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REPORT NO. 656

SOME OBSERVATIONS ON THE WINTER FEEDING HABITS OF BROOK TROUT IN RELATION TO NATURAL FOOD ORGANISMS PRESENT

by

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Section I-B is the furthest downstream of the new channels excavated along Hunt Creek during the fall of 1940 (see attached map). Water first flowed through I-B on October 16, 1940. Because adult aquatic insects had almost entirely disappeared before this date, the first appearance and subsequent increase of invading bottom organisms in the newly-created habitat was observed with considerable interest, it being realized that almost all of the invaders must, perforce, be supplied by drifting from natural habitats in the original channel upstream.

The first bottom-inhabiting organisms detected were larvae of the black fly, Simulium, probably S. venustum. They were first noticed, in exceedingly small numbers, on October 23, one week after the new channel was opened.

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*The assistance of E. L. Cooper with the stomach analyses here reported is gratefully acknowledged.

The subsequent increase of organisms was very gradual, and for some time numbers were too scant to permit accurate determination by the square-foot sampling method. A sample taken on December 20, however, yielded 187 organisms, divided among eight species, and totaling 0.20 cubic centimeters in volume (Table 4). The fauna continued to increase. On January 24, 1941, a square-foot sample produced a total of 19 species, representing 701 organisms, with a volume of 0.925 cubic centimeters (Table 5). This sample was taken in a mixture of fine to moderate gravel near the lower end of the section. Three days later (January 27) a sample taken near the middle of the section from a bottom of sand and moderate to coarse gravel showed the same number of species, but an increased number of larvae and pupae of the large midge, <u>Chironomus modestus</u>, a total of 999 organisms measuring 1.325 cubic centimeters (Table 6). Still further up the section, another sample was taken from sand and moderate gravel bottom on February 4. Here the occurrence of a large number of small mayfly nymphs (<u>Baetis vagans</u>) helped raise the volume of the sample to 1.575 cubic centimeters. Twenty-one species comprising 1,535 individual organisms were taken (Table 7).

Such a rapid influx of bottom organisms into the newly-created habitat was not expected. It must be re-emphasized that this channel was excavated <u>after</u> almost all adult aquatic insects had laid their eggs and perished due to the lateness of the season. Consequently, almost all of the organisms revealed by the samples must have drifted into the area from upstream, either as eggs or as nymphs and larvae. This conclusion is also favored by the fact that relatively sessile, clinging forms such as case-forming caddis larvae were of rare occurrence. In only one sample (Table 5) was a case-forming caddis represented, and then by only three specimens. One writer* has stated that when a West Virginia stream was scoured out by a flood in late August, the bottom fauna increased over four times in seven weeks. Another**, reporting on bottom fauna recovery in South Willow Creek, a high-gradient mountain stream in Utah which had been scoured out entirely by a cloudburst on August 7, listed the following figures: August 20, no bottom organisms found; Sept. 22, average numbers per square foot 152, average volume 0.30 cc.; Nov. 11, average numbers per square foot 1,040, average volume 1.57 cc.; March 2, average number per square foot 803, average volume 1.79 cc. Thus, there was noted here a five-fold increase in the bottom fauna in the first seven weeks' time, although in both streams there may have been some oviposition by adult aquatic insects before the onset of winter.

Moffett (loc. cit.) also concluded that species having the shorter life cycles were the first to re-establish themselves, but considered that the action of drift in transporting organisms was of greatest significance in the repopulation. He also noted a fact frequently borne out by our own work, namely, that as winter progresses, numbers of organisms per unit area generally decrease, but volumes meanwhile increase, growth of individual specimens more than compensating for reduction in numbers.

Our fall and winter rate of faunal influx is in good agreement with the recovery results quoted above, despite the fact that this influx began more than two months later in the season than did the recovery in either of the

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*Surber, E. W. Rainbow trout and bottom fauna production in one mile of stream. Trans. Amer. Fish. Soc. 66:193-202 (1936) 1937.

