number of individuals and more species. The stoneworts are generally present in numbers on marl beds, although by no means invariably so.

Stony or gravelly soils.—The stony soil present in some parts of the marginal area of the lake is another type which is adverse to the growth of plants. Its chemical composition is favorable to most of the species, but its physical composition is so unfavorable that below the water-level this soil is usually barren, and above it, supports only a simple plant association.

Black mud or impure peat.—This material is present in Walnut Lake in smaller amounts than any other. It is both chemically and physically adapted to the requirements of plants, being rich in proper mineral substances in an available form and in the necessary organic compounds, and is furthermore easily penetrated both by roots and subterranean stems. It is thus capable of supporting a relatively large number of species and many individuals in a comparatively small space. Wherever this material is present between the critical depths for marginal plants in Walnut Lake, the greatest variety and the largest numbers of plants are present.

Peat.—Peat is composed of the same kind of material (but of slightly different origin) as the black mud into which it grades some distance below water level. It is brownish in color, coarser in texture, and generally has less finely divided mineral matter than the black mud. It is formed by the growth and partial decomposition of those plants which live near, above or below, the water surface, where the soil is so wet that the dead parts cannot dry up or completely disintegrate under the action of the agencies producing decay. Peat constitutes the substratum upon which grow most of the plants of the sedge, shrub and coniferous tree zones of lakes. In Walnut Lake it is chiefly confined to very shallow water, or to areas now above the water level, and overlies beds of marl.

Effects of aquatic and marsh plant associations on their habitat.—The growth of plants on any of the types of soil mentioned above tends to produce an accumulation of plant debris upon their surface, which is not removed under usual conditions, and thus slowly raises them towards or above the water level. The ultimate end of this process is an improvement of both soil and drainage conditions, since the decayed vegetable matter is rich in plant food. The slowly rising surface of the peaty mass is eventually brought above the water, where it sooner or later dries and improves the substratum in texture through more thorough decomposition, and makes it much more habitable for plants.

It is apparent that if an accumulation of the sort just mentioned begins below the water surface, the original plant association which starts it will be displaced by another, as soon as there is sufficient up-building to improve the light and heat conditions, so that the shoreward plants can advance upon the new territory.

This new association in its turn will be driven out, when it has so modified the habitat by adding to the deposit that still another more aggressive group of plants can thrive upon it. Such changes, particularly in their early stages, take place very slowly, however, and it is only by continuous and prolonged observation, or by the study of carefully made vertical sections of the deposit that the facts pointed out can be verified. That they exist is evident when the theoretical considerations given above are applied to explain the observed facts.

The limited areas occupied by the peaty formations at Walnut Lake do not offer special facilities for securing evidence of the displacement of one plant association by another, but the contact of the peat of the sedge marshes with the underlying marl gives a record of the change from the simple associations of the stoneworts to the more complicated one of the bulrush zone, and to the still more aggressive one of the sedge zone.

The plant zones represented in the lake.—From the effects of soil conditions and steepness of slope of the bottom on the occurrence and abundance of seed-plants in lakes, it is not surprising to find in Walnut Lake considerable areas of what should be available shallow water but sparsely occupied by vegetation, and the representative plants which characterize certain zones, either wanting entirely or present in small colonies in the most favorable soils, or, at best, forming a broken zone interrupted by bare spots. Another apparent anomaly found here is the extension of the stoneworts from the deeper water practically over a large proportion of the shallow part of the lake, which, except for the marl, presents a most perfect environment for aquatic plants. Instead of having a dense growth of seed-plants with floating or partly emerged leaves, this area is largely bare of noticeable vegetation, except for scattered bulrushes, and it is only by close inspection that the carpet of stoneworts can be seen. That this condition is due to the adverse conditions presented by the marl as a soil is shown by the presence of the usual arrangement of seed-plants, where the more favorable soil conditions are found, and also by the presence of a considerable admixture of either organic matter or debris with the marl, where the higher or seed-plants grow in abundance.

Of the first nine zones, given in the list above, which might be present in the lake between the bottom and the upper limit of that portion of the basin where soil drainage is sufficiently established to preclude swamp conditions, only four are at all complete. These are the deep water, including the stoneworts, the pond-weed, the bulrush and the sedge zones. On the remaining five, some are merely suggested and others are absent altogether.

The sedge zone.—It has been pointed out in another place that the slopes about the lake are relatively steep and well drained above the level of the water, and that they come down nearly to the water line, being separated from the margin of the water by a narrow shelf of flatter land around much of the shore, which has been somewhat widened since the outlet was cut. Owing to these conditions, there is relatively little of the soil about the lake which is marshy, and, while there are quite broad expanses of sedge marsh at the west side and in places on the east side, the sedge zone, as a whole, is narrow, although extending nearly around the lake.

The sedge zone is characterized by grass-like plants, with usually triangular stems and a different arrangement of flowering and fruiting parts from that of the grasses. Several large genera and many species of plants are included under the general term "sedge," some of which grow on high ground, but the swamp and marsh types are the most conspicuous members of the family.

Many other types of plants occur in the sedge zone, some of which are larger and more conspicuous than the sedges with which they are associated; of these may be mentioned the swamp loose-strife and the cattail flag. There are also at least two types of habitat represented in the sedge zone at Walnut Lake, the wet marsh, extending into water from 1 to 2 feet deep, and the moist slope rising to the woods, or, more frequently, to the zone of pasture grasses which come from the higher land to meet it. These two were not carefully differentiated, however, since both have the same general relation to the other plant zones of the lake. The dryer parts of the sedge zone were well represented at stations 23 and 32, while the wet parts are shown in numerous figures as described below. The most conspicuous sedges of this zone were the Sartwell's, water, slender and tussock sedges, the twig-rush, which was unusually abundant, and a few spike-rushes, while true rushes, the cattail flag, and swamp loosestrife were frequent in some areas. Many other plants grew in this association, but they were not recorded. Among the figures accompanying the report, the following show portions of the sedge zone and its relations to others. Plates 16 and 19 show parts of the sedge zone of station 16, where the beach is practically covered by sedges. The bulrush zone is almost wanting along this shore. Plates 19 and 20 show the sedge zone at station 32, where there is also a stony beach and a steep bank, at the foot of which the sedge zone ends abruptly. Plate 22 illustrates the flatter type of shore, on which the sedge zone broadens out into a marsh at station 46. Plate 23 is a spring-time picture of the shore of station 3, here the sedge marsh is growing above the platform of marl, and the sedges reach out to the edge of the water.

Plate 26 is a portion of the shore of station 16, where the sedges border a beach composed almost wholly of shells; the plants are encroaching on the beach slightly. Plate 27 is another view, made in spring, of a portion of the sedge marsh of station 16, showing the sedge in winter conditions and extending into the water. Plate 28 also shows the sedge marsh at station 6 in winter condition. Plates 29 and 30 are views of station 15, showing the sedge zone in its relation to the landward shrub and tree zones and the lakeward bulrush zone. Plate 31 is another portion of the sedge marsh at the west side of the lake, and shows well the close relationship often existing between the sedge and the strictly aquatic zones, when the depth of water is sufficient to permit. In the foreground is shown the beginning of the artificial outlet where the water is deep enough to permit the growth of water-lilies close to the sedge-covered banks. Beyond the outlet the bulrush zone merges into that of sedges. Plates 35, 37 and 36, especially 35, show the sedge zone modified by swamp loosestrife; sedge plants are shown in the foreground and at the right of the picture, where the sedges form a nearly pure stand. It will be seen that from this area the sedge zone runs back toward the left behind the swamp loosestrife, two-thirds across the picture.

It is evident from these and other illustrations that the swamp loosestrife is a plant of the sedge zone, becoming dominant when present. Plates 43, 44, 45 and 46 show the sedge marsh at station 41, near the extreme southern end of the lake. Plate 52 shows another type of plant belonging to the sedge zone, although it sometimes invades the shallow water of the bulrush zone; this is the cattail, which forms a narrow zone against the swamp tree zone at station 40, and shown in the background of the picture. Plate 51 shows more clearly the relations of this plant at the same station, and it will be observed that lakeward of the denser part of the zone the plants appear scattered, and grow in the water. These may be advance guards of a general movement lakeward over the whole of the adjacent shallows. Plate 53 shows another part of this station in which the cattail grows in small stools, in shallow water covered densely with the minute fronds of a species of duck-weed and water-lily leaves. Plate 54 gives an excellent idea of the relationship between the cattail covered areas and other zones at station 40. Sedges are growing in the water on the left of the picture.

The bulrush zone.—As mentioned above, this zone is one of shallow water, occurring in depths of about 5 feet up to, or sometimes where soils are suitable slightly above, the surface, merging into the sedge zone. The bulrushes

formed an almost continuous zone around the lake, although this zone was faint, or even broken, in places where conditions were adverse, as on barren shoals. It was clearly defined along the west shore at stations 15, 4 and 20, while at station 54 there was such a dense growth of bulrushes that during the summer a boat could hardly be pushed through it.

The most conspicuous plant of this zone, and the one which gives it character was the lake bulrush, but associated with it were not infrequently found the white and yellow water-lilies, pond-weeds, hornwort, water milfoil, cattail, greater bladderwort, pickerel weed, and, more frequently than any other, the stoneworts. The bulrushes grew alone on marl shoals with the stoneworts, and the other plants mentioned were only found commonly where there was a layer of black, organic mud, or ooze, above the marl, in which the plants rooted. Some species were never found except where this substratum was present. The maximum size of the lake bulrush (12 feet in length) was attained at the edge of the shoal on the east side of station 54, where the water was 5 feet deep, the extreme depth in which the plant was found growing. Among others, the following figures illustrate the relations of this zone in different parts of the lake:

Plate 47.—This is one of the best general views of a pure growth of bulrushes, showing how sparsely they grow, and, when seen in masses, how completely they shut off from view objects behind them.

Plate 17.—A picture of the beach at station 23, with a few bulrushes growing on it, above water.

Plates 29 and 30 show part of the bulrush zone of station 15.

Plates 41 and 42 give views of the relation of the bulrush and sedge zones in shallow water at station 7.

Plates 48 and 49 illustrate conditions on the margin of an opening in the bulrush zone at station 54, where the water-lilies grow around the opening and among the bulrushes.

Plate 50 is the part of the bulrush zone at station 54 where there were many nests of the black bass.

The lake bulrush is apparently somewhat indifferent to marl as a substratum, but grows larger and in denser masses where organic matter is present. As said before, it is accompanied in such places by a much greater variety of associate plants, chiefly submerged aquatics from the pond-weed zone and the water-lilies. On pure marl the stoneworts are its only associate, except for very stunted pond-weeds. A resident of the neighborhood, who was much interested in the history of the lake, reported that a few years ago the bulrushes formed a solid zone entirely around the lake, so thick that a boat could with difficulty be pushed through it. This report is in part confirmed by the abundance of dead root-stocks and underground stems of this species on most of the shoals where there are now very few living plants.

The pond-weed zone.—This was a belt of vegetation growing on the lakeward side of shoal water, between the approximate depths of 3 and 25 feet; it thus ranged from less than a hundred to several hundred feet in width.

In no case were any except microscopic plants collected from water more than 27 feet deep, and but a single seed-plant, the water weed, from more than 20 feet. The characterizing plants of this zone were the pond-weeds, of which several species were common and conspicuous, but it might well be considered the zone of submerged plants, since but few of the types growing in it have even floating leaves, the only parts to reach the surface being the flowers.

Several plants growing in this zone are also peculiar in having but the slightest attachment to the bottom, or even in some cases no roots (for example the hornwort and bladderwort). Moreover, the vegetative parts, such as buds and branches, of most of the plants of this zone are able to live indefinitely when floating about in the water with no root connection with the soil, and by virtue of this trait are scattered widely about the lake.

Besides pond-weeds, the seed-plants noted as abundant and generally distributed in this zone were, water milfoil (at least two species), water weed, hornwort and slender naias. Throughout this zone there was also an abundance of stonewort in both deep and shallow water. All of the species of this association, because of the ease with which they propagate vegetatively, were often more common in shallow than in deep water, and made luxuriant growth in such places in the bulrush zone as they established themselves, as noted above. But it was discovered that plants of these types dredged from water from 15 to 20 feet deep at station 3, on the 9th of May were all of a bright green color and in active condition, while individuals of the same species on the adjacent shoals were all apparently dead, or had not yet started to grow. It thus seems as if the conditions for plant growth were better in deep water than in shallow, at that time of the year.

At station 16, also, it was noted that, early in the season, there were no pond-weeds in water less than about 5 feet deep, but in July and August they became conspicuous in water about 3 feet deep, and were scattered, less noticeably, over the shoal in even shallower places. In the cove which constituted station 7, there was a strong development of the plants of the pond-weed zone, in shallow water and on a peaty bottom. In the spring, stoneworts and an aquatic moss, *Hypnum*, were the chief plants there, but during the early part of May other plants began to appear, and during the summer white and yellow water-lilies, water weed, hornwort, water milfoil, a number of pond-weeds, bladderwort, and water persicaria covered the bottom, but, except for the water-lilies, did not grow quite to the surface.

As early as July, at the south end of the lake, the water in the small shallow bay called station 41 was practically entirely filled by water weed, stonewort, hornwort, water crowfoot and other plants, several of which were prevalent in the pond-weed zone. The density of this mat of vegetation is shown on the right in Plate 45, just in front of the sedge growth. The little spots on the water are floating masses of green algæ with grasses entangled in them. The luxuriance of the vegetation at this spot is doubtless accounted for by the presence of from 2 to 4 feet of soft, black mud in the bottom of the bay.

Another station at which the plants of the pond-weed zone were found in quite shallow water, to the exclusion of other types, was station 54a. This habitat was a circular opening in the bulrush covering of the shoal, and had a bottom soil of partly decomposed vegetable matter, superimposed upon marl. The most abundant plants were stoneworts, reaching a length of 2 feet or more, and growing nearly to the surface of the water, water milfoil, hornwort, slender naias, greater bladderwort, while the white water-lilies grew along the edge of the bulrushes, among which were cattails, and less often the pickerel grass.

As has been pointed out above, the controlling factors in this apparently anomalous situation of these plants of the pond-weed zone are, presence of favorable soil, light and temperature conditions, readiness to migrate, and, what is more important, the absence of competition of more aggressive types.

The water-lily zone.—This was developed in but few places, and apparently only where the soil conditions were improved by the presence of organic matter. At station 31, there was an area lakeward of the swamp loosestrife covered by the leaves of the water-lilies. They grew here in water from 2 to 6 feet deep, while below them there were some pond-weed sand a dense growth of stoneworts covering the bottom. Plates 33 and 34 indicate the position of the water-lilies in relation to the marginal zone.

There was also a somewhat extensive development of water-lilies at station 26, in much the same relationship to the swamp loosestrife as at station 31, except that here was a broader zone, extending out perhaps a hundred feet to where the water was 8 or 10 feet deep. The bottom in this area, as noted elsewhere, was of black mud made up of decomposed plant remains.

Water crowfoot.—Practically a part of the water-lily association at this station was a dense growth of the white water crowfoot, which covered the water with a carpet of delicate white blossoms about the middle of June. This area is shown in Plates 37, 39, and 40, which gives its evident relations to other plant groups near it. White and yellow water-lilies were also present at station 7 (Plates 41 and 42) both in shallow water within the cove and in deeper water beyond the mouth. Here again these plants were lakeward of the bulrushes, and grew in a substratum of peaty material a foot or more thick over the marl foundations.

Another extensive development of water-lilies was at station 54a, where, as shown in Plates 47 and 49, they formed a rather dense growth along the margin of the bulrush zone. The soil of the station was a black mud above a bed of marl. There was also an unusually wide area of water-lilies at the west end of station 40, where they extended out from the shore for 200 feet to the edge of the shoal. As seen in Plates 51, 53 and 54, the water-lilies are here closely associated with cattail on the shoreward margin of the zone. The soil was chiefly a soft, dark-colored mud.

These were practically all of the areas of these plants worth mentioning, and in looking over the record given above, it seems apparent, as stated at the outset, that the water-lilies depend for their development largely upon the presence of a soil rich in organic matter, and wherever this is present in shallow water, they are likely to become conspicuous.

Other zones.—The zones of plants shoreward of the sedge zone were studied in but a desultory way, since their relationship to the special work of the investigation was remote. It may be said, however, that there were fragments of a shrub zone where conditions were favorable, and Plates 35, 37 and 38 show portions of this. The narrowness of the shelf about the lake, and the abrupt transition from this to the steep banks and clearing, are responsible for the absence of the shrub society.

No trace was found of the coniferous tree zone so common about many of the lakes of southern Michigan. The only conifers seen were the low junipers on the dry bank of the north side of the lake, at station 32 (Plates 18 and 20.)

