LIFE HISTORY OF THE SCAVENGER WATER BEETLE, HYDROUS (HYDROPHILUS) TRIANGULARIS, AND ITS ECONOMIC RELATION TO FISH BREEDING.

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CONTENTS.

INTRODUCTION.

In recent revisions of the scavenger water beetles Say's species *triangularis* has been referred to the genus Hydrous instead of Hydrophilus, and the latter genus has been considerably restricted. This revision is fully accepted, but to facilitate recognition both names have been included in the title of the present paper.

The European species, *Hydrous piceus*, has been described and figured in detail by many eminent entomologists, but our American species have thus far received only scant attention. This is the more to be regretted because they differ in many important particulars from their European relatives.

The beetle of the present investigation always forms, or is likely at any moment to become, one of the important factors in the life of every fishpond. Hence, an exact knowledge of its habits and life history is essential if we are to deal with it intelligently. During the summer of 1918 an unusual opportunity for obtaining the life history of this beetle was presented at the United States Fisheries Biological

Station, Fairport, Iowa, when one of the small fishponds was drained. While the water was receding and immediately after the pond was emptied, about 100 fully developed larvæ of *Hydrous triangularis* were obtained, together with numerous specimens in younger stages. Six egg cases were found, of which one contained half a dozen newly hatched larvæ, another was full of undeveloped eggs, and the remaining four were empty.

From the shores of the pond, just above the former water line, were obtained 15 pupæ in various stages of development. Several of the mature larvæ were observed digging their way into the earth as the water lowered, and these were closely watched until they transformed into pupæ. Some of the pupæ were preserved at once, others were left until they emerged as adult beetles. In this way the entire life history was obtained, together with many suggestive facts in reference to the habits. Fifty larvæ, including some smaller ones, were cut open and the contents of their digestive canals carefully examined to ascertain their ordinary food. Owing to these unusual facilities for observation it has been possible to solve practically all the problems connected with the life history, including some that have hitherto remained unanswered by the European observers.

MATING AND EGG LAYING.

The mature beetles almost certainly live through the winter, and mating and egg laying begin in the early summer and continue at least until the last of July. No female has yet laid more than one batch of eggs in captivity, but it seems probable that at least some of them do this in their natural environment.

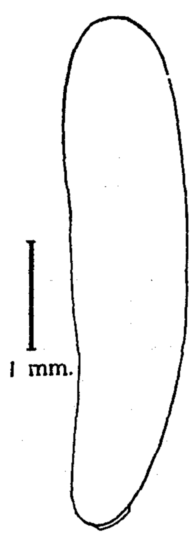

FIG. 1.—Side view of a single egg.

The eggs are in the form of an elongated ellipsoid, 4.25 to 4.5 mm. long and about 1 mm. in diameter (fig. 1), and are bright yellow in color when first laid. As is the custom with many of the Hydrophilidæ, the eggs are inclosed in a silken case. In the present species this case is attached to floating leaves, bits of trash, etc., and not to living plants, and it floats upon the surface of the water.

The construction of one of these cases was described for the European species by Lyonet (1832) and afterwards by Miger and Lancret (1804). Something evidently was lacking in the aquarium experiments of these observers, because the formation of the egg case required a very long time—five hours for the female watched by Lyonet and three hours for the one watched by Miger. Possibly the European species is a slower worker than the American, or one female may work more slowly than another. At all events the following observations made by George B. Lay in the Fairport laboratory, July 27, 1916, and witnessed in large part by the present author, show that a case can be constructed much more rapidly than this.

A female *Hydrous triangularis* was noticed starting an egg case at 1 p. m. in one of the laboratory aquaria. She abandoned this effort, however, as there were not enough water plants in the aquarium to work with. After these had been supplied she began to spin another case at 1.25 p. m. Assuming a position, back downward, her body almost parallel with the surface of the water and close to it, she held herself in place by means of the floating water plants (Potamogeton and Elodea), and moved her spinneret rapidly to and fro sidewise, at the same time pushing the material backward with her hind legs. After spinning the roof of the case in this manner for a few minutes she turned over without removing her spinneret. Her body was considerably inclined, with her head some distance below the surface, and she opened her wing cases slightly to supply herself with fresh air at periods varying from 15 to 90 seconds, the shorter period the more common. This mode of taking in air through the lifting of the posterior ends of the elytra is in marked contrast to the method normally used (see p. 29). It required a longer period to make the floor of the case, since it is much more convex than the roof,

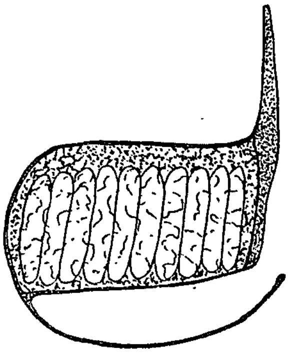

FIG. 2.—Longitudinal section through center of an egg case, showing a thick layer above the eggs, a floor beneath them, and an open chamber under the floor, in which the newly hatched larvæ gather.

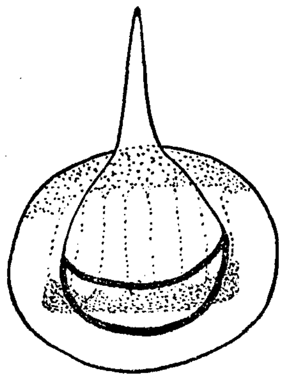

FIG. 3.—End view of egg case, showing triangular plate with lunate opening beneath it. The floor beneath the eggs inside the case does not reach the side walls, leaving a free passage to the chamber beneath.

but it was finished by 2 o'clock. The ends of the threads forming the floor were apparently fastened directly at either end to the previously completed roof, leaving a ridge or seam where the two joined.

When the case was thus far completed, she began egg laying. The roof was covered on the inside with a thick layer of loosely woven silk inclosing large open spaces. From this layer the eggs were suspended with their long diameters vertical, each egg held in place by a thin meshwork of silken threads, which were attached to the thick layer above and to one another and formed a continuous floor below the egg mass (fig. 2).

At 2.15 she stopped laying and, after removing her spinneret, swam about for a time, evidently resting. On returning to the case it required several efforts to replace her spinneret in the open end, but once adjusted she began to weave the triangular plate across the upper part of the open end, leaving below it a lunate opening (fig. 3). The plate was considerably thicker than the rest of the case and was fastened on the inside to the layer of loosely woven silk that covered the roof. Last of all she finished the mast, and while doing this she kept her wing covers separated enough to supply herself continuously with fresh air. The triangular plate and the mast were of the same bright yellow as the eggs and remained this color for several hours.

The whole process lasted only 1 hour and 20 minutes, and the actual time consumed in spinning and egg laying was exactly 1 hour. The completed egg case is ellipsoidal in shape, the roof and floor somewhat flattened, and the side walls strongly convex. One end is tightly closed and the other has a lunate opening beneath the triangular plate, which gives free access to the space beneath the egg mass. The triangular plate is narrowed above into the mast, which rises vertically about 10 mm. above the roof of the case and tapers to a rounded point. On cases found floating in the pond both the triangular plate and the mast are dark brown in color, almost black, due to the action of the sunlight upon the silk.

The mast has been represented as a small tube with dense walls, whose suggested function is the admission of air into the egg chamber. Miger and Lancret (1809, p. 442) said:

> It is a mistake to suppose that the turned-up point of the cocoon serves as a mast. It is not unlikely that the drawn-out point serves for the supply of air to the cocoon.

Lyonet (1832) confessed:

> I do not know the use of this little mast. Perhaps it enables the insect to get rid of an excess of silky matter.

Laker (1881, p. 82) wrote:

> The spike consists of a substance somewhat thicker and stronger than the rest of the cocoon and is hollow throughout the greater part of its length, except that it is crossed and recrossed inside with a dark, threadlike substance, thus somewhat resembling a horn stuffed with tow. The apex of the spike does not, however, appear to terminate in an orifice, but is closed. It does not seem to me that this spike can serve as a balance to the cocoon, because the nests are usually attached to some kind of support. I may, however, mention that I cut off the spike from two of the cocoons, and in both these cases the eggs did not hatch. It is, however, possible that this may have arisen from some other cause, although these particular cocoons appeared to be similar in every respect to others of which the eggs matured in due course. The cocoons from which the spikes were removed subsequently sank. These nests are so constructed that when floating loose the spike retains its proper position, and even if the cocoon be held so that the spike is parallel with the water, and then suddenly released, it immediately rights itself. If, however, the spike be partially submerged and then released, the cocoon turns bottom upward.

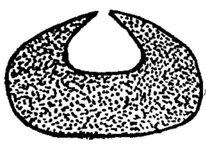

FIG. 4.—Cross section of mast of egg case, showing how the edges are rolled back to form an open tube.

In the six egg cases examined by the present author the mast or spike is not a tube at all, but a thick flat layer of closely woven silk, whose edges curl backward and almost meet along the side next to the body of the case. In this way a partially closed tube is formed, but there is a narrow slit running its entire length which manifestly disqualifies it from serving as an air tube (fig. 4). Furthermore, as Laker says, it is closed at the apex, and we may now add that it is also closed at the base, affording no connection whatever with the inside of the case. This fact does not seem to have been noted by any of these observers, but it disposes once for all of the supposition that the mast has anything to do with supplying air to the eggs.

Laker's suggestion that the eggs did not hatch in two of the cocoons because he cut off the spike may or may not be true, but evidently the immediate cause was the sinking of the cases, or "cocoons" as he calls them. The egg case must float at the surface of the water if the eggs are to develop properly. One of those obtained by the present author had sunk to the bottom of the pond, and although the spike and every other part was normal and intact, yet the eggs were undeveloped.

