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January 11, 1950

Report No. 1240



# A PRELIMINARY INVESTIGATION OF THE BURROWING MAYFLIES IN NORTHERN MICHIGAN STREAMS


Burton P. Hunt


ABSTRACT


Investigation has revealed four species of burrowing mayflies in the streams of northern Michigan. Hexagenia limbata (Serville) is the most common species, is widely distributed in both streams and lakes throughout Michigan and is the species most frequently encountered in northern Michigan streams. H. recurvata Morgan is widespread geographically but appears to be restricted to small, very cold tributary streams and is not common in the majority of the river systems. H. rigida McDunnough has not been located in streams proper but has been found only in a few lakes through which streams flow and in the impoundments on the lower Au Sable River. The fourth species, Ephemera simulans Walker, is widely distributed in both lakes and streams but is apparently more abundant in the former. This insect is smaller than the hexagenids and although widespread is not abundant in most streams.

Local names given to the adult winged stages of these mayflies are fish fly, Canadian soldier, June fly, caddis and Michigan Caddis. The two latter names are particularly unfortunate since they attach to these mayflies


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the common name of a very different group of aquatic insects, the true caddis. The "caddis hatch" of certain streams is the local name for flights of the emerging and mating adults. The immature insect or nymph, is purely aquatic in habit and is widely known by the name of "wiggler."

Length of life cycle of all four species is similar and is probably two years from egg to adult in northern streams. In brief the life cycle of H. limbata is as follows: Eggs, which are deposited by the female on the water surface, sink to the bottom of the stream and hatch into tiny nymphs after 3 or 4 weeks. The nymphs then take up a burrowing existence in the mud bottom where they construct U-shaped burrows which open to the mud surface at both ends. These burrow entrances can frequently be seen on mud banks and bars in streams. Nymphs are predominantly restricted to mud bottom and are not found in numbers in sand, gravel or rocky bottoms. When maturity is reached, usually in June and July in the northern part of the state, the nymphs leave the bottom mud, swim to the water surface where the nymphal skin splits just back of the head and the winged fly emerges in a matter of seconds. The newly emerged fly, known as a subimago or sub-adult, flies to shore where it rests from 20-36 hours before it molts to become a sexually perfect adult or imago and is ready to mate. Emergence of the winged fly from the nymph begins after dark and usually continues until midnight or shortly thereafter. Trout often feed extensively upon the emerging flies at this time. The imagoes mate just at dusk while flying in huge swarms high above the stream. Once having mated the females then fly down towards the water where they "crash land" on the surface and extrude the eggs which sink to the stream bottom. Mating flights are often very heavy resulting in the stream surface being covered with floating females which drown after laying their eggs. These mating flights, which often cause large scale feeding on the part of trout, are the "hatches" usually witnessed by fishermen.

Average size H. limbata female (body length 1 inch) produces about 5,500 eggs of which 97.4 per cent can be expected to hatch when incubated in the laboratory.

Quantitative bottom sampling over a three-year period showed that the average number of nymphs per square foot of mud bottom was 8.0 and 16.6, respectively at two stations on the North Branch Au Sable River and was 138.3 at a station on the main stream of the Au Sable near Luzerne. Largest number of nymphs per square foot of bottom encountered at the last named station was 356. Bottom sampling in other streams has shown that while occasionally more than 100 nymphs per square foot were found, the average was usually less than 30. It is estimated that, for a stream to produce hatches of adults in sufficient numbers to be noticeable to the fisherman and cause large scale rises of trout, at least 8 percent of the bottom must be of suitable mud and that the average number of nymphs per square foot must be 16 or more. Very small nymphal populations or their entire absence in some fast flowing streams is apparently due to this lack of suitable mud habitat.

"Hatches" of major extent of H. limbata are known to occur on the following rivers and their major tributaries: Au Sable, Manistee, Boardman, Pere Marquette, Muskegon, Maple and Black. Judging from the nymphal populations seen by the writer, undoubtedly large emergences occur on part of many other rivers, namely: Escanaba, Middle Branch Ontonagon, Manistique, including the Fox, East Branch of the Fox and other tributaries, and the Tahquamenon, including the Sage River. Probably rather heavy "hatches" of this insect occur annually on many other streams but have gone unnoticed by the majority of trout fishermen.

Importance of these mayflies, both nymphs and adults, as food for trout during the emergence and mating season is great for they are then readily available to fish. Evidence indicates that the nymphs are not eaten extensively during other times of year probably because of their burrowing habits. Many fishermen consider that the best and most productive angling of the trout season is to be had during the short period in which the winged stages of these insects are present on the streams. It is also undoubtedly true that more large trout are caught during the "hatches" of these mayflies on the Au Sable, Manistee, Pere Marquette and other well known trout streams, than at any other period during the open fishing season.

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# A PRELIMINARY INVESTIGATION OF THE BURROWING MAYFLIES IN NORTHERN MICHIGAN STREAMS



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## INTRODUCTION

Of all the aquatic insects in the trout streams of Michigan, few arouse as much interest on the part of both fisherman and fish as do the winged stages of burrowing mayflies. Many fishermen consider that the best and most productive angling of the trout season is to be had during that short period in which the winged stages of these insects are present on the streams. It is also undoubtedly true that more large trout are caught during the "hatches" of these mayflies on the Au Sable, Manistee, Pere Marquette and other well known trout streams, than at any other period during the open fishing season.

Common names of the adult stage of the burrowing mayflies are fish fly, Canadian soldier, June fly, caddis and Michigan caddis. The two latter names are used locally in the Au Sable, Manistee, and Boardman River areas, and are particularly unfortunate since they attach, to these mayflies, the common name of a very different group of aquatic insects. The "caddis hatch" of these streams is the local name for the emergence and mating activities of the burrowing mayflies. Nymphs are universally called "wigglers" by bait dealers and fishermen.

Interest of fishermen, stemming from the sight of the swarming of these insects, and from the experience of fishing when they are on the water and the usually wary trout are rising all about, has resulted in many inquiries concerning the life history and distribution of these insects. It is well known to fishermen that "hatches" are very heavy on some streams and light or absent on others. These observations naturally give rise to the question "Why?"

In order to obtain sufficient information to answer some of the questions asked by both fishermen and biologists, an investigation was carried on from June to September, 1949, to determine the species involved, their distribution, and salient facts concerning the life history and environmental requirements of these insects in northern Michigan streams. Information secured during this period is further supplemented by data secured at three stations on the Au Sable River from 1946 to 1948.

## DISCUSSION OF SPECIES

Four recognizable species of burrowing mayflies have been encountered in the streams of northern Michigan. Three of these are hexagenids, and the fourth belongs to the genus *Ephemera*. Each of these will be treated separately.

### *Hexagenia limbata* (Serville)

The writer has followed the classification adopted by Spieth (1941) in which all hexagenids which have marginated cross veins, uneven coloration of the membrance in the costal margin of the mesothoracic wing, and the penis of the male strongly hooked, are considered to belong to a single species, *limbata*. Forms encountered in this study which previously have been described as species but are considered by the writer to be of only subspecific rank, or more probably only color phases, are H. viridescens (Walker) and H. occulta (Walker). While the color phases whichagree with descriptions of these two forms can be recognized, both, as well as intergrades between the two, occur together in a single mating flight, which is a strong indication that a single but variable species is involved. Collections of adults and nymphs of Hexagenia from the waters included in this report and from other localities have led to the conclusion that H. limbata occurs in both lakes and streams and is the most common and most widely distributed hexagenid in Michigan. The specific description in Needham, Traver and Hsu (1935) which best fits the Michigan forms of H. limbata is that given for H. occulta (Walker).

Although it is difficult to distinguish nymphs of some closely related forms of Hexagenia, it is quite easy to differentiate between the nymphs of limbata and the other two hexagenid species encountered. The former is characterized by a dome-shaped frontal prominence (Figs. 1 and 1a), slightly upcurved tusks (Figs. 2 and 2a), a bifid, simple gill on the first abdominal segment and long, filamentous gills on the remaining segments. The form of the genitalia and dorsal abdominal color pattern which characterize the adult can be seen in larger male nymphs (Fig. 3).

Lengths of full-grown male nymphs range from 17-27 mm., of females from 23-35 mm. Body lengths of imaginal males range from 18-26 mm., of females from 21-29 mm (Fig. 4).

H. limbata is the common species of warmer streams (summer temperatures above 63°F.) in Michigan and has been found in almost every river system sampled by the writer. Additional sampling in streams where it was not found would undoubtedly reveal its presence there. It thrives equally well in small creeks and large rivers providing that a satisfactory

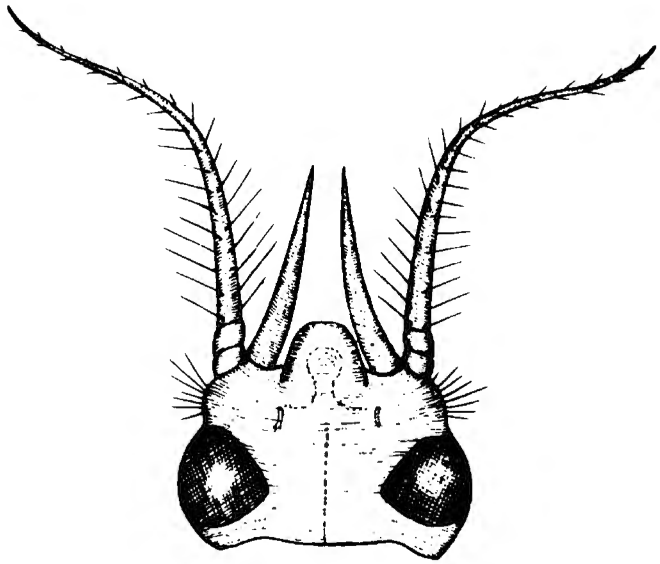

FIG. I
HEAD OF MALE NYMPH OF
H. LIMBATA, 22 M.M. LONG.

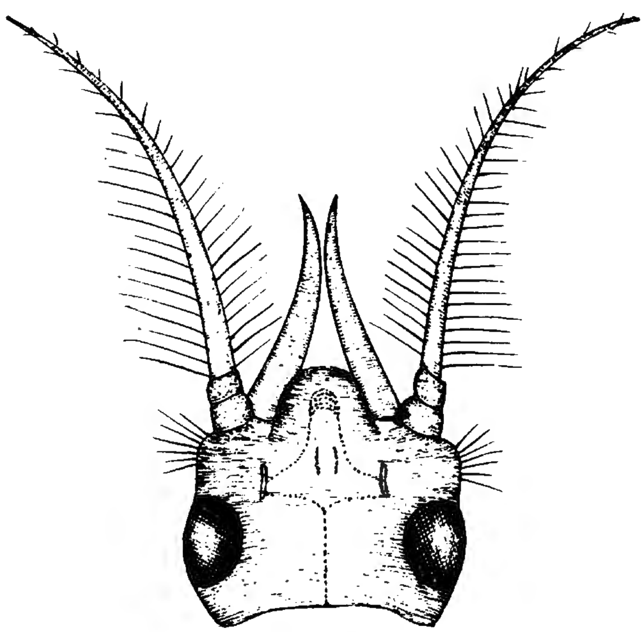

FIG. Ia
HEAD OF FEMALE NYMPH OF
H. LIMBATA 22 M.M. LONG

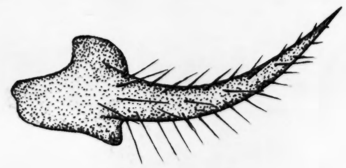

FIG. 2
RIGHT TUSK OF MALE
H. LIMBATA NYMPH 22 M.M. LONG

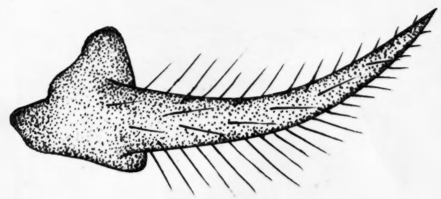

FIG. 2a
RIGHT TUSK OF FEMALE
H. LIMBATA NYMPH 30 M.M. LONG

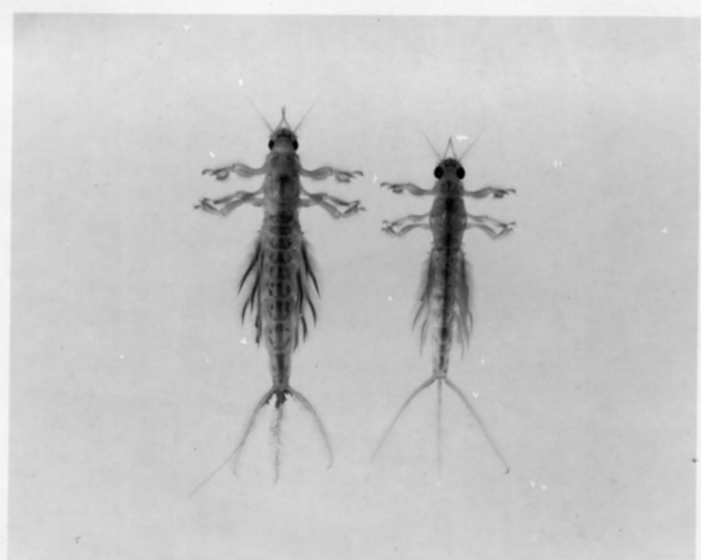

Fig. 3 Large nymphs of H. limbata. Female left, male right. Male is in last instar.

Fig. 4 Adults of H. limbata

nymphal habitat is present in the form of mud banks or bars. It appears to be absent only from small, cold creeks in which summer water temperatures ordinarily do not rise above 63° F. Localities where this species has been found by the author in Northern Michigan streams are shown in Fig. 5.

Hexagenia recurvata Morgan

This species is well defined and easily differentiated from all other hexagenids, both in the adult and nymphal stages. Adults are as large as H. limbata and are bronze in color with no well defined color pattern on the dorsum of the abdomen. Male genitalia are recurved and quite distinctive for the species.

Nymphs are characterized by a general bronze color, lack of dorsal abdominal color pattern, short, stout, straight tusks (Fig. 6), a single, simple gill on the first abdominal segment, and rather short, bushy gills on the remaining segments. The frontal prominence (Fig. 7) is characteristic as well as the very hirsute tusks and paucity of hairs on the comparatively short antennae.

This species is widely distributed in northern Michigan but has been found only in cold creeks and rivers where summer water temperatures rarely rise above 63°F. Apparently it is restricted to these cold waters (Fig.5) and does not occur in warmer streams or lakes. In some streams, such as Hunt Creek, Montmorency County, and West Branch of Big Creek, Oscoda County, nymphs of H. recurvata and H. limbata are found together in some sections in which water temperatures are such that both species can live. The environment in these areas is apparently transitional between the optimum conditions for each species since only recurvata occurs nearer the headwaters and only limbata is found in the lower reaches of the streams. Probably the distributional overlap described above occurs in all streams where the two species are found.


Fig. 5 Distribution of H. limbata and H. recurvata in northern Michigan streams

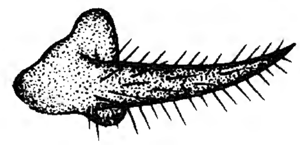

FIG. 6
RIGHT TUSK OF FEMALE
H. RECURVATA NYMPH 22 M.M. LONG

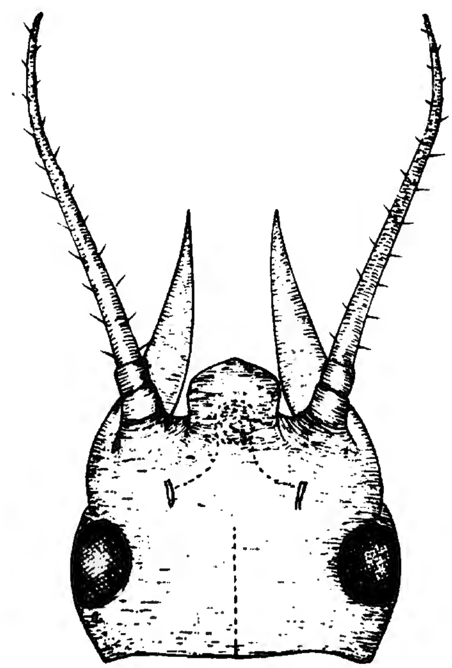

FIG. 7
HEAD OF FEMALE NYMPH OF
H. RECURVATA 22 M.M. LONG

The wide geographical but restricted ecological distribution of *H. recurvata* suggests that the species may at one time have been much more widely distributed in the river systems. Present distribution further suggests that since individuals occupy only cold streams, usually widely separated geographically from others, they represent relict populations currently isolated by changed ecological conditions (principally water temperature).

### *Hexagenia rigida* McDunnough

Spieth (1941) stated that this species is found in the same habitat as *H. limbata* and occurs in both lakes and larger streams. The writer has not found the nymphs of *rigida* in streams in Michigan although they may possibly occur in some. It is common in the lower reaches of the Au Sable River, but thus far has been collected only at the various impoundments from Mio Pond to Foote Dam. Nymphs were never encountered at the stream collecting station located about one-half mile upstream from Mio Pond, an indication that this species should be considered a lake form rather than a river form. The writer has seen specimens from Lake Huron, Lake Erie, Burt Lake, Otter Lake (Houghton County), and the Au Sable impoundments. It is possible that the species is widely distributed over the state.

Characters which identify the adult are the characteristic abdominal color pattern and the long, nearly straight penis of the male. Average size is slightly smaller than *H. limbata*, and the general coloration is somewhat similar, although the differences are constant.

The nymph can be differentiated by the conical frontal prominence (Fig. 8) and by the long, slender, sharply upcurved tusks (Fig. 9). In general appearance the nymph resembles that of *H. limbata*, but the differences mentioned plus the color pattern and genitalia, visible in larger nymphs, are sufficient to identify it.

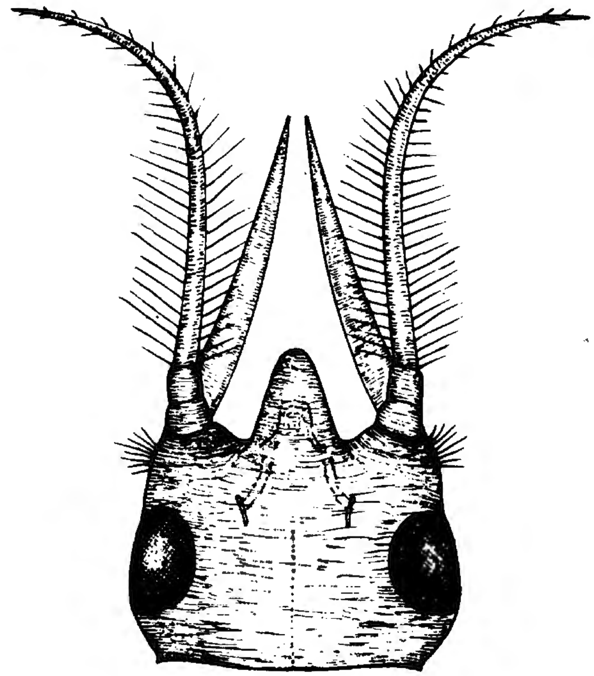

FIG. 8
HEAD OF FEMALE NYMPH OF
H. RIGIDA, 30 M.M. LONG

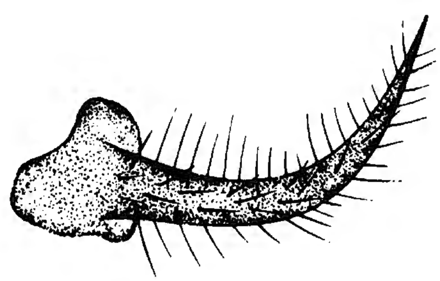

FIG. 9
RIGHT TUSK OF FEMALE
H. RIGIDA NYMPH 30 M.M. LONG

Ephemera simulans Walker

All Ephemera thus far collected in Michigan by the writer have been referred to the species simulans. However, it is very probable that other species occur in the state. Individuals of this species are easily separated from the hexagenids both as adults and nymphs although much resembling them in general form.

