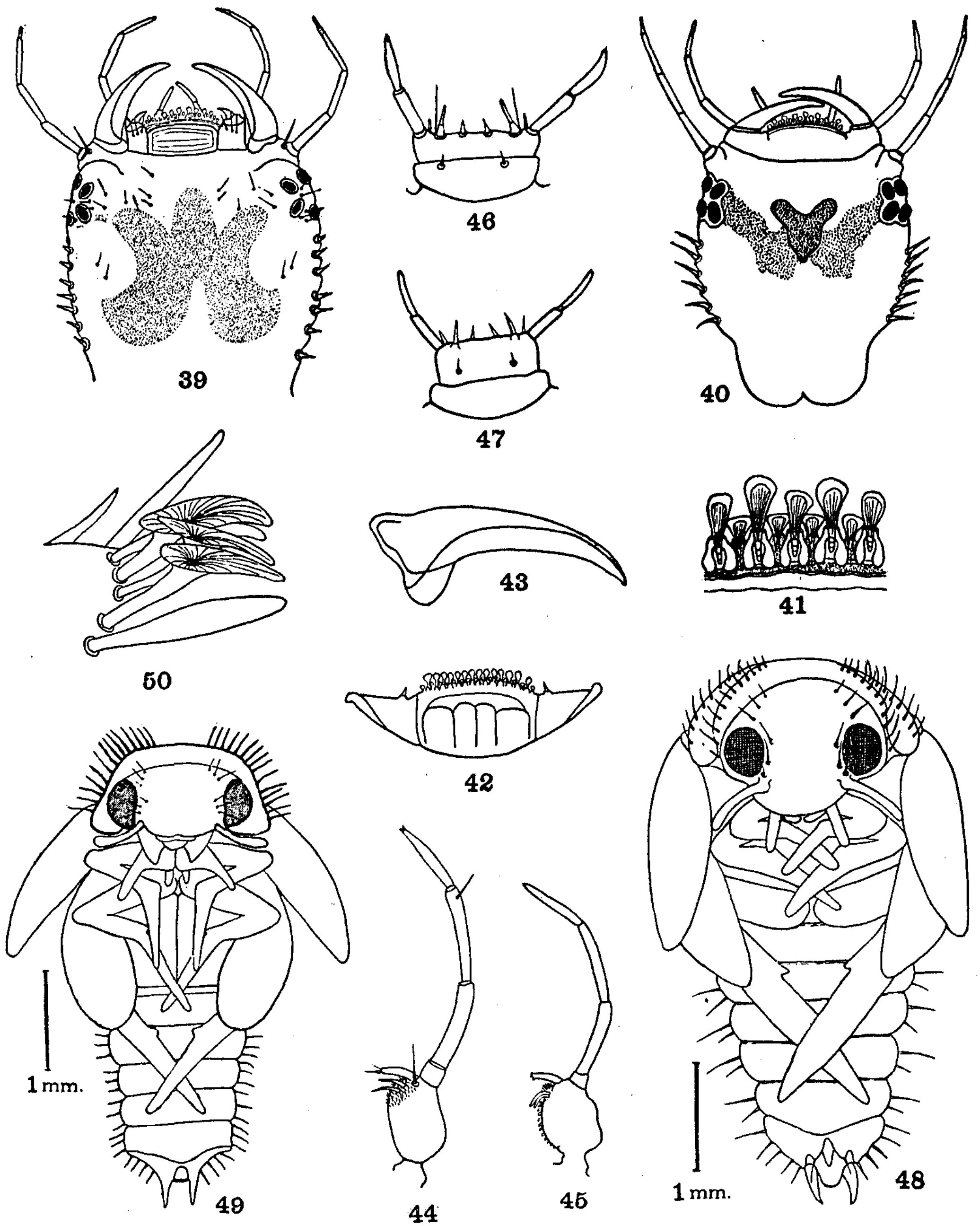


FIG. 39.—Dorsal view of head of larva of *Laccophilus maculosus*, showing color pattern. FIG. 40.—The same, *Laccophilus proximus*. FIG. 41.—Anterior margin of head, *maculosus*. FIG. 42.—The same, *proximus*. FIG. 43.—Mandible of *maculosus*. FIG. 44.—Maxilla of *maculosus*. FIG. 45.—Maxilla of *proximus*. FIG. 46.—Labium of *maculosus*. FIG. 47.—Labium of *proximus*. FIG. 48.—Pupa of *maculosus*. FIG. 49.—Pupa of *proximus*. FIG. 50.—One segment of the foreleg of a male *maculosus*, showing the form of the sucking disks.

The last segment is prolonged backward on the dorsal surface into a short papilla, from beneath whose base arise the divergent cerci, which are as long as the last three segments and are heavily fringed with hairs. The entire surface of the last two segments is sparsely covered with short hairs, others are found on the lateral margins of the other segments, and each sclerite bears a row of short spines along its posterior margin. The legs are comparatively long and slender but are strong enough to support the larva and are well fringed with swimming setæ.

The antennæ are not on the dorsal surface but on the lateral margins of the head behind the bases of the mandibles (fig. 39). Each is four-jointed, the three basal joints about the same length, the terminal joint less than a fourth as long. The labro-clypeus has a peculiar fringe on its anterior margin, which helps to identify the larva. It is made up of two rows of processes of the form shown in Figure 41, one row dorsal to the other. The processes of the dorsal row are much larger and longer than those of the ventral row and alternate with them.

The mandibles are long, slender, and grooved on the inner margin nearly to the base; when closed they overlap more than half their length. In the maxillæ the cardo is short and narrow, the stipes much longer and wider, the palp three-jointed, the joints about the same length, while the galea is reduced to a fingerlike process tipped with a sensory papilla and two small setæ, and the lacinia is wholly wanting, or may be represented by two stout curved spines inside the base of the galea. The tip of the stipes is densely covered with short hairs. The labium is twice as wide as long, and the palps are attached to its antero-lateral corners; they are two-jointed, the joints about the same length and unarmed; there is no ligula. Inside of each palp are a long hair and a stout jointed spine, and there is a pair of much smaller simple spines near the mid line; the mentum also bears a pair of small spines (fig. 46).

The color of the living larva is a pale, greenish-yellow, unmarked on the ventral surface except on the last two segments of the abdomen. On the dorsal surface, however, the following parts are more or less brown: The mandibles, the frontal margin of the head, the lateral margins behind the eyes, the brown widening as it approaches the thorax, a fleur-de-lis design at the center of the head, its lateral arms extending outward and forward toward the eyes, and each of the dorsal sclerites. The anterior and posterior margins of the sclerites are considerably darker in color than the rest of the surface, and in the last two segments the brown and the deeper margins follow the sclerites around the body, becoming the exceptional markings on the ventral surface mentioned above. There is a very narrow brown line along the margin of each leg, another along the inner margin of each femur, and a ring around the top of each leg joint. In some larvæ the brown of the dorsal surface has a decided greenish tinge, while in others it is deepened almost to black, especially along the margins of the sclerites, but in preservatives the green entirely disappears and the black is considerably lightened. The contents of the digestive canal show as a black streak through the center of the body and often surge backward and forward in rhythmic pulsations.

Pupation.—As would be expected from its locomotor ability, this larva travels from the water's edge when ready to pupate as far as, and often farther than, the larger species. Having found a suitable place, it burrows into the earth and forms its pupal chamber less than half an inch beneath the surface, often near a grass or plant stem. Having completed the chamber, the larva remains in it for one or two days before pupating.

Description of the pupa.—Length 5 mm., width 3 mm. The pupa is greenish-white in color, the green being deeper through the center of the body, and is very frail. It must be handled with the utmost care to avoid crushing it out of shape. It is not at all active, but lies inertly in the pupal chamber in whatever position it may be placed. After a time, however, it readjusts itself and assumes the usual position, the body arched upward into a semicircle, the dorsal surface uppermost, resting upon the stout spines of the prothorax, the tips of the third legs, and the two strong cerci.

The head is drawn into the prothorax and down onto the metathorax. There are three styli inside the anterior end of each eye, two inside the posterior end and two on the base of the labrum. Along the anterior and posterior margins of the pronotum are 12 or 14 styli on either side running inward from the lateral margins, but leaving a wide vacant space in the center. On the dorsal surface near the center of the segment is a single seta on either side. The mesothorax and metathorax have two styli at the base of each elytron and a wing and a row of 10 or 12 on the posterior margin across the center. There is a similar row across the posterior margin of each of the first seven abdominal segments, the lateral styli being longer than those in the center; there is a row of five along each lateral margin of the eighth segment.

The eyes are large, light reddish-brown in color, and widely separated; the antennæ extend diagonally outward and backward to the edge of the elytra; the maxillary palps are short and reach just beyond the first legs. The femora of the first and second legs are at an angle of 45° with the body axis, the tibiæ and tarsi are nearly in a straight line and overlap at the center of the body; the femora of the third legs are at an angle of 90° with the body axis, or drawn a little farther forward than that; the tibiæ and tarsi are in a straight line and overlap as in the other legs, their tips reaching the middle of the penultimate abdominal segment (fig. 48).

The following table gives the time spent in the pupal chamber before pupating and the length of the pupal stage in 10 specimens:

Entered chamber.	Pupated.	Emerged.	Entered chamber.	Pupated.	Emerged.
1919.			1920.		
July 12	July 13	July 18.	Aug. 6	Aug. 8	Aug. 14.
July 15	July 17	July 23.	Aug. 8	Aug. 9	Aug. 15.
July 17	July 19	July 24.	1921.		
1920.			July 14	July 17	July 23.
July 16	July 17	July 23.	July 18	July 20	July 26.
July 20	July 22	July 26.	July 19	July 21	Do.

Habits of the adult.—The hind legs of this species are very heavily fringed with swimming setæ, and hence it can swim rapidly and with much agility. It is also the best jumper of all the beetles studied with the exception of *Thermonectes ornaticollis*, and the jumping is accomplished by the hind legs. This beetle is found in every fishpond except 6D, and could probably be found there if the search were made persistent enough. Its small size makes it harmless to the fish, and in its turn it serves as food for fish, frogs, and some of the other beetles.

Description of the adult.—General outline ovate, nearly elliptical, but somewhat narrowed posteriorly and strongly depressed. Total length 6 mm., greatest width 3.50 mm. Thorax very short, more than three times as wide as long and without widened margins; scutellum practically invisible; elytra widest near the center, obliquely truncated anteriorly and posteriorly, with one or two rows of minute punctures. Tarsi of the first two pairs of legs in the male enlarged and armed with spongy, prehensile hairs, two rows on the basal joint and one row on the second and third joints. The coxæ of the third legs are expanded into broad processes, concealing the coxal cavities. The coxal plates in the male are furnished with a stridulating file, whose ridges begin at the inner margin near the center and extend outwards and backwards. The third legs are much flattened and armed with two rows of long swimming setæ; the spines on the inner margin of the tibia near its distal end are unequal and distinctly emarginate at their tips. The antennæ are cylindrical, filiform, and 11-jointed; the mandibles have a wide terminal margin, which is only slightly reentrant, with an acute ventral tooth and a blunt dorsal one. The maxillary palps are four-jointed, somewhat club-shaped and rather short; the labial palps are very short and two-jointed. The head, thorax, and under parts are reddish-yellow, the elytra black, each with four submarginal spots and three basal lines of greenish-yellow.

Laccophilus proximus Say. Figures 40, 42, 45, 47, 49.

Laccophilus proximus (Say, 1825, pp. 101 and 514).

Eggs.—In this species, as in the preceding one, the eggs are probably deposited singly in the stems of water plants.

Habits of the larva.—This larva has the same habits and eats the same food as the *maculosus* larva, but is much less cannibalistic. Indeed, not once did it betray any such tendencies, and when the two species were kept together, although the *maculosus* larvæ attacked one another and also killed and ate the *proximus* larvæ, the latter never retaliated.

Description of the larva.—This species is considerably smaller than the preceding for two reasons—the first three and the last abdominal segments are actually shorter, and then the larva keeps all the segments telescoped even when suspended from the surface film during breathing. Hence, while the *maculosus* larva averages about 8 mm. in length when fully grown, the *proximus* larva is only from 6 to 6.5 mm. long.

Proximus is also much the darker of the two, the entire upper surface being dark brown, with the margins of the sclerites nearly black. In the center of the dorsal surface of the head is a dark brown

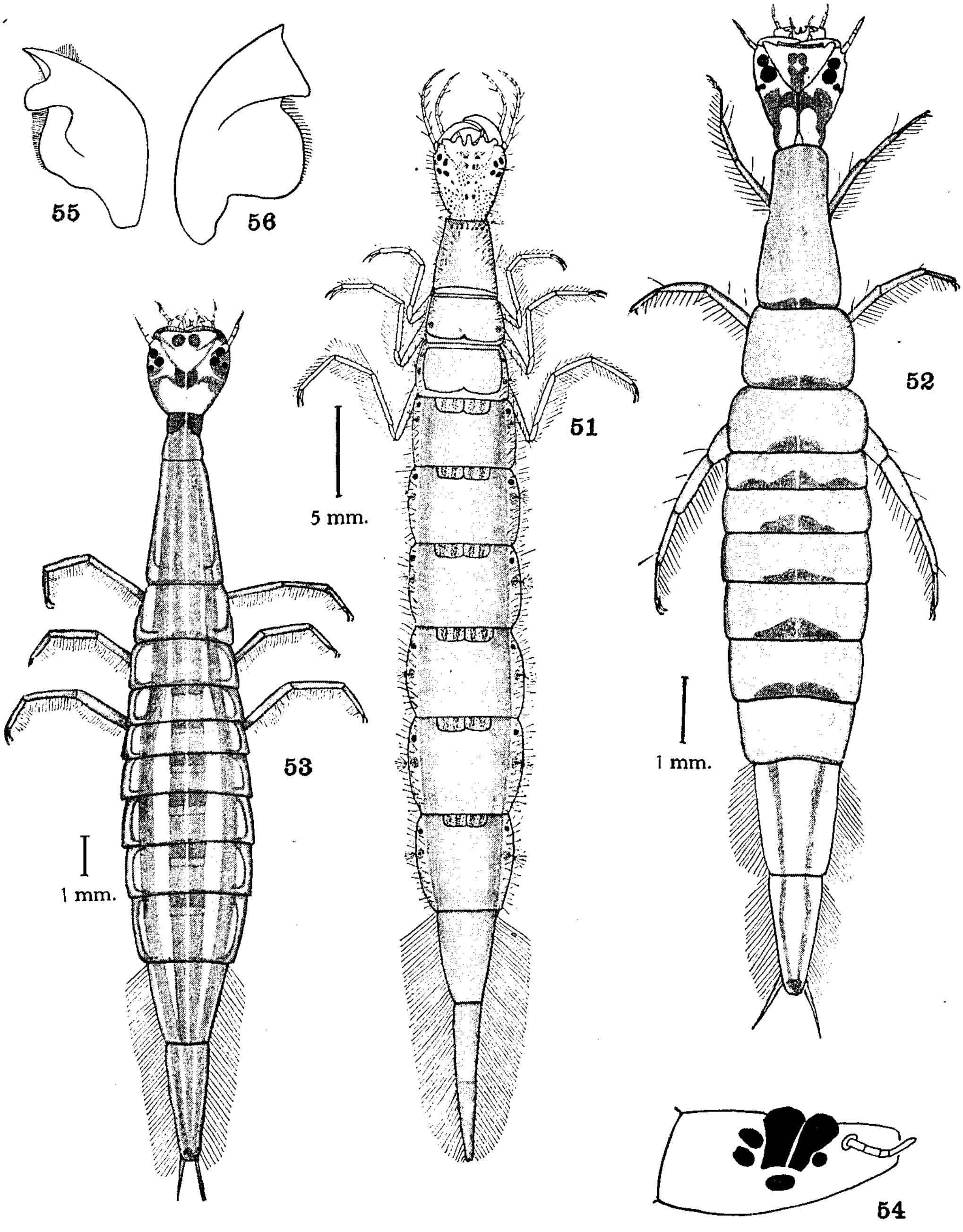


FIG. 51.—Larva of *Cybister fimbriolatus*, dorsal view. FIG. 52.—Larva of *Thermonectes basilaris* FIG. 53.—Larva of *Thermonectes ornaticollis*. FIG. 54.—Side view of head of basilaris, showing deep penetration of dorsal eyes. FIG. 55.—Mandible of adult beetle, *T. basilaris*. FIG. 56.—The same, *T. ornaticollis*.

triangular shield, clearly outlined by a very narrow yellow margin. The apex of the triangle is posterior and the base anterior, each of the three sides are emarginate, and the anterior corners are broadly rounded. From each side a broad ribbon of dark brown extends a short distance outwards and backwards, then turns at a right angle forwards and outwards to the eyes (fig. 40, p. 288). The brown band along each lateral margin behind the eyes is much wider than in the preceding larva, and there is often a large brown spot on the base of each mandible.

The labrum, with the peculiar fringe on its anterior margin, is relatively wider and fills nearly the entire space between the bases of the mandibles. The sculpture on its surface is also radically different, being made up of longitudinal instead of transverse lines. The maxilla differs as in Figure 45 (p. 288); the labium is relatively longer and narrower; in *maculosus* the palpiger is more than four times as wide as long, but in the present species it is only a little more than twice as wide as long (fig. 47, p. 288). There are other minor differences, but the present larva can be easily recognized by its darker color, by the telescoping of the body segments, by the shortness of the first three abdominal segments, and by the pattern of the dark figure in the center of the dorsal surface of the head.

Description of the pupa.—This pupa is 4.5 mm. long and 2.5 mm. wide, light green in color, darker on the dorsal surface and through the center of the body, with the posterior portion of the digestive canal a dark brown, almost black; the wings, legs, and mouth parts are white, the eyes and posterior cerci light brown. In comparison with the pupa of the preceding species the head is more quadrangular, with a truncated anterior margin, slightly emarginate at the center. The femurs of the first legs extend outward at right angles to the body axis, and the tarsi are turned backward parallel with the axis and some distance apart. The tarsi of the second legs are crossed but reach back nearly to the posterior ends of the wings. The tarsi of the third legs are also crossed and extend backward only to the sixth segment. The eighth segment is much shorter than in *maculosus* and the cerci are narrower and straighter.

Description of the adult.—Sharp (1882), in his excellent memoir of the Dytiscidæ, said with reference to this species: "In the three individuals I have examined I can find no distinction from *maculosus* except the darker color and more indistinct markings of the elytra, which, however, are so similar in the two that I am inclined to think them one species." Blatchley (1910), however, in his Coleoptera of Indiana, distinguished them as separate species, and an examination of the mouth parts confirms his opinion. In the mandibles the terminal tooth of the present species is longer and more slender, the secondary dorsal tooth is farther removed and its inner margin reaches nearer to the base of the appendage, and the ciliated ridge does not reach the base. In the maxillæ the palp is longer and more slender; the rest of the appendage is much shorter and thicker. In the lower lip the mentum is much longer and narrower and of an entirely different shape; the labial palps are longer, much thicker, and more densely setose. These differences, combined with those found in the larva and pupa, fully warrant the separation of the species. This beetle is not quite as widely distributed as the preceding, but is still common in most of the ponds. Both larvæ and adults are so small that they can not harm young fish but furnish excellent food.

Genus THERMONECTES Crotch.

Thermonectes (Crotch, 1873, p. 402).

A genus of medium-sized, rather convex species, which are excellent swimmers and agile jumpers. The head is dull yellow with the vertex and an M-shaped mark black; the thorax is also yellow with two transverse black lines. In the males the front tarsi are strongly dilated and bear two or three large basal sucking disks and numerous smaller unequal ones. The hind tarsal claws are unequal. Neither the larvæ nor the adults ever menace young fish or display any tendency toward cannibalism, but are exceptionally peaceable.

Thermonectes basilaris (Harris). Figures 52, 54, 55, 57, 58, 60, 62, 64, 65, 67, 69, 70, 72, 73.

Acilius basilaris (Harris, 1828, p. 8).
Thermonectes basilaris (Sharp, 1882, p. 684; pl. 17, fig. 212).

Eggs.—The eggs are laid singly below the surface of the water in the stems of crex grass, rushes, or other water plants and hatch in four or five days.

Habits of the larva.—Four of these larvæ were captured August 6 and kept in an aquarium for a week, when two of them died and the other two pupated on being placed in artificial mud chambers. This

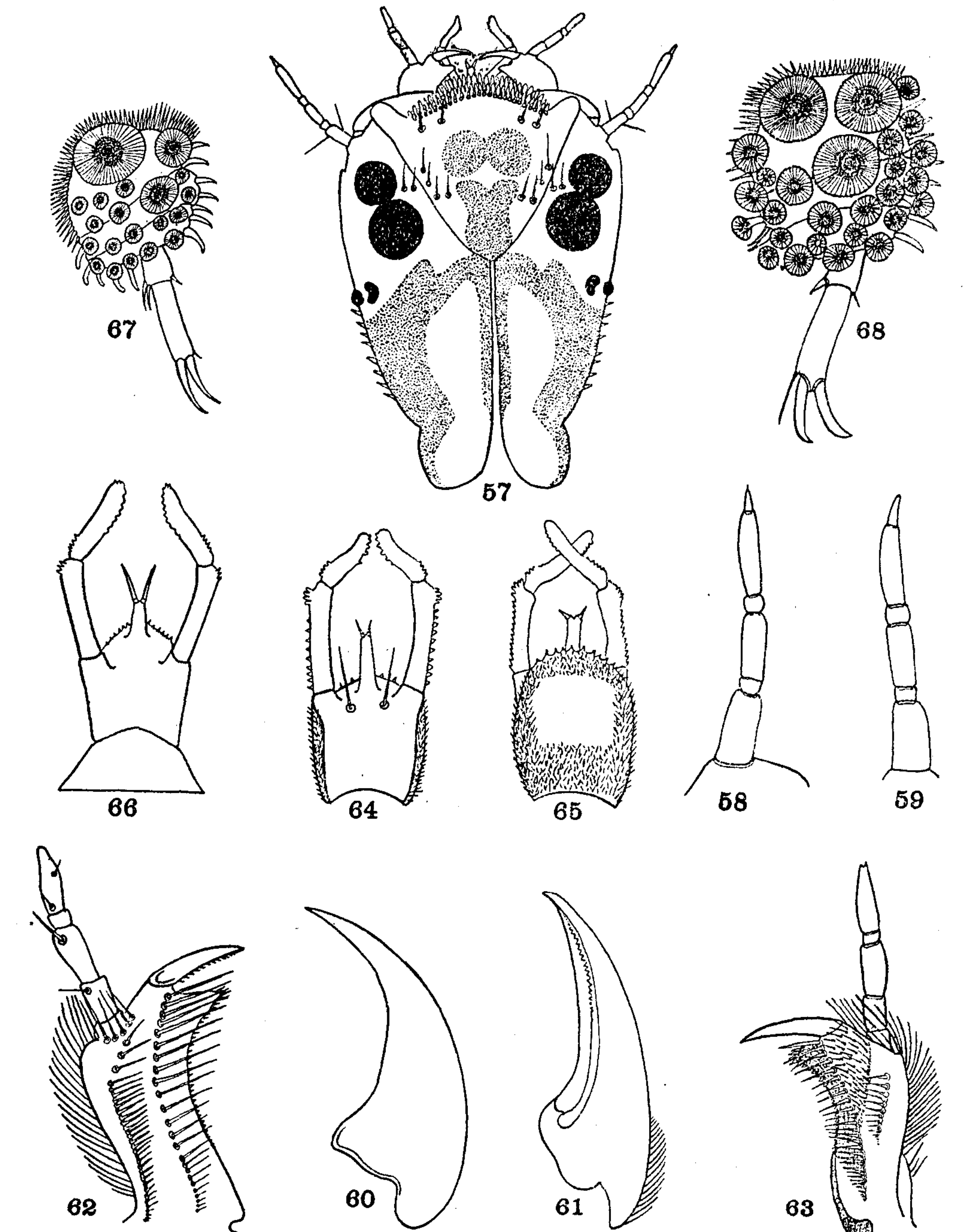


FIG. 57.—Dorsal view of head of larva of *T. basilaris*, showing color pattern and frontal border. FIG. 58.—Antenna of *basilaris*. FIG. 59.—Antenna of *ornaticollis*. FIG. 60.—Mandible of *basilaris*. FIG. 61.—Mandible of *ornaticollis*. FIG. 62.—Maxilla of *basilaris*, dorsal view. FIG. 63.—Maxilla of *ornaticollis*. FIG. 64.—Ventral view of labium of *basilaris*. FIG. 65.—Dorsal view of same. FIG. 66.—Ventral view of labium of *ornaticollis*. FIG. 67.—Front tarsus of *basilaris*, showing size, number, and arrangement of sucking disks. FIG. 68.—The same, *ornaticollis*.

larva swims with an even and rapid motion, propelling itself by short strokes of the legs, twisting and turning its body in different directions. During its progress it thrusts its tail frequently to the surface for breathing and seems unable to remain long under water. While at the surface it holds itself in place by depressing the cerci down upon the surface film. When disturbed, it snaps its body, often to quite a distance, by a sudden contraction of the longitudinal muscles of the abdominal segments. The same convulsive movement is made when the larva is placed in a preservative. It is aided considerably by the fringes of swimming hairs along the lateral margins of the last two abdominal segments. Sometimes a flexion of these two segments upon the segment just in front of them can be seen, and at other times a flexion of the abdomen upon the thorax, but usually no such movement is visible, because of its abruptness.