The zone of broad-leaved swamp trees was chiefly represented at the northeast side of the lake, at station 40, and presented the usual characteristics of a wet swamp forest of the region. White elm, black ash, soft maple, swamp white oak and other swamp trees grew in the wet soil, and cast a dense shade in which, on the stools formed by the crowns of the tree roots, muskrat houses and other elevations, grew a variety of shrubs and herbs; most abundant of the latter were sedges, grasses and the touch-me-not. The pools between the trees were covered during the summer by duckweed and filamentous algæ. The conditions in this association are shown in Plates 51, 52, 53, 54 and 55. At other places along the lake shore there were small areas where conditions invited an invasion of limited numbers of trees of this zone, but they were not extensive enough to form a typical society.

Flora of the highlands.—As has been stated, this type was not examined in detail. It consisted principally of farm clearings. The distribution of the trees, now left only in woodlots, indicates that the forest was formerly dense, and the trees of good size, the kind of association found depending upon the type of soil covering a given area. The heavier soils of the moraines, the clay loams, where well watered, were covered by the hard-maple and beech, associated with red, white and bur oaks, basswood, walnut, hop hornbeam and other trees of the mesophytic or moist, drained soil type. In slightly dryer areas the hickories and white oak dominated, although in strong mixture with some of the other kinds, and on sandy loams this association passed into nearly pure white oak, then to black or yellow oak and white oak associations, and finally, on very dry sites, becoming a forest, with black and scarlet oaks, of "the oak openings" type, on such areas as the sandy, glacio-fluvial deposits, both south and north of the lake.

Portions of numerous figures show the scanty tree growth in the woodlots and pastures in the vicinity of the lake, but few of them were made to illustrate specially this type of association, and show little detail.

LIST OF PLANTS COLLECTED AT WALNUT LAKE.

In the partially annotated list given below are included all of the aquatic plants referred to in this report, and also the ones that we collected at Walnut Lake. It is not intended, however, to give an idea of the extensive flora of the region.

*Algæ.**

1. *Aphanothece stagnina* (Spreng.) A. Br. Abundant in summer at stations 7 and 41, forming, upon the bottom, blue-green gelatinous balls each an inch or so in thickness.
2. *Anabæna* sp. The material obtained was too immature for the species to be determined. It formed brownish masses on submerged plant stems at stations 40 and 37.
3. *Gloiotrichia natans* (Hedw.) Rab. Species determination doubtful as plants were immature. Taken at station 23.
4. *Scytonema ocellatum Lyng.* Station doubtful.
5. *Spirogyra* sp. A very common and conspicuous alga at stations 7, 40, and 41, where it formed a large part of the surface scum.
6. *Mougeotia* sp. Taken at station 40.
7. *Zygnema* sp. Very common; occurring mixed with *Spirogyra*.
8. *Vaucheria* sp. Abundant at station 40, where it formed tufts over the bottom.
9. *Conferva bombycina.* Taken in the ditch at station 7.
10. *Draparnaldia plumosa* Ag. Found at station 40.
11. *Batrachospermum boryanum* Sirdt. Taken in the outlet of the lake.
12. *Dichotomosiphon tuberosus* (A. Br.) Ernst. Taken at stations 33 and 47.
13. *Chætomorpha chelonum* new species. Found at station 26, on the back of a painted turtle. This has been described by F. S. Collins.†

*The specimens of algæ obtained were identified by Mr. F. S. Collins of Malden, Mass.
†Rhodora, IX, pp. 198–199.

Diatoms.

On July 20 some bottom soil was dredged from a depth of forty feet at station 200. Like all bottom material taken from deep water, and microscopically examined, it was found to contain many diatoms. Specimens of the bottom material were sent to Dr. H. H. Chase of Linden, Michigan, who found ten species of diatoms in the material, as follows:

14. *Coccoei scutellum* Ehrb.
15. *Cyclorella meneghiniana* Kutz.
16. *Cymbella gastroides* Kutz.
17. *Gomphonema acuminatum* Ehr.
18. *Colletonema lacustre* Agardh.
19. *Melosina varians* Ag.
20. *Navicula radiosa* Kz.
21. *Navicula radiósa acuta* Grun.
22. *Nitzschia linearis* W. S. var. *tenuis* Grum.
23. *Surtella ovalis* var. *angusta* Kz.
24. *Synedra ulna* var. *lanceolata* K.

Characeæ.

Stoneworts.*

25. *Nitella* sp. This was found only in late summer. It was abundant along the mouth of the outlet, and was also noted in very shallow water near the shore at station 23.
26. *Chara contraria* A. A. Brown. The few stoneworts collected were identified as this species, with the exception of a specimen without fruits that seemed to be *Chara fragilis*. Stoneworts were very abundant in the lake, and they formed a rank growth in the shallower part of the pond-weed zone. On marl shoals small stoneworts were common, and were used by some of the sunfish as places for the attachment of their eggs. In shallow, rather quiet water, as at station 41, 7 and 54, the growth of chara was luxuriant.

Moss.

27. *Hypnum* sp. Very common at station 7, forming a thick mat over the bottom. A few fragments were also taken in our dredge at station 200. It is referred to as the "water-moss" in this report.

Horse-tails.

28. *Equisetum* sp. Horse-tails formed a large patch in shallow water at station 40, where common sunfish were nesting upon the bottom among them. These plants were also numerous in the sedge zones of some other stations, as at station 23.

*Seed-plants.**

29. Broad-leaved cattail, *Typha latifolia* L. Common at stations 40 and 54. Also formed conspicuous growths at other places about the lake, as the patches in marshes and in the sedge zone.
30. Bur-reed, *Sparganium eurycarpum* Engelm. Found in sedge zone at station 40.
31. Floating pond-weed, *Potamogeton natans* L. *Common in shallow parts of the pond-weed zone of stations 15, 24, 46 and others. It grew in patches whose position was clearly indicated by the floating leaves of the plants.

*The specimens of these plants collected were determined by Miss Ellen Bach of the University of Michigan.
*The species marked with a * were identified by C. A. Davis.

32. Large-leaved pond-weed, *Potamogeton amplifolius* Tuckerm.* Very common; the most abundant pond-weed in the lake.

33. Various-leaved pond-weed, *Potamogeton heterophyllus* Schreb.*

34. Shining pond-weed, *Potamoge'on lucens* L.*

35. White-stemmed pond-weed, *Potamogeton prœlongus* Wulf.*

36. Eel-grass pond-weed, *Potamogeton zosteræfolius* Schum.*

37. Slender naias, *Naias flexilis* (Willd.) R. & S. Abundant in the pond-weed zone in water less than fifteen feet deep. Also in shallow water at stations 7 and 41.

38. Water-weed, *Philotria canadensis* (Michx.) Britton. Abundant in the pond-weed zone, growing at all depths in this region; also in shallow water at stations 7 and 40.

39. Greater duckweed, *Spirodela polyrhiza* (L) Schleid. Abundant at station 40, growing with other duckweeds.

40. Ivy-leaved duckweed, *Lemna trisulca* L. Abundant at station 40.

41. Lesser duckweed, *Lemna minor* L. Abundant at station 40. (See Plates 53 and 55.)

42. Pickerel-weed, *Pontederia cordata* L. Patches found at stations 26, 40 and 54.

43. Lake bulrush, *Scirpus lacustris* L. An abundant and conspicuous plant characterizing the bulrush zone of the shoals of a number of stations. Besides growing in the water, it was often found on wet ground with the sedges, sometimes forming distinct patches near marsh borders. Bulrushes grew throughout the spring and summer, but only dead ones were present till about the middle of May, when the new growth became conspicuous.

The importance of the relation of bulrushes to fish life is evident, when it is recalled that black bass, rock bass, common sunfish and blue-spotted sunfish prefer for nesting the shoals where these plants abound to any others. They use the cleaned roots and root stocks of the plants, which were practically the only stable objects in the finely divided marl of the bottom, as points of attachment for their eggs. The stems also furnish shelter for the old and young, and doubtless prevent, to a considerable extent, the effect of wave action on the nests, as well as furnishing places of refuge, and feeding grounds, for many types of food fish.

44. Water persicaria, *Polygonum amphibium* L. Occasionally solitary plants of this species were found in very shallow water on a number of shoals, including those of stations 6, 7, and 31.

45. Large yellow pond-lily, *Nymphaœ advena* Soland. This species was abundant at stations 6, 7, 26, 4, 54, 41 and 51. The plant is interesting because of its very large underground stems or root stocks, and its habit of developing submerged leaves early in the season before the floating or emerged ones appear. The flowers of this plant are also often emersed on erect peduncles.

46. White water-lily, *Castalia tuberosa* (Paine) Gregge. Common at stations 26, 40, 54 and 31. This species has an interesting habit of developing tuber-like branches on the sides of the large root stocks, which, when mature, break from the parent stem and, floating about, may find favorable lodgement and develop into new plants.

47. Hornwort, *Ceratophyllum demersum* L. This species was abundant at all depths in the pond-weed zone, and at other places even in shallow water as at stations 7, 26, 54, and 41.

Its usual lack of roots, and great power to propagate from any part broken off, as well as its indifference to weak light, makes this an exceptionally wide-spread plant in any lake where it occurs.

48. White water crowfoot, *Batrachium divaricatum*. (Schrank) Wimm. This plant formed a dense growth at station 26, covering the water at one time with the white, emerged blossoms. It also occurred, although less abundantly, at stations 7, 40 and 41 (Plate 40).

49. Swamp loosestrife, *Decodon verticillata* (L.) Ell. This plant, found at stations 7, 41, 31 and 26, was one of the most interesting ones found about the lake. It formed dense tracts at stations 31 and 26, and much less noticeable ones at the others. The plant grows in wet soil or in shallow water, and is herbaceous, dying down each year to just above the water level, but is woody and perennial below it. Wherever it touches the water the bark becomes very thick and great amounts of loose, very white, thin-walled tissue, called ærenchyma, develop. This is supposed to assist the plant to live with its roots in the water. The long herbaceous branches bend over, and where they touch the water send out roots and buds which grow into branches; the stem becomes woody and covered with the ærenchymatous tissue below the water and just above, and eventually establishes itself as a new plant at about the distance from the parent that the branch reached. The branch connection dies the first winter and the new plant becomes independent. The drooping branches are shown in Plate 65, and the characteristic thickening near the ends of the branches with the roots which touch water is shown about the middle of Plate 66, while, in the background, and at either side, may be seen the well-established plants. See also report Mich. Biol. Surv., 1906, pp. 204–208th.

50. Spiked water milfoil, *Myriophyllum spicatum* L. Abundant at station 54, where it blossoms freely in July and August. This is also a slightly rooted plant, and frequently has floats with no roots.

51. Various-leaved water milfoil, *Myriophyllum heterophyllum* Michx. This plant grew somewhat abundantly in the shallow water near the swamp loosestrife border at station 26. It differs from M. *spicatum* in having well-developed, nearly entire, small leaves on the part of the interrupted flower spike above water.

52. The greater bladderwort, *Utricularia vulgaris* L. Common at stations 54 and 7, and noted at other stations less frequently. A rootless, or rarely rooting plant, with great numbers of small, bladder-like enlargements on the divisions of the finely dissected leaves, the function of which seems to be to supply the plant with nitrogen by imprisoning the small aquatic animals which find their way into them until they die, and afterwards absorbing the nitrogenous compounds resulting from their decay. The bladders have a very interesting and complicated structure for holding the animals prisoners, and a well developed system of internal glands which act as absorbing organs. For a fuller account of this interesting type of plants see Darwin *

*Darwin, C. Insectivorous Plants.

THE FAUNA OF WALNUT LAKE.

BY T. L. HANKINSON.

As the principal purpose of this investigation was to inquire into some of the ecological factors making up the fish environment in Walnut Lake, the work on the general fauna was purely incidental to that relating to the fish. The following discussion, therefore, makes no pretense of being more than a series of notes upon the animal forms which were observed while studying the fish, or upon those types having a close ecological relation to them.

Protozoa.

The one-celled animals noted here were such relatively conspicuous types as *Arcella*, *Difflugia*, *Vorticella*, etc., seen while materials from the bottom (algæ, etc)., were being microscopically examined. The shells of *Arcella* were common among the fragments of algæ taken from the intestines of golden shiners in August, the fish having undoubtedly picked up the protozoans with the plants to which they were attached, but, nevertheless, the morsel of protoplasm constituting the animal must have served as food for the fish. *Ophrydium versatile* O. F. M. was the most noticeable protozoan in the lake, its large, greenish, jelly-like colonies being so abundant upon some of the shoals, in early summer, that they almost completely covered the bottom. In late summer this form was not seen. In the early part of August the water and plants growing in it on station 15 were blackened by great numbers of a *Vorticella*-like protozoan, which was not identified.

Sponges.

No sponges were found in Walnut lake, either by the members of the party or by Professor N. A. Harvey, of the Normal College at Ypsilanti, who made a careful search for them in the summer of 1905.

Flat Worms and Round Worms.

Parasitic worms were commonly found in the fish opened for study, both in the enteric cavity and in the body cavity. All of these organisms were preserved and sent to a specialist for identification.

Annelid Worms.

A small, few-bristled worm of this type, about an inch in length, was found abundantly in material dredged from the bottom in deep water. It was associated here with midge larvæ, which it resembled in having a reddish color; it was commonly found in whitefish stomachs with midge larvæ. Unfortunately the material sent away for determination was destroyed in transit. The leeches seen in the lake were collected and were determined by Dr. J. P. Moore of the University of Pennsylvania as follows:

1. *Glossiphonia stagnalis* (Linn.)
2. *Placobdella parasitica* (Say).
3. *Placobdella rugosa* (Verrill).
4. *Eropdella punctata* (Leidy).

Taken at stations 4, 7, 15, 32, 41 and 45. One was obtained from the stomach of a black bass caught at station 15, on May 9. Egg cases of the species were found under stones at station 45 on May 20.

5. *Dina fervida* (Verrill). One obtained from the stomach of a perch caught at station 54.
6. *Hæmopsis marmoratus* (Say). One from station 20.
7. *Pisciola punctata* (Verrill). Taken from the pectoral fin of a black bass.
8. *Macrobdella decora*. This is the largest species of leech found. It was common at station 7, in the early part of summer.

Crustaceans.

The most common crustaceans were the entomostracans, which occurred as plankton or free-swimming forms in deep water, and also about plants on the shoals, where they seemed especially abundant. In the latter habitat the smaller fish fed freely upon them, and they formed a large part of the food of the fry of the larger fish. In late summer the deep water forms of the genus *Daphnia* came to form apparently the entire food of the white-fish, as nothing else was found in their stomachs at this time of year.

The amphipods were less numerous, and only two specimens were collected; these were identified by Miss Ada Weckel as *Eucrangonyx gracilis* Smith and *Hyalella knickerbockeri* Bate.

Crayfish were common, and many were found in shallow water in the early spring as soon as the ice had left. At this season they were sometimes found attached to the gill net when it was drawn from near the bottom, where it had been set in from 15 to 30 feet of water. About 40 specimens were collected from eight different stations during the spring and summer, and all were of the same species, *Cambarus propinquus* Gir., which is the most common species in Michigan, according to Ortmann. A single specimen was taken in the lake with eggs attached to the abdomen. Two other species, *Cambarus diogenes* Gir., and *C. bartoni robustus* Gir., were caught on the outlet on May 2nd. Dr. Ortmann states that the former has been reported but once before from the state, viz., from Detroit by Faxon. Crayfish are eaten by a number of species of fish found in Walnut Lake, and form a very important, if not the chief, food of the black bass, rock bass and perch.

Insects.

As in the case of other invertebrates, no attempt was made by the field party to get a representative collection of insects from the lake and its environs, and whatever time was given to these animals was devoted to working on those forms found to be important as fish food. A special report has been written upon the aquatic insects of the lake by Dr. Needham, and is published as Appendix III of this report. A large number of specimens were also collected at the lake, in June, by Mr. A. Franklin Shull. The following are the more important notes made during the season:

May-flies.—No very large flights of adult insects were noted, although they were commonly seen about the lake. The larvæ of *Hexagenia* were eaten in large numbers by the common sunfish and to some extent also by other species. But few of these larvæ, probably because of their burrowing habits, were found elsewhere than in fish stomachs. *Heptagenia* larvæ, on the other hand, were found in large numbers on the lower surfaces of stones along the shore, and were also often taken from fish stomachs.