Adults are much smaller. Large females are as large as average size hexagenid males, and darker in color. The forewing, instead of being clear as in Hexagenia, is covered with varying numbers of dark blotches, giving it a spotted appearance. Three long caudal tails are present instead of the two in Hexagenia. Length of the adult body ranges from 11-17 mm.

The nymph is most easily differentiated from those of Hexagenia by the deeply notched frontal prominence (Fig. 10), a very marked generic character. Tusks are very slender and little curved. The abdomen is marked by black spots which form longitudinal rows on both dorsal and ventral aspects of the abdomen. Length of grown nymphs ranges from 14-22 mm.

This species is common in both lakes and streams, apparently being more abundant in the former. It is widely distributed in the state and probably occurs in most lakes and stream systems although the numphs were not found as frequently as those of Hexagenia. This statement must be tempered by the fact that much more effort was expended in search of Hexagenia nymphs. The habitat of Ephemera differs from that of Hexagenia in that nymphs seem to prefer much sandier situations, most often being found in very sandy mud and sometimes in nearly pure sand bottoms. Temperature requirements of E. simulans appear to be about the same as those of H. limbata.

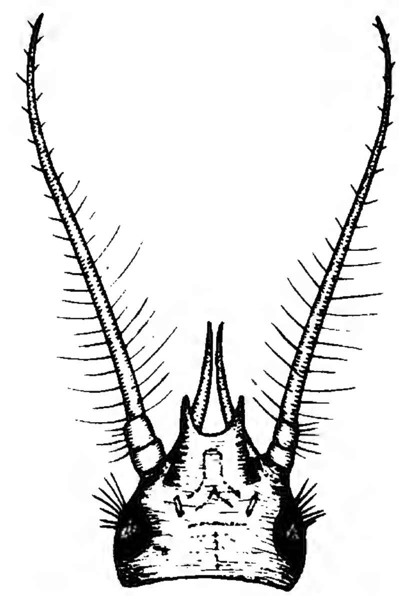

FIG.10
HEAD OF FEMALE NYMPH OF
EPHEMERA SIMULANS, 16 M.M. LONG

## LIFE HISTORY

In brief, the known life cycle of Hexagenia and Ephemera is as follows. Eggs hatch on the bottom of lake or stream and young nymphs immediately enter soft mud to begin a burrowing existence which continues until they are mature. When fully grown, and when other conditions are favorable, the nymph leaves the bottom mud and swims to the surface, where the nymphal skin splits and the winged subimago emerges. Emergence occurs largely during the forepart of the night. The subimago immediately flies toward the nearest land, where it seeks shelter in trees, shrubs, boat houses, or other suitable resting places. It remains rather quiet for a day or two, and then molts to become a sexually perfect adult or imago. On the evening following final transformation the imagoes mate at dusk in swarms high above the edge of the lake or stream. The females then fly out over the water and deposit their eggs on the surface. Eggs at once sink to the bottom and in a few weeks a new generation of nymphs hatches out to renew the cycle.

The length of time required to complete the various life history stages has been found to vary under different environmental conditions (chiefly temperature). Pertinent facts concerning the life history of the various species will be given separately.

### Hexagenia limbata

A two-year life cycle has been determined for this species in the following waters: Lake Winnipeg (Neave, 1932), Western Lake Erie (Dr. David C. Chandler, personal communication), and Douglas Lake, Michigan (Lyman, MS). The writer has previously found that the life cycle of this species is usually completed in one year in Gun, Pine and Big Silver Lakes in southern Michigan. The one variable environmental factor operating in the above-mentioned cases is temperature. Summer temperatures in the southern Michigan lakes studied ranged from 70°-93°F., while water temperatures in the other lakes mentioned above rarely rise above 75°F.

Length of life cycle in the Au Sable River, as indicated by size frequency distribution of the nymphs at different times of the year from 1946-1949, is two years (Table 1). Study of the table shows that at the time of the emergence season two definite size groups of nymphs were present (June 21, 1946, June 12, 1947, June 14, 1948, June 20, 1949). The group of larger nymphs were maturing rapidly for most individuals had reached the last instar stage and were destined to emerge in a short time. The smaller size group, consisting of half-grown nymphs, remained in the stream after the transformation of the larger individuals and did not develop to the last instar stage during the remainder of the summer.

In early fall two size and age groups of nymphs were again present, the larger group being composed of specimens which were destined to mature the following year, and the smaller group consisting of individuals hatched from eggs deposited during the preceding June and July. Corresponding size-frequency groups are in evidence on corresponding dates for each of the three years covered by collections. Growth of nymphs collected in the Au Sable in 1949 and reared in containers placed in the stream substantiated the interpretation of the size frequency curves worked out previously from the natural population.

A comparison of the Au Sable River with Lake Winnipeg, Western Lake Erie, and Douglas Lake shows that approximately the same summer water temperatures obtain in each case. Since temperature is such an important factor in growth of *Hexagenia*, it is not surprising that the length of the life cycle would be the same in these various waters. Length of life cycle is determined by rate of growth, and the reason for a one-year life cycle in certain southern Michigan lakes and a two-year life cycle in the Au Sable River is obvious when summer water temperatures and the period they are operative are considered and a comparison made of growth rates of nymphs

Table 1 . Size frequency distribution of H. limbata nymphs, Au Sable River

(Figures in parentheses indicate number of nymphs in last instar)

| Date | No. measured | MALES Length in mm. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/21/46 | 92 | .. | .. | .. | .. | 1 | 1 | 5 | 3 | 7 | 8 | 6 | 1 | 4 | 1 | .. | 1 | 3 | .. | 1 (1) | 4 (4) | 7 (7) | 5 (5) | 11 (11) | 13 (13) | 7 (7) | 1 (1) | 2 (2) |
| 6/12/47 | 77 | .. | .. | .. | .. | .. | 2 | 2 | 6 | 4 | 9 | 2 | 3 | 5 | 1 | 2 | .. | .. | .. | 7 (7) | 13 (11) | 9 (9) | 4 (4) | 2 (2) | 4 (4) | 1 (1) | 1 | .. |
| 8/4/47 | 152 | .. | .. | 1 | 7 | 15 | 20 | 21 | 15 | 12 | 12 | 4 | 3 | .. | 1 | 2 | 6 | 8 | 8 | 4 | 7 | 1 | 4 (1) | 1 | .. | .. | .. | .. |
| 9/15/47 | 123 | .. | .. | .. | .. | 3 | 1 | 9 | 9 | 6 | 8 | 5 | 9 | 6 | 6 | 6 | 11 | 14 | 10 | 7 | 9 | 2 | 2 | .. | .. | .. | .. | .. |
| 10/12/47 | 121 | .. | .. | .. | .. | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 9 | 6 | 5 | 1 | 7 | 9 | 7 | 5 | 10 | 8 | 7 | 8 | 2 | .. | .. | .. |
| 3/11/48 | 78 | .. | .. | .. | 1 | 1 | 3 | 5 | 4 | 6 | 7 | 4 | 3 | 2 | 1 | .. | .. | 5 | 7 | 4 | 4 | 6 | 7 | 6 | 1 | 1 | .. | .. |
| 5/10/48 | 140 | .. | .. | .. | .. | 2 | 3 | 4 | 9 | 6 | 5 | 6 | 4 | 1 | 5 | 3 | 7 | 11 | 9 (1) | 8 | 7 (2) | 20 (7) | 17 (10) | 10 (6) | 3 (1) | .. | .. | .. |
| 6/14/48 | 110 | .. | .. | .. | .. | 3 | 2 | 2 | .. | 4 | 10 | 7 | 4 | 7 | 6 | 1 | 3 | .. | 4 (3) | 8 (8) | 10 (9) | 10 (10) | 13 (13) | 8 (8) | 5 (5) | 3 (3) | .. | .. |
| 8/6/48 | 227 | .. | .. | 4 | 7 | 17 | 21 | 20 | 5 | 10 | 18 | 21 | 20 | 19 | 13 | 10 | 12 | 3 | 5 | 8 | 4 | 5 | 2 | 1 | 2 | .. | .. | .. |
| 6/20/49 | 65 | .. | .. | .. | .. | .. | .. | 1 | .. | 1 | 5 | 3 | 4 | 9 | 7 | 7 | 4 | 3 | 2 | 3 | 2 (1) | 3 (1) | 6 (5) | 2 (2) | 2 (2) | .. | .. | 1 (1) |
| 8/8/49 | 101 | .. | .. | 2 | 4 | 6 | 9 | 6 | 7 | 10 | 6 | 4 | 7 | 6 | 3 | 1 | 2 | 4 | 6 | 6 | 4 | 2 | 3 | 1 | 2 | .. | .. | .. |

Table 1 (Contd.). Size frequency distribution of H. limbata nymphs, Au Sable River
(Figures in parentheses indicate number of nymphs in last instar)

| Date | No. meas-ured | FEMALES Length in mm. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 |
| 6/21/46 | 102 | .. | .. | .. | .. | .. | 2 | 1 | 3 | 2 | 6 | 3 | 10 | 6 | 4 | 3 | 2 | 1 | 1 | .. | .. | .. | 1 | 1 | 2 (2) | 5 (4) | 3 (3) | 2 (2) | 9 (9) | 6 (6) | 13 (13) | 4 (4) | 2 (2) | 7 (7) | 2 (2) | .. |
| 6/12/47 | 81 | .. | .. | .. | .. | .. | .. | .. | 5 | 6 | 8 | 6 | 7 | 3 | 3 | 2 | .. | .. | 1 | 1 | .. | 1 | 2 | 1 | .. | 7 (4) | 3 (2) | 6 (4) | 7 (5) | 1 (1) | 3 (3) | 3 (3) | 2 (2) | 1 (1) | 1 (1) | 1 (1) |
| 8/4/47 | 183 | .. | .. | .. | 3 | 4 | 17 | 15 | 16 | 26 | 17 | 18 | 9 | 7 | 1 | 2 | 1 | 1 | .. | 4 | 5 | 10 | 9 | 3 | 3 | 2 | 2 | 3 | 1 | 1 | 2 | .. | 1 | .. | .. | .. |
| 9/15/47 | 132 | .. | .. | .. | .. | .. | .. | 8 | 19 | 17 | 12 | 8 | 7 | 5 | 2 | 4 | 4 | 4 | 6 | 2 | 3 | 4 | 1 | 3 | 6 | 5 | 2 | 8 | 1 | 1 | .. | .. | .. | .. | .. | .. |
| 10/12/47 | 140 | .. | .. | .. | .. | .. | 2 | 7 | 11 | 9 | 7 | 10 | 7 | 10 | 3 | 5 | 1 | 2 | 10 | 3 | 5 | 2 | 3 | 6 | 4 | 3 | 9 | 7 | 6 | 4 | 3 | 1 | .. | .. | .. | .. |
| 3/11/48 | 82 | .. | .. | .. | 2 | 3 | 2 | 3 | 4 | 7 | 5 | 7 | 4 | 2 | 2 | 2 | 3 | 3 | .. | 1 | .. | 2 | 4 | .. | 3 | 3 | 6 | 6 | 3 | 1 | 1 | 3 | .. | .. | .. | .. |
| 5/10/48 | 145 | .. | .. | .. | .. | .. | 2 | 1 | 8 | 3 | 5 | 2 | 6 | 2 | 3 | 1 | 3 | 2 | 2 | 3 | 7 | 4 | 6 | 5 | 7 | 6 (2) | 15 (5) | 13 (7) | 19 (10) | 7 (2) | 6 (5) | 5 (5) | 2 (2) | .. | .. | .. |
| 6/14/48 | 107 | .. | .. | .. | .. | .. | .. | 2 | 6 | 6 | 8 | 6 | 12 | 9 | 4 | 5 | 5 | 6 | 2 | 1 | 1 | .. | 1 | 1 (1) | 1 (1) | 1 (1) | 2 (2) | 3 (3) | 6 (6) | 7 (7) | 5 (5) | 4 (4) | .. | 1 (1) | 1 (1) | 1 (1) |
| 8/6/48 | 232 | .. | .. | .. | 3 | 19 | 28 | 32 | 10 | 5 | 8 | 8 | 4 | 9 | 10 | 9 | 12 | 11 | 16 | 10 | 4 | 7 | 4 | 5 | 8 | 6 | 2 | 1 | .. | .. | .. | .. | .. | 1 | .. | .. |
| 6/20/49 | 78 | .. | .. | .. | .. | 1 | .. | .. | .. | 2 | .. | 1 | 2 | 1 | 4 | 6 | 7 | 6 | 8 | 4 | 6 | 3 | 4 | 2 | 3 | 1 (1) | 2 (2) | 1 (1) | 4 (3) | 3 (3) | .. | 1 (1) | 2 (2) | 1 (1) | 1 (1) | 2 (2) |
| 8/8/49 | 115 | .. | .. | .. | 3 | 2 | 4 | 5 | 7 | 6 | 10 | 8 | 9 | 11 | 9 | 3 | 6 | 3 | 1 | .. | 2 | 1 | 2 | 3 | 4 | 6 | 3 | 5 | 1 | 1 | .. | .. | .. | .. | .. | .. |

in the two localities (Fig. 11). The size composition of nymphs in samples from other trout streams both in the Lower and Upper Peninsula indicates that a two-year life cycle is the rule in these waters.

Since it appears that the length of life cycle varies with environmental factors, generalizations can be stated which can be expected to apply in waters having similar environmental features. Thus the conclusion that a 2-year life cycle is in effect in northern trout streams is quite justified. Length of life cycle in northern lakes may well vary with individual lakes depending upon local conditions. A reexamination of data secured from two lakes in the Au Sable River region (Hunt, I.F.R. Report No. 1194) has led to the conclusion that a 1-year life cycle occurs in those lakes rather than the 2-year life cycle previously reported.

On June 20, 1949, 100 small nymphs 4-11 mm. in length were collected and placed in buckets containing a bottom layer of finely screened stream silt. These nymphs were designated as Group 1. On the same date another lot which ranged from 10-20 mm. in length was placed in a galvanized tub containing previously settled, screened stream mud (Group 2). After the nymphs had become established in the mud the buckets and tub were submerged in the Au Sable River near the bank (Fig. 12). The containers were so arranged that 2-3 inches of water flowed over the top rim. It is suspected that some nymphs escaped but enough remained on August 20, 1949, when they were screened out and preserved, to indicate the rate of growth. Lengths of nymphs of the two groups both at the beginning and end of the experimental growth period are presented in Table 2. Both groups were considered to be one year old at the time of capture. The small nymphs of Group 1 were individuals which had grown slowly and those of Group 2 had grown much faster. Growth rate of the two groups is shown in Fig. 13. It is clearly seen that since none of the nymphs reached maturity by the end of August, they were destined to spend a second winter in the stream and would not mature before

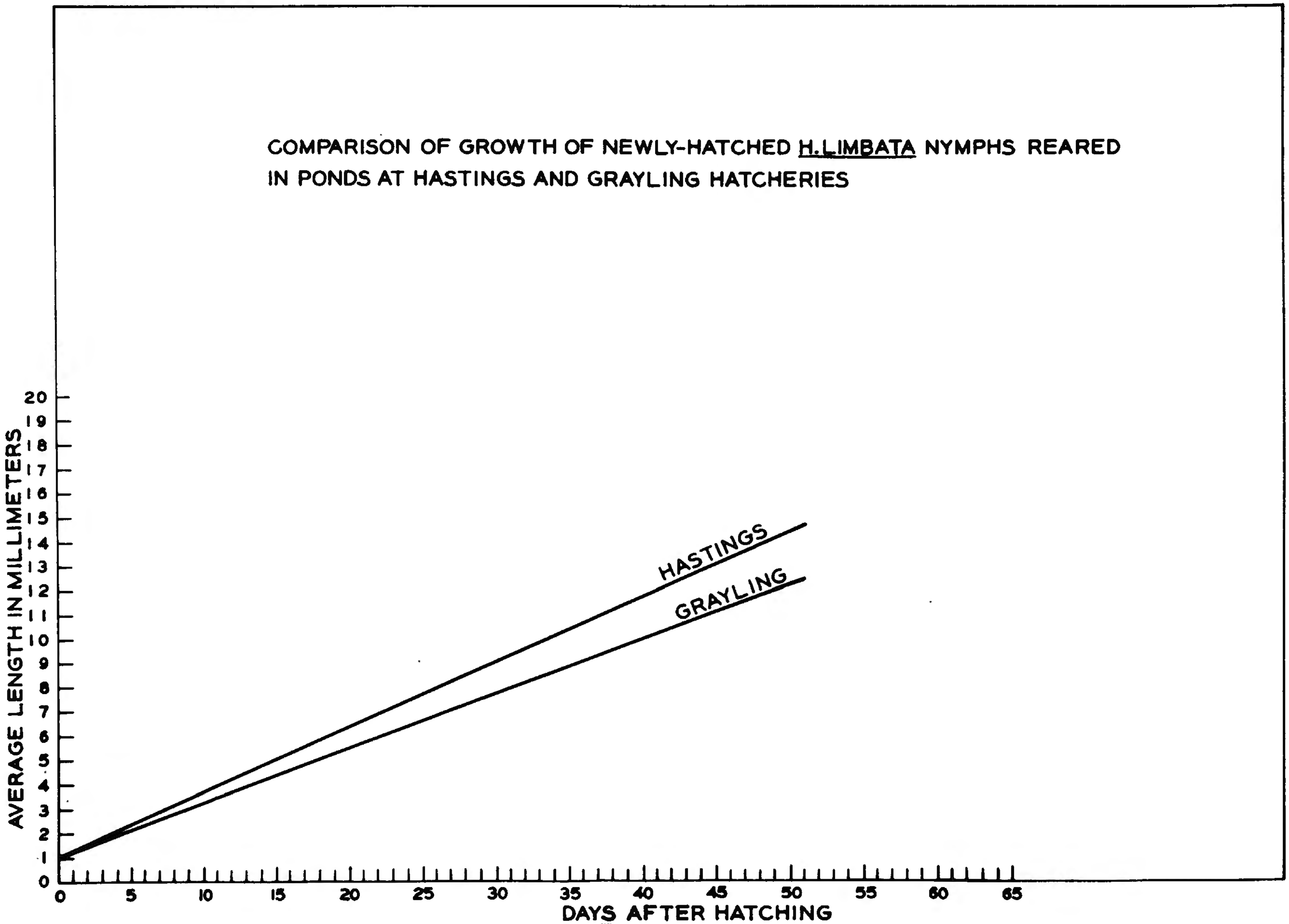
COMPARISON OF GROWTH OF NEWLY-HATCHED H. LIMBATA NYMPHS REARED
IN PONDS AT HASTINGS AND GRAYLING HATCHERIES
AVERAGE LENGTH IN MILLIMETERS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
HASTINGS
GRAYLING
0
5
10
15
20
25
30
35
40
45
50
55
60
65
DAYS AFTER HATCHING

Fig. 11

Fig. 12. Containers, used for rearing nymphs, in position in Au Sable River.