When swimming about, the last two segments of the abdomen are almost always carried at an elevation of 45° dorsally, as though constantly reaching for the surface. At the same time the abdomen between the thorax and the penultimate segment is curved downward. Whenever swimming ceases the buoyancy of the posterior end of the body carries it rapidly upward in a sinuous path, due to the curve of the abdomen and the angulation of the last two segments. There is seldom any need of positive effort in reaching the surface. Whenever there is the larva approaches the surface either tail first or head foremost indifferently; in the latter case it stops just before reaching the surface and inverts its body.

This larva feeds close to the surface upon whatever it can catch and snaps continually at the Notonecta and Belostoma nymphs that are swimming there. After seizing its prey it swims about, holding it in its mandibles, and jerking its head and prothorax from side to side much as a terrier shakes a rat. This movement evidently assists it in thrusting its mandibles through the hard skin of its prey. After the mandibles are fixed satisfactorily it remains quietly suspended from the surface film and sucks the juices out of its prey. When it wishes to obtain a new hold, it again swims about and shakes its prey and then quiets down, repeating this until all the juices have been extracted and nothing but the shell of the body is left.

In the aquarium they were fed with dragonfly and damselfly nymphs, mayfly larvæ, the nymphs of Belostoma and Notonecta, and the larvæ of Tropisternus. Out of these they always selected the Tropisternus larvæ first and ate them until they were all gone, then took the Belostoma nymphs, and finally the Notonecta nymphs. They refused to touch any of the other food, and they showed no tendency to fight with one another no matter how hungry they became. Some of the Tropisternus larvæ were larger in diameter, though not as long as the Thermonectes larvæ, but the latter had no difficulty in killing them because of superior agility.

Description of the larva.—General form spindle-shaped, narrowed strongly both anteriorly and posteriorly; length 17.5 mm., greatest width, through the second and third abdominal segments, 2.5 mm. (fig. 52, opp. p. 291). Head yellow on the dorsal surface with the following parts reddish-brown: The mandibles, the tips of the antennæ, the tips of the labial and maxillary palps, the anterior margin of the frons, irregular figures along the median line, across the head, and along the lateral margins behind the eyes; eyes black. Thorax and abdomen reddish-brown on the dorsal surface, white on the ventral surface except the last two abdominal segments, which are reddish-brown like the back. On the dorsal surface there is a curved yellow diagonal line on each of the first six abdominal segments, about half-way between the mid line and the lateral margin and extending backward nearly across the segment. A second spot, outside of the first and more inclined, appears on the second, third, fourth, and fifth segments.

Chitin sclerites cover the entire tergum of the thorax and abdomen and extend onto the pleurum a a short distance on either side, so that their lateral margins are not visible in dorsal view. These margins and also a projection which extends forward beneath the preceding sclerite are considerably darker in color. Inside of the lateral margin is a second narrow dark line on the mesothorax and metathorax and on the fifth and sixth abdominal segments; there are two such lines on the first four abdominal segments.

The sclerite on the mesothorax does not reach the spiracle, that on the metathorax just covers it, and those on the abdomen segments extend slightly beyond it. The sclerites of the last two abdominal segments extend entirely around the body, and the spiracles of the seventh segment open on the ventral surface. The ventral margins of the pleura of the first six abdominal segments are fringed with short silky hairs. On the sixth segment this fringe curves outward and becomes continuous with the much longer lateral fringes of the last two segments. There is a pair of oblong chitin plates on the mid line of the prothoracic sternum, which together are about half the length and width of the segment. The tracheæ show through in the last two segments as longitudinal dark brown lines.

Head obovate, widest through the eyes, its length to its width as 11 to 8, narrowed into a short neck posteriorly. Epicranial suture more than half the entire length; frons triangular with convex sides and prominent knobs at the anterior angles. The fringe along the frontal margin is made up of four rows of club-shaped processes diminishing in size from in front backward. There are no laciniate laminæ as in the *ornaticollis* larva, nor any sharp spines as in the Acilius larva. The two large eyes protrude as black hemispheres from the dorsal surface; only two of the other four are visible in dorsal view, and they are minute.

The prothorax is twice as long as wide, the posterior margin a little more than half as wide again as the anterior, the sides nearly straight. The mesothorax and metathorax increase in width, the latter being twice as wide as long. The abdominal segments increase regularly in length; the first two increase slightly in width, the third is the same width as the second, and the remaining segments diminish regularly in width. The last segment is broadly rounded at the tip and carries two slender cerci on its ventral surface a short distance in front of the end.

The antennæ are six-jointed, the second and fourth joints short and subspherical, the sixth joint also short but finger-like. The mandibles have a fringe of long hairs on the outer margin near the base.[1] The maxillæ are curved considerably and have a decided hunchbacked appearance; the spinous process is acuminate and has a row of minute hairs along its inner margin; the inner distal corner is sharply rounded and bears a tuft of small spines, which are continued down the inner margin. There are two longitudinal rows of stiff spines on the dorsal surface, the outer one strongly curved to follow the contour of the outer margin, the inner one much less curved. The palps are four-jointed, the third joint spherical, the basal joint shorter than the second and fourth, which are about equal (fig. 62, p. 292).

The labium is narrow and elongate; on the dorsal surface the palpiger has a raised and papillated margin on all four sides, covered with minute hairs and with a row of short spines across the distal margin. The ventral surface is smooth and bare, except for two long setæ near the base of the ligula. The palps are two-jointed, the joints about the same length, the basal joints with a row of spines along their outer margins, the terminal joints with a few spines on the outer margins at the base and on the inner margins at the tip. The ligula is long, narrow, and tapering, and carries at its tip two short, divergent, two-jointed spines. The legs are long and slender and well supplied with swimming setæ.

When taken from the pupal chamber just before pupation, the larva has diminished to 15 mm. in length, the width has increased to 2.9 mm. The color is now a uniform brown on the dorsal surface and light yellowish-white on the ventral surface, except the last two segments, which are brown. The head also is brown on both surfaces, the sclerites have lost their lateral dark lines, and the spiracles show through them as black dots. The four small eyes are black, the two larger ones have a decided reddish tinge.

Pupation—When the larva is fully grown, it selects a spot on the land that is well shaded and where the mud is rather soft. Here a foot or more from the water's edge it constructs its pupal chamber, which is subspherical in shape and 12 to 14 mm. in diameter. It is made of little pellets of mud stuck together rather loosely and rests upon the surface of the ground Its walls are so thin and friable that it is practically impossible to pick it up intact, except by cutting out a section of the mud beneath it. The building of the chamber occupies one to one and a half hours, and when it is completed the inside is smoothed by the larva rubbing it with its body The larva then folds the last two segments of the body forward and the head and thorax backward above them, like the Dineutes larva, and rests upon its back on the bottom of the chamber. The prepupal period lasts one and a half to two days. At the end of that time the skin splits along the dorsal mid line from the base of the head to the penultimate abdominal segment and is flattened out against the inner wall of the chamber, to which it adheres firmly. The pupa emerges upon its back on the bottom of the chamber and rests there for 24 hours, then it reverses its position and rests upon the long styli on the pronotum and the cerci at the posterior end of the abdomen, the dorsal surface uppermost and the body strongly arched.

[1] This fringe was accidentally omitted from Fig. 60; it should be the same as in Fig. 61.

Description of the pupa.—The pupa is white in color, except the eyes, which are dark reddish-brown and the face, which has a reddish tinge (fig. 69, p. 297). It is 8 mm. long, including the caudal cerci and 5 mm. wide. It is obovate in outline and quite strongly depressed. The segmentation is distinct and is rendered more conspicuous by the rolling up of the posterior margin of each segment into a ridge, which is low and flat on the ventral and lateral surfaces but stands out prominently on the dorsal surface, being highest at the mid line. The prothorax projects forward around the base of the head and carries on its frontal margin a fringe of long hairlike styli. On each lateral margin is a short process armed with five spines, and on each side of the dorsal mid line is a group of three stout styli. On the dorsal surface of the second thoracic segment are three spinelike styli on either side near the anterior margin and close to the mid line. On the third segment are four similar styli near the anterior margin, three near the posterior margin, one on the posterior margin near the base of the wing, and another near the mid line, nine in all on each half of the segment. On each of the first four abdominal segments are three large isolated styli on either side of the mid line along the posterior crest and one at the side of the segment behind the spiracle. The fifth segment has only two near the mid line and one behind the spiracle; the sixth and seventh segments carry a single pair of stout clawlike styli on the mid line and one behind the spiracle. The eighth segment has a compound handlike spine with three fingers on each lateral margin anteriorly and a single spine posteriorly. Its ventral surface is split back at the center, and the rudimentary ninth segment protrudes a pair of caudal cerci, short, stout, and bifid at the tip. When the pupa is on its back, all these styli and spines help to keep it above the earth floor of the pupal chamber.

The antennæ lie along the front margins of the elytra, and the maxillary palps extend straight backward beyond the tibiæ of the first legs. The femur of the first legs stands at right angles to the body axis, and the tibia is folded back tightly against it; the two tarsi are parallel to the body axis and well separated. In the second legs the tibiæ and femora are at right angles to each other, and both at an angle of 45° to the body axis; the tarsi are parallel to the axis and only slightly separated. In the third legs the tibiæ and femora are arranged like the second pair, but the tarsi are in line with the tibiæ and meet on the mid line. The time spent in the pupal stage is four or five days; two larvæ were taken from the pupal chambers they had constructed on the shore of pond 5D on July 6 and placed in artificial mud cells; they pupated July 7, and the adults emerged July 11. A male pupa reared in August, 1921, remained six days in the pupa stage.

Habits of the adult.—The adults swim with an even rapid motion, the posterior legs being the chief propelling organs. They rest at the surface with the posterior legs extending out at right angles from about the center of the body and the posterior end of the abdomen elevated above the surface film. When out of water, they move with considerable agility and can jump well, though not quite as vigorously as the following species. As indicated in the table, this is one of the rarer species, and it was fortunate that its life history could be secured.

Description of the adult.—General form elliptical in outline, a little broadened anteriorly and more pointed posteriorly, with a length of 10 mm. and a width of 6 mm. In the female the transverse yellow bar on the thorax is enlarged and turned diagonally backward at either end but does not meet the yellow on the lateral margins. In the male it is not enlarged or turned backward at the ends and it does meet the yellow margin. In both sexes the elytra are black with a transverse row of spots near the base and a wide margin yellow. The black is not an even wash of color but is made by many small black dots, more or less confluent.

The antennæ are 11-jointed, all the joints about the same length and width, except the basal one, which is lengthened at the expense of the second joint. Joints 3 to 7 each carry a small seta on the outer margin at the tip, and joints 3 to 11 have a sensory papilla on the inner margin near the distal end. The mandible is very thick, with a blunt emarginate tip, ending in an acute point at the ventral corner and a rounded tooth at the dorsal corner. The maxillæ are well developed with long, four-jointed palps; the labial palps are also long but only three-jointed and emarginate at the tips. The tip of the second joint develops broad dorsal and ventral wings, armed with sensory papillæ, on the inner margin.

In the males the front tarsi are broadly dilated and bear three larger basal disks and numerous smaller unequal ones. The basal joint carries the 3 large ones and 5 smaller ones, the second and third joints carry 6 each, all small but unequal in size. The largest basal one is twice the diameter of the other two, and they in turn are twice the size of the smaller ones. The fringing hairs are evenly developed and are not interrupted at the point where the tarsus joins the tibia (fig. 67, p. 292).

The femora of the second legs are armed on the posterior margins with long conspicuous setæ, increasing in length towards the tip. The coxæ of the third legs are large, the spurs at the tips of the tibiæ are unequal and distinctly emarginate, the tarsi are armed with long swimming setæ, and the claws at their tips are unequal.

Thermonectes ornaticollis (Aubé). Figs. 53, 56, 59, 61, 63, 66, 68, 71, 74, 147, 148.

Dytiscus ornaticollis (Aubé, 1838, p. 140).
Thermonectes ornaticollis (Sharp, 1882, p. 678).

Eggs.—The eggs of this species are probably deposited singly in the stems of water plants like those of the preceding species.

Habits of the larva.—It swims usually with a uniform motion and fair rapidity, but without any movement of the body. When disturbed, however, it snaps its body like the *basilaris* larva by suddenly lashing the last two segments of the abdomen against the water. This ability to jump or snap the body is retained after the larva comes out of the water, and even after it is inside of the pupal chamber. If an attempt is made to pick up such a larva, it will sometimes jump 8 or 10 inches in this manner. Its breathing habits are similar to those already described for the preceding species.

In the pond it swims about close to the surface and snaps up the copepods and Entomostraca that swarm there. It frequently seizes small objects floating on the surface and draws them beneath the water. After testing them in its mandibles it rejects those that are unfit for food and retains the others. In an aquarium it eats mayfly larvæ, is very fond of the larvæ of both species of Tropisternus, and is able to kill them when they are fully as large as itself. As both species of Tropisternus are abundant in the ponds from which the Thermonectes larvæ were taken it is probable that they constitute at least a portion of the regular food of the latter. After it has killed its prey it usually swims to the surface and hangs from the surface film by means of its cerci, breathing and sucking the juices of its victim. It is much the most graceful and beautifully colored larva of any here described. It is easily recognized, is harmless, and furnishes good fish food.

Description of the larva.—The general structure is the same as that of the *basilaris* larva, but the following differences may be noted. Its total length, including the posterior cerci, is 22 mm., its greatest width is 3.5 mm. In color the dorsal surface of the head and neck is yellow, with the following black markings: The tips of the antennæ and maxillary palps; the bases of the maxillæ and mandibles; two circular spots close together, one on either side of the mid line, near the anterior margin of the head another pair of triangular spots behind the eyes, fused on the mid line, with a wide band extending from the side of each to the lateral margin of the head behind the eyes; the entire eye areas; a semicircular spot on either side of the neck behind the head. The dorsal surface of the thorax and abdomen is light yellowish-brown, the sclerites narrowly edged with black, with a secondary edging on the lateral margins inside of the first. Inside of this row of secondary edgings is a longitudinal stripe of dark brown, connecting anteriorly with the black line on the lateral margin of the head and running the whole length of the body. There is another dark brown stripe on either side close to the mid line; along the mid line and between the stripes are bands of light yellowish-brown.

The terminal joint of the antenna is relatively larger than in the *basilaris* larva; the mandibles have a fringe of hairs on the outer margin near the base and a row of fine teeth in the groove near the tip. The maxillæ are similar with a fringe of long hairs along the outer margin and the addition of a dense covering of spines and hairs over the inner half of the basal portion. The labial palps are armed with short spines on the outer distal margin of the basal joint and on the outer margin of the terminal joint near the base and at the tip. The inner margins of the terminal joints are sinuate for their distal half. The ligula is relatively shorter than in the preceding species, but the two-jointed spines at its tip are longer, being fully as long as the ligula itself.

Two of the eyes—the dorsal members of the anterior and middle pairs—are much larger than the others, are reddish in color, and protrude strongly from the surface of the head. The posterior pair are much smaller and are close together on the lateral surface of the head, only the dorsal member of the pair being visible from above. The ventral members of the first two pairs are on the ventral surface of the head and are separated from the dorsal members by wide intervals, the space between the two members of the middle pair being fully four-fifths of the thickness of the head. None of these last four eyes project at all from the surface of the head. The underlying pigment of the two larger eyes is not confined to the surface immediately beneath the skin but penetrates downwards and backwards nearly

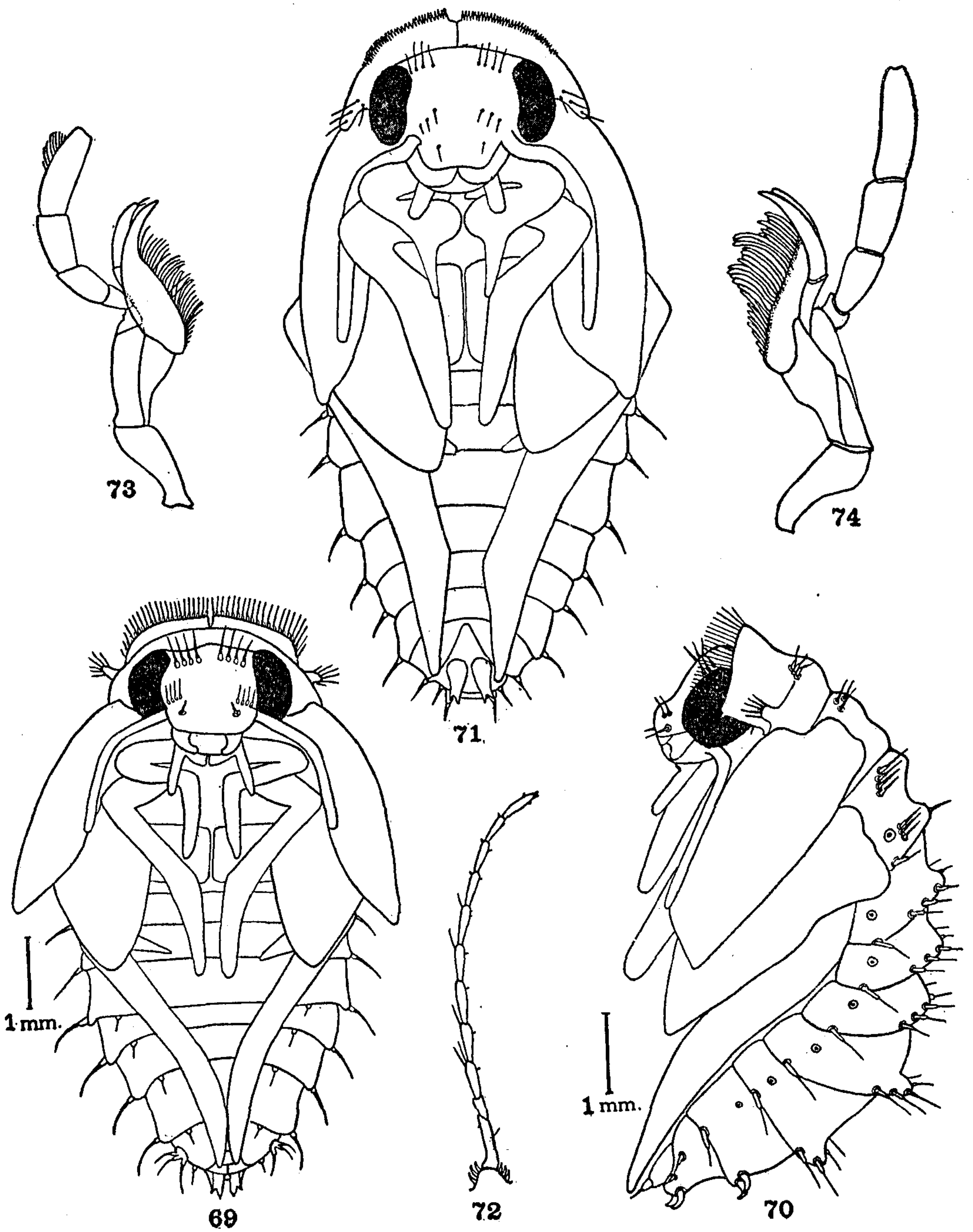


FIG. 69.—Ventral view of pupa of *Thermonectes basilaris*. FIG. 70.—Side view of same, showing arrangement of spines. FIG. 71.—Ventral view of pupa of *T. ornaticollis*. FIG. 72.—*T. basilaris*, antenna of adult beetle. FIG. 73.—Maxilla of adult beetle. FIG. 74.—Maxilla of adult *T. ornaticollis*.

to the ventral surface. This arrangement of the eyes and penetration of the pigment is the same in the two species here described, and in the Acilius larva, which follows, but nothing like it was noted in any of the other larvæ. It thus serves to denote the close relationship of this genus with Acilius.

Pupation.—This larva does not travel as far from the water's edge as the preceding but builds out of mud pellets a similar pupal chamber, which is ellipsoidal and about 14 by 16 mm., outside measure. This is often built beside a grass or rush stem or under a pile of rubbish and its walls are so thin that the larva often tears them asunder by snapping about when disturbed. Since the inner diameter of the chamber is only a trifle more than half the length of the larva, the latter is of necessity folded upon itself, like the species already described. Similarly the skin splits open along the dorsal mid line from the base of the head to the seventh abdominal segment and is flattened against the inside of the chamber wall. About 30 hours elapse between the completion of the chamber and pupation.

Description of the pupa.—This pupa differs from the preceding in the following particulars. In size it is half as large again, measuring 13 to 14 mm. in length and 6 to 7 mm. in greatest width. The front margin of the prothorax is armed with a row of short spines rather than long styli and there are no processes on its lateral margins. The antennæ are longer and reach nearly to the tips of the wings. The first and second legs are not as long, and the latter do not reach the tips of the elytra; the third legs are the same length, but all three pairs are much stouter. The length of time spent in the pupal stage varies considerably as can be seen from the following table compiled from eight larvæ reared to the adult stage.

Completion of chamber.	Pupation.	Emergence.	Completion of chamber.	Pupation.	Emergence.
Aug. 3	Aug. 4	Aug. 8.	Aug. 4	Aug. 4	Aug. 8.
Do	do	Aug. 9.	Do	Aug. 5	Aug. 10.
Do	do	Do.	Do	do	Do.
Do	Aug. 3	Aug. 7.	Aug. 5	Aug. 6	Aug. 11.

Description of the adult.—This beetle may be distinguished from the preceding species by the following differences: In size it averages fully one-half longer and one-third wider, having a length of 15 to 16 mm. and a width of 8 to 8.5 mm. In color the sides of the M-shaped mark on the head do not touch the eyes, but there is a distinct yellow band between the two, whereas in the preceding species they do touch the eyes and there is no band. On the thorax of *basilaris* the two transverse black bands touch the anterior and posterior margins, respectively, and there is a single yellow band between them. In *ornaticollis* they do not touch these margins and there are three yellow bands. Across the bases of the elytra in the preceding species is a black band, which turns backward a short distance at the outer corners; in the present species the bases are yellow, and this color extends along the inner margins nearly or quite to the posterior ends. In *ornaticollis* the distal half of the lateral margins of the elytra is heavily fringed with long hairs, in *basilaris* it is nearly smooth. The rounded tooth at the dorsal corner of the mandibles of the preceding species is bordered on either side by a deep sinus; in the present species there are no sinuses. The labium here is relatively shorter and wider; in the preceding species it is longer and narrower. In the dilated tarsus of the male of this species the basal joint is longer than the second and third joints together, and carries 10 disks, 2 large ones on the proximal and 1 on the distal margin, the 3 about the same size and forming a triangle, the other disks much smaller and unequal on the lateral and distal margins. The second joint carries 5 on the inner and 2 on the outer margin; the third joint carries 10 irregularly arranged, 5 of medium size and 5 smaller ones. In the preceding species the basal joint is also longer than the second and third joints together, but it carries only 8 disks, 1 large one at the outer proximal corner, 1 half as large at the inner proximal corner, another the same size on the distal margin, and 5 much smaller ones along the outer distal area. The second and third joints each carry 6 disks about the size of the smallest ones on the basal joint along the inner and distal margins.

These differences in the adult beetles, together with the life histories here presented, effectively establish the present as a distinct species rather than a variety of *basilaris*. Blatchley (1919) arrived at the same decision from his study of the adults in opposition to Leng and Mutchler (1918, p. 90), who considered *ornaticollis* as a mere variety of *basilaris*.

Genus ACILIUS Leach.

Acilius (Leach, 1817, p. 69).

This is a genus of medium-sized species, which are somewhat obovate in form and have the upper surface in the male smooth and regularly punctate; in the female usually sulcate but still distinctly punctate. The front tarsi in the male are dilated and armed with one large and two medium-sized disks and a number of smaller ones. The middle tarsi are equal, and the hind claws are equal. Neither the larvæ nor the adults have been known to attack or injure young fish, and the larvæ show no cannibalistic tendencies but live peaceably with one another, even in an aquarium.