**Moffett, J. W. A quantitative study of the bottom fauna in some Utah streams variously affected by erosion. Bull. Univ. Utah 26(9):1-32, 1936.

streams discussed in the cited publications, thus ruling out almost entirely the possibility of colonization by direct oviposition. It is, therefore, quite certain that the rapid spreading of organisms in the new channel was due to the swift current of Hunt Creek in the experimental area which must constantly dislodge and transport large numbers of food organisms.

On January 18, 1941, members of the Institute staff blocked off Section I-B for the first time since it was connected with the stream on October 16, 1940. Screens were placed across the lower end of the section, and flash boards were placed at the upper end to divert the entire flow through the original channel. Section I-B was thus drained down, and all the trout occupying the area, 34 in number, were recovered. Of these, 22 were retained for stomach analysis. The size range was as follows: Standard length, 49 to 103, average 66.8 millimeters; total length, 59 to 132, average 80.3 millimeters; weight, 1 to 19, average 5.0 grams. Average condition factor was calculated as 1.66.

In comparing Tables 1 and 2 which summarize, respectively, the feeding habits of the 22 trout and the average of three square-foot bottom samples taken January 24, 27, and February 4, the first fact to catch the eye is that while aquatic Diptera (midges, black flies, etc.) composed about 85 per cent of the total volume of stomach contents, they made up only approximately 57 per cent of the total volume of bottom fauna. Mayfly nymphs accounted for about 25 per cent, by volume, of the bottom fauna, but only 7.5 per cent of the total diet. Stone fly nymphs, ranking third in importance in the bottom fauna with 6.5 per cent, ranked sixth in the trout diet, making up only 0.3 per cent of the total volume (although again ranking third in numbers).

On a numerical basis alone, aquatic Diptera composed 80 per cent of the diet, but only 57.7 per cent of the bottom fauna. Mayflies, likewise, made up only 18.8 per cent of the diet, but almost 40 per cent of the bottom fauna.

Stoneflies, accounting for three per cent of the total numbers in the bottom, entered into the diet by only 0.6 per cent.

The low position of stoneflies in the diet, as compared with their numbers in the stream, probably indicates that these nymphs, which normally occupy the under side of stones, seldom come within reach of feeding trout. This was suggested by the writer in Report No. 662, discussing analyses of stomachs collected during the 1940 fishing season. Stoneflies, as a group, can hardly be unpalatable to trout. Muttkowski*, writing of the streams of Yellowstone National Park, Wyoming, stated that on the basis of the "...examination of hundreds of stomachs of trout, especially the cutthroat trout ... it is evident that stoneflies ... form about 90 percent of the food of the trout." Hazzard and Madsen** found that stoneflies accounted for 16.5 per cent of the total food taken by a series of 36 cutthroat trout taken from the streams of Teton Park, Wyoming, during the summer months.

In each of the cited reports, the dominant stonefly was the large species *Pteronarcys californica*, sometimes called the salmon-fly, which attains a length of 2.5 to 3 inches. The stoneflies found in Hunt Creek range in size from *Allocapnia*, only about 1/4 inch long, to *Isogenus*, which seldom exceeds an inch. The heavy utilization by trout of the large western species is, therefore, probably to be explained by the much greater size of the insect, and possibly, also, by differences in method of feeding between the two species of trout.

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*Muttkowski, R. A. The food of trout in Yellowstone National Park. Roosevelt Wildlife Bull. 2(4):471-497. February, 1925.

**Hazzard, A. S., and M. J. Madsen. Studies of the food of the cutthroat trout. Trans. Amer. Fish Soc. 63:198-203. 1933.

It is shown in Table 3 that a single adult caddisfly, Neophylax autumnus, was found in one stomach. Normally "hatching" in late fall, members of this species occasionally emerge in midwinter; and the trout are apparently not unwilling to take surface food at this time.