It seems reasonable to conclude, therefore, that the spike or mast, if it has any function, is concerned with floating the egg case and with keeping it right side up in the water, since both of these conditions are essential to the successful hatching of the eggs.

The number of eggs in a case varies considerably, but may be given as usually between 100 and 130. Garman (1881) found 107 eggs in the single case he examined, Matheson (1914) counted 112 and 130 in two cases, and the present author obtained 121 in one case and 117 in another. The larger end of the egg is next the roof of the case, the lower end being somewhat narrowed and also in the outer row of eggs considerably tapered on the outer side, as is admirably shown in the figures given by Miger and Lancret (1809).

When the eggs hatch, the larvæ issue from the lower ends and escape into the chamber beneath the egg mass. Here they crawl about for several (about 12) hours before venturing out into the open water.

THE LARVA.

On leaving the egg case the young larva is about 9 mm. long, measured from the tips of the mandibles to the tips of the posterior cerci. At first its color is an almost uniform light yellowish brown, but the dorsal surface quickly becomes darker with the exception of two irregular lines, one on either side of the median line and quite close to it, which extend from the anterior margin of the thorax to the tip of the abdomen. The outer sides of the light dorsal lines are accentuated with black on the thorax and darker brown on the first abdominal segments. On entering the pupal chamber these color distinctions are practically obliterated and the entire surface, dorsal and ventral, becomes a uniform brownish black.

The skin is densely clothed with short hairs, giving it a velvety appearance, and scattered among them are much longer hairs or setæ irregularly arranged. Along the lateral margins where the dorsal and ventral surfaces meet is a double ridge or fold of the skin, which stands out quite prominently. On the dorsal half of this ridge is a row of small papillæ, one and sometimes two on each segment. There are two other rows of similar papillæ, one on the dorsal and one on the ventral surface, close to the ridge. Each papilla carries a tuft of long setæ, varying in number from three or four to seven or eight. This double ridge remains light yellowish brown like the ventral surface until the final change when the larva is ready to pupate. Along the dorsal margin of this ridge on either side are the spiracles, but they are closed in the larva and take no part in respiration.

At the posterior end of the abdomen, opening dorsally upward and backward, is a deep transverse groove, from the bottom of which open the large longitudinal air tubes or tracheæ, by means of which the larva breathes. The anterior and posterior margins of this groove form a pair of lips, which can be opened or closed at will and thus control the breathing. The posterior lip extends diagonally upward and backward to the level of the dorsal surface of the last abdominal segment, but though it thus appears in a dorsal view it really belongs to the ventral surface. At its center is a narrow chitinous flap extending from the margin of the lip back along the outer surface (fig. 5, *fl*). The lateral edges of the flap are turned forward, giving it the shape of the letter U, and it forms the posterior or ventral cover of the anal opening. Inside of this flap the end of the intestine (*i*) projects a little from the floor of the groove and the anus (*a*) opens halfway from the floor to the edge of the lower lip. In front of the anus is a fingerlike papilla on either side, tipped with a long bristle. When the lips of the groove are closed, these papillæ (*p*) come together in front of the anus and form an anterior or dorsal cover for the anal opening. In this way the anus can operate when the lips are closed, and whatever passes out of it is kept away from the tracheal openings. The central portion of the anterior lip is also somewhat chitinized over a trapezoidal area extending from the edge of the lip forward along the dorsal surface the full length of the last segment.

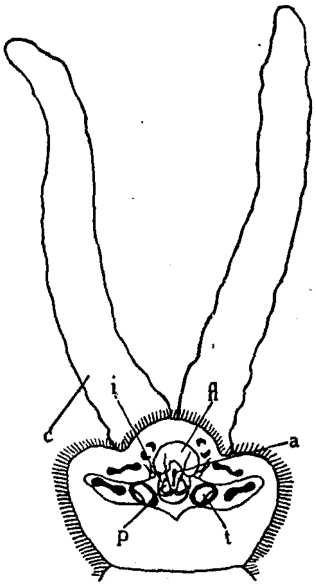

FIG. 5.—Transverse groove on dorsal surface of last segment of abdomen. *a*, anus; *c*, cerci; *fl*, chitin flap; *i*, intestine; *p*, papillæ; *t*, openings of tracheal air tubes.

On either side of the intestine, in the deepest portion of the groove, is the opening of the tracheal air tube (*t*), which is elliptical in outline, with the long diameter inclined at an angle of 45° to the body axis. Each opening is covered with a membraneous valve slit along the outer margin of the ellipse, which effectually closes the opening to the entrance of water.

On the ventral surface of the last abdominal segment are the cerci, two slender cylinders from 3 to 4 mm. in length in a full-grown larva and about 0.5 mm. in diameter. They are more or less wrinkled transversely and normally are naked, but often become covered with growths of algæ and Protozoa. There is no central lumen in these cerci, but the entire space is filled with tissue and contains many muscles. When the larva rises to the surface of the water to breathe, the cerci naturally flatten themselves along the surface film at right angles to the longitudinal body axis. This not only furnishes the larva with a secure hold upon the surface film, but it also opens the lips of the transverse groove and holds them open as long as the larva remains at the surface. When the hold upon the surface film is released, the cerci trail backward in the water and close the transverse groove. In front of the

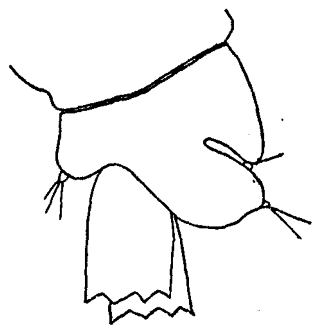

FIG. 6.—Side view of last segment of abdomen, showing depth of dorsal groove and the papilla on the ventral surface.

center of each cercus on the ventral surface of the last abdominal segment projects a short rounded knob, carrying on its tip a tiny papilla armed with a single seta (fig. 6).

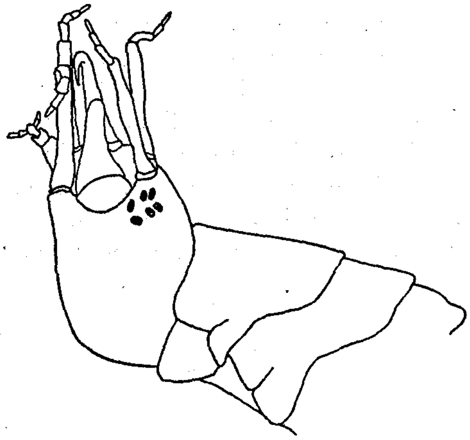

FIG. 7.—Side view of head, showing its inclination to thorax.

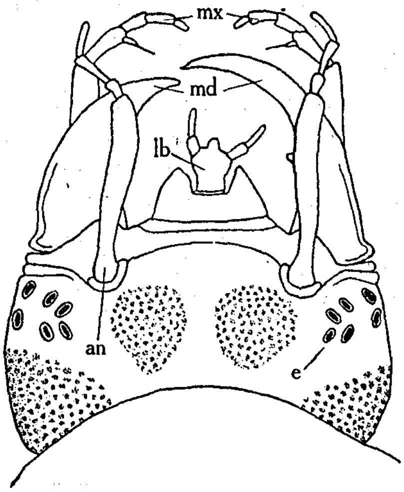

FIG. 8.—Dorsal view of head. *an*, antenna; *e*, eyes; *lb*, labium; *md*, mandibles; *mx*, maxillæ.

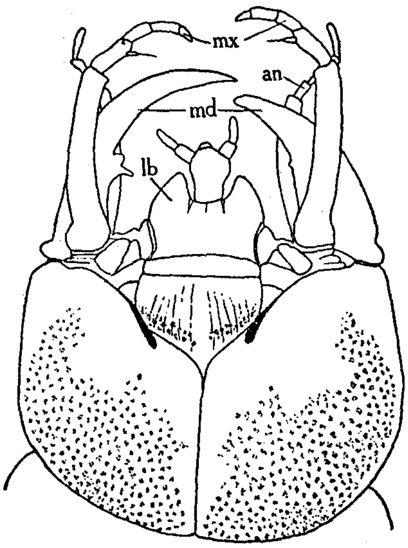

FIG. 9.—Ventral view of head. *an*, antenna; *lb*, labium; *md*, mandibles; *mx*, maxillæ.

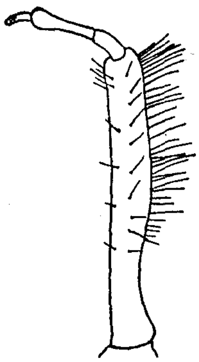

FIG. 10.—Dorsal view of left antenna.

HEAD.

The head has the form of an ovoid, flattened dorsoventrally, evenly rounded posteriorly, narrowed and squarely truncated anteriorly, and a little more convex on the dorsal than on the ventral surface, the latter being divided by a central longitudinal groove. The head is inclined upward at an angle of 30 to 45° with the body axis, and its outer surface is very hard chitin (fig. 7). It is brownish yellow in color, spotted with dark brown. On the ventral surface the spots cover the whole of the basal portion and extend forward in two long points on either side. There is also a narrow band of spots across the base of the lower lip. On the dorsal surface the spots cover the basal portion behind the eyes, and there is a large patch behind and inside of each antenna (fig. 8).