Acilius semisulcatus Aubé. Figures 21, 75–78.

Acilius semisulcatus (Aubé, 1838, p. 132).

Eggs.—Miall quoted Régimbart as saying that Acilius lets its eggs drop at random upon the mud while swimming about (Miall, 1895, p. 40), but it would seem probable, judging from its ovipositor, that some are inserted in the stems of water plants.

Habits of the larva.—Thirty larvæ were obtained from pond 7D when it was drained and were kept in an aquarium for 10 days. Nearly every kind of larvæ in the ponds was offered to them as food, but the only thing they ate, as far as observed, was a few small snails. Efforts were also made to induce them to pupate but without success. From their great similarity to the larvæ of the two species of Thermonectes, from their size and from their close correspondence to the known larvæ of Acilius as found in Europe, it is reasonable to assign them to the genus Acilius. And since *semisulcatus* is the only species found in the ponds they have been referred to this species.

They are larger and even more graceful and agile than the larvæ of the two Thermonectes species just described. They swim rapidly and easily, always keeping the abdomen curved upward, often at an angle of 45°. When resting on the bottom or on any support, the abdomen is curved into a crescent shape, the center of the curve in contact with the support. When they wish to rise to the surface, they can usually do so by simply letting go of the support. The air within the tracheæ is then buoyant enough to carry them up tail first. Occasionally they are forced to swim with slight movements of the legs or by a sort of jerking motion of the abdomen, and the tail is still kept upward. At other times they swim up head first and when near the surface elevate the tail and thrust it above the water. After doing this the body is allowed to drop downward, and they hang from the surface film for a long time, supported by their cerci.

Like Thermonectes they can flex the body suddenly at the first abdominal segment and straighten it with equal rapidity, both movements being imperceptible to the naked eye. The result is a snap or jump that often throws the larva several inches. This is undoubtedly the "peculiar indescribable motion of the whole body away from the point of disturbance" declared by Needham and Williamson (1907) to be characteristic of one of the larvæ studied by them. They added also: "Sometimes it makes just one quick dodge, and sometimes it goes through a series of wriggling movements so swiftly executed that the eye can not follow them" (1907, p. 489). They ascribed their larva to a species of Acilius, which it may well have been, since the figure they gave (fig. 8, b, p. 491) of the maxilla compares favorably with Figure 76, although the palp had not yet acquired the short spherical penultimate segment. When a larva dies and sinks to the bottom of the aquarium, it is always found with the body sharply flexed at the first abdominal segment and must be straightened before being preserved.

Description of the larva.—General form an elongate spindle 24 mm. long and 3.15 mm. wide, narrowed considerably both anteriorly and posteriorly, widest through the third and fourth abdominal segments, whose diameter is a little less than one-seventh of the body length. The color pattern affords the readiest means of recognition and is given in detail. General color olive yellow; head with the following black—the tips of the antennæ, maxiliæ, and palps, the eye areas, the anterior margin of the labro-clypeus, a spot on either side of the mid line just behind the anterior margin, a broad band connecting the posterior ends of the eye areas, and irregular spots on the sides and dorsal surface at the base of the head. On the dorsal surface of the thorax and abdomen the sclerites cover the entire tergum and extend onto the pleurum, so that their lateral margins are invisible in dorsal view. Each sclerite is narrowly bordered

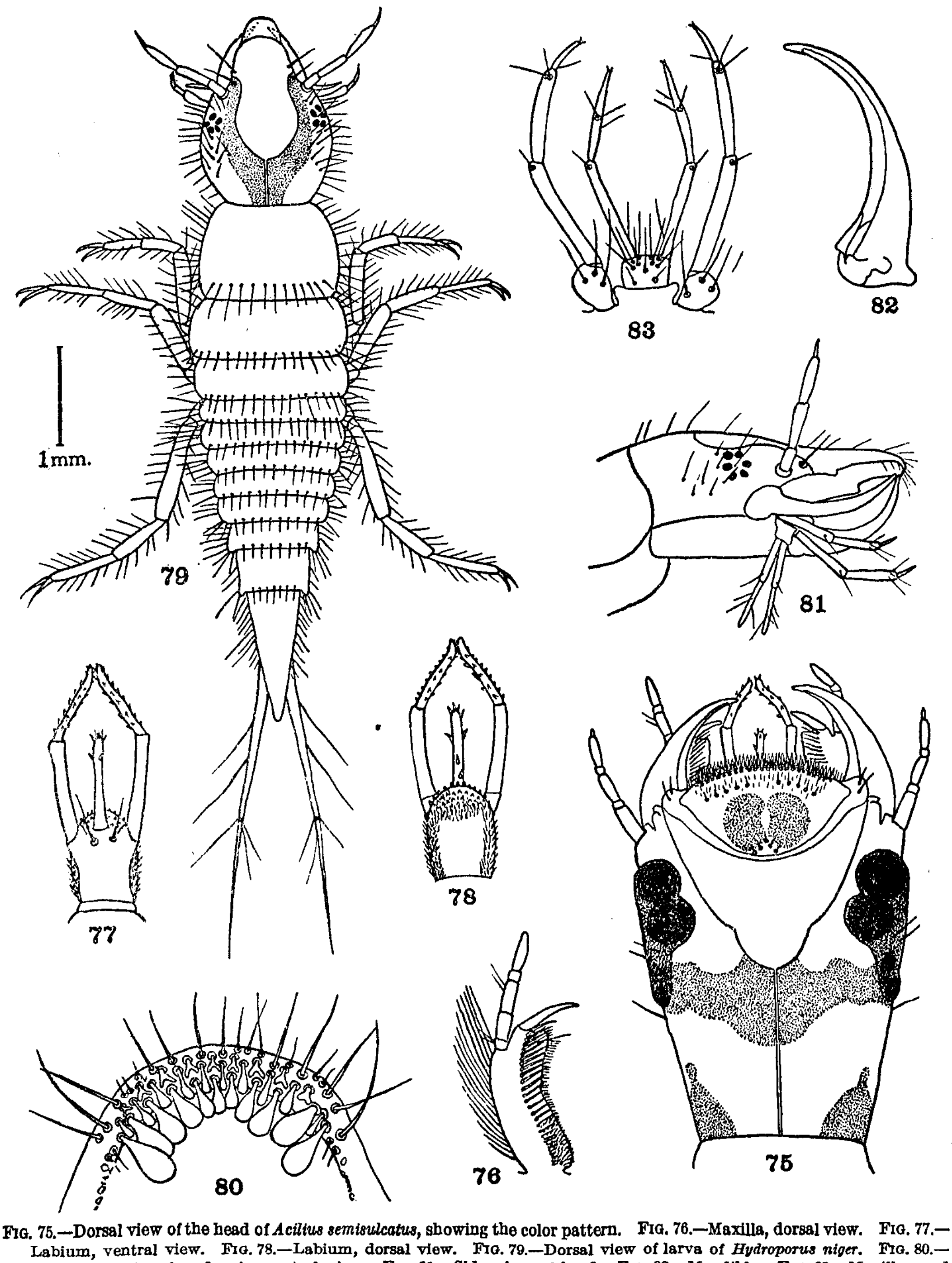


FIG. 75.—Dorsal view of the head of *Acilius semisulcatus*, showing the color pattern. FIG. 76.—Maxilla, dorsal view. FIG. 77.—Labium, ventral view. FIG. 78.—Labium, dorsal view. FIG. 79.—Dorsal view of larva of *Hydroporus niger*. FIG. 80.—Frontal margin of proboscis, ventral view. FIG. 81.—Side view of head. FIG. 82.—Mandible. FIG. 83.—Maxillae and labium, ventral view.

with dark brown along the anterior and lateral margins and much lighter brown along the posterior margin. On the lateral margins of all except the prothorax there is a second narrow dark line above the one along the edge, and on the first six abdominal segments a third much wider line and a fourth very narrow line. On the prothorax a narrow brown band runs from the anterior margin nearly to the posterior margin on either side of the mid line. These bands widen and diverge slightly posteriorly. Begining again in the mesotharax and a little wider, they extend to the posterior margin of the seventh, abdominal segment, being interrupted by narrow yellow transverse lines near the posterior margin of each abdominal segment. Outside of these bands and separated from them by a longitudinal yellow stripe is a wider brown band on either side, beginning with the third and ending with the seventh abdominal segment. All these brown bands deepen in color posteriorly and the two on either side fuse just in front of the transverse yellow line in each segment.

On the central bands are small areas much deeper in color, a pair at the anterior margin of each segment. Those on the mesothorax and metathorax and the first two abdominal segments are minute and are partially concealed beneath the posterior margin of the sclerite in front. On the seventh segment the brown bands fuse across the posterior two-thirds of the segment, leaving only the mid line yellow. On the eighth segment the entire surface is yellow, with a narrow black band at the extreme posterior end and the two tracheæ showing as a dark longitudinal line on either side. The fringes along the lateral margins of the seventh and eighth segments aré dark brown, almost black; the cerci are a much lighter brown. On the legs the edges of all the joints are pencilled with dark brown. The entire under surface is yellowish-white, except the seventh segment, which is tinged with brown. There is a fringe of silky black hairs along the ventral margins of the abdominal pleura on either side and scattered hairs across the posterior margin of the second, third, fourth, and fifth abdominal segments. The spiracles and the tubes connecting them with the tracheæ are jet black; those of the seventh abdominal segment open on the ventral surface.

Head an elongate trapezoid, one-half longer than wide, widest through the eyes, narrowest at the posterior margin, with straight sides. Epicranial suture nearly half the length of the head; frons triangular with curved sides, the anterior margin bordered with a thick fringe composed entirely of short stout spines, arranged in several rows. There is a transverse row of long setæ just in front of the dark spot on the frons. Between the fringe and this row of setæ the surface is covered with scattered minute spines. Around the dark spot and through its center longitudinally are short setæ.

The antennæ are six-jointed, the first, third, and fifth joints stout and about the same length, the second and fourth joints almost spherical and less than one-fourth as long, the terminal joint a narrow fingerlike process of about the same length as the second and fourth joints. The mandibles are of the usual dytiscid form, rather short and stout, and they do not overlap much when closed. The maxilla is similar to that of Thermonectes and consists of a long curved basal portion with a single row of spines on its dorsal surface, a fringe of long hairs along its outer margin, another fringe of short hairs along its inner margin, and a slender, acute spine at the distal end. The palp is four-jointed, the first, second, and fourth joints about the same length, the third joint spherical and much like the similar ones in the antennæ. The labium is elongate; the palpiger is one-half longer than wide and rounded at the distal end. Its dorsal surface along the lateral margins and across the distal end is raised somewhat and thickly set with small spines. Each palp is composed of two slender joints, of about the same length and together reaching the tip of the maxilla. The terminal joint is sparsely armed with small spines; the ligula is slender, as long as the basal joint of the palps, and sparsely armed with spines.

The prothorax is twice as long as wide, the posterior margin where it is widest being twice the width of the anterior, the sides concave. The mesothorax and metathorax are one-half wider than long; the abdominal segments increase regularly in length backwards, the first three increase slightly in width, the fourth is the same width as the third, and the remaining segments decrease rapidly. At the posterior end of the body are two slender cerci, one-third as long as the last segment.

Habits of the adult.—This beetle is an excellent swimmer, being surpassed in this respect only by Cybister and Dytiscus, and in its jumping ability it comes very close to Thermonectes and Laccophilus, but it is a very poor walker and flounders along awkwardly. In the ponds it is active and restless, moving about almost continuously and scarcely pausing except now and then to eat its prey. It feeds upon dragonfly and damselfly nymphs, the nymphs of Belostoma and Notonecta, mayfly larvæ, and the larvæ of hydrophilid beetles. It did not attack any of the dytiscid larvæ in the ponds, possibly because they are difficult to catch.

Description of the adult.—General form broadly obovate, 14 to 15 mm. long, 7 to 8 mm. wide; dull yellowish-brown on both dorsal and ventral surfaces, the thorax and elytra with yellow margins and the posterior abdominal segments with ventral yellow spots on either side. Head with the base and a broad M-shaped mark black; thorax with a narrow black line near each lateral margin of the disk and two wider transverse ones. In all the females obtained the elytra were broadly sulcate or grooved; in the male they were smooth with a subapical yellowish cross bar. The front tarsi of the male are broadly dilated; the basal joint bears a large sucking disk at its posterior proximal corner and two very much smaller ones on its anterior margin. The second and third joints bear numerous rows of minute hairs terminating in sucking disks along both anterior and posterior margins, and the posterior ones extend onto the basal joint distal to the sucking disk. These tarsi are thus quite different from those in other genera and help in identification.

Genus DINEUTES MacLeay.

Dineutes (MacLeay, 1825, p. 30).

This is a genus of fair-sized beetles belonging to the Gyrinidæ, or whirligig beetles; they are more or less oval in form and quite strongly depressed. The upper surface is bronzed, shining, and finely reticulate, and in the only species found in the Fairport ponds the ventral surface is black and shiny. The front tarsus of the males is dilated only a little and is clothed with rows of short tubular suckers. The adults are harmless and never injure or attack young fish, but the larvæ have been known to kill and eat small fish under somewhat abnormal conditions.

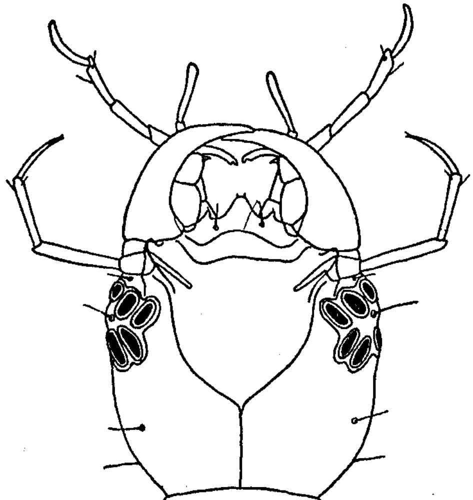
Dineutes americanus Say. Figures 84–94.

Dineutes americanus (Say, 1825, p. 107).
Cyclinus assimilis (Kirby, 1837, p. 78).
Dineutes assimilis (Wickham, 1893a, p. 330, pl. 9; 1894, p. 39).

Eggs.—The eggs were found in clusters varying from 7 to 40 in number on the under surface of the leaves of *Potamogeton illinoensis* in pond 2D. They were white in color and were arranged diagonally at an angle of 45° with the mid rib of the leaf, all on one side near the base. They were regular elongated ellipsoids, 1.85 mm. long and 0.64 mm. in diameter. The egg shell consists of a thin and smooth inner membrane covered with a much thicker layer composed of short cylinders placed end to end and packed so closely together as to become more or less hexagonal. The cylinders are of different diameters and their outer ends are rounded into hemispheres. This thick prismatic layer covers what may be called the top of the egg, namely, the surface next to the leaf, runs down on either side and onto the bottom surface, but leaves quite a wide strip through the center of this surface uncovered. The two edges of the thickened layer meet at the posterior end of the egg but not at the anterior end. Each egg is glued separately to the leaf by a transparent colorless cement, which extends the whole length of the egg and projects slightly beyond the ends. The egg is apparently not flattened at all on the top next to the leaf. The larva is folded lengthwise inside the eggshell in the same manner that the mature larva afterwards folds itself inside the pupal chamber. The dorsal surface of the thorax and the first five abdominal segments are next to the surface of the leaf, the rest of the abdomen is folded up against them and the head is folded against this posterior abdomen with the antennæ and mouth parts fully extended. The lateral gills are closely appressed to the sides of the body.

When the egg hatches, the shell splits lengthwise on the bottom through the space uncovered by the prismatic layer from end to end. The larvæ all hatch at about the same time and crawl around on the surface of the leaf amongst the empty eggshells for several hours before swimming away. The hatching occurs five or six days after the eggs are laid.

The newly hatched larva.—As soon as it is once straightened out the newly hatched larva is from 5 to 5.5 mm. long, and the head, which is the widest part of the body, is 0.75 mm. in diameter. This larva is like the fully matured one, except that the prothorax is as wide as the mesothorax and metathorax, and the first two pairs of lateral gills are plumose like the others.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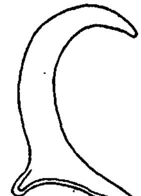
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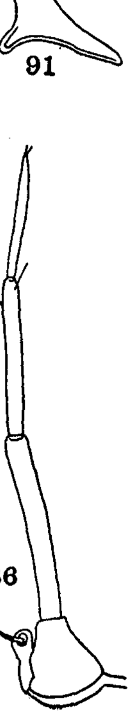
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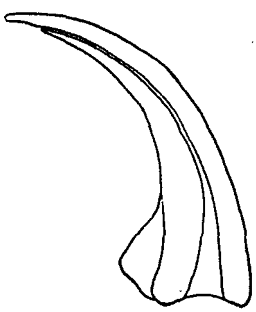
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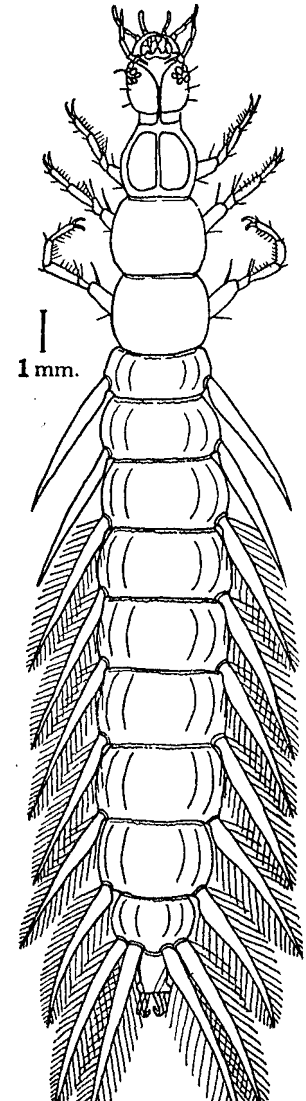

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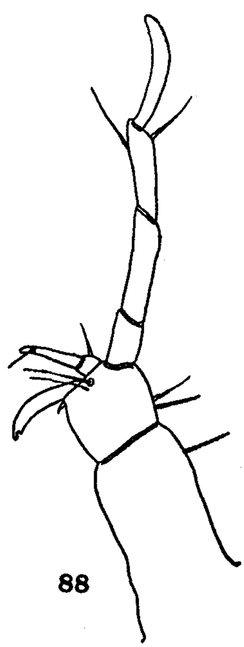
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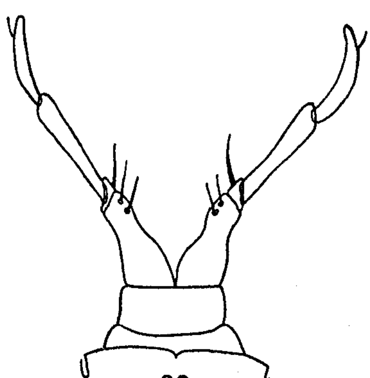
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FIG. 84.—Dorsal view of larva of *Dineutes americanus*. FIG. 85.—Head of same, enlarged. FIG. 86.—Antenna. FIG. 87.—Mandible. FIG. 88.—Maxilla, dorsal view. FIG. 89.—Labium, ventral view. FIGS. 90 and 91.—External and internal hook on last segment of abdomen.

Habits of the larva.—This larva swims with a sinuous motion of the whole body up and down after the manner of a flatworm. There are no swimming fringes on the legs, but instead the eight posterior pairs of lateral gills are heavily fringed on both sides, and thus serve for locomotion as well as for breathing. By lashing them up and down the larva can move either forwards or backwards with great rapidity. On the land it crawls quite rapidly; being unable to lift the posterior part of the abdomen above the ground, it aids locomotion by using the last segment with its hooks like the posterior prolegs of the caterpillar, arching the abdomen upward like the so-called inchworm. It can also jump quite a distance by snapping its body in the same manner as the Thermonectes larva. When two larvæ come together out of the water, the first instinct is self-preservation, and each jumps back as far as it can.

In an aquarium the larva rests nearly always on the bottom and not on the water plants, and the abdomen maintains a constant trembling motion up and down, which is evidently its mode of breathing. Hence, it never needs to come to the surface for an air supply.

It is not very voracious but will defend itself fiercely when attacked and will catch anything that is unfortunate enough to crawl against it. It sometimes attacks and kills small fish as is related on page 250. It shows a preference for the nymphs of damselfleis and mayflies and the larvæ of Corethra and Chironomus.

Description of the larva.—The larva has the appearance of a small centipede, owing to the presence of lateral gills along the abdominal segments (fig. 84). When full grown it measures 25 to 30 mm. in length and 3 to 3.5 mm. in width. The body is made up of the head, 3 thorax and 10 abdomen segments, and is seven times as long as wide and strongly flattened. The general color is white, lighter on the ventral surface and in the lateral gills, and faintly tinged with yellowish-brown on the dorsal surface. The eyes are black, but the following parts are dark brown—the mandibles, a triangular spot between the bases of the antennæ and the eyes, the neck on both the dorsal and ventral surfaces, the posterior margin of the dorsal plates on the first thorax segment, and a small spot on the dorsal surface of the base of each leg in the shape of an inverted V.

The head is elliptical in outline, one-third longer than wide, flattened dorsoventrally, but with both surfaces convex, almost squarely truncated anteriorly with a small rostrum on the mid line, bordered on either side by a short pointed tooth. The antennæ project from the dorsal surface of the head behind the outer corners of the bases of the mandibles. Each is four-jointed, the three terminal joints filiform and diminishing a little in length and diameter, the basal joint much wider and shorter. The mandibles are alike, each is slender, curved, acute, and suctorial, the inner tube opening through a slit near the tip.

The maxillæ are a little longer than the antennæ and are attached to the ventral surface of the head just inside the bases of the mandibles. The basal joint is long and stout, the second joint about half the length but nearly as wide. To its outer corner is attached the four-jointed palp, the three distal joints about the same length, the proximal one about half as long. At the inner corner is a long curved process, emarginate at the tip, representing the lacinia, and between the lacinia and palp is a two-jointed galea, the terminal joint much longer and narrower than the basal, both joints armed with a long seta. There are also two setæ on the dorsal surface opposite the base of the galea, two on the outer margin near the basal joint, and a small curved spine on the inner margin at the base of the lacinia. The labium is peculiar in that the bases of the palps are fused on the mid line; the palps themselves are three-jointed with a small fold or wrinkle between the first and second joints; obviously there is no chance for a ligula.

As in the Dytiscidæ, the eyes are 12 in number, a group of 6 just behind the base of each antenna and all visible in dorsal view. Their arrangement may be seen in figure 85, p. 303; the two dorsal eyes are close together with their long axes at right angles to each other. The other eyes are separated a short distance laterally and a much longer distance longitudinally, and their long axes are parallel, respectively, to those of the dorsal pair. All the eyes protude slightly from the surface, and in the space between them a seta is located. Posteriorly the head is narrowed into a short neck, covered with two narrow plates on the dorsal surface, but naked on the ventral surface.

The three thorax segments are about the same length, but the first one is a quarter narrower than the other two and carries a pair of dorsal plates. The other segments and the abdomen are destitute of dorsal plates, since this is not a burrowing larva.

The 10 abdominal segments are represented in length by the numbers 11, 15, 18, 18, 19, 19, 20, 20, 15, 10, and in width by the numbers 28, 31, 33, 35, 34, 34, 33, 30, 21, 8. From the posterior corners of each segment is given off a pair of narrow, conical gills, 10 times as long as wide, contracted at the base and tapered to an acuminate point. The ninth segment carries two on either side instead of one, and the tenth segment has none. Each gill contains a narrow central tracheole, and the eight posterior pairs are heavily fringed with hairs, although the first two pairs are naked. The tenth segment is naked, a little longer than wide, and armed at its posterior end with four sickle-shaped hooks, the inner one on either side considerably larger than the outer one. Miall (1895, p. 36) said of these hooks in the Gyrinus larva that they "are believed to be of use in climbing." They are also used during the construction of the pupa case, holding the posterior end of the larva securely in place while it gathers the materials for making the case.

Pupation.—When the larva is full grown, it crawls out of the water and up the bank, and its lateral gills shrivel up and fall off, except the last double pair and the single pair just in front of them, which are used for locomotion. The distance traveled and the place finally selected appear to depend upon the moisture of the earth, which must be soft enough to be easily worked but not moist enough to be muddy. The larva is quite particular in its choice and often covers a considerable area before finding a location that suits it.