With the foregoing in mind, the question naturally arises as to whether the disparity between total bottom fauna and total food taken is to be explained on the basis of actual selection -- expression by the trout of definite partiality for certain food organisms -- or on that of availability. Hess and Rainwater* recently proposed a calculation of ratios which they claim will supply a numerical value for the dietary preferences of trout. They do this very simply by dividing the ratios of organisms available and consumed. For example: "... if mayflies and stoneflies are available in a ratio of 2 to 1 respectively and the numbers eaten by the fish are in the same ratio, there is an equal preference for each organism (mayflies 2/2=1; stoneflies 1/1=1); but if four times as many mayflies as stoneflies are eaten, the preference ratio becomes 2 to 1 in favor of the mayflies (mayflies 4/2=2; stoneflies 1/1=1)."

The authors continue: "The accuracy of this measure of preference, then, depends upon the accuracy of the methods we use for determining the number of organisms available and the number eaten by the fish." They devote the balance of their paper to the presentation and discussion of a commendable if small-scale attempt to determine experimentally the rate at which various natural food organisms are digested at various water temperatures by brook trout. Thus, they leave the subject indicated by the title of their paper dangling

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*Hess, A. D., and J. H. Rainwater. A method of measuring the food preference of trout. Copeia, 1939, No. 3:154-157. Sept. 9, 1939.

without support. The old question of how to measure availability is ignored, for it is palpably absurd to consider that all forms found in bottom samples are equally available to trout.

However, although the authors do not suggest it, there seems to be a good possibility that their proposed method for measuring food preference of trout is actually, instead, a plausible method for measuring availability. Thus if, as is the case in the work here reported, aquatic Diptera and mayflies are present in the stream in a ratio of 3 to 2, and four times as many Diptera as mayflies are eaten, the <u>availability ratio</u> might be expressed as 2.65 in favor of Diptera ($\frac{4/1}{3/2} = \frac{4}{1.5} = 2.65$). There is little ground for supposing, in this instance, that there was any significant disparity in the rate at which small weakly-sclerotized mayfly nymphs of the genus <u>Baetis</u> and aquatic Diptera as represented by large midge larvae and pupae and large blackfly larvae, were digested.

That the digestive rate of the fish here considered was very low was shown by an interesting discovery. The fish were collected at 2:00 p.m. and placed in a tub full of water. Not until 5:00 p.m. were they killed and their stomach contents removed. At this time, three hours after the fish were removed from the stream, many of the midge and blackfly larvae and one large aquatic earthworm were still alive, and sufficiently vigorous to crawl out of the mouths of the freshly-killed fish and creep about the pan in which they had been placed. Certainly, digestion in these trout must have approached a standstill. The retarding of the digestive rate, which is almost certainly the result of low water temperatures, obviously was not accompanied by a lack of appetite, for the stomachs were well-filled. But it is questionable how much nutritional benefit accrues to the fish from such feeding. Examinations of the entire alimentary tract of trout taken in the winter have, on repeated occasions, demonstrated the presence, all through the intestine and near the vent, of soft-bodied, easily-digested food organisms still almost wholly intact. Peristaltic movements of the gut, then, may during cold weather move food organisms through and out of the alimentary tract before they have been digested. It would seem very advisable to examine this possibility further. If but little nourishment comes to the fish from natural feeding in cold weather, food supplies during the coldest part of the year would not be a critical factor in trout success. And, by the same token, experimental evidence might show that artificial feeding of hatchery trout during the coldest weather is inefficient and unnecessary. Some light should be thrown on this question by experiments now under way in Diversion Sections II-B, III-A and III-B at the Hunt Creek Experiment Station.

Referring to Table 3, it will be seen that the 22 stomachs contained a total of 5,541 specimens distributed among 32 species. The average number of food organisms per stomach was 252, the average volume of contents of an individual stomach 0.425 cubic centimeters. Table 2 shows that the average square foot of bottom contained approximately 1,114 specimens with an average volume of 1.275 cubic centimeters. Thus, an average square foot contained three times the volume and slightly over four times the number of food organisms occurring in the average stomach at the time of collection. It cannot be certainly stated, however, that all of the feeding represented by the stomach contents had been carried on in Section I-B, although the probabilities favor this view.