Dragon-flies and damsel-flies.—While adults of many species of these graceful and showy insects were numerous about the margin of the lake, larvæ were never found abundant. The few specimens of the latter collected, came chiefly from the muddy bottoms in shallow water, as at stations 7 and 41. The larvæ, however, were often found in the stomachs of rock bass and blue-spotted sunfish, less frequently in those of the common sunfish.

Grasshoppers.—These insects, while not inhabiting the aquatic parts of the stations, were abundant in the sedge and other landward zones, especially in late summer, and often fell into the water, where they were eaten by blue-gills and doubtless by other species. The insects were commonly noticed floating on the water surface, and occasionally a fish would be seen to "turn up" and capture one.

Aquatic Hemiptera or bugs.—These did not appear to be common, and but few species were collected. Among the forms obtained were back-swimmers and a small relative of the giant water bug, *Zaitha* sp. Water striders were seen at times in quiet places near the shore, darting over the surface. Water-scorpions were frequently caught, and their eggs were common on water-lily leaves. Along the beaches, on warm days, toad-bugs were numerous.

Neuropterous insects.—Both the adult and larval forms were common. The most conspicuous of these were the adults of a species of *Sialis*, which appeared in numbers on the bulrushes during the latter part of May, and their egg masses were found attached to these plants in quantities after that time. The larvæ were found in some fish stomachs.

Caddice-flies or case-worms (so called from the interesting habit which the predaceous larvæ have of building protecting tubes or cases of sand, shells, or other fragmental material, from the bottom on which they live). Cases made of shell fragments were often seen on barren shoals, in early spring, and these larvæ were found in some of the stomachs of the fish examined. Many of these insects were collected by Dr. Needham and are more fully discussed in his report.

Flies (Diptera).—The two-winged insects were common. The type of most importance as fish food (not only of this order, but of all the insects of the lake) was the midge, *Chironomus.* Adults of this form were exceedingly abundant in the vicinity of the marshy parts of the lake shore, during the latter part of April, as mentioned in the description of station 3. See figures 12 and 13. These were identified by O. A. Johannsen as *Chironomus niveipennis.* It was, however, in the larval and pupal stages that they were generally eaten by fish. During the spring and until about June 1st, when the fully-grown larvæ were apparently more numerous and certainly more generally distributed in the lake than at any other time, they constituted the principal food-material found in the stomachs of whitefish. After this time few whitefish were collected; see tables page 251.

Sayomyia (Corethra).—This is a kind of gnat, the larvæ of which were quite common in deep water. They were taken with midge larvæ from the deep-water stations, and were sometimes found in whitefish stomachs.

Beetles.—Parts of aquatic beetles were not recognized among the food material of any fish examined, but the elytra and other parts of terrestrial beetles were often found.

Spiders.

Little attention was given to these animals, and no facts were obtained to show that they were at all closely related to the fish life of the lake. None were found in the food material from any fish, but, as they were commonly seen running over the water surface near shore, they were doubtless occasionally taken by fish, and the negative data have little significance, in view of the soft bodies of spiders, and the small numbers of stomachs examined, as well as the hasty examinations made. Water-mites were common in shallow water, and some collections of them were made.

Mollusks.

While living univalve mollusks were scarce, except in places where bottom vegetation was heavy, and rarely abundant even here, the empty bleached shells were abundant on nearly all of the marl shoals, sometimes almost completely covering them over considerable areas. There were also portions of the shore where immense numbers of these shells had been cast upon the beach and sorted by the waves, according to size, (Plate 26). Another beach of this sort formed part of station 44; from this a handful of shells was picked up and sent to Mr. Bryant Walker, who found the following species:

Limnæa desidiosa Say.	*Planorbis parvus* Say.
Physa sp. (too young to identify)	*Valvata tricarinata* Say.
Physa heterostropha Say.	*Amnicola limosa* Say.
Planorbis bicarinatus Say.	*Amnicola lustrica* Pils.
Planorbis campanulatus Say.	*Pisidium* (several species).

In late spring the following living snails were collected from algæ (chiefly Vaucheria):

Valvata tricarinata Say.	*Planorbis parvus* Say.
Amnicola limosa Say.	*Pisidium* sp.

On August 6th, small snails, *Limnæa desidiosa* Say, were found in large numbers near the shore in very shallow water at station 32. Bivalve mollusks, or "mussels," were common, but not conspicuous; the smaller ones were sometimes found in shallow water, but large ones seemed to be limited to deeper parts of the shoals, near the landward margin of the zone of pond-weeds. These were apparently of one species, which was identified by Mr. Walker as *Anodonta grandis footiana* Lea. Shells and fragments were sometimes found in fish stomachs. Glochidia were found attached to each of the ten specimens of Johnny darters taken at station 49, on May 22, and also on the specimen of the same species taken at station 41, on April 27.

Amphibians.

Incidentally to the work of studying the fish, the following amphibians were collected or noted:

1. American toad, *Bufo americanus* (Le Conte).—Toad eggs were abundant in the marsh (station 36), on April 12th and April 26th, and the animals were heard about the lake until about the middle of May.

2. Common tree-toad, *Hyla versicolor* Le Conte.—This noisy species was heard calling from the woods, orchards, farm-yards, and other places in the neighborhood of the lake. On May 16th, they were noticed abundant about a water-hole in an orchard a few rods from the lake, on the high ground south of the strip of timber forming part of station 23. The chorus of their voices from this place could be heard for a long distance, and they were doubtless breeding in the pool.

3. Leopard frog, *Rana pipiens* Schreber.—This was the commonest frog. It made its home chiefly in the marshes and sedge areas of the lake, and was

not seen on higher ground, and only occasionally in the lake. On April 13th a specimen of this species was caught in the fyke net, which was set at station 200, several feet from shore, and in about 40 feet of water. On the 18th of April, eggs were found in the lake, where the water was but a few inches deep at station 44, about 30 feet from the shore, while on the 20th a mass of eggs was found attached to an isolated swamp loosestrife plant, in five feet of water at station 31. From these observations it is apparent that the species enters the lake occasionally, but evidently not in numbers.

In early April, immediately after the ice melted, leopard frogs became common and noisy in the marshes and about them, and the first eggs were found on April 8th, in the marshy part of station 46, in water 8 inches deep and of a temperature of 8.5° C. These eggs were unsegmented and were probably very recently deposited. On the 11th and 12th of April this species and its eggs were very numerous in a small marsh at station 36, and individuals were also seen spawning at that time. Frog eggs were often found during April, and small tadpoles, probably of this species, became abundant in the latter part of the month, in low, wet, sedge-covered places. After this time the adult frogs ceased calling and were not heard in May.

4. Green frog, *Rana clamitans* Latreille.—An abundant frog, being noted chiefly during the late summer at stations like 7, 40 and 41, where submerged plants were abundant, and where large specimens were sometimes found. Transformation stages were caught in the ditch at station 7, in July, and numerous small adults of the species, just transformed, were found on the wet beach at the west end of station 23, in August, while their tadpoles were common in shallow water on the same shoal.

Reptiles.

1. Garter snake, *Thamnophis sirtalis* (Linnæus). Common about the lake on both high and low ground.
2. Water snake, *Natrix fasciatus sipedon* (Linnæus). This form appeared to be rare, and only three were taken in the entire season.
3. Blue racer, *Bascanion constrictor* (Linnæus).—But a single specimen of this snake, a large one 54 inches long, was taken. It was caught in the timber zone of station 23, on May 16th.
4. Milk snake, *Lampropeltis doliatus triangulus* (Boie).—On August 24th a specimen of this snake was found at station 31.
5. Snapping turtle, *Chelydra serpentina* (Linnæus).—Specimens of this turtle were sometimes caught in the fyke net, but the species was not common. The largest one noted was caught at station 6, on May 4th, and had a shell 11 inches long and 8 inches wide.
6. Musk turtle, *Aromochelys odoratus* (Latreille).—This was the most common turtle in Walnut Lake, and large numbers were seen crawling on the bottom, both on shoals and in the pond-weed zone, especially during the spring. On June 25th, 91 eggs of the musk turtle were found buried slightly above the water level in the walls of a muskrat house at station 40, and 70 were taken from another at station 7 (Plate 67).
7. Blanding tortoise, *Emydoidea blandingi* (Holbrook).—Taken with the painted turtle and musk turtle on the shoal of station 16.
8. Western painted turtle, *Chrysemys marginata* (Agassiz).—Individuals were commonly seen, although the species was not abundant in the lake. The stomach of a specimen taken July 2nd, at station 26, was found distended with the leaves of some small-leaved pond-weed, probably *Potomogeton pusillus* L. or *P. foliosus* Raf. C. A. Davis, who identified the leaves, says regarding them, "It seems as if they had been scooped up from a mass of drift material, such as sometimes accumulates in shallows, rather than bitten off by the animal." With this material were found water milfoil buds, bunches of filamentous algæ, and fruits of the slender naias.

Birds.

No especial effort was made to study the birds of the region. Aquatic forms and others that might affect fish life were noted, and a list of the species observed, with a few notes upon them are given below. Only the forms that could be positively identified are listed.

1. Pied-billed grebe, *Podilymbus podiceps*.—Throughout the summer, two were often seen in the vicinity of station 26.
2. Loon, *Gavia imber*.—Often seen on the lake in late spring.
3. American bittern, *Botaurus lentiginosus*.—A few were observed about the lake at different times during the summer. Often heard "pumping" on the marshy point on the west side of the lake.
4. Least bittern, *Ardetta exilis*.—Occasional in late summer at station 7.
5. Great blue heron, *Ardea herodius*.—A single individual was often seen at different places during the summer.
6. Green heron, *Butorides virescens*.—Common throughout the summer.
7. Black-crowned night heron, *Nycticorax nycticorax nævius*.—One or two noted during the summer.
8. American coot, *Fulica americana*.—One seen in late spring at station 12.
9. Greater yellow-legs, *Totanus melanoleucus*.—Common in May; often present in large flocks on the beaches.
10. Solitary sand-piper, *Helodromas solitarius*.—One seen at station 40 on May 3.
11. Spotted sandpiper, *Actitis macularia*.—Common in summer.
12. Kildeer, *Oxyechus vociferus*.—Common in large flocks, especially in late summer.
13. Belted kingfisher, *Ceryle alcyon*.—Common.
14. American crow, *Corvus brachyrynchos*.—Common. A nest was found in the timber zone of station 23. Often seen feeding along shore of lake.
15. Red-winged blackbird, *Agelaius phœniceus*.—Abundant and conspicuous about the marshes. Especially common at stations 54, 40 and 7.
16. Swamp sparrow, *Melospiza georgiana*.—Common in marshes about the lake. Often heard singing in early summer.
17. Barn swallow, *Hirundo erythrogaster*.—A very abundant species throughout the summer. Hundreds often seen over the lake, capturing insects on the wing. They were also found roosting among the rushes at station 54. The stomachs of two caught in an insect net contained many insect fragments, chiefly those of beetles, but no remains of aquatic species were noted. These birds were sometimes seen upon the beach near the water edge.
18. Tree swallow, *Iridoprocne bicolor*.—Often seen with the barn swallow flying over the lake.
19. Waxwing, *Ampelis cedrorum*.—Common along the edge of the woods near the lake, at station 32, in early summer.
20. Long-billed marsh wren, *Telmatodytes palustris*.—Commonly heard at stations 54 and 7 in early summer.

Mammals.

Muskrat, *Fiber zibethicus* (L.).—This is the only mammal noted that could be considered an inhabitant of the lake. It was often seen swimming near shore, and its houses were common at stations 40 and 54. There was one also at station 7 and a few at 41. This animal undoubtedly has much effect upon the fish life, since it removes quantities of vegetation from certain areas of the lake, and in other ways disturbs conditions in the shoal water. Observations made in July and August made it appear that a curious effect, noted in many places where the bulrushes were dense, was produced by the muskrat. Many rushes were cut off close to the water surface. This was first attributed to ice action in the spring, but this cause was made improbable by the fact that rushes were being cut down in late summer in large numbers. A farmer boy living near the lake stated that these animals cut off the young bulrushes a few inches above the surface of the water, and gather them into rafts or platforms upon which they sit while eating. A large number of such rafts, as shown in Plate 68, were found at station 54. Some of the bulrush stubble possibly produced in this way is shown in Plate 69.

SUMMARY AND CONCLUSION.

BY T. L. HANKINSON.

In our opinion the results of the work done at Walnut Lake fall into two classes: (1) the determination of the fish life, and the habits of the species, and (2) the study of the lake as a fish environment. The results of the first class are so diverse that no generalizations are advisable, and it only remains to sum up the environmental conditions presented by the lake, and their effect upon the fish life. Walnut Lake may, in the terminology of Forel, be classified as a lake of the temperate type and second order, as the temperature of the surface water varies widely both above (summer) and below (winter) the point of maximum density of water (39.2° F.), and the bottom temperature undoubtedly undergoes slight fluctuations. These two conditions are the almost necessary results of the geographic position of the lake in the temperate zone, and its depth.

As may be seen from the contour map, the basin consists of a shallow marginal shelf whose outer margin has an approximate depth of 25 feet, and lakeward of which the bottom drops rather regularly to 70 feet and then in places to a little over 100 feet. Briefly, the shoals are marl, and covered by a sparse growth of vegetation, but the margins, from depths of 5 to 25 feet, support a rather luxuriant growth of aquatic plants; lakeward of this zone, the bottom has only a very scanty plant growth, consisting principally of diatoms. According to Forel the limit of extensive plant growth marks the limit of the littoral region, and the almost plantless area within this zone should be classed as the abyssal region. On this basis the boundary between the littoral and abyssal regions in Walnut Lake is approximately marked by the 25-foot contour.

The conditions that characterize the littoral region are: shallow water, a variable temperature approximating that of the air, a relatively good development of vegetation, a considerable abundance of invertebrates,

abundance of light and oxygen, considerable wave action. The littoral zone, as has long been noted, is usually divided into a large number of minor habitats by variations in the influence of the environmental factors such as wave action, soil composition, depth, etc. Where other factors are generally uniform the increasing depth off shore breaks up the environment into smaller units, as shown by the concentric zones of aquatic plants. Just how far the local distribution of fish corresponds to the habitats indicated by the plants cannot be determined until many more observations are at hand, but it is evident from our observations that the littoral region supports a characteristic fish fauna. According to our observations it is the principal habitat of the smaller species, such as the blunt-nosed minnow, straw-colored minnow, barred killifish, Johnny darter, least darter, golden shiner, *Etheostoma iowæ*, Cayuga minnow, and black-chinned minnow, and furthermore furnishes spawning grounds for such larger fish as the sunfishes and bass. The fish life is apparently adapted to these conditions. The small fish find protection in the vegetation, and it seems fair to assume that the larger fish must of necessity spawn here, as the lower temperatures and lack of oxygen of the depths could only retard the development of the eggs. The observation that in Walnut Lake the principal home of these species is the pond-weed zone, is an interesting one. It may be that the more abundant vegetation in this habitat affords better protection than do the barren shoals, or it may be that the shoals are so frequently unfavorable, owing to the variation in wave action, temperature, etc., that the fish occupy the relatively more stable conditions of the pond-weed zone as a permanent habitat, only visiting the shoals.

The conditions in the abyssal region are quite the reverse of those in the littoral zone. The temperature must be rather constantly about that of the maximum density of water, water perpetually calm, the light feeble, vegetation scanty, pressure considerable, and the animal life abundant. As a rule the abyssal region is characterized by an abundance of nitrogenous matters and a lack of oxygen, owing to the fact that all pelagic forms, when they die, sink to the bottom and decay, thus tending to transform the proteids into simpler compounds (the nitrates) with a consumption of oxygen. Owing to the dearth of cholorophyll bearing plants these nitrogenous compounds cannot be converted into protoplasm again with a renewal of the oxygen in the water, so that there is in general a dearth of oxygen until the spring and fall circulation periods, when the aerated water of the surface is mixed with the water rich in nitrogen from the depths. As Prof. Reighard has pointed out (see p. 195), there is, relatively speaking, considerable oxygen in the deep water of Walnut Lake during the summer stagnation period, so that we may expect that there is relatively little decomposition taking place on the bottom, a circumstance probably due to the fact that there is little plankton in the lake.

The fish of the abyssal region of Walnut Lake are also characteristic, the whitefish and common sucker being found here apparently more than elsewhere. It follows from this that the whitefish is adapted to the conditions in the abyssal region of this lake, as shown on a preceding page (200), and possibly will do well only under these conditions; at any rate, this hypothesis should govern future plantings, until the subject has been investigated more fully.

APPENDIX I.

DESCRIPTION OF APPARATUS AND METHODS OF RECORDING OBSERVATIONS.

BY T. L. HANKINSON.