Then there must be a convenient support to which the pupa case may be attached. The under surface of a dead grass or rush stem was usually chosen, since it was near enough to the ground for the larva to reach after building material and at the same time far enough removed to give the space requisite for the completed case. The case is made of pellets of earth stuck together with saliva. The earth apparently is not chewed and thoroughly mixed with the saliva after the manner of the mud wasps; rather, a mouthful of material is seized by the mandibles, wet with saliva, and pressed into place, and there is no smoothing of the outside surface or shaping by the mandibles. The outside of the case is rough, but the curve of the walls is quite regular. Sand grains, small fragments of rock, bits of wood, and pieces of leaves are mixed with the mud pellets in the walls. The larva clings to the grass stem with its posterior hooks and constructs the case around its own body. When the case is finished, except a small orifice at one end, the larva transfers enough material to the inside of the case and completes it from there. The case is 13 to 16 mm. long, 8 to 10 mm. wide, and is usually a fairly regular ellipsoid. The walls are about 1 mm. in thickness, except at the ends, where it is increased to 2 mm. A full-grown larva is about 30 mm. long, and hence its body must be folded inside the case; it assumes the form of the letter C, the ventral surface inside. After resting two or three days the skin splits open along the dorsal mid line from the base of the head to the ninth abdomen segment and flattens out against the inside of the case.

Description of the pupa.—General shape oblong, rather squarely rounded anteriorly, more pointed posteriorly, the head folded down upon the thorax and invisible in dorsal view. Length 10.5 mm., width 4.5 mm. through knees of first legs. Color yellowish-white, turning later into brown on the dorsal surface; eyes black. The eyes are divided as in the adult, each half a hemisphere, the flat surfaces facing each other and connected by a narrow cord. The front of the head reaches well beyond the bases of the first and second legs, and the maxillary palps project diagonally from beneath the upper lip. The basal joints of the legs are at right angles to the body axis and the knees project beyond the lateral margins. The tips of the first legs meet on the mid line, those of the second legs are separated a short distance, and those of the third legs are widely separated. The elytra are considerably shorter than the wings and are squarely truncated at their tips, whereas the wings are bluntly pointed.

On the ventral surface of the pupa there are no setæ, except a ragged fringe across the anterior margin of the prothorax and at the posterior end of the abdomen. The dorsal surface is plentifully supplied with setæ, as shown in Figure 93. When the pupa case is horizontal, the pupa rests usually upon its back, and when the case is vertical upon the tip of the abdomen.

These pupæ can not be preserved like the others in 95 per cent alcohol, nor in a mixture of 95 per cent alcohol and 10 per cent formaldehyde. In either preservative the pupa flattens out completely in a day or two and is absolutely worthless. Carnoy's mixture of glacial acetic acid, absolute alcohol, and chloroform is the only preservative tried that gave satisfactory results.

Wickham (1893a) noted that this pupa is much more quiescent than is usual with the Coleoptera, and he could only detect the faintest movement of the abdomen in the specimens he observed. If the pupa be overturned in its case, however, or be irritated with a needle, it will prove to be lively enough and will wriggle about vigorously.

The duration of the pupal period is seen in the following table:

Entered chamber.	Pupated.	Emerged.	Entered chamber.	Pupated.	Emerged.
1919.			1920.		
July 8	July 10	Died.	July 20	July 23	July 28.
July 13	July 15	July 20.	July 21	July 22	Do.
July 14	July 16	July 21.	Do	July 23	July 29
Do	do	Do.	July 22	do	Do.
			Do	July 24	Do.
1920.					
July 20	July 23	July 28.			

Habits of the adult.—This genus includes the largest of the whirligig beetles, and the present species is the most abundant of any found in the fishponds. Although nowhere occurring in such swarms as characterize the closely related genus Gyrinus, the aggregate, nevertheless, forms a very respectable percentage of the pond fauna.

The locomotion is peculiar, whirling or spinning around a vertical axis, or circling in companies on the surface of the water; they seem never to move straight away in any direction. They swim with great rapidity and dive like other beetles, but spend most of their time on the surface film, and hence with the upper portion of their bodies in the air. To fit them for this mode of life, the under surface of the body is very flat lengthwise but quite convex transversely, and is hence shaped much like the bottom of a canoe. They skim the surface so rapidly and whirl about with such agility that it is extremely difficult to catch them without a net. They can fly well and frequently fly into the laboratory at night, but they can not rise from the surface of the water; they must climb up a grass or rush stem in order to spread their wings.

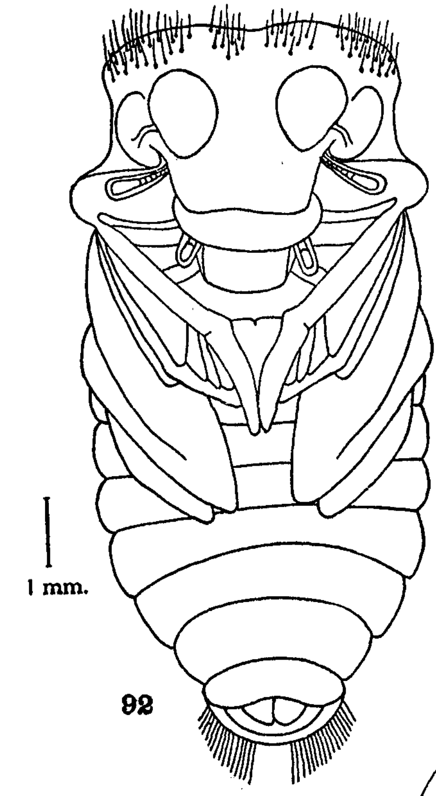
The adults are carnivorous like the larvæ, but have rather the habits of scavengers, feeding upon dead animal matter that finds its way into the ponds and floats on the surface. Miall (1895, p. 33) quoted the following observation by W. F. Baker:

> I was once watching some Gyrini when a gadfly came flying round my head. I struck at it and knocked it into the water stunned if not dead. Two or three Gyrini seized it and shortly afterwards the whole swarm clustered round. In a short time nothing was left except the wings of the fly, which were allowed to drift away. This is the only occasion on which I have seen anything of the sort. I could never get captive Gyrini to eat dead flies.

That the genus Dineutes responds more readily to artificial feeding is manifest from the following: The adult *Dineutes americanus* in pond 2F were fed with freshly killed insects, including two kinds of grasshoppers, two grass moths of different species, two damselflies (*Ischnura verticalis* and *Enallagma hageni*), a dragonfly (*Leucorhinia intacta*), a butterfly (*Phyciodes tharos*), and a mayfly imago (*Hexagenia* sp.), and they ate them all voraciously. As many would seize the insect as could crowd around it, grasping it with their mandibles. Then they would swim off, sometimes going fairly straight away, sometimes whirling around in wild curves and sometimes diving beneath the surface, but always holding on to their prey and tearing out mouthfuls of the insect tissues. When one bit off more than he could swallow at once, he would hurry away with it, pursued by a hungry crowd, each intent on snatching it from him, and he was lucky if he could keep it long enough to finish devouring it.

Another habit became conspicuous during the hot weather of the summer. Ordinarily the adult whirligigs are more or less scattered over the surface of the pond, but on hot days they show a decided preference for the shade. Most of the ponds have a small pier running from the shore to the outlet pipe to facilitate the handling of the latter. This pier is made of short lengths of plank with spaces between and casts a shadow which is either solid or streaked with rays of light according to the time of day. All the adult Dineutes in the pond on hot days gathered in this shadow about the middle of the forenoon and remained until late in the afternoon. When the shadow was solid they scattered indiscriminately over it, but when it was crossed with streaks of sunshine they carefully avoided the latter. The accompanying photograph (fig. 4, frontispiece) shows them thus congregated beneath the pier of pond 5D. It was taken about noon by H. W. Clark.

Description of the adult.—General outline an elongated ellipse 11.5 to 12.5 mm. long, 4.5 to 5 mm. wide, thus almost two and a half times as long as wide, the last segment in the female and the last two segments in the male projecting behind the elytra. Both dorsal and ventral surfaces distinctly convex; only the first legs visible in dorsal view, the others folded beneath the body. Above black, the elytra



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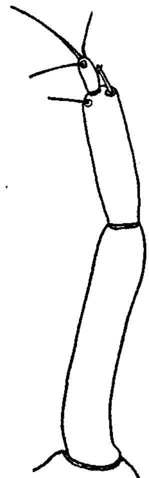
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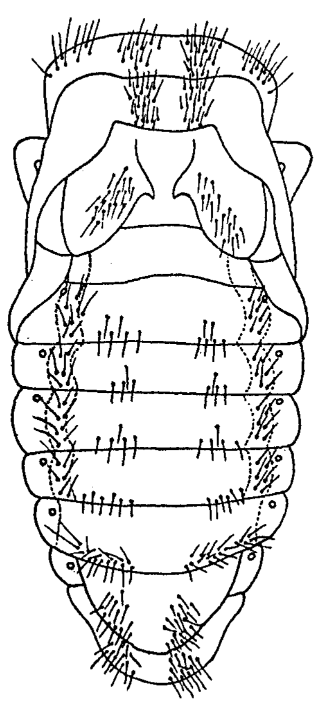
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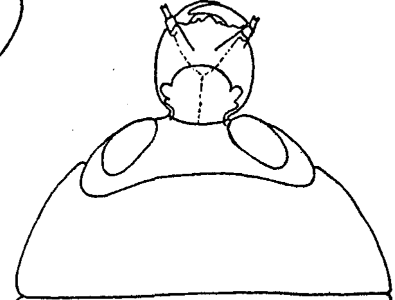
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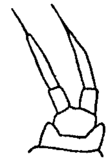
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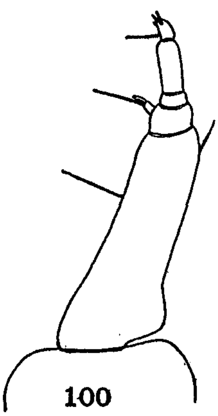
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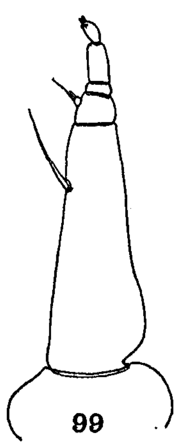
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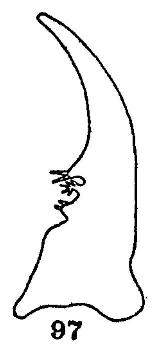
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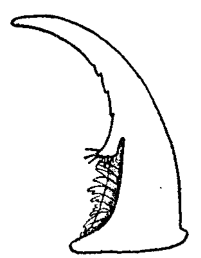
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FIG. 92.—Ventral view of pupa of *Dineutes americanus*. FIG. 93.—Dorsal view of the same. FIG. 94.—Head of adult beetle with old larva head still adhering to it. For some reason the epicranial suture did not open and allow the larva to withdraw its head at the time of pupation. FIG. 95.—Antenna of larva of *Berosus pantherinus*. FIG. 96.—Right mandible of *Berosus striatus*. FIG. 97.—Left mandible of same. FIG. 98.—Left mandible of *B. pantherinus*. FIG. 99.—Maxilla of *striatus*. FIG. 100.—Maxilla of *pantherinus*. FIG. 101.—Labium of *striatus*.

strongly bronzed; beneath black very shining; abdomen tinged with brown; legs brownish-yellow. Elytra of the male feebly sinuate both on the lateral margins and near the tips, the latter separated but little and the angles only slightly produced backwards. In the female both sinuations are more pronounced, the tips are more widely separated, and the angles are more distinctly produced.

The antennæ are peculiar and are very similar to those of Gyrinus, which are usually cited by authors as the type of what is known as the irregular form. Each antenna is made up of two parts, a proximal portion of three joints and a distal portion of seven joints. The second proximal joint is produced into a wide wing, which curves up around the base of the distal portion of the antenna. To the inside of this wing is attached the third proximal joint, and the first distal joint is fastened by a minute neck to the dorsal surface of this third joint. The distal portion of the antenna is club-shaped and six-jointed, the first joint apparently made up of three joints fused. Miall (1895, p. 34) said: "The peculiar form of the Gyrinus antenna is probably a means of keeping it dry." In this antenna the enveloping wing of the second proximal joint and the long fringes of hairs on the third joint assist in keeping the sensory terminal portion dry.

The mandibles are large and strong but are blunt and approach the herbivorous type more closely than the carnivorous. The maxillæ are sharp and sickle-shaped and typically carnivorous; the palp is five-jointed and somewhat club-shaped. The labium is well developed, with large circular paraglossæ and three-jointed palps.

The fore legs are prehensile, and in the male the tarsal joints are slightly dilated and their ventral surface is covered with rows of suckers that stand out like the pile on velvet. Each sucker is a narrow tube enlarged at the tip into a cup-shaped disk.

Genus GYRINUS Geoffroy.

Gyrinus (Linnaeus, 1758, p. 412).
Gyrinus (Geoffroy, 1762, p. 193).

This is a genus whose species are smaller, narrower, and more convex than those of the preceding genus. Each elytron has 11 rows of distinct punctures and when held so as to reflect the light usually shows a yellowish tint. The legs vary from yellow to reddish-brown in color and are relatively longer than in the genus Dineutes. The species vary so little that they are hard to distinguish; four have been reported from the fishponds but are not found there regularly. They seem rather to be itinerant visitors from the river and occur most frequently on the ponds that are nearest the river.

Gyrinus ventralis Kirby, 1837, p. 80.
Gyrinus limbatus Say, 1825, p. 109.

Neither of these species breeds in the Fairport fishponds, but the adults are occasionally found there in considerable numbers, and hence the more important facts in their life history will be of interest. These facts are taken from various authors and apply equally to the two species.

Eggs.—The eggs are laid in rows on the leaves or stems of water plants and closely resemble those of the preceding genus in shape, in color, and in time of hatching.

Habits of the larva.—It swims and breathes in the same manner as the larva of Dineutes already described. According to Miall (1895, p. 39): "The Gyrinus larva feeds upon water insects and possibly upon other aquatic animals. Failing these it will eat the tender parts of submerged plants." According to Needham the larvæ also "feed upon the body fluids of bloodworms and other small animal prey" (1916, p. 221). It is difficult to understand how a larva like this, whose mouth parts are typically carnivorous, and whose mandibles are suctorial like those of the Dytiscidæ, can eat vegetable food as stated by Miall.

Description of the larva.—This larva is similar to that of Dineutes, except that the first two pairs of lateral gills are fringed with hairs like the other pairs. This larva is only about 14 mm. in length and is widest through the second thoracic segment, which is nearly 2 mm. in width. The abdomen

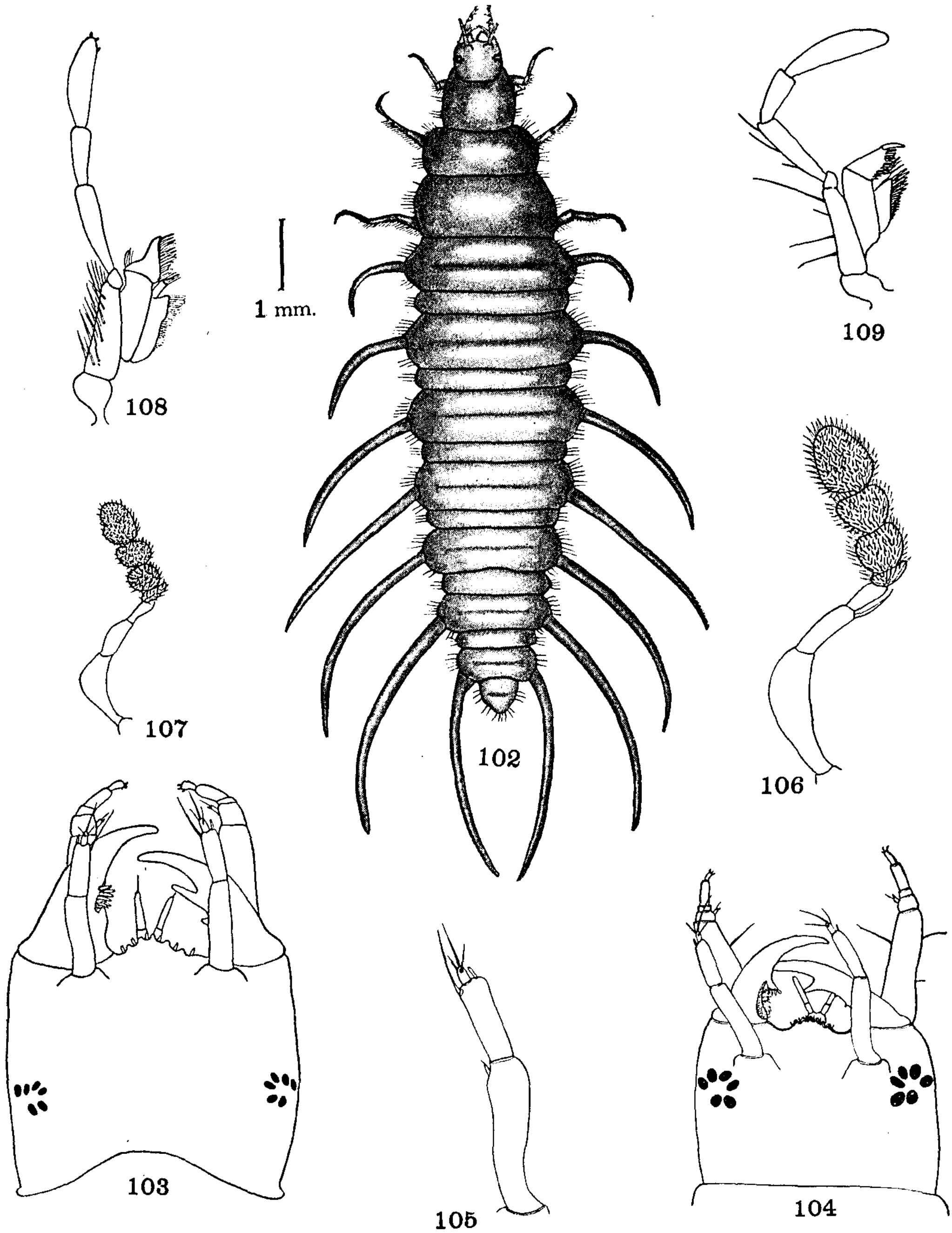


FIG. 102.—Dorsal view of larva of *Berosus striatus*. FIG. 103.—Head of same enlarged. FIG. 104.—Head of larva of *Berosus pantherinus*. FIG. 105.—Antenna of larva of *B. striatus*. FIG. 106.—Antenna of adult beetle, *striatus*. FIG. 107.—The same, *pantherinus*. FIG. 108.—Maxilla of adult *striatus*. FIG. 109.—Maxilla of adult *pantherinus*.

contains 10 segments, and the last one is armed with two pairs of sharp, curved hooks similar to those on the Dineutes larva. The mouth parts are also similar, the mandibles being sharp-pointed, perforated by a slit near the apex, and hence suctorial. The lateral gills increase in length backwards and contain tracheoles, which give off smaller branches to the gill walls. The legs are long and slender and destitute of swimming hairs.

Pupation.—According to Miall (1895, p. 39):

The pupa of Gyrinus is so well hidden that few naturalists have ever seen it. Modeer, quoted by De Geer, says that about the beginning of August the larva creeps out of the water by climbing up the water-plants, and then spins a grayish cocoon pointed at both ends. Inclosed in this cocoon it changes to a pupa and emerges as a perfect insect towards the end of the same month. Modeer adds that the pupa is very liable to the attacks of Ichneumons.

It hardly seems possible that this larva would depart so far from the custom of the Dineutes larva as to spin a cocoon of silk. The Dineutes cocoon is grayish and pointed at both ends, but it is certainly made of mud pellets, although it looks oftentimes as if it were made of silk. It seems more probable that the Gyrinus cocoon is also made of mud, and the larva would be just as susceptible to the attacks of Ichneumon flies while constructing it.

Description of the pupa.—This pupa is similar in all respects to that of Dineutes but is much smaller and entirely white in color. The bases of the first swimming legs project similarly beyond the lateral margins and are at right angles to the body axis. The labrum is very distinct, and the head has a large prominence on either side just above the base of the antenna.

Habits of the adult.—These gyrinids prefer gently running water and congregate in swarms on the surface of the river (fig. 5, frontispiece), but careful search has failed to reveal a single larva, pupa, or pupa case around any of the ponds. Hence, except for the food which the adults occasionally furnish to the fish, they do not enter into the ecology of the ponds at all. They fly with ease but like the Dineutes adult can not take flight from the surface of the water. Westwood (Miall, 1895, p. 33) said that he found their food to consist of small dead floating insects, and it thus resembles closely that of Dineutes. Fowler (Miall, 1895, p. 33) remarked that the broad and blunt mandibles indicated a partially vegetable diet, though the sharp and sickle-shaped maxillæ favored a different conclusion, and Miall himself (1895, p. 33) added that in captivity the adults feed upon water-plants. Miall also adds an interesting item that these adults when handled give off from the joints of the body a milky fluid that has the odor of cockroaches. The male is capable of producing a squeaking noise by rubbing the under side of the elytra against the dorsal surface of the posterior abdomen segments.

Genus BEROSUS Leach.

Berosus (Leach, 1817, p. 92).

This is a genus of small, convex, and elongate beetles, usually of a yellowish color with darker spots on the thorax and elytra. They are herbivorous, both the adults and the larvæ feeding on green algæ. The antennæ of the adults have only seven segments, and the posterior tibiæ and tarsi are densely fringed with swimming hairs.

Berosus striatus (Say). Figs. 96, 97, 99, 101–103, 105, 106, 108, 110.

Hydrobius striatus (Say, 1825, p. 108).

Egg cases.—The egg cases are attached to the stem or leaf of some submerged plant. The case and its fag[2] much resemble one of the old-fashioned long-handled warming pans, in which coals were placed for the purpose of warming up a bed before sleeping in it. The case proper is circular or elliptical in outline, about 2 mm. long, 1.5 mm. wide, and 0.33 mm. high, the length being measured continuous with that of the fag. It is surrounded by a narrow band or margin of silk, which fastens it securely to the support. Both the upper and the under surfaces are quite convex. The fag is ribbon-like, from 4 to 6 mm. long and about 0.2 mm. wide, and it usually clings to the support, running up from the case toward the surface of the water but never quite reaching it. Each case contained from three to five eggs, which apparently require from 8 to 10 days to hatch.

[2] See p. 332.

The newly hatched larva.—The newly hatched larva is 2 mm. long and 0.35 mm. wide through the metathorax. It is light gray in color, the chitin areas tinged with yellowish-brown, and the entire surface covered with minute setæ. The legs and lateral gills are much longer in proportion to the body than those of the mature larva, and the metathorax is wider than the abdomen, but otherwise it is an almost exact minature of the mature larva.

Habits of the larva.—These larvæ are very sluggish; they can not swim at all but crawl about slowly over the vegetation, their long tracheal gills standing out rigidly on either side like rods. They cover themselves with green algæ and lie inert for hours at a time, only coming out after food. When disturbed, they curl up slightly and feign death, and it is often difficult to determine whether they are really dead or not. They are the most inactive of all the larvæ here studied but are as persistent crawlers as the Peltodytes larvæ. They can not be kept in a mud cell unless the latter is securely sealed. They are also hard to kill and will live for an hour or an hour and a half when placed in 95 per cent alcohol. They breathe entirely through the lateral gills, which contain tracheoles, and hence have no need to come to the surface for air. They eat, as far as could be observed, nothing but algæ, Chara, Nitella, etc. Two larvæ were kept a long time in an aquarium with an abundance of Entomostraca, snails, and insect larvæ of various kinds. They refused them all and ate only vegetable food.

Description of the larva.—General form spindle-shaped, slightly depressed, widest through the second abdominal segment, much narrowed both anteriorly and posteriorly. Total length on the mid line 10 mm.; greatest width 2.5 mm.; greatest thickness 2 mm.; length of posterior gills 3 mm. Body made up of the head, 3 thorax segments, and 8 abdomen segments. Each of the first seven abdomen segments carries a single pair of tracheal gills, which are cylindrical and threadlike and increase in length from in front backwards. These gills, unlike those of the gyrinid larva, are entirely naked. The last segment has no gills and is very small. Color a grayish-yellow, deepening to brown on the thorax and along the sutures between the joints.

Head quadrangular in outline; antennæ three-jointed, joints diminishing greatly in length and width; first joint with a sensory papilla on the inner margin at the distal end; second joint with a long seta at the distal end on the inner margin and a sensory papilla on the outer margin; third joint minute, armed with three unequal setæ.

Mandibles asymmetrical, the right one with three blunt conical teeth on the inner margin, the distal tooth the largest, the middle one less than half as large, and the proximal one a mere knob. The left mandible also has three teeth, nearer the base, much closer together and about the same size. Just above them and hiding them in dorsal view is a bunch of radiating comblike spines.