If, as is indicated by the findings recorded above, there is in Hunt Creek a continual and abundant downstream drift of current-borne food organisms dislodged from their normal habitat, it may not come amiss to call attention to the great practical value that would attach to a thorough and uninterrupted investigation of the extent and significance of the drift. Such a study should not only afford useful information on which to base estimates of the food-increasing value of stream-improvement devices and the probable time interval elapsing between their installation and their attainment of desirable food production, but also upon the relative importance, in trout feeding, of drift-borne bottom organisms and organisms established in their normal bottom habitats.

Needham (p. 152)*, reporting the results of operating drift nets in some of the streams of central New York during three months of summer, shows that bottom-inhabiting insects made up only 6.98 per cent of the total numbers of food organisms so collected. Since even the total numbers were relatively small, it must be concluded either that his net was not effective in removing all drift-borne forms from the current, or that the streams studied by him are not readily comparable with Hunt Creek in this respect.

A few attempts at drift net operation have been made by the writer on various Michigan trout streams. The chief drawback of the method lay in the fact that once an insect lodged in the net, current pressure very soon killed and crushed it, so that it was impossible to conclude what percentage of the forms captured were alive when first trapped. It should be possible, however, to devise some method for recovering organisms from the drift without damaging them.

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*Needham, P. R. Trout streams. Comstock Publishing Co., Ithaca, N. Y., pp. 1-233 + i-x. 1938.

SUMMARY

1. Water was first admitted to the newly-excavated stream diversion Section I-B on October 16, 1940.
2. The first bottom organisms to invade the new habitat, blackfly larvae, were observed one week later.
3. Nine weeks after the section was opened, a square-foot bottom sample contained 187 organisms representing eight species with a volume of 0.20 cc. Subsequent bottom samples gave the following results: January 24, 1941, 19 species, 701 organisms, volume 0.925 cc.; January 27, 19 species, 999 organisms, volume 1.325 cc.; February 4, 21 species, 1535 organisms, volume 1.575 cc.
4. Thirty-four brook trout were removed from the section when it was first blocked off on January 18, 1941. Of these, 22 were retained for stomach analysis.
5. A comparison of stomach contents with bottom samples revealed that feeding and natural occurrence of food organisms were not in the same ratio. Possible explanations are suggested, with comments on methods of measuring availability.
6. The digestive rate had fallen so low that insects and worms were able to crawl out of the stomachs of the trout three hours after being devoured. Possible practical applications of this finding are mentioned.
7. Possible significance of drift of bottom organisms to trout feeding and stream improvement is discussed.