The eyes (*e*) are six in number on either side and are situated outside the bases of the antennæ and behind the mandibles. Each group of six is arranged in two transverse rows, somewhat concave toward each other like parenthesis marks. The interval between the two outside eyes is longer both longitudinally and transversely than between the two inside ones. Each eye is elliptical in outline, the long axes of the ellipses in the two rows inclined toward each other. The chitin integument over each eye is transparent, and beneath it can be seen the retinal pigment, which is uniformly black. In larvæ taken from the pupal chamber this

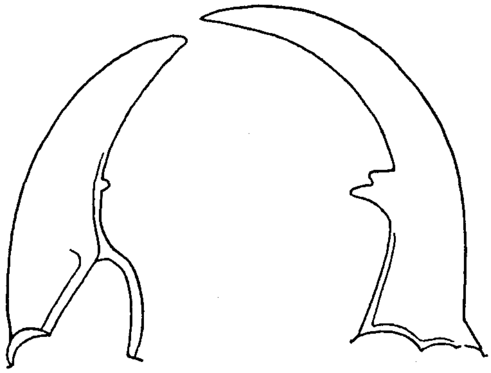

FIG. 11.—Dorsal view of mandibles.

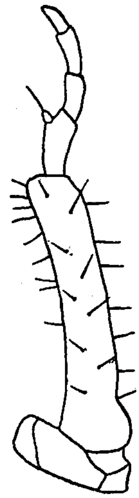

FIG. 12.—Ventral view of left maxilla.

black pigment entirely disappears, the eyes being apparently withdrawn preparatory to forming the compound eyes of the adult.

The antennæ (*an*, figs. 8 and 9) project from the dorsal surface of the head behind the inner corners of the bases of the mandibles. Each consists of a basal joint and three terminal joints, the former twice as long as the three latter combined and three times their diameter. The basal joint carries a fringe of long hairs along its inner margin and much smaller and widely scattered hairs over its entire surface. The three terminal joints are destitute of setæ and hairs (fig. 10).

MOUTH PARTS.

The mandibles (*md*, figs. 8 and 9) are not alike; the right one is always longer and more slender than the left, and the tooth on its inner margin is very much larger and bifid at the tip (fig. 11). Indeed, the tooth on the left mandible is hardly more than a small spine on the inner margin, and even that is sometimes wanting. The outer margin of the base of each mandible is flush with the lateral margin of the head, and the two mandibles shut down across the mouth like the blades of a pair of scissors, the right mandible being ventral to the left. In consequence of the wide interval between their bases the mandibles have no power of chewing, but can only bite or cut.

The maxillæ (*mx*, figs. 8 and 9) are a trifle longer than the antennæ and are attached directly below them on the ventral surface of the head. Each is apparently six-jointed, the basal joint very short and wide and the second joint twice the length of the four terminal joints combined and about twice the diameter of the third joint. The four terminal joints diminish regularly in length and diameter. On the inner margin of the third joint near the distal end is a small papilla, tipped with a single bristle. The second joint is covered with widely scattered hairs; the other joints are naked (fig. 12).

Matheson (1914, p. 342) said of this maxilla: "The cardo is greatly elongated, the lacinia being reduced to a mere joint. The palpus is three-jointed." It seems better to interpret the basal joint as the cardo, the second joint as the greatly elongated stipes, and the third joint as the palpifer. The three terminal joints then become the maxillary palp, while the subgalea, the galea, and the lacinia are represented by the tiny knob on the palpifer. This interpretation corresponds exactly with that given by Dimmock (1909, p. 13) for the larval maxilla of a Carabid beetle.

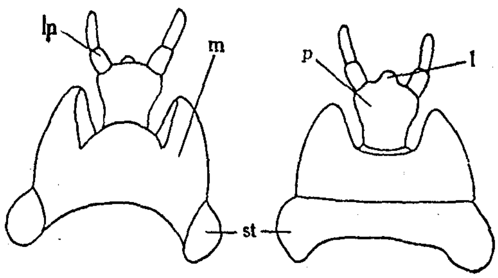

FIG. 13.—Ventral (left) and dorsal views of labium. *l*, ligula; *lp*, labial palp; *m*, mentum; *p*, palpiger; *st*, submentum.

The labrum or upper lip is cut squarely across between the bases of the mandibles and apparently renders but little actual service. The labium or lower lip, on the contrary, is well developed and plays an important part in feeding. The submentum is not visible in ventral view but is clearly seen from the dorsal surface. The mentum is prolonged into a triangular lobe on either side of the palpiger; the latter has a well-defined ligula and carries on either side a two-jointed labial palp (fig. 13).

THORAX.

The thorax is made up of three segments that increase slightly in width backward. The first one is longer than the others and has a well-defined transverse groove at about its center; the other two have only lateral indentations and short transverse wrinkles that do not form continuous grooves. The second and third segments each carry a pair of spiracles, but there are none on the first segment.

ABDOMEN.

The abdomen is composed of eight segments, the first one a little wider than the last thorax segment, the second wider still, and the remaining six decreasing regularly in width, the terminal one being only one-fifth the width of the second. At first the segments are smooth and free from wrinkles, but with advancing development transverse grooves begin to appear and increase until in the fully matured larva each segment has three or four secondary grooves, and it is very difficult to select the true intersegmental sutures.

There is a pair of spiracles on each segment, the anterior ones being larger than the posterior, with the exception of the last pair, which are much the largest of all. These open on the dorsal surface in the bottom of the groove already described and are the only ones that function during larval life.

LOCOMOTION.

The larvæ live in the water until ready to pupate and show two methods of locomotion, walking and swimming. The legs are strong, and in spite of the long abdomen the larva can crawl actively about over the bottom of the pond and even out in the open air. When endeavoring to escape impending danger, it moves with considerable rapidity, but hardly fast enough to be called running.

When pond 2E was drained, the Hydrous larvæ continued crawling about over the bottom for two days after the water had entirely disappeared. By that time the bottom had become so thoroughly dried that they could no longer find any shelter from the hot sun. One hundred or more were gathered and preserved, and probably all the others perished. During their endeavors to find shelter some traveled 100 feet, surmounting various obstacles in their way, such as stones, water-logged fragments of wood, and the débris usually found on the bottom of a pond. This shows that they can travel long distances, if necessary, when hunting for a suitable place to pupate, and the fact that they usually select a spot near the water's edge would indicate that the presence of moisture is the chief essential.

Swimming is accomplished by both leg and body movements. To increase the power of the legs as swimming organs, the femora of all three pairs have a fringe of heavy setæ along their outer margins, the tibiæ are strongly flattened and have a slightly heavier fringe along both outer and inner margins, and the tarsi are also flattened and have a very short fringe along the inner margin, each tarsus ending in a single long and stout claw. The body in swimming moves rhythmically up and down in a manner very similar to that of a leech; but the combined effort of body and legs produces only a slow progress, with frequent stops, and it is a very simple matter to catch these larvæ in a dip net

BREATHING.

The larva breathes air through the two tracheal trunks that extend the whole length of the body. So far as known there are no tissues or organs that extract air from the water. Hence it must come frequently to the surface in order to renew its air supply and is easily seen and captured at such times. When seeking fresh air, it swims almost vertically upward until close to the surface, then turns head downward and thrusts the posterior end of the abdomen and the cerci above the surface film. The cerci fall onto the surface film at right angles to the body axis, thus supporting the larva in position and at the same time opening the mouths of the air trunks. When it has finished taking in air, the tip of the abdomen is drawn beneath the surface film, thereby straightening out the cerci parallel with the body axis and closing the mouths of the air trunks. Fifteen to twenty minutes is the length of time which usually elapses between successive intakes of air. When the larva is resting, however, it frequently remains beneath the water for a much longer period. On the contrary, when actively feeding, the larva often comes to the surface and supports itself on water plants or something of the sort in such a position that the tip of its abdomen can remain constantly out of water.

FEEDING.

The prey is caught entirely with the mandibles, which seize it like a pair of forceps. While the larva moves about continuously in search of food, it can not be said in any sense to chase its prey, but is content with whatever it happens upon. Once within its grasp the prey is squeezed to death by the powerful mandibles, if that be possible. The carcass is then manipulated between the antennæ, the maxillæ, and the labium, being turned around, moved back and forth, and folded and unfolded as if it were between the tips of four fingers and a thumb. Every second or two the mandibles close down on it like a pair of scissors, mashing it, cutting or rending it asunder, and cramming it down the throat all in one movement.

When eating snails the procedure is somewhat different. The snail is seized by the mandibles and the head is thrown backward until the snail touches the dorsal surface of the thorax. It is then held between the head and thorax as in a vise and is very quickly crushed and eaten. The outlets of the ponds at Fairport had a cement wall on either side for 10 or 15 feet. These walls were often lined with small snails just above the water's surface and made a favorite hunting ground for the Hydrous larvæ. The latter swim or crawl along just beneath the surface until they see a snail. The head is then thrust above the surface and the snail is grasped between the mandibles and torn loose from the wall. The larva then reverses its body, the tip of the abdomen is thrust up into the air while the head, holding the snail, is carried beneath the surface. After the snail is consumed the larva reverses ends again and hunts for another. It sometimes happens that the snail gets a chance to set itself upon the wall after it is seized. In such cases the larva is often unable to tear it away and has to leave it and try another. But occasionally, either through design or accident, it comes back and tries the same snail again in a few minutes.

Some of the authors mentioned have commented upon the skill with which the larva extracts the snail from its shell. If the contents of the digestive canal are any evidence, the larva seldom extracts the snail at all but simply crushes the shell and swallows the shell fragments along with the body of the snail.

FOOD.

The accompanying table presents the results of the examination of the contents of the alimentary canals of 52 Hydrous larvæ. The lengths of the larvæ are given in millimeters, and they present a range in size from 20 to 61 mm., the last six in the table being fully grown and ready for pupation.

