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AVAILABILITY OF AQUATIC INSECTS AS FOOD OF THE SPECKLED TROUT, *SALVELINUS FONTINALIS*

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During the past 50 years an increasing number of papers has been published on the feeding habits of speckled trout. Some of these have dealt with feeding in lakes, others with the feeding in streams. Among the latter, the paper by Clemens (1928) on food of trout from streams in Oneida County, New York, gives an excellent analysis of the food of trout of different sizes along with a review of the pioneer literature on the subject. Needham (1930) published his findings on the feeding of trout in New York streams, giving a most comprehensive treatment of the seasonal changes in food from month to month throughout the whole year. Ricker (1934) has followed the feeding of different sizes of trout throughout the summer season in some Ontario streams. In all these treatments and others which have been done, the importance of aquatic insects in the diet has been demonstrated.

In the above papers the findings are for trout from many streams and many areas in those streams so that a good general picture of the feeding in those localities has been obtained. In the present work a collection of fish was taken from one restricted rapids in an effort to determine what elements of the bottom fauna were utilized by trout. The Oxtongue River in Algonquin Provincial Park was chosen as the site. The project formed part of the program of the Ontario Fisheries

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The particular rapids was about 100 feet in length, 30 feet in width and was located immediately below a dam carrying about a 12-foot head of water in Tea Lake above. Below the rapids the river was more gently flowing, to the next rapids about a half mile downstream. While most of the fish were taken from the one restricted area, a few were taken from a similar rapids further downstream.

Fishing was carried on almost daily at different hours of the day from June 9 to September 11, 1940. Angling with brown hackle flies, sometimes with an insect larva or nymph attached to the fly, provided the only means of catching the fish.

One hundred and twenty-seven trout were taken and, of the 118 of these which were measured, 16 were from 5 to 6 inches; 18 from 6 to 7 inches; 35 from 7 to 8 inches; 18 from 8 to 9 inches; 16 from 9 to 10 inches; 7 from 10 to 11 inches; 5 from 11 to 12 inches; and 3 from 12 to 13 inches. The disproportionately great 7- to 8-inch group may be significant as indicating a large class of this size in the population or it may indicate merely a predilection on the part of the trout of this size for taking the particular type of bait offered. In weeks from June 9 to September 11, respectively, 41, 25, 23, 10, 10, 4, 0, 0, 0, 0, 0, 0, 8, and 6 trout were caught. The catch, on the basis of fishing effort (fish per rod hours), was 2.68, 1.50, 1.98, 1.16, 0.87, 0.84, 0, 0, 0, 0, 0, 0, 1.20, and 0.73, respectively. Figure 1 shows that no fishing was done in the two periods July 20-27 and August 9-16, but on 3 days previous to July 20 no fish were caught and there were no rises to the fly. This held true for all fishing from then to September 1. The fish taken on September 1 were all relatively large males and were feeding voraciously.

The period during which no fish were caught corresponded with a general increase in water temperature which concided for the most part with the removal of stoplogs from the dam. This allowed warm surface water from the lake to flow over the dam, thus raising both the level of the water in the rapids and its temperature.

It is worth noting here that smallmouth black bass (*Micropterus dolomieu*) took the trout fly very actively in the period during which the trout were not taken and their stomach contents were almost identical with those of trout, the food being almost entirely insects. These bass were about 5 inches in length and frequented the rapid water where trout formerly had been active. The creek shiner (*Notropus cornutus*) appeared in the rapids in August and took the fly readily. A few small perch were taken by the same methods throughout the summer.

The stomach contents of these fish were examined and counts were made of the numbers of insects of the various groups represented, together with their total volume. The contents of only the cardiac portion of the stomach were considered since in the pyloric portion digestion is advanced to the point where the insects are too fragmentary to be readily identified.

By means of a cage trap which was cleared daily and covered a square yard of bottom in the rapids, the kinds of insects emerging and their relative numbers were determined (Ide, 1940). This is recorded below as emerging material. An estimate was also made of drift material as it flowed out of the rapids by placing a small wire gauze seine of 14 meshes to the ~~square~~ inch at the lower limit of fast water. This seine was 12 inches wide and totaled 72 square inches. It was cleared daily at approximately the same hour. No bottom samples were taken to determine the aquatic stages of the insects.