INSTITUTE FOR FISHERIES RESEARCH

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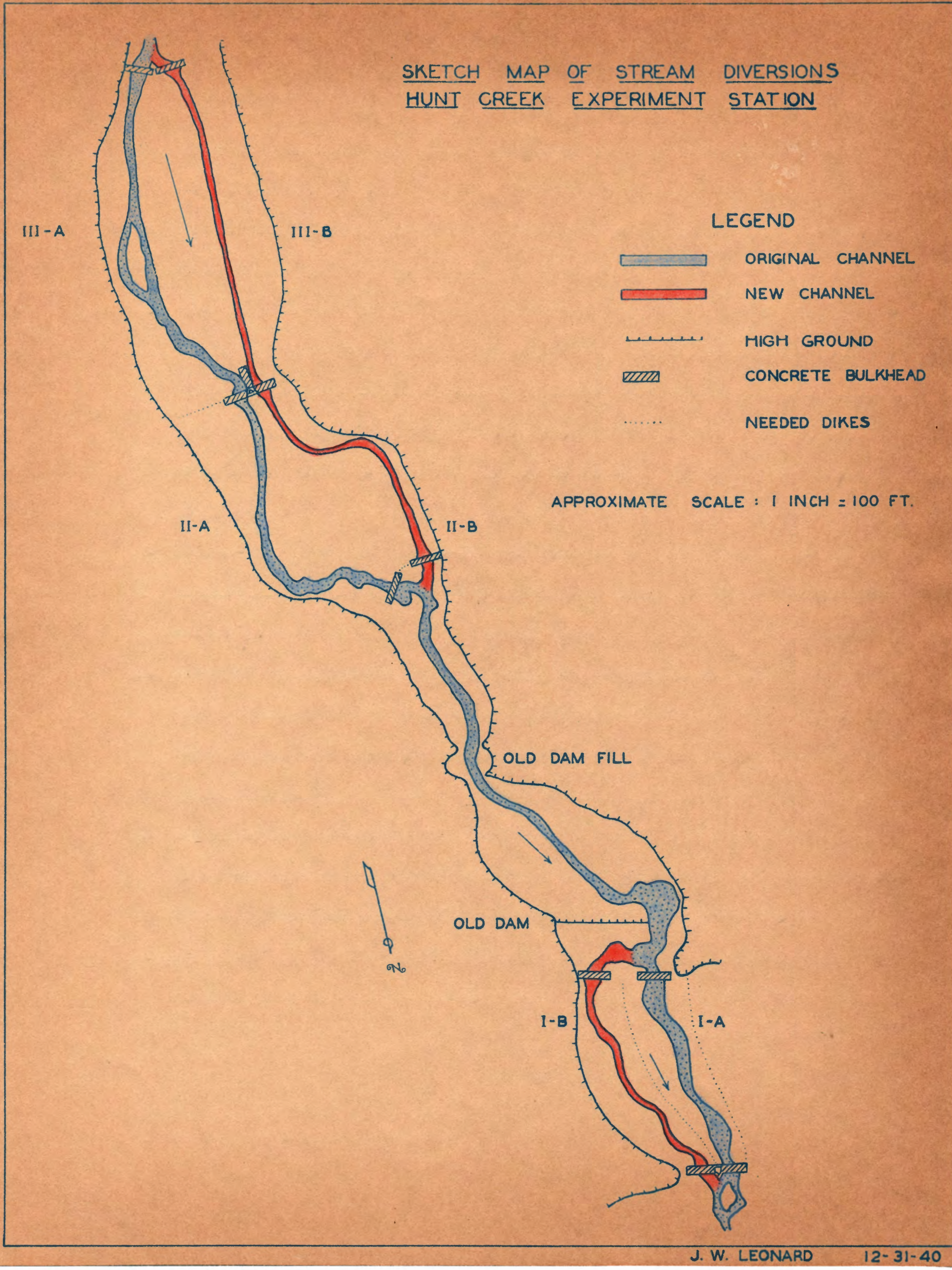

J. W. LEONARD 12-31-40

Table 1

Trout stomach analyses, Hunt Creek, Diversion Section I-B.
Based on 22 trout taken January 18, 1941.
Diet summarized by major groups of food organisms,
in order of importance on a volumetric basis.

ORGANISM	Number of species	No. of individuals	No. of stomachs containing organisms	Most organisms in any stomach	Least organisms in any stomach	Av. no. of organisms in stomachs containing them	Per cent of total volume
DIPTERA (Flies and midges)	14	4,435	22	690	25	201.6	84.7
EPHEMEROPTERA (Mayflies)	3	1,042	22	141	3	47.4	7.5
ANNELIDA (Aquatic worms)	1	2	2	1	1	1.0	4.0
TRICHOPTERA (Caddisflies)	7	20	13	5	1	1.5	1.6
MALACOSTRACA (Shrimp)	1	3	2	2	1	1.5	1.6
PLECOPTERA (Stoneflies)	3	38	15	7	1	2.5	0.3
HEMIPTERA (Water bugs)	1	1	1	1	1	1.0	0.3

Table 2

Average of three square-foot bottom samples taken from Diversion Section I-B, January 24 to February 4, 1941, all from similar situations. Listed in order of importance on a volumetric basis. Numbers of individuals shown to nearest whole number unless lower than one.