While the description of apparatus and other forms of equipment and the methods used in recording observations are of little interest to the general reader, it has been thought best to insert a short account of these for the benefit of teachers and investigators who have special interest in this kind of work, and who may wish exact information concerning the apparatus and methods employed.

The equipment may be classified under three heads:

(1) Collecting.
(2) Observing.
(3) Recording.

I. *Collecting Apparatus.*

(1) *The Boat.*—The boat used was about 16 feet long by 4 feet wide; it was flat-bottomed and exceedingly well adapted to the kind of work done. It was borrowed from the Michigan Fish Commission, through the kindness of Superintendent Seymour Bower and Mr. J. L. Brass, who sent it from the Bass Hatchery at Drayton Plains.

(2) *Fyke nets.*—The fyke net consists essentially of a long bag net, or funnel, distended by hoops, from the mouth of which vertical nets (the leaders or wings) extend on outward on both sides. The bag-net tapers gradually to small size, and may have a trap towards the smaller end. Two nets of this type were used, the one borrowed from the Zoological Laboratory of the University of Michigan had a one-inch mesh, had a funnel about 20 feet long and 3 feet high at the mouth, and 40 foot wings. This net was very useful in collecting fish from shallow water stations. The second net of this type was purchased for this work, and differed from the other in having the funnel but 12 feet long and 5 feet high, while the wings were each 60 feet long. The larger end of the funnel and the wings were of inch mesh, but the smaller end of the funnel was of half-inch. The chief use made of the net was in the deeper parts of the pond-weed zone. Plates 70 and 71 show these nets.

(3) *Gill net.*—This is essentially a long, straight, rectangular net of large mesh, weighted on the lower side and buoyed above, so that when in use it stands upright in the water. When set it is sunk to the bottom, its position marked by buoys, and it catches the larger fish by entangling them when they try to get through the meshes.

Three nets of this type were available, but of these only one was generally used. This was the property of the State Biological Survey, and was 300 feet long, 7 feet deep, and of 2½ inch mesh. It was the only apparatus which was a success in catching fish in the deepest water of the lake. The other two gill-nets were borrowed from the U. S. Fish Hatchery at Put-in-Bay, Ohio, and were 200 by 6 feet; one had one-inch and the other a ½-inch mesh. These were used but little.

(4) *Drag Seines.*—This seine is a long net, sometimes rectangular, sometimes tapering at the ends, which is weighted at the lower edge and buoyed at the upper edges. Strong ropes are attached to the ends of the net, with

which it is drawn. Various types of these seines are in use by fishermen, but all are used to enclose a larger or smaller area of water temporarily, and then drawn. The drag net is usually set in shallow water and dragged ashore along with such fish as are enclosed by it. Three large nets of this sort and two small ones were used. The largest was borrowed from the U. S. Bureau of Fisheries and was of inch mesh, 100 feet long, 12 feet wide at the middle and tapering to 8 feet at the ends. A second net was the property of the State Biological Survey, and was of inch mesh, and 60 by 12 feet. The third large net was a minnow seine, purchased in the summer to make collections of the small fish in the pond-weed zone. This was of ⅜-inch mesh, 50 feet long, 12 feet high, tapering to 8 feet at the ends. Minnows and other small fish were caught in shallow water near shore by "Common sense" minnow seines, made of coarse mosquito netting; two of these, 20 by 4 feet, and 8 by 4 feet, respectively, were used.

(5) *Trammel net.*—This type consists of three nets fastened together at the edges, the outer two of large twine and coarse mesh, the mid-one somewhat larger than the others, so that it is loosely held in folds between them, and is of finer twine and small mesh. Fish pass through the large meshes readily, only to be entangled by the finer net within, which, because of its fulness, pushes readily through the coarser meshes and forms pockets which hold the fish securely. The trammel-net used was 100 by 6 feet; the mesh of the outer nets was 8 inches, and of the middle one one inch; this was used for shallow water, as it could be used regardless of the nature of the bottom or the density of vegetation growing there. Plate 72 is of this net set at station 54.

(6) *Dip nets.*—These are too well known to need description. Several were used for collecting fish and other animals.

(7) *Set-line or Trawl.*—This is a well-known device for exposing a larg-number of baited hooks for some time in places favorable for fish. It consists of a stout line, to which hooks with leaders of proper length are tied at regular intervals. In use, this line of hooks, properly baited, is stretched at a suitable distance above the bottom and marked by buoys. From time to time the fisherman examines it, rebaits the bare hooks, at the same time taking off the fish caught. Such a set-line was rigged and set for several weeks at station 225, but with few results, a whitefish being the only fish caught.

(8) *Dredges.*—This useful type of collecting implement consists essentially of a bag-net, the mouth of which is held open by a metal framework, to which is attached a rope for dragging the net along the bottom. Two of these, a "triangle dredge" and a circular one, were borrowed from the Michigan Fish Commission. The "triangle dredge," is so-called from the triangular shape of the frame to which the net is attached. The one used was a bag-net of scrim, about 2 feet deep, the mouth of which was held open by a heavy, equilateral triangular iron rim, the sides of which were about 2 feet long. The front edges of the rim were provided with saw-like teeth bent outward, so that when dragged along the bottom they would stir up the mud and such organisms as were in it, so that some of them would be taken in the net. The dredge was kept upright when in use by iron rods each 3 feet long, extending backward from each angle of the triangle, parallel with the direction of the net. This was the dredge used most, and was efficient in getting large samples of bottom material and the small animals living in it. A second dredge, which was little used, had a circular metal

mouthpiece without teeth, and four bars, like sled runners extended back from it.

(9) *Plant hooks.*—These, as the name implies, are hooks for dredging plants from the bottom in deep water. They were similar to those described by Pieters*, and were made as follows:

Four large hooks of heavy, strong wire were placed in one end of an iron pipe 18 inches long, at right angles to each other, and a piece of the same wire bent to form a ring in the other end, and the pipe was filled with melted lead. A line was fastened to the ring, and the hook was used for collecting plants from deep water being very efficient for the purpose, as shown by Plate 73.

A small bag-net about 6 inches in diameter and 2 feet long was fastened to the hooks, so that it dragged behind them to catch insects and other organisms disturbed by the hooks, and some of the mud stirred up by it; this was a useful addition to the drag. The combined apparatus was called "the hook and net drag."

(11) *Birge net.*—This was used but a few times in making small collections of plankton.

(12) *Soil sampler.*—This was a tool similar in form to that figured by Pieters†, and was made from a tin funnel and an iron pipe.

(12) *Walker dipper.*—This name was given to a copper dipper of about a quart capacity, having a bottom of wire cloth, and a handle with a screw clamp by means of which it could be quickly fastened to any convenient pole. It is the invention of Mr. Bryant Walker, who has long used it in collecting mollusks in shallow water, and who presented two of them to members of the survey party. There were very useful for making collections where the water was shallow.

(13) *Trap lantern.*—An acetylene bicycle lamp with funnels and reflectors, below which was a vessel containing potassium cyanide, was used to attract and capture flying insects at night. The apparatus was hung to trees or posts, near the lake or the outlet, and left over night. This lamp was invented by Dr. J. G. Needham.

(14) *Sieve net.*—This is a rectangular tray of heavy tin, having a long handle running at right angles with the bottom, which was made of wire netting. It was used like a hoe in shallow water, and was made for Dr. Needham's use after a design of his own.

II. *Equipment for making observations.*

1. *Water glass.*—This is a simple apparatus, consisting of a pane of glass set tightly into a deep frame which will keep out water. Of the four used, two were ordinary galvanized iron pails, with glass bottoms, and two were metallic trays, also with glass bottoms; one of the latter was 1½ feet and the other 3 feet square.

These glasses were placed on the surface of the water, and by looking through them, the effect of waves, or reflection and polarization, from the water was done away with. Under ordinary conditions of lighting objects 12 or 15 feet below the water surface could be distinctly seen. A wooden box with a pane of glass tightly set in the bottom will answer as well as the more expensive metal ones, and will furnish a means of obtaining a great amount of information regarding the habits of aquatic animals to any one living near a lake or stream.

*Pieters, A. J. Plants of Western Lake Erie. U. S. F. C. Bulletins, Vol. XXI. Washington, 1901, pp. 57–79.
†Pieters, A. J. loc. cit., p. 58.

2. *Searchlight.*—This was loaned by the U. S. Bureau of Fisheries, and was found valuable for getting records of fish in shallow water at night.

3. *Thermometers.*—A series of standard chemical thermometers, obtained from the Bausch and Lomb Optical Company, were used in taking deep-water temperatures, and a Negretti-Zambra deep sea thermometer was borrowed from Professor A. E. Birge of the University of Wisconsin, and used for a few days.

4. *Thermophone.*—This instrument was purchased for the investigation, but had been used only a short time at the opening of the season when it got out of order, and it was late in the season before it could be repaired, so but few readings were made with it.

5. *Anemometer.*—A small portable hand instrument, owned by the State Biological Survey, was constantly used to make observations on the velocity of the wind whenever other observations were made.

6. *Aneroid barometers.*—A pocket aneroid, the property of the Michigan Geological Survey, was used to obtain daily record of the atmosphere pressure near the lake level.

7. *Barograph.*—This instrument also belonged to the Michigan Geological Survey, and was kept running continuously from about May 1st to the middle of August.

8. *Turbidimeter.*—The standard candle turbidimeter, of the pattern used by the Bureau of Hydrology of the U. S. Geological Survey, was furnished by the Michigan Geological Survey, and used to measure the amount of turbidity of the water at various times.

9. *Colorimeter.*—This also was of the type used by the Bureau mentioned above, and was a part of the equipment furnished by the Michigan Geological Survey.

10. *Aquaria.*—Four aquaria were borrowed from the U. S. Bureau of Fisheries and were used for making photographs of live fish, for rearing insects, and for keeping aquatic animals which were under special observation. The aquaria were supplied with water from a metal watering tank, elevated somewhat above them, into which the water was pumped from the outlet of the lake. The position of this tank and arrangement of the aquaria are shown in Plate 74.

III. *Equipment for making records.*

1. *Field notes.*—The loose-leaf system of records was used, and the sheets for the day were carried in aluminum holders, which were found convenient for the purpose. The form reproduced below was used in recording observations at definite stations.

Locality.. Sheet............
Station..........Date..........190..Observer........Time of day.....
Air temperature..............Wind, direction......velocity...........
Water temperature, surface........bottom........other depths........
Sky............Light...........Air pressure.........................
Precipitation.........................Turbidity.....................
Bottom...
(a) Plants

(b) Invertebrates
(c) Vertebrates other than fishes

(d) Fishes observed but not taken

(e) Fishes taken: Method.......................Nets..................
Hauls.........................Depths............................
Names

Further notes on sheet...

2. *Cameras.*—A 4 x 5 reflex camera was used to make photographic notes to accompany the written ones, instead of sketches. For larger landscape work, a 6½ x 8½ and a 5 x 7 camera were used. For making pictures of living fish in the aquaria a 5 x 7 "graflex" camera was available on several occasions. Altogether several hundred photographs were made during the season, some of which are used to illustrate this report.

IV. *Miscellaneous equipment.*

1. *Tents.*—Two small tents, belonging to the Michigan Geological Survey were used for storage and field laboratories, for the rougher work.
2. *Preservation methods.*—The fish collected were preserved in formaldehyde according to a method used by R. E. Richardson of the Illinois Laboratory of Natural History. The fish were thoroughly hardened by leaving them in a 10% solution of formalin for a few days, after which they were transferred to a 2% solution for permanent preservation. Insects and a few other specimens were placed in alcohol, but relatively very little of this preservative was used.

Plant specimens were either pressed or preserved in 2% formalin solution. Large milk cans were used for storage of fish specimens, and the usual forms of glass vials, bottles, and jars were employed for small and delicate material.

APPENDIX II.

DATA ON STOMACH CONTENTS OF FISH TAKEN IN WALNUT LAKE.

BY T. L. HANKINSON.

The following tables, while not in any way pretending to give a complete account of the numbers of fish caught and examined, may give some indication of the food of the food-fish, especially the whitefish, thereby giving some information as to what is a proper habitat in which they will thrive. Other data regarding the same subject will be found in the section relating to various stations, with other similar facts which would not admit of tabulation.

Table 1.—Data relating to fish taken in fyke net in the pond-weed zone, station 3.

Name of fish.	Date.	Time of day.	Length of fish, inches.	Food.	Remarks.
Common sucker.......	April 9	9:45 A.M.	20		All fish taken on April 9, in from 10-15 ft. of water.
Rock bass............	April 9	9:45 A. M.	6	Much insect material; apparently mostly midges. A dragon-fly larva.	
Yellow perch..........	April 9	9:45 A. M.		3 Hexagenia larvæ and about 200 Daphnia.	
Common sunfish......	April 9	9:45 A. M.	6	Insect material. Nature?	
Yellow perch.........	April 10	9:30 A. M.	5½	Daphnia, with undeterminable material.	
Yellow perch..........	April 10	9:30 A. M.	6	Midge larvæ and Daphnia.	
Yellow perch..........	April 12	8:00 A. M.	4¾		
Blue-gill..............	April 12	8:00 A. M.	3	Many midge larvæ; 16 counted.	
Large mouth black bass	April 12	8:00 A. M.	8½	Stomach empty.	
Common sunfish.......	April 13	8:00 A. M.	3¾	Midge larvæ, caddice worms, an amphipod.	
Yellow perch..........	April 15	8:00 A. M.		Midge larvæ.	All fish taken on April 15, in from 12½ ft. of water.
Yellow perch..........	April 15	8:00 A. M.		Midge adults or pupæ.	
Yellow perch..........	April 15	8:00 A. M.		Midge larvæ and pupæ.	
Yellow perch..........	April 15	8:00 A. M.	6	10 midge larvæ and 6 pupæ	
Yellow perch..........	April 15	8:00 A. M.	5¾	May-fly larvæ and undeterminable material.	
Rockbass.............	April 15	8:00 A. M.	8		
Yellow perch..........	April 17	9:00 A. M.	5	65 midge pupæ.	
Yellow perch..........	April 20	2:00 P. M.		85 pupæ and adults of midges	
Yellow perch..........	April 20	2:00 P. M.		98 midge pupæ.	

Table 2.—Data regarding fish taken and examined at station 6.

Name of fish.	No. taken.	Date.	Length of fish, inches.	Food.
Common bullhead	1	April 28.	4 5-16	Crayfish, Hexagenia larvæ.
Yellow cat	2	April 28.	11¾, 12	Empty.
Common sucker	5	April 28.	15 to 18	Not examined.
Common sunfish	1	April 28.	7⅛	35 Hexagenia larvæ.
Blue-gill	14	April 29.	8 to 9	Midge adults, pupæ and larvæ, Hexagenia larvæ, *Sialis* larvæ, crayfish, dragon-fly larvæ, leeches. May 2—Hexagenia larvæ, Heptagenia larvæ. May 9—Caddice worms and Hexagenia larvæ.
Large-mouth black bass	1			A small perch, 4¼ inches long.
Wall-eyed pike	1			Empty.

*Table 3.—Data relating to fish taken at station 15.**

Name of fish.	No. taken.	Date.	Length of fish, inches.	Food.
Blue-spotted sunfish	1	May 4.	5¾	A small crayfish.
Common sunfish	2	May 4.	6⅜	6 midge larvæ.
Blue-gill	3	May 4.	8⅛	A crayfish 1 inch long, 3 caddice worms, 54 midge larvæ; the latter formed about 30% of the stomach contents.
Common sunfish	3	May 9.	6	(a) 8 heptagenia larvæ, 3 hexagenia larvæ, 3 midge larvæ; (b) 12 heptagenia larvæ, 6 caddice worms, 3 midge larvæ, 3 leeches; (c) Fragments of a crayfish, with much undeterminable insect material.
Large-mouth black bass	1	May 9.	9½	A number of small unidentifiable fish.
Common sunfish	15	June 9.		(a) Dragon-fly larvæ, 10 heptagenia larvæ, 2 hexagenia larvæ, 2 midge larvæ. (b) 17 heptagenia larvæ, 8 hexagenia larvæ, 4 caddice worms, a small crayfish and a leech.
Perch	400	April 23.	2 to 10½	
Yellow cat	3	" "	9¼ to 11	
Common bullhead	1	" "	12	
Rock bass	1	" "	7¼	
Common sunfish			6	
Perch	124	April 24.	4 to 9½	
Perch	525	April 25.	2 to 6	
Wall-eyed pike	2	April 26.	26	1 with perch 4 inches long, other empty.
Whitefish	1	April 26.	13½	Several midge and May-fly larvae
Common sucker	3	" "	17¼	Larvæ.
Whitefish	1	" "	19	Mostly midge larvæ.
Large-mouth black bass	1	" "	15	Empty.
Wall-eyed pike	1		19	Empty.
Common sucker	1	Later same day	16¼	
Whitefish	1	Later same day	18¼	A few whitened snail shells.
Common sucker	1	July 6.	17½	
Yellow perch	11	Aug. 11.	4 to 5¼	
Large-mouth black bass	5	" "	2½ to 3	
Blue-gill	5	" "	2½	
Blue-spotted sunfish	2	June 9.	7 to 8	(a) Three small crayfish, dragon-fly larvæ. (b) A small fish so far digested as to be unidentifiable.

