1. *Chrosomus erythrogaster* Rafinesque. Several specimens were taken in the stream two miles above the section considered here, and they may occur farther down.
2. *Margariscus margarita nachtriebi* (U. Cox). The only specimen, taken July 25, was 2.75 inches long.
3. *Semotilus atromaculatus* (Mitchill). Occasionally taken on a hook, and schools of young about one inch long were seen in stony sections. It is said to have been much commoner about 20 years ago.

Spawning of the creek chub takes place early in June; on June 9, 1930, two ripe males and a female extruding eggs were taken.

The food of five specimens 0.88 to 1.38 inches long taken August 14, 1930, was as follows:

	Per cent. by volume
Larvae of Polycentropidae	40
Other? caddis larvae and pupae	13
Larvae of Chironomidae	20
Adult terrestrial fly	7
Gastropod	20

The result of the examination of the stomachs of six specimens 3.5 to 7.5 inches long taken May 17 to June 9, 1930, is as follows:

	Per cent. by volume
Diatoms, fragments of vascular plants and bottom ooze	52
Heptagenid nymphs	5
Unidentified insect	5
Gastropod (*Lymnaea stagnalis*)	38

The young chub were not found where small trout or most other small fish occur, hence they do not come directly into competition with other stream fish. For the larger specimens, six stomachs are not sufficient for a generalization, but the principal items listed are not found in trout stomachs. The absence of crayfish is surprising. In any case, the scarcity of the species makes it an unimportant factor in the life of the stream as enemy, competitor, or food of the trout.

4. *Rhinichthys atronasus* (Mitchill). Occasional or perhaps frequent in the beaver-meadow section, not seen below. The examples collected ranged from 1.5 to 2.75 inches in length. Stomachs of nine specimens taken July 12, 1928, and one taken July 25, 1930, contained the following:

	Per cent. by volume
Nymphs of *Ephemera*	16
Nymphs of Baetidae	20
Larvae of Chironominae	50
Pupae of Chironominae	3
Terrestrial insects	11

This is very similar to the food of sculpins taken at the same time.

TABLE 9. Stomach contents of *Eucalia inconstans*

	7 specimens 0.19-0.63 inches July 21, 1930	11 specimens 1.00-2.06 inches June 17-September 4, 1930
Entomostraca		
Cyclops	11	7
Chydorus	—	7
Bosmina	11	1
Pleuroxus	—	4
Ostracoda	36	18
Hyalella knickerbockerii	—	8
Insecta		
Nymphs of Baetidae	—	5
Nymphs of Corixidae	—	11
Larvae of Tanypinae	—	2
Larvae of Chironominae	28	11
Pupae of Chironomidae	14	4
Larvae of Tipulidae?	—	15
Adult terrestrial fly	—	3
Gyraulus parvus	—	4

5. *Eucalia inconstans* (Kirtland). Frequent in the lower section, below station 5. Specimens of the stickleback were most easily obtained in late summer and fall. It was often seen lurking in the shelter of logs, lily pads, *Potamogeton*, or *Chara*. Several individuals appear in the stomachs of the speckled trout.

The food of specimens collected June 17 to September 4, 1930, is presented in table 9.

From a consideration of these percentages, it is evident that the food of the stickleback consists chiefly of Entomostraca and aquatic insects, in approximately equal quantities.

TABLE 10. Stomach contents of sculpins (*Cottus bairdii*) in the Mad river

A. 21 sculpins less than two inches long

	10 specimens 0.50-1.00 inches July 4-October 20, 1931	11 specimens 1.06-2.00 inches June 14-September 4, 1931
Oligochaeta	3	—
Cyclops	2	1
Chydorus	3	—
Pleuroxus	1	+
Ostracoda	1	6
Nymphs of Heptagenidae	—	24
Nymphs of Baetidae	20	32
Larvae of *Culicoides*	—	5
Larvae of Tanypinae	14	24
Larvae of Chironominae	56	6
Nymphs of Corixidae	—	2

B. 35 sculpins 2.05-3.7 inches long, taken May 3-September 4, 1930

	Per cent. by volume
Lumbriculidae?	9
Copepoda and Ostracoda	+
Hyalella knickerbockerii	1
Cambarus sp.	5
Nymphs of Perlidae	2
Nymphs of *Ephemera* cf. *simulans*	42
Numphs of Heptagenidae	8
Nymphs of Baetidae	14
Larvae of caddis flies	8
Corixidae	+
Chironomidae	5
Gyrinus larvae	1
Vegetable matter	1
Stones and sand	3

6. *Cottus bairdii* Girard. Abundant everywhere in the stream. During the day sculpins are often seen resting on the bottom among sticks or stones, or are to be found hidden in the *Chara* and other weeds. At night they are probably more active, since a few

were caught in a minnow trap at that time. In winter they frequent the same parts of the stream as during the warm weather. There is no evidence that they congregate on the spawning beds of the trout in the fall to eat their eggs; no sculpins were seen near any of the springs where trout were spawning.

The sculpins' spawning time appears to be about the middle of May. On May 3 and 10 females were taken with eggs nearly ripe; by June 14 specimens were spent. On May 30 eyed eggs and small fish were found in two trout stomachs. On July 3, the young of the year, averaging 0.6 inches in length, were to be found abundantly on bare mud bottom at depths of two to ten inches.

Stomachs for analysis were obtained not only from specimens captured by seine, dip net, *etc.*, but also from specimens which speckled trout had eaten. Table 10 gives the results of these analyses.

It is evident that the young sculpins do not depend to any extent on Entomostracan food, but rather favour Chironomid larvae, among which Chironominae predominate. Small Baetid nymphs, mostly weed-clinging species, are found in even the smallest specimens. Sculpins one to two inches long take fewer Chironomids, which are chiefly of the Tanypinae and have increased their consumption of mayflies, taking Heptagenidae as well as Baetidae. After reaching two inches in length they begin to eat the burrowing nymphs of *Ephemera* in considerable numbers, so that they form over 40 per cent. of the bulk of their food. Other mayflies make up 22 per cent., Chironomids are reduced to five per cent., and crayfish, stonefly nymphs, caddis larvae, *etc.*, make up the total.

It is noteworthy that sculpins are entirely bottom feeders; no terrestrial insects were found in the stomachs, and with the exception of a very few Chironomid pupae, the aquatics were all in the active feeding state. Even during the great emergence of *Ephemera* in June, no nymphs about to transform were found in the stomachs. Its fondness for the immature nymphs, and its great abundance, suggest that the sculpin is the principal cause of the rapid reduction in the numbers of that species throughout the summer.

6. The Speckled Trout—*Salvelinus Fontinalis*

The Mad river has been considered a good trout stream from the time of the earliest settlements. Fishing was at first unrestricted; parties came from towns many miles distant to catch spawning trout in the fall and salt them for winter use. Nothing is known to the author of the history of fishing in the stream; whether or not there has been over-fishing in the past, as is suggested above, or fluctuations in numbers of the trout owing to other causes. At present fishing is closed to the public on all parts of the stream included in this survey, and fishing rights are leased either to clubs by the year, or to individuals by the day. It is difficult, therefore, to arrive at an estimate of the number of trout captured in a year, but in the mile and a half under consideration it probably lies between one and two thousand. At least 80 per cent. of these are taken between May 1 and June 15. The average length of the trout caught and kept is about nine inches, the minimum size limit is seven inches. The open season lasted from May 1 to September 15 in 1930.

The stomachs of 265 trout from the Mad river have been examined in order to find their food supply at all times of the year and at all ages. The results are presented in tables 11 to 15. The total volume of food in a stomach was measured by displacement of alcohol in a graduate, or very small amounts were estimated. The volume of each item was then calculated from its estimated percentage of the total bulk. Final averages were obtained by adding together the volumes of each item, and calculating its percentage of the total volume of stomach contents.

All of the trout in these tables were taken from the Mad river itself, not from tributaries. Fingerlings were all obtained in the beaver meadow section (see figure 2), the remainder farther down stream, from station 5 to the mill dam. For the food of fingerlings taken in Dogwood creek see table 4.

Three important causes of variation in the kind and amount of food taken by a trout throughout its life are its increase in size, migration to a different habitat, and the change of the seasons.

Changes with increase in size. The smallest trout examined were taken on May 22, or about three months after they had hatched (table 11). They were lying in shallow water, close to shore, and from this location were able to take a number of small flies and Hymenoptera which fell on the surface of the water, as well as the hopping Podurids which made their home there. More than half of their food, however, was truly aquatic, consisting chiefly of midge larvae, with a Psychodid pupa and many small *Canthocamptus*.