Emerging material (excluding the 2 weeks when no collections were taken).—From the square yard sampling area a total of 15,087 insects emerged during the period from June 9 to September 15, with a total volume of 67 cubic centimeters. Notable in this list is the great dearth of Ephemeroptera which in many other places is a dominant group. This will explain the apparent discrepancy in stomach-content results when compared with those reported by other workers. (In recent experiments with this method Sprules (1942) has demonstrated that hourly collecting of the insects from the cage rather than daily collecting gives a much higher figure for emergence.)

TABLE 1. PERCENTAGES OF DIFFERENT AQUATIC INSECT GROUPS EMERGING FROM ONE SQUARE YARD OF BOTTOM

	Numbers per cent	Volume per cent
Trichoptera	22.4	60.5
Ephemeroptera	1.5	2.9
Plecoptera	0.3	13.2
Simuliidae	32.5	11.6
Empidae	10.4	5.2
Chironomidae	32.0	4.7
Other insects	0.9	1.9

Drift material.—This material was divided into five categories in which vegetable debris was not considered although it formed a considerable bulk. There were: (1) aquatic, comprising larvae and nymphs; (2) emerging, comprising pupae of caddisflies, subimagos of mayflies and Simuliidae where both males and females were taken in about equal numbers; (3) Exuviae of aquatic insects, comprising an inedible component; (4) aerial, including terrestrial insects and the flying stages of aquatic insects; and (5) lacustrine forms such as *Cladocera* and *Chaoborus* larvae and pupae which came from the lake above. In the table the numbers of pupal exuviae and cocoons of *Simulium* have been omitted. They bulked very large and their inclusion would have greatly changed the relative percentages of the groups as indicated by the high percentage shown when these were included in the volume column.

TABLE 2. PERCENTAGES OF DIFFERENT COMPONENTS OF THE DRIFT

	By number per cent	By volume per cent
Aquatic	55.0	9.6
Emerging	3.1	6.3
Exuviae	16.5+	56.1
Aerial	15.4	23.4
Lacustrine	10.0	4.6

In general we may conclude that in this particular situation the casualties among the aquatic insects were small and that the bulk of drift material was inedible exuviae. There were several exceptions to this general conclusion. For instance, the high figure for aerial stages was due almost entirely to one incident which assumed the proportions of a catastrophe. When the water was raised suddenly in the stream by removing stoplogs from the dam many adult caddisflies which had been resting on the stones above water were dislodged and swept downstream. The high percentage of aquatics by number largely resulted from the many casualties in small hatching caddis larvae which were dislodged and lost before they could become entrenched on the stones. This explains the small volume supplied by the aquatic category in spite of the rather high number of individuals. That this particular location is unusual in the small amount of edible drifting material is evident from a study of drift elements in the Oswego River system (Needham, 1927) in which the importance of this source of food to the trout is stressed.

Bottom organisms.—While no samples were taken in this rapids, it was noted that *Simulium* larvae and pupae were present in large numbers on the exposed surfaces of the stones and that Trichoptera larvae were mainly those of the Hydropsychidae and related families which constructed their nets and shelters on the exposed upper surfaces.

The contents of all stomachs showed the following proportions (a departure from the usual treatment is the separating of the emerging material from other categories):

TABLE 3

	By number per cent	By volume per cent
Aquatic (including fish, crayfish and leeches as well as aquatic stages of insects)	66	64
Emerging	18	24
Aerial	16	12

In the aquatic, dominant items forming 90 per cent by volume of the whole were fish 29 per cent, Trichoptera larvae 27.4 per cent, *Simulium* larvae 18.1 per cent, *Simulium* pupae 2.8 per cent and Odonata nymphs 12.2 per cent. The feeding on these larvae is apparently an active foraging on the surface of the stones where they are available. *Simulium* larvae are frequently in conspicuous patches and as many as 600 larvae were found in one stomach. The finding of groups of *Simulium* cocoons with their pupae adhering together is also indicative of feeding by attacking these insects in their position on the stones. Trichoptera larvae were probably taken by the same method.

In the emerging group Trichoptera pupae (mainly Hydropsychidae) formed 57 per cent by number and 92 per cent by volume of the whole. *Simulium* males and females were taken in numbers as they moved to the surface of the water to emerge but they did not bulk large on account of their small size. Ephemeroptera subimagos were insignificant in numbers but since this group of insects was represented in the stream by very few individuals this is not surprising.