Table 2. Growth of H. limbata nymphs reared in the Au Sable River in 1949.

| Date | Males | | | | Females | | | | Avg. length in mm., all nymphs |
|---|---|---|---|---|---|---|---|---|---|
| | Number measured | Length in mm. | | | Number measured | Length in mm. | | | |
| | | Min. | Max. | Avg. | | Min. | Max. | Avg. | |
| Group 1 | | | | | | | | | |
| June 20 | 100* | 4 | 11 | 7.8 | 100* | 4 | 11 | 7.8 | 8.5 |
| Aug. 20 | 18 | 16 | 23 | 19.8 | 46 | 18 | 30 | 25.4 | 23.8 |
| Group 2 | | | | | | | | | |
| June 20 | 56 | 10 | 18 | 13.0 | 71 | 10 | 20 | 15.7 | 14.8 |
| Aug. 20 | 13 | 20 | 25 | 22.5 | 39 | 21 | 33 | 29.3 | 27.6 |
| Group 3 | | | | | | | | | |
| July 5 | 500* | 1 | 1 | 1.0 | 500* | 1 | 1 | 1.0 | 1.0 |
| Aug. 24 | 51 | 3 | 17 | 11.5 | 54 | 4 | 21 | 13.0 | 12.5 |

* All nymphs included; sex not determined

**Fig. 13** GROWTH OF _H. LIMBATA_ NYMPHS REARED IN CONTAINERS IN AU SABLE RIVER, 1949

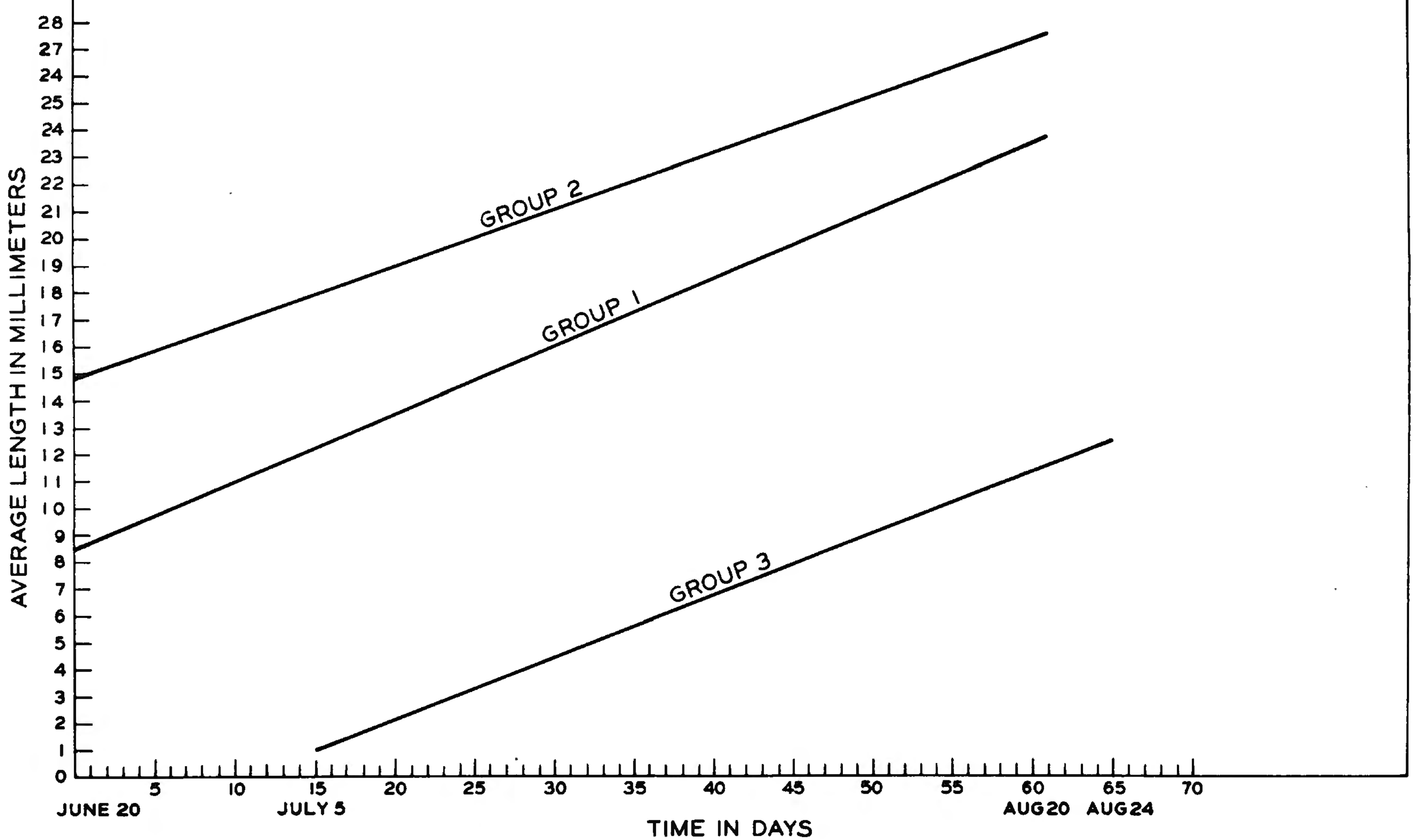


Fig. 13

June, 1950. It should be stressed that although nymphs in Group 1 were very small in June, their growth rate was rapid enough to bring them into the size range at which maturity occurs by late August. These nymphs would have grown still larger if allowed to remain in the stream during late summer and unquestionably would have matured early the following summer. Growth rate of the larger nymphs of Group 2 was somewhat slower than Group 1 but most individuals had reached a point of development where one or two more molts would have brought them to the last instar and maturity. Observation has shown that in the Au Sable River nymphs which reach the next to last instar in late summer remain in that stage until the following spring. Rearing has shown that large nymphs collected in late fall will mature and transform in 30-40 days after being placed in aquaria with water temperatures ranging between 70°-80°F. Conclusions are that larger nymphs grow more slowly during the latter part of the summer than do smaller ones. The size of individuals in Groups 1 and 2 on August 20 corresponded very closely with that of larger nymphs screened from mud banks in an area near the containers the same day. There can be no doubt that essentially all one-year-old nymphs reach a length and stage of development very near that acquired at maturity by the end of the second summer. More rapid growth of nymphs which enter the second summer not more than one-third grown compensates for the slow growth which occurred early in life.

Growth rate of young-of-the-year nymphs is shown by Group 3, (Table 2, Fig. 13). Eggs secured from female imagoes captured during mating flights were incubated and hatched in the laboratory. About 500 newly-hatched nymphs, designated as Group 3, were placed in galvanized buckets containing screened mud and submerged in the East Branch of the Au Sable River at the Grayling Fish Hatchery. These individuals were removed and preserved on August 24, 50 days after growth had commenced. In the interval the average length of these nymphs had increased from approximately 1.0 mm. to 12.5 mm. Lengths reached at the end of the growing period corresponded closely to the smaller size frequency mode on August 8, 1949 (Table 1), and with the size of young nymphs secured from the river on August 20, 1949.

Comparison between growth of nymphs of known size and age and that shown by length-frequency curves of specimens from the natural environment shows that nymphs reach an average length of approximately 11 mm. at the end of the first summer, 22 mm. at the end of the second summer, and transform early the third summer at an average length of approximately 25 mm. It is known that growth ceases during winter and is not resumed until water temperatures rise to about 50°F. A composite growth curve for an entire life cycle, based on size frequency data and experimental growth rates, is shown in Fig. 14.

Egg production, fertilization and hatching

The number of eggs produced by limbata females is of importance in evaluating the reproductive potentialities of the species. No counts were made of the number of eggs produced by females in the Au Sable River. However, total egg counts made on 24 females from Pine, Gun, and Big Silver Lakes revealed that a straight line relationship exists between number of eggs and body length. There is no reason to think that egg production of the Au Sable River form differs from that of the lakes; therefore it may be assumed that the number of eggs produced by females from the Au Sable River varies from about 3,000-8,500, depending on the size of the female. The average size female produces about 5,500 eggs.

Fertility of eggs was found to be high. Eggs stripped from 39 females collected during mating flights were incubated in the laboratory and counts made of the number of eggs which hatched. The results are as follows:

Fig. 14. COMPOSITE GROWTH CURVE OF H. LIMBATA NYMPHS IN THE AU SABLE RIVER. TWO YEAR LIFE CYCLE.

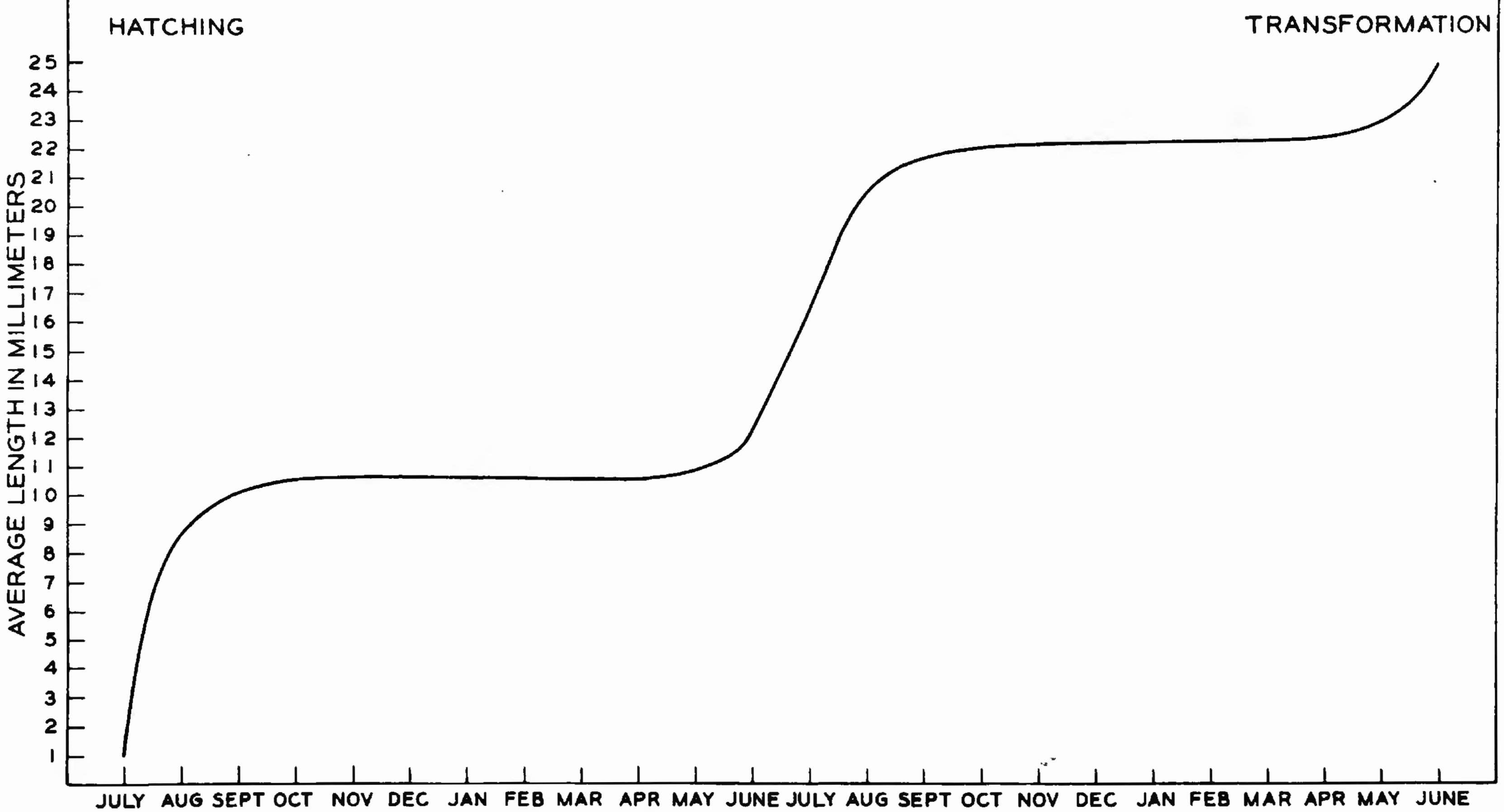


Fig. 14

| | Number of females stripped | Total eggs examined | Number of eggs hatched | Percent eggs hatched |
|---|---|---|---|---|
| | 1 | 351 | 338 | 96.3 |
| | 15 | 436 | 427 | 97.9 |
| | 22 | 456 | 442 | 96.7 |
| | 1 | 269 | 265 | 98.5 |
| Total | 39 | 1,512 | 1,472 | 97.4 |

The high percentage of successfully hatched eggs is slightly better than the 96.3 percent obtained from a total of 110 females from four different sources. Thus an average size female potentially produces 5,250 young nymphs. It is more than likely that under natural conditions the loss of eggs before incubation is completed is enormous.

The rate of embryonic development and length of incubation period is controlled largely by temperature. The shortest incubation period under experimental temperature conditions was 11 days, and the longest 94 days. At temperatures ranging from 62°-73°F., which is typical of the Au Sable River at the time *Hexagenia* are mating, eggs contained in two-quart jars placed in the river began to hatch in 20-26 days after incubation began. In most cases hatching of a clutch of eggs is completed in 4 days after it first begins but under certain conditions some eggs develop slowly and take months to hatch. This phenomenon was first observed while incubating a large number of eggs in a single container in the laboratory. Hatching began 18 days after incubation began and about half the eggs were hatched within a week. A diminishing number of nymphs continued to hatch until 98 days after the eggs were collected. Circumstances surrounding the position of eggs in the incubation jar, later duplicated with similar results, seemed to drastically influence the rate of embryonic development. Examination revealed that in some areas on the bottom of the egg container eggs were piled on top of each other 10 to 20 layers deep and solidly attached together by the naturally adhesive material around the eggs. Eggs on the periphery of these masses, and those located singly or in masses no more than three layers deep, hatched in three weeks. Embryos in eggs within these masses, however, developed very slowly and hatching was greatly delayed. Eggs nearest the center of the large egg masses hatched last of all. The reasons for this delayed development are not known, but the conclusion must be reached that some condition resulting from the crowding or smothering of the eggs had delayed their development. A possibility exists that interference with proper exchange of gases between the deeply buried eggs and the surrounding medium may have occurred and adversely affected embryonic development. Even though these embryos developed slowly, most of them eventually hatched (93.2 percent). Similar results were obtained by covering eggs firmly attached to the bottom of jars with 2-3 inches of stream silt. In these cases development of embryos was greatly retarded so that hatching did not occur until 2-3 weeks after uncovered eggs in jars in the same stream had hatched. It may be inferred from these experiments that eggs covered by silt in natural waters take much longer to hatch than those exposed to the water and that possibly embryos may be killed from being buried too deeply. The fact that eggs may take months to hatch under some conditions probably explains the finding of very small nymphs (3-5 mm.) in late fall and early spring in both lakes and streams. It appears that most eggs deposited in natural waters hatch within a short time, as evident from the large numbers of newly-hatched nymphs which appear all at once in bottom samples during midsummer.

Eggs become sticky within about one minute after deposition in water and firmly adhere to any solid object with which they come in contact. Those coming to rest in silt become covered with fine particles which adhere to the egg. Individual eggs are heavier than water and sink in still water at an average rate of one foot in 80 seconds. In rivers, it is expected that eggs would be distributed by the current and most of them would eventually find lodgment in eddies and along the side of the stream where the current is reduced sufficiently to allow them to sink.

Burrowing

Nymphs construct burrows when very small (2-3 mm.) and subsequently live their entire lives in burrows of their own construction. Burrowing is accomplished by digging action of the forefeet accompanied by pushing movement of the hind legs and strong dorsal-ventral undulations of the abdomen, which propel the body forward (Fig. 15). Nymphs can completely disappear from sight in soft mud in a few seconds. After entering the mud, gill action commences, producing water currents along the path of entry, thus enlarging the burrow. The front portion of the burrow is completed by mud particles being drawn towards and past the nymphs by gill-induced water currents until an opening is formed at the mud surface. After an hour or so the burrow is completely formed and is characteristically U-shaped, with the two arms extending upwards at about a 45° angle, each opening to the surface. The size and depth of the burrow depends on the size of nymph constructing it. The nymph remains near the bottom of the burrow during day-light hours and maintains a constant flow of water through the tunnel by gill movements. Nymphs were never seen to leave the burrows except to transform, although they were frequently seen feeding at night with their heads at the burrow's entrance.

Maximum depth to which nymphs burrowed in aquaria was not greater than five inches, and most individuals were less than four inches deep. Observations in the field led to the conclusion that nymphs do not burrow deeper than 6 inches.

In streams with sizable populations of nymphs, the surface of mud banks and bars is besprinkled with burrow openings, making location of nymphs easy.

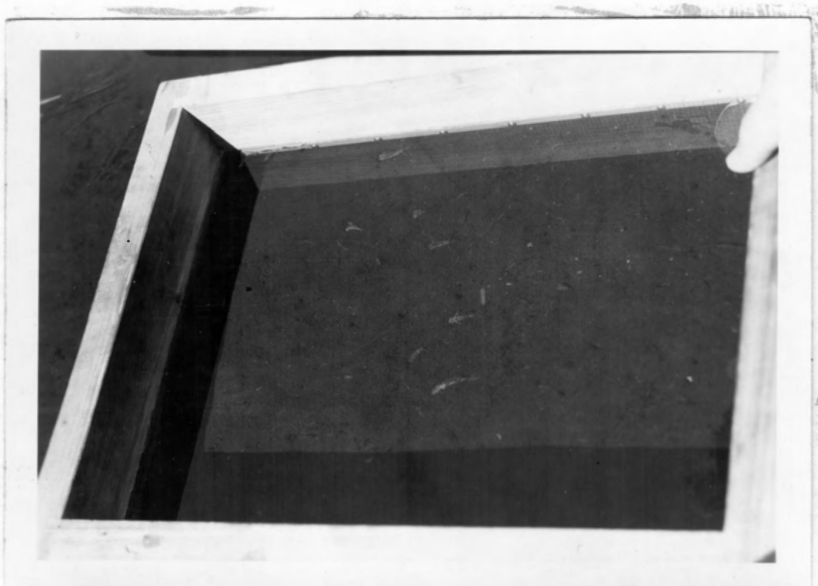

Fig. 15 Hexagenia nymphs beginning to burrow into a silt bank. (Photograph by Leonard N. Allison)

One such area in the Au Sable River is depicted in Fig. 16. Here the density of the nymph population averaged about 45 individuals of all sizes per square foot of surface area.