In July, at an age of five months, the trout had increased to almost twice their length in May, and consumed on an average over six times as much food. They were no longer interested in Entomostraca, but their (percentage) consumption of Chironomidae was about the same. Since the fingerlings at this time usually stayed in the middle of the stream, among the weeds, their consumption of terrestrial insects was not as great as before; Cercopidae were the principal victims. These gaps were filled by the larger stream insects—mayflies, stoneflies, and caddis flies; *Ephemera* and *Baetis* were the important genera. Even fish were already represented.

The next size group adequately represented was taken in the lower part of the river in late July and early August. The average length of the individuals in this group was 4.9 inches and they were a year and six months old. Table 12 compares their food with that of fish of larger size. The noticeable changes are a decrease in the amount of the smaller insect foods with increasing size, and an increase in the larger foods—fish and crayfish. A comparison of the stomach contents of trout of various sizes at other seasons enlarges these observations, so that we may conclude:

TABLE 11. Food of fingerling trout in the Mad river

	May 22 1930	July 8-25 1930	September 6 1930
Number of specimens examined	5	11	2
Average length in inches	1.04	1.96	2.25
Variation in length	0.91-1.25	1.63-2.31	—
Average volume of contents in cubic mm.	4.5	28.	5.
Average number of Nematoda	0	4	9
Vegetable matter	—	2	—
Entomostraca: *Canthocamptus*	9	—	—
Hyalella knickerbockerii	—	5	—
Araneida (spiders)	—	1	—
Aquatic insects			
Collembola: Poduridae	18	—	—
Nymphs of Ephemeroptera:			
Ephemera	—	13	—
Baetidae	—	12	90
Nymphs of Plecoptera	—	1	—
Larvae of Trichoptera	—	3	—
Pupa of Psychodidae	9	—	—
Larvae and pupae of Chironominae	31	37	10
Larvae of Tanypinae and *Culicoides*	4	2	—
Terrestrial insects			
Homoptera	—	12	—
Diptera	20	2	—
Coleoptera	—	2	—
Hymenoptera	9	1	—
Unidentified	—	5	—
Fish	—	4	—
Total surface food	47	18	100
Total submersed food	53	82	

(*a*) Stream insects, principally immature mayflies and caddis flies, bulk large in the stomach contents of smaller trout, constituting about 40 per cent. of the food of those near the legal limit of size (seven inches). In large trout, they average not more than 15 per cent. of the food at most times of the year. Moreover, the large trout take proportionately more of the larger insects (*Ephemera* nymphs and Phryganeid larvae) than of the smaller. It is also interesting to note that the cases of caddis larvae are most frequently found in the larger specimens; small trout are more dexterous in extracting the "worm" from its hiding place.

TABLE 12. Stomach contents of trout of varying size, July 28-August 14, 1930

Number of specimens examined	14	16	5	6
Average length in inches	4.9	7.0	8.4	11.3
Variation in length	4.2-5.4	6.2-7.8	8.0-9.0	10.0-13.2
Average volume of contents in cubic mm.	120	220	270	1050
Average number of Nematoda	6	12	9	106
Seeds of *Nymphaea*	8	48	16	30
Other vegetable matter	+	1	—	—
Pelycypoda: *Sphaerium*	—	3	—	—
Crustacea: *Cambarus*	—	6	19	50
Hydrachnida	2	—	—	—
Aquatic Insects				
Ephemerida: *Ephemera*	32	8	3	+
Others*	1	+	—	—
Trichoptera: Limnephilidae	5	2	—	—
Others**	3	+	3	—
Larval cases	2	2	6	—
Heteroptera: Corixidae	21	1	+	+
Gerridae	2	—	—	—
Diptera: Chironomidae	3	—	—	+
Coleoptera	2	1	—	1
Terrestrial Lepidoptera	2	—	—	—
Terrestrial Coleoptera	—	+	—	—
Fish: *Cottus*	—	3	35	—
Unidentified	8	16	—	6
Trash	9	6	17	13
Total surface food	2	2	—	—
Total bottom food	98	98	100	100

*Includes nymphs of Baetidae.
**Includes larvae of *Molanna*, *Polycentropus* and *Mystacides*, and unidentified pupae.

(*b*) Crayfish are rarely found in trout less than six inches long, become important (20 per cent.) in the six to eight inch group, reach a maximum in the eight to ten inch group (35 per cent.), and decline somewhat in larger fish (25 per cent.).

TABLE 13. Stomach contents of trout six to eight inches long

	May 16 to May 24	May 30 to June 1	June 6 to June 14	June 28 to June 30	July 23 to Aug. 14	Sept. 5	Nov. 18
Number of specimens examined	36	10	24	10	16	11	7
Average length in inches	7.1	7.4	7.2	7.6	7.0	6.7	7.1
Variation in length	5.9-7.9	7-7.8	6-7.8	5.1-8.5	6.2-7.8	5-8.2	5.6-7.8
Average volume of contents in cubic mm	940	1650	1850	390	220	120	565
Average number of Nematoda	13	14	93	67	12	8	19
Seeds of Nymphaea	—	—	—	—	48	—	1
Other vegetable matter	1	+	+	+	1	—	—
Hirudinea	8	14	2	—	—	—	—
Pelecypoda: *Sphaerium*	—	—	—	—	3	—	—
Gastropoda	2	1	+	—	—	—	—
Crustacea: *Cambarus*	23	29	7	15	6	—	2
Hyalella	+	—	—	—	—	—	—
Arachnida	+	—	—	—	—	—	—
Aquatic Insects							
Ephemerida: *Ephemera*	11	5	74	9	8	60	—
Blasturus	+	7	1	—	—	—	—
Siphlonurus	+	+	—	—	—	—	—
Others*	5	3	2	11	+	1	—
Odonata: Coenagrionidae	—	+	—	—	—	—	—
Aeshnidae	—	5	1	—	—	—	—
Plecoptera	+	—	—	—	—	—	—
Neuroptera: *Sialis* and *Chauliodes*	+	—	—	—	—	—	6
Trichoptera: Phryganeidae	21	+	+	4	—	3	—
Limnephilidae	3	6	1	10	2	—	—
Others**	+	2	1	4	+	10	1
Larval cases	9	3	+	2	2	5	1
Heteroptera: Corixidae	+	2	+	10	1	2	1
Gerridae	+	1	—	—	—	—	—
Diptera: Simuliidae	1	—	+	—	—	—	—

TABLE 13.—*Continued*

	May 16 to May 24	May 30 to June 1	June 6 to June 14	June 28 to June 30	July 23 to Aug. 14	Sept 5	Nov. 18
Chironomidae	3	+	+	+	—	1	+
Empididae	+	+	+	—	—	—	—
Coleoptera	—	+	—	+	1	—	4
Terrestrial Lepidoptera	—	—	1	—	—	—	—
Terrestrial Diptera	—	—	—	—	—	8	—
Terrestrial Coleoptera	+	1	+	+	+	—	7
Terrestrial Hymenoptera	+	1	+	—	—	—	+
Fish: *Cottus*	8	17	6	7	3	—	—
Eucalia	—	—	—	17	—	—	—
Unidentified	4	3	3	3	16	—	—
Eggs of *Salvelinus*	—	—	—	—	—	—	75
Trash	1	1	1	7	6	11	1
Total surface food	2	11	70	12	2	8	7
Total bottom food	98	89	30	88	98	92	93

*Includes nymphs of *Hexagenia viridescens*, *Ecdyurus tripunctata*, *Caenis* and other Baetidae, sub-imagos and imagos of *E. tripunctata*, and others.

**Includes larvae of *Molanna*, *Mystacides*, *Helicopsyche*, *Polycentropus*, Hydropsychidae; imagos of *Mystacides*, pupae of Hydroptilidae, and other unidentified pupae and imagos.