Of the aerial group Trichoptera adults formed 46 per cent, *Simulium* adult females 22 per cent, terrestrial insects 16 per cent and others 16 per cent by volume. The *Simulium* adult females are included in the aerial group because of a chance observation. About 2 weeks after the main emergence of *Simulium* from the water great masses of dead females were found floating on the surface of the water, forming a thick layer in eddies and backwaters of the rapids. These individuals were picked up in great numbers, probably many at a time, by the trout, over 1,600 being found in one trout of 10 inches.

I have followed Clemens' and Needham's policy in listing the frequency of occurrence of organisms or, in other words, the number of stomachs in which a particular type of organism occurred. In 127 stomachs some of the more abundant forms occurred as follows:

Trichoptera adults	73	stomachs
Trichoptera pupae	103	"
Trichoptera larvae	100	"
Simulium adults	76	"
Simulium pupae	49	"
Simulium larvae	82	"
Chironomid pupae	62	"
Chironomid larvae	77	"
Terrestrial insects	33	"
Ephemeroptera adults (imagos)	8	"
Ephemeroptera nymphs	30	"
Fish	13	"

With the single exception of the Trichoptera, the larval stages of insects occur more frequently in the stomachs than do other stages. This is to be expected if these larvae are reasonably available as they are present on the bottom for relatively long periods of time. It is rather significant that caddis pupae, although they are only available for a brief instant when they are coming to the surface of the water to emerge, are taken by more trout than are larvae. Leonard (1938) has found a similar situation in the great abundance of Chironomid pupae in some small trout, seven times as many pupae as larvae being taken although the samples of the bottom showed from 40 to 300 times as many larvae as pupae. That the pupae of Trichoptera are taken in large numbers though they are available for a short period only would seem to indicate that they are particularly vulnerable at this stage because of their size, movements, and isolation from surrounding objects.

The emergence of aquatic insects is more pronounced in certain seasons than in others. From Table 4 it may be ascertained that nearly 70 per cent by number and about 77 per cent by volume of the emerging material is out by July 20 for the period investigated (see 2 weeks missed in latter half of summer). Consequently, the emerging material is utilized in the early part of the summer while at other times the fish are restricted more to aquatic stages on the bottom and the examination of the stomachs revealed a higher percentage of aquatic material at this time.

TABLE 4. WEEKLY EMERGENCE OF AQUATIC INSECTS FROM 1 SQUARE YARD OF BOTTOM

	Numbers per cent	Volume per cent
June 9-15	19.1	23.4
16-22	10.2	15.4
23-29	12.7	16.5
30 to July 6	8.8	10.8
July 7-13	14.4	7.5
14-20	4.5	3.5
21-27		
28 to August 3	3.5	4.3
Aug. 4-11	2.1	2.1
12-17		
18-24	3.6	1.7
25-31	5.5	4.9
Sept. 1- 7	10.5	5.6
8-15	5.1	4.3
Total	100.0	100.0

Different species of aquatic insects emerge over particular periods of the day, some very restricted and others with a more protracted period. By collecting insects from the cage every 2 hours the time during which particular groups were emerging was determined. *Simulium,* for instance, began to emerge between 6:00 a.m. and 8:00 a.m., the maximum emergence occurred between 10:30 and 12:30 a.m., and a small number of individuals continued to emerge even as late as 4:00 p.m. Most of the Chironomidae and Trichoptera, on the other hand, emerged during the night with smaller numbers during the forenoon and afternoon.

Trout taken early in the morning contained no *Simulium* adults in the cardiac portion of the stomach. Those taken during the forenoon when *Simulium* males and females were emerging contained large numbers of these insects. Fish taken during the afternoon and evening had a smaller number than those taken during the forenoon. It would appear that these small insects quickly pass through the anterior part of the stomach. Large organisms remain correspondingly longer.

In this connection the fish themselves show a greater feeding activity during the forenoon and again in the evening. The examination of stomachs of trout taken at different hours of the day showed that only a small amount of food was present in the stomachs of trout taken very early in the morning. Fish taken later in the morning had a large amount of food. From noon to early afternoon the fish caught again had less in their stomachs, with an increase in stomach content of fish caught in the evening when they again began to feed actively. Hore (1940) by recording strikes at artificial fly cast at intervals throughout the day records the feeding activity diminishing in the following order, 5:00 to 8:00 p.m.. 8:00 to 11:00 a.m.; 5:00 to 8:00 a.m.; 2:00 to 5:00 p.m.; and 11:00 a.m. to 2:00 p.m. This work was carried out on the Apple River in Nova Scotia. Some insects emerging during the periods of cessation in feeding of the fish are relatively unavailable as they emerge.