Type of bottom into which nymphs can or cannot burrow deserves considerable attention and will be discussed later. Nymphs cannot burrow into sand but are often found in muddy sand in streams where the sand is fine and makes up one-half to two-thirds of the mixture. Sufficient fine silt must be present to act as a binder on the sand grains and prevent a burrow from collapsing. Compact silt in streams, and soft marl mud in lakes, seemingly provide ideal burrowing media. Each becomes less suitable in proportion to the amount of undesirable material, such as sand, detritus, gravel, etc., mixed with it. Since water soils vary greatly in composition and are not well classified or described, it is a problem in itself to properly determine the relationships between various types of bottom and the burrowing nymphs. For this reason a general definition of a suitable bottom type must suffice at present. To be satisfactory as a burrowing medium, mud must be soft but not so flocculent that a burrow cannot be maintained; firm enough for a burrow to be constructed, but not so hard that nymphs cannot burrow readily; contain comparatively little sand and detritus and be free of appreciable quantities of decomposition gases. Although nymphs are often found in all kinds of bottom ranging from near-flocculent material to almost pure sand, large nymphal populations were encountered only in mud, the nature of which approached that of the optimum burrowing medium described above.

Emergence

When full grown, the nymph leaves the burrow and swims rapidly to the surface, where transformation to the winged subimago stage occurs. The nymphal skin splits along the top of the head and thorax and immediately the body of the subimago begins to protrude upwards and forwards. Once the legs

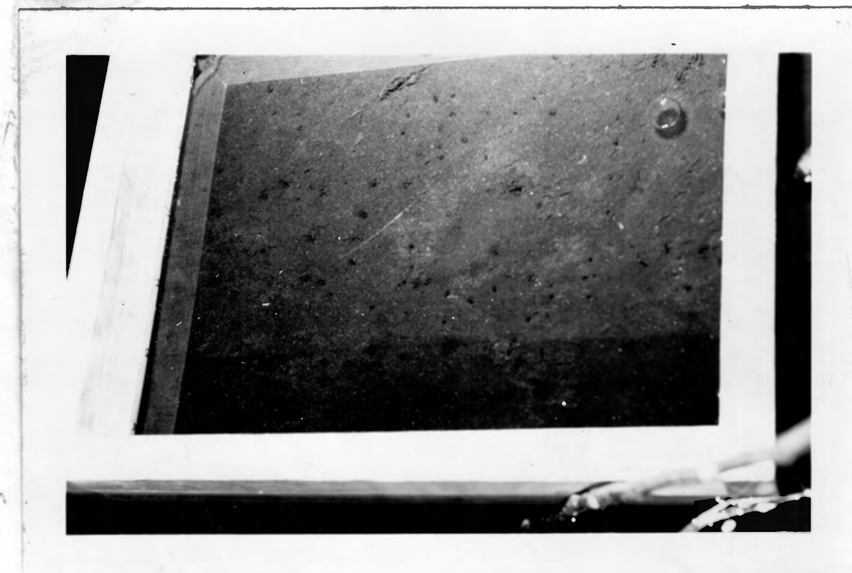

Fig. 16 Openings to burrows of <u>H. limbata</u> nymphs on surface of a silt bank, Au Sable River.
(Photograph by Leonard N. Allison)

and wings are freed, they instantly unfold and are immediately put to use as the newly-emerged individual flies heavily and erratically to shore. The act of transformation from the splitting of the nymphal skin to completion of emergence is usually completed in 15-30 seconds, although in some cases more than a minute may be required. Occasionally nymphs are unable to transform and eventually die in the process.

On the Au Sable River, emergence usually begins about one hour after darkness falls, reaches a peak from about 10:30-11:30 P.M., E.S.T., and may continue until shortly after midnight. None were ever observed emerging during the daytime or in early morning. A few emerging subimagoes have been observed on East Fish Lake, Montmorency County, and on the Manistee River at sundown, but this does not refute the generality that emergence occurs after dark and is confined to the forepart of the night. Emergences were always heaviest on warm nights and invariably light on nights when the temperature dropped rapidly.

While transforming, nymphs and subimagoes are very vulnerable to fish and many of them are eaten. Trout were seen to feed extensively on them late at night.

Emergence does not necessarily occur at the same time each year, for growth and maturing of nymphs is dependent upon water temperatures. In early and warm seasons emergence occurs early in the summer and tends to be concentrated into a short period. In colder years it occurs later in the summer and tends to be protracted over a greater period. A summary of emergence data on the Au Sable secured from observations made by the writer, Dr. J. W. Leonard, and Dr. Leonard N. Allison, of the Institute staff, and others is as follows:

| Year | Approximate date of first emergence | Approximate period of heavy emergence | Date of last observed emergence |
|---|---|---|---|
| 1946 | June 21 | ... | ... |
| 1947 | June 25 | July 4-July 20 | Aug. 6 |
| 1948 | June 11 | June 20-July 13 | Aug. 11 |
| 1949 | June 10 | June 17-July 10 | Aug. 12 |

Adequate reports are lacking for other streams, but it is probable that emergence periods for H. limbata in other rivers in the general vicinity of the Au Sable do not differ materially. In 1949, emergence on the Manistee River occurred at the same time as that on the Au Sable. Little information is available concerning appearance of the winged stages on the streams of the Upper Peninsula, but judging from the number of last instar nymphs collected July 19-22 and recollections of fishermen, it occurred during June and July, 1949 on some streams but was probably one or two weeks later than in the Au Sable area.

Subimago, imago, and mating flights

The newly-emerged fly seeks refuge in vegetation along the shore and rests quietly during the subimaginal stage. Length of time spent as a subimago is dependent somewhat on temperature. During warm weather the final molt usually occurs in late afternoon or early evening of the day following emergence. Cold weather prolongs the subimaginal stage to the following day, and experimental evidence indicates that under adverse weather conditions three days may elapse before the subimago molts to become mature.

The subimago is a dull colored fly with opaque wings and comparatively short legs and tails. In general color it differs considerably from the imago and many fishermen consider that the two stages are actually different kinds of insects.

After the subimaginal molt, the imago also remains quietly resting in the vegetation until mating time arrives. Shortly before the mating dance occurs imagoes become increasingly restless until they leave their resting places to engage in mating activities. The active imaginal stage lasts from a few hours to perhaps four days, depending upon weather conditions and whether the individuals mate. It is probable that most males live long enough to engage in mating activities on two successive days at least. Females usually drown immediately after oviposition, but those which return to shore usually die within a day after depositing their eggs. When eggs are retained, female imagoes may live for three days and probably are able to oviposit at the end of that time.

Swarming of H. limbata is an interesting and conspicuous event but is not seen by most people since it happens after dark and an observer must be on the stream and use a light to properly appreciate the activity which occurs. Night fishermen are well aware of the tremendous numbers of flies which are on the water immediately following a mating flight and take advantage of the intensive feeding activity of trout, both large and small, which ensues.

Swarming of H. limbata was observed many times at various places on the Au Sable, Manistee, and other rivers, and in every instance the mating dance began just at dark, about three-quarters of an hour later than on southern Michigan lakes. On a number of occasions during the 1949 season, the first dancing flies were seen at precisely 9:30 P.M., E.S.T., and within minutes thousands of individuals were engaged in the dance high (60-80 feet) above the stream. After copulation, females could be seen flying at lower and lower levels until from a height of 10-20 feet they began plunging into the water to struggle with wings outspread as they discharged their eggs. Mating flights usually lasted about 45 minutes, although sometimes longer. At the end of heavy flights, spent females literally covered the water surface and gathered in huge drifts in eddies. Spent females floating in an eddy on the Au Sable River after a light mating flight are shown in Fig. 17. Male imagoes seldom are found on the water during or after mating flights. After swarming,

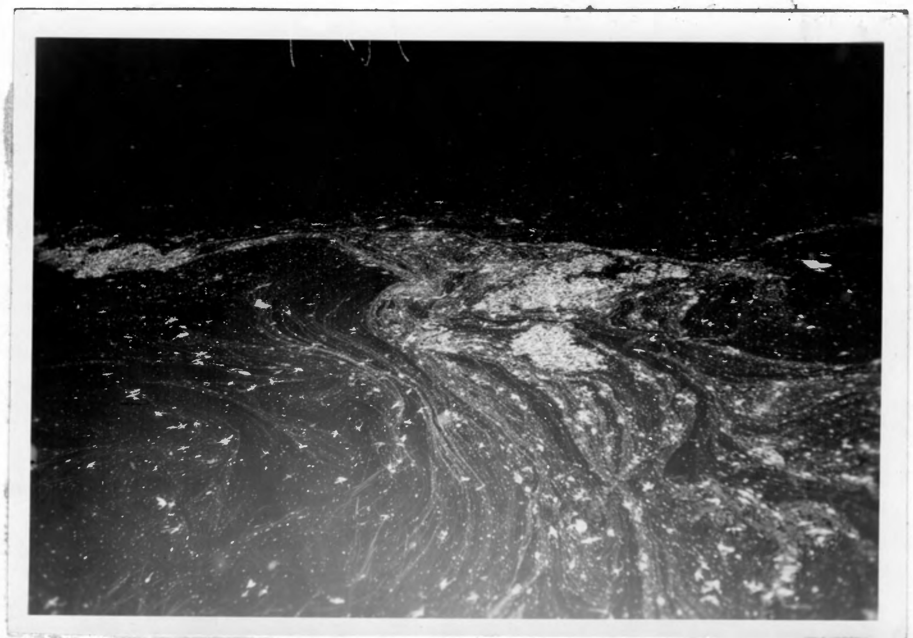

Fig. 17 Spent H. limbata females floating in an eddy on the Au Sable River during a light mating flight.
(Night photograph by Leonard N. Allison)

they return to the vegetation along the shore to die or await the mating dance of the following day. The following conclusions, drawn from extended observations of the swarming of H. limbata on both lakes and streams, are that: (1) females mate only once and oviposit within 3 to 10 minutes after copulation; (2) practically all females "crash land" on the water surface, immediately extrude the two egg packets which dissolve on contact with water, and drown; (3) males remain high above the water and return to vegetation along the bank after mating; (4) males may, and probably do, mate more than once; (5) mating flights occur during stormy and rather windy weather but are prevented by very strong winds against which individuals cannot fly; and (6) when prevented from mating one night by adverse weather both males and females can do so the following night.

The publicized "caddis hatches" and "mayfly hatches" of many Michigan streams are apparently the mating flights of Hexagenia and, in all probability, are composed of one species only, namely limbata. While the other species of burrowers discussed in this report undoubtedly swarm in goodly numbers at times on some streams, their occurrence is of minor importance when compared to activities of the widely distributed and abundant limbata.

"Hatches" of major extent are known by the writer to occur on the following main streams or major tributaries of northern Michigan rivers: Au Sable, Manistee, Boardman, Pere Marquette, Muskegon, Maple, and Black. Judging from the nymphal populations of limbata seen by the writer, undoubtedly large emergences occur on parts of many other rivers, namely: Escanaba, Middle Branch of the Ontonagon, Manistique, including the Fox, East Branch of the Fox and many other tributaries, and the Tahquamenon, including the Sage River. Since large nymphal populations often occur only in limited sections of rivers, resulting flights of adults are likewise limited to those sections. Probably rather heavy "hatches" of limbata occur annually in many streams but have gone unnoticed by the majority of trout fishermen.

## *Hexagenia recurvata*

Various authors have concluded that the life cycle of this species requires two years for completion (Needham, Traver and Hsu, 1935).

Occasional collections of nymphs in Fuller and Hunt Creeks, Montmorency County, from 1946 to 1949, and many other streams in the summer of 1949, show that two size and age groups of nymphs are present most of the year--a strong indication that a two-year life cycle is in effect in Michigan waters. Growth rate of *recurvata* nymphs is about the same as that of *H. limbata*, but individuals of the same age tend to be of more uniform size even in different streams. There is evidence to show that emergence and mating occur within a very short period; subsequent egg hatching should, therefore, occur over a similarly short period and give rise to a relatively uniform age group of nymphs.

Nymphs collected in late June, 1949, from a number of streams averaged 12.5 mm. in length. By mid-August, when young-of-the-year were present, the larger nymphs averaged 20 mm. in body length. The size frequency distribution of nymphs collected in 1949 is shown in Table 3. The presence of two age and size groups is plainly seen in August, as well as the growth of the one-year-old nymphs since June. Only one group is evident in June since young-of-the-year nymphs were too small to be taken with the sampling screens.

Samples of nymphs taken in April and May from Fuller and Hunt Creeks have shown two size groups present--one very large with most individuals in the last instar, and another consisting of half grown nymphs. Thus there seems to be no doubt that this species completes its life cycle in two years. The suggestion often voiced that some burrowing mayflies have a three-year life cycle appears to be unfounded in the opinion of the writer.

Table 3. Size frequency distribution of H. recurvata nymphs collected in various streams in 1949.

| Date | Number Measured | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Length in Millimeters | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | MALES | | | | | | | | | | | | |
| June 20-28 | 38 | | | | 2 | 6 | 7 | 10 | 7 | 5 | 1 | | | | | | | | | | | | |
| Aug. 8-15 | 40 | | 1 | 1 | 2 | 3 | 4 | 3 | 2 | | 1 | 4 | 5 | 6 | 3 | 2 | 3 | | | | | | |
| | | | | | | | | | | | FEMALES | | | | | | | | | | | | |
| June 20-28 | 38 | | | | 4 | 2 | 3 | 4 | 5 | 9 | 7 | 3 | 1 | | | | | | | | | | |
| Aug. 8-15 | 48 | | | 3 | 2 | 3 | 1 | 5 | 4 | 2 | 3 | | | | | 7 | 8 | 2 | 3 | 3 | .. | 1 | 1 |

Little data are available concerning the life history or habits of this species in Michigan although certain phases have been studied by workers in the eastern part of the United States. Eggs hatched in the laboratory in 14 days in New York (Needham, Traver and Hsu, 1935), and it appears quite likely that the incubation period in the cold streams occupied by the species in Michigan would require from 3-4 weeks. Few adults have ever been collected by the writer and no egg counts have been recorded. Number of eggs produced by females is probably similar to H. limbata. It is quite probable that the important features of the life history, such as emergence, subimago and imago stages, and mating activities parallel those of H. limbata. The time of year in which emergence occurs differs markedly from other hexagenids covered in this report. Although no living adults have been collected in the field by the writer, emergence occurred early in June, 1947 on Fuller Creek, Montmorency County. Spent females were found on the stream on June 13, and a few grown nymphs remained in the stream at that time. In 1948, emergence occurred between May 10 and June 14, indicated by the abundance of last instar nymphs on the former and a lack of them on the latter date. No adult nymphs were found during the latter part of June, 1949, in any streams sampled. It can be concluded that this species ordinarily emerges in May or early June in Michigan, preceding the appearance of H. limbata by about three to four weeks.

Burrowing habits of recurvata nymphs are similar to those of other hexagenids. Although they seem to thrive in scantier, sandier, and more dense mud than limbata, the largest nymphal populations were always found in firmly packed mud banks of the type best suited for burrowing.

This species is probably of little value generally as an aid to angling by causing extensive "rises" of trout since in the main it is restricted to small creeks inhabited mostly by small brook trout. In a few larger cold creeks, such as Hunt Creek, Montmorency County, and the South Branch of the Boardman, Grand Traverse County, sizable nymph populations indicate that adult flies are produced in sufficient numbers to stimulate trout feeding and aid the fisherman in making catches. The Fox River near Seney (Schoolcraft County) is the largest stream in which it was found. Although both H. limbata and recurvata occur in the river at that point, nymphs of the latter predominate and should produce "hatches" of sufficient size to interest both fish and fishermen.

Hexagenia rigida

Although this species was not found in streams proper, it may occur in the lower reaches of larger rivers and may be of some importance to fish and fishermen in those areas. Neave (1932) and Chandler (personal communication) found that the habits, length of life cycle, time of emergence, and life history phases of this species were similar to limbata and in many waters nymphs of the two species live side by side. The writer stripped eggs from 13 females obtained at Mio Dam. Hatching began 11 days later, and 93 percent of the eggs produced nymphs. An attempt to rear the nymphs failed due to accidental loss of specimens.

Based on present knowledge, the conclusion may be drawn that rigida is of little or no importance in the economics of Michigan trout streams.

Ephemera simulans

This small burrowing mayfly has a wide geographical distribution and occurs in lakes and both large and very small streams, although usually more abundant in the former. It is important as fish food, as both nymphs and adults. In Big Silver Lake, Washtenaw County, Douglas Lake, Cheboygan County, and probably in many other lakes it is as abundant and probably as important as the hexagenids. Although frequently encountered, large numbers of nymphs were seldom found in the rivers investigated although they are widely distributed in some streams such as the Au Sable River.

Length of life cycle of <u>Ephemera</u> apparently varies in the same fashion as that of <u>H. limbata</u>, being influenced by the temperature of the environment. It was clearly evident from collections of nymphs and observations of emergence made by the writer in Big Silver Lake, Washtenaw County, that a one-year life cycle is in effect in that body of water. Collections of nymphs of stream ephemerids were inadequate to definitely determine the length of life cycle in northern rivers, but the limited data available suggest that two years are required for nymphs to mature. Cronk (1932) and Ricker (1934) concluded that the species has a two-year life cycle in certain Ontario waters.

No egg counts have been made but it is estimated that females produce between 2,000 and 3,000 eggs. Eggs secured from copulating females hatched in the laboratory after 14 days incubation and 93.8 percent of them proved to be fertile.

Nymphs construct and maintain burrows similar to those of <u>Hexagenia</u> although the preferred bottom type seems to be very sandy mud rather than firm silt or marl. Where nymphs of the two genera occur, there is always some overlapping in lateral distribution, but neither commonly occurs in the habitat best suited for the other. In lakes, most <u>Ephemera</u> nymphs are found on or adjacent to sandy shoals, while in streams they are most abundant in very sandy mud banks or along the edges of silt bars where silt, sand and gravel are thoroughly mixed. At times, nymphs have been found in nearly pure sand although never very abundant in such places. Specimens can burrow deeply into soft mud but seem to remain near the surface in a very sandy substrate. Nymphs have been seen to burrow into find sand no more than one-half inch deep and remain covered for hours, yet no burrow opening was visible.

Emergence occurs principally in the forepart of the night although emerging subimagoes sometimes appear in late afternoon. At Big Silver

Lake and East Fish Lake, Montmorency County, nymphs transform during May and early June, usually two to three weeks before winged Hexagenia first appear, although emergence of the two overlaps in some seasons. On the Au Sable River both genera were seen emerging together in the early part of the summer during 1947 and 1948. Appearance of Ephemera always precedes that of Hexagenia, and most nymphs of the former will have transformed before emergence of the latter is well underway.

Subimaginal and imaginal stages are similar to those described for H. limbata. Mating activities are also much like those of Hexagenia although the mating dance occurs earlier in the evening, often while the sun is still above the horizon.

Large mating flights of this species have not been seen by the writer on streams but are presumed to result in active surface feeding on the part of trout equal to that caused by their larger relatives. Lake fishes have been seen to feed extensively on ovipositing females.

## DENSITY OF NYMPHAL POPULATIONS

Number of nymphs per unit area of suitable bottom varies greatly with the seasons in different streams and in different sections of the same stream. Sampling from June, 1946 to August, 1948, showed that the average number of nymphs per square foot of bottom at three stations on the Au Sable River was as follows: Station 1 (North Branch at Twin Bridges) 8.0, Station 2 (North Branch at Kellogg's Bridge) 16.6, Station 3 (Main Stream near Luzerne) 138.3. The percentage of total bottom at the various stations which was composed of silt is as follows: Station 1, 6 percent; Station 2, 18 percent; Station 3, 12 percent. The largest number of individuals taken in any square foot sample was 356. Many square-foot samples taken at different places in the Au Sable system contained from 40 to 70 nymphs. Details of sampling in the Au Sable River will be given in a later report.