TABLE 14. Stomach contents of trout eight to ten inches long

	May 17 to May 24	May 30 to June 1	June 6 to June 14	July 28 to August 4	Oct. 23	Nov. 18
Number of specimens examined	28	12	6	5	3	6
Average length in inches	8.6	8.9	8.8	8.4	8.7	8.7
Variation in length	8.0-9.9	8-10	8.0-9.8	8-9	7.5-9.8	8-10
Average volume of contents in cubic mm	1800	3630	2480	1370	680	167
Average number of Nematoda	15	16	178	46	28	28
Seeds of *Nymphaea*	—	—	—	16	—	—
Other vegetable matter	+	+	1	—	3	5
Hirudinea	1	+	—	—	—	—
Pelecypoda: *Sphaerium*	+	—	—	—	—	—
Crustacea: *Cambarus*	5	69	13	19	37	4
Hyalella	+	+	—	—	—	—
Arachnida	+	+	—	—	—	+
Aquatic Insects						
Ephemerida: *Ephemera*	8	4	76	3	13	—
Blasturus	1	1	+	—	—	—
Siphlonurus	16	5	—	—	—	—
Others*	1	+	+	—	13	—
Trichoptera: Phryganeidae	7	+	—	—	6	—
Limnephilidae	3	2	—	—	+	—
Others**	1	1	+	3	—	—
Larval cases	7	1	—	6	3	—
Heteroptera: Corixidae	+	1	+	+	—	2
Gerridae	+	+	—	—	—	—
Diptera: Simuliidae	+	—	—	—	—	—
Chironomidae	+	+	+	—	—	—
Coleoptera: Dytiscidae	—	—	—	—	1	—
Terrestrial Diptera	—	+	—	—	—	—
Terrestrial Coleoptera	+	+	—	—	—	9
Terrestrial Hymenoptera	+	—	—	—	—	—

TABLE 14.—*Continued*

	May 17 to May 24	May 30 to June 1	June 6 to June 14	July 28 to August 4	Oct. 23	Nov. 18
Fish: *Cottus*	43	5	10	35	19	10
Unidentified	+	2	—	—	—	—
Eggs of fish: *Cottus*	—	6	—	—	—	—
Salvelinus	—	—	—	—	—	68
Trash	4	2	—	17	7	5
Total surface food	2	3	76	0	9	7
Total bottom food	98	97	24	100	91	93

*Includes nymphs of *Hexagenia viridescens*, *Ecdyurus tripunctata*, unidentified Heptagenids and Baetids, and a few sub-imagos and imagos.

**Includes larvae of *Molanna*, *Mystacides*, *Oecetis*, *Helicopsyche*, Philopotoamidae, Polycentropidae, pupae of Hydroptilidae, and other pupae and imagos.

TABLE 15. Stomach contents of trout ten to fourteen inches long

	May 2 to May 11	May 17 to May 24	June 8 to June 14	July 28 to August 14
Number of specimens examined	13	13	4	6
Average length in inches	11.0	11.6	11.4	11.3
Variation in length	10-13	10-14	10.5-12.8	10-13.2
Average volume of contents in cubic mm.	4070	1580	16500	1050
Average number of Nematoda	14	16	121	106
Seeds of *Nymphaea*	—	—	—	30
Other vegetable matter	+	+	+	—
Hirudinea	+	+	—	—
Gastropoda: *Gyraulus*	+	—	—	—
Crustacea: *Cambarus*	10	26	—	50
Hyalella	—	+	—	—
Aquatic Insects				
Ephemerida: *Ephemera*	1	4	99	+
Ecdyurus and *Blasturus*	—	1	+	—
Odonata: Agrionidae	+	+	—	—
Coenagrionidae	—	—	+	—
Neuroptera: *Sialis*	—	+	—	—
Trichoptera: Phryganeidae	3	8	—	—
Limnephilidae	1	+	+	—
Others*	+	4	+	—
Larval cases	4	12	+	—
Heteroptera: Corixidae	+	+	—	+
Diptera: Chironomidae	+	1	+	+
Coleoptera: Dytiscidae	—	—	—	+
Terrestrial Diptera	+	—	—	—
Fish: *Cottus*	73	30	—	6
Unidentified	+	7	—	13
Trash	6	2	+	—
Total surface food	+	1	100	—
Total bottom food	100	99	+	100

*Includes larvae of Hydroptilidae, *Helicopsyche*, *Molanna*, and *Mystacides*. One stomach contained 20 specimens of the last.

(*c*) Fish are not to be entirely disregarded as a food supply for even the smallest trout. With increasing size, the proportion of fish taken increases; at seven inches it is 15 per cent., at nine inches 30 per cent., and at 12 inches it is not far from 50 per cent.

One important exception to the above statements must be noted. For about ten days early in June trout of all sizes from six inches up feed principally on the emerging nymphs and sub-imagos of *Ephemera*. They made up about 99 per cent. of the total food of the four large specimens, and about 75 per cent. of that of the smaller groups.

Seasonal changes. Tables 13 to 15 are arranged so that the variation in food from month to month may be easily noted. The figures shown must not be taken entirely at their face value. The occurrence of a single large sculpin or crayfish has a great effect upon the percentage recorded, especially where only a few specimens have been averaged. Hence, due consideration must be given to the number of stomachs from which each figure has been calculated.

The total quantity of food taken varies in a similar manner in all of the size groups. Starting at a fairly high figure in mid-May, it reaches a maximum at the time of the great rise of *Ephemera* early in June, drops rapidly immediately thereafter, then falls off more slowly throughout the summer and early autumn to a minimum just before the breeding season. The larger the trout is, the more marked are these fluctuations; on an average, the stomach contents in early June are about ten times as bulky as in early autumn. The increase in volume seen in the six to eight inch class at spawning time is because of the consumption of eggs by the males.

Our only clue to the amount of food taken during winter is given by six specimens averaging six inches in length, taken on January 7, 1931, in a large spring off Dogwood Creek. Their stomachs averaged only 70 cubic mm. of food each, consisting of the following:

	Per cent. by volume
Needles of Conifers	2
Mollusca: *Physa*	7
Crustacea: *Gammarus*	14
Hydrachnida	+
Ephemerida	+
Trichoptera: Phryganeidae	15
Limnephilidae	24
Heteroptera: Corixidae	10
Diptera: Chironomidae	22
Coleoptera: Dytiscidae	5

Discussion. We have already divided the invertebrate fauna of the river into forms of constant and forms of intermittent occurrence. This distinction may also be detected by an examination of their distribution in the trout stomachs throughout the season. The more important forms may be discussed from this point of view:

Leeches. Exceptional; although present in the stream all year, they were found in the stomachs only in spring.

Cambarus propinquus. Common in the stream and in the stomachs throughout the year.

Ephemera cf. *simulans.* Found throughout the year; excessively abundant at time of emergence.

Siphlonurus. Very abundant in a few stomachs near time of emergence.

Phryganeidae. Larvae common in May, and the young appear again in August. In the interval occasional pupae and imagos are taken.

Limnephilidae. Larvae not uncommon in May and June; imagos appear in late June and in October.

Corixidae. Most important in the fall and winter, when a large species is dominant.

Chironomidae. Most commonly taken as pupae in May.

Many of the invertebrates which were found to be frequent or abundant in the stream occur only rarely in the trout stomachs. These are usually forms which burrow deep in the mud, or lie concealed among the weeds, *e.g.* *Sphaerium*, *Pisidium*, *Haemopis*, *Ephemerella temporalis*.

Others are protected by their large size and unwieldy exoskeletons, *e.g.* *Helisoma trivolvis*, *Lymnaea stagnalis*, and the largest crayfish. Still others are concealed for the most of their lives, but become available to the fish at the time of their emergence, *e.g.* *Siphlonurus*, Chironomidae (though many larvae of the latter are eaten by very small trout). *Blasturus* rivals *Ephemera* in abundance in the stream, but early in the spring the nymphs migrate shoreward and transform in the flood pools and shallow borders. Hence they escape the attention of the trout during the period covered by our food study, the only individuals commonly found in the stomachs being female imagos which have returned to the water to lay their eggs. Finally, there are a few forms which are common in the stream and equally so in the stomachs: *Ephemera*, Phryganeid and some Limnephilid caddis flies, Corixidae.

Vegetable materials are found in trout stomachs from a variety of habitats, but not usually in large quantities. The seeds of *Nymphaea*, taken by the Mad river trout at midsummer, are a rather unusual item.

7. Vertebrates other than Fish

Amphibia. *Rana clamitans* Latreille, the green frog, was common among the lily pads along the lower section of the river. Year-old tadpoles were often seen along the mud banks in water up to two feet deep. The stomach of one contained chiefly mineral matter (mud), with a slight admixture of diatoms, filamentous algae, fragments of higher plants, and organic debris. One or two of the records of "unidentified fish" in the stomach contents of trout may be referable to this animal.

Other Amphibia known to frequent borders of the river during their spawning season are: *Bufo americanus* Halbrook, *Hyla versicolor* LeConte, *Rana pipiens* Schreber.

Reptilia. No reptiles were observed in or near the river. The absence of turtles is noteworthy.