In rapids many of the insects are on the under sides of stones and therefore relatively immune from attack except when they come to the surface to emerge. Even those larva which are on the upper surfaces will often be inaccessible in shallow rapids where the fish are unable to reach all sections. Similarly large weed masses, well recognized as conducive to the production of great numbers of aquatic insects, give a certain protection to the insects which they harbor. Only a certain percentage in the peripheral zones is easily accessible to the feeding fish (Mottram, 1940).

The prevailing weather influences the availability of aquatic organisms, particularly in cold weather when the insects individually take a longer time to emerge from the water. Under certain circumstances they may fail to rise off the water entirely, remaining an easy prey to surface feeding trout (Ide, 1935; Mottram, 1940).

Availability varies with the size of the organism relative to the size of the fish. Some organisms are obviously too large for smaller fish. White (1930) records Chironomid larvae, among the smallest of the aquatic insects, as forming about 70 per cent of the volume of the stomach contents of speckled trout fry. In trout of larger size, large insects are utilized and, in still larger trout, crayfish and finally fish are used in increasing proportion. In the present investigation it was

TABLE 5

		June				July				August			September		
A.	2.68	1.50	1.98	1.16	.87	.84	*	0	0	*	0	0	1.20	.73	*Salvelinus*
B.	9⅜	7⅛	6⅞	6⅞	7¼	8							9½	7⅝	*Salvelinus*
C.	0	.41	.16	.22	.26	1.48		.68	3.50		2.40	2.25	.20	.18	*Micropterus*
D.								1.22	.50		1.60			.27	*Notropis*

A.—Fish per rod hour. B.—Average length in inches. C.—Fish per rod hour. D.—Fish per rod hour. *—No fishing.

found that fish constituted about 70 per cent of the bulk of food of 12- to 13-inch trout. This is not universally true, however, since large speckled trout caught in lakes are frequently found to contain nothing but *Cladocera* and other plankton organisms in their stomachs.

In any study of the productivity of a stream from the standpoint of trout production, determination of the availability of insects forms an essential feature. In the present paper the importance of the emerging individual in the trout diet has been shown by separating these individuals, in the counts made of stomach contents, from other components of the diet. That some of these organisms, because of their greater degree of availability, are utilized more than others, would indicate that a study of the life cycles, relative abundance, habits, and distribution of aquatic insects is desirable. Investigations of conditions which promote the increase of these more desirable groups and the factors which make them available to the trout should also be investigated. Mottley (1938) offered criticism of existing techniques for arriving at the productivity of streams and made suggestions for procedure in determining the standing bottom fauna. He has, however, overlooked the importance of determining the turnover rather

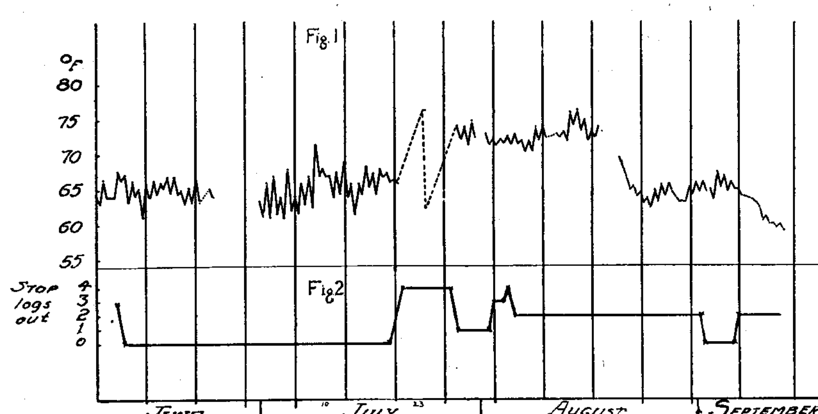

Figure 1.—Temperature of water. Figure 2.—Depth of water according to the number of stoplogs removed from the dam above the rapids.

than the standing crop; a meager bottom fauna in the lower reaches of a stream may, by faster growth, produce as much or more than a richer bottom crop in the upper portions of the stream.

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