* First six listed caught by a trammel net; the last four by drag seine, and others by gill net or fyke net.

*Table 4.—Data relating to fish taken at station 4.**

Name of fish.	No. taken.	Date.	Length of fish, inches.	Food.
Pike.................	3	April 3.	12 to 17	Perch.
Perch................	1		9½	Empty.
Common sunfish.......	3		5 to 7	4 larvæ and 4 adult midges, 2 hexagenia larvæ and a small leech.

* Caught by drag net.

Table 5.—Data relating to fish taken at station 7.

Name of fish.	Date.	Length of fish, inches.	Food.
Blue-gill.................	April 25.	8¼	Midge larvæ and undeterminable material.
Rock bass...............	May 1.	9	2 crayfish.
Black bass...............	May 1.	4¼	1 crayfish.
Black bass...............	May 1.	4½	2 crayfish.
Common sunfish..........	May 1.	9¾	2 caddice worms, 2 caddice worm pupæ, 9 hexagenia larvæ, 1 heptagenia larvæ, 2 crayfish.
Common sunfish..........	May 1.	6	1 dragon-fly larvæ, 1 heptagenia larvæ, 3 hexagenia larvæ.
Common bullhead........	May 1.	13½	2 dragon-fly larvæ, 32 hexagenia larvæ, 2 midge larvæ 1 minute mussel.
Black bass	May 1.	9½	1 small crayfish, miscellaneous insect material, water moss.
Blue-gill.................	May 4.	8¼	1 hexagenia larvæ, 2 heptagenia larvæ, 105 midge (?) larvæ.
Common sunfish..........	May 4.		16 hexagenia larvæ.
Black bass...............	May 4.	9	5 small crayfish.
Blue-spotted sunfish......	May 4.	9	4 small crayfish.
Blue-spotted sunfish......	May 5.	2½	1 small crayfish and a leech.
Blue-spotted sunfish......	May 5.		1 leech.
Blue-gill.................	May 5.	5¼	May-flies, midge pupæ and amphipods.
Black bass...............	May 6.	9¼	Crayfish fragments.
Common sunfish..........	May 6.		8 Hexagenia larvæ, 2 heptagenia.
Rock bass...............	May 7.	1⅝	Midge larvæ.
Tadpole stone-cat.........	May 23.	1½	Insect fragments: legs, heads, etc.
Rock bass...............	May 30.	9¼	Crayfish fragments.
Black bass...............	May 31.		
Wall-eyed pike...........	June 12.	22½	Empty.
Common bullhead........	June 13.		Crayfish fragments.
Yellow cat...............	June 13.	11	Crayfish fragments.
Black bass...............	June 13.	14¼	Crayfish.
Perch....................	June 27.	1½	Copepods.
Mud minnow.............	July 1.	2	Entomostracans and hydrachnids.
Golden shiner............	July 8.		Filamentous algæ and midges, entomostracans, Arcella shells.
Golden shiner............	July 8.		Filamentous algæ, Arcella shells.
Mud minnow.............	July 11.	3⅛	Insect material, entomostracans.
Yellow catfish............	July 11.	3½	Midge larvæ and May-fly larvæ.
Common bullhead........	July 11.	1¼	Midge larvæ, entomostracans.
Black bass...............	July 11.	1¼	Entomostracans.
Golden shiner............	July 16.	3	Filamentous algæ, apparently all spirogyra.
Golden shiner............	July 16.	3	Same as last.
Golden shiner............	July 16.	3¼	Same as last.
Blue-gill.................	July 16.	2½	Insects and entomostracans.
Common sunfish..........	July 16.	2¾	Midges and other insects.

Table 6.—Data relating to fish taken at station 41.

Name of fish.	Date.	Length of fish, inches.	Method of capture.	Food.
Large-mouth black bass...	May 31.	2½	Minnow seine	A least darter.
Black bass..............	May 31	2½	" "	Two least darters.
Blue-spotted sunfish......	May 31.	3½	" "	Dragon-fly larva.
Blue-spotted sunfish......	May 31.	1½	" "	Miscellaneous insect material, legs, etc. Some hydrachnids.
Barred killifish...........	May 31.	1¼ to 3		Insect material, midge larvæ.
Perch..................	June 26.	1⅜	" "	Entomostracans.
Perch..................	June 26.	1⅜	" "	Entomostracans, with badly digested other food.
Rock bass..............	June 26.	2⅝	" "	Crayfish fragments.
Rock bass..............	June 26.	2½	" "	Crayfish fragments.
Least darter............	June 26.	1⅛	" "	Entomostracans and insect material.
Perch..................	June 26.	4	" "	Several small crayfish, each about ⅜-inch in length. Part of a small fish, which was about ½-inch long.

*Table 7.—Data relating to fish taken at station 54.**

Name of fish.	Date.	No. taken.	Length of fish, inches.	Food.
Common bullhead........	May 1.	2	11, 17	Crayfish fragments.
Yellow cat.............	" "	1	11	
Pike..................	" "	6	12½–14½	Small perch, 3 darters, 1 least darter.
Blue-gill................	May 3.	1	4¼	40 midge larvæ, 4 caddice worms.
Large-mouthed black bass.	" "	1	5¼	Empty.
Pike..................	" "	2	9, 14	Small perch in one, other had nothing.
Rock bass..............	" "	5	4½–8¾	(a) 2 dragon-fly larvæ and 2 May-fly larvæ. (b) 2 dragon-fly larvae and 2 May-fly larvæ. (c) Parts of 8 small crayfish. (d) A crayfish 2½ inches long. (e) Hexagenia larvæ, a leech, and 4 small crayfish.
Blue-gill................	May 7.	1	8	Miscellaneous insect material.
Large-mouthed black bass.	" "	2	13½, 14	A small crayfish in one, also one in the other.
Pike..................	" "	1	14¼	Empty.
Blue-gill................	" "	3	3½–7	In one stomach 60 midge pupæ and some larvæ.
Long-eared Sunfish......	" "	1	7¼	A few midges and other insects.
Common sunfish.........	May 9.	3	6–6¼	(a) May-fly larvæ, 2 leeches. (b) Dragon-fly larvæ and 2 caddice worms. (c) May-fly larvæ.
Common sunfish.........	May 9.	4	5½–7	May-fly larvæ and a leech in two, another with nothing, and a fourth with some very small crayfish.
Large-mouthed black bass.	May 9.	1	8½	A leech.

* Taken with trammel net.

*Table 8.—Data relating to fish taken at station 200.**

Name of fish.	Date.	No. taken.	Length of fish, inches.	Food.
Perch..................	May 14.	100		
Common sucker.........	Aug. 6.	13	16 to 19	3 feeding on midge larvæ; 1 had a mass of Daphnia in the alimentary canal.
Whitefish...............	Aug. 6.	3	14–17½	Stomach filled with Daphnia.
Common sucker.........	....	2	16½	One empty and the other full of Daphnia.
Whitefish...............	Aug. 17.	1	14½	Full of Daphnia.
Wall-eyed pike..........	....	1	2 feet	Small fish.
Common sucker.........	Aug. 18	12	16, 17	Midge larvæ, many Daphnia.
Whitefish...............	....	5	12–17	Midge larvæ, many Daphnia.

* All but perch taken in gill net.

*Table 9.—Data relating to fish taken at station 225.**

Name of fish.	Date.	No. taken.	Length of fish, inches.	Food.
Whitefish...............	April 18.	2	16, 17	200 or more midge larvæ; 90% of the food in stomachs.
Whitefish...............	May 5.	3	16–17	Midge larvæ.
Whitefish...............	May 9.	2	14–18½	Midge larvæ.
Common sucker.........	May 11.	1	....	3 dozen dragon-fly larvæ; pupæ of same fly.
Whitefish...............	May 12.	1	....	3 small mussels, some marl and undeterminable material; no midges.
Common sucker.........	May 14.	3	17	
Whitefish...............	....	2	16,17	(a) A midge pupæ, 85 midge larvæ, 10 Sayomvia. (b) 60 midge larvæ, 3 Sayomyia, a bone of some fish.
Whitefish...............	May 15.	2	....	Empty.
Whitefish...............	About the middle of June.	1	....	Midge larvæ, a lot of fish bones and pieces of fish, probably from the bait on the line.

* Taken in gill net except last whitefish, which was caught on set line.

APPENDIX III.

NOTES ON THE AQUATIC INSECTS OF WALNUT LAKE

WITH ESPECIAL REFERENCE TO A FEW SPECIES OF CONSIDERABLE IMPORTANCE AS FISH FOOD.

By JAMES G. NEEDHAM.

In June Prof. Reighard wrote me that the Survey at Walnut Lake was finding insects an important element in the food of fishes there, and asked whether I could not come myself or send some one to study them. Having no one to send at the time, and being greatly interested in the matter because of former similar findings of my own, I determined to go myself, if only for a little while. I was then on the point of departure for the meeting of the American Association for the Advancement of Science at Ithaca, and I stopped off *en route* to spend part of three days at Walnut Lake going, and a week, returning from the meeting. Of these ten days—June 26–8, and July 8–14, I was favored by accessibility of quarters to collecting grounds, by good weather and good equipment, and especially by the intelligent aid of the two men in charge of the station work, Mr. T. L. Hankinson and Mr. Elmer McDonald. But even with these advantages, and with the aid of additional collections made before my arrival and after my departure, it was manifestly impossible to do more than scratch the surface of the insect problem in a few spots. Aquatic insects are a great host, and there is none of them whose life history is not beset with many unsolved problems.

Both Director Lane and Professor Reighard recognized the limitations and merely asked that I should proceed with such collecting and observations as would be possible during my stay. The results are embodied in the following pages.

In company with Mr. C. C. Adams and the station staff I first visited all the collecting stations on the lake, looking out for the most favorable places for finding insects. Then I made a hasty examination of insects collected by Mr. Hankinson from fish stomachs, to see which appeared to be the important species. These proved to be, as usual, midges and May-flies, whose larvæ live in water of some depth.

The activities of the adults begin after sundown: so, at the lake, until dark or later, I spent every evening at the exceedingly difficult task of observing the swarming and mating habits, and succeeded in filling a few gaps in our knowledge of the more important species. I collected by day with a dredge in deep water, or with nets along shore. A single trap lantern, run every night, supplemented the collections with tens of thousands of specimens and a goodly number of additional species, mostly aquatic insects. I made a single trip down the outlet of the lake and found in the rapid part of the stream a fine station for collecting Parnid beetles.

A few species of great importance as fish food, however, received the greater share of my attention, and my observations thereon comprise the first part of the following paper, the second part being an annotated list of the aquatic insects observed, and the third part some observations made in cooperation with Mr. McDonald on a dipterous gall upon the submerged petioles of the yellow water lily.

I. THE IMPORTANT FOOD SPECIES.

Professor Hankinson's detailed report on the food of the fishes of Walnut Lake, given elsewhere in these pages, demonstrates again the great importance of the larvæ of midges of the genus Chironomus and of Mayflies of the genus Hexagenia, and shows that fishes which forage on rocky shores, feed to some extent also upon the larvæ of Mayflies of the genus Heptagenia. These insects have several common characteristics. They all have a very short period of adult life, during which no food is eaten: the mouth parts in all are rudimentary. The adult life of all is concerned solely with reproduction, and they all leave the water with the sexual products practically mature. They all transform in open water, leaving their cast off skins floating upon the surface, and fly to some shelter on shore. They are all nocturnal or crepuscular in their adult habits, and in consequence, are very difficult of observation.

Chironomus.

This great genus of midges is represented by a considerable number of species at Walnut Lake. A few of the larger species that live in the deeper water are doubtless of most importance as fish food: for it is the larger larvæ that are found in their stomachs. The largest species of the genus, *Chironomus plumosus*, was common, and, finding there my first opportunity for making observations on the habits of this species, I gave to it the greater share of my attention and time. I give a special account of it below, following this with some general observation on the structure and habits of a number of others of the larger members of the genus.

It may be said of the larvæ of the larger species of Chironomus that they are the well known "blood worms," one lifts with a dip net out of the black bottom mud of any deep pool, an inch or less in length, cylindric, of a bright transparent red color, legless, save for a pair of short prolegs at each end of the body, the anterior ones ending in a disheveled brush of soft hairs, the posterior ones bearing slender double-arched claws, hairless save for two conspicuous tufts of bristles on the end of the last segment of the body above and a few microscopic hairs about the head, living in thin-walled tubes of homespun silk covered with adherent silt, and when torn from their tube swimming with figure-of-eight-shaped loopings of the body, they are easily recognizable by any one.

Chironomus plumosus, Linn. *The Plumed Midge.*—This species is easily recognized by its great size (11 to 12 mm. in length of body); it is the largest of the genus. It is common at Walnut Lake, but would not be likely to be found so except by a collector specially looking for it. An occasional specimen may be seen flying across the water from its place of transformation to find shelter among the trees on shore. Near the water's edge one will occasionally be flushed from a tree trunk or from an overhanging bough, and on sweeping the shore vegetation in sedgy areas with an insect net, one will often be taken from the dry summit of a typha stem. But few of the adults are discoverable except by watching for their evening flights.

Swarming and mating habits.—*Chironomus plumosus* appears on the wing for its mating flight at a time about midway between sundown and dark. Unfortunately, before its appearance nightfall has covered the surrounding woods and meadows with blackness against which the midges cannot be seen at all; they are only visible against the background of the lighted sky above. Hence one cannot see them coming from their resting places to join the company in flight. How eagerly I watched for this, only to have the curtain of darkness fall to the edge of the horizon before any of the plumed midges had been sighted. Then a few would appear overhead, three or four or five of them, eight or ten meters high, and would quickly fall to flying horizontally back and forth upon a regular beat. Gradually they would be joined by others; but they never form thick clouds, as do many of the smaller species. The individuals stand well apart in their flight, with usually several decimeters space between them. After a little while one could determine by changing his base of observation that a considerable area was overhung by the hovering midges.

Their habit is to fly swiftly forward head to wind for a distance of about 10 meters, and then holding the body to the same position still, to drift rather more slowly backward to the starting point. This is repeated continuously by all the individuals in the flight, though not quite synchronously. When a good breeze is blowing they move quite horizontally, and in straight lines; when it is calm their movements are a little less regular. There seems always to be enough movement of the air to determine their position in flight, which is always head to windward. Even at the height of 10 meters one could see by looking carefully that nearly all the individuals were males. An occasional female could be recognized by her distinctly larger size. With a little practice the females could be followed through the entire course of their brief mating flight; for while the males appear to hover with the swarm through the whole period of observation, each female flies but a few minutes. She could be seen entering the swarm, rising in flight as if coming from some resting place in the marshes. She would take her place in the company, falling into step, so to speak, and moving back and forth at a proper interval, in straight horizontal lines. Then, while in her windward course, a male would be seen to approach, to grasp her from above with his feet, and the two would appear as one for an instant. Then, having seized her abdomen with his claspers he would turn about face just at the time when she reached the windward end of the beat, and, heading the opposite way, after the manner of midges in copulation, in apparently active flight, lead the return course to the leeward end of the beat. There they would separate, the male returning to the swarm, the female leaving for parts unknown. She was always lost from view almost immediately. I could only see that in departing her flight had no relation to the wind; she flew obliquely downward, usually in the direction of the lake, but once or twice apparently in the opposite direction toward the trees. The whole mating act occupied hardly more than one or two seconds of time.

The laying of the eggs I did not succeed in observing. The triangle dredge brought up from the bottom a single clump of Chironomus eggs in 30 feet of water, forming so large a mass it could hardly have been laid by any other of our species. It was taken July 9th at station 5, placed in bottle of water in the laboratory, and there the eggs hatched on the 11th and 12th. The young larvæ swam freely upward and outward to become aggregated upon the lighted side of the bottle. Each still carried a little mass of unabsorbed yolk. Doubtless this is the time of their distribution over the bottom. Doubtless this is the time they get into the plankton in greatest numbers; the plankton chironomids are usually minute ones. By the 13 of July about half of those larvæ that had hatched were constructing such sort of cases on the bottom of the bottle and on the paper label it contained as the scanty sediment in the bottle allowed.