The maxilla is five-jointed, the basal joint more than twice the combined length of the other four, with a large seta on its inner margin. The second joint is short and subquadrate and bears on its inner margin a small knob armed with a sensory papilla and a seta. Of the remaining joints the fourth is longer than the third and fifth combined, while the fifth is tipped with four small sensory papillæ. The labial palps are two-jointed, the distal joint twice the length of the basal and tipped with a single seta; there is no ligula.

The eyes are behind the center of the head and are arranged as shown in Figure 103 (opp. p. 309). The first six abdominal segments are each divided into a larger anterior portion bearing the lateral gills and a smaller posterior portion; the last two segments are entire. Each anterior portion is further divided by a transverse groove or wrinkle.

Pupation.—The larva crawls but a short distance from the water's edge and hollows out its pupal chamber in the soft earth 1½ to 2 inches beneath the surface. It occasionally pupates within 24 hours after the completion of the chamber but more often remains several days before transforming.

Muttkowski (1918, p. 414) stated with reference to the family Hydrophilidæ:

> Only a single species, *Berosus* sp. (probably *striatus*) Say, is represented in the lake (Mendota), and this species is quite rare. The larva occurs in sandy depths up to 6 meters. I was able to breed the species and discovered that the pupa is aquatic and a water-breather like the larva, but the emerged adult escaped before I had seen it.

If he had seen the emerged adult he would have discovered his mistake, for this pupa is certainly terrestial like all the others here described.

Description of the pupa.—General form an elongate oval, 6 mm. long and 3.25 mm. wide, the posterior end rather bluntly pointed. The color is white, usually with a decided greenish tinge; the eyes are at first light brown but deepen with age. Just before emergence the white changes to yellow, the head blackens, the dorsal surface of the prothorax shows the two semilunar black spots, and the wings are darkened.

The antennæ stand out at right angles to the body axis; the long maxillary palps extend back beyond the bases of the second legs. The femora of all three pairs of legs are at right angles to the body axis; the tibiæ of the first pair are folded tightly against the femora; the tarsi are parallel with the body axis and some distance apart. In the other two pairs of legs the tibiæ and tarsi are in line and extend diagonally backwards to the mid line. At the posterior end of the abdomen are two strong cerci, each armed with a single long moniliform spine.

The large styli on the dorsal surface of the body are arranged as follows: 10 along the anterior margin of the pronotum, 8 along the posterior margin, 1 on each lateral margin, and a row of 4 across the center, 24 in all. Schiødte (1872) in his figure of a Berosus larva showed 26 pronotal styli, but out of 40 pupæ belonging to this and the following species not one showed more than 24 styli. There is also a similar stylus inside the base of each elytron and wing, two on the first abdominal segment, four on each succeeding segment to and including the seventh, the lateral ones being near the longitudinal center of the segment instead of on the posterior margin, two much smaller ones on the eighth segment and two tiny setæ above the bases of the cerci on the ninth segment. Each stylus has a thickened base that ends in two short teeth and a thread-like terminal portion. The pupa rests a part of the time on these styli with its back downward, but its normal position is the other side up resting upon its cerci and the styli of the head and pronotum, with its body strongly arched. Out of 25 pupæ reared to the adult stage 20 remained in the pupal chamber five days, while the other 5 emerged in four days.

Habits of the adult.—These beetles swim well but rather slowly; on the land they walk with considerable agility and can even run, while their powers of flight are indicated by the fact that they are frequently captured in trap lanterns some distance from the water. They were also among the first beetles to appear in the newly filled ponds described on page 237. None of those under observation ate anything but green algæ, although they had abundant opportunity to take animal food. This species is found in nearly all the ponds and furnishes excellent fish food, while both the larvæ and the adults are too small to injure even the youngest fish.

Description of the adult.—General outline elongate oval 4 to 5 mm. in length, the narrowed end anterior; very convex; thorax as wide as the base of the elytra. Head black, with a bronzed surface, finely and evenly punctate; eyes grayish-brown; thorax greenish-yellow tending to orange, with a semilunar fuscous spot on either side of the mid line; scutellum elongate; elytra greenish-yellow, each with 10 distinct longitudinal striæ of coarse black punctures and 8 to 11 small, remote, indistinct black spots, those along the center paired, the others single. Ventral surface dull brownish-black, legs, palps, and antennæ yellow; bases of the femora brown.

Antennæ clavate, seven-jointed; first joint elongate, semilunar, second and third joints shorter, narrower, and straight, with a long seta on the outer margin of the second joint. Last four joints swollen, increasing in length distally and covered with fine hairs. Mandibles with three rows of large teeth, the outer row with three teeth, the middle row with two, and the inner row with a single tooth. Inside of the latter, along the inner margin, is a row of stout curved spines. Maxillæ of typical form, the stipes with coarse hairs along the outer margin; palp three-jointed and clavate. Labial palps also three-jointed and pilose.

Berosus pantherinus Leconte. Figures 95, 98, 100, 104, 107, 109, 111.

Berosus pantherinus (Leconte, 1855, p. 364).

Egg cases.—The egg cases of this species are similar to those of the preceding species but are not flattened as much, the case proper is not circular in outline, and the fag is shorter and wider. They contain, however, about the same number of eggs, which require the same length of time to hatch.

Habits of the larva.—This larva has the same habits as the preceding one and feigns death in the same way, but it is not as sluggish as *striatus* and does not lie inert for such long periods. It eats nothing but algae.

Description of the larva.—It is much smaller than *striatus*, being only 6 mm. long and 2 mm. wide. The body is not tapered as much as in *striatus*, especially posteriorly; the lateral gills are flattened instead of being cylindrical and are relatively much longer and narrower, the posterior pair being fully as long as the entire body. Furthermore, these gills are trailed inertly along the sides of the body instead of standing out rigidly. The anterior margin of the prothorax is not reentrant but is cut squarely across. The head is shorter, and the eyes are in front of the center, the anterior ones being opposite the bases of the antennæ. The antennæ and mouth parts are much the same as in the preceding species, but the left mandible instead of having three teeth covered with processes has one large tooth with a row of processes around its broad tip. A deep groove extends along the inner margin of the mandible from this process to the base, and from the bottom of the groove project a row of irregular and unequal teeth. The inner margin in front of the groove is also irregular.

Description of the pupa.—The pupa is similar to that of *striatus* and is armed with the same jointed styli, but the body is much narrowed and shortened posteriorly and is greener in color. The elytra, wings, and legs are lengthened, the tips of the wings reaching the anterior margin of the penultimate abdomen segment and the tips of the third legs projecting beyond the basal joint of the cerci. The latter are much longer, and their terminal portion is more distinctly moniliform. The head is considerably longer and narrower, and the maxillary palps project backwards to the bases of the third legs.

Description of the adult.—This beetle is the same size as the preceding species. The thorax has two black spots instead of the semilunar lines of *striatus*, and each elytron has 10 distinct black spots—2 near the base, 4 in an irregular transverse line in front of the center, 3 in another irregular line behind the center, and 1 near the tip. The basal joint of the antenna is shorter and more strongly curved, and the second joint lacks the spine at its tip. The labium is longer and narrower, and the labial palps are not as heavily armed with setæ. This species is more restricted than the preceding in its distribution among the fishponds, but wherever it is found it furnishes excellent fish food.

Berosus peregrinus Herbst.

Berosus peregrinus (Herbst, 1797, p. 314).
Berosus peregrinus (Richmond, 1920, p. 48; pl. 10).

A life history of this species, lacking the pupal stage, was given by Richmond, and from it the following abstract has been condensed.

Egg case.—Chestnut-shaped, cap end flat, cap continuous with a long narrow ribbon, the opposite end rounded. Length of case 0.32 mm.; width 1.20 mm.; height 1.60 mm. Length of ribbon 4.50 mm. Each case contained from 2 to 4 eggs which hatched in 6 to 8 days.

Description of the larva.—General form similar to that of *striatus*, but the head and prothorax are relatively much wider. Total length 5.60 mm.; greatest width (second abdominal segment) 1.68 mm. Head ovate, a little wider than long; antennæ nearer the lateral margins than in the two preceding species; ocular areas circular and close behind the bases of the antennæ. Prothorax the same width and length as the head, meso and meta thorax slightly widened; body broadest through the second abdominal segment, then rapidly narrowed. The lateral gills are as short as those of *striatus*, are much more slender, and are trailed alongside the body like those of *pantherinus*. Color a uniform yellowish-white, the chitin areas yellowish-brown.

The mandibles are asymmetrical and resemble more closely those of *striatus*; the left one has three larger teeth on the inner margin, covered with smaller ones. The basal joint of the maxilla is not as long as in the other species and is armed along its inner margin with a row of five stout setæ. The labium is small, with two-jointed palps, each tipped with five short setæ and one long one.

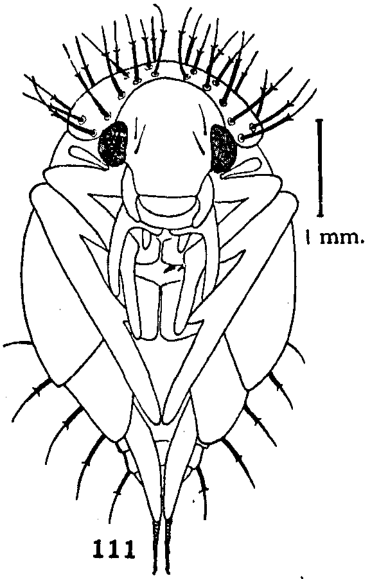
Description of the pupa.—Schiødte (1872) stated the distinguishing characters of this pupa as follows:

Motory styli of abdominal tergites in fours; abdominal tergites with a small lateral tubercle on either side; spiracles not concealed; abdominal pleurites not distinctly separated from the tergites; styli of pleurites very short and conical; lateral styli of abdominal tergites very long and slender; prothoracic styli also long and slender; cerci elongate, tapering, crooked and distally moniliform.

His figure showed 26 pronotal styli instead of the 24 found in the two preceding species.

Description of the adult.—This species is the same size as the other two. It is distinguished from *striatus* by the facts that the second, third, and fourth abdominal segments in the male have a slight longitudinal keel and that there is only one tooth instead of two in the middle of the notch on the fifth segment of the abdomen. It is distinguished from *pantherinus* by the fact that the spots on the elytra are very indistinct and are more or less fused in couples.

It is much less abundant in the fishponds than the other two species, and only a few specimens were obtained, but both the larvæ and the adults furnish good fish food without being at all destructive.



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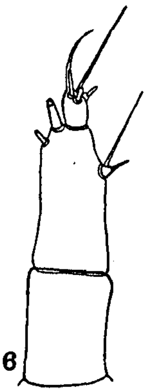

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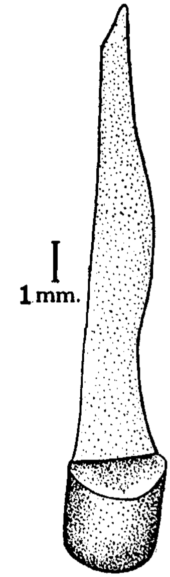

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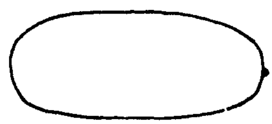

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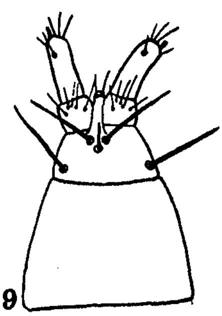

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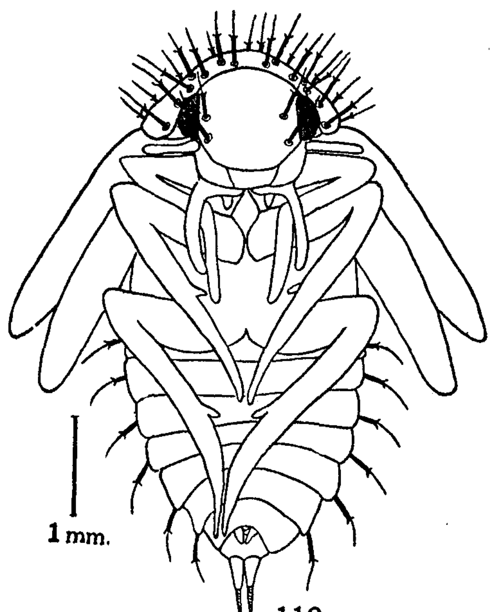

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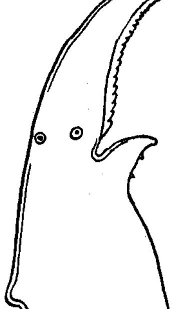

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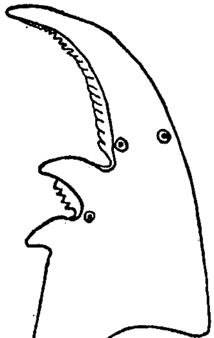

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FIG. 110.—Ventral view of pupa of *Berosus striatus*. FIG. 111.—The same, *B. pantherinus*. FIG. 112.—Egg case of *Enochrus nebulosus*. FIG. 113.—Egg of same. FIG. 114.—Right mandible of newly hatched larva. FIG. 115.—Left mandible. FIG. 116.—Antenna. FIG. 117.—Antenna of *Enochrus diffusus*. FIG. 118.—Labium of *nebulosus*, ventral. FIG. 119.—Labium of *diffusus*.

Genus HYDROPHILUS DeGeer.

Hydrophilus (DeGeer, 1774, p. 371).
Hydrocharis (Hope, 1838, p. 125).

This is a genus of medium-sized beetles, in which the prosternum, instead of being grooved where it meets the anterior end of the sternal crest, is entire and is raised into a sharp keel. These are very active beetles, swimming rapidly and running about on land with great agility. The adults appear to feed entirely upon algæ; but the larvæ are as voracious as those of Hydrous and Tropisternus, and although they have never been observed attacking young fish they are amply large enough to do so. It is hence deemed expedient to include here an abstract of the excellent description given by Wickham (1895) of the only species found in the Fairport fishponds. The adults of this species are well distributed among the ponds, in at least two of which they are very abundant, but careful search every year for the larvæ and pupæ has resulted negatively.

Hydrophilus obtusatus Say.

Hydrophilus obtusatus (Say, 1823, p. 201).
Hydrocharis obtusatus (Bowditch, 1884, p. 1).
Hydrocharis obtusatus (Wickham, 1895, p. 168).
Hydrophilus obtusatus (Richmond, 1920, p. 31; pl. 1, figs. 1-2; pl. 6, figs. 1-10).

Egg case.—The egg case of this species is similar to that of Hydrous, but is smaller and is nearly always covered with a dead leaf or something of the sort. The case is white except the fag [3] and the base of the cover, which are brown; it is 10 to 12 mm. long, 9 to 10 mm. wide, and 8 to 9 mm. high. The fag is cylindrical and tapers to a sharp point; it is 7 to 10 mm. long and is enlarged at its base into a plate 4 to 5 mm. high. About 40 eggs are deposited in each case, and they hatch in 6 or 7 days.

Habits of the larva.—These larvæ are very similar to those of Hydrous, both in structure and habits. They swim in the same manner and come to the surface to breathe, supporting themselves upon the surface film by means of their cerci. When young, they feed readily upon Cyclops and other Entomostraca, and when fully grown they eat tadpoles, insect larvæ, and the larvæ of other beetles. According to Bowditch (1884), they require 30 days to become fully matured, and then they pupate and remain in the pupa state until the following spring. This statement was strongly questioned by Richmond (1920) and seems equally impossible to the writer. If it were true the pupa would certainly be frozen during the winter, and it is not the kind of a pupa to be capable of withstanding such an experience.

Description of the larva.—Color of dorsal surface greenish, head and prothorax chestnut, ventral surface lighter. Form elongate spindle-shaped, broadest at the middle of the abdomen. Length 26 to 28 mm. Width 5 to 6 mm. Head narrower than the prothorax, inclined obliquely upward, the frontal margin lobed at the center, the ventral surface with four long mottled patches more than half the entire length. Antennæ three-jointed, basal joint very long and fringed with short setæ along the inner margin, second and third joints much shorter. Mandibles with two teeth on the inner margin, the distal one much larger than the proximal. Maxillæ with a long basal joint, a short second joint armed at its inner distal corner with a short process, a third joint half as long as the second, and two terminal joints each of which is about as long as the second joint. Labium large, the mentum irregularly hexagonal, with a distinct tooth on either side near the apex; palps two-jointed, the second joint much the longer; ligula more than twice as long as the basal segment of the palps and slightly tapered. Abdominal segments with two dorso-lateral rows of blunt spines on either side, and a row of lateral filamentary appendages, each tipped with two setæ, on the first seven segments. The eighth tergite forms the superior valve of the stigmatic atrium and bears a large chitinized plate; its posterior margin is divided into four lobes, each tipped with several setæ. The first seven tergites each show a transverse row of four tubercles and each tubercle is tipped with a seta. The lateral filamentary appendages are longer than in Tropisternus or Hydrous but do not function as gills.

[3] See p. 332.

Description of the pupa.—This pupa is 15 to 16 mm. long and 8 mm. wide through the thorax; it is clear green in color, becoming brown about the head and appendages as it matures. The general form is elongate-obovate, the posterior end bluntly pointed. The dorsal surface of the head and prothorax is armed with large curved styli similar to those on the Hydrous pupa. These are arranged as follows: 2 above each eye, 3 very long ones at the anterior corners of the pronotum, 3 shorter ones just inside of them on the anterior margin, 3 on each lateral margin, a transverse row of 4 in front of the center, another transverse row of 3 behind the center, and 10 along the posterior margin, making 35 in all on the pronotum. There are two similar styli on the mesothorax and two more on the metathorax, and six on each of the first seven abdominal segments, the lateral ones mounted on small tubercles. The eighth segment has four tubercles on its posterior margin, each armed with a stylus. The ninth segment terminates in two divergent cerci, nearly 3 mm. long and bifid at their tips. The maxillary palps are very long and reach back beyond the bases of the second legs. The wings and elytra are very short and do not reach beyond the fourth abdominal segment.

Description of the adult.—Length 14 to 16 mm. Male longer than the female, the latter very obtuse posteriorly; dorsal surface black and shining; ventral surface dark reddish-brown and pubescent. Each elytron shows four rows of distinct punctures, the outer row being double. The metasternal spine does not project behind the coxæ of the hind legs.

Genus LACCOBIUS Erichson.

Laccobius (Erichson, 1832, p. 20).

This is a genus of minute but very active beetles, whose diminutive size is more than offset by their agility both in the water and on the land. The adults are dark-colored and have the habit of burrowing in the mud or débris on the bottom of the pond and remaining there entirely concealed. They are vegetable eaters and are so small they can do no possible harm, but both the adults and the larvæ make good fish food.

Laccobius agilis Randall. Figure 146.

Laccobius agilis (Randall, 1838, p. 19).
Laccobius agilis (Richmond, 1920, p. 43; pl. 9, figs. 1-11).

This is one of the rarer species in the Fairport fishponds, but a few larvæ and pupæ were obtained in addition to the adults. Since figures of the egg case, the newly hatched larva, and the mature larva have been published by Richmond in the paper cited above (1920), that of the pupa is the only one here presented. No egg cases were found in the fishponds, therefore the description is borrowed from Richmond.

Egg case.—General form nearly spherical, 1.40 to 1.60 mm. in diameter, the fag [4] a hollow filament 7 to 10 mm. long; attached to roots or blades of grass at the water's edge, or to stones. Each case contains from 2 to 11 eggs, which hatch in from 7 to 11 days, the larvæ breaking through the side of the case.

Habits of the larva.—These larvæ are poor swimmers, and their usual mode of locomotion is by crawling over the vegetation or along the bottom of the pond. They breathe in the usual manner by means of a stigmatic atrium at the posterior end of the abdomen. When breathing, they usually rest upon the leaf or stem of some convenient water plant, thrust the end of the abdomen above the surface of the water, and then open the atrium. The side of the aquarium was also often used for this purpose. Sometimes the larva swims to the surface head upward and, inverting its body, endeavors to thrust the atrium above the water. This proves difficult, and it may try half a dozen times before succeeding, but once in position, the edges of the opened atrium will support the larva, and it hangs from the surface film. These larvæ are not cannibals and may be confined together without eating one another. The only things they were observed to eat in the aquarium were a few very small snails.

Description of the larva.—General form oblong, four times as long as wide. Length 5.8 mm.; greatest width through second abdominal segment 1.5 mm. Head quadrangular, slightly elevated, often

[4] See p. 332.

retracted under the prothorax as far as the ocular areas. Thorax a little wider than the head; abdomen a little wider than the thorax, the first seven segments about the same width with scalloped margins, the eighth segment narrower, as wide as long, with a large dorsal sclerite, the ninth and tenth segments rudimentary; there are no cerci except the minute ones connected with the atrium.

Antennæ short and three-jointed, the second joint the same width as the first and much longer, with a long finger process at the outer distal corner; terminal segment not much larger than this finger process, tipped with three long setæ and several sense cones. Mandibles asymmetrical, curved, and acuminate, the right one with three inner teeth decreasing in size proximally, the left one with two toothed areas, each pectinated dorsally. Maxillæ five-jointed, the basal joint (stipes) swollen and longer than the rest of the appendage, its inner margin with five stout setæ, the second joint (palpifer) a little wider than long with a short finger process on its inner margin. Labium small, palpiger widened distally, palps two-jointed, the terminal joint four times the length of the basal and tipped with many sense cones. Ocular areas outside the bases of the antennæ; eyes in two nearly parallel rows. Color dirty-white to grayish-brown.

Pupation.—Richmond (1920) reported that of two larvæ placed in a terrarium one pupated on the surface of the earth and the other burrowed just beneath the surface. All the pupæ found by the writer were beneath the surface and 2 to 3 feet from the water's edge. This larva seems to select drier mud than some of the others, and its pupal chamber is about 4 mm. in diameter, slightly longer than wide. When the chamber is completed, the larva transforms almost at once and remains in the pupa stage four or five days.

Description of the pupa.—The most striking characters of this pupa are its exceptional width and the great length of all three pairs of legs. It is 3.70 mm. in length, including the cerci, and has a width of 2.25 mm. through the thorax. It thus has the shape of a short and very wide spindle, which is sharply tapered both anteriorly and posteriorly. When first formed it is bright sea-green in color, but soon becomes white with black eyes. As development proceeds the legs, wings, and elytra become tinged with brown.

There are two styli above each eye, situated about half way between the eye and the mid line. The anterior and posterior margins of the pronotum each carry 10 styli, and there is a transverse row of 4 across the center of the segment. The meso and meta notum each have two styli, and there is a transverse row of 4 across each of the first 7 abdominal segments, the lateral one on either side mounted on a small tubercle. The eighth segment has two small dorsal processes close to the mid line, and the ninth segment ends in two cerci armed with long moniliform spines.

The antennæ are carried outward nearly at right angles to the body axis; the femora of all three pairs of legs also extend in the same direction, while the tibiæ and tarsi are curved inward to the mid line. The tarsi are all tipped with spines; the first pair reach the first abdominal segment, the second pair reach the center of the seventh abdominal segment, and the third pair extend well beyond the body to the center of the cercal spines. The spurs at the tips of the tibiæ on the hind legs are fairly prominent but are concealed by the tarsi of the second legs.

Description of the adult.—General form short and stout, nearly as wide as long and strongly convex. Length 2 to 3 mm. Head and prothorax blackish-iridescent with a broad yellow margin on the thorax. Elytra pale with dark striæ; undersurface black, legs and palpi pale. Head covered with fine wrinkles, the margin in front of the eyes yellow; thorax three times as wide as long, as wide at the base as the elytra and sparsely covered with fine punctures. On the elytra the punctures are very small and are set close together in distinct and regular rows.

Genus ENOCHRUS Thomson.

Enochrus (Thomson, 1859, p. 18).
Philydrus (Solier, 1835, p. 315).