Food of 52 Hydrous larvæ taken from pond at Fairport, Iowa.

[The figures indicate percentages, the entire food being 100.]

Number of specimen.	Length of specimen in millimeters.	Snails: Physa and Planorbis.	Chironomus larvæ.	Chironomus pupæ.	Caddisfly larvæ.	Libellulid nymphs.	Erythemis nymphs.	Anax nymphs.	Damselfly nymphs.	Crayfish species.	Cypris species.	Daphnia species.	Hydrous larvæ.	Hydrophilus larvæ.	Berosus larvæ.	Philhydrus species, adult.	Haliplus species, adult.	Gyrinid larvæ.	Dytiscus larvæ.	Laccophilus species, adult.	Belostomid nymphs.	Tadpoles.	Fish.
1	20	20	80																				
2	22	60	40																				
3	25		100																				
4	28	30	70																				
5	28	20	50														10		20				
6	30	20	80																				
7	30	50	50																				
8	32		40			10																	50
9	32		100																				
10	33	100																					
11	35	10	15																				75
12	35	75	25																				
13	36	100																					
14	38	10	60																				30
15	38		40			50																10	
16	40	60	10														30						
17	40	15	10						25														50
18	40	50	50																				
19	42	10	30				10			30			10	5			5						
20	42																					100	
21	42	75	15																			10	
22	42		75	25																			
23	43	60	35	5																			
24	44	50	48					1															1
25	44	20	30								10												40
26	45	100																					
27	45		100																				
29	45	50	20																				30
30	45	60	10										10	10		10							
31	45	50	20																				30
32	45	60	35	5																			
33	45	70	30																				
34	46	100																					
35	46	55	20																25				
36	46	30	50	5	10					5													
37	46	50	50																				
38	47	60	35					5															
39	48	2	5		2										50			1	5				35
40	48	20	10		40																		30
41	48	40	40																		20		
42	50	5	25								10	10						50					
43	50	80	20																				
44	50	100																					
46	52	40	10										50										
47	54	100																					
48	55																	100					
49	55		100																				
50	60		20									2					10			20			48
51	60	20	20	5	10		5			5			20		10				5				
52	61	40		5		10			3		1	1		20		10					10		
Average	40.7	38.25	30.5	1.25	1.50	1.50	0.50	0.25	0.75	1.00	0.60	0.50	2.00	1.00	1.40	0.60	1.30	3.25	1.30	0.60	0.75	2.50	8.25

From a study of this table several facts stand out quite clearly.

1. The chief food of the Hydrous larva consists of snails and Chironomus larvæ; a mere glance down the first two food columns is convincing proof of this. Nineteen of the 52 specimens had eaten nothing else, 3 others had eaten only Chironomus pupæ in addition, and in 4 others these two foods constituted 90 to 98 per cent of the total eaten. In other words, half of the larvæ had lived entirely upon snails and Chironomus species. Only 2 out of the entire number are credited with having eaten none of these two foods. It is also worthy of note that 4 of those that had eaten nothing else were fully grown.

2. The young larvæ up to 30 mm. in length eat nothing beside these two foods except one another, for they are confirmed cannibals, and when first hatched, unless there is plenty of acceptable food, and sometimes even when such food is abundant, they eat one another voraciously until all but one are gone; and some of them keep up this cannibalism when they are fully grown, in proof of which witness the accompanying records of Nos. 19, 30, 46, and 51. By this means their numbers are greatly reduced and they are naturally held in check. On reaching a length of 30 mm. they begin to seek larger prey and attack other beetle larvæ, dragonfly nymphs, tadpoles, and small fish. By the time they reach 40 mm. in length their diet has become quite varied. Nos. 19, 30, 39, 42, 50, 51, and 52 show a very mixed diet and, especially the last two, probably ate everything they could capture.

3. They do eat fish and in considerable quantity; 10 of the 52 had eaten fish to the extent of 30 to 75 per cent of their total food, and there were a few fishbones in the intestine of another larva.

In judging the damage thus inflicted, however, we must remember several facts. First, all the larvæ examined were taken from this one pond which contained only young buffalo fish (*Ictiobus cyprinella*), the hatch of the year. These little buffalo fish ate some of the smaller Hydrous larvæ, and possibly these constituted as large a percentage of their food as they themselves contributed to the food of the larger larvæ; but there were no fish to keep down the full-grown beetle larvæ, as there would be in a pond containing both adults and young. Consequently, the contest between the fish and the beetle larvæ was one-sided and very much in favor of the larvæ. Again, the presence of thousands of these young fish in the confined area of a small pond gave the beetle larvæ another advantage. The fish were comparatively easy to catch, and there was abundant opportunity to prey upon them. Accordingly, the percentages here obtained are probably above the average and are certainly higher than would be expected in a pond containing adult fish as well as young. Furthermore, when the larva does eat fish there is enough for it to fill up on without eating anything else.

But after making due allowance for all these considerations the fact still remains that the Hydrous larva does eat fish when it has an opportunity, and therefore becomes a menace to successful fish raising in ponds. The methods to be used in guarding against this menace will be discussed later.

THE PUPA.

PUPATION.

When the larva is fully grown, it assumes a uniform brownish-black color, as already stated, there being no difference in shade between the dorsal and ventral surfaces. It then crawls out of the water and searches for a place to bury itself. The distance to which it travels varies considerably and may be from 2 to 8 or 10 feet from the water's edge. The selection of a spot apparently depends upon the consistency of the soil as well as upon its moisture content. Black clayey loam is preferred to sandy soil, but under compulsion almost any kind of soil will answer. Two larvæ were kept in an aquarium where nothing but clear sand was available, and in this they buried, pupated, and finally emerged without apparent inconvenience.

The larva uses its mandibles to some extent for digging, biting off chunks of earth and thrusting them to one side and backward; but the burrowing is mainly accomplished by thrusting its flattened head forward and then enlarging the hole by sidewise and up-and-down movements. After reaching a depth of 2 or 3 inches in this manner the larva begins a rotary movement of its entire body, swinging both ends horizontally around the longitudinal center as an axis. During this movement the head and tail are raised until the body assumes the shape of a crescent or semicircle, the ventral surface convex, the dorsal concave (fig. 14). As a result the pupal chamber when completed is subspherical in shape, the upper portion flatter than the lower, and is usually about 40 mm. in diameter. The smoothness of the walls depends in large measure on the consistency of the soil. When the soil contains the right amount of clay and moisture the walls are very smooth, but when the soil is sandy the walls are rough.

It requires 36 to 48 hours to complete this chamber, but after it is apparently finished the larva still keeps up its rotary motion at intervals until it is ready to pupate. Pond 2E was drained July 15. From its shores were obtained two pupal chambers, apparently just formed and containing larvæ. These were transferred to the laboratory and kept on moist sand. One larva pupated during the night of July 20 and the other during the night of July 23. Both kept up the rotary motion until the day before pupation; then they remained quiet, the head and tail being withdrawn from the sides of the chamber and curled over the back. Finally, the skin split along the back of the thorax; the head was withdrawn, leaving the hard chitinous covering of the larval head, with the antennæ, the cornea of the eyes, and the mouth parts intact; the abdomen was withdrawn, leaving the larval cerci in like manner intact; and the larva was transformed into a pupa.

After pupation the larval skin, with the head and mouth parts, was pressed into the earth on one side of the pupal chamber, and the pupa assumed its characteristic position. It may be noted that Lyonet (1832) said of the larva of *Hydrous piceus:*

> I therefore put it upon freshly turned-up soil, on which I scattered some grass. It made a hole, which it lined with grass, and remained within it several days in a curved position, lying on its back.

This lining of the pupal chamber with grass was probably accidental, some being carried in by the larva during its burrowing; but it is worthy of note that the larva remained in the chamber lying on its back and that the subsequent pupa rested also back downward. In our American species both larva and pupa rest upon the ventral surface.

DESCRIPTION OF PUPA.

The general form of the pupa is ovoid, narrowed to a rounded point posteriorly and strongly flattened dorsoventrally. In dorsal view the prothorax entirely conceals the head, which is folded down onto the breast, and the knees of the legs are just visible at the sides of the body, the first pair opposite the posterior margin of the prothorax, the second pair in contact with the first and opposite the groove between the pro and meso thorax, and the third pair opposite the posterior margin of the first abdominal segment. Only the bases of the elytra and wings are visible, the rest of them being carried around the sides of the body onto the ventral surface. In ventral view (fig. 16) all the body regions and their appendages are visible.