Sampling in other streams has shown that in none of them is the density of the nymphal population as a whole equal to that of the Au Sable. Some individual samples in other streams have yielded more than 100 nymphs per square foot, but such instances were rare. Usually the number per square foot was less than 30.

Small areas of particular concentration of nymphs will be found occasionally in any stream which harbors them even though the overall population and habitat is not great.

The following tentative classification of streams relative to Hexagenia productivity is presented with trepidation. It should be kept in mind that the densities of nymphs corresponding to grades of stream are at best approximations and that in evaluating a given stream not only the number of nymphs but also the amount of nymphal habitat must be considered.

| Grade | Average number nymphs per square foot | Density of "hatches" |
|---|---|---|
| Poor | 1-5 | Not noticeable |
| Fair | 6-15 | Sparse |
| Good | 16-40 | Medium to heavy |
| Excellent | 41-100 | Very heavy |

It is suspected that there is a relationship between number of nymphs and amount of suitable bottom which does not follow a direct proportion curve. Indications are that with increase in amount of habitat beyond the point necessary for maintaining the species in the stream (estimated at 0.5 percent of the total bottom area), the nymphal population increases in numbers disproportionately faster.

A tentative classification of the production of H. limbata nymphs in streams, based on the relative amount of suitable mud habitat present, is as follows:

| Grade | Percentage of bottom composed of suitable burrowing habitat |
|---|---|
| Nymphs lacking | less than 0.3 |
| Nymphs barely established | 0.3 - 1.0 |
| Poor | 1 - 4 |
| Fair | 5 - 7 |
| Good | 8 - 10 |
| Excellent | 11 - 50 |

The above scale, based on measurements and estimates, is at best an approximation and should not be considered as an inflexible standard in judging the productivity of streams. It is not illogical to assume, however, that a greater survival rate of young is effected in areas with more abundant habitat than in sections where it is of lesser extent. This assumption, if true, would largely explain the extreme abundance of nymphs in many sections of the Au Sable River.

It is quite evident to the writer that a prohibitive amount of stream mapping and bottom sampling would have to be done before what seem on the surface to be generalities concerning relationship between nymphal populations and extent of habitat can be brought into the realm of definite measurable quantities and ratios.

## FACTORS INFLUENCING DISTRIBUTION OF NYMPHS

### Temperature

It has been determined that temperature is the most important factor influencing the geographical range of aquatic insects and that within the limits set by temperature, a number of other factors determine the local distribution of each species (Ide, 1935; Sprules, 1947). Observations by the writer on the distribution of burrowing mayflies in Michigan have led to the same conclusion.

As previously mentioned, *H. limbata* has a wide range of temperature tolerance, being found in waters where the maximum summer temperatures rise above 90°F. It has been found that nymphs of limbata grow very slowly when the temperature ranges between 50° and 60°F. They are apparently not able to complete nymphal development before perishing in streams with such low water temperatures; therefore the species is excluded from very cold streams. The lower limiting summer temperature appears to be about 63°F., below which they cannot grow sufficiently fast to mature in their normal life span.

*H. recurvata*, on the other hand, has a comparatively narrow temperature toleration range and its distribution is limited by high water temperatures. It appears that the upper limit of summer water temperature suitable for the species is about 63°F., with the optimum some 5-8 degrees lower. Since most streams in Michigan are warmer than this in summer, temperature conditions preclude a widespread distribution of the species.

*H. rigida* and *E. simulans* appear to have temperature requirements similar to those of *H. limbata* but other factors apparently are important in limiting their distribution and abundance.

### Bottom types and current

These two factors are inseparable since current largely determines the bottom types, and both are of great importance in local distribution of species of aquatic insects. None of the burrowing mayflies shows a current demand--known to be a limiting factor for some species of insects--consequently current can be considered as of importance only in the manner in which it affects the stream bottom type.

Since burrowing nymphs must live in mud and cannot exist in loose sand, gravel or rubble bottom, their numbers and distribution are restricted by the amount, depth, extent, and nature of silt deposition in a stream. The Au Sable River has the largest *Hexagenia* population of any Michigan stream sampled by the writer, the reason being the low gradient of the stream and resultant extensive silt deposition especially along the sides of the channel, forming an abundance of habitat suitable for the burrowing nymphs. Quite in contrast to the Au Sable is the Sturgeon River, flowing into Burt Lake. In this stream the gradient is so great that the rapid current in the lower sections of the river precludes mud deposition in sufficient quantities to maintain a Hexagenia population.

An analysis of the dynamics of moving water is quite beyond the scope of this report. However, certain factors responsible for silt deposition were quite obvious. Current velocity readings, using a Bentzel Velocity Tube, showed that silt is deposited in streams only where the rate of current flow drops below 0.5 foot per second. Current velocities taken at the edges of silt banks, at the line of demarcation between sand and silt, ranged from 0.30-0.45 feet per second. Numerous measurements taken on well established silt bars always showed current velocities less than 0.3 foot per second regardless of the depth of water over the silt. Mixtures of sand and fine mud or clay were sometimes found to form bars where the current velocity ranged as high as 0.4 foot per second. In the Au Sable River many mud banks lie parallel to channels in which the mid-water current velocity reaches 1-2 feet per second. In these areas the current bordering the mud banks, which often have vertical sides 8-10 inches high next to the channel, is slowed to less than 1 foot per second and the mud is further protected by growths of aquatic plants, chiefly Elodea, which slow the current at the mud surface sufficiently to prevent erosion.

Silt deposits, which form the micro-habitat of burrowing mayflies in streams, occur in a variety of places and may be of any size from a few square inches to hundreds of square feet, depending upon the stream gradient, water depth, presence of obstructions of various kinds, bank indentation, vegetation, change in current velocities which accompany change in direction of flow, and pool formation (Fig. 18, 19). The influence of all of these factors can be observed in any stream in which mud deposition occurs. In most streams silt deposition occurs only along the margins near the bank where the current is slowed. Mud deposits in a rapid stream are shown in Fig. 20. In this case mud bottom constitutes 4 percent of the total area. It should be noted that in three areas small silt banks have been formed in small indentationsin the bank while one has formed behind a log which, jutting out from the bank, has deflected the current. In this section of the South Branch of the Boardman River, the mud is heavy, contains a good deal of fine sand and provides a good habitat for *H. recurvata*. Obstructions, chiefly logs of varying size, play an important role in slowing the current and causing silt deposition behind them (Fig. 21). It can be seen from the figure that logs deflect the current and provide a calm area in which mud particles can settle.

In slow flowing streams silt banks are often formed on the inside of curves when the current is directed mainly towards the opposite bank. This type of mud deposit is common in the Main Stream of the Au Sable River.

Aquatic vegetation can be an important aid in forming and holding mud banks. In late summer dense growths of vegetation occur in many streams and although the plants themselves are largely found rooted in mud, they often aid in slowing the current and producing new silt deposits.

Since silt bars are easily eroded, it is obvious that changes in them will occur with rising and falling water levels which influence currents. In one area of the North Branch of the Au Sable River under observation for several years, one silt bed, which had been well established for a year, vanished with a change in current caused by dense growths of algae, and was not re-established. In another sectinn where silt was

Fig. 18 Slow flowing section of Manistee River west of Frederic. Small silt deposits along margin of stream contain many H. limbata nymphs.

Fig. 19. North Branch of Au Sable River at Twin Bridges, north of Lovells. Sampling micro-habitat located at stream margin between tufts of sedges.

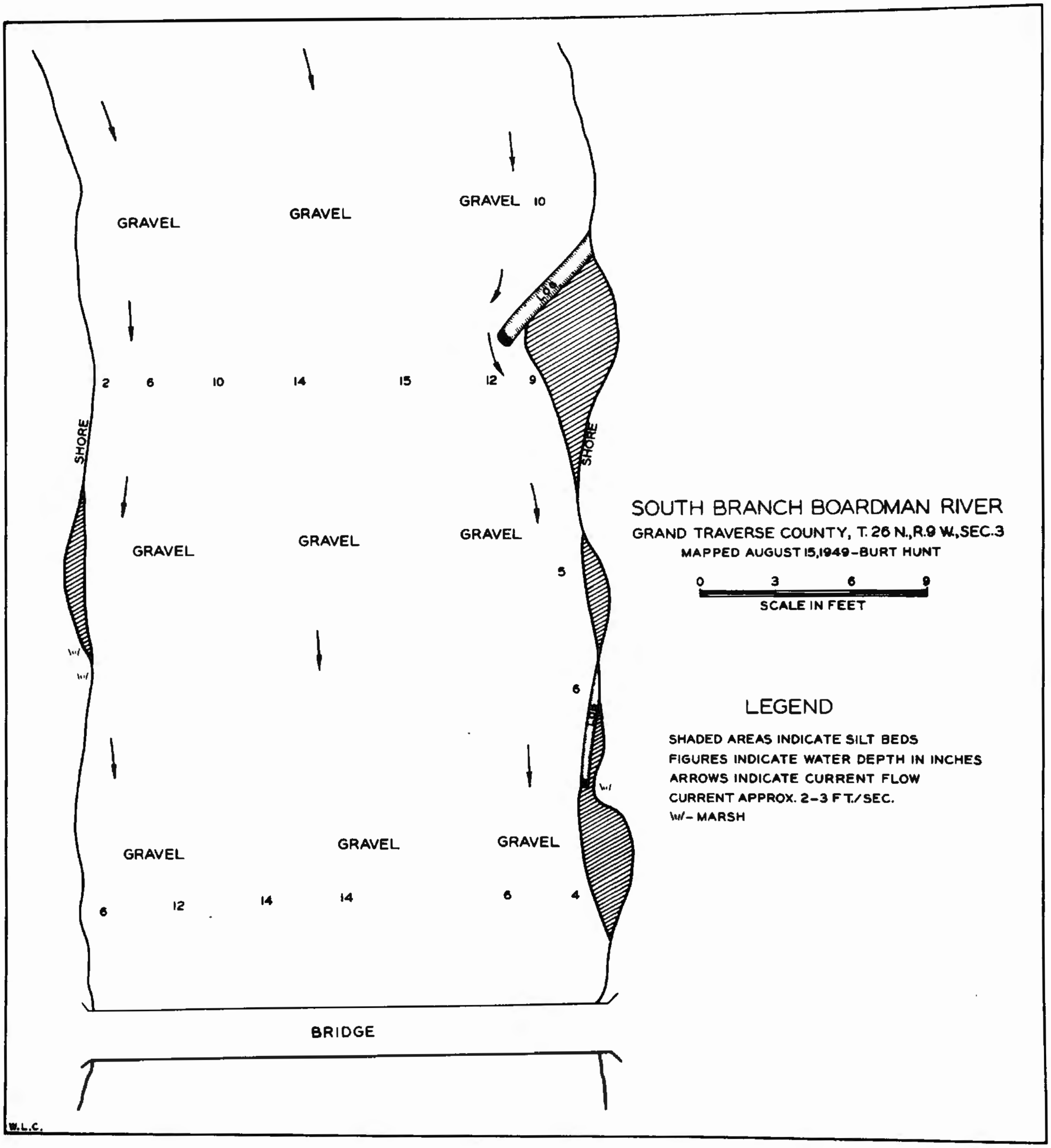


Fig. 20 Map of stream showing location of mud deposits in which H. recurvata nymphs were abundant.

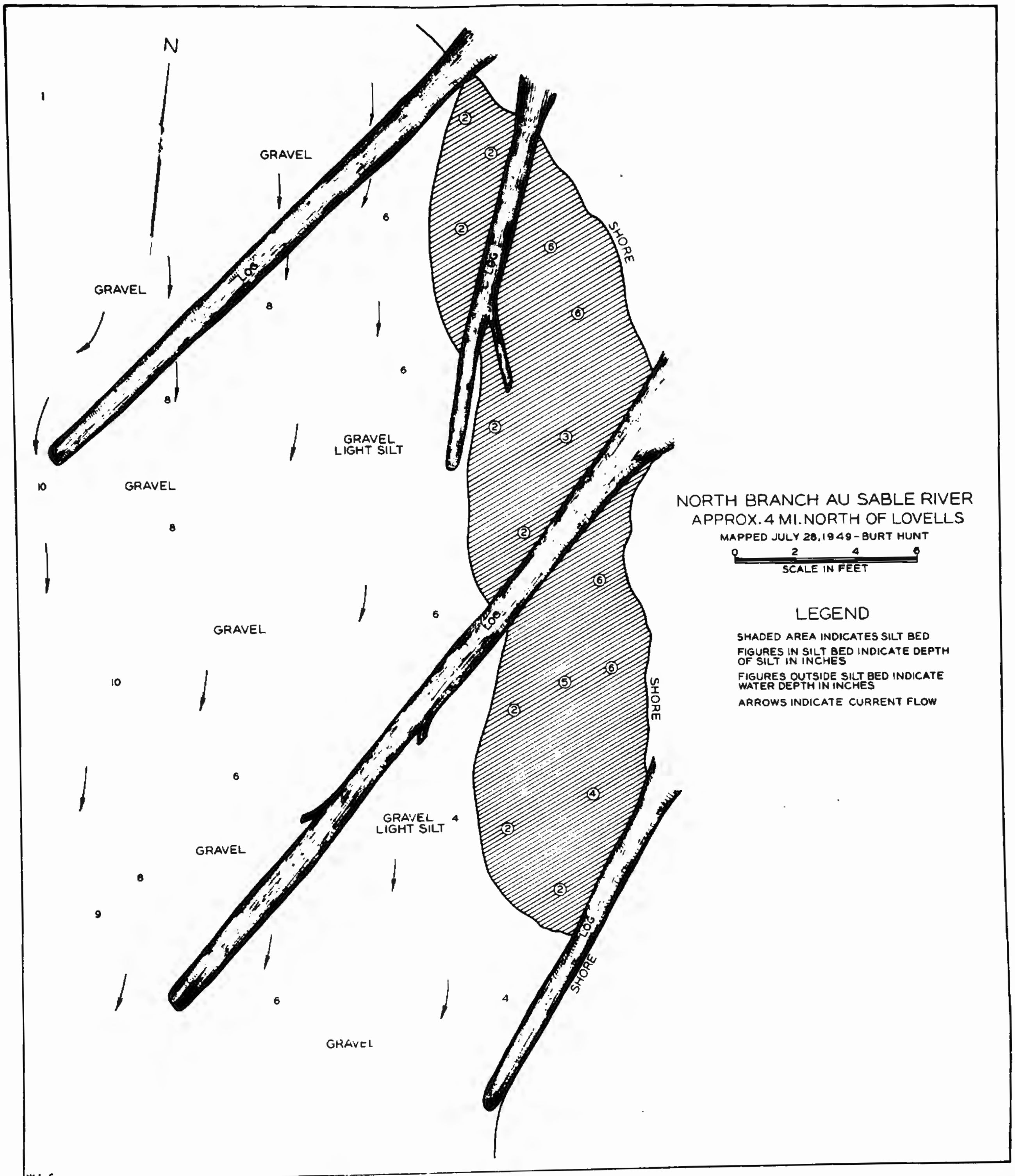


Fig. 21 Extensive silt bed formation below logs in North Branch Au Sable River

deposited between tufts of sedges along an irregular shoreline, the silt bank remained during the course of three years but was continually changing in size with increase or decrease in the water level. Other areas, located behind obstructions which were occasionally overtopped by increase in water level and which successfully deflected the current during periods of low levels, were sometimes covered with several inches of mud and at other times swept clean of silt. One large mud bank, located on the inside of a curve in the river, remained unchanged for three years.

Obviously nymphs are exposed and swept downstream whenever the silt bank is swept away by changing currents. The ultimate fate of these displaced individuals is not known, but it can be safely assumed that some fall prey to fish and that others, since they are quite strong swimmers, find lodgment in other silt banks further down stream. That the latter often happens is shown by the appearance of large nymphs in newly formed silt deposits.

Physical analyses of mud deposits in Hunt Creek and Au Sable River (Tables 4 and 5) revealed that the chief constituents were sand, detritus, and finely divided organic debris. All three samples were taken where nymphs were known to occur and were burrowing successfully. Sample 1 in Hunt Creek and the Au Sable River sample were from areas containing large numbers of nymphs, whereas fewer specimens were present in the mud bank from which Sample 2 from Hunt Creek was taken. The difference in the number of nymphs in the different samples may or may not be significant. It should be noted, however, that Hunt Creek Sample No. 2 contained a great deal more water, therefore being less firm than the other samples.

It is quite evident that a great deal of work would have to be done on bottom materials before definite conclusions could be drawn on the relationship between the composition of bottom muds and the burrowing ability and requirements of nymphs.

Table 4. Physical analyses of silt banks, Hunt Creek, Montmorency County. Samples washed through set of 6 Tyler Standard Scale screens. Measurements of dry weight.

| | Sample 1 | | Sample 2 | | |
|---|---|---|---|---|---|
| Meshes per inch | Materials retained by screen in grams | Percentage of total | Materials retained by screen in grams | Percentage of total | Materials |
| 4 | 1 | 0.3 | 2 | 1.4 | detritus |
| 8 | 1 | 0.3 | 2 | 1.4 | detritus |
| 14 | 2 | 0.6 | 3 | 2.1 | woody debris, coarse sand |
| 35 | 4 | 1.2 | 16 | 7.1 | woody debris, sand |
| 65 | 119 | 35.3 | 27 | 19.2 | woody debris, sand |
| 100 | 92 | 27.3 | 18 | 12.9 | fine sand, organic debris |
| pan | 110 | 32.6 | 72 | 51.4 | very fine sand, organic debris |
| Loss in washing | | 2.4 | | 4.5 | |
| Water | | 60.5 | | 80.6 | |
| Dry matter | | 39.5 | | 19.4 | |

Table 5. Physical analyses of silt banks, Au Sable River. Sample washed through set of 6 Tyler Standard Scale screens. Measurements of dry weight.

| Meshes per inch | Materials retained by screen in grams | Percentage of total | Materials |
|---|---|---|---|
| 4 | 8 | 2.2 | detritus |
| 8 | 6 | 1.6 | detritus |
| 14 | 6 | 1.6 | woody debris, coarse sand |
| 35 | 30 | 8.3 | woody debris, sand |
| 65 | 88 | 24.5 | organic debris, fine sand |
| 100 | 61 | 17.0 | organic debris, fine sand |
| pan | 158 | 43.9 | very fine organic debris, sand |
| Loss in washing | | 1.0 | |
| Water | | 51.5 | |
| Dry matter | | 48.5 | |

## Water depth

Observations suggest that water depth, providing other conditions are favorable, is of little or no importance in determining distribution of H. limbata nymphs. These insects are known to successfully inhabit lake bottoms at depths as great as 60 feet and in East Fish Lake, Montmorency County, limbata nymphs range downward to a depth of 32-35 feet. In the various Michigan rivers investigated nymphs have been found at depths ranging between 1 inch and 4 feet. A check on several pools and channels deeper than this showed the bottom to be composed of sand or gravel with no mud deposits whatever. Thus it is most probable that nymphs do not occur in most streams at depths greater than 3-4 feet due to lack of habitat at greater depths. There is every reason to believe, however, that they would occur in deeper portions of a stream if a suitable mud bottom were present.