This is a genus of small beetles, oval or elliptical in outline, blackish or brownish-yellow in color, and covered with fine punctures regularly arranged. Each elytron has also four rows of coarser punctures. These beetles are not as agile as Laccobius and do not hide as persistently, but they swim fairly well and can run quite fast. They frequent the smaller ponds and are found either at the water's edge or close

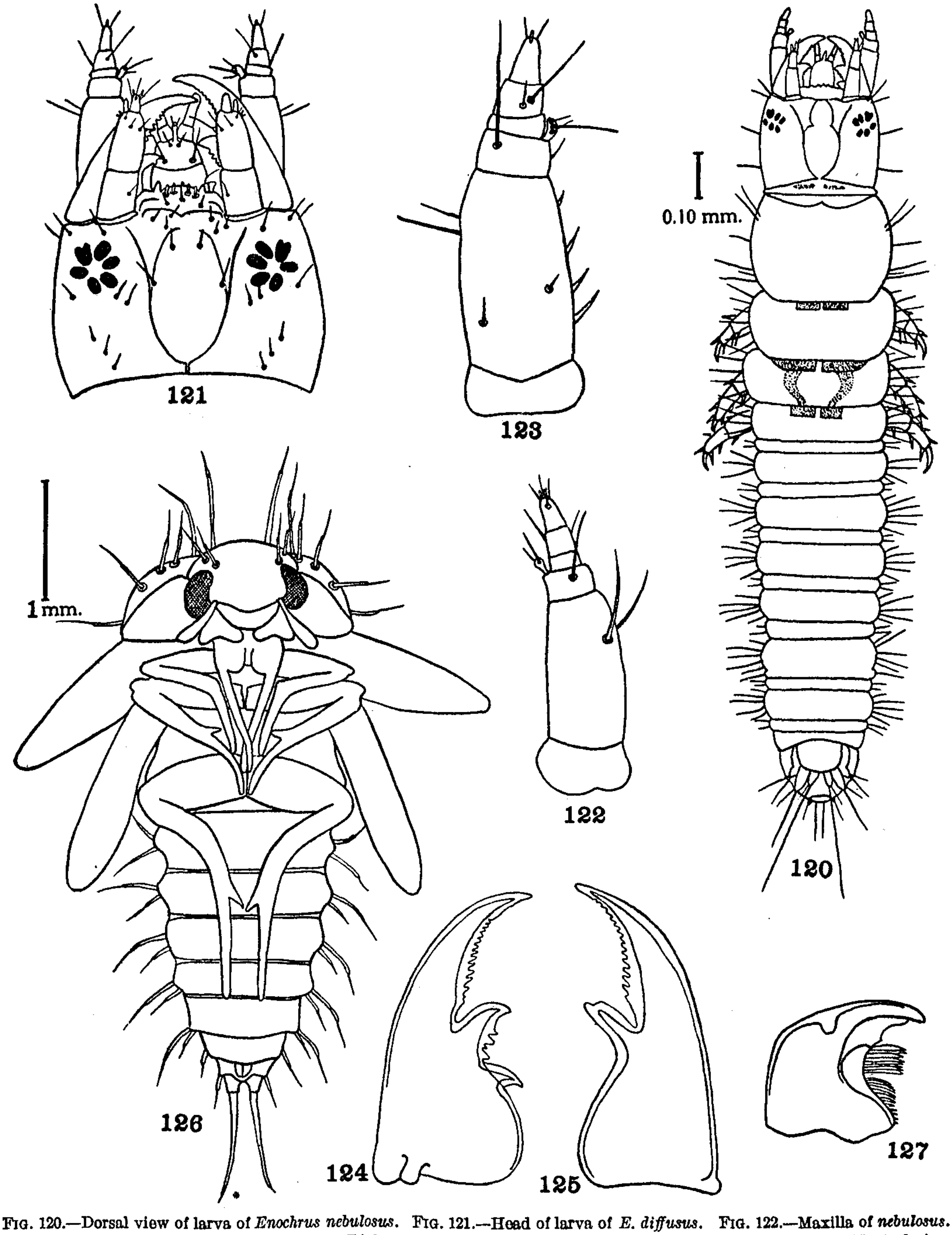

FIG. 120.—Dorsal view of larva of *Enochrus nebulosus*. FIG. 121.—Head of larva of *E. diffusus*. FIG. 122.—Maxilla of *nebulosus*. FIG. 123.—Maxilla of *diffusus*. FIG. 124.—Right mandible of *diffusus*. FIG. 125.—Left mandible. FIG. 126.—Ventral view of pupa of *nebulosus*. FIG. 127.—Mandible of adult beetle, *nebulosus*, dorsal view.

to it in the Spirogyra and Mougeotia. Apparently they feed entirely upon these algæ. They are not abundant anywhere in the Fairport fishponds, but both the adults and the larvæ make excellent fish food.

Enochrus nebulosus (Say). Figures 112–116, 118, 120, 122, 126, 127.

Hydrobius nebulosus (Say, 1825, Supplement vol. 2, p. 277).
Philydrus nebulosus (Richmond, 1920, p. 69, pl. 1, fig. 9).

Egg case.—The egg case of this species is 3 mm. long, 2.50 mm. wide, and 2 mm. high at the center of the cap end. The side next to the support is flattened and fastened rather securely. The cap is semicircular and slightly concave, the hinge margin straight, the free edge evenly rounded. The fag[5] is in the form of a flat ribbon, a little narrower than the case itself, and uneven in width, but in general tapering toward the free end. It is 8 to 12 mm. long and 1 to 1.70 mm. wide and is fastened to the support so that it does not float in the water. Eight cases were found in pond 13B upon the undersurface of the leaves of *Potamogeton illinoensis.* Each contained from 12 to 20 eggs, and they all hatched together six days after being brought into the laboratory. Compare with this Richmond's record (1920, p. 66):

> Ten egg cases were made by a single specimen of *Philydrus nebulosus* during February (indoors) and some of them were placed below the surface of the water. The time required for hatching is from six to nine days.

The eggs are regular ellipsoids 0.56 mm. long and 0.25 mm. wide, with a small triangular projection at the end which is fastened to the wall of the case.

Habits of the larva.—These larvæ are very sluggish and crawl about slowly over the vegetation or on the bottom close to the water's edge. They burrow in the mud or even crawl out of the water and may be found under stones or débris close to the water, where it is always moist. When kept in a glass dish indoors, they crawl up the sides of the dish above the surface of the water but never far enough to become dry. In walking they use the large tubercles on the ventral surface of the abdomen just as a caterpillar uses its prolegs, and the end of the abdomen functions like the posterior prolegs of the caterpillar. As Richmond has stated (1920) the true legs move first, then the prolegs, and finally the end of the abdomen, the whole motion being rhythmic. On a leaf or on the side of a glass dish they frequently cling to the surface with their prolegs and the end of the abdomen and raise the head and thorax into the air, reaching about in different directions. They can also move backwards in the same manner as the Tropisternus larva, but with much less speed and agility. They can not, or at least they do not, swim. When thrown into the water they immediately rise to the surface in consequence of the large amount of air in their tracheæ. They then float about with the posterior end of the abdomen above the surface film until they strike some object upon which they can crawl.

They showed no tendency to eat others of their own kind, as is the custom with most of the hydrophilid larvæ, but fed upon the minute Entomostraca, Bryozoans, etc., in the aquarium. A Potamogeton leaf with egg cases attached was floated upon the water, and the larvæ after emerging browsed around upon this leaf and apparently found enough to eat.

Description of the newly hatched larva.—Length, including the maxillæ, 2 mm.; width through the metathorax 0.35 mm. Color gray with black eyes and the chitinized portions of the body and appendages brown. General form elongate but rather thickset, the abdomen not much narrowed posteriorly and rather bluntly rounded. Head quadrangular, wider than long, slightly elevated, with almost straight sides. Frontal margin sinuate; frons elongate, campanulate, reaching the entire length of the head and practically obliterating the epicranial suture. Eyes fairly close to the bases of the antennæ, all six visible in dorsal view, the first (anterior) one enlarged, the sixth reduced in size, removed from the others, and twisted so that its axis is nearly horizontal.

The antennæ are short, the tip of the second joint not quite reaching the palpiger of the maxillæ, the two basal joints of the same width, the first one a third shorter than the second, the third a fourth of the length and a third of the width of the second. The second joint bears on its inner margin, a little distal to the center, a sense cone tipped with a seta, and a long seta ventral to the base of the cone. On its outer margin at the distal end, on a level with the base of the third joint, is a finger process, nearly as long as the third joint, and outside of its base two sense cones. The third joint is tipped with several long sense cones and a few setæ.

[5] See p. 332.

The mandibles are asymmetrical, the left one with a single large tooth on the inner margin, the right one with two. The distal portions of the two mandibles are about the same size and curvature, and each has a row of well-defined teeth extending from its base nearly to the tip. The large tooth on the left mandible has two minute spines on its proximal margin, while the same margin of the distal tooth on the right mandible has a row of four saw teeth. The proximal tooth on the right mandible is much smaller than the distal one and is unarmed. By comparing the figures here given of the mandibles with those published by Richmond (1920) of the mandibles of *perplexus* it will be seen that the former are much more prominently toothed and that the proximal tooth on the right mandible is much nearer to the distal one, as Richmond (1920) himself stated.

The maxillæ are long and stout. When the tips of the mandibles just touch each other in front of the head, the antennæ, the mandibles, and the labial palps all reach the same level, which is about the center of the palpiger of the maxillæ. Thus, the distal half of the palpiger and the whole of the palps project beyond the other appendages. The cardo is fused with the stipes, and the junction of the two is indicated by constrictions on the lateral margins. The stipes is large and stout and not much narrowed distally; it is one-half longer than the palpiger and palpus together, with two large setæ on the outer margin just beyond the center. The palpiger is about half the diameter of the stipes, its length to its width as 9 to 14. At its inner distal corner is a club-shaped process as long as the first joint of the palpus and tipped with two setæ. The palpus is three-jointed, the joints increasing in length distally in the proportion of 5, 7, and 9. The basal joint has a single seta on its dorsal surface near the outer margin, the second joint has one on the inner margin, and the terminal joint is tipped with two setæ and three sense cones.

The labium is proportionally large, with a pentagonal gula one-half wider than long; its postero-lateral margins are four times the length of the antero-lateral ones. The submentum is small; the mentum is barrel-shaped, about as long as wide. The palpiger is dome-shaped and three-fifths as long as the mentum; the ligula is a little longer than the basal joint of the palps and slightly enlarged at its tip. The labial palps are two-jointed, the terminal joint three times as long as the basal and tipped with setæ and sense cones, but without any setæ at its base.

The prothorax is as long as the head and one-fourth wider, with strongly convex sides; the mesothorax and metathorax diminish in length, but are as wide as the prothorax. The abdomen is slightly narrower than the thorax, the first seven segments distinct and similar, slightly narrowing posteriorly, the eighth and ninth segments rudimentary, representing, respectively, the superior and inferior valves of the stigmatic atrium. Spiracles present on the mesothorax, metathorax and the first seven segments of the abdomen. These abdominal segments also bear laterally one large and two small tubercles on either side and a row of four across the dorsal surface, all armed with long setæ. On the ventral surface each segment from the third to the seventh inclusive carries near each lateral margin a prominent tubercle, which is armed with recurved spines instead of setæ and serves as a proleg.

The mature larva.—When mature, the larva is 6.40 mm. long and 1.35 mm. wide at the first three abdominal segments. The head, the thorax, and the anterior abdomen are light brown, the posterior abdomen is gray. The head is 0.45 mm. long and 0.55 mm. wide; the first joint of the antenna is nearly as long as the second; the serrate flap of the labrum is retained and becomes a little more prominent on the right side, and thereby asymmetrical. The serrations on the terminal blades of the mandibles are completely retained, but those on the proximal margin of the median teeth have entirely disappeared. Neither the maxillæ nor the labium have changed.

This larva crawls fully as far from the water's edge as the much larger Tropisternus larva and locates its pupal chamber in rather dry mud, pupation taking place almost as soon as the pupal chamber is completed.

Description of the pupa.—General form elongate-ovate, 4.50 mm. long, exclusive of the cerci, and 1.90 mm. wide through the prothorax, the abdomen much narrowed posteriorly. Entirely white except the eyes, which are dark brown, almost black, and the cerci and styli, which are light brown.

Head smooth with two supraorbital styli on either side, but no tubercles near the vertical margin. Pronotum somewhat three-lobed anteriorly, its posterior margin straight but not indented in front of the elytra. Twenty-four styli, 10 on the lateral and anterior margins, the 2 on the median lobe much longer than any of the others, 8 on the posterior margin, 2 on the median lobe posterior and outside of the long anterior ones, and 4 in a curved transverse row behind them. Mesonotum and metanotum with a single stylus on either side near the elytron and wing; scutellum prominent in the center of the mesonotum.

Antennæ inclined backward at an angle of 45° with the body axis, mandibles, and maxillæ very prominent, the maxillary palps extending beyond the tips of the first legs. Basal joints of all three pairs of legs nearly at right angles to the body axis, tibiæ of the first two pairs flexed back against them, tibiæ of the third legs curved inward at an angle of 45°. Tarsi of the first legs flexed sharply backward, of the other two pairs nearly continuous with the tibiæ; tibial spines prominent on the second and third legs. Tergite of first abdominal segment with four styli; tergites of the second to seventh abdominal segments inclusive with six styli; eighth and ninth tergites with two each. Eighth sternite with a pair of appendages on its posterior margin, touching each other on the median line and extending backwards over the ventral surface of the ninth segment to the bases of the cerci. Posterior outer corners of the ninth sternite prominent and acute; cerci two-jointed, fleshy, tapering, 1 mm. in length.

The duration of the pupal stage in 2 beetles whose larvæ were brought into the laboratory and placed in artificial pupal chambers was 4 and 5 days, respectively. On first emerging, the entire beetle is dark gray, the antennæ and mouth parts white, and the legs reddish-brown. The color darkens rapidly, the eyes first becoming black, then the elytra dark brown, and finally the thorax and head dark brown also.

Habits of the adult.—The adults live wholly in the floating Edogonium, Hydrodictyon, and Spirogyra and have never been taken in a net while sweeping other parts of the ponds. They seem, however, to prefer the undersurface of the leaves of Potamogeton as a support for their egg cases, and only two of the latter were found among the algæ. These beetles swim well and crawl about among the algæ rapidly, but they can not jump or run. They feed apparently entirely upon the algæ, and being common in several ponds and entirely harmless they furnish excellent fish food.

Description of the adult.—This species is distinguished from others of the genus chiefly by the fact that the prosternum is distinctly carinated. The general form is elliptical, 4 to 4.50 mm. long and 1.60 mm. wide. All the specimens obtained in the Fairport ponds were dark yellowish-brown, a little paler toward the margins, with the entire undersurface black.

Antennæ nine-jointed, the three terminal joints much enlarged, almost spherical and densely covered with fine hairs. The ninth joint is much larger than the eighth and the eighth larger than the seventh. The sixth joint is three times as wide as long, with a tuft of hairs on its outer distal corner; the first joint is sharply bent near the base. Mandibles short and stout, the tip at right angles to the basal portion; a secondary tooth ventral to the tip and on the inner margin a distal tuft of coarse straight spines and a proximal row of stout curved setae. In the maxillæ the palps are very long, nearly twice the length of the body of the appendage, and the galea is armed with rows of curved blunt spines. The labial palps are very short and do not appear at all in the pupa, being concealed by the other mouth parts.

Enochrus diffusus. (Leconte.) Figures 117, 119, 121, 123–125.

Philydrus diffusus (Leconte, 1855, p. 371).

Two egg cases were obtained from the same pond, 13B, as those of the preceding species and also from the leaves of *Potamogeton illinoensis.* They hatched in seven days, and the young larvæ were reared to a length of 4 mm.; but they could not be carried further, and no pupæ were obtained. The identity of the larva, therefore, is not absolutely proved, but since only two species of this genus have ever been found in the pond after repeated search it is reasonable to refer the present specimens to the second species.

Egg case.—The egg cases are considerably smaller than those of *nebulosus* and quite different in structure. Apparently a flat strip of silk 2.50 mm. long and 2 mm. wide is first spun and securely fastened to the undersurface of the leaf. Upon this 10 or 12 eggs are placed in a single layer and secured by strands of loose silk. Then another strip of silk is spun over the eggs and fastened around the edges to the first strip. And finally a short and wide fag [6] 5 mm. in length is added. This is as wide as the

[6] See p. 332.

first strip where it joins the latter, but tapers toward the free end. The case thus has no cap and is very strongly flattened, so much so in fact that the first one found was taken for a simple piece of ribbon, but in pulling it from the leaf it was torn open and revealed the eggs inside. These eggs appeared freshly laid and hatched in seven days after being taken into the laboratory.

Habits of the larva.—The habits of these larvæ are very similar to those of the preceding species. They have the same method of locomotion by means of the prolegs and the end of the abdomen and spend most of their time above the surface of the water. Apparently they never swim but crawl about slowly over the vegetation and along the sides of the aquarium. They feed readily upon the chironomids and entomostracans in the aquarium and do not show any tendency to fight with one another. Those under observation also ate a batch of snail's eggs that happened to be upon the same leaf as their own egg case.

Description of the newly hatched larva.—Length 2.35 mm.; width through the metathorax 0.32 mm. Color gray, the eyes black, the head and thorax dark brown. The general structure of the body is the same as that of the preceding species, with the following differences. The antennæ are shorter and much stouter, but the armature is very similar. The mandibles are longer and more slender, with differences in the teeth, which are shown in the figures. The maxillæ are considerably stouter, and the stipes is armed with four or five large and strong spines on the ventral surface near the inner margin. The labium is also stouter, the palpiger bears five large setæ; the basal joints of the palps almost fuse on the mid line beneath the ligula, and each is armed with five setæ on its dorsal surface. The head is much wider than long and is covered with scattered setæ on its dorsal surface. The labro-clypeus is also more heavily armed with spines and setæ. The large spines at the sides show up prominently in dorsal view, and the whole dorsal surface is more or less corrugated.

Enochrus perplexus (Leconte).

Philhydrus perplexus (Leconte, 1855, p 371).
Philydrus perplexus (Richmond, 1920, p 67; pl 14, figs 1-10).

Richmond (1920) succeeded in securing the complete life history of this species, which he presented in the reference given above, together with excellent pictures of the larva in different stages of development and of the egg case. He also gave a very short (three and a half lines) description of the newly hatched larva of *Enochrus* (*Philydrus*) *ochraceus* (p. 70), with a figure of the egg case, and another brief description of the newly hatched larva of *Enochrus* (*Philydrus*) *hamiltoni* (p. 71).

Genus TROPISTERNUS Solier.

Tropisternus (Solier, 1835, p. 308).

This is a genus of medium-sized beetles of an oval or elliptical form, smooth and shining black in color, with the dorsal surface strongly convex. They are by far the most common beetles in the fishponds and are so abundant that they play an important part in the economy of fish culture. They are all of them excellent swimmers and are agile upon land, walking and running well, but not jumping at all. They feed largely upon Anabæna and Clathrocystis, which float upon the surface of most of the ponds during the summer months. Neither the adults nor the larvæ molest young fish, while they themselves furnish excellent fish food.

Tropisternus lateralis (Fabricius). Figures 128–136, 139.

Hydrophilus lateralis (Fabricius, 1775, p. 228).
Tropisternus nimbatus (Say, 1825, p. 205).
Tropisternus lateralis (Blatchley, 1919, p. 318).

The egg case and the eggs.—The female of this species attaches her silken egg case to some convenient water plant, the stem or the leaf of grass growing in the water, the leaf of Convolvulus grown in from the edge of the pond, or the stem of Sagittaria. Failing these, any other water plant may be chosen or the case may be attached to floating débris. Often several cases will be found upon the same support, and as many as 12 have been seen upon one grass leaf. The actual spinning of the case was witnessed several times and may be described as follows: Taking a position back downward upon a floating support, or head upward on an erect stem, the female holds herself in position with her front and middle legs. She then moves her spinneret rapidly from side to side, guiding the thread with her hind legs. Where the silk comes in contact with the support it is flattened for a short distance and pressed against the surface, to which it adheres firmly. In this way is formed a little bag with a rounded bottom, one side being flattened against the support and the mouth of the bag left open. These bags are from 6 to 10 mm. long and from 4 to 5 mm. in diameter, and it takes a female about 20 minutes to complete one. The work is interrupted only by the necessity of obtaining fresh air, which happens about twice during the entire period.

When the bag is completed, the eggs are deposited in it. Each egg is wrapped in silk, leaving the larger end loosely inclosed, while the silk about the smaller end is gathered into a narrow strand which is securely fastened to the side of the case that is flattened against the support. The egg does not stand perpendicular to this side of the case but is inclined a little toward the open end. Each is fastened to the others that come in contact with it, as well as to the side of the case. The number of eggs in a case varies greatly; sometimes there are only 6, and again the number may rise to 20 or even 24. The eggs in 31 cases were counted in August, 1919, with the following results: Two contained 6 eggs, nine contained 7 eggs, seven contained 8 eggs, three contained 9 eggs, two contained 10 eggs, one contained 11 eggs, three contained 12 eggs, two contained 14 eggs, one contained 17 eggs, and one contained 24 eggs. The fastening of the eggs in place occupies three to five minutes according to the number of eggs laid. After completing the bag and before depositing the eggs the female usually takes a short rest of about five minutes.

As soon as the eggs are deposited she spins a cover for the open end of the case, which is fastened to the side of the case next to the support, but elsewhere is left free. It is pushed into the case a little and is made somewhat larger than the opening, so that the margin is held in place by friction. The open end of the case is then prolonged 0.5 mm or more beyond the cover, and the side next to the support is spun into a narrow flattened ribbon, 20 to 60 mm. in length, which gradually tapers toward the tip, and which is not attached but floats freely in the water. As soon as the ribbon is long enough the beetle transfers her hold from the support to the ribbon, and as she spins rises gradually away from the support. The spinning of the cover and the ribbon occupies about 10 minutes, and the female remains beneath the water the entire time.

During the spinning of the case, the deposition of the eggs, and the spinning of the cover and ribbon, the female is attended by the male, who clings to her back just behind the head, thus leaving the posterior end of the body free. He can not, or at least does not, remain beneath the water as long as the female, but leaves her and rises to the surface frequently for fresh air, returning to her immediately. His function seems to be one of protection against disturbance, particularly from other males of the same species, which he drives away whenever they appear. When the case is finally completed, the male and female separate and rest for a long time. The same pair construct at least several cases, but just how many could not be determined. The eggs hatch in about three days.

Richmond (1920, p. 31) gave as the first characteristic of the Hydrophilidæ, to which the present genus belongs, the following: "Egg cases characterized by their horny mast and comparatively larger size." Although that statement is correct in general, there are just enough exceptions to prove the rule, and the present species is one of those exceptions. Out of several hundred egg cases not one was found with a "mast," but every one had a long narrow ribbon as just described. This is the more noteworthy since both the species that follow finished their cases with a mast.

The egg case of the present species may be characterized as follows: The case proper one-and-a-half to two times as long as wide, considerably flattened and fastened lengthwise to the support, with a fag [7] in the shape of a narrow ribbon three to six times as long as the case itself and of the same color and texture as the latter. It is flexible, never fastened to the support but sometimes clinging to it, and usually floats freely in the water.

Habits of the larva.—This larva swims rapidly, not only using the swimming setæ on its legs, but also utilizing the tufts of hairs along the sides of the abdomen by means of a vertical undulatory motion. This latter movement enables it to swim backward as well as forward, and so great is its agility that it can dart forward to capture its prey and then shoot backward to avoid danger. When out of the water, it can also move either backward or forward quite rapidly by means of similar undulations or can even lift its body free from the ground like the larva of Laccophilus or Coptotomus.

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[7] See p. 332.