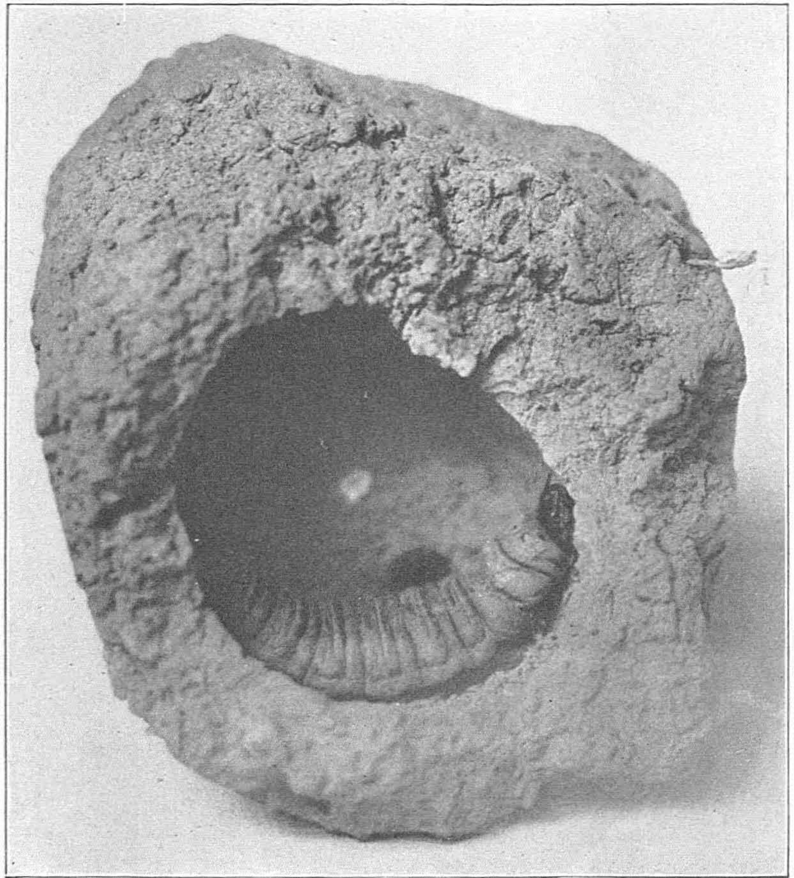

FIG. 14.—Photograph of larva inside the pupal chamber, showing characteristic position.

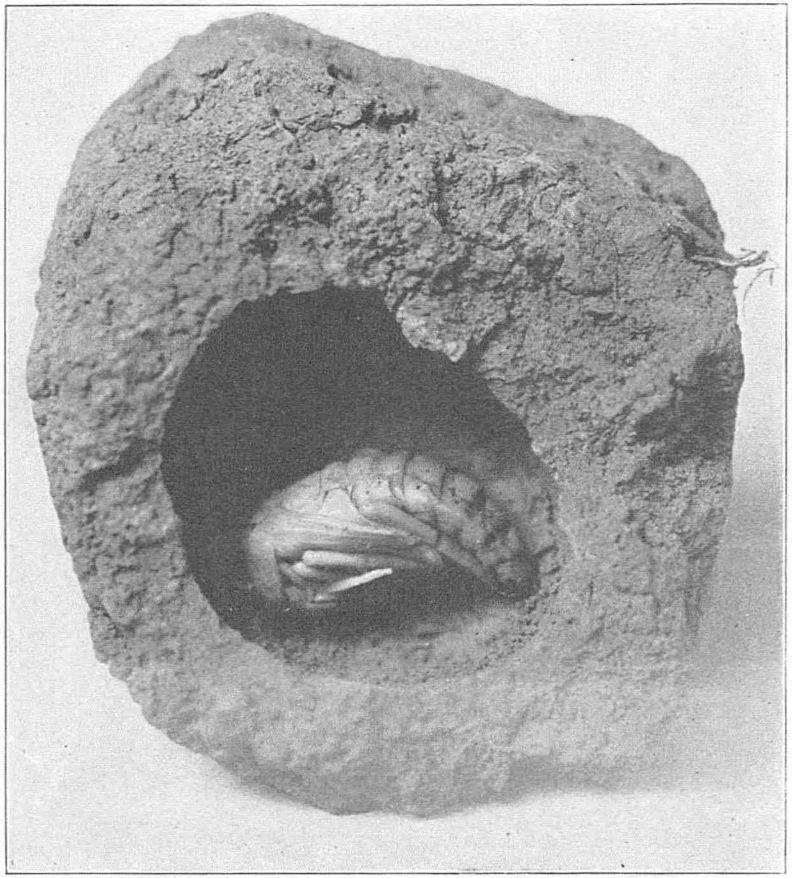

FIG. 15.—Photograph of pupa inside the pupal chamber, showing arched position, ventral surface downward.

The pupa is snow white throughout when first transformed, but the eyes begin to darken in a very short time, and then the various appendages, including the legs and wing pads, and finally the body itself, the color assumed being a reddish brown. Of a dozen pupæ obtained by the present author all were white when taken from the pupal chamber except one that transformed within 10 or 15 minutes. Four of them remained white on preservation, indicating that they had been formed but a short

FIG. 16.—Ventral view of pupa.

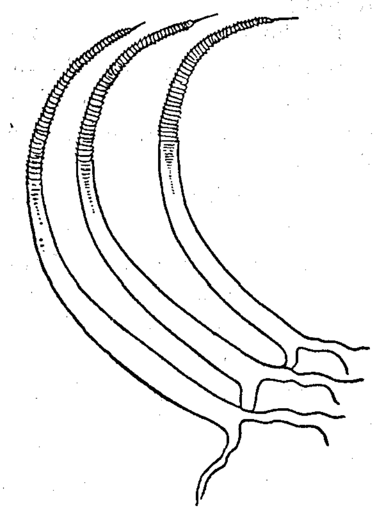

FIG. 17.—The three curved spines at an anterior corner of the pronotum.

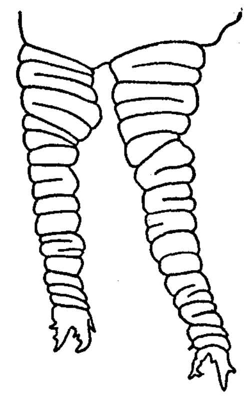

FIG. 18.—The posterior cerci of the pupa.

time. The others turned to various shades of reddish brown within 24 hours, the depth of shade probably varying with the length of time that had elapsed since pupation. Two of them became dark brown over the entire surface, approaching black in the eyes, the maxillary palps, the tarsi of the legs, and the last two joints of the abdomen. In one pupa this color was communicated even to the bases of the cerci and the large anterior spines. If the pupa is undisturbed in the darkness of the pupal chamber, it probably remains white until the pupa skin begins to separate from the underlying tissues preparatory to transformation. The pupa whose chamber was opened just as it was about to transform was dark gray-brown in color, but this color was in the skin, for the beetle that emerged was snow white.

The average total length of the pupæ was 35 mm., the greatest width at the third thoracic segment 15 mm., the thickness of the combined head and thorax 12 mm.; the posterior cerci were 4.25 mm. long and the anterior spines were 5.5 mm. long.

The head of the pupa is curved downward onto the chest, its anterior margin just reaching the bases of the second legs. This folding back of the head leaves the prothorax as the most anterior portion of the pupa. The eyes are partially concealed beneath the anterior corners of the prothorax, and just inside the center of each eye is a small spine. Elsewhere the head is smooth and its length is about equal to the width through the eyes. At the posterior margin of the head on the dorsal surface there is a small, transversely elliptical spot on either side of, and close to, the median line. The surfaces of these spots are depressed a little, especially on their posterior margins, and they turn much darker in color than the surrounding tissue. They entirely disappear in the adult beetle.

The antennæ, the mouth parts and legs, and the long posterior spine of the metasternum are encased in separate sheaths, the antennæ curved around beneath the eyes as in the imago and the maxillary palps extending backward ventral to all the other parts as far as the first abdominal segment. The articulations of the antennæ, the palpi, and the tarsi of the legs are distinctly visible in older pupæ. In the sheaths inclosing the legs there are separate branches for each of the large spines at the distal ends of the tibiæ.

Attached to the pupa case at each anterior corner of the pronotum are three curved styli 5.5 mm. long. They are reenforced at their bases by rootlike processes formed of folds of the pupa case, making them very strong. They taper gradually from the base to the tip, and the distal third is transversely ridged and terminates in a short and slender bristle (fig. 17). Around the posterior and lateral margins of the pronotum is a row of 12 short styli, similarly ridged for their entire length and each tipped with a bristle. On the dorsal surface of the second thorax segment is a pair somewhat larger, one on either side of the scutellum, and another pair on the third thorax segment. The dorsal surface of each abdominal segment except the last bears a transverse row of four similar styli. The two central ones are about the size of those on the thorax but the lateral ones are nearly as large as those at the anterior corners of the pronotum. The last segment of the abdomen bears a single pair smaller than any of the others and directed backward from its posterior margin just above the cerci. On the ventral surface of each abdominal segment from two to six, inclusive, close to either lateral margin is a single tiny stylus.

All these styli are ribbed for their entire length and tipped with bristles. They are also a part of the pupa case and are left behind with the case in the pupal chamber when the beetle emerges. Their use is thus explained by Lyonet (1832), who reared the larvæ of the European species *piceus:*

In the damp earth which the pupa requires the hooks fullfil a purpose of great importance. The skin of the pupa is very delicate. Lying on damp earth it could hardly escape injury, and the weight of the body might easily give it a distorted shape; but the pupa protects itself from these dangers by assuming an unusual attitude. It extends itself back downward in a horizontal position and supports the weight of its body by the three sets of hooks as upon a tripod. In this attitude, though surrounded on all sides by moist earth, it keeps its body from actual contact with any object until it has assumed its final shape.

These observations on the attitude of the pupa and the use of the hooks were confirmed later by Miger and Lancret (1809), and are quoted by Miall (1895, p. 73). They may be true of the European *H. piceus*, but the American species here described certainly rests in the pupal chamber with the back uppermost, as noted by Matheson (1914, p. 343).

Furthermore, the body is strongly curved upward instead of being horizontal, so that the central portion is lifted still farther above the floor of the chamber (fig. 15). The reason for this, as well as another use for the spines, was revealed on digging out some of the pupæ just after a heavy rainstorm. Two of the pupal chambers were found partly flooded with water, but the pupæ, resting upon their spines, with their backs strongly arched, had thereby kept their spiracles well above the water and so prevented drowning.