Aves. Many species of birds are directly or indirectly connected with the life of the river. Only those more obviously related to the stream life can be discussed.

Lophodytes cucullatus (L.). A hooded merganser was seen several times on the river during the fall. An immature specimen, collected on November 20 by Mr. Arthur Neff, contained the following food organisms:

	Per cent.
Filamentous algae	1
Three crayfish—*Cambarus propinquis*	99
One Corixid	+

Anas rubripes Brewster. A flock of a dozen black ducks came down to the river at times during late summer and autumn, and were observed to be feeding over the mud bottom. Sphaeriidae suggest themselves as probable components of their food. A flock of domestic ducks was also observed to frequent the lower part of the river.

Botaurus lentiginosus (Montagu). American bittern. At least one pair nests each year in a swale along the bank of the river. They were observed feeding in shallow water.

Actitus macularia (L.). Spotted sandpipers. Frequented the stream all summer.

Tringa solitaria Wilson. Solitary sandpiper. Rare.

Oxyechus vociferus (L.). Killdeer plover. Occasional.

Streptoceryle alcyon (L.). Kingbird.

Sayornis phoebe (Latham). Phoebe.

Quiscalus quiscula aeneus Ridgway. Bronzed grackle.

Petrochelidon albifrons (Rafinesque). Eaves swallow. A small colony nested within 100 yards of the river.

Hirundo rustica erythrogastris Boddaert. Barn swallow.

Seiurus noveboracensis (Gmelin). Water thrushes. Frequented the shores, under overhanging shrubbery.

Turdus migratorius L. Robin.

Flycatchers and swallows are drawn into stream ecology, as destroyers of aquatic insects in their winged state. No data are at hand as to the extent of their depredations.

Phoebes have been observed to catch and eat imagos of *Perla* and *Chauliodes*, and a sub-imago *Hexagenia viridescens*. Doubtless many other birds destroy mayflies and caddis flies when they are resting on leaves or bark.

The bittern, sandpipers, and, to a lesser extent, the plover, regularly feed by the river's brim, and their food was doubtless chiefly immature aquatic insects. During exceptionally low water, when many *Chara* beds were laid

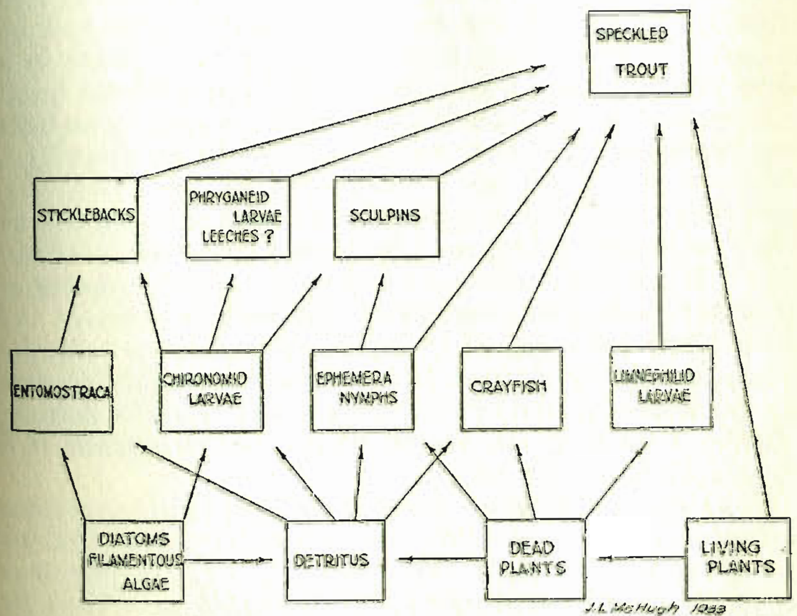

FIGURE 10. Food pyramid of the speckled trout in the Mad river

bare and their fauna exposed, they were joined by land birds such as robins and grackles.

Mammalia

Vespertilionidae. Bats were frequently seen hunting along the stream while mayflies were rising.

Lutreola vison Schreber. Mink were seen on several occasions.

Ondatra zibethica (L.). Tracks and burrows of musk-rats were occasional along the stream.

Homo sapiens (L.). Man is probably the principal enemy of the adult speckled trout.

8. Interrelations of the Biota

Briefly the fundamental food cycle in a stream is: animals eat plants. Many animals, however, do not feed directly on plants, but on other animals which feed on plants. In some cases, indeed, many links intervene in a food chain between the basic plant foods and a large carnivorous animal. Complex food pyramids may thus be built up, every one of which has its base in plant materials (figure 10).

Plant material in the stream may conveniently be divided into: (1) larger aquatic plants, including *Chara;* (2) diatoms and filamentous algae; (3) dead fragments of plants, including non-aquatic species, *i.e.* bits of leaves and wood; and (4) finely divided plant material, partially decomposed and unidentifiable, which with a certain amount of dead animal matter, forms the detritus of the bottom. Plankton algae, which are of paramount importance in a lake, are negligible in smaller streams.

Larger aquatic plants are apparently of small importance directly as food for animals. Larvae of *Donacia* are known to feed on stems of some species, but to most stream dwellers they are much more readily available when dead. They are extremely important in providing extensive surfaces for the growth of small algae, especially diatoms. These are eagerly eaten by many animals, including presumably the phytophilous Entomostraca, snails, and some Chironomids. The bottom fauna is mainly nourished by the dead and decomposing remains included in (3) and (4) above. Crayfish, *Ephemera* nymphs, Limnephilid larvae, and probably many Chironomine larvae feed chiefly on debris of this sort, mixed with a few diatoms and occasionally some animal matter. These vegetable-feeders support a considerable number of

carnivores, among which are to be included Phryganeid larvae, Tanypine midges, and probably the abundant leech *Haemopis plumbeus.*

Almost all of the animals mentioned above are reduced in numbers by fish. Entomostraca are eaten by very young trout and sculpins, and by sticklebacks of all ages. Chironomid larvae are the staple food of all small fish (one to two inches long), being gradually replaced in the larger sculpins and trout by other stream insects, particularly *Ephemera* nymphs. Above this size trout turn to larger invertebrate foods (crayfish and leeches, as well as the bigger insects) and finally begin to take other fish, principally sculpins.

It is easy then to realize that the food supply of any carnivore, such as the speckled trout, is made up of a great many diverse elements which are interrelated in a most complex fashion, though all are finally dependent upon vegetable matter in one state or another.

Figure 10 is the food pyramid of the speckled trout, drawn in an incomplete fashion, which omits many of the less important components. It is typical of what might be compiled for any fish, bird, or animal which plays a part in the life of the stream.

9. Summary of Mad River Investigation

The part of the Mad river included in this study is a slow-flowing trout stream, situated in the highlands of southern Ontario. Its water rises to a fairly high temperature in summer (maximum 24° C.), is alkaline, rich in lime and carbonates, low in carbon dioxide, and contains a good quantity of oxygen at all times. Its bed is of mud or marl-gravel, mostly covered by aquatic plants, and with an average maximum depth of about four feet (1.3 metres). It is rich in invertebrate life, various species of which form several ecological associations, depending upon depth, type of bottom, and presence or absence of weed beds. The principal fish are sculpins, and speckled trout. The first named is most abundant; it feeds almost exclusively on insects which it obtains from the bottom of the stream. The speckled trout depends on larger insects, crayfish, and sculpins. It sometimes takes insects as they rise to the surface of the river; this is particularly true of one abundant mayfly. Amphibians, birds, and mammals play their part in the life of the river as destroyers of more truly aquatic vertebrates and invertebrates.

SLOW SOFT-WATER TROUT STREAMS

Streams of this type are the soft-water relatives of the Mad river, and occur throughout the pre-Cambrian region, where Laurentian granites and gneiss prevail. They are much commoner than is the Mad river type, and, because usually situated in a forested country, they attain to a much larger size before the temperature rises high enough to place them among the "warm rivers". The most apparent difference between the two is in the type of vegetation: *Chara* is absent from the soft water, while *Brasenia* has not been found in the hard, and *Castalia* is very rare. No extensive faunal studies have been made of the soft-water type; but their fish appear to be more numerous and more varied, including *Notropis cornutus*, *Semotilus atromaculatus*, *Catostomus commersonii*, *Eupomotis gibbosus*, *Perca flavescens*, and in some cases even *Micropterus dolomieu*. Examples of this type of river are found in the quiet reaches of the Oxtongue, East, and Nipissing, all flowing out of Algonquin park, Ontario.