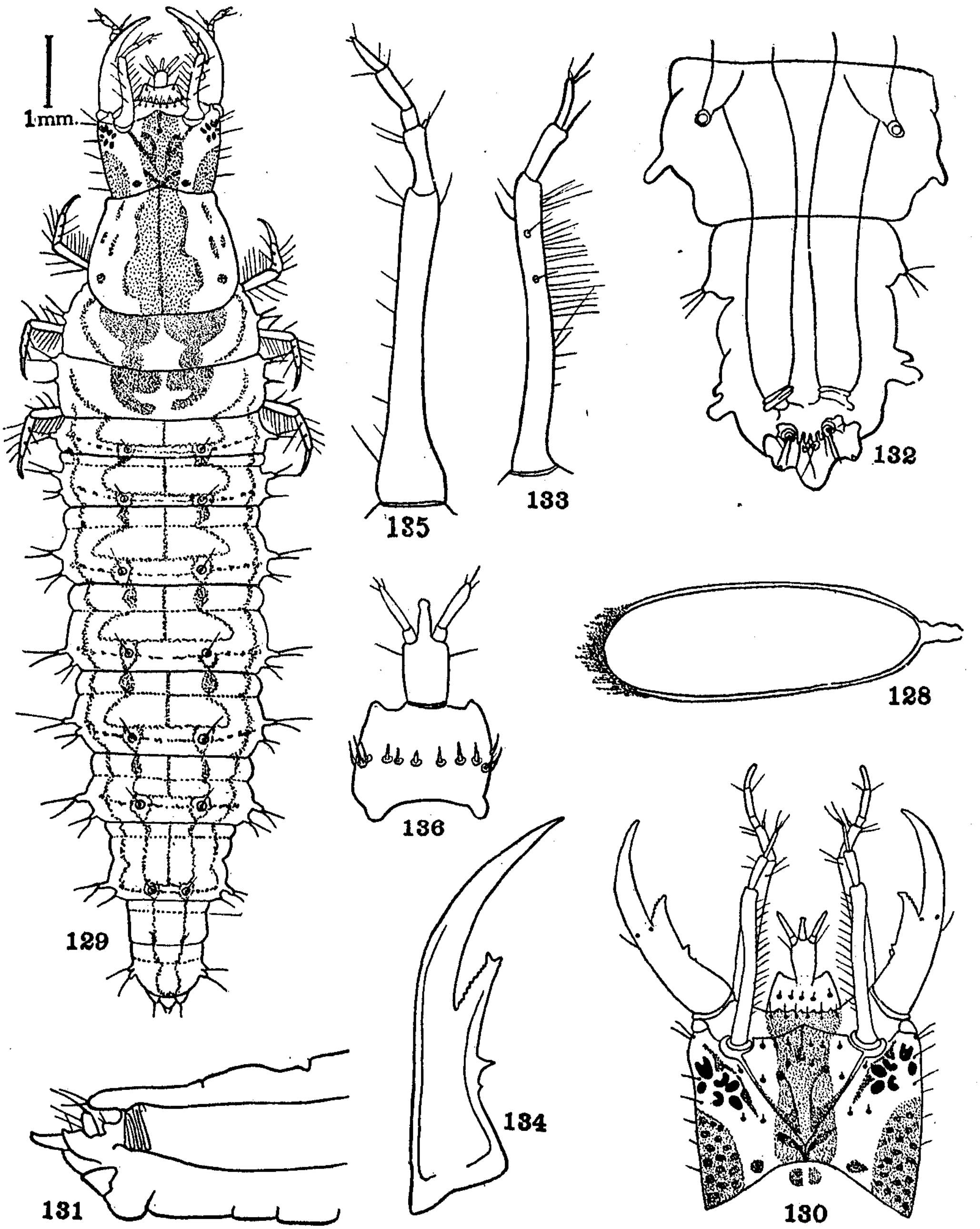


FIG. 128.—Egg of *Tropisternus lateralis*. FIG. 129.—Dorsal view of larva of same. FIG. 130.—Head enlarged, showing color pattern. FIG. 131.—Side view of posterior end of abdomen. FIG. 132.—Dorsal view of same. FIG. 133.—Antenna. FIG. 134.—Mandible. FIG. 135.—Maxilla. FIG. 136.—Labium, ventral view.

On coming to the surface to breathe it swims upward, tail first, then reverses its body and thrusts its abdomen above the surface film, but having no cerci it can not cling to this film for any length of time. Its usual procedure is to cling to some support with its legs while breathing. Its exertions when eating demand a constant air supply, and it usually seizes its prey and swims to the nearest water plant. It then backs up the stem, dragging its prey after it until it can thrust its abdomen above the surface. It can thus eat and breathe at the same time, and it is engaged in doing both nearly all the time. There is nothing in its makeup which sanctions an eight-hour day or one day of rest in seven. It works constantly from the earliest streak of dawn until the last rays of twilight disappear and keeps this up until it is fully matured. It is the very personification of voracity and gluttony and will eat any kind of an insect adult or larva that it can overpower. Like the Hydrous larva it partakes freely of its own kind, even of its brothers and sisters, and of those hatched in any egg case only one or two survive, and they have eaten all the others. This wholesale cannibalism is the salvation of the other smaller denizens of the ponds; without it they would speedily disappear, but with it they obtain a chance to live. In the ponds the favorite food of these larvæ is mayfly larvæ and damselfly nymphs; they also eat *Pelocaris femorata*, a bug of very questionable reputation, and the nymphs of back swimmers and water boatmen, both of which are very harmful to young fish.

This is one of the larvæ mentioned by Comstock (1912) that swim with their prey to a leaf or stem near the surface. Resting on this support it raises its head out of the water and, holding it vertically upward, crushes its prey to pulp between its powerful jaws, letting the juices run down its open throat. It is never content with the juices alone, however, as is the dystiscid larva, but always swallows the pulp.

Description of the newly hatched larva.—This larva is 3.85 mm. long, including the mouth parts, and 0.7 mm. wide. Head trapezoidal, considerably narrowed posteriorly; frontal sutures straight; epicranial suture longer than in the *glaber* larva and shorter than in the *mixtus* larva; frons flat and narrow triangular, the base of the triangle (anterior side) a fourth shorter than the sides, the apex acute. Anterior margin of head not concave but approximately straight; teeth of labro-clypeus small, the two outside ones the largest, the two next to them much smaller and the same size as the one in the center, the remaining two mere points, sometimes wholly lacking. There are two spines near the center of the frons set well back from the frontal margin and six others in a transverse row just behind the frontal margin, and a single spine on each lateral margin in front of the center. There are no spines on the lateral expansions of the epistoma except at the outer frontal corners, where there are two, one behind the other.

The first eye (farthest anterior) is the largest; outside of its posterior end is a seta, another stands behind the fourth eye, and a third behind the sixth eye, and there are two more widely separated near the fronto-antennal suture. The colored area on either side of the head behind the eyes carries three setæ.

The basal joint of the antenna is two-thirds as long again as the two terminal joints, and the tip of the latter nearly reaches the point of the mandible. The fingerlike appendage at the end of the terminal joint has only a single segment. The mandibles are the most slender of the three Tropisternus species here described, are curved but little, and are very acuminate. The distal tooth on the inner margin is also the most slender, its bifid tip is the most acuminate, and the teeth on its inner margin are the longest and sharpest in the three species. The middle tooth on the left mandible is long, slender, and acuminate; it is not double but is inserted in the groove nearer its ventral margin. The proximal tooth is minute, triangular, acute, and single; it is inserted on the ventral margin of the groove, and its edge is not produced transversely. On the right mandible there are two small proximal teeth, side by side, one on either margin of the groove, and a trifle larger than the proximal tooth of the left mandible. The maxilla is more slender than in the other two species, but otherwise similar to them. The labium also is slender but short, and the tips of its palps only reach the distal third of the maxillary stipes. The mentum has nearly straight sides, its anterior angles are produced but little, and are rather bluntly rounded. The ligula is conical, considerably tapered, and apparently jointed near the tip. The terminal joint of the palpus is nearly five times as long as the basal and ends in the usual armature of sense cones and setæ.

The mature larva.—General form spindle-shaped and considerably depressed, with tufts of silky hairs along the sides of the abdomen and other smaller ones scattered sparsely over the body. When fully grown the larva has a length of 10 to 12 mm. and a width across the third abdominal segment of 3 to 3.5 mm. Each of the abdominal segments is divided into a narrower anterior and a wider posterior portion, and along each lateral margin is a fold of skin that is raised into a papilla near the center of the posterior portion of each segment. There are similar folds on the dorsal and ventral surfaces close to the lateral fold, and they also are raised into papillæ opposite the lateral papillæ. Between the dorsal and lateral papillæ and a little in front of them lie the spiracles, which remain closed until the time of pupation.

The color is yellow, tending to orange on the head and thorax, lighter and grayish on the abdomen. The eyes are black, and the following markings are cinnamon brown: The tips and teeth of the mandibles; a stripe through the center of the head lengthwise, containing a herringbone figure of deeper brown; a spotted area on either side behind the eyes; four longitudinal stripes on the ventral surface of the head; irregular markings on the dorsal surface of the thorax and abdomen, as shown in Figure 129 (p. 323). The ventral surface of the thorax and abdomen is dull yellow. In general, the brown markings increase with age, and when the larva enters the pupal chamber the entire dorsal surface is dark brown, almost black.

The antennnæ are even more slender than in the newly hatched larva; the basal joint is more curved and becomes sparsely fringed with long hairs on its inner margin. The base of each antenna is about half-way between the lateral margin and the mid line. The mandibles also remain slender, but become blunter with age; the proximal tooth on the inner margin of the left mandible becomes smaller and often entirely disappears. The maxillæ are practically unchanged, except that the palpifer has increased slightly in relative length. The labium now has a transverse row of large spines across its dorsal surface near the base; the palps are two-jointed, the terminal joint four times as long as the basal and tipped with one long seta and several short ones.

Each of the longitudinal tracheæ is enlarged in the last two abdominal segments and acts as a reservoir for air. The two open into the bottom of a transverse pocket just beneath the dorsal surface at the posterior margin of the last segment. The overhanging dorsal surface is rounded into four narrow lobes and forms the roof of the pocket or atrium. The floor is formed by the ventral surface, which is divided into three lobes, the median one much longer and wider than the lateral ones, and all projecting considerably beyond the dorsal surface. Each lateral lobe carries on its posterior margin a claw that curves upward and assists in keeping the atrium closed while the larva is beneath the water. On the floor in front of the opening of each trachea is a large finger process, projecting upward and tipped with long hairs. Nearer the median line and farther back is another pair of much smaller processes, also projecting upward and tipped with a single long hair. The breathing apparatus thus resembles very closely that described by Miall (1895, p. 91) for *Hydrobius fuscipes*.

Pupation.—When fully grown, the larva crawls quite a distance from the water's edge and hollows out a pupal chamber from 2 to 2½ inches beneath the surface, in which it remains two or three days before pupating. It continues to breathe through the atrium, and the spiracles do not function until after its transformation.

Description of the pupa.—General outline elongate-obovate; greatest width 4 mm. through the bases of the wings; total length, including the cerci, 9 mm. Color at first a pale greenish-white, becoming snow-white in preservatives, except the eyes, which are reddish-brown. On the dorsal surface the styli are arranged as follows: 10 along the anterior margin of the pronotum longer than the others; 4 smaller ones near the mid line and removed a little from the margin; 2 posterior to the center of the segment; 1 on each lateral margin and 8 across the posterior margin; 1 either side of the scutellum on the mesonotum; 2 on the metanotum; 4 on the first abdominal segment; 6 on each of the following six segments, the two lateral ones close together and mounted on small tubercles; 2 much smaller ones on the posterior margin of the eighth segment at the tips of small and indistinct lobes. Each of these styli have a thickened, fleshy, and moniliform base, tipped with a corkscrew seta. There are no supraorbital styli. The ninth segment terminates in two fleshy and superficially annulate cerci, which are stout and divergent at the base and then curve like parenthesis marks. Each is bifid at the tip, the two points ending in stout spines, and there is another stout spine on the outer margin near the center.

The antennæ extend outward at right angles to the body axis; the maxillary palps reach back to the bases of the third legs, and the labial palps do not quite reach the posterior margin of the second legs. The femora of all the legs stand at right angles to the body axis; the tibiæ of the first legs are folded tightly against the femora; the tarsi are turned backward parallel with the body axis and widely separated. The tibiæ and tarsi of the second and third legs are in line with each other, and their tips meet on the mid line of the body; each has separate pockets for the spines at the distal ends of the tibiæ. The large metasternal spine does not quite reach the tips of the second legs.

Inside the pupal chamber the pupa rests upon the large spines of the prothorax and the posterior cerci, the dorsal surface uppermost and strongly arched. Of 10 pupæ reared in 1919, 4 remained three days in the pupa stage, 4 remained four days, and 2 remained five days. Of 10 pupæ reared in 1920, 6 remained only three days in the pupa stage, while the other 4 remained four days. The pupae reared in 1920 emerged two weeks earlier in July than those in 1919, which may have had some influence on the length of the pupal period.

Habits of the adult.—When first emerging from the pupa stage, this beetle is yellowish in color with black eyes, but with no other pigment visible. After emerging it remains about three days in the pupal chamber before coming out into the light, gradually turning a reddish-yellow, and finally black with yellow margins on the thorax and elytra. If taken from the chamber during this time and thrown into the water, it floats lightly on the surface like a whirligig beetle and swims for the shore or the nearest vegetation. Evidently it can not submerge itself and manage its air supply at that stage. When fully matured, it is an excellent swimmer and is also agile upon land, walking and running easily but not jumping. It feeds largely upon Anabæna and Clathrocystis, which float upon the surface of most of the ponds during the summer. Turning bottom upward and clinging to the surface film with its legs, the beetle scoops in the floating algæ with its labial and maxillary palps. Sometimes it clings to floating objects and reaches the algæ from that foothold.

Description of the adult.—General form elongate-ovate, with evenly rounded outlines, the abdomen often projecting a little from beneath the elytra. Total length 8 to 10 mm.; greatest width (through the thorax) 3 to 3.50 mm. Dorsal surface olive-black, shining; the head, thorax, and elytra with a narrow margin of pale yellow, and sparsely covered with fine silky hairs, longer on the margins, especially toward the posterior end of the elytra. Ventral surface black, the antennæ, maxillæ, legs, and wide margins on the thorax and elytra yellow. Bases of the femora and outer margins of the tarsi black, eyes pale lavender.

The antennæ are nine-jointed, the last four joints enlarged into a densely pilose club. Mandibles with a long and acute terminal tooth and a squarely truncated secondary tooth, the truncated edge cut into smaller teeth. From the posterior margin of the second tooth two divergent series of small comb teeth extend toward the base of the mandible. The maxillæ are typical in form, the palps elongate, four-jointed, the last joint nearly one-third longer than the preceding one. The labial palps are three-jointed, short, and pilose.

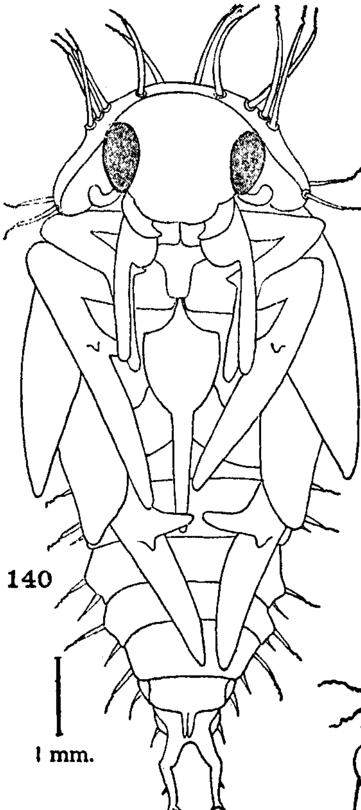
This beetle is easily recognized by the yellow borders of the thorax and elytra, which stand out sharply in contrast with the shiny black of the dorsal surface. It is decidedly the most abundant species around the fishponds; it is present and breeding in every one of them except the small 6D, and it is probably found there at times. Although the larvæ are such ferocious little cannibals, they are not large enough to menace young fish, but, on the other hand, their exceptional abundance makes them an important factor in fish food.

Tropisternus glaber (Herbst). Figures 137, 140, 142, 143, 145.

Hydrophilus glaber (Herbst, 1797, p. 398).
Tropisternus glaber (Wickham, 1893a, p. 340).
Tropisternus glaber (Richmond, 1920, p. 35, pl. 7, figs. 1-9).

Eggs and egg case.—This beetle also spins a silken egg case similar to that of the preceding species but a little larger, and nearly always with a spike instead of a ribbon for a fag.[8] These cases are 6 to 9 mm. long, 8 to 12 mm. wide, and 4 to 5 mm. high at the mouth. The number of eggs in a case varies greatly but averages about 10 or 12. Three or four days intervene between the laying and the hatching of the eggs. About 100 egg cases of this species were found in 1921 in pond 9D, in little patches of Œdogonium floating at the surface of the water. Under these conditions they were somewhat different from those described by Richmond (1920) and may be characterized as follows: Nearly spherical, about the same length and width, not flattened at all but fastened at various places to the algal strands, so that the case lies horizontally in the water. The cap is circular in outline, stands vertically upright, and is prolonged into a cylindrical fag [8] which tapers to a sharp point and which is always darker in color and coarser in texture than the white case and cap.

[8] See p. 332.



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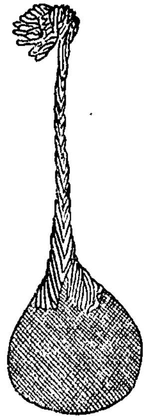

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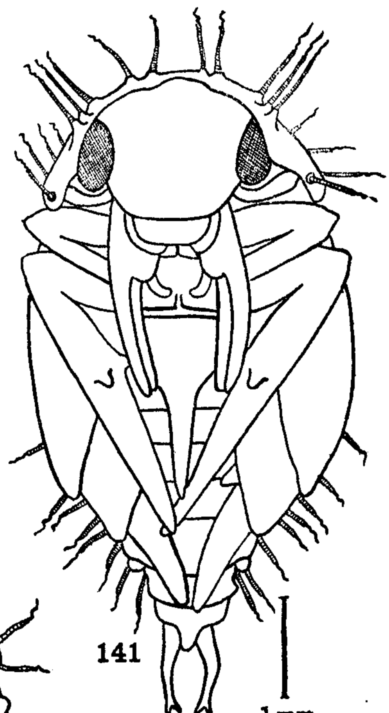

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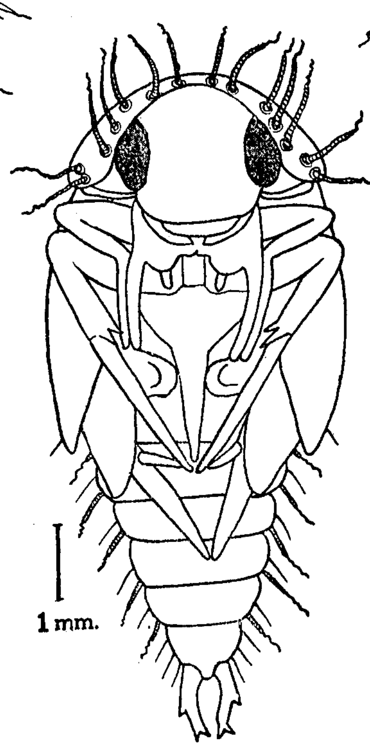

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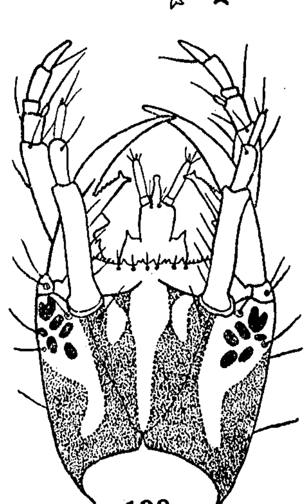

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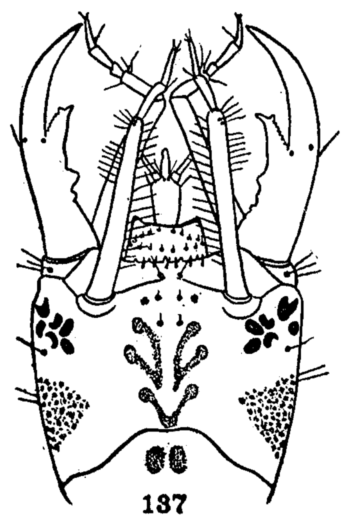

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FIG. 137.—Head of larva of *T. glaber*. FIG. 138.—Head of larva of *T. mixtus*. FIG. 139.—Ventral view of pupa of *lateralis*. FIG. 140.—The same, *glaber*. FIG. 141.—The same, *mixtus*. FIG. 142.—Fag of egg case of *mixtus*.

Comstock in Manual of the Study of Insects (1912, p. 527, fig. 636) gave a picture of one of these cases. Referring to it in the text he stated: "Some species deposit as many as a hundred eggs in one of these waterproof packages (fig. 636)." The cases are waterproof only in the sense that water does not injure them and not in the sense that water can not enter them, since they are left open to allow the exit of the larvæ. Again, the large floating cases of Hydrous and not the one figured by Comstock are the ones that contain 100 eggs.

Description of the newly hatched larva.—Length 4.5 mm., and width of the thorax 0.8 mm.; color light brown. Head trapezoidal, about the same length and width, slightly narrowed posteriorly; fronto-clypeal sutures indistinct; frontal sutures straight, converging and uniting to form an epicranial suture less than one-twelfth of their own length. Frons flat and broadly triangular, the three sides of the triangle about equal. Anterior margin of head somewhat concave, the lateral expansions of the epistoma projecting in front of the labro-clypeus. The teeth of the latter are large and include a conical tooth at the center larger than any of the others and, on either side of it, two smaller teeth close together and a larger one removed a little distance. The sinuses on either side of the central tooth, between the two teeth and the distant one, and on the outside of the latter, each carry a short and stout spine. The frontal margin of the epistoma has no spines except two at each outer corner, side by side, about the same size as those on the labro-clypeus. Near the anterior margin of the frons is a transverse row of four small setæ nearly in a straight line; a fourth of the distance behind them are two more, one on either side of the mid line. There is a seta outside the sixth eye, another outside the fifth eye, and a row of three behind the ocular area. The first (anterior) eye is only a little larger than any of the others.

The basal joint of the antenna is only a third longer than the other two joints together, but the terminal joint projects beyond the tips of the mandibles. The fingerlike appendage on this joint is apparently two-segmented. These antennæ are much stouter than those of the *lateralis* larva, especially the second and third joints. The mandibles are the stoutest and most strongly curved of the three species here described, and their tips are comparatively blunt. The distal tooth on the inner margin is also stouter, its bifid tip is more bluntly rounded, and the teeth on its inner margin are shorter and coarser. The middle tooth on the left mandible is broadly triangular and not double but stands apparently in the center of the groove. The proximal tooth is minute and on the ventral margin of the groove, but its proximal edge runs across the groove nearly to the dorsal margin. On the right mandible there are two small proximal teeth, side by side, one on either margin of the groove. The maxillæ are stouter than those of *lateralis* but otherwise similar to them. The labium is also stout and shorter than in *lateralis*, the tips of its palps reaching just beyond the center of the maxillary stipes. The mentum has convex sides, and its anterior corners are produced into blunt spines; the ligula is cylindrical and only slightly tapered; the terminal joint of the palpus is four times the length of the basal joint.

The mature larva.—When fully grown the larva is 12 to 15 mm. long and 3 to 4 mm. wide. This larva is very similar to that of *lateralis* but is somewhat larger, darker in color, and more densely clothed with hairs. The papillæ on the abdomen are longer, more numerous, and carry larger tufts of hairs; the mandibles are stouter, shorter, and not as acuminate; the maxillæ are shorter and stouter, and the upper lip of the stigmatic atrium is evenly rounded instead of being cut into narrow lobes. Figure 130 shows the upper surface of the head of a mature *lateralis* larva, while that of the mature *glaber* larva is shown in Figure 137, and the two larvæ can be distinguished by the color patterns. The yellow on the dorsal surface of the head and the five yellow stripes on the ventral surface are much more pronounced in the present species. Sometimes this larva has a brown streak through the head along the mid line of the dorsal surface, but even then the color pattern is distinctly visible. This larva, like the preceding species, undergoes changes with age; the antennæ and maxillæ become more slender, and their basal joints increase in relative length. The mandibles are less acuminate, but the proximal teeth on their inner margins remain broader, blunter, and closer to the distal teeth than in the *lateralis* larva. The labium broadens, and the mentum acquires a formidable set of short spines on its dorsal surface. When fully matured, the larva becomes almost black and is densely covered with papillæ and hairs.

The habits and food are the same as those of the *lateralis* larva; Richmond (1920, p. 35) said that the *glaber* larvæ he reared in an aquarium "fed readily on entomostracans and small tadpoles."

Description of the pupa.—The pupa is like that of the preceding species, with the following differences. It is slightly longer (9.5 mm.) but no wider· the labrum and the distance between the eyes is wider; the maxillary and labial palps are shorter and stouter; the wings are about the same length; the metasternal spine is longer and not as stout; the cerci are longer and more slender; the third legs reach the penultimate abdominal segment; the eyes are not as red and are considerably lighter in color.

Of 10 larvæ reared in 1919, 6 remained in the pupa state four days, 2 remained five days, and 2 six days. Of 10 larvæ reared in 1920, 2 remained in the pupa state three days, 6 remained four days, and 2 remained five days. Wickham (1894), in endeavoring to rear the larva of a bombardier beetle which had infested the pupa of *Dineutes americanus*, substituted in place of the gyrinid food a pupa of the present species and it was accepted by the parasite. Another *glaber* pupa was infested with the maggots of a species of Phora, one of the Diptera. These two instances would indicate that the pupæ of the present species are susceptible to the attacks of parasites of this sort.