The scutellum stands out prominently on the dorsal surface of the second thorax segment, the elytra being drawn away from it onto the ventral surface. These elytra pads each show four distinct longitudinal ridges beside the two margins, with broad intervening furrows. The pads of the true wings are smooth. These four pads are apparently fastened in position by being cemented to the outside of the pupa case, and also to the outside of the cases covering the second and third legs. In only one instance was this cement loosened after preservation in alcohol.

At the posterior end of the last segment is a pair of large cerci 4.25 mm. in length. Each is cylindrical, considerably enlarged at the base for a third of its length and then abruptly narrowed and of the same diameter for the rest of its length. Both portions are transversely wrinkled, and the tip is armed with a short bipartite claw, one or both of the rami being often toothed (fig. 18). These cerci are also part of the pupa case and are left in the pupal chamber when the beetle emerges. They are muscular, with considerable freedom of motion, and evidently serve the pupa partly as false legs for support in connection with the anterior spines and partly as a means for adjusting its position in the chamber. If a pupa is inverted in the pupal chamber, it can right itself by means of convulsive movements of these cerci, together with the posterior abdomen, the latter supplying the muscular power and the cerci furnishing the point of leverage with their sharp claws against the walls of the chamber. If the pupa is disturbed, it simply kicks itself about vigorously, using the abdomen and cerci in the same manner.

It is worthy of note that all the hydrophilid pupæ formed in earth chambers are similarly provided with cerci, although these differ in structure in the various species.

During the transformation from the larva into the pupa the mode of respiration is changed. The larva breathes through the posterior openings of the tracheal trunks, as already described, but these disappear in the pupa and in their place fully developed spiracles appear along the sides of the thorax and abdomen, as in the adult beetle. These spiracles open to the exterior through the pupa case, and hence the pupa not only breathes through them but if it is submerged under water it drowns, having no provision for keeping them covered with a film of air like the adult beetle. (See p. 30.)

The length of time spent in the pupal chamber varies considerably, but averages from two and a half to three weeks. This period is divided as follows: From 5 to 8 days are passed by the larva after the pupal chamber is completed and before pupation; from 7 to 12 days are passed in the pupa state; and 4 or 5 days are spent by the adult beetle after transformation before it emerges. The table below gives these periods for four beetles that were under observation continuously.

Periods spent in pupal chambers by four beetles.

Number of specimen.	Completion of pupal chamber.	Pupation.	Transformation.	Emergence.
1	July 15	July 20	July 27	July 31
2	..do.....	July 23	Aug. 3	Aug. 7
3	July 16	July 22	Aug. 2	Aug. 6
4	...do.....	July 23	Aug. 4	Aug. 9

THE ADULT BEETLE.

A pupa was dug up on July 27 that was just ready to transform, and the adult beetle crawled slowly out of the pupa case while being watched. At the instant of transformation the entire body was white, but in the sunlight to which it was exposed the head, prothorax, scutellum, and legs became a rich mahogany red even before it had entirely gotten out of the pupa case. The elytra became light salmon pink; the wings and abdomen remained white. The color first appears on the wings as a faint salmon pink along the ribs and veins, which gradually deepen to a reddish-brown. The web of the wing slowly loses its bleached-white aspect, but remains colorless, of course, even in the matured adult.

The elytra stretch to their full size almost instantly on being set free from their pads, and in the course of an hour become dark reddish-brown. The abdomen remains white longer than any other portion of the body—several hours, in fact—then gradually turns reddish-brown. The color appears first on the ventral surface along the central carina and the sutures between the segments, and gradually spreads in all directions. On the dorsal surface the last and smallest segment is colored first, then a faint line appears along the center, which slowly spreads outward on either side. The beetle above mentioned came out of the pupa case about 10 a. m., and by the next morning it was entirely black on the upper surface, while the under surface still remained a dark mahogany brown.

This rapid change of color was not due wholly to the influence of the sunlight, for the first beetle on the list just given, which transformed during the night of July 27, was entirely black on the upper surface the next morning, and it had remained in the darkness of the pupal chamber all the while. The fourth beetle on the list was taken out of its pupal chamber several times, but would not remain in the light and returned to the chamber. On August 9 it came out voluntarily and did not return again. The final color of the adult beetle is a rich olive black, very shiny above and piceous beneath, while the antennæ, palpi, and tarsi are a deep mahogany brown, often black.

EXTERNAL CHARACTERS.

The adult beetle has the outline of an elongated oval, 34 to 40 mm. long and 15 to 16 mm. wide. The thickness of the thorax is 8 to 9 mm. The dorsal surface is not as convex as in the species *ovatus*. The prosternal prominence, into which the front end of the sternal spine fits, is closed in front, and there are more or less distinct triangular yellow spots along the ventrolateral margins of the abdomen. These color spots are more distinct on the second, third, and fourth segments than on the others and are partly due to the fact that the skin is here pubescent and partly to a lighter color in the skin itself.

This genus is distinguished first by its size, the species being fully twice as large as any other North American hydrophilid. Then, the last four joints of the nine-jointed antennæ are of peculiar shape and form a distinct club. Along the center of the ventral surface of the thorax there is a continuous ridge that projects in front into the prosternal prominence already mentioned and is prolonged behind into a large, acute spine. The tarsi of the middle and hind legs are strongly compressed and fringed with hairs, making powerful swimming organs.

The pro, meso, and metasterna, the coxæ of all three pairs of legs, the trochanters and bases of the femora of the first legs, and all of the first segment of the abdomen are covered with a dense yellow pubescence, becoming blackish in older specimens. This serves to hold the air film that covers the ventral surface when the beetle is under water. The scutellum is almost an equilateral triangle, the base being scarcely shorter than the sides. Each elytron has four rows of coarser punctures, the outer row being double, and there is an additional partial row along the distal portion of the sutral margin. Between these the surface is covered with minute wrinkles and finer, scattered punctures. There are also scattered punctures along the base of the upper lip, on the lateral margins of the head in front of and inside of the eyes, along either side of the mid line of the head, on the lateral margins of the pronotum, and in an oblique line on either side extending from behind the eyes backward and inward and not quite reaching the center. There is no definite arrangement of the punctures at any of these places, but they are very distinctly visible.

ANTENNÆ.

These are attached just in front of the eyes and curve around below them, being concealed in dorsal view. They are nine-jointed; the basal joint is longer and wider than the four that follow it and is curved. The second joint is one-fourth the length and three-fifths the width of the basal joint; the next three joints are the same size, half the length, and the same width as the second joint. The sixth joint is deeply bilobed; the ventral portion is enlarged and flattened into a spoonlike lamina, which extends outward beneath the seventh joint and covers all of it except the very tip; the dorsal portion is a short fingerlike process. Each of the seventh and eighth joints has a long process arising from its anterior margin and curving upward and backward. These two processes and the dorsal lobe of the seventh joint are tipped with tufts of long, coarse hairs. The ninth segment is flattened into a lamina with rounded angles, which is curved upward and backward, like the processes on the preceding joints, and has a fringe of short hairs. The surfaces of these last four joints are uniformly covered with a pile of short hairs that can not be wetted by water (fig. 19). According to Miall (1895, p. 81):

FIG. 19.—Right antenna of adult beetle.

> The antennæ are used only for breathing by the submerged insect. Their place as feelers is supplied by the long and forward-directed maxillary palps.

MOUTH PARTS.

The mandibles are fully as powerful in the adult as in the larva. Each consists of a single chitin sclerite, curved into a clawlike tip, which is bifid and armed on the inner side with three long and stout teeth; the distal tooth is tripartite at the tip, the other two are bipartite (fig. 20).

Each maxilla is made up of two basal pieces and three outer parts with their subdivisions. The portion that joins the head, the cardo, is somewhat trapezoidal, narrowed and emarginate proximally, widened and armed with a fringe of hairs distally. The stipes is jointed to the cardo almost in a straight line and serves as a support for the outer parts. The palpifer at the distal end of the stipes is short and cylindrical; the maxillary palp attached to it is four-jointed, slender, and cylindrical, the terminal joint shorter than the second and third joints and neither enlarged nor flattened. To the outer margin of the stipes is attached the subgalea, which is deeply emarginate at its proximal end, while at its distal end is hinged the two-jointed galea, each joint about the same length and width. The lacinia on the outer margin of the subgalea is heavily fringed with hairs and carries a long fingerlike digitus (fig. 21).

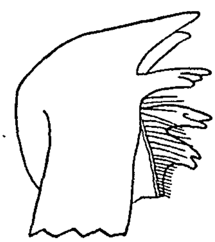

FIG. 20.—Ventral view of mandible of adult beetle.

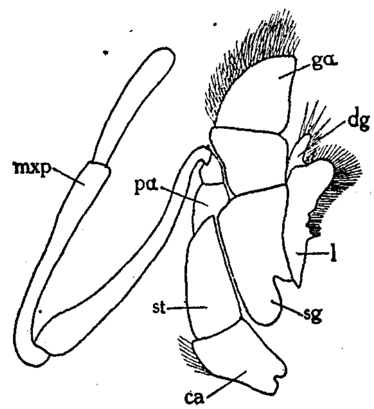

FIG. 21.—Ventral view of right maxilla of adult beetle. *ca*, cardo; *dg*, digitus; *ga*, galea; *l*, lacinia; *mxp*, maxillary palp; *pa*, palpifer; *st*, stipes; *sg*, subgalea.

FRONT TARSUS OF MALE.