SWIFT HARD-WATER TROUT STREAMS

Most of the good trout streams of southern Ontario are of this kind; they are very typically represented by the lower part of the Mad river.

The climate, vegetation, and geological features of the Mad river region have already been described (pp. 25 *et seq.*).

The lower Mad falls through the Devil's Glen over lime-encrusted pebbles and stones, dolomitic boulders, and in some places, bed rock. Several water falls five to fifteen feet (1.5 to 4.5 metres) high are found in its course, but for the most part the stream is a succession of rapids. At station 1, where the water samples were taken and most of the collecting done, the bottom was of stones three inches to a foot (8 to 30 cm.) in diameter.

Most of the water of the lower Mad river comes from the reaches above. Along the sides of the glen are numerous rock springs which fall down moss-covered slopes to the river below. In summer they are with rare exceptions colder than the river and reduce its temperature one or two degrees. The volume of flow is subject to large diurnal fluctuations, especially in summer, owing to the opening and closing of the gates at the mill above. For example, on August 13 the flow rose from 7 to 38 cubic feet (0.02 to 1.1 cubic metres) per second in the course of five minutes. Seasonal variation in the volume of flow is much the same as in the upper Mad. Temperatures, pH, and oxygen contents taken throughout the year are recorded in table 16. They present no unusual features, except, perhaps, the uniformly high concentration of dissolved oxygen.

Aquatic vegetation in the lower Mad is confined to cryptogamic plants. Mosses such as *Fontinalis* and *Fissidens* and algae such as *Cladophora* are most conspicuous. There is also a microscopic algal flora which is responsible for the deposition of limy encrustations on the stones of the river bed.

The invertebrate fauna is quite different from that of the upper Mad river; many of the animals show adaptations which enable them to withstand or to avoid the strong current:

Oligochaeta and Hirudinea. Absent.

Crustacea. *Hyalella* absent; *Cambarus bartonii robustus* replaced *C. propinquus*.

TABLE 16. Seasonal variation in water of the lower Mad river

Date	Time	Rate of flow (feet per second)	Volume (cubic feet per second)	Temperature C.	Temperature F.	pH	Oxygen* cc/1	Oxygen* p.p.m.	Oxygen* Per cent. saturation
May 19, 1930	11.30 a.m.	5.4	135	7.7	46	7.8	8.2	11.7	103
June 13, 1930	4.30 p.m.	3.0	48	18.4	65	7.9	5.4	7.7	88
June 30, 1930	2.30 p.m.	2.7	33	19.2	66.5	..	5.7	8.1	95
July 24, 1930	4.30 p.m.	..	15	21.0	70	..	..	..	..
August 13, 1930	3.40 p.m.	1.5	7	18.0	64.5	..	..	..	..
August 13, 1930	4.30 p.m.	3.2	38	17.6	63.5	..	..	..	..
August 16, 1930	4.00 p.m.	..	..	19.3	67	..	5.9	8.4	98
September 4, 1930	2.10 p.m.	1.5	7	17.8	64	7.8	5.6	8.0	89
October 19, 1930	5.00 p.m.	..	5	1.8	35	7.7	8.8	12.6	98
January 16, 1931	4.30 p.m.	..	10	0.0	32	7.4	8.5	12.1	90
March 23, 1931	11.00 a.m.	3.0	15	0.3	32.5	7.7	8.7	12.4	94
April 19, 1931	11.45 a.m.	6.0	300	9.2	48.5	7.6	7.5	10.7	100

*The water was probably saturated with respect to oxygen at all times, because the samples were taken below along rapids and falls. Values less than saturation are low because the water had to be carried some distance before it was analysed, and a small amount of gas would escape from it.

Ephemeroptera. *Ephemera* cf. *simulans* absent, but many stone-clinging Baetids and Heptagenids were found, *e.g. Leptophlebia, Baetis, Chirotenetes, Ephemerella, Ecdyurus, Heptagenia*, and *Epeorus*.

Odonata. *Boyeria vinosa*.

Plecoptera. Large nymphs of *Perla* and *Acroneuria* are common; smaller forms are *Isoperla, Chloroperla, Alloperla, Nemoura*, and *Leuctra*.

Neuroptera. *Chauliodes*, not uncommon.

Trichoptera. Phryganeids absent; the large Limnephilid *Stenophylax scabripennis* with a case of sticks is found in the pools, but the larvae of *Neophylax* or *Mystrophora* are more typical case-builders, since they use sand grains exclusively. Others are free living, *e.g. Rhyacophila*, or spin nets of various sorts, as *Philopotamus, Chimarrha, Polycentropus*, and the abundant Hydropsychids. A few small forms build fragile cases of plant material, and live in the shelter of the mosses or algae on the stones, *e.g. Micrasema?* and *Lepidostoma*. Dr. Betten has identified the following imagos, which were taken on this part of the river:

Rhyacophila fuscula. 8.vi.-25.vii.30.
Rhyacophila carolina. 30.vi.30; 6.ix.30.
Rhyacophila sp. 38. 9.vi.30.
Rhyacophila sp.? 18.vi.30.
Mystrophora americana. 23.v.30.
Philopotamus distinctus. 25.vii.30; 13.viii.30; 13.xi.30.
Chimarrha socia. 8.vi.30.
Chimarrha aterrima. 25.vii.30.
Diplectrona modesta. 25.vii.30.
Hydropsyche sp. 30. 15-17.v.30.
Hydropsyche sp. 31. 23.v.-22.vii.30.
Hydropsychodes analis. 23.v.30.
Hydropsychodes sp.? 25.vii.-14.viii.30.
Molanna blenda. 23.vi.30.
Stenophylax scabripennis. 7.ix.30.
Rheophylax submonilifer. 23.v.30.

Atomyia sp. 23.v.30.

Heteroptera. Not found.

Diptera. *Antocha* and a few Chironomids frequent the crevices in the limy encrustation of stones, while *Simulium* larvae are found on bare surfaces. In the weeds live larger crane-flies such as *Dicranota*.

Coleoptera. The only common beetles are *Helmis*, *Psephenus*, and *Dryopus*. The two last are the flat clinging "water-pennies".

Mollusca. Not found here. In moderately swift sections *Sphaerium* may be abundant.

The fish taken at station 1 include only *Salvelinus fontinalis*, *Semotilus atromaculatus*, and *Cottus bairdii*. About a mile down stream *Catostomus commersonii* was observed; it probably cannot ascend the intervening falls. Almost all of the numerous species of stream insects are readily taken by the trout in the stream (table 17). In spring the large *Ephemerella* is often caught just as the sub-imago is emerging from the nymphal skin. *Epeorus humeralis*, several species of *Ecdyurus*, *Leptophlebia*, *Baetis*, *Chirotenetes*, and *Ephemera guttulata* are also found, in greater or lesser abundance. The stoneflies include large *Perla* nymphs, and smaller *Isoperla* and *Leuctra*. Hydropsychidae are preponderant among the caddis flies; most of the pupae are probably of this family. Other forms are Hydroptilidae, *Rhyacophila fuscula*, *Philopotamus*, *Chimarrha*, *Polycentropus*, *Helicopsyche*, and Limnephilidae. The lithophilous cranefly *Antocha* is the principal dipterous larva; other Tipulidae, Chironomidae, and rarely *Simulium* also occur. Though most often taken while still immature, aquatic insects of all families are occasionally captured when in the imagal state.

As the summer advances, the number of aquatic insects taken decreases, and that of terrestrial insects and spiders increases. Cicadellidae, Muscidae, Scarabeidae, and Formicidae are among the families most often represented.

Trout from the Noisy river, Dufferin county, Ontario, a stream very similar to the lower Mad, had taken essentially the same foods, though with a greater proportion of land insects (table 17).