Normal annual fluctuations in water level, known to be as great as 13 inches during a summer in the Au Sable River near Grayling, greatly affects nymphs located in mud bars on the periphery of the stream. Receding water levels leave considerable areas of nymphal habitat exposed to the air at times. Checks made on the inhabitants of such mud banks in the Au Sable River during periods of steadily dropping water levels in the summer of 1949 indicated that nymphs did not remain in their burrows to be stranded but left the exposed banks and followed the retreating water. It seems unlikely that any loss of nymphs results from a drop in water level providing it is gradual and deeper water is at hand into which they can move. It is possible that in certain instances a decrease in water depth resulting in the exposing of a large area of level bottom inhabited by nymphs could result in loss of most of the population. Such situations where this might happen are undoubtedly rare in Michigan streams.

Mr. Fenton W. Carbine, formerly of the Institute staff, has informed the writer that large numbers of Hexagenia nymphs followed the rapidly receding water level when ponds at the Drayton Plains Rearing Station were emptied to remove fish. These nymphs eventually congregated in enormous numbers in the seining basin at the outlet. However, some individuals were known to have remained in their burrows in exposed mud bottom and later were eaten by birds or perished from desiccation.

## Chemical factors

All waters investigated thus far have been alkaline. Experiment has shown that nymphs can tolerate waters with pH ranges from 7.4-9.6, but it is not known if the organisms are able to tolerate acid conditions since no opportunity to thoroughly examine waters with pH less than 7.0 has presented itself. It seems quite certain that chemical conditions normally extant in most of the rivers in Michigan are within the toleration range of nymphs and do not operate as limiting factors in either the distribution or density of nymphal populations.

## Vegetation

Heavy growths of vegetation, which occur on mud deposits in many streams in late summer, apparently do not interfere seriously with the burrowing nymphs. Sampling has shown that specimens are still present in silt banks solidly covered with dense Elodea. Nymphs appear to be more numerous in open mud banks than in adjacent ones with heavy vegetation, an inconclusive indication that some movement by nymphs may occur to escape from densely vegetated areas.

## Winter conditions

Observations made during severe winter weather revealed that nymphs remained in the same mud banks occupied in the summer and were apparently suffering no ill effects from the ice cover. In all areas examined, shelf ice extended out from the bank, completely covering the mud banks near shore (Fig. 22). Sufficient water lay between the ice and mud so that no freezing of the latter occurred except at the water's edge (Fig. 23). It is quite probable that formation of anchor ice may occasionally destroy some nymphs. Data secured during the winter of 1947-48 indicated, however, that nymphal populations in areas which have been repeatedly sampled for several years suffered little or no damage or displacement during the winter.

## Stream improvement devices and burrowing mayfly habitat

An increasing amount of improvement work is being done in Michigan trout streams--in many cases drastically altering the configuration of the stream bed (Clark, 1948; Shetter, Clark and Hazzard, 1949). The effect of various improvement devices and alteration of depths and water currents on aquatic insect fauna is not well known. Examination of improved sections of northern trout streams revealed that although artificial obstructions are involved, the same relationships exist between silt deposition and current velocity as in streams in their natural state.

One of the principal objectives of stream improvement is to narrow and deepen the water, resulting in an acceleration of flow and digging action by the current. Improvement structures which accomplish this usually are not conducive to silt bed formation, although sand removal and gravel exposure occur to the benefit of many other aquatic insects. Deflectors, which often cause the current to be slowed both above and below them, are instrumental in silt bar formation in the areas of reduced current velocity. Two deflectors which have silt beds established behind them are shown in Figures 24 and 25. Permanence of such silt deposits depends largely on the protection from currents furnished by the deflector. The silt bed behind the structure in Fig. 24 was often washed away with a rise in water level

Fig. 22. Hunt Creek, Montmorency County, March, 1948. Shelf ice covering silt deposits along margin of stream.

Fig. 23. Au Sable River, March, 1948. Shelf ice removed to show open water which covered mud occupied by nymphs to a depth of 3 inches.

Fig. 24. Upstream view of area behind an old deflector, North Branch Au Sable River. Silt bed behind deflector is transitory, changing with fluctuations in water level.

Fig. 25. Upstream view of area behind old deflector, Clam River. Excellent silt bed containing hundreds of nymphs, which shows indications of becoming filled in and grown over to form solid ground.

and was as frequently re-established with receding water levels. In some situations involving deflectors which had been in position for several years, it appeared that a succession of events had occurred which resulted in extinction of Hexagenia habitat. In several instances structures aimed at narrowing the channel had at first caused silt beds to form behind them. Additional mud and fine sand had continually found lodgment there until the entire bar rose above the water and became covered with terrestrial vegetation, thereby becoming a portion of the shore.

In many streams, old improvement structures, chiefly deflectors, were noted to have silt bars formed near them which appeared to be quite permanent. One such situation is shown in Fig. 26. In this instance numerous nymphs were present in the rather firm mud deposits which totaled 75 square feet (11 percent of the stream bottom). In areas where the current is slow and silt normally is deposited in large quantities under natural conditions, the addition of log deflectors has apparently increased the formation of mud banks considerably. Both behind and in front of the numerous deflectors shown in Fig. 27, large mud banks have been formed so that approximately 40-50 percent of the stream bottom is composed of silt--only the centrally located channel having a sand or gravel bottom. The mud banks in this section form an ideal habitat for H. limbata nymphs, for the number of specimens of all sizes present in this area in June, 1949, ranged from 20 to 96 per square foot of bottom.

Deflectors constructed of Wakefield sheet piling, or single tongue and groove sheeting (the latter is extensively used at the present time), sometimes cause formation of silt deposits in the slack water behind them. One such deflector is depicted in Fig. 28. Although the silt behind this structure was extensive and deep (up to 9 inches), it was composed of very fine material, was quite flocculent, and contained few nymphs. In time the silt in such situations may become more firm and thereby more satisfactory as a burrowing

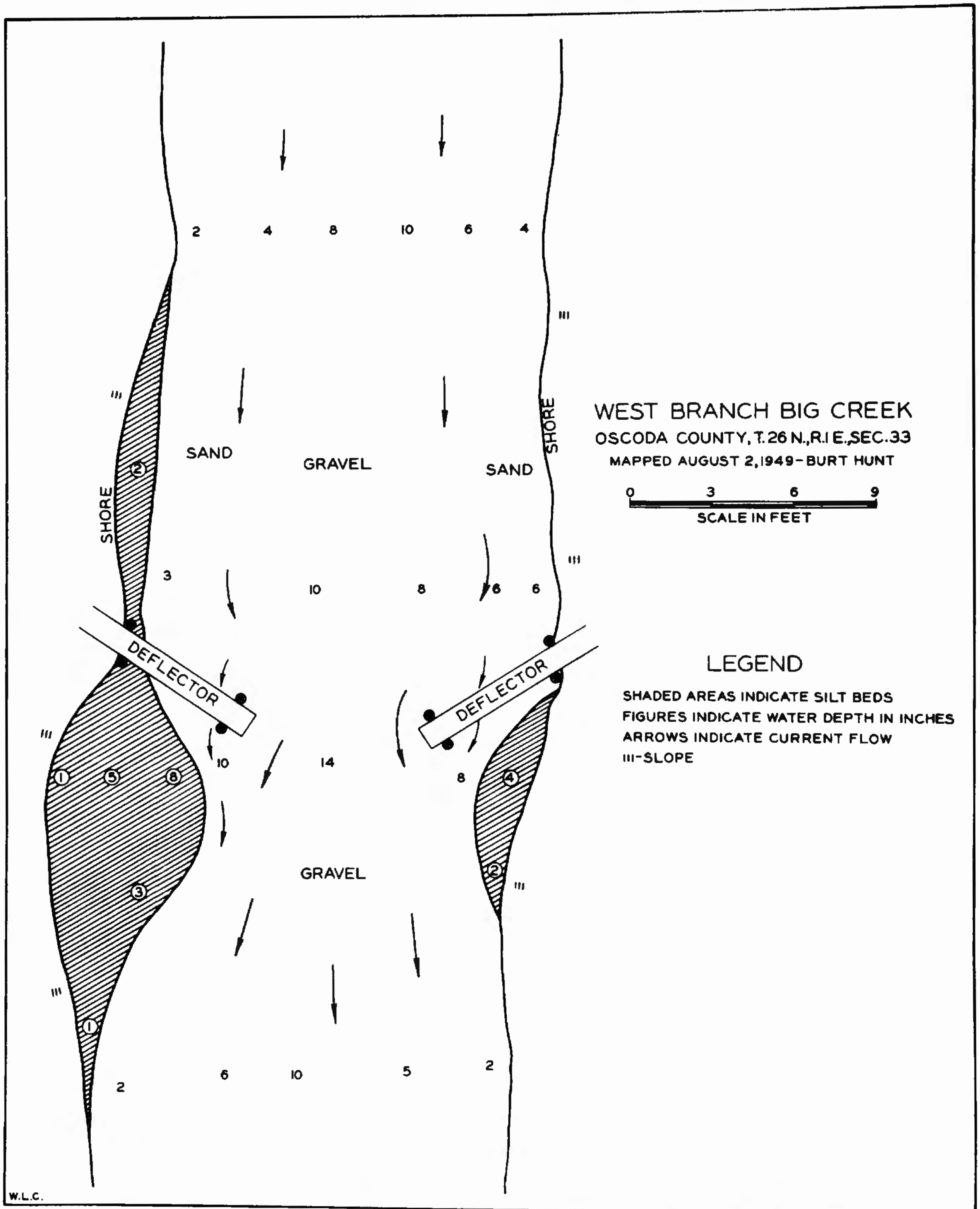


Fig. 26 Mud bank formation above and below an old deflector. Excellent burrowing mayfly habitat.

Fig. 27. Au Sable River west of Frederic. Old log deflectors which have caused formation of extensive mud banks.

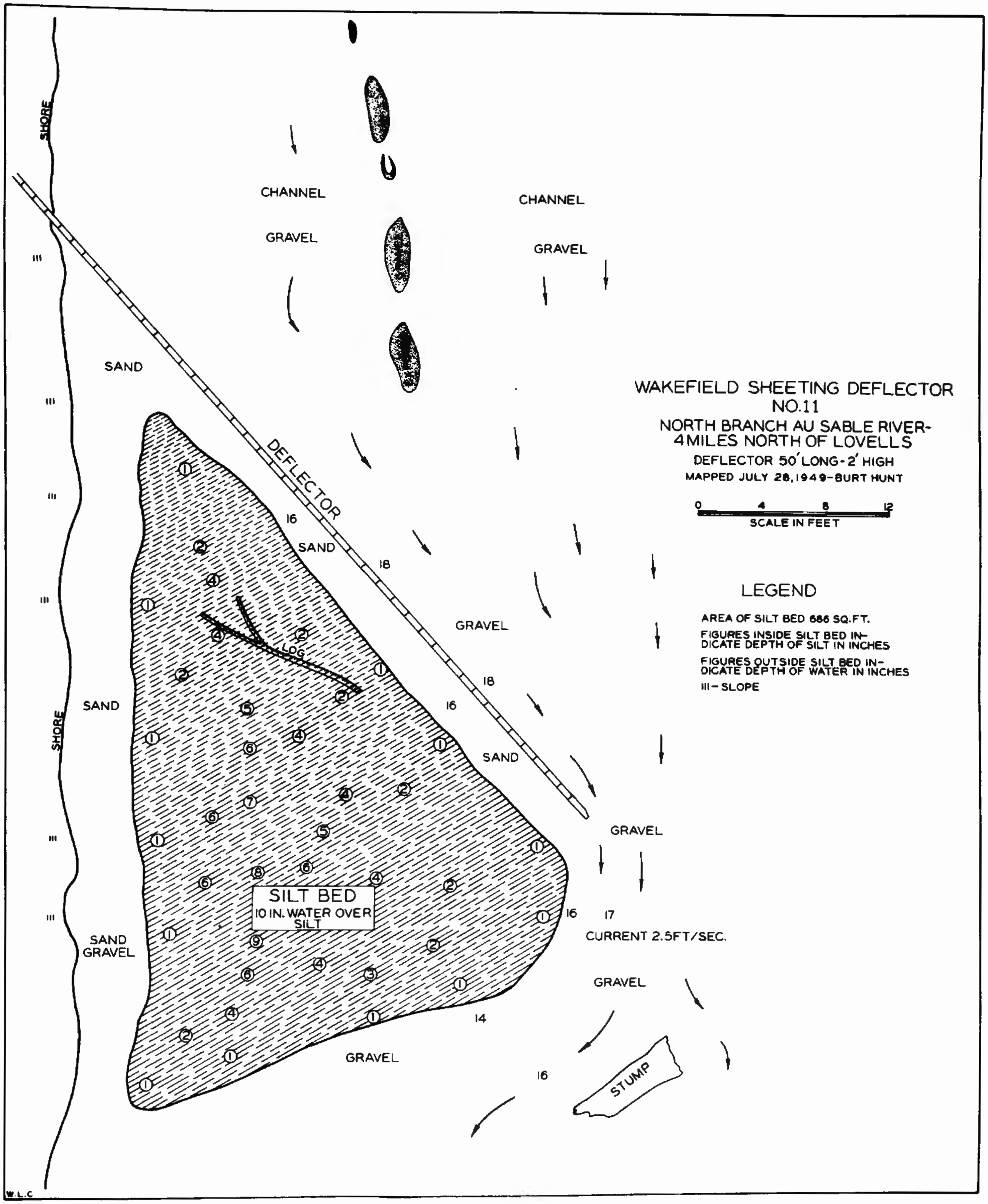


Fig. 28 Silt deposit behind sheet piling deflector

medium for nymphs. A rise in the upstream water level of more than 7 inches would result in the overtopping of this deflector and washing away of the silt. More than likely, many such silt deposits are temporary and furnish an insecure home for burrowing mayflies, while others may be comparatively permanent. Many sheet piling deflectors in the Manistee River in the vicinity of Deward had no more than 1-2 inches of very fine silt behind them. Should these deflectors continue to divert the water during periods of high levels, it is possible that good mud banks may eventually be built up behind them and provide additional habitat for Hexagenia nymphs. However, the stream at this point contained little silt and few nymphs were present.

Deflectors, constructed of sheeting, located in the Manistee River above Cameron bridge west of Frederic showed no silt deposition behind them. The current is rapid in this area and strong back currents flow behind the deflectors keeping the bottom swept bare of mud. In this section little mud bottom is apparent any place and it is doubtful if installation of structures of any type, other than dams, would result in mud bar formation. Wherever the natural stream gradient is high it appears that currents on all sides of structures are too pronounced to allow silt deposition.

* * * * *

A summarization of the relationships between Hexagenia nymphs and bottom type and factors which influence the latter follows:

(1) Hexagenia nymphs require a soft mud, clay or marl bottom in which to burrow and live and are not found on sand, gravel, rubble or other types of stream bottom. Thus the nature of the substrate is a limiting factor which largely determines the abundance and local distribution of nymphs.

(2) Silt is deposited where current velocities fall below 0.5 feet per second and velocities less than 0.3 feet per second usually are extant over well established silt banks.

(3) Features of a stream bed which slow the current and allow silt deposition are: low gradient, eddies, bank indentations, curves and turns, pools, vegetation, and obstructions of various kinds.

(4) Permanency of silt deposits depends on extent of rise and fall of water levels and resulting changes in velocity and direction of currents.

(5) Improvement devices, as well as natural obstructions, can alter the flow of water so that silt deposition will occur both above and below them.

(6) Structures, such as stumps, digger logs, cover logs, etc., do not aid in formation of mud banks, and narrowing of the stream or otherwise increasing the rate of current flow tends to eliminate silt deposition.

(7) Deflectors which slow the current both above and below them cause silt deposition in areas of reduced velocity and create additional burrowing mayfly habitat.

(8) Installation of numerous deflectors or partial dams to cause large mud banks to form would increase the Hexagenia habitat but might render the stream less suitable for trout and perhaps result in higher water temperatures.

(9) Streams with high gradient contain little mud bottom naturally and present stream improvement structures do not materially increase the amount of mud deposition.

(10) Low gradient streams normally have considerable mud deposits and structures which further slow the water cause further silt deposition.

(11) It is doubtful that streams with normally high current velocities can be satisfactorily altered to produce extensive amounts of burrowing mayfly habitat.

## IMPORTANCE OF BURROWING MAYFLIES AS TROUT FOOD

There is no question but that the winged stages are consumed in large numbers when available during the comparatively short emergence and mating season. During heavy "hatches", trout were often seen feeding steadily on imagoes and subimagoes for one-half to three-quarters of an hour and then to stop, apparently gorged. Nothing is known concerning the nutritional value of the winged stages, but presumably it would be low for spent females and somewhat higher for subimagoes.

The occurrence of *H. limbata* in stomachs of trout taken by angling at different times and places is shown in Table 6. Results of the stomach analyses of these fish have not been reported previously. All fish except those from the Sturgeon River near Wolverine (11 rainbow trout) came from sections of stream which contain considerable numbers of *H. limbata* nymphs and some nymphs of *E. simulans*. Burrowing mayflies occurred in trout stomachs taken from the Au Sable and Manistee Rivers only in June and early July during the emergence period. Mature nymphs, subimagoes and imagoes were eaten at this time. Stomachs collected from the two streams both before and after the period during which emergence was occurring contained no nymphs. Two brook trout out of 21 captured in the West Branch of Big Creek, Crawford County (a tributary to North Branch of the Au Sable River which contains a good population of *H. limbata* nymphs) had eaten one and two nymphs, respectively. A report (being prepared by Wayne Tody) on the food of brook and brown trout collected at Twin Bridges on the North Branch of the Au Sable River shows that burrowing mayfly nymphs were eaten infrequently and were a minor item in the

Table 6. Occurrence of H. limbata in trout stomachs

(Number of brook trout 46, brown trout 37, rainbow trout 15)

| Date | Locality | Number stomachs examined | Number fish containing burrowing mayflies | | | Percentage of stomachs containing nymphs or adults |
|---|---|---|---|---|---|---|
| | | | Nymphs | Adults | Both | |
| July 7, 1947 | Au Sable River Main Stream | 3 | ... | 3 | 3 | 100.0 |
| Aug. 4-8, 1947 | Nr.Br. Au Sable River, Kellogg Bridge | 4 | ... | ... | ... | 0.0 |
| May 11, 1948 | Big Creek, Crawford Co. | 21 | 2 | ... | 2 | 9.5 |
| May 12, 1948 | Nr. Br.Au Sable, Twin Bridges | 11 | ... | ... | ... | 0.0 |
| June 17, 1948 | Nr.Br. Au Sable,Kellogg Bridge | 10 | 1 | ... | 1 | 10.0 |
| June 17-21,1949 | Au Sable River, Main Stream | 5 | ... | 4 | 4 | 80.0 |
| July 7-14, 1949 | Au Sable River, Main Stream | 9 | ... | ... | ... | 0.0 |
| Aug. 2, 1949 | E. Br. Au Sable, Grayling | 3 | ... | ... | ... | 0.0 |
| June 23-24,1949 | Manistee River | 10 | 3 | 5 | 7 | 70.0 |
| July 5, 1949 | Manistee River | 2 | 2 | ... | 2 | 100.0 |
| July 15, 1949 | Manistee River | 9 | ... | ... | ... | 0.0 |
| Aug. 4, 1949 | Sturgeon River, Wolverine | 11 | ... | ... | ... | 0.0 |
| | | 98 | 8 | 12 | 19 | 19.4 |

diet of both species of trout. From data available, it seems probable that nymphs are not readily available to trout in streams except during their migration to the surface to transform and when they are disolodged from the silt banks during high water. Since nymphs are present in large numbers during the entire year, they should occur more frequently in stomachs collected in spring and late summer if they were available to fish. A study of the feeding habits of brook trout in Hunt Creek, Montmorency County (Barrett, I.F.R. Report No. 919) revealed that few burrowing mayfly nymphs were consumed by trout.