The last joint of this tarsus is as long as the other four joints, oval in outline and strongly flattened. The dorsal claw is very long and stout, while the ventral one is much reduced in size. Along the inner margin, behind the bases of the claws, is an elliptical area whose ventral surface is covered along its margins with rows of tiny suckers, like those on the tarsi of the male Dytiscus, but much smaller. Those at the distal end of the area are tipped with stiff bristles, the others are naked. A long papilla extends outward from the distal end of the area between the bases of the two claws and is tipped with a tuft of stiff bristles. Another papilla, also tipped with bristles, is found on the ventral surface of the joint near its outer margin, behind the base of the small ventral claw (fig. 22).

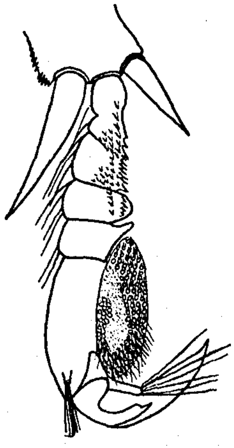

FIG. 22.—Tarsus of front leg of adult male beetle.

FOOD.

Miall stated on the same page quoted above (1895, p. 81), "the food of the adult Hydrophilus is largely vegetable, but it will prey upon small aquatic insects." He kept four specimens in an aquarium with plenty of vegetation but no animals larger than Daphnia, and they remained perfectly healthy. Similarly, the present author placed in an aquarium with plenty of vegetation but no animal food two of the beetles that had been reared from pupæ. They lived for three weeks and appeared perfectly healthy, eating up the water plants every two or three days. Under natural conditions, however, the adults also eat animal food and sometimes kill and eat fish. The female that spun the egg case described on page 10 celebrated the completion of her task by killing and eating a small buffalo fish that happened to be in the aquarium. It is quite possible that out in the pond where other animal food was abundant she might have chosen something else; but since there was an abundance of fresh plant food in the aquarium, which she passed by, she evidently craved something containing proteids. The adults sometimes congregate in large numbers and would then become a serious menace if they should choose to attack the young fish. In fact, the adult, although it feeds largely upon vegetation and may live and apparently thrive for a long time without other food, nevertheless stands as a constant potential menace to the breeding of fish.

RESPIRATION.

The mode of respiration of the adult Hydrous is peculiar. It was first correctly described by Nitzsch (1811, pp. 440–458; Pl. 9) and afterwards in greater detail by Miall (1895, p. 75). This latter account agrees in every detail with that observed by the present author in the American species and may be summarized as follows:

In the adult beetle there are two pairs of thoracic spiracles and seven pairs of abdominal spiracles. Those on the meso and metathorax and the anterior abdomen segments are considerably larger than the others, and it is through these that respiration chiefly takes place. The space between the elytra and the dorsal surface of the body is filled with a large flattened bubble of air. On the under surface also the hairy tracts already noted on the thorax and first abdominal segment and on the sides of the other abdominal segments retain a film of air. This film joins the dorsal air bubble at the groove between the pro and meso thorax and along the margins of the elytra. The spiracles open into this combined air supply, the larger ones being nearer the groove just mentioned.

When the Hydrous wishes to renew its air supply, it does not thrust the posterior end of the body out of the water as does Dytiscus. On the contrary, it assumes a position approximately parallel with the surface of the water and inclines the body sidewise, so as to bring the angle between the head and prothorax on one side above the surface. At this angle a funnel appears leading to the air film on the thorax below. At the same time the antenna on this side is moved outward. Its four enlarged terminal joints lie in the air film beneath the overhanging edge of the prothorax and in the space between the prothorax and the head. These joints are fringed with long bristles and covered with fine short hairs, which can not be wetted by water. Hence, when they move outward the air film is carried along with them, clinging to the hairs and bristles. As soon as any part of these unwetted joints comes to the surface of the water the air film breaks and a passage is thereby opened through the funnel from the outside air to the air film on the ventral surface of the thorax. The terminal joints are drooped downward at an angle with the rest of the antenna, and the air passage is thus inclosed between the hairy side of the thorax and the vertically arranged antennal joints, also covered with hair. The size of the opening is determined by the distance to which the antennal joints are carried from the side of the body. The vitiated air is expelled and the fresh air drawn in by rhythmical movements of the abdominal segments and the elytra.

Especial attention is called to the fact that the air enters and leaves the dorsal bubble only by way of the air film on the ventral surface of the thorax and is never taken directly into the space beneath the elytra.

ECONOMIC RELATIONS.

Having shown that both the larvæ and adults are a considerable menace to young fish and having gained a fairly complete knowledge of the life history of this beetle, its relations to pond fish culture may be discussed more intelligently.

RELATION TO VEGETATION.

The kind as well as the amount of vegetation in a pond is of great importance. Both the adult and the larva of Hydrous use various water plants as a hunting ground from whence to obtain their food, as a hiding place to escape their enemies, and as a means of reaching the surface to obtain oxygen. The adult beetle also feeds upon living plant tissue, and the female attaches her egg case to floating leaves or bits of dead vegetation. Accordingly, the inference would be that the greater the amount of vegetation in a pond the better it would be adapted to the breeding of these beetles, but this does not prove to be true. The adults seem to manifest a decided choice in the kind of vegetation and are easily discouraged by a superabundance, and of course the eggs are laid and the larvæ are developed wherever the adults may choose.

The four ponds of series E are as nearly alike in all their relations as possible. However, No. 1 was covered during the summer of 1918 with an abundance of blanket algæ, largely Hydrodictyon, while there were only floating patches along the shores of the other three ponds. No Hydrous beetles, larvæ, or pupæ were found in or around pond No. 1, although diligent search was made for them; in the other three ponds they were very abundant. The banks of earth separating ponds 1 and 2 and 2 and 3 are as nearly alike in size, height, and vegetation as could be desired. And yet when pond No. 2 was drained and the adult beetles were compelled to seek shelter elsewhere, almost without exception they went to pond No. 3 and not to pond No. 1.

Again, in series F pond No. 1 was not disturbed in 1918, while ponds 2 and 3 were drawn and cleared of water plants. In consequence pond 1 was carpeted with a dense growth of *Elodea canadensis*, excluding almost everything else, while ponds 2 and 3 contained only small amounts of vegetation. Repeated searching failed to discover a single hydrophilid or dytiscid beetle in pond 1, although there were plenty of haliplids, but they were all abundant in ponds 2 and 3, although only a few of the genus Hydrous itself were obtained.

In series D, ponds 1, 3, and 6 were filled with water plants in 1918, 1 and 6 containing abundant blanket algæ, while 3 was entirely carpeted with Naias and Potamogeton. Beside the Haliplidæ almost no beetles were obtained from these three ponds, while in ponds 2, 4, 5, and 7 other families were abundant both in species and in actual numbers.

From these data it would seem fairly conclusive that the adult beetles both possess and exercise a definite choice of habitat; and though a moderate amount of water vegetation may prove attractive it is possible to have too much, and thereby repel the beetles. Hence, if the fishpond be kept abundantly supplied with water plants there will be little danger from Hydrous; it will not breed in sufficient numbers to become a menace.

RELATION TO FERTILIZATION.

In order to secure the propagation of small Crustacea, insect larvæ, and other minute organisms in great numbers as food for young fishes, various organic fertilizers have been used. Our knowledge of the economic importance of these fertilizers, and especially of the relative value of the different kinds, is still very rudimentary and incomplete. We do know, however, that by placing well-rotted manure in a limited amount over the bottom of a pond that has no appreciable current running through it the supply of animal food for young fishes will be greatly increased. An experiment of this nature was conducted in pond No. 2E during the season by H. W. Clark, of the Fairport staff. The pond was drained, manured, and refilled in May. The fact we wish to note here is that the presence of the manure proved attractive to beetles, especially the Hydrophilidæ, as well as to other insects and Crustacea. When the pond was drained in July, it proved to be literally swarming with beetle larvæ and adults, while the pupæ were equally abundant around the shores. In all, 15 species of beetles were obtained from this one small pond, an eighth of an acre in area, with the larger genera, Hydrous, Dytiscus, and Hydrophilus in especial evidence. All the material for the present paper was secured here, and in addition an abundance reserved for future use. It would seem, then, that if fertilizers are used to increase the food supply the fish breeder must be prepared to find also an increased number of these obnoxious beetles.

ENEMIES OF THE EGGS.

The eggs are so well protected in their floating silken case that they are seldom destroyed. Sometimes, however, the egg case gets overturned by being driven into the rushes and other water plants along the shore during a high wind. Apparently this is fatal to the hatching of the eggs. Two such overturned egg cases, with dead eggs partially developed, were found on the shores of pond 2, series E. It is not probable, however, that this accident occurs with any frequency, the cases being so well balanced that it is difficult to overturn them.

Again, the Ichneumon flies, which work such havoc with the eggs of many other water insects, seem unable to get at the eggs of Hydrous. This is apparently due to the density of the triangular plate that covers the upper, exposed part of the open end of the case and also to the thick layer of porous silk that lines this plate and covers the top of the egg mass, the only points from which the flies can get access to the eggs.

ENEMIES OF THE LARVÆ.

The Hydrous larva is its own worst enemy, and a very generous percentage of larvæ hatched are eaten by their brothers and sisters. This is especially true if an abundance of attractive food is not forthcoming at the time of hatching, and it continues to operate during the entire life of the larva. Referring to the table already discussed (p. 21), the fact may be emphasized again that they often eat one another voraciously until all but one are gone. By this means alone, therefore, they will be kept within certain bounds, for as soon as there is any danger of overproduction other food becomes scarce and they fall to eating one another. It is hardly too much to say that this cannibalistic habit is the salvation of the other insect denizens of the fishpond. Otherwise they would have very little chance in the struggle for existence.