The further life history of this species has not been traced. Dr. Johannsen has described larvæ and pupæ from the Renwick marshes at Ithaca, N. Y. which he has referred to this species with a high degree of probability. The larvæ I found by dredging in 100 ft. of water in Walnut Lake were not the same species described by Dr. Johannsen; neither were those obtained earlier in the season from whitefish stomachs; neither were these last the same as those I dredged. It is highly probable, however, that this is one of several deep-water species of Walnut Lake, for in addition to the occasional very large pupa skins found floating on the surface, Mr. Hankinson has taken the newly emerged imagos on the surface over deep water.

I was able to determine approximately the number of eggs produced by this species by capturing a newly emerged female, keeping her until mature, dissecting out the ovaries and counting the eggs. The newly emerged adult is still reddish in color, especially at the sutures between body segments, the red color of the blood still showing through the slowly darkening cuticle. The ovaries contained in this case about 3000 eggs.

Chironomus meridionalis Joh.—I observed the swarming and mating habits of this species also on several evenings. At station 1 small swarms could be observed almost anywhere along shore as darkness was falling. The swarms maintained an elevation of but one to two meters above the ground. The flight of individuals was head to wind always, through a distance of hardly more than a meter, then a drifting backward to the rear of the swarm, forward and backward, in endless repetition, not, however, in straight lines, as in *Chironomus plumosus*, but with much irregular weaving up and down, and with a constant shifting of relative positions in the swarm. The females stay longer in the swarm in this species. I watched one female twenty minutes from her entering and then lost her without seeing the conclusion of her flight. I observed copulation in a number of other instances; it occurs quite as in *Ch. plumosus*, and has the same sequel—the female departs immediately thereafter, and the male returns to the swarm and resumes flying.

Chironomus albistria Walker.—Mr. McDonald found this species living in green petioles of *Nymphœa advena*, and showed them to me on my first visit to Walnut Lake. I was greatly interested to know a species with such a habit, and suggested that he rear some of the larvæ. This he did, obtaining his first imagos on July 10th. The adults were not observed at large, and nothing is known of their habits. Larvæ and pupæ are described below.

Formerly I found at the campus pond in Lake Forest, Ill., the dead leaves of typha teeming with larvæ of the chironomid *Tanypus carneus*, and I innocently supposed they were eating the leaves, until I made an examination of their stomach contents. This revealed to me the fact that their diet within the leaves was practically the same as that of other chironomid larvæ living upon the pond bottom—diatoms and the minuter algæ—while the tissue of typha were not eaten at all; this was shredded and used to cover the silken tubes within which the larvæ dwelt in the excavations in the leaves, much as others live upon the pond bottom.

The larvæ of *Chironomus albistria* live in elongated excavations in the green nymphæa petioles, having one or more blackish minute openings to the outside. These openings, being slightly discolored, were an easy means of recognizing infested stems. The earliest of the leaves that reach the surface of the water were the ones most infested, and the longest internal chambers, with the largest external openings leading into them, were found near the base of these. However, many of the tunnels were cut high up on young vigorous petioles, and looked as if made by the chironomus larvæ themselves from the beginning; so I was curious to see whether these larvæ were eating green plant tissue. I examined the stomach contents of half a dozen larvæ of different sizes, freshly brought in from the field. In the smaller ones I found only algæ and silt. In all of the larger ones I found a little, and in one of the largest, much, nymphæa tissue. Certain parts of this tissue are exceptionally easy to recognize—the internal hairs, for instance, which spring from junction cells in walls separating the normal air spaces of the tissue of the petiole, and project into those spaces; these hairs are covered with microscopic prickles, and are easily recognizable even in fragments, while whole hairs were frequently found, and in the case of the one larva that had eaten most freely of the tissue, whole junction cells fairly well isolated from their surroundings, and bur-like with groups of these hairs projecting in all directions from them, were present.

The larvæ entering the nymphæa tissue needs but remove a few thin partition walls in order to have space enough to live in. It spins about itself the usual thin tissue of silk, and for a covering uses the materials of the demolished air-space partitions. Over the outside of the older parts of its case, and in the vestibule of its chambers diatoms and other very minute algæ flourish abundantly, as they do all over the outside of the stems. And the manner of life of these larvæ is not greatly different from that of their congeners on the pond bottom. Doubtless they are more protected during larval life; they show also some modifications of the minuter structures of the feeding organs to be mentioned in the following descriptions.

The larva when fully grown measures 16 mm. in length and 1 mm. in diameter. It is of the usual cylindric form, of a bright transparent red color, with a reddish brown head. The two caudal tufts contain each six very close set yellowish hairs, and there are two isolated hairs below the tufts above the anal gills. The latter are four as usual, thick, obtuse and hardly longer than the anal prolegs; there are no other abdominal gills. The claws of the prolegs are obliquely U-shaped. The labial border (Fig. 19) is of a very unusual form, being elongate and deeply bilobed, with no very distinct teeth save the two very large ones that terminate its lobes, and that are separated by a triangular space of their own width. There are faint indications of two low teeth nearer the median line, and of five outside on each lateral margin. The epipharyngeal comb is poorly developed, consisting of a row of three obtuse, triangular tubercles (Fig 19 m).

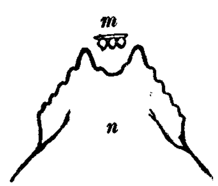

Fig. 19.—*Chironomus albistria* Walker. m—The epipharyngeal comb of the larva; n—the labial border; both x 55.

The pupa measures 12 mm. in length. It is red in color, darkening with age with the appearance of the adult pigmentation. It possesses the usual thoracic tufts of respiratory filaments, sessile, short, spreading and very finely divided by successive branchings. Across the apex of the 2nd abdominal segment on the dorsal side there is a fine line of minute chitinous black

teeth, which scarcely extends down upon the sides. The postero-lateral expansion of the 8th abdominal segment ends in a digitate comb of about five posteriorly directed teeth, of which the middle one is longest and strongest, the second and fourth shorter and sub-equal, and the first and fifth minute or rudimentary, and before these on the lateral margin of the segment is a row of four slender distant spinules. The bifid ventral appendage of the end of the abdomen is slightly longer than the body of the caudal fin; the fringe of the fin is semi-circular in outline and continuous over the two lobes; it is composed of very fine silky yellowish hairs, and is one-half longer than the 9th segment.

REMARKS ON TWO OTHER CHIRONOMUS LARVÆ FOUND IN DEEP WATER IN WALNUT LAKE, AND ON THE MEANS OF DISTINGUISHING THE SPECIES.

I have had for study two species of Chironomus larvæ from Walnut Lake obtained from deep water, one taken by myself with a triangle dredge in 100 feet of water, and examined both fresh and preserved; the other taken from the stomach of a whitefish by Mr. Hankinson. The former is apparently identical with the species I found making up the greater part of the food of the brook trout in Bone Pond near Saranac Inn in the Adirondacks in 1900 (figured in detail by Dr. Johannsen on pl. 49 of Bull. 68, N. Y. State Museum). What the species is, is not yet known. Likewise, it is not yet known to what species of adult the other larvæ which the whitefish were eating so extensively in April belongs. It is doubtless a smaller species; the larva lacks blood gills on the penultimate abdominal segment. It is quite like the larva of *Ch. fulviventris* as described in Bull. 86, N. Y. State Museum and figured in plate 22, Figs. 19 and 24–26; but it differs from that species in at least two characters of the sort that usually distinguish species in this genus. (1) The teeth of the labial border are similar as far out from the middle as the third in these two species, but of the remainder each side, it is the seventh (Fig. 20*q*), and not the fourth that is prolonged beyond the level of the tips of the others. (2) The three pieces of the epipharyngeal comb are three-toothed in fulviventris; they are five-rayed in the Walnut lake species (Fig. 20*p* .

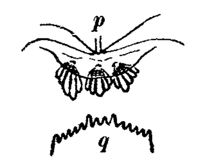

Fig. 20.—Unknown Chironomus larvæ from stomach of whitefish; p—epipharyngeal comb, x 310; q— labial border, x 55.

It should be obvious at once that the most immediate and insistent need of such studies as that in progress at Walnut Lake is further life history work upon these important species. In order to assist any one who may take up that work in the discrimination of species among the larvæ of the genus, I present herewith a semi-diagrammatized figure (Fig. 21) of the mouth parts of the larva of *Chironomus viridicollis*, a species which I have bred from a sluggish stream (the Skokie), near lake Forest and I designate in that figure the typical parts of the curious and complicated mouth apparatus in this genus. It will be observed in the living larva that the mandibles do not oppose each other in the usual way, but instead swing obliquely downward against the toothed edge of the labial border; that the epipharynx and the whole ventral border of the labrum and roof of the mouth has developed an armature of combs and rakers directed backward toward the mouth opening; and that the front of the head is developed into a narrow, rounded prominence, beset with hairs, the lowermost of which are often decurved and pectinated. The homologies of all these parts are by no means clear as yet. The more important parts are designated by tentative and provisional names in the explanation to the figure. The shape, number and proportions of the teeth in the labial border and in the epipharyngeal comb have been found most useful hitherto in the discrimination of the species, and figure 21 and the excellent plates in the monograph by Johannsen will abundantly illustrate the sort of differences likely to be found between them.

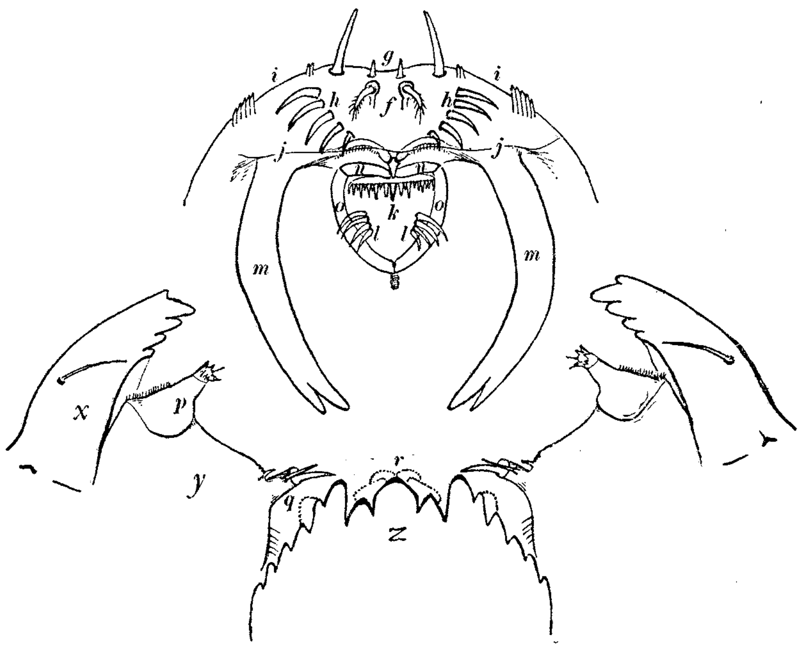

Fig. 21.—Semi-diagrammatic figure of the buccal apparatus of the larva of *Chironomus viridicollis* V. d. W., viewed from below, the mandibles, *x*, and maxillæ, *y*, spread out laterally, and the top of the mouth moved a little anteriorly so as to show all of the epipharyngeal armature (based on drawings by Mr. H. R. Stewart). The line *j-j* represents the labral margin of the mouth; the parts above it are on the front of the head, outside the mouth; the parts below it are in the roof of the mouth. The ill defined fringe of fine bristles along this margin has sometimes been designated as the anterior comb. *f*, the pedunculate palps (only their peduncles are shown in Miall and Hammond's *The Harlequin Fly* Fig 16), *g*, frontal sensory hairs; *h*, *h*, labral or external rakers; *i*, *i*, lateral papillæ; *k*, epipharyngeal (or posterior) comb; *l*, *l*, epipharyngeal or internal rakers; *m*, *m*, lateral arms; *n*, *n*, anterior cross bar; *o*, *o*, U-bar; *p*, maxillary palpus; *q*, lacinia of the maxilla; *r*, hypopharynx?; *z*, the labial border, heavily chitinized (in situ, the mandibles swing obliquely downward against this border).

A simple mode of manipulation enables one to mount preparations of the heads of chironomus larvæ for the microscope to show the above designated parts. The heads are cut off and boiled for a few minutes in a weak solution of caustic potash, then mounted ventral side up in balsam after the usual methods. A slight pressure upon the cover will usually cause the mandibles to swing outward, exposing fully the more important structures. The

parts may, of course be dissociated with needles and placed in any desired position.

The larval cases of Chironomus.—As already stated for *Ch. plumosus*, the larva begins a day or two after hatching to construct a case to dwell in. The basis of construction is the more or less silk-like secretion of the remarkable salivary glands, which hardens on contact with the water. It is spun out not in threads, but in tenuous sheets of more or less flocculence, to which silt adheres readily, protectively coloring the whole exterior. Since the larva crawls into the bottom silt and fashions its case there, it is probable that there is no voluntary adding of pieces to the outside as with caddis fly larvæ, but that the secretion holds fast automatically to whatever touches it. That it holds silt securely is evidenced by the figure in plate 75, which was made from cases taken up in a dredge in 100 feet of water, sifted roughly, carried to the laboratory, and lifted out with a forceps on to a white plate before being photographed. These are not portable cases, they are mere run ways or silk-lined tunnels through the silt. They are usually open at both ends, and may readily be torn open anywhere. They are usually many times as long as the larvæ that live in them. The same diatoms and other algæ are found adhering to them and to the bottom silt generally as are found in the larval stomachs. The cases are very fragile, many will not stand to be lifted out of the water by one end. They are not eaten with the larva but are winnowed out. Such sweeping or fanning action of the fins as results from the labor that many fishes perform in the making of their nests would be more than sufficient to tear up the cases and dislodge the contained larvæ.

Fishes eat, and doubtless by preference, the larger larvæ. Some indirect evidence on this point was obtained by comparing the sizes of a lot that had been eaten with a sample catch taken from the lake bottom with the dredge. A short haul was made in 100 feet of water and about half a bushel of black bottom mud was brought up and sifted for Chironomus larvæ. These were separated by Mr. McDonald according to sizes into four groups and counted with the following results:

Length of larvæ.	Number.	%
12–18 mm.	6	1.25
9–10 mm.	75	15.
8–9 mm.	225	46.
7–8 mm.	185	37.75
	491	100

Then a well preserved lot of larvæ from the stomach of a whitefish (No. 680*) were likewise similarly separated into groups and counted, with the following results:

Length of larvæ.	Number.	%
12–18 mm.	99	57
8–12 mm.	70	40
7–8 mm.	5	3
	174	100

Clearly the fishes eat the larger larvæ.

*This fish had eaten also 5 Sayomyia larvæ, 1 Hexagenia larva and a little mussel, Pisidium.

Hexagenia variabilis Eaton.—This species is common at Walnut Lake, though little in evidence by day. An occasional specimen can be seen flying upon transformation from open water to the woods on shore. At rest on shore, they are conspicuous enough because of their large size. They sit rigidly, and, if approached quietly, allow themselves to be picked up with the fingers. I could not discover any place or time of swarming, nor find any considerable number of individuals on the wing at any given place. Yet the abundance of the cast skins that float upon the surface shows that a considerable number of imagos are emerging all the while. In Bull. 47, N. Y. State Museum, I published an account of the life history of this species with figures of larval and adult stages.

The eggs are probably laid upon the surface of the water, the female falling flat upon the water with wings outspread and liberating them there. I frequently saw females floating thus at nightfall, but was not able to demonstrate that they were ovipositing. Many other Mayflies liberate their eggs in this manner. The eggs doubtless settle to the bottom, tending apart as they fall, and becoming scattered somewhat, according to the depth and currents of the water. The larvæ live as shallow burrowers in the bottom silt. The length of the larval life is unknown. When grown they swim to the surface and transform there. The subimago emerges suddenly from a rent in the back of the old larval skin, its wings expanding fully almost at once; it stands for an instant on the surface and then flies away toward the shore. This transformation occurs at any time of the day or night. The final moult, the casting of the subimago skin occurs within 24 hours thereafter, the period intervening being spent in inactivity. The evening following is probably the period of adult activity—the time when the mating flight occurs, and when the eggs are laid, though observations are yet lacking upon these points.

I was able to determine at Walnut Lake the egg-laying capacity of this species. I captured sub-imagos when leaving the water or when resting on shore, kept them through their final moult until fully adult and obtained their eggs. I was preparing to get the eggs by dissection of my first specimen when I made a curious discovery. I placed the fully adult female upon water in a watch-glass and with fine scissors, snipped off her head. Immediately she began depositing her eggs* in the water beneath her, pouring them out rapidly from both oviducts, and not ceasing until they were all deposited (this I determined by dissection later). This occupied not more than two minutes. A partial count and estimate of the number of eggs thus laid put it at about 9000. The method thus found being so easy of application, I repeated the performance with a number of other females, obtaining somewhat smaller numbers, though the lowest estimate was 7850 eggs. The average number was about 8000.