Nymphs of the burrowing mayflies seem to be of much more consequence in the diet of trout in lakes than in streams. Leonard (1947) found that nymphs of H. occulta (= limbata) were an important and steady article of food in the diet of rainbow trout in Birch Lake, Cass County. Ephemera simulans nymphs were also eaten but to a much lesser extent (op. cit.). Unassembled data in the files of the Institute for Fisheries Research indicate that nymphs of H. limbata form a substantial portion of the food of brook trout in East Fish Lake, Montmorency County. The stomach of a rainbow trout 18.5 inches long, taken in a gill net set on a shoal in Big Portage Lake, Washtenaw County, on November 25, 1946, contained 513 nymphs of E. simulans and 5 nymphs of H. limbata.

INVENTORY OF NORTHERN MICHIGAN STREAMS

Bottom samples were taken in a number of streams to determine the species of burrowing mayflies present and the density of nymphal populations. The number of nymphs taken in quantitative and qualitative samples was used as a basis for approximating the number of nymphs per square foot of mud and silt bottom only. Reconnaissance of small sections of the streams provided data for an estimate, based on numbers of nymphs and amount of habitat, of the overall production of mayfly nymphs.

The major stream systems of the Lower and Upper Peninsula, and miscellaneous streams, are treated in separate sections of this report.

## Streams of northern part of Lower Peninsula

### Au Sable River System

The Au Sable system supports the largest nymphal population of burrowing mayflies and the heaviest flights of adults of any northern Michigan stream known to the writer. Numbers of nymphs are greatest in the Main Stream and major tributaries and are present in quantities in many of the smaller creeks as well. The Main Stream and major tributaries rate as good to excellent in the production of burrowing mayflies. Samples, too numerous in aggregate to mention individually, have been taken in the following sections: Main Stream from near the headwaters to mouth, East Branch along its entire length, North Branch along its entire length, South Branch from Roscommon to mouth, Big Creek (a tributary to the North Branch) in several areas, and Big Creek and Lost Creek (both in Oscoda County) in several areas.

*H. limbata* occurs throughout the entire system except in the East Branch of Big Creek, Oscoda County, a stream that is too cold for it. The second species, *H. recurvata*, has been found thus far only in the two branches of Big Creek, Oscoda County, but will probably be found in any creek which has very low year-round water temperatures. The third species which occurs in the system, *H. rigida*, has been found only in the impoundments on the lower river. The fourth species, *Ephemera simulans*, occurs throughout the drainage, but is commonly found in numbers only in certain localities.

### Boardman River System

This stream, like the Au Sable, contains a burrowing mayfly population along its entire length and in the major tributaries. The localities sampled are as follows:

STATION 1. Boardman River, vicinity of Kalkaska, Kalkaska County, (Fig. 29), T. 27 N., R. 7 W., Secs. 15 and 17. Stream small; sand bottom; silt banks uncommon. Species present: H. limbata. Approximate density: 10 nymphs per sq. ft. "Hatches" of the big mayflies occur in this part of the stream. Large numbers emerge from the impoundment near the town of Kalkaska, but stream emergences are light.

STATION 2. South Branch Boardman River near junction with Main Stream, Grand Traverse County, (Figs. 20 and 30), T. 26 N., R 9 W., Sec. 3. Only H. recurvata was found in this locality, the stream apparently being too cold for limbata. Approximate density: 18 nymphs per sq. ft.

STATION 3. Boardman River, immediately below junction with South Branch, Grand Traverse County, (Fig. 31), T. 26 N., R. 9 W., Sec. 4. Stream bottom largely sand and gravel; water rather rapid. Mud deposits are sparse and limited to areas along the bank. Nymphs of three species occurred at this station: H. recurvata, H. limbata, E. simulans--approximate number of nymphs per square foot: 3, 3, and 1, respectively. Limited habitat and resultant low nymphal populations preclude significant "hatches" of any of the three species in this locality.

STATION 4. Boardman River at County Road 611, T. 26 N., R. 10 W., Sec. 21. Stream moderately rapid; sand, gravel bottom with silt deposits limited to small areas along the banks. H. limbata nymphs only--approximate density: 2 per sq. ft.

STATION 5. Boardman River downstream from Station 3, T. 26 N., R. 10 W., Sec. 21. Stream 70 feet wide; rapid; sand, gravel and rubble bottom. Mud deposits very limited. Species found: H. limbata and H. recurvata. Approximate density of nymphs per square foot: 2 and 1, respectively.

STATION 6. Boardman River near Beitner, Grand Traverse County, (Fig. 32), T. 26 N., R. 11 W., Sec. 3. The river at this point is very wide and slow with

Fig. 29. Boardman River at Kalkaska. Station No. 1. Nymphs of H. limbata present in limited numbers.

Fig. 30. South Branch Boardman River at River System Station No. 2. Nymphs of H. recurvata common in mud deposits.

Fig. 31. Boardman River immediately below junction with South Branch. Station No. 3. Silt limited in amount. Three species of burrowing nymphs occur here but none are abundant.

Fig. 32. Boardman River above Traverse City. Station No. 6. H. limbata nymphs abundant in this wide, slow portion of the river. Extensive habitat present.

extensive areas of silt. Only *H. limbata* occurred at this station--approximate density: 47 nymphs per sq. ft. Inspection of mud banks revealed that nymphs were very abundant in this locality. Emergence should be heavy in this area. Unconfirmed reports are to the effect that large "hatches" do occur in this section of river in season. In the opinion of the writer, the portion of the stream from approximately three miles above this station to the mouth is the only section of the entire river containing a sufficiently large nymphal population to produce noticeable numbers of adults.

Manistee River System

Many sections of the river have extensive "hatches" of large mayflies, during which many large trout are caught by anglers each year. Burrowing mayfly nymphs occur throughout the system, being most abundant in sections where the stream gradient is low. That part of the river from the Red Bridge, west of Frederic, to Sharon has a fair to good population of nymphs and flights of adults sufficiently heavy to produce large-scale "rises" of trout. The lower reaches of the river were not investigated, but it is certain that large populations of nymphs are to be found in the impoundments as well as in the river itself. *H. limbata* is distributed throughout the system; *H. recurvata* was found only in small, cold creeks; and *E. simulans* was collected only in a few localities.

STATION 1. Intensive sampling was undertaken in the section of river between Deward, Crawford County, and a point in Kalkaska County two miles downstream from the highway bridge at M-72. *H. limbata* nymphs alone were found in this portion of the river and were abundant in many places. The river below Cameron Bridge is better adapted for burrowers than the upper part of this section. The record number of nymphs per square foot for the entire river--190--was taken in this area. The stream gradient is considerably greater than the Au Sable, resulting in a much lower percentage of bottom composed of silt and a correspondingly lower nymphal population. Nymphs are sufficiently numerous to classify this section of river as a fair burrowing mayfly stream.

STATION 2. North Branch of Manistee River at M-72, Kalkaska County, T. 27 N., R. 6 W., Sec. 24. Stream small; cold; sand bottom with little silt. H. recurvata was the only burrower found. Approximate density: 0.5 nymph per sq. ft.

STATION 3. North Branch of Manistee River near Sharon, Kalkaska County, T. 25 N., R. 6 W., Sec. 6. Stream moderately rapid; sand and gravel bottom; silt in backwaters limited in extent. Two species present: H. limbata and E. simulans--approximate density: 4 and 3 nymphs per sq. ft., respectively.

STATION 4. Manistee River at Sharon, Kalkaska County, T. 25 N., R 6 W., Sec. 6. Current rapid. River wide. Gravel and sand bottom. Silt along edges of stream only. H. limbata only. Approximate density: 11 nymphs per sq. ft.

STATION 5. Manistee River at Highway M-66 near Smithville, Kalkaska County, T. 25 N., R. 7 W., Sec. 33. Stream wide; sandy; moderately slow. Good mud banks along edge of river containing many nymphs of H. limbata. Approximate density: 55 per sq. ft.

STATION 6. Manistee River near Baxter, Wexford County, T. 24 N., R. 10 W., Sec. 9. River wide and deep; moderately rapid. Very sandy silt beds along edge of stream. H. limbata nymphs appeared to be common. Difficulty in sampling precluded estimates of abundance.

STATION 7. Silver Creek near Manton, Wexford County, T. 24 N., R. 10 W., Sec. 23. Rapid stream about 12 feet wide; dense mud deposits along edge of stream. Water cold; air 80°F. and water 60°F. at 4:00 p.m. H. recurvata nymphs only. Approximate density: 22 per sq. ft.

STATION 8. Buttermilk Creek, near Manton, Wexford County, T. 24 N., R. 10 W., Sec. 24 (Fig. 33). Moderately slow stream; 8-12 ft. wide; mud banks quite extensive. Air 80°F., water 60°F. at 4:30 p.m. Two species present: H. recurvata and H. limbata--approximate density: 48 and 1 nymph per sq. ft., respectively.

STATION 9. Cedar Creek, near Manton, Wexford County, T. 24 N., R. 9 W., Sec. 20. Sandy, shallow stream with little silt. Air 80°F., water 77°F. at 5:00 p.m. H. limbata only. Approximate density: 3 nymphs per sq. ft.

STATION 10. Hopkins Creek, near Morey, Missaukee County, T. 24 N., R. 8 W., Sec. 35. Stream 15 feet wide; sandy with light silt deposits. Air 79°F., water 60°F. at 5:30 p.m. H. recurvata only. Approximate density: 3 nymphs per sq. ft.

STATION 11. Small tributary to East Branch of the Pine River near Tustin, Osceola County, T. 20 N., R. 10 W., Sec. 24. Creek 5 feet wide; bottom all silt; air 70°F., water 58°F. at 11:00 a.m. H. recurvata only. Approximate density: 9 nymphs per sq. ft.

STATION 12. Pine River near Hoxeyville, Wexford County, T. 21 N., R. 12 W., Sec. 28. River rapid; no silt deposits. A few H. limbata nymphs found in muddy sand. Approximate density: 0.5 per sq. ft. No "hatches" could be expected on this portion of the river.

STATION 13. Little Manistee River at Highway M-37, Lake County, T. 19 N., R. 13 W., Sec. 11. Sand bottom stream; silt not extensive--restricted to edge of stream. H. limbata only. Approximate density: 8 nymphs per sq. ft. Light hatches could be expected on this portion of the river.

Fig. 33. Buttermilk Creek, Wexford County, tributary to Manistee River. H. recurvata nymphs very abundant in this small, cold creek.

Maple River System

A number of bottom samples were taken from the section of stream between Brutus and Burt Lake in the summer of 1946. The bottom is predominantly sand, but mud banks were extensive in a few areas. Nymphs of H. limbata were common in local situations where mud banks were established. Approximate density: 13 nymphs per sq. ft. Fair "hatches" of adults occur on this stream each season. It is quite probable that burrowers occur throughout the system.

Muskegon River System

Samples were taken only in the upper reaches of the system; however, it is safe to conclude that H. limbata is distributed throughout the entire system and is probably very abundant in the impoundments and lower reaches of the river.

STATION 1. Muskegon River at Highway M-55, Missaukee County, T. 23 N., R. 5 W., Sec. 35. Predominantly sand bottom with some very sandy silt along the stream margin. H. limbata only--approximate density: 4 nymphs per sq. ft.

STATION 2. West Branch Muskegon River at Highway M-55, Missaukee County, T. 23 N., R. 5 W., Sec. 33. Predominantly sand bottom. H. limbata nymphs occur in sandy silt--approximate density: 3 nymphs per sq. ft.

STATION 3. Muskegon River at Paris, Mecosta County. T. 16 N., R. 10 W., Sec. 15. Stream wide; shallow; predominantly sand bottom. Muddy sand on edge of stream contained many small H. limbata nymphs--approximate density: 27 per sq. ft.

STATION 4. Clam River at Highway M-66, Missaukee County, T. 21 N., R. 7 W., Sec. 6. Bottom predominantly sand with extensive mud deposits behind deflectors and along margin of stream. H. limbata nymphs abundant--approximate density: 67 per sq. ft. The occurrence of such large numbers is an indication that heavy emergences of adults occur in season in this portion of the stream.

Pere Marquette River System

The three species of burrowing mayflies commonly encountered in northern Michigan streams occur in this system, their distribution being determined largely by water temperatures. Bottom sampling, conducted only in the upper portions of the system, revealed that *H. limbata* occurs in the Main Stream and major tributaries and *H. recurvata* is restricted to small, cold creeks. *E. simulans* was found only in a few localities. It is quite certain that *limbata* is abundant in the lower portions of the river.

Extensive "hatches" are known to occur on the Main Stream and larger tributaries in the Baldwin area.

STATION 1. Big South Branch Pere Marquette River near Biteley, Newaygo County, T. 16 N., R. 14 W., Sec. 27. Stream bottom largely sand. Muddy sand bars limited in extent and good silt bottom lacking. *H. limbata* nymphs not common--approximate density: 2 per sq. ft.

STATION 2. McDuffee Creek, tributary to Little South Branch Pere Marquette River, Newaygo County, T. 16 N., R. 12 W., Sec. 27. Stream 10-12 feet wide with extensive mud banks. Small *H. limbata* nymphs common--approximate density: 21 per sq. ft.

STATION 3. Little South Branch Pere Marquette River, Newaygo County, T. 16 N., R. 12 W., Sec. 20. Stream small; warm; numerous small deposits of silt composed largely of woody debris. *H. limbata* uncommon--approximate density: 1 nymph per sq. ft.

STATION 4. Pere Marquette River at Highway M-37, Lake County, T. 17 N., R. 13 W., Sec. 15. Stream rather rapid with some good mud banks along the margin. *H. limbata* nymphs abundant--approximate density: 67 per sq. ft. Sizable emergences should occur in this section.

STATION 5. Danaher Creek at Highway M-37, south of Baldwin, Lake County, T. 17 N., R. 13 W., Sec. 34. Creek 4-6 feet wide; very warm; sand bottom.

Only E. simulans was found--approximate density: 11 nymphs per sq. ft.

STATION 6. Baldwin Creek at Highway US-10, Lake County, T. 17 N., R. 13 W., Sec. 2. Stream below bridge rather slow with extensive mud banks. H. limbata nymphs abundant--approximate density: 55 per sq. ft. This large population of nymphs should produce extensive emergences of adults.

STATION 7. Sanford Creek at Highway US-10, Lake County, T. 17 N., R. 13 W., Sec. 1. Creek 8-10 feet wide; rather rapid; sand bottom. Muddy sand banks in some areas. Only H. recurvata was found at this point. Approximate density: 4 nymphs per sq. ft. Since the stream is cold (59°F., air 75°F.), no other burrowing mayflies could be expected to occur in this creek.

Pigeon River System

This stream was investigated only in the vicinity of the Pigeon River State Forest Headquarters. The stream gradient is high; current rapid; and silt banks uncommon. H. limbata nymphs were present in limited numbers. A noticeable "hatch" could not be expected on this portion of the stream. It is doubtful if nymphal populations are large in any part of the river.

Rifle River System

Few burrowing mayflies are to be found within this system. No "hatches" were seen by the writer in 1942, when a survey of the river was made, nor have they been observed by members of the staff at the Rifle River Area. The writer found a spent female and one nymph of H. limbata in Gamble Creek at Lupton on June 28, 1949. Although suitable silt beds were present, additional nymphs could not be found. It is quite likely that E. simulans occurs in the system. The seeming paucity of burrowing mayflies is probably due to the lack of adequate habitat.

Sturgeon River System

This river, flowing through Otsego and Cheboygan counties and emptying into Burt Lake, is very rapid and contains practically no silt deposits from Wolverine to Indian River. Bottom sampling in this portion of the river in 1946 and 1949 failed to yield even one burrowing nymph. Lack of habitat explains the absence of H. limbata from the lower river since the species is very abundant in Burt Lake and Indian River. Low water temperatures and limited habitat probably explain its absence in the upper reaches of the system. Areas sampled further upstream and in the West Branch are listed under stations.

STATION 1. Sturgeon River east of Vanderbilt, Otsego County, T. 32 N., R. 2 W., Sec. 21. H. recurvata nymphs occur in muddy sand along edge of stream--approximate density: 4 nymphs per sq. ft.

STATION 2. Sturgeon River near Gaylord, T. 31 N., R. 3 W., Sec. 14. Stream small and cold. H. recurvata nymphs uncommon--approximate density 2 per sq. ft.

STATION 3. West Branch of Sturgeon River near Wolverine, T. 33 N., R. 3 W., Sec. 14. Only H. recurvata nymphs found at this station--approximate density: 3 per sq. ft.

Thunder Bay River System

Sizable hatches of Hexagenia should occur on parts of the Main River and some of the major tributaries. Nymphs of the three common species of burrowing mayflies have been collected at various localities within the system.

STATION 1. Hunt Creek, Montmorency County. H. recurvata nymphs have been found to occur in the stream from near the headwaters to County Road 612. Few have been found further downstream. H. limbata occurs from the mouth upstream to about the A Bridge in the Experiment Station grounds. E. simulans has been found from County Road 612 downstream to the mouth. Density of nymphs varies greatly. In good mud bottom as many as 21 limbata and 25 recurvata nymphs per sq. ft. have been collected, although usually the numbers are much less. E. simulans is not abundant.

STATION 2. Gilchrist Creek at County Road 612, T. 29 N., R. 3 E., Sec. 15. Stream small and sandy with few mud deposits. Both H. limbata and recurvata occur at this point, but both were scarce.

STATION 3. Thunder Bay River at mouth of Hunt Creek, T. 30 N., R. 3 E., Sec. 34. Stream wide and sandy with some good silt deposits along margin. Nymphs of H. limbata and E. simulans quite common. Density of the former, 11; and of the latter, 5 per sq. ft.

STATION 4. Upper South Branch Thunder Bay River, Oscoda County, T. 28 N., R. 4 E., Sec. 26. Stream moderately rapid; wide; considerable deposits of silt. H. limbata nymphs common--approximate density: 16 nymphs per sq. ft.

Miscellaneous Collections

The writer has made collections in a number of localities which further show the widespread distribution of the burrowing mayflies. In some instances none have been found in sampling areas. These negative records are also included. These miscellaneous collections are listed as follows:

1. Au Gres River at Au Gres, Arenac County. Few nymphs of H. limbata taken on July 11, 1942.

2. Black River, Cheboygan County. Qualitative sampling one to two miles below Black Lake, July 21, 1946, revealed numerous nymphs of H. limbata.