Certain of the dragon-fly nymphs, especially those of Anax, Aeschna, and the larger Libellulids, eat Hydrous and Dytiscus larvæ. This has been discussed in a previous paper upon the economic relations of the dragonflies (Wilson, 1920, p. 201).

The common bullfrog must be reckoned as a possible enemy of the Hydrous larva. Dyche (1914, specimen No. 129, p. 153) examined the stomach of a large bullfrog, which contained "a larva over 2 inches long of a water beetle." This may have been either Dytiscus or Hydrous, it is not stated which, but if the frog can eat one it can eat the other, and in all probability it does so occasionally.

Several of our common fishes, notably the green sunfish (*Lepomis cyanellus*) and the bluegill (*Lepomis pallidus*) are fond of Hydrous larvæ and frequently eat them. This has already been noted by Forbes (1888), and his observations have been confirmed at Fairport, the exact data being reserved for future publication. On many occasions during the summer seasons of 1917 to 1921 the author threw full-grown Hydrous larvæ either into pond 6, series D, which is stocked exclusively with adult large-mouthed black bass, or into one of the tanks in the tank house, where specimens of the same bass are often kept under experimentation. In every instance the larva was instantly seized and swallowed, sometimes almost before it struck the surface of the water. This indicates that not only do these fish eat the larvæ when they can get them, but that the larvæ ought to make successful bait when fishing.

ENEMIES OF THE PUPÆ.

It might seem at first sight that the pupa was admirably protected by being buried in the moist earth, but even there it is subject to certain dangers. The first of these is from ants. Two pupæ were unearthed in July that were half eaten up by small ants, which literally filled their pupal chambers. Of course, a larva when ready to pupate will seldom choose an ants' nest in which to form its pupal chamber, and it will not often happen that ants drive one of their galleries into a pupal chamber after it is formed; but the finding of these two half-eaten pupæ shows that this does happen occasionally, and the larger the number of ants along the shores of a pond the greater are the chances of its occurrence.

Another and much more serious danger for the pupa lies in a change in the moisture content of the earth in which the pupal chamber is built. If the amount of moisture in the soil is greatly changed in either direction, it is likely to prove fatal to the pupa. If it be raised excessively, then the chamber will be flooded and the pupa will be drowned. It is to guard against this very accident that the pupa skin is provided with the long curved spines described on page 24, while the pupa also arches its body strongly upward in order to lift the spiracles above any ordinary flooding. However, the pupal chamber is never far from the water's edge, and any continued rise in the water will flood it so completely that these safeguards will no longer avail. Two pupal chambers on the shore of pond 2, series E, were filled with water, and as a result the two pupæ they contained were drowned within a few minutes.

On the other hand, the soil that was moist enough when the larva began its pupal chamber may become baked and dried by the time the adult beetle is ready to emerge, and the latter may thus become imprisoned and unable to get out. The abrupt draining of this same pond 2, series E, caught some beetles in just this way. As long as the water remained at its normal level the soil would have continued soft and moist; but when the water was entirely removed the hot sun soon dried and baked the mud so firmly that the adult beetles were caught and imprisoned in the pupal chamber. Two were found thus imprisoned on August 12. They were alive and vigorous and would possibly have remained so until released by the resoftening of the earth after the pond was filled again. Similarly, a piece of moist earth from the pond shore containing three pupæ of Berosus, another hydrophilid genus, was brought into the laboratory July 16. It was not known at the time that it contained these pupæ, and after it had served its purpose it was allowed to become dry and hard. When thrown out on August 15, it broke and revealed three live adult beetles, which could never have escaped through their own efforts.

In The Canadian Entomologist for January, 1894, Ashmead published the descriptions of two new hymenopterous parasites from water beetles. These had been reared by H. F. Wickham—one from the pupa of a Gyrinus species and the other from the pupa of *Dineutes assimilis*. Similarly, half a dozen hymenopterous larvæ were obtained from a Hydrous larva just as the latter was about to pupate after remaining several days inside its pupal chamber. Evidently some hymenopter had succeeded in laying its eggs in this larva while it was hunting for a suitable spot for its pupal chamber. The eggs had hatched into maggots and these were busy devouring the tissues of the beetle larva. It is doubtful whether this larva would have been able to pupate, but even if it did the maggots would have continued their destruction and there would not have been enough of the pupal tissues left for the final transformation into the adult beetle. These Hydrous larvæ usually escape such attacks, because of the shortness of the interval between coming out of the water and burrowing into the earth, but evidently they do get caught sometimes.

ENEMIES OF THE ADULT BEETLES.

Dyche (1914, p. 149) has stated that the common bullfrog is especially fond of the larger water beetles, Hydrous and Dytiscus. Thirty frogs were captured from the ponds on the State hatchery grounds near Pratt, Kans., in April, 1910, and their stomach contents were examined. No effort was made to distinguish the two genera of beetles from each other. Twelve of the frogs had eaten these beetles, and amongst them had consumed 27 specimens, over two apiece. Another large frog captured the following year contained four of these beetles (p. 155). Dyche added that more than half the food mass of frogs taken from natural lakes and ponds in Kansas was frequently made up of insects, and that these large water beetles usually formed a considerable percentage of such insect food. Unfortunately the bullfrogs also eat many small fish and hence could not be utilized to keep down the beetles.

Two little green herons were shot on one of the fishponds August 10. On examining their stomachs the remains of adult Hydrous beetles were found in one of them.

McAtee and Beal (1912, pp. 19 and 24) stated that various beetles, chiefly aquatic, compose 23.3 per cent of the food of the horned grebe (*Colymbus auritus*), and that the black tern (*Hydrochelidon nigra surinamensis*) feeds extensively on dragon-fly nymphs, dytiscid beetles, and crawfishes. A bird that eats dytiscid beetles eats also hydrophilid beetles in all probability, and it is reasonable to suppose that other water birds, with reference to whose food we have no data, eat these beetles in considerable quantities.

During the seasons when the beetles migrate from one locality to another they are often attracted by the electric lights in large towns and cities at night and can be found in the morning upon the pavement or earth beneath. Blatchley (1910, under *Hydrophilus triangularis*, p. 255) said: "Sometimes attracted by thousands to electric lights in Indianapolis and the larger cities."

William J. Gerhard, of the Field Museum of Natural History of Chicago, has records (unpublished) of the finding of Hydrous and hydrophilids under the electric lights of Chicago before the use of arc lights was discontinued 10 years ago. These records show that the finding of Hydrous in varying numbers was a regular occurrence every spring toward the last of May, and when we remember the other large cities which are as favorably situated as Indianapolis and Chicago we are impressed with the magnitude of this agent of destruction. It must cause the death of almost unbelievable numbers of these beetles every year.

Under certain conditions, particularly in early summer, large numbers of insects are sometimes found along the shores of the Great Lakes. Needham has published a paper on this subject in The Canadian Entomologist for 1904, but he failed to mention any of the large water beetles as being destroyed in this way; but Carl L. Hubbs, of the Field Museum at Chicago, noted May 20, 1917, on the beach near Winnetka, Ill., amongst a similar lot of insects a hundred or more *Hydrous triangularis* (unpublished records). These insects had been washed ashore after a storm, but it was not ascertained definitely whether they were all dead, although it is probable that most of them were. Evidently this is another way in which numbers of these beetles may be destroyed yearly. Cinnamon teal, pintail, and wood ducks were recorded by D. C. Mabbott (1920, p. 62) as eating species of adult Hydrous beetles, but not in sufficient numbers to make them serious enemies.

GENERAL SUMMARY.

Both sexes of *Hydrous triangularis*, in the larval as well as the adult stage, feed upon fish fry whenever conditions are favorable, and thus may become a serious menace to pondfish culture. If adult fish are kept in the same pond with the fry, it is not probable that the beetle larvæ will more than hold their own. Many adult fish, notably the sunfishes, eat Hydrous larvæ and thus keep them within due bounds; but if the fry are placed in a separate pond, and especially if any effort is made to increase the supply of natural food, precautions against the beetles may become necessary.

There are several ways in which the beetles may be checked. If the pond is thickly carpeted with such water plants as Naias or Potamogeton, or is plentifully supplied with blanket algæ, duckweed, or *Elodea canadensis*, the danger from these water beetles will be greatly diminished; but this kind of vegetation is not altogether desirable in such quantity.

The mating season of the adults comes about the last of May, and at that time both sexes fly about at night in considerable numbers. If a trap lantern be constructed according to any of the standard patterns close to the shore of the pond and be furnished with a light for two or three weeks at that season, it is probable that many of the adult females could be caught before they began to lay eggs, and in this way the larvæ could be reduced in numbers.

Again, if the pond be raised 15 or 20 inches for two or three hours once a week during July and August when the larvæ are pupating, the pupal chambers will be flooded and the pupæ will all be drowned. This reduces the number of adults, and there are not as many to produce larvæ; but it is a precaution against the future rather than a remedy for the present.

When full-grown larvæ actually appear in sufficient numbers to menace the fish fry, they must be removed at once, if the remedy is to be effective. The best and practically the only way to do this is to drain the pond, removing the fish fry temporarily to another pond or to large aquaria. After the water is out the large beetle larvæ become very conspicuous and may be quickly and entirely removed.

In half an hour after being drained, pond 2, series E, which furnished the material for the present paper, was entirely freed from Hydrous larvæ, and they did not appear in it again during the summer. After the larvæ have been removed the fry may be returned to the pond with safety.

The adults, being vegetable eaters, do not kill fish except rarely, and then in such small numbers that the loss is never serious. While Hydrous larvæ have become a nuisance several times in the Fairport fishponds and have necessitated the removal of fish fry to other ponds, there has never been an instance when the adult beetles have been known to attack the young fish.

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