The eggs are translucent whitish, oblong, broadly rounded on the ends, and show no visible micropyle. They are already filled at laying with minute yolk balls. The chorion is very thin and transparent, and the gelatinous envelope is exceedingly scanty, and at first little adhesive, insomuch that the eggs roll freely about in the water. However, after they have lain in the water a few hours a gelatinous connection is easily seen between two eggs that lie in contact, and any silt in the water becomes attached to them. These eggs being unfertilized, showed no signs of further development.

It was most interesting to see this automatic response on the part of the

* This reaction does not follow like treatment of any other Mayfly on which I have tried it—not even the closely allied *H. bilineata* Say.

female to an unusual stimulus, leading to the complete performance of the last important act of her life. I doubt not that it may be brought about in other ways. Mr. Viereck showed me a pair of this species that he had caught somewhere in Pennsylvania on his way to the Ithaca meeting. Having no cyanide bottle he killed them by pinching the thorax, whereupon the female extruded *into the air* in two oblong packets the entire contents of her ovaries.

Along the wave-washed, marl-floored shallows between stations 1 and 7, and between stations 7 and 15 I could find any evening a number of adult females flying. They were certainly "going through the motions" of laying eggs, falling flat upon the surface with wings outspread, rising, flying on, and falling again, or sweeping along for a time close to the jutting edge of the sedge zone at the shore. But I caught a dozen or more of them at different times and they were all spent females, with no eggs remaining. This, always just as darkness was closing in. They had laid their eggs probably earlier in the evening, and perhaps farther out from shore. The larvæ are found mainly in deeper water.

Heptagenia pulchella and the *twilight procession of swarming species.*—This is in every respect a very different May-fly, more nocturnal, more secretive, more fragile, with depressed larvæ that cling closely to stones, preferably on wave-washed shores. The larvæ are eaten by shore-feeding fishes, and are easily collected by picking them from stones quickly lifted out of the water, but the imagos are infrequently seen. Subimagos, at leaving the water fly to lights occasionally; they transform within twenty-four hours and probably mate and oviposit the night following their last moulting, though this has not yet been observed.

There is a regular procession of crepuscular insects appearing on the wing for their mating flight on the shore of Walnut Lake during July. Directly after sundown the little red-eyed fly, *Synechis simplex* Walker, appears in ill defined companies darting about in irregular, though chiefly horizontal flight, usually near, but not over the water. Then the beautiful May-fly, *Ephemera simulans*, appears in companies of males over the edge of the water. The flight of one of these companies is a most delightful performance to witness, it is so light and graceful, and appears, withal, so exhilerating. Yet it is all up and down in vertical lines. With upturned head each individual flies rapidly upward, mounting quickly to a height of ten or fifteen meters, then spreading its wings out horizontally it falls upon them, with long fore legs extended forward and longer tails extended backward full length, rudderlike, keeping it always head to wind. Thus it descends floating on the air, yet not drifting, until, at the lower level of the swarm (four or five meters above the water), it lifts its head and rises rapidly again in flight. And the whole company flying and falling thus, weaving up and down in vertical lines, and passing and repassing each other, create a scene of great animation.

About as soon as the flight of the *Ephemera* swarms is well established, *Chironomus plumosus* appears in the horizontal flight that I have described on preceding pages. *Chironomus meridionalis* also appears nearer the ground. Then, as the darkness deepens, the May-fly *Cænis*, the smallest of all the *Ephemera*, comes out to perform in little swarms, which one may see if he chance to come close enough; they are hardly visible for a distance of more than a few feet. These are males also, which weave up and down in straight lines hardly rising higher than one's head.

Last of all the visible performers, *Heptagenia*, appears when it is almost too dark to see, in small companies of males, which weave up and down *obliquely*, flying forward and upward, head to wind, and drifting and settling downward and backward to the starting point. How high these go could hardly be told on the several occasions when I watched them, the white forms being little visible against the sky (one could see them but a few feet) but they descend to a level easily within reach of a net. Whether females come near these swarms when in search of mates I was wholly unable to observe. Detailed knowledge of the mating and ovipositing habits of this species will be gleaned with great difficulty. A search light which we brought into requisition at station 1 was of no practical assistance in observing any of the flights above described.

I reared this species at Saranac Inn, N. Y., in 1900, and published a description of the larvæ in Bull. 47, N. Y. State Museum, p. 421 (Pl. 15, Fig. 15). The importance of the larvæ as fish food may be gathered from the facts Mr. Hankinson has furnished elsewhere in this report. The food of the larvæ consists of such dead plant materials, and living algæ intermixed therewith as they may find about the under surfaces of the stones to which they cling. It is intermixed with much silt and with some sand. I examined a number of specimens carefully and could find no animal remains whatever.

II.—ANNOTATED LIST OF THE SPECIES OBSERVED.

Plecoptera. Stoneflies.

1. *Chloroperla brunneipennis* Walsh. Two males of this species came to a trap lantern set by the aquaria on the outlet of Walnut Lake on the night of July 1st. They were the only stoneflies seen.

Ephemerida. Mayflies.

1. *Ephemera varians* Walsh.—Swarming flights (described above) of thispecies I observed off stations 1 and 15. The species was apparently coms mon earlier in the season, for it would have been hard to get during my stay so many specimens as Professor Hankinson took on the 29th of May at station 46. The larvæ were taken at a number of stations on the softer marl bottoms. Their food consists of marl and the substances intermixed therewith. It is readily dissected out of the alimentary canal as a cylinder of apparently pure marl, which when crushed on a cover glass reveals scanty amounts of remains of filamentous algæ, and of the disintegrating fragments of the higher plants from shore. I could discover in it no animal remains whatever.

2. *Hexagenia variabiliis* Eaton.—I took adults of this species on every day of my stay at Walnut Lake. Mr. Hankinson took a subimago in transformation on the 25th of June. His fish food data will show the wide seasonal and dietary range of the species. I have already given an account of its habits so far as known.

3. *Heptagenia pulchella* Walsh.—Probably occurs at all the stations where there are stones or timbers to which the larvæ can cling. They are easily collected in abundance at station 23. While we were coursing round with a searchlight in the bow of the boat at station 54 a number of subimagos, apparently just risen from the water, came to the light. I have given above brief and fragmentary notes on the habits of the species.

4. *Callibætis ferruginea* Walsh.—Of this species I collected at station 7 a few males, swarming just before dark, weaving up and down in a small company, and a single female, swept from a clump of Decadon near by—July 7th. Although I did some collecting hereabout, I did not find the larva.

5. *Blasturus cupidus* Say.—Two female subimagos of this species were found floating on the surface at station 225 on the 14th of May., probably having drifted out with the wind from shore; this is not characteristically a deep-water form.

6. *Ephemerella excrucians* Walsh.—A few larvæ of this species were collected at stations 6, 26 and 28 during the month of May.

7. *Ephemerella* sp.—A single curious larva *with prominent head tubercles*, was taken on the 26 of May (Coll. No. 927).

8. *Cœnis diminuta* Say.—Imagos and subimagos of this species came to our trap lantern at station 1 in some numbers on the nights of 7th, 9th, and 13th of July. I observed the males swarming in their flights at stations 1 and 7. I took a few larvæ in a triangle dredge at station 4, and in a sieve net at station 7. The larvæ are so small and cling so closely to the stems, even when withdrawn from the water that they are not often seen.

Odonata. Dragonflies and Damselflies.

1. *Gomphus spicatus* Hagen.—This species was flying not uncommonly when I first arrived at the lake on June 26, and a few specimens were captured when they alighted on the boat that day and the day following. I found young larvæ abundant at station 1, and sifted out quite a number of them from the bottom marl with a sieve net. There were taken from most of the shore stations at different times during the season. The cast nymphal skins were found associated with those of the following species, which see.

2. *Dromogomphus spinosus* Selys.—This species was coursing the surface of the lake with the foregoing one late in June, and would alight once in a while on the boat, where two specimens were captured. I found the cast nymphs skins at station 27, where there is a narrow beach of sand, some three feet wide, with stunted sedge growth at its landward side. They lay at the rear of the sand, among the projecting sedge roots, and were hard to find, though not uncommon. The bottom slopes rapidly here, and is silted with marl and strewn with coarse gravel. Bottom collecting on such a shore should find the larvæ.

3. *Basiæschana janata* Say.—A single cast larval skin of this species was found clinging to a stem that overhung the outlet brook about 100 yards distant from the lake.

4. *Aeschna clepsydra* Say.—Occasional adults of this species were seen coursing the lake during July. One male captured served for identification. A few large nymphs of the genus that may as well as not be of this species were collected during May.

5. *Anax junius* Drury.—This ubiquitous species, so common to the southward, was at Walnut Lake rather rare. I saw but one or two specimens flying. I captured a single nymph at station 7.

6. *Macromia illinoiensis* Walsh.—This fine species is very common about the chara beds on the bottom of the lake, especially where the growth is sparse, exposing flat bottom areas on which the larvæ may lie hidden. There are few finer examples of protective coloration than these larvæ present, nevertheless, they are much eaten by fishes. If overturned by the fishes in fanning the bottom, they would be readily seen with the light yellow color of the under surface of the body exposed. I took larvæ with the triangle

dredge at station 4 and in the deeper water opposite; also with a sieve net at station 1, and they have been taken in many other places in the lake, always in connection with a scanty growth of chara. Mr. McDonald found larval skins of this and the next following species on the sedges at the bank at station 34. No adults were observed.

7. *Epicordulia princeps* Hagen.—This species was constantly seen in flight over the lake. None were captured, however. Being easily recognizable in flight, it was not deemed desirable to make the effort necessary to catch even a single specimen. The copius masses of gelatinous egg strings seen commonly about the borders of the lake hung upon projecting stems just below the surface of the water, doubtless belonged either to this or to the species next following. I took larvæ of this species at stations 1 and 7, and Mr. McDonald took cast skins from shore at station 34 as noted above.

8. *Tetragoneuria cynosura* Say.—This species was rather common, one or two specimens were taken on my first visit for the sake of certain determination. I found the larvæ abundant at station 7 and they were collected sparingly at other places. Doubtless some of the egg masses referred to above belonged to this species. I have figured these in Bull 47, N. Y. State Museum, p. 491.

9. *Somatochlora* sp.—Several young larvæ that I took with sieve net at station 7 are nearest this genus, but are not like those of any of the known larvæ described therein.

10. *Perithemis domitia* Drury.—I saw a single male of this species sitting on a nymphæa leaf at station 54, and though I did not capture it, I was close enough for certain identification.

11. *Celithemis elisa* Hagen.—This beautiful insect was very common all about the lake. During sunshine the adults were flying in pairs all about the bulrush beds, while the solitary males exercised "squatter sovereignty" over little areas, perched on the top of some tall stem standing in the midst of his domain. During the first week of July the cast larval skins were hanging thickly to the bulrush stems. I collected the nymphs at station 7.

12. *Celithemis eponina* Drury.—I took a single larva of this species at station 7, and I think I saw one or more of the adults in flight.

13. *Leucorhinia intacta* Hagen.—Common, especially about the nymphæa beds. I collected the larvæ at station 7.

14. *Sympetrum rubicundulum* Say.—This species was just becoming common on the wing at the time of my departure. That was too early for many *Sympetra*. Doubtless other species would be found later in the season.

15. *Pachydiplax longipennis* Burmeister.—A few specimens of this species were seen in June, and one was captured. The larva apparently was not encountered.

16. *Mesothemis simplicicollis* Say.—I captured a single adult of this species July 14, by the outlet to Evans' pond, near Walnut Lake. Mr. Hankinson took two larvæ at Orchard Lake on the 18th of June.

17. *Ladona exusta* Say.—I captured a single adult of this species at station 20 on June 26.

18. *Libellula luctuosa* Burmeister (= *basalis* Say).—Not uncommon about the shallows bordering the lake; belongs to the fauna of pools and shallow ponds rather than to that of lakes.

19. *Libellula pulchella* Drury.—This is an abundant species of some importance to fishes that feed in shallow water. In all collecting with hand nets from the bottom it was encountered. It was abundant at stations 1 and 7. In such places the females could frequently be seen ovipositing

by dipping the tip of the abdomen repeatedly and rapidly into the surface of the water.

20. *Tramea lacerata* Hagen.—Two adults of this species, apparently, were seen but not taken. No larvæ of this genus were encountered.

21. *Calopteryx maculata* Beauvois.—This species swarmed about the outlet, more abundantly in the rapid places in the stream, where many females could be seen busily depositing their eggs in the trailing and hardly submerged stems of *Potamogeton nuttalli*.

22. *Lestes unguiculata* Hagen; 23. *Lestes rectangularis* Say.—These two species were both found among the vegetation on the west shore of the lake —single male specimens of each.

24. *Lestes vigilax* Hagen. 25. *Lestes inequalis* Walsh.—These two species were found on the outlet a hundred yards distant from the lake—single male specimens of each.

26. *Argia violacea* Hagen.—Common all around the lake and down the outlet; more characteristic of flowing than of still water.

27. *Nehallennia irene* Hagen.—Abundant about the outlet. Could be swept in the sedge zone about the lake almost anywhere.

28. *Enallagma hageni* Selys; 29. *Enallagma ebrium* Hagen; 30. *Enallagma civile* Hagen.—All found about the lake border, the first most common, the last least common. Transforming in the bulrushes everywhere, but no attempt was made to identify the larvæ.

31. *Enallagma antennatum* Say.—Very common about the outlet.

32. *Enallagma signatum* Hagen; 33. *Enallagma pollutum* Hagen.—Both very common, especially about stations 15 and 54. The latter is the latest flying of all Odonata, pairs being seen on the wing repeatedly when it was too dark to tell without capturing them in a net and looking more closely, whether they were big Mayflies (*Hexagenia*) or not.

34. *Ischnura verticalis* Say.—Rather uncommon; taken only a few times.

Hemiptera.

The following species of this order were kindly determined by Mr. J. R. de la Torre Bueno of New York City:

Corisa sp.—Young individuals not uncommon about submerged vegetation.

Notonecta variabilis Fieb.—Common at station 7.

Ranatra quadridentata Stal.—Adults were rarely seen, but half grown larvæ were common at many places in shore vegetation. A few floating typha stems bristling with the curious appendages of the contained ranatra eggs were found at station 7.

Belostoma (formerly *Zaitha*) sp.—A few adults were taken with a sieve net from the ditch back of station 7.

Gelastocoris sp.—This undescribed species was common on the narrow strip of sandy beach at station 27.

Acanthia sp.—Not uncommon on mud at edge of water.

Gerris marginatus Say; *Gerris sp.* (undescribed).—Common everywhere on the water at the edge of the standing vegetation.

Neuroptera.

Sialis infumata Say.—This orl fly was very abundant at Walnut Lake early in the season. Larvæ were collected on the bottom in many places during April and May, and they were then being eaten commonly by fishes.

About the latter end of May the adults were abundant ; those in the collection bear the date of May 23rd. I took off station 3, in thirty feet of water, a half-grown larva of the next season's brood.

Chauliodes rastricornis Say.—A few young larvæ, probably of this species were found singly crawling on the under surfaces of nymphæa leaves.

TRICHOPTERA. Caddis flies.

Determined by Dr. C. Betten.

Phryganeidæ.

1. *Neuronia semifasciata* Say.—One female was collected on May 31st (No. 936) and another came to a lighted window of the laboratory on July 7th.

2. *Neuronia concatenata* Walker.—A number of specimens came to the window with the preceding species July 7th; two others, undated, bear the collection number 1383.

Limnophilidæ.

3. *Platycentropus hostis* Hagen.—One male (No. 1383).

4. Larvæ of an undetermined *Limnophiline*, in cases of vegetable matter covered with small bits of mussel shells and stones (the larger 33 mm. long) were taken, 4 on April 6th, and 4 on April 7th (Nos. 25 and 30).

5. Another *Limnophiline* larva, in a case ballasted after the manner of the case of Goera, was taken on the 10th of July.

Sericostomatidæ.

6. *Heliocpsyche* sp.—Several larvæ were taken from stones in a riffle in the outlet of Walnut Lake (the location for Parnid beetles mentioned elsewhere) on July 10th, and a single adult was swept from the sedges on the adjacent bank.

7. *Lepidostoma* sp.—One male, July 12th.

Hydroptilidæ.

8. *Agraylea* sp.—Trap lanterns drew a few female specimens during July.

9. *Oxyethira* sp.—A single female captured on the 25th of June bears the number 1313.