3. Cheboygan River, Cheboygan County. Cast nymphal skins of H. limbata recovered above city of Cheboygan on July 21, 1946.

4. Indian River, Cheboygan County, between Burt and Mullett Lakes. Cast nymphal skins recovered in early July, 1946.

5. Rapid River, Kalkaska County, T. 28 N., R. 7 W., Secs. 21, 30. Intensive sampling on June 26, 1949 at the two locations listed above yielded no burrowing mayfly nymphs. No suitable habitat was located in the two areas. No nymphs were found at the head of Antrim Pond although conditions appeared to be satisfactory for H. recurvata.

6. Sucker Creek, Alcona County, T. 27 N., R. 8 E., Sec. 8. This stream, which flows into Hubbard Lake, was visited several times during the summer of 1947. Silt deposits were abundant and H. limbata nymphs were very numerous. Evidence of a large mating flight was encountered on July 9, 1949. Quantities of spent females were found caught in stream drift.

Streams of the Upper Peninsula

A brief survey of several river systems in the Upper Peninsula of Michigan, made during late July, 1949, showed that burrowing mayflies (principally H. limbata) are widely distributed throughout that part of the state and that the nymphs are abundant in many localities. No adults were seen except at the Straits of Mackinac and near the mouth of the Escanaba River; furthermore, last instar nymphs were seldom encountered, an indication that the seasonal emergence period had passed. Information volunteered by local people was to the effect that the big mayflies had been seen during June and early July. From the limited data available, it appears that the emergence period of H. limbata in Upper Peninsula streams occurs at about the same time or slightly later than on streams of the northern part of the Lower Peninsula. The writer suspects that a difference of two weeks or more may exist between the peak of the emergence period in the two areas but has little factual evidence to support this contention.

"Hatches" of the burrowing mayflies in Upper Peninsula streams have received little or no publicity, indicating that few trout fishermen are aware of the appearance of these flies on the streams. Since the adults are in evidence almost exclusively at night, it is probable that they would go unnoticed unless anglers were regularly engaging in night fishing. Nymphal populations are sufficiently large in many localities to produce sizable "hatches."

Major river systems are treated separately in the following section and pertinent information is given for each sampling station.

Escanaba River System

Sampling on the Escanaba River showed that the genus *Hexagenia* is widely distributed throughout the entire system. Two species were found: *H. limbata*, in all parts of the Main Stream and in many tributaries, and *H. recurvata* only in small tributaries in which the temperature was low. Judging from the *Hexagenia* distribution in the Au Sable River system, it can be assumed with some assurance that *H. recurvata* occurs in all of the cold (below 63°F.) tributaries of the system. It has been found that streams cold enough to be considered typical brook trout waters usually contain *H. recurvata*. A rather large nymph population was found only at Station 4, the one place where extensive silt beds occurred. The widespread distribution indicates that a well established *Hexagenia* population is present in the river system. The small extent of silt beds and the resulting comparatively small number of nymphs at most stations, which may or may not be characteristic of the entire river, has led to the belief that only moderate "hatches" of these mayflies could be expected in any season. However, the adults should be present in sufficient numbers during the emergence period to be noticed by fishermen and cause extensive feeding of fish.

It is quite probable that the small nymph populations of the small tributaries would not produce enough adults to cause "hatches" sufficiently large to be noticed by fishermen.

Statements of a fisherman at Gwinn were to the effect that large "hatches" of the big mayflies do occur on the river and that the flights in late June, 1949, were quite heavy on several evenings and resulted in an extensive "rise" of trout.

STATION 1. 7/19/49. Main Stream west of Gladstone, Delta County, T. 40 N., R. 22 W., Section 24. Water brown; very slow. Air temperature 76°F., water 75°F. at 1:00 p.m. The river at this point is 100 to 200 feet wide and very slow. Nymphs, cast nymph skins and subimagoes of H. limbata were found. Sand bottom near shore, but probably plenty of silt in this area since the stream is lake-like in character.

STATION 2. 7/19/49. Main stream 3 miles south of Gwinn, Marquette County, T. 44 N., R. 25 W., Section 4. Water brown; rapid. Air 74°F., water 73°F. at 3:00 p.m. Stream 60 feet wide; deep; precipitous banks and canal-like channel; bottom principally sand and rubble; occasional small silt bed. H. limbata nymphs common in one silt bed examined. Approximate density: 7 nymphs per sq. ft.

STATION 3. 7/19/49. East Branch of Escanaba at Gwinn, Marquette County, T. 45 N., R. 25 W., Section 21. Water brown; rapid. Air 76°F., water 73°F. at 4:00 p.m. Stream about 40 feet wide; bottom principally sand, gravel and rubble; silt beds small and scattered. H. limbata nymphs common where silt had accumulated to depths of 2 or more inches. Approximate density: 4 nymphs per sq. ft.

STATION 4. 7/19/49. Middle Branch of Escanaba River northwest of Gwinn at M-35, Marquette County, T. 45 N., R. 26 W., Sec. 11. Water brown; slow. Air 74°F., water 73°F. at 4:30 p.m. Stream 80-100 feet wide; bottom sand with extensive mud banks. One large mud bank sampled yielded large numbers of very small nymphs of H. limbata. Approximate density: 21 nymphs per sq. ft.

STATION 5. 7/21/49. Middle Branch of Escanaba River at bridge on US-41, Marquette County, T. 47 N., R. 28 W., Sec. 7. Water brown; moderately rapid. Air 76°F., water 61°F. at 1:30 p.m. Stream 40-60 feet wide; bottom principally sand and gravel with silt limited to small pockets. *H. limbata* nymphs present but uncommon. Approximate density: 1 nymph per sq. ft.

STATION 6. 7/19/49. Green's Creek, tributary to Middle Branch of the Escanaba, at bridge on M-35, Marquette County, T. 45 N., R. 26 W., Sec. 2. Water white; moderately rapid. Air 76°F., water 66°F. at 4:45 p.m. Creek 5-10 feet wide; bottom predominantly sand and gravel; silt in limited quantities. A few nymphs of *H. recurvata* were discovered. Approximate density: less than 1 nymph per sq. ft.

STATION 7. 7/19/49. Sweitzer's Creek, tributary to East Branch of Escanaba, at bridge on M-35, Marquette County, T. 46 N., R. 26 W., Sec. 10. Water white; moderately rapid. Air 76°F., water 69°F. at 5:00 p.m. Creek 8-15 feet wide; bottom predominantly sand; silt in limited amounts. *H. limbata* nymphs present but not common. Approximate density: less than 1 nymph per sq. ft.

STATION 8. 7/19/49. Warner Creek, tributary to East Branch of Escanaba, at bridge on M-35, Marquette County, T. 46 N., R. 26 W., Sec. 4. Water light brown; moderately rapid. Air 76°F., water 65°F. at 5:15 p.m. Creek 6-10 feet wide; bottom principally gravel, rubble; silt limited in quantity. Nymphs of two species, *H. limbata* and *H. recurvata*, were found. Approximate density: 3 *limbata* and less than one *recurvata* nymph per sq. ft.

*Ontonagon River System*

The river was sampled in several places but burrowing mayflies were found only at Station 4. This does not indicate that they are absent elsewhere in the river system.

STATION 1. 7/20/49. Big Beaver Creek, tributary to East Branch of the Ontonagon River, near Kenton, Houghton County, T. 48 N., R. 37 W., Sec. 25. Water light brown; moderately rapid. Air 75°F., water 63°F. at 4:00 p.m. Creek 10-12 feet wide and up to 3 feet deep. Creek runs through meadow in this section. No Hexagenia nymphs were found although suitable mud occurred in a few small areas. H. recurvata probably occurs in this stream.

STATION 2. 7/20/49. Middle Branch of Ontonagon River below Bond Falls, Ontonagon County, T. 46 N., R. 39 W., Sec. 1. Water brown; rapid. Air 71°F., water 70°F. at 6:00 p.m. Stream bed very rocky with little mud. No Hexagenia were found although thorough search was made in two small mud bars which were quite suitable for the burrowing nymphs. The rocky nature of the stream below the falls would preclude Hexagenia from occurring here. It would be very surprising if large numbers of limbata do not occur in the impoundment above the falls.

STATION 3. Middle Branch of the Ontonagon River at the Watersmeet Rearing Station, Gogebic County, T. 45 N., R. 39 W., Sec. 23. Water brown; moderately rapid. Air 71°F., water 70°F. at 7:00 p.m. Stream bed composed of sand and fine gravel. No silt bars were found in 200 yards of stream. Hexagenia were absent from this section due to the lack of habitat. Ephemera nymphs were common in muddy sand near shore.

STATION 4. 7/20/49. Middle Branch of the Ontonagon River about two miles upstream from Watersmeet, Gogebic County, T. 45 N., R. 39 W., Sec. 19. Water brown; moderately rapid to slow. Air 70°F., water 70°F. at 7:30 p.m. Stream 30-50 feet wide and ranging to 4 feet in depth. Extensive silt beds were found in 200 feet of stream. Numerous bends with resulting slowing of current is apparently responsible for silt deposits on both the inside and outside of bends in some places. Mud banks were firm, 2-10 inches in depth, and of the right constitution to afford an excellent habitat for Hexagenia nymphs.

H. limbata nymphs were abundant, as indicated by numerous burrow openings in all silt deposits. Density in one mud bank sampled was 29 nymphs per square foot. One last instar nymph was found, indicating that emergence of these mayflies was still continuing. The location and nature of mud banks in this section of stream are similar to those found in the lower sections of the North Branch of the Au Sable River, and the nymph populatinn is comparable in the two streams.

The abundance of nymphs in this portion of the river suggests that seasonal emergence and mating flights should be heavy and sufficiently conspicuous to be noticed by anglers and afford good fishing. Mr. Arthur K. Adams reports that he observed adult Hexagenia on the stream in July, 1949.

Burrowing nymphs of Ephemera were also found to be common in sandy-silt. Density about 12 nymphs per square foot. These nymphs are sufficiently numerous in this section to produce sizable flights of adults.

Sturgeon River System

The Sturgeon River system, Baraga and Houghton Counties, was sampled at four stations, but no Hexagenia nymphs were located at any of them. Stations were located as follows: No. 1, at the crossing of US-41, T. 48 N., R. 32 W., Sec. 17; No. 2, near Pelkie, T. 51 N., R. 34 W., Sec. 20; No. 3, on the West Branch of the Sturgeon River near Alston, T. 50 N., R. 36 W., Sec. 12; No. 4, Boulder Creek, tributary to Silver River, T. 49 N., R. 36 W., Sec. 9.

The one important reason for the absence of Hexagenia in sections of this stream examined is the complete lack of habitat. No silt banks were in evidence, the bottom being composed of boulders, rubble, sand and gravel.

Otter River System

This system was examined only at the Otter River Trout Rearing Station, Houghton County, on the North Branch of the Otter River, T. 52 N., R. 35 W., Sec. 25. No burrowing mayfly nymphs were encountered, and according to Dr. J. W. Leonard, few occur in the stream. Both H. limbata and H. rigida have been collected from Otter Lake by Dr. Leonard, which proves they occur in the river system. Bottom of the stream is largely sand and gravel with very little silt.

Manistique River System

Sampling in this system in streams in the vicinity of Seney showed that two species of burrowing mayflies (H. limbata and H. recurvata) are widely distributed and occur in considerable numbers. Sizable "hatches" of both species should occur in season. The apparent paucity of fly fishermen in the area may account for the "hatches" not being seen and publicized. Mr. Leland Anderson has reported that enormous emergences of Hexagenia occur on the Manistique Lakes. There is no doubt that H. limbata occurs throughout the warmer parts of the stream system. The emergence period of both species had passed for no last instar nymphs were found. No samples were taken in the Manistique River proper, but several tributary streams were visited. Areas sampled are as follows:

STATION 1. 7/21/49. Star Creek, tributary to West Branch of the Manistique River at Highway M-28, Alger County, T. 46 N., R. 17 W., Sec. 26. Water brown; slow. Air 73°F., water 63°F. at 4:30 p.m. Stream 15-25 feet wide; principally sand bottomed; extensive silt beds near bridge. H. limbata nymphs common--approximate density 12 nymphs per sq. ft.

STATION 2. 7/22/49. Fox River at Germfask (Fig. 34), Schoolcraft County, T. 45 N., R. 13 W., Sec. 34. Water brown; moderately rapid. Air 59°F, water 64°F at 8:00 a.m. Stream 60-80 feet wide; bottom largely sand and gravel. Sandy silt bars not common, but many very small H. limbata nymphs were found in them--approximate density: 52 nymphs per sq. ft.

Fig. 34. Fox River at Germfask, Station 2, Manistique River System. H. limbata nymphs common.

STATION 3. 7/21/49. Fox River near Seney, (Fig. 35), Schoolcraft County, T. 46 N., R. 13 W., Secs. 18, 29. Water brown; moderately rapid. Air 70°F., water 60°F. at 6:45 p.m. Stream 40-50 feet wide; bottom largely sand and gravel. Sandy silt bars fairly common. H. limbata nymphs were found together with those of H. recurvata. Approximate density of the former, 5 nymphs; and the latter, 15 nymphs per sq. ft. This section of stream is a zone of transition between the distribution of the two species.

STATION 4. 7/22/49. East Branch of the Fox River east of Seney, (Fig. 36), at Highway M-28, Luce County, T. 46 N., R. 12 W., Sec. 33. Water brown; slow. Air 60°F., water 62°F. at 9:45 a.m. Stream 25-35 feet wide; bottom sand with extensive mud banks. In this section silt was deep and formed an excellent habitat for burrowing mayflies. Extensive sampling resulted in finding only 2 H. recurvata nymphs but large numbers of H. limbata--approximate density of the latter: 40 medium to large size nymphs per sq. ft.

STATION 5. 7/22/49. East Branch of Fox River upstream from Station 4, Schoolcraft County, T. 46 N., R. 13 W., Sec. 4. Water clear; rapid. Air 60°F., water 54°F. at 9:15 a.m. Stream 15 feet wide; sand bottom; silt uncommon. Only H. recurvata found here--approximate density: less than 1 nymph per sq. ft. The stream appears to be too cold for limbata at this point.

Tahquamenon River System

Comparison of the abundance of nymphs in this system with other rivers indicates that fair "hatches" should occur on the Sage River, and very heavy ones on the main stream near Newberry. At the time samples were taken the emergence period was undoubtedly over since only two last instar nymphs were encountered. Certainly the adults should appear in sufficiently large numbers in many sections of this stream system to be noticed by anglers, providing they were on the streams at night, and to cause large-scale "rises" of trout.

STATION 1. 7/22/49. Tahquamenon River at Newberry, Luce County, T. 46 N., R. 10 W., Sec. 23. Water brown; slow; Air 64°F., water 70°F. at

Fig. 35. Fox River at Seney. Station 3, Manistique River System. H. limbata and recurvata common.

Fig. 36. East Branch of Fox River at M 28. Station 4, Manistique River System. Extensive mud banks and large population of H. limbata nymphs occur here.

11:45 a.m. Stream large with extensive mud banks along shore. Mud banks in this area are ideal for burrowing nymphs which were very abundant. H. limbata alone was found--approximate density: 86 nymphs per sq. ft.

STATION 2. 7/22/49. West Branch of Sage River at Highway M-28, Luce County, T. 45 N., R. 9 W., Sec. 11. Water brown; slow. Air 64°F., water 62°F. at 1:45 p.m. Stream 15 feet wide; sand bottom; silt beds common. H. limbata only was collected--approximate density: 8 nymphs per sq. ft.

STATION 3. 7/22/49. East Branch of Sage River at Highway M-28, Luce County, T. 45 N., R. 8 W., Sec. 8. Water brown; slow. Air 64°F., water 63°F. at 2:30 p.m. Stream 30 feet wide; sand bottom; silt beds common. Nymphs of H. limbata were quite abundant--approximate density: 15 per sq. ft.

Miscellaneous collections

Collections were made in the following streams of the Upper Peninsula which further show the distribution of burrowing mayflies in the Upper Peninsula.

1. Menominee River at Menominee, Menominee County. Subimaginal H. limbata were collected at a street light on July 10, 1940. These specimens were thought to be emerging from both the river and Lake Michigan.

2. Michigamme River at Republic, Marquette County. Several nymphs of H. limbata were secured from the river in 1940.

3. Rock River at Highway M-28, Alger County, T. 47 N., R. 21 W., Sec. 22. Nymphs of H. limbata and E. simulans were collected on July 21, 1949. Both were quite numerous.

4. Six Mile Creek at Highway US-41, near L'Anse, Baraga County, T. 50 N., R. 34 W., Sec. 1. Sampled on July 21, 1949. No burrowing mayfly nymphs were found although conditions appeared to be suitable for H. recurvata.

5. Sturgeon River at Highway US-2, Delta County, T. 40 N., R. 19 W., Sec. 6. Bottom sampling on July 19, 1949 revealed neither burrowing mayfly nymphs nor suitable habitat for them.

## LITERATURE CITED

Barrett, Paul H.
1943. The feeding habits of brook trout in Hunt Creek, Montmorency County, Michigan, during the 1941 fishing season. Institute for Fisheries Research Report No. 919 (unpublished).

Clark, O. H.
1948. Stream improvements in Michigan. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 270-280, Figs. 1-8.

Cronk, Myra W.
1932. The bottom fauna of Shakespeare Island Lake, Ontario. Univ. Toronto Studies, No. 36; Publ. Ontario Fish. Res. Lab., 43:31-65.

Hunt, Burton P.
1948. A preliminary survey of the wiggler population of Crooked Lake, Alcona County, and McCollum Lake, Oscoda and Alcona counties, Michigan. Institute for Fisheries Research Report No. 1194 (unpublished).

Ide, F. P.
1935. The effect of temperature on the distribution of the mayfly fauna of a stream. Univ. Toronto Studies, No. 39; Publ. Ontario Fish. Res. Lab., 50:3-76.

Leonard, Justin W.
1947. Differences in the occurrence of nymphs of two species of burrowing mayflies in fish stomachs. Annals of the Entomological Society of America, Vol. 40, No. 4, Dec., 1947, pp. 688-691.

Lyman, F. Earle
1940. Limnological investigation of the Ephemeroptera in Douglas Lake, Cheboygan County, Michigan, with special reference to the distribution of immature stages. MS.

Neave, Ferris
1932. A study of the mayflies (Hexagenia) of Lake Winnipeg. Contrib. Can. Biol. Fish., N. S., 7:179-201.

Needham, James G., Jay R. Traver and Yin-Schi Hsu
1935. The biology of mayflies. Comstock Pub. Co., N. Y., i-xvi, 1-759.

Ricker, William E.
1934. An ecological classification of certain Ontario streams. Univ. Toronto Studies, Biol. Ser. No. 37; Publ. Ont. Fish. Res. Lab., 49:1-114.

Shetter, David S., O. H. Clark and Albert S. Hazzard
1949. The effects of deflectors in a section of a Michigan trout stream. Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 248-278.

Spieth, Herman T.
1941. Taxonomic studies on the Ephemeroptera, II. The genus Hexagenia. Amer. Wild. Nat., 26 (2): 233-280.

Sprules, Wm. M.
1947. An ecological investigation of stream insects in Algonquin Park, Ontario. Univ. Toronto Studies, Biol. Ser. No. 56; Publ. Ont. Fish. Res. Lab., 56:1-81.

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