TABLE 17. Food of trout in swift hard-water streams

	Mad river May 24 and June 8 1930	Mad river August 16 and September 6 1930	Noisy river July 2 to July 21 1928
Number of specimens examined	10	7	7
Average length of trout in inches	6.6	7.7	5.7
Variation in length	5.8-9.5	5.8-9.5	4.5-8.0
Average volume of contents in cubic mm.	790	270	660
Average number of Nematoda	90	5	7
Vegetable matter	+	+	—
Crustacea: *Cambarus bartonii*	12	26	6
Araneida—spiders	—	6	2
Aquatic insects			
Ephemeroptera: *Epeorus*	4	—	2
Ephemerella	21	—	—
Baetis	5	2	+
Others	6	3	—
Odonata: Zygoptera	—	+	3
Plecoptera	2	2	10
Trichoptera: Hydropsychidae	4	1	—
Other larvae	5	2	4
Unidentified pupae	10	8	13
Heteroptera: Corixidae	—	2	+
Diptera: Tipulidae	6	12	—
Chironomidae	2	1	+
Others	+	—	+
Coleoptera	1	12	1
Terrestrial insects			
Orthoptera	1	+	—
Hemiptera	—	—	10
Lepidoptera	+	12	—
Diptera	2	5	5
Coleoptera	12	5	15
Hymenoptera	1	1	11
Fish: Cyprinidae	6	—	—
Trash	+	—	—
Total surface food	18	30	57
Total submersed food	82	70	43

The Pine river, also in Dufferin county, is another similar stream, although perhaps somewhat warmer in the places where specimens were obtained. It contains rainbow trout, *Salmo irideus*, as well as the native speckled trout.

TABLE 18. Food of Pine river fishes

	Salvelinus fontinalis June 17	*Salmo irideus* June 17	*Salmo irideus* June 17 to 21	*Semotilus atromaculatus* July 4	*Rhinichthys* spp. July 4 to 27
Number of specimens examined	3	15	4	7	12*
Average length in inches	6.6	5.7	9.9	4.1	2.3
Variation in length	5.5-7.2	4.9-6.4	7.2-14.5	2.8-6.8	1.6-3.8
Average volume of contents in cubic mm	1340	650	2630	200	60
Average number of Nematoda	7	1	2	?	—
Pilamentous algae and diatoms	—	15	38	—	—
Polyzoa: *Plumatella*	—	—	—	—	66
Gastropoda	3	—	—	—	+
Crustacea: *Cambarus*	7	8	7	51	10
Aquatic insects					
Ephemeroptera	33	25	1	—	—
Plecoptera	—	2	4	—	—
Trichoptera	10	14	3	10	13
Heteroptera: Gerridae	1	—	—	—	—
Diptera: Chironomidae	1	+	+	—	8
Others	—	3	2	13	—
Coleoptera	—	2	+	—	1
Terrestrial insects					
Hemiptera	1	4	—	1	—
Lepidoptera	—	+	—	—	+
Diptera	—	1	+	—	—
Coleoptera	9	4	5	20	+
Hymenoptera	34	22	8	4	2
Fish: *Cottus*	—	—	31	—	—
Total surface food	83	65	21	26	2
Total submersed food	17	35	79	73	98

*Includes three *R. cataractae* and nine *R. atronasus*. The food of the two species was similar.

Other common fish are the horned dace, *Semotilus atromaculatus*, the small dace *Rhinichthys cataractae* and *R. atronasus*, a sculpin *Cottus cognatus*, and the sucker *Catostomus commersonnii*. Some data are at hand concerning the food of the first four, which are summarized in table 18. The diet of the two species of trout was essentially the same at the time these specimens were taken (June), except that the rainbows consumed a considerable quantity of algae, including *Cladophora*, *Mougeotia*, and diatoms. Metzelaar (1928) has found large quantities of algae in rainbow trout from Michigan. Crayfish formed half of the food of the horned dace, which are thus competitors of the larger trout. The long-nosed and black-nosed dace (*Rhinichthys*) consume *Plumatella*, an organism which the other fish do not touch.

SWIFT SOFT-WATER TROUT STREAMS

The Oxtongue river rises from numerous lakes and streams in the south-western corner of Algonquin park, district of Nipissing, Ontario. It is first to be recognized immediately below the dam of Tea lake, which section is referred to here as the upper Oxtongue. Fifteen or twenty miles (about 30 km.) below this point it enters a lake having the same name—an elongate body of water two square miles (5 square km.) in extent. Immediately below this lake the lower Oxtongue begins, in which section most of the studies were made. Its location is longitude 78° 58′ W. and latitude 45° 18′ N. Five miles (8 km.) below this point it empties into the lake of Bays and finally into Georgian bay by way of the Muskoka river.

Immediately below Oxtongue lake, the river flows down through a rather narrow valley in a long series of rapids and pools. The basal igneous rock of the region, nowhere deeply covered, is exposed along the sides of the gorge, and in places forms the bed of the stream. The slopes on either side are wooded with coniferous and deciduous trees, among which yellow birch, red maple, and poplars predominate.

The rapid studied is about 50 feet (16 metres) wide and up to four feet (1.3 metres) in depth, averaging 28 inches (70 cm.). The current is fast, and volume of flow large: over 300 cubic feet (8.5 cubic metres) per second late in May. The water is dark brown in colour, and rises to a rather high temperature—about 23°C.—on hot summer days, but is, of course, well oxygenated. It is "soft", *i.e.* deficient in lime and magnesium, as shown by an analysis made at 1.00 p.m. on May 30, 1930: free carbon dioxide 1.3 parts per million, acid carbonate (HCO_3) 6, hardness 40, the last two expressed as parts per million of $CaCO_3$. Table 19 summarizes most of the available information concerning water conditions in the Oxtongue river.

TABLE 19. Water characteristics of the lower Oxtongue river

Date 1930	Time	Rate of flow (ft. per sec.)	Vol. (cu. ft. per sec.)	Temperature		pH.	Oxygen		
				C.	F.		cc/1.	p.p.m.	Per cent. sat.
May 30	1.00 p.m.	4.5	315	13.2	56.0	..	6.5	9.3	93
July 18	6.00 p.m.	..	..	22.4	72.5	6.2	5.85	8.3	102
Sept. 20	4.45 p.m.	3.0	135	17.6	63.5	..	5.9	8.4	93

The only vegetation noticed in the rapids consisted of rock-clinging algae. *Cladophora* was very abundant in July, and in September many of the stones were covered with *Zygnema* and *Mougeotia*.

The following list of invertebrates is based upon collections made in May, July, and September, 1930.

Porifera
- *Spongilla*. Rare.

Polyzoa
- *Plumatella*. Rare.

Turbellaria
- *Planaria*. Rare.

Hirudinea
- A small white leech was distributed occasionally and rather uniformly, in sand under the stones.

Crustacea
- *Cambarus bartonii bartonii*. Rare; occasional in the less rapid parts.

Ephemeroptera
- *Leptophlebia mollis*. Frequent.
- *Ephemerella deficiens*. Occasional.
- *Ephemerella* sp. Occasional.
- *Baetis*. Frequent.
- *Epeorus humeralis*. Frequent.
- *Heptagenia hebe*. Occasional.
- *H. pullus*. Occasional.
- *Ecdyonurus canadensis*. Rare.
- *Ecdyonurus* sp. (*fusca* group). Occasional.

Odonata
- *Ophiogomphus rupinsulensis*. Imagos taken on upper Oxtongue.
- *Boyeria vinosa*. Imagos taken on upper Oxtongue.

Plecoptera
- *Perla*. Large nymphs which are to be referred to two species of this genus or of *Acroneuria* were occasionally collected.
- *Isoperla*. Rare.
- *Alloperla*. Frequent.

Trichoptera
- Hydroptilidae. Abundant.
- *Rhyacophila fuscula*. Occasional.
- Hydropsychidae. Frequent, at least two species were represented. In the upper Oxtongue, August 16, 1929, they were abundant.
- *Polycentropus ?* Occasional.
- *Chimarrha*. Occasional (two species).
- *Lepidostoma*. Rare.
- Limnephilidae. Occasional.

Diptera
- *Simulium*. Extremely abundant. On May 30, the larvae were found covering every stone as closely as did the *Cladophora* later in the summer. As many as 800 individuals were taken from four

square inches (26 square cm.) and a conservative estimate for the whole rapid is 5,000 per square foot (54,000 per square metre). Pupae were frequent, being anchored to the downstream side of stones. Most of these larvae transform and emerge in June; a search on July 16 revealed only three specimens among the stones where they were formerly so numerous.

Tanypinae. Rare.

Chironominae. Occasional. Chironomid larvae are less common in soft-water streams, perhaps because of the absence of any limy encrustation on the stones, in the fissures of which they are wont to lie. The Tipulid *Antocha*, which has a similar habit, was absent.

Bibiocephala. Occasional.

Coleoptera

Helmis. Occasional.

Psephenus. Rare.

The invertebrate fauna of these soft-water trout streams is very similar to that of hard-water rivers having a similar temperature; many of the same species of insects are found in both situations. The characteristic feature of the soft-water association is its enormous population of *Simulium* larvae, beside which the numbers found in hard waters are quite insignificant. The adult females of this insect are well known as the biting black-flies which at times make life unbearable in the northern woods. Another dipterous larva which appears to prefer soft waters is of the Blepharocerid genus *Bibiocephala*.