10. *Hydroptila* sp.—Four larvæ and one pupa in parchment cases 6 mm. long by 1½mm. wide, were taken from Nymphæa petioles July 12th.

11. *Hydroptilid* larva of undetermined genus, in parchment cases 4 mm. long by 1 mm. wide at the one end tapering to ½ mm. wide at the other, taken with the preceding species, and attached like the cases of that one to the erect nymphæa petioles by two hold fasts at each end. These were obtained while collecting the stem-infesting *Chironomus* and *Hydromyza* larvæ, and were very common; they might have been obtained in great numbers.

A large number of additional adult *Hydroptilidæ* were obtained by the trap lantern on the nights of the 25th of June and the 7th, 12th and 13th of July, but being mostly females, preserved in alcohol, they are hardly identifiable.

Hydropsychidæ.

12–23. Four species of the genus *Hydropsyche* came to the trap lantern on the 25th and 26th of June, and 12th and 13th of July; nearly all females.

Likewise, 3 species of the genus *Plectrocnemia*, and two of *Holocentropus*, one of each of these latter being very common. A species of *Tinodes* is likewise represented in the lantern catch of the same date by a number of females. Several larvæ of *Chimarrha*, and of one other undetermined *Hydropsychid* were taken from the rocks in the outlet of the lake on July 10th.

Leptoceridæ.

24. *Molanna cinerea* Hagen.—This species swarmed around a search light that was carried in the prow of the boat at station 54 on the night of July 13th, and a few were taken. A few additional came to the trap lantern.

25. *Triænodes ignita* Walker.—This species came commonly to the trap lantern, a few on the 25th of June and on the 7th of July, and many on the 13th.

26–35.—Four species each of *Oecetis* and *Leptocerus*, one *Leptocella* and one *Setodes*, came also to the trap lanterns with the foregoing on the 25th of June and the 7th to the 13th of July. A few of these represented in some numbers by both sexes, will doubtless later be more specifically determinable.

At least 35 species are represented in the collection, nearly all obtained in the trap lantern on four favorable evenings. The material was not adequately cared for, being merely dumped into alcohol; it is sufficient, however, to indicate that there is a good caddisfly fauna in Walnut Lake to reward the more careful labors of the future collector.

Coleoptera.

Haliplus ruficollis, DeG.—Three adult specimens I took with a seive from the trash in the ditch back of station 7 on July 11th. Though especially sought for, not a single *Dytiscid* was seen.

Gyrinidæ were not very common, but could be found in the more sheltered places among shore vegetation.

Gyrinid larvæ were taken not infrequently. I took a small one at station 1, and a larger one in deeper water at Station 7. A large one taken by Mr. McDonald at station 47, and put in a vial of water to be brought home alive with some larvæ of *Chironomus albistria*, was of a beautiful transparent red color when I received it, half an hour later; but three of the midge larvæ had become white; the color was transferred with their blood.

A single adult *Tropisternus* was taken on June 26th.

A number of small larvæ of *Hydrophilidæ* were taken with a seive net in the ditch back of station 7.

A few specimens of *Berosus* sp. came to a trap lantern set beside the aquaria on the outlet the night of July 12th.

Macronychus glabratus Say.—Abundant on stones in the rapids a mile from the lake—the station for the following Parnidæ also.

Stenelmis sp.—Likewise abundant.

Elmis bivittatus Lec.—One specimen taken.

Elmis quadrinotatus Say—Common.

Ancyronyx variegatus.—One specimen taken.

Galerucella nymphœa—Common about the nymphæa beds, the larvæ feeding in considerable numbers on the leaves.

Donacia palmata—Common about nymphæa beds.

Donacia. sp.—Less common, about the Scirpus covered areas.

DIPTERA.

Tipulidæ. Craneflies.

Goniomyia subcinerea O. S.; *Goniomyia blanda,* O. S.—Came commonly to light, the former in greater numbers.

Limnobia cinctipes Say—Under linden trees on shore; rarely attracted to light.

Amalopis inconstans O. S.—In deep shade on shore; rarely attracted to light.

Erioptera chlorophylla, O. S.—One of the commonest *Tipulidæ* at Walnut Lake, if not the commonest. It could be found by sweeping vegetation anywhere near shore. Taken in the trap lantern every night, and often in considerable numbers.

Antocha opalizans, O. S.; *Erioptera straminea,* O. S.; *Erioptera caloptera,* Say; *Erioptera parva,* O. S.; *Erioptera septentrionis,* O. S.; *Geranomyia canadensis,* Westw.; *Ulomorpha pilosella,* O. S.; *Limnophila quadrata,* O. S.; *Rhamphidia flavipes,* Macq.—All came to light; all could be collected by sweeping under the edges of the tree growth on shore.

Bittacomorpha clavipes.—A ditch back of the Decadon beds at station 26. The north inlet to the lake sheltered this species in abundance.

Tipula sp. Common throughout the sedge zone.

Toxorrhina magna O. S.—A single female specimen taken from a boat as it flew overhead at station 15 just before dark on July 8th.

CULICIDÆ. Mosquitos.

Psorophora ciliata Fabr.—A few specimens only of this species came to the trap lanterns.

Anopheles punctipennis Say.—Common; many taken in trap lantern.

Anopheles maculipennis Meigen.—Not common; but few seen.

Culex perturbans.—The predominant mosquito, whose biting was not uncommonly bad.

Sayomyia punctipennis Say.—Abundant; taken by thousands in the trap lantern when set with out-look over the lake. Larvæ perhaps of this species were eaten by whitefish.

CHIRONOMIDÆ. Midges.

The species named below have been determined by Dr. O. A. Johannsen of Cornell University:

Rhyphidæ.

Rhyphus punctatus (trap).
Chironomus plumosus, Linn.
Tanypus monilis (some in trap) numerous.
Tanypus sinuosa.
Protenthes culiciformis.
Procladius pusillus (trap).
Chironomus meridionalis (numerous).
Chironomus tentans.
Chironomus albistria (bred).
Chironomus similis (numerous).
Chironomus scalaenus var. (trap).

Chironomus pallidus (trap).
Chironomus devinctus (trap).
Chironomus brunneipennis (trap).
Chironomus halteralis (trap) numerous.
Chironomus decorus.
Chironomus plumosus
Chironomus nigricans
Chironomus viridicollis.
Cricotopus trifasciatus (some in trap) numerous.
Cricotopus sylvestris.
Metriocnemus exagitans (trap).
Tanytarsus flavellus (trap).

Tabanidæ.

These and the following families have been determined by Mr. D. W. Coquillett of Washington, D. C.:

Tabanus lineola Fabr.; *Chrysops striatus* O. S.; *Chrysops plangeus* Wied.; *Chrysops niger* Macq.—All common along shore.

Stratiomyiidæ.

Odontomyia vertebrata Say; *Odontomyia plebeja* Loew.—Occasionally seen flitting over vegetation about the shores. Egg masses were rather common on projecting bur-reed leaves.

Leptidæ.

Chrysopila proxima Walker.—Common at the outlet.

Scatophyagidæ.

Hydromyza confluens Loew.—This species, which makes galls in the petioles of nymphæa leaves is especially discussed further on.

Empididæ.

Syneches simplex Walker.—This is the species that leads the procession of swarming species after sundown, as detailed in preceding pages.

Cyrtidæ.

Ogcodes costatus Loew.—On willow tree overhanging water at outlet.

Syrphidæ.

Eristatis bastardi Macq.—Over shallow water about aquatic plants everywhere.

Eristalis flavipes Walker; *Eristalis transversus* Wied.—Common about the shores.

Helophilus conostonus Will.—Common on iris flowers in the edge of the outlet.

Ephydridæ.

Hydrillia hypoleuca Loew.—Swarming upon white water lilies, blackening the flowers within by their abundance.

III.—AN AQUATIC GALL ON THE YELLOW WATER LILY, *Nymphæa advena*.

While collecting the larvæ of the midge *Chironomus albistria* Walker, from their holes in the petioles of nymphæa Mr. McDonald and I frequently came upon galls associated with them in the stems. These galls appear to be the first made known upon a member of the water lily family (Nymphæaceæ); also the first known to be made by a member of the dipterous family Scatophagidæ; also the first to be found deeply and constantly submerged. Therefore a brief account of them should not be without interest.

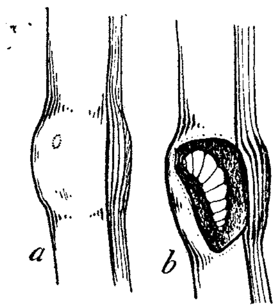

Fig. 22.—Gall-bearing petioles of *Nymphæa advena*. *a*, external views of the gall; the dotted circle marks the epidermal window, through which the adult emerges. *b*, the gall cut open, showing the larva of *Hydromyza confluens* within.

The galls are rounded swellings upon the petiole, distending it and increasing it by a fifth to a third its normal diameter (Fig. 22). They may occur anywhere, except close to the surface or close to the bottom of the water. They are placed singly along the petiole, but occasionally are close enough together to appear superficially confluent. They occur most frequently upon the stalks of the earliest of the leaves that reach the surface (not at all upon the short stalked and wholly submerged leaves of earliest spring), and very sparingly upon the later leaves. On a vigorous plant with eleven floating leaves and two flower stalks, examined at station 26 on July 12th, nine pupæ and three larvæ were found in the petiole of the oldest leaf, while three were found in the two petioles next younger. Probably the attack of the gall maker begins when the first leaves reach the surface in late spring; then they have their first opportunity to reach the proper place of oviposition by crawling down the stalk.

The insect that causes the gall to grow is the larva of the fly *Hydromyza confluens* Loew (family *Scatophagidæ*). No observations were possible upon any stages except the later larval, and pupal, and the transformation to the adult. The cavity within the gall is rather close fitting until the larva is well grown, but becomes larger and its walls become discolored later. Just before transformation to the pupal stage the larva eats a hole out to the epidermis, and returns to the center of the cavity; this hole is a passage of exit for the adult, which then has only to break through the transparent epidermal window to gain its liberty.

The grown larva measures 9 mm. in length and 2 mm. in greatest diameter; it is shorter and thicker when contracted. The body is of a somewhat fusiform outline, rather obtuse at each end, gradually thickened to the fourth or fifth segment, and then slowly tapered posteriorly. The color is white.

No head is visible, but only a blackish mouth at the front end, below. A perforate cribriform plate of an inconspicuous brown color at each side of the prothoracic segment close behind the mouth terminates the longitudinal tracheal trunk of each side; this is shown at *d* in Fig. 6, dissected out entire. The air trunks end posteriorly in three pairs of radially placed slits, the lower one of which has its margin prolonged in a stout triangular sharply pointed spine. This spine is shown at the end of the body in Figure 6a; it is shown in side view enlarged more at Figure 6b; and the end view of spiracular aperatures of both air trunks are shown in their relative positions at Figure 6c. The form and position of this spine suggest that it may be used to break open the walls of air spaces in the nymphæa tissues, as a correspondingly placed spine connected with the spiracle in the larva of the beetle *Donacia* is used to puncture the tissues from the outside.

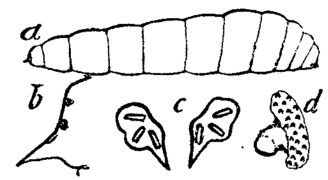

Fig. 23.—The larva of *Hydromyza confluens*. *a*, side view of the whole larva; *b*, the caudal peritreme spine, greatly enlarged; *c*, posterior view of the respiratory aperatures; *d*, the prothoracic spiracular apparatus, removed and enlarged (the mark close behind the mouth in the upper figure shows the location of this.)

At transformation, the larval skin contracts into a puparium, the anterior spiracular apparatus becomes pushed out upon each side to form a prominence as high as wide, and the perforations appear as minute roughness upon its surface; the posterior spines remain projecting; the contracted body within shapes itself into the pupa, and between this and the anterior end of the puparium is clearly seen through the transparent wall the furcated buccal armature that lined the larval mouth.

The decaying of the tissues about the walls of the gall when the leaf gets old, together with the perforation of the wall by a passage for exit, weaken the stalks, and they break readily across the top of the gall during the pupal stage of the contained insect. Thus the pupae are readily obtained. Some of those obtained on the 12th of July were placed alive in a dry bottle, and several of these transformed the next day. About the same time adults were noticed commonly about the lily beds, sitting upon the leaves, and taking flight readily upon approach. On the night of July 13th, while we were boating with a search light about station 54, they flew in some numbers to the light. This species will doubtless be found commonly about Nymphæa beds in the United States, notwithstanding that it appears to have been reported hitherto only from Canada.

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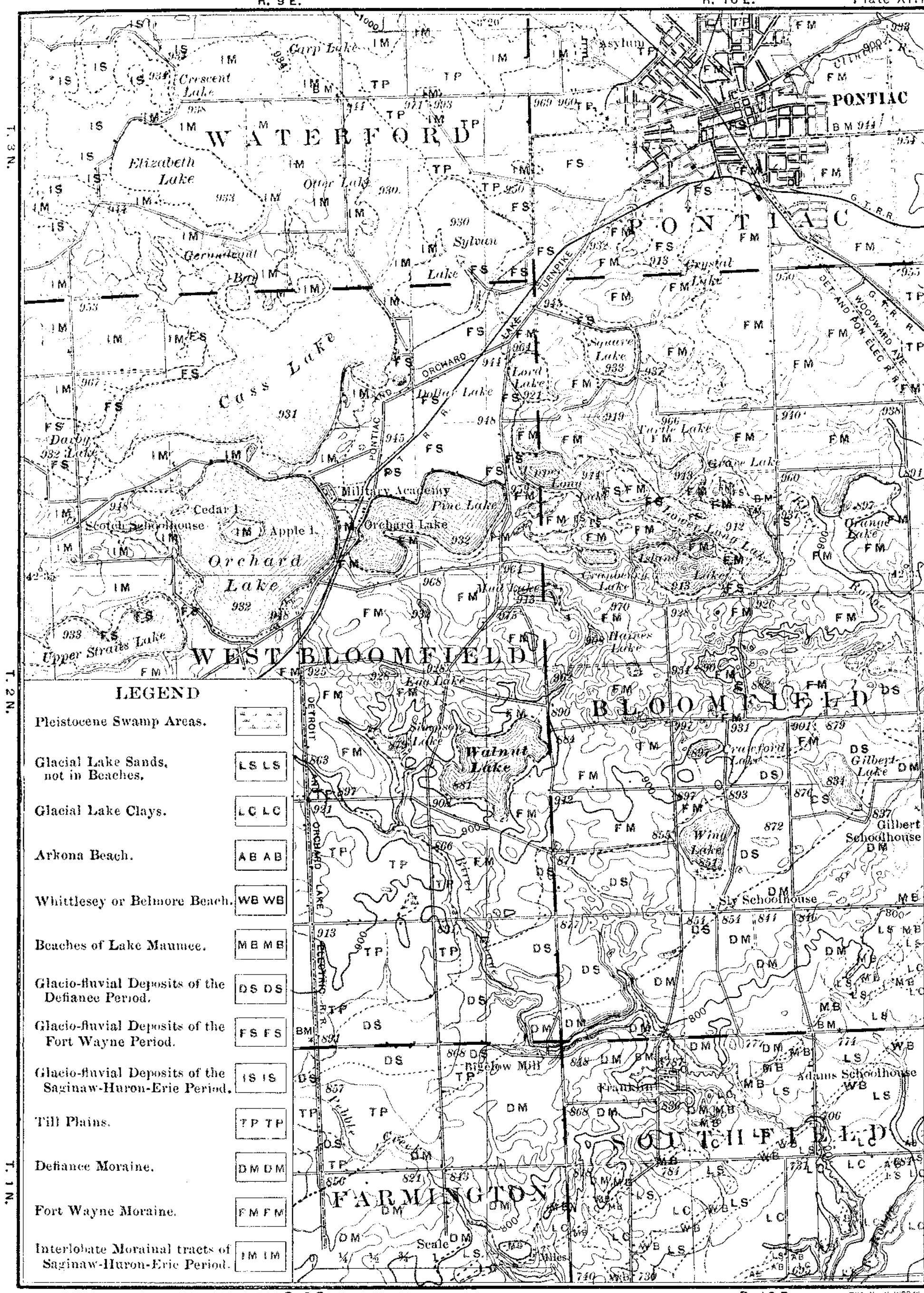

SURFACE GEOLOGY OF THE VICINITY OF WALNUT LAKE

Compiled by Charles A. Davis, from a manuscript map by Frank Leverett, U. S. Geological Survey.

Topographic base by the United States Geological Survey, 1906. Contour interval 20 feet. Datum is mean sea level.