The adult beetle.—The adults are larger than those of either of the other two species here described, attaining a length of 9.50 to 11 mm., and rarely reaching 12 mm. The form is a much broader oval, and the punctures of the elytra are larger and more distinct. The head, thorax, and elytra are entirely black on the dorsal surface and more or less bronzed, with no yellow stripe or silky hairs along the lateral margins. Ventral surface also entirely black, dull on the body, but shiny on the legs and sternal crest, the five basal joints of the antennæ, the laciniæ and palps of the maxillæ, and the labium yellow. Basal joint of the antenna considerably longer than in the preceding species and more strongly curved. Terminal tooth of mandibles shorter and secondary tooth longer; labial palps shorter, the setæ at the tips subterminal.

This species has never been seen feeding on Anabæna or Clathrocystis but stays beneath the surface and eats Chara, Nitella, etc. While this species is not as abundant as the preceding it is still found in every pond but two, and it breeds as prolifically. For this reason it becomes an important item in the food of the young fish.

Tropisternus mixtus (Leconte). Figures 138, 141, 144.

Hydrophilus mixtus (Leconte, 1855, p. 368).

Egg case and eggs.—The egg case is from one and a quarter to two times as wide as long, strongly flattened and fastened to the support transversely, the mouth usually projecting slightly beyond the edge of the support. The fag[9] is in the shape of a slender cylinder made of twisted strands which stands rigidly upright in the water, is the same diameter throughout, and is usually frayed at the tip (fig. 142, p. 327). When the mouth of the case does not reach the edge of the support, the side next to the support is prolonged to the edge as a broad ribbon, securely fastened, and the fag is attached to this ribbon. The fag is always darker in color and coarser in texture than the case, the cap, and the broad ribbon. Case 6 to 8 mm. long, 7 to 10 mm. wide, and 4 to 6 mm. high at the mouth; fag 8 to 12 mm. long.

The egg is much shorter and broader than that of *lateralis;* the latter is three times as long as wide, but the egg of the present species is less than two and a half times as long as wide. From 8 to 12 eggs are laid in a single case, and they hatch in four or five days.

Habits of the larva.—The habits of these larvæ are very similar to those of the other two species but differ in one marked particular. The larvæ of the other two species begin their cannibalistic ravages inside the case as soon as they get out of the egg. Many of the larvæ are eaten by their brothers and sisters before they emerge from the egg case, and sometimes out of an entire brood only one will be left to crawl forth eventually. The present larvæ, however, act in a radically different manner. Thirty cases were brought into the laboratory and placed in a small aquarium and allowed to hatch. A few larvæ appeared at about the right time and then disappeared overnight. At first it was supposed that they had crawled out of the aquarium in some way, and a cover was placed over it to prevent this. No more larvæ appeared, however, and after a day or two the cases were taken out and opened separately. Two-thirds of them were entirely empty, containing neither eggs nor larvæ. The other third were packed full of active vigorous larvæ, each case containing from 25 to 35 and one 42 larvæ. They were packed very closely inside these cases but were not tangled, for the moment the case was opened they separated and swam away in different directions. As the cases contained only 10 or 12 eggs apiece, the larvæ must have crawled from two cases into a third one and bunched with the larvæ of the latter until it was as full as it would hold. Moreover, they seemed to be living in perfect harmony; there was no evidence either then or subsequently that they were at all cannibalistic. In no instance was one of them seen to attack

[9] See p. 332.

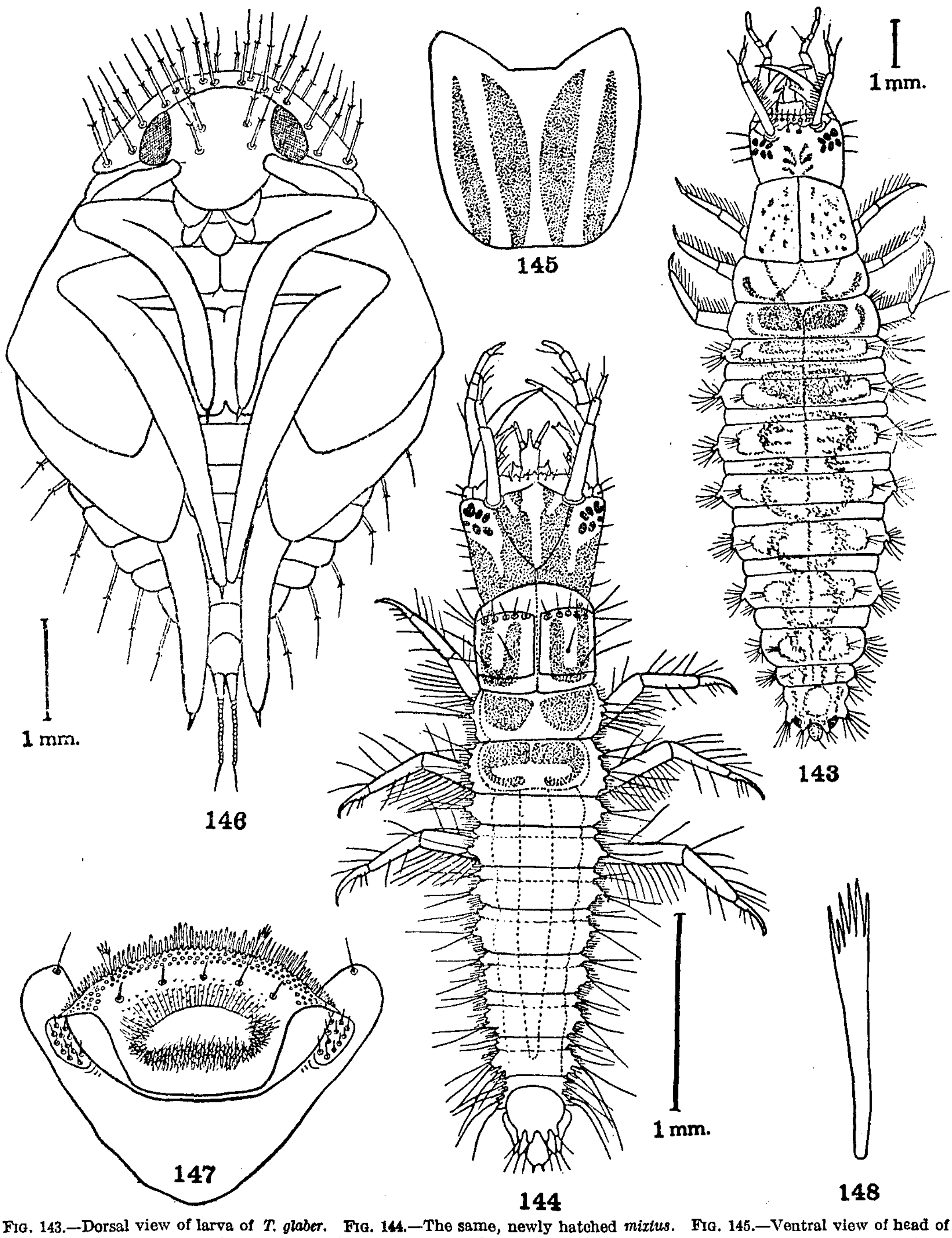

FIG. 143.—Dorsal view of larva of *T. glaber*. FIG. 144.—The same, newly hatched *mixtus*. FIG. 145.—Ventral view of head of *glaber*. FIG. 146.—Ventral view of pupa of *Laccobius agilis*. FIG. 147.—Frons of *Thermonectes ornaticollis*. FIG. 148.—A single lacinate spine of the same, enlarged.

and kill another, even though food was scarce. The simple fact that they do thus herd together in such numbers shows an entirely different disposition from that of the other two species. In the ponds they fed readily upon snails, entomostracans, damselfly nymphs, mayfly larvæ, and small tadpoles. In all other respects their habits were identical with those of the two preceding species.

Description of the newly hatched larva.—This larva is 4 mm. long, including the mouth parts, and 0.75 mm. wide. Head nearly quadrate, not appreciably narrowed posteriorly; fronto-clypeal suture distinct; antennal sutures wavy rather than straight, converging posteriorly into the shortest epicranial suture of the three species here described, only one-twentieth the length of the antennal suture. Frons triangular, the anterior side or base one-fifth shorter than the other two sides, the apex or posterior angle broadly rounded. Anterior margin of the head only slightly concave, the lateral expansions of the epistoma barely protruding beyond the clypeus. The latter has rather small teeth, larger than those of *lateralis* but not as large as those of *glaber*. The central one and the two outside ones are the same size and larger than the other four. The transverse row of six small spines are all about the same size and equally distant from the margin. The frontal margin of the epistoma also carries on either side a row of 10 or 11 small spines, increasing in size outwardly, the largest one at the outer corner.

The first (anterior) eye is larger than any of the others; behind the sixth eye stands a seta, and there is a row of four along each lateral margin of the head behind the eye area. The basal joint of the antenna is shorter than in the other two species and is only three-fifths longer than the other two joints together. The terminal joint is a little shorter than the second joint and less than half its diameter; the fingerlike appendage at its tip has apparently two segments.

The mandibles are stouter than those of *lateralis* but not as stout as those of *glaber*. The distal tooth on the inner margin is like that in the preceding species, its bifid tip bluntly pointed, the teeth on its inner margin quite distinct. The middle tooth is not double, but is short, broadly triangular, and acuminate, and stands in the center of the groove. The proximal tooth is minute and stands on the ventral margin of the groove, its proximal edge running across to about the center of the groove. The two proximal teeth on the right mandible stand side by side, one on each margin of the groove. The maxillæ are stouter than in the two preceding species but otherwise similar to them. The labium is relatively longer, the terminal setæ of its palps reaching the distal end of the maxillary stipes. The mentum has convex sides, and its anterior corners are produced into short and acute spines.

The mature larva.—When fully matured, the larva is 11 to 13 mm. long, 3.25 to 3.75 mm. wide. This larva may be recognized at once by the color pattern; along the median line of the dorsal surface of the head and curving backward from the eye areas on either side are broad stripes of orange-yellow, narrowed posteriorly. Between these on each side is a wide stripe of dark, cinnamon-brown, running from the base of each antenna back to the prothorax, and another wide brown stripe on either lateral margin behind the eyes. These stripes are all uniform in color and not spotted. On the prothorax in place of the longitudinal dashes of the other species there is a three-sided parallellogram on either side of the mid line, the anterior end lacking. The mesothorax and metathorax have dark brown sclerites like those of the other species but differing somewhat in shape. The abdomen is light brown dorsally, the margins of each segment slightly darkened, but without other markings. The lateral tracheæ show through as a wide dark line along either side.

This larva has a larger number of papillæ along the sides of the abdomen and is more densely covered with hairs than either of the others. The basal joints of the antennæ remain less than twice the length of the other two joints together, and are comparatively stout. The labium is narrow but elongate, and the tips of the labial palps reach well beyond the distal tooth on the inner margin of the mandibles.

Description of the pupa.—Total length, including the cerci, 6.50 mm., greatest width, through the bases of the second legs, 3.35 mm. Length of metatarsal spine, including the wide base, 1.75 mm. In the *lateralis* pupa this spine is 2.40 mm. long, and in the *glaber* pupa it is 3 mm. long. Length of cerci 1 mm. This pupa differs from the two preceding ones in the following particulars: The space between the eyes is wider; the labial palps are longer; the metasternal spine is actually shorter, but its tip reaches the middle of the fifth abdominal segment; the tarsi of the second legs and the tips of the wings reach the middle of the sixth segment; and the tips of the third legs reach the anterior margin of the last segment. The cerci are as slender as those of *glaber* but lack the spines on the outer margins. The mesotibial and metatibial spines are less distinct. The duration of the pupa stage is four or five days, as in the other species.

Habits of the adult.—The habits of the adult are the same as those of the other two species, and the food is the same as that of the preceding species. This beetle is not as agile as *lateralis* but is rather clumsy when out of the water.

Description of the adult.—The adult is from 8.5 to 9 mm. long. This species is distinguished from *lateralis* by the lack of the yellow margins on the thorax and elytra and from *glaber* by the fact that the elytral punctures are of quite different sizes intermingled with one another, and the beetle is considerably smaller. The anterior portion of the sternal crest and the apical halves of the femora and tibiæ are brownish-yellow instead of black. The species is only found in a few of the ponds and then not abundantly, but it furnishes as good fish food as the others and is harmless.

Genus HYDROUS Leach.

Hydrous (Leach, 1817, p. 165).

The only representative of this genus found in the Fairport fishponds is *Hydrous triangularis* (Say), which has already been fully described and figured by the writer in this Bulletin, Vol. XXXIX, pages 9 to 38; 23 text figures.

Genus DONACIA Fabricius.

Donacia (Fabricius, 1775, p. 195).

This genus is represented in the Fairport fishponds by the single species *Donacia æqualis* Say. The complete life history of this species with description and figures of the larva, pupa, imago, and cocoon is given by A. D. MacGillivray (1903, p. 321).

CAP ATTACHMENT ON EGG CASE.

The name and the function of the attachment to the cap of the egg case has provoked considerable discussion amongst the various investigators who have studied the water beetles, but without any satisfactory results. It has been designated by many as a "mast," but this is open to several objections. Whatever name is selected should be one that will apply to the egg cases of all hydrophilids indiscriminately. A mast is tall, upright, rigid, and more or less cylindrical, but in some hydrophilids (Tropisternus, Enochrus, Berosus) this attachment is flat, ribbonlike, and floats pliantly in the water. In others (Laccobius, Helophorus) it forms a hollow tube for the exit of the larvæ, and in one genus (Hydrobius) it forms a wide collar or cape around the cap end of the case. The term mast is an evident misnomer for anything in the shape of a ribbon or collar.

This cap attachment has also been called a "balancer" or "equipoise," but either of these names implies that it maintains or at least helps to maintain equilibrium. Since the great majority of the egg cases are fastened securely to some support, it is manifestly impossible for anything of this sort to affect their equilibrium. The only cases to which such a term would be applicable are those of Hydrous and Hydrophilus, and other genera certainly have an equal claim to recognition.

In striving to interpret the function of this cap attachment it has usually been taken for granted that it was in some way necessary to the development of the eggs. The investigator has thus been prejudiced in his observations, and all his efforts have been directed toward discovering in what way such an attachment could benefit the eggs, rather than toward finding its real function. The first and most obvious suggestion has been that this cap attachment contributed in some way to the aeration of the eggs. Unfortunately in the only instances where this would be possible from a physical standpoint, the attachment proves to be solid and covered on the outside with a glazing impervious to air. In the great majority of cases the eggs are wholly immersed in water and the only method of aeration is through the water itself.

There are several genera (Ochthebius, Hydroscapha, Cymbiodyta, etc.) that do not construct any case at all but deposit their eggs either singly or in a mass in or near the water. Evidently, therefore, eggs can be developed without the help of this cap attachment. Why not infer that the eggs of all the genera can be thus developed and seek some other explanation for the attachment? In order to test whether the attachment is essential to egg development in genera whose egg cases possess it, 30 egg cases of *Tropisternus glaber* were brought into the laboratory and their attachments were cut off, taking care not to injure the cases themselves. These cases were in various stages of development, some just completed, others from one to three days old. They were gathered and the attachments removed on July 18, the larvæ began to hatch on July 22, and the last of them appeared on July 27. From these 30 cases were obtained 363 larvæ, an average of 12 for each case, and on examining the cases at the close of the experiment it was found that only four eggs had failed to hatch. This certainly is up to the normal percentage of hatching and proves conclusively that the cap attachment is not essential to the development of the eggs. What then is the attachment and what reason can be given for its existence?

In the great majority of cases the attachment is different in color and texture from the rest of the case. Miger claimed that in Hydrous (Hydrophilus) there were three secretions—one the normal secretion for the construction of the case, another for spinning the loose covering which surrounds the eggs, and the third for making the cap attachment. There is a similar difference in the egg cases of *Tropisternus glaber* and *T. mixtus*, but in the case of *T. lateralis* there are only two kinds of silk, that which forms the cap and its attachment ribbon not being distinguishable from that which forms the case itself. According to Richmond (1920) this last is true of many other hydrophilids.

These facts seem to indicate that the true explanation of this cap attachment is the one originally given by Lyonet, but apparently not appreciated by any entomologist since his day. In speaking of the "mast" of the egg case of the European species *Hydrous piceus*, Lyonet said: "I do not know the use of this little mast. Perhaps it enables the insect to get rid of an excess of silky matter" (1832, p. 135). In the account here given of the spinning of the egg case of *Tropisternus lateralis* it is shown that the case is spun first out of the normal silk secretion, then the eggs are laid and fastened in place inside the case with the loose silk, and finally the cap and its attachment are made. The normal silk secretion is white in color and fine in texture, and it forms the body of the case. During the laying of the eggs some of the contents of the oviducts may come out with the eggs and mingle with the silk secretion, making it thinner and looser in texture, thus forming the loose fibers used for covering the individual eggs. When the egg-laying ceases, the silk secretion returns to its normal texture and is used to form the cap and in many genera the cap attachment, both of which are then like the case itself. In other genera, however, the dregs of the contents of the silk glands are different in color and texture, and so the cap attachment and sometimes the cap itself differs in these particulars. The attachment is simply the result of the efforts of the beetle to completely empty its silk glands of their contents and has no relation whatever to the development of the eggs. If this be the explanation of the construction of this attachment, the name "fag" is suggested for it, signifying the end or loose end, the latter or meaner part, of the weaving.

In Tropisternus, furthermore, the tip often unravels and forms a sort of fringe, which carries the same idea a little farther. In Hydrous and Hydrophilus the last of the contents of the silk glands is gummy or mucilaginous and dries in the air, because the egg cases of these genera float on the surface of the water. In consequence the surface of the fag and at least the basal half of the cap are smooth and more or less shiny. The fag also is much stiffer than in other genera. It is possible, however, that a similar result would be obtained if the fag of the egg cases of other genera were dried in the air instead of under water.

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1862. *Idem*. *Ibid.*, pp. 209–286.
1863. New species of North American Coleoptera, Part I. *Ibid.*, Vol. VI (1867), No. 167, 86 pp.

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1883. Classification of the Coleoptera of North America. Smithsonian Miscellaneous Collections, Vol. XXVI, No. 507, xxxviii+567 pp. Washington.

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1888. Water beetles of Staten Island. Proceedings, Staten Island Association, April 14, 1888. New York.
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1913a. Dytiscus flying in January. *Ibid.*, p. 160.

LENG, CHARLES W., and ANDREW J. MUTCHLER.
1918. Insects of Florida. V. The water beetles. Bulletin, American Museum of Natural History, Vol. XXXVIII, pp. 73–116, 2 figs. New York. [Regarded *Thermonectes ornaticollis* as a variety of *T. basilaris* and not as a separate species.]

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1871. On the so-called suckers of Dytiscus and the pulvilli of insects. The Monthly Microscopical Journal: Transactions, Royal Microscopical Society, Vol. V, pp. 267–271, Pl. LXXXIX. London. [Gave a detailed account of the structure of the anterior tarsus of the male Dytiscus and called attention to the viscid secretion discharged by the cupules, which greatly increases their adhesion.]

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MENTZSCHEFAHL, A. VON.

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MIALL, L. C.

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ORCHYMONT, A. D'.

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PAGANETTI-HUMMLER, G.

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PLATEAU, FÉLIX.

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1876b. Report on the insects collected by Captain Jones' expedition to northwestern Wyoming in 1873. *Ibid.*, pp. 187–192.

1876c. Report on the insects collected in the vicinity of Spring Lake Villa, Utah Co., Utah, during the summer of 1875. *Ibid.*, pp. 193–205.

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1887. Essai d'études sur certaines larves de Coléoptères. Annales, Société Linnèenne de Lyon Nouvelle série, T. 33, pp. 131–259, Pls. I and II. [*Ochthebius* (*Calobius*) *quadricollis* Muls, p. 141.]

RICHMOND, E. AVERY.

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SCHAUPP, F. G.

1879. List of the described coleopterous larvæ of the United States, with some remarks on their classification. Bulletin, Brooklyn Entomological Society, Vol. II, pp. 1, 13–14, 21–22, 29–30. [Under the Dytiscidæ, Gyrinidæ, and Hydrophilidæ it was stated that no larva of a North American species had been described up to that date.]

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1914. Aquatic beetles, especially Hydroscapha, in hot springs, in Arizona. Proceedings, Entomological Society of Washington, vol. 16, pp. 163–168. Washington.

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1913. Coleoptera, Hydrophilidæ, Histeridæ [of the Seychelles]. Transactions, Linnean Society of London, vol. 16, pp. 193–234, Pl. XIV.

SHARP, DAVID.

1875. On three new species of Hydrophilidæ. The Entomologist's Monthly Magazine, Vol. XI, pp. 247–250. London.

1880. Insecta. Coleoptera. Biologia Centrali-Americana. Vol. 1, Part 2, xv+824 pp., 19 col. pls.

1882. On aquatic carnivorous Coleoptera or Dytiscidæ. Transactions, Royal Dublin Society, Vol. II (Series II), pp. 179–1003, Pls. VII–XVIII. Dublin.

1883. Revision of the species included in the genus Tropisternus (fam. Hydrophilidæ). Transactions, Royal Entomological Society of London, pp. 91–117. London.

SHERMAN, JOHN D., JR.

1913. Some habits of the Dytiscidæ. Journal, New York Entomological Society, Vol. XXL, pp. 43–54. New York. [Excluded large bodies of water as unfavorable for beetles and divided the others into meadow ponds, ponds, and pools of the forests, running water, and springs, giving the species found in each and their habits.]

SOLIER, A. J. J.

1835. Essai sur les Collaptérides. Annales, Société Entomologique de France, T. 4, pp. 249–420, Pls. V–IX. Paris. [Genus Philydrus established on p. 315.]

STEIN, FRIEDRICH.
1847. Vergleichende Anatomie und Physiologie der Insekten. Erste Monographie. Ueber die Geschlechts-Organs und den Bau des Hinterleibes bei den weiblichen Käfern. 8+139 pp. Berlin.

THOMSON, CHARLES GUSTAV.
1859. Skandinaviens Coleoptera, Synoptiskt Bearbetade. Vol. 1. Lund. [Enochrus established, p. 18.]

WARD, JOHN J.
1914. Some new discoveries in natural history. A tool-using insect. Strand Magazine, vol. 48, pp. 523–525, 5 figs. London and New York.

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WICKHAM, H. F.
1893. Studies on the male tarsus in some adephagous Coleoptera. Bulletin, Laboratories of Natural History, State University of Iowa, Vol. II, No. 4, pp. 322–329, Pls. V–VIII. Iowa City. [Described the dilated tarsi of three species of Cybister, one of Thermonectes, one of Acilius, five of Dytiscus, and one of Colymbetes.]

1893a. Description of the early stages of several North American Coleoptera. *Ibid.*, pp. 330–344, Pl. IX. [Included *Gyrinus picipes* Aube, *Dineutes americanus* Say, *Tropisternus glaber* Herbst, and *Brachinus janthinipennis*.]

1894. On some aquatic larvæ, with notice of their parasites. The Canadian Entomologist, Vol. XXVI, pp. 39–41. London, Canada. [Included a bombardier beetle and a hymenopter on the pupa of *Dineutes americanus*, and an ichneumon on the pupa of a species of Gyrinus, while a pupa of *Tropisternus glaber* was infested with the maggots of a species of Phora, one of the Diptera.]

1895. On the larvæ of *Hydrocharis obtusatus* and *Silpha surinamensis*. Entomological News, Vol. VI, pp. 168–171, Pl. VI. Philadelphia. [An abstract given on page 314.]

1895a. The Coleoptera of Canada. The Canadian Entomologist, Vol. XXVII, pp. 69–76, 117–122, 149–153, 181–186, 213–216. London, Canada.

1911. A list of the Coleoptera of Iowa. Bulletin, Laboratoris of Natural History, State University of Iowa, Vol. VI, No. 2, pp. 1–40, Iowa City.

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1923. Life history of the scavenger water beetle (*Hydrous* (*Hydrophilus*) *triangularis*) and its economic relation to fish breeding. Bulletin, U. S. Bureau of Fisheries, Vol. XXXIX, 1923–24, pp. 9–38, 22 figs. Washington.

WINTERSTEINER, FRED.
1913. Environment of Hydrophilidæ. Journal, New York Entomological Society, Vol. XXI, pp. 54–55. New York. [All the Hydrophilidæ except the Sphæridini are aquatic, yet only four genera, Hydrous, Tropisternus, Hydrophilus, and Berosus, can swim. The rest crawl about on submerged vegetation.]

WRIGHT, A. H.
1920. Frogs: Their natural history and utilization. Appendix VI, Report of the U. S. Commissioner of Fisheries for 1919, Bureau of Fisheries Document No. 888, 44 pp., 22 pls., 2 figs. Washington. [See quotation on page 248.]

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ZAITZEV, PH.
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