In other brown-water streams the relative abundance of the various organisms is somewhat different from that observed in the Oxtongue. For example, in one river a great number of sponges and many colonies of *Cristatella* were found; in another *Plumatella* occurred frequently; in the East river, a more northerly branch of the Muskoka, there were found Hydropsychid larvae quite different from the species common in the Oxtongue. But the present

survey is far from complete, and these species may abound in parts of the last-named river.

An incomplete list of fish occurring in the river is: *Salvelinus fontinalis*, *Catostomus commersonnii*, *Semotilus atromaculatus*, *Eupomotis gibbosus*, and *Micropterus dolomieu*. Specimens of the two game species, taken in the upper Oxtongue, August 16-24, 1929, were examined for stomach contents, and the results set forth in table 20. Difference in habitat of the two species is reflected in food differences. The trout, taken in the swift water, had eaten insects characteristic of the lotic association: Simulid and Hydropsychid larvae; the bass, in more quiet backwaters, must be content with imaginal caddis flies, a few other insects, and small fish. Large bass are rarely found near the rapids; they prefer the slow deep reaches of the river, which belong in the "slow soft-water trout stream" division of this classification. Nothing is known of the relation of trout to bass in those surroundings.

TABLE 20. Food of game fish in the Oxtongue river, August 16-24, 1929

	Trout *S. fontinalis*	*Bass* * *M. dolomieu*
Number of specimens examined	19	6
Average length of fish in inches	6.3	5.4
Variation in length	5.1-7.3	4.7-6.0
Average volume of contents in cubic mm	490	130
Average number of Nematoda	0	+
Vegetable matter	+	—
Aquatic insects		
Ephemeroptera	+	—
Trichoptera: Imagos and pupae	15	50
Larvae of Hydropsychidae	18	—
Heteroptera: Gerridae	+	—
Diptera: Chironomidae	5	8
Simuliidae	61	6
Others	+	12
Terrestrial insects		
Hemiptera	+	—
Diptera	+	—
Coleoptera	+	—
Fish	—	24

*The bass stomachs were examined by Mr. A. L. Tester.

From the East river, which is close to and very like the Oxtongue, and from the Nipissing, a similar stream in the northern part of Algonquin park, the author has been able to secure specimens of other fish associated with the speckled trout in these brown water rivers. Table 21 shows the food of the chub, shiners, perch, and sunfish in the two rivers, and of trout from these and two other rivers of the Algonquin park region.

From a study of tables 20 and 21 it will be seen that none of the "forage" fish, with the exception of the horned dace, is a serious competitor of the game fish in these rivers. The shiners and sunfish take algae and Bryozoa which trout do not touch; the two perch examined had also favoured Bryozoa; two small suckers confined themselves to Entomostraca and midge larvae, which they had probably taken in quiet water. The horned dace, both in these streams and in others, show a preference for crayfish, thus coming into direct competition with the bass and with the larger trout. They are themselves often eaten by the trout, along with shiners (*Notropis cornutus*) and suckers (*Catostomus commersonnii*).

Figure 11 gives an idea of the food relationship of vertebrates to invertebrates in these streams. Bass have been omitted, because they occurred in only two of the streams examined, and in any case are more usually found in the slower sections.

Soft-water trout streams commonly attain to a much larger size than do the trout streams of calcareous regions. From this we might conclude that trout are able to tolerate higher temperatures when in water poor in lime and with a low pH. A more probable explanation is that, since in Ontario to-day soft-water streams almost always flow through a completely forested watershed, they are not as easily warmed up, and consequently reach large proportions before their temperature rises to the critical point above which trout are no longer able to survive. The information necessary for a decision between these two alternatives is not yet available.

WARM RIVERS

The transition from the trout stream to the warm river is a fairly abrupt one, and is characterized by an increase in the number of species of all kinds of organisms: plants, invertebrates, and vertebrates; and by the disappearance of some of the types characteristic of the colder waters. Among the latter is the speckled trout.

The Credit river illustrates these changes well. In some of its upper reaches it approximates closely to the swift

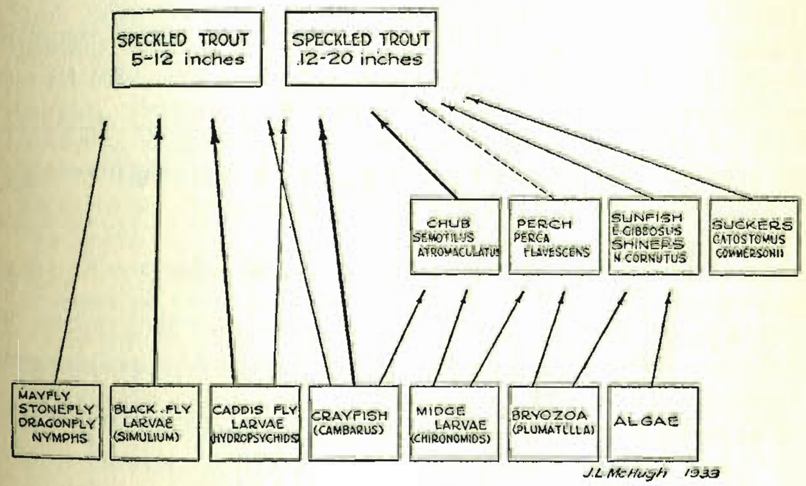

FIGURE 11. Biotic relationships in swift soft-water trout streams

trout stream type, of which the lower Mad river was our example. A mile below Credit Forks, where it is still a fair trout stream, *Semotilus atromaculatus*, the two species of *Rhinicthys*, and *Catostomus commersonii* were abundant; a *Cottus* and two *Catonotus flabellaris* were taken. A few miles below this point trout no longer occur commonly, and other stream fish appear and become abundant. Plants, too, increase in variety, including in the rapid water *Potamogeton pectinatus*, *P. heterophyllus?*, and in the quiet stretches *P. natans*, *P. americanus*, *P. richardsonii*, *P. perfoliatus*,

TABLE 21. Food of fish in swift brown-water streams

	Speckled trout *S. fontinalis*			Sucker *C. commersonii*	Horned dace *S. atromaculatus*	Shiner *N. cornutus*	Sunfish *E. gibbosus*	Perch *P. flavescens*
Number of specimens from East river	0	0	3	0	2	8	0	1
Number of specimens from Nipissing river	0	0	7	0	5	10	6	1
Number of specimens from Petawawa river	2	0	0	2	2	2	0	0
Number of specimens from Madawaska river	3	5	0	0	0	0	0	0
Average length in inches	17.3	14.6	7.8	5.6	5.8	5.7	4.3	4.8
Variation in length	16-18	13.5-15	6.0-9.5	4.8-6.5	4.5-8.8	4.5-6.5	3.8-4.9	4.2-5.5
Average volume of contents in cubic mm.	35000	4400	340	250	300	400	220	50
Filamentous algae	—	—	—	—	3	39	73	—
Diatoms	—	—	—	6	—	—	—	—
Bryozoa: *Plumatella*	—	—	—	—	—	54	15	90
Gastropoda: *Ferissia*	—	—	—	—	—	—	12	—
Crustacea: Cladocera	—	—	—	18	—	—	—	—
Copepoda	—	—	—	14	—	—	—	—
Ostracoda	—	—	—	12	—	—	—	—
Cambarus bartonii	10	18	—	—	97	—	—	—
Aquatic insects								
Ephemeroptera	—	+	3	—	—	—	—	—
Odonata	+	—	—	—	—	2	—	—
Plecoptera	+	3	9	—	—	—	—	—
Megaloptera: *Chauliodes*	+	—	—	—	—	—	—	—
Trichoptera: Hydropsychidae	+	51	9	—	—	—	—	—
Unidentified	+	4	13	—	—	—	—	—
Larval cases	—	6	—	—	—	—	—	—
Heteroptera: *Rhagovelia*	—	—	3	—	—	—	—	—
Diptera: Simuliidae	+	1	20	—	—	—	—	—
Chironomiidae	+	+	2	50	—	+	—	10
Others	—	—	5	—	—	—	—	—
Coleoptera: *Psephenus*	—	—	1	—	—	—	—	—
Terrestrial insects	—	—	+	—	—	—	—	—
Fish: (dace, shiners, suckers)	82	15	35	—	—	—	—	—
Frogs	3	—	—	—	—	—	—	—
Total surface food	0	0	2	0	0	0	0	0
Total bottom food	100	100	98	100	100	100	100	100

P. crispus, P. zosterifolius, Elodea canadensis, Vallisneria spiralis, Heteranthera dubia, Ceratophyllum demersum, Nymphaea advena, Myriophyllum spp., and a great variety of upright emergent species. Studies of the fish fauna were made near the mouth of the river by Dymond *et al.* (1929). They record from a stony bottom: *Catostomus commersonnii, Hypentelium nigricans, Nocomis micropogon, Rhinicthys cataractae, Semotilus atromaculatus, Notropis whipplii, N. rubellus, N. cornutus, Hyborhynchus notatus, Noturus flavus, Esox lucius, Percina caprodes, Boleosoma nigrum, Poecilichthys coeruleus, Catonotus flabellaris, Microperca punctulata,* and *Micropterus dolomieu;* and from quiet lagoons with muddy bottom and abundant vegetation: *Catostomus commersonii, Moxostoma rubreques, M. aureolum, Cyprinus carpio, Notropis deliciosus, N. cornutus, Notemigonus crysoleucas, Hyborhynchus notatus, Ameiurus nebulosus, Noturus flavus, Esox lucius, Anguilla rostrata, Micropterus dolomieu, Helioperca incisor, Pomoxis sparoides,* and *Ambloplites ruprestris.*

The precise factor or factors which limit the occurrence of speckled trout in these warm rivers is not fully understood; temperature, hydrogen-ion concentration, oxygen supply, turbidity, paucity of spawning beds, competition of such fish as the creek chub, and active destruction by such fish as the black bass and pike have all been suggested. Creaser and Brown (1927) have demonstrated clearly the high negative correlation which exists between water temperature and the occurrence of trout, which correlation, of course, does not at once establish a direct causal connection. The view of Breder (1927), that the effect of temperature is made apparent only through decreased oxygen content, is not substantiated by my observations, nor by the experiments of Gutsell (1929). It has already been vigorously attacked by Creaser in a later paper (1930). The last author has apparently eliminated the ordinary physico-chemical water characteristics, other than temperature, as possible direct causative agents in determining the "voluntary toleration limit" of the species. There remain the biological characteristics, notably the presence of enemy or competitor fishes, to be considered before temperature can finally be accepted as the immediate limiting factor.

Creaser (1930) says: "The maximum temperature for natural self-sustaining brook-trout waters is now rather well established as about 19° C. or 66° F. When the temperature goes higher than this maximum for any considerable period the brook-trout soon disappear." He considers 19° C. the voluntary toleration limit, rather than the "lethal limit", which Embody (1922) found may be as high as 28° C. How long a "considerable period" may be is, of course, debatable, but if a stream rises above 19° C. for from two to six hours on all the hot clear days of midsummer, its fish must be fairly well adapted to such temperatures. The Mad river, an excellent trout stream, rose above 19° C. on many occasions in 1930, commonly remaining so for a period of 12 hours, and on one occasion for more than 36 hours (*cf.* figure 4). The temperatures of a number of Ontario streams, taken on a clear day in summer, are shown below. Many of these are obviously a degree or more below the probable maximum for the day, and there is no assurance that any (except those for the Mad river) represent the seasonal maximum.

It is clear that many good Ontario trout streams commonly attain at least to 21 or 22° C. in summer, and probably remain at this point for several hours each bright day. (The curve of water temperature is quite flat near its maximum.) The limit of 24° C. maximum temperature, selected from these data and used in the classification to separate "warm rivers" from "trout streams", may even prove to be too low when additional data are available from the brown-water streams of the north. In any case it cannot claim great exactitude when applied to individual examples. There is a suggestion that the presence or absence of other fishes is of first-rate importance in border-line cases; for example, would the Mad river retain its present large trout population if bass, suckers, *etc.*, had access to its waters? Again, trout caught near the lower limit of their stream habitat are commonly of large size; whatever factor denies the species

a more extended range must evidently bear most heavily upon the younger specimens.

We may agree with Creaser and Brown that "the temperature difference between a very good and a very poor trout stream is very slight" not more than about 2° C. But the evidence from these streams is that the voluntary toleration limit of speckled trout is close to 24 °C. (75° F.),

County or District	River	Date	Time	Temperature C.	Occurrence of speckled trout
Muskoka..	Upper Oxtongue..	August 16, 1929	3.15 p.m.	18.8	Abundant
Dufferin...	Credit near Inglewood.....	August 30, 1928	4.40 p.m.	20.1	Occasional
Ontario...	Siloam outlet	August 15, 1928	2.40 p.m.	20.8	Present
Simcoe....	Lower Mad......	July 24, 1930..	4.30 p.m.	21.0	Frequent
Grey......	Styx............	July 8, 1930...	5.15 p.m.	21.0	Frequent
Dufferin...	Noisy...........	July 2, 1928...	4.05 p.m.	21.3	Frequent
Bruce.....	Sauble..........	July 11, 1930..	6.00 p.m.	21.5	Rare
Grey......	Upper Mad......	July 6, 1928...	3.00 p.m.	22.3	Abundant
Dufferin...	Boyne..........	July 17, 1928..	3.30 p.m.	22.4	Frequent
Muskoka..	Lower Oxtongue..	July 18, 1930..	6.00 p.m.	22.4	Occasional
Muskoka..	East............	July 19, 1930..	6.00 p.m.	22.8	Frequent
Dufferin...	Pine............	July 4, 1928...	3.00 p.m.	22.9	Frequent
Grey......	Mad............	July 25, 1930..	5.00 p.m.	23.1*	Abundant
Grey......	Mad............	July 27, 1930..	6.15 p.m.	23.4*	Abundant
Grey......	Mad............	July 28, 1930..	6.00 p.m.	23.9*	Abundant
Bruce.....	Lucknow creek...	July 10, 1930..	5.00 p.m.	23.8	None
Bruce.....	Lower Saugeen...	July 10, 1930..	6.00 p.m.	24.8	None
Peel......	Credit at mouth..	July 13, 1927..	4.40 p.m.	25.5	None

*Recording thermometer maximum for the day.

rather than 19° C. (66° F.). In fact, if a maximum of 19° C. were to be taken as the limiting temperature, many of the best trout-fishing streams in Ontario would be excluded.

GENERAL SUMMARY

In the past aquatic biology has been largely concerned with the investigation of lakes. The conditions which obtain in fluviatile waters are more varied, but equally susceptible to systematic ecological treatment. The detailed examination of one type of stream and a similar though less comprehensive survey of other types serve as an introduction to such a study of Ontario waters.

The characteristics which distinguish one river from another have to do with its size, the physical and chemical properties of its water, the texture of its bottom, and the nature and abundance of its flora and fauna, all of which are correlated in greater or lesser degree. In formulating a classification of Ontario streams, volume of flow and temperature have been used for the primary groupings, current speed and bottom texture to separate the secondary classes, and quantity of dissolved solids in the water for the final subdivision.

Small streams or "creeks", are to be divided on a temperature basis into spring creeks and drainage creeks. The colder types at least are marked off into distinct classes according as their bottom is of stones, sand, mud, or humus. With each sort of bottom is associated a peculiar fauna, which is greatest in quantity over rich humus, and almost nil in barren sand beds. In soft water, speckled trout are typically the only fish in such streams; in hard waters the sculpin (*Cottus* sp.) and stickleback (*Eucalia inconstans*) are often present in small numbers.

Larger streams are also to be separated on account of their temperature, the dividing point—a summer maximum of 24° C.—being near the limit for the frequent occurrence of speckled trout. In the cooler type, trout are dominant, having associated with them the horned, black-nosed, and long-nosed dace, sculpin, sometimes the common sucker, and in soft waters the chub *Couesius*. In the warm rivers trout do not occur, the important piscivorous fishes being pike and Centrarchids, which are accompanied by a great variety of minnows, suckers, catfish, darters, *etc.*

The Mad river is one of the slow mud-bottomed trout streams, and is the one which has received most detailed attention in this paper. Most good Ontario trout streams are swift and stony, and, of course, have a fauna quite distinct from the slower rivers. Although soft waters are in most respects very similar to hard waters as regards fauna and flora, a few organisms, *e.g. Chara* and *Simulium*, appear to have their distribution or numbers controlled by the carbonate content of the water or some associated factor.

Because of the value of their game fish, the extension of our knowledge of the biology of the various classes of streams is of prime economic importance. Scientifically, such information will make our understanding of river communities more nearly comparable to what is now known of lakes.

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