ORGANISM	Number of individuals	Per cent of total volume
DIPTERA (Flies and midges)	643	56.9
EPHEMEROPTERA (Mayflies)	422	24.8
PLECOPTERA (Stoneflies)	33	6.5
TRICHOPTERA (Caddisflies)	8	5.9
ANNELIDA (Aquatic worms and leeches)	4	5.2
MALACOSTRACA (Freshwater shrimp)	1	0.7
HYDRACARINA (Water mites)	2	trace
COLEOPTERA (Beetles)	0.3	trace
TURBELLARIA (Flatworms)	0.3	trace
Totals	1,113.6	100.0

Average volume, 1.275 cubic centimeters per square foot.

Table 3

Trout stomach analyses, Hunt Creek, Diversion Section I-B. Based on 22 trout taken January 18, 1941. Size range: Standard length, 49-103 mm.; total length, 59-132 mm.; weight, 1-19 grams.

Average standard length: 66.8 mm.
Average total length: 80.3 mm.
Average weight: 5.0 g.

Average Condition Factor: k = 1.66

ORGANISM	Number of species	No. of individuals	No. of stomachs containing organisms	Most organisms in any stomach	Least organisms in any stomach	Av. no. of organisms in stomachs containing them	Per cent of total volume
ANNELIDA (Worms)							
Lumbriculidae	1	2	2	1	1	1.0	4.0
MALACOSTRACA (Shrimp)							
Gammarus sp.	1	3	2	2	1	1.5	1.6
EPHEMEROPTERA (Mayflies)							
Ephemerella invaria - N	1	6	5	2	1	1.2	trace
Blasturus nebulosus - N	1	1	1	1	1	1.0	trace
Baetis vagans - N	1	1,035	22	141	3	47.0	7.5
PLECOPTERA (Stoneflies)							
Leuctra tenuis - N	1	1	1	1	1	1.0	trace
Allocapnia torontoensis - N	1	36	15	7	1	2.4	trace
Isogenus frontalis - N	1	1	1	1	1	1.0	0.3
HEMIPTERA (Water bugs)							
Corixidae - A	1	1	1	1	1	1.0	0.3
COLEOPTERA (Water beetles)							
Bidessus sp. - A	1	1	1	1	1	1.0	trace
TRICHOPTERA (Caddisflies)							
Hydroptilidae - L	1	1	1	1	1	1.0	trace
Mystrophora americana - L	1	1	1	1	1	1.0	trace
Mystrophora americana - P	1	1	1	1	1	1.0	trace
Chimarrha aterrima - L	1	2	2	1	1	1.0	trace
Hydropsyche sparna - L	1	8	6	2	1	1.3	1.0
Limnophilidae - L	1	4	4	1	1	1.0	0.3
Neophylax autumnus - A	1	1	1	1	1	1.0	0.3
Brachycentrus americanus - L	1	2	1	2	2	2.0	trace
DIPTERA (Midges, blackflies)							
Tipulidae - L	1	12	8	5	1	1.5	0.3
Tipula sp. - L	1	3	1	3	3	3.0	1.0
Rhaphidolabis sp. - L	1	2	1	2	2	2.0	0.3
Chironomus modestus - L	1	596	22	174	1	27.0	27.5
Chironomus modestus - P	1	18	8	10	1	2.2	0.5
Chironomidae - L	3	380	20	47	1	19.0	1.9
Chironomidae - P	3	2	1	2	2	2.0	trace
Ceratopogonidae - L	1	1	1	1	1	1.0	trace
Simulium sp. - L	1	3,420	22	622	6	155.4	53.2
Chrysops sp. - L	1	1	1	1	1	1.0	trace

Average number of organisms per stomach: 252
Average volume of stomach contents: 0.425 cubic centimeters.

Table 4

Square-foot stream bottom sample taken from Diversion Section I-B in 4 inches of water over fine to moderate gravel.

December 20, 1940, 9:00 a.m. Air 34°F., water 38°F. Light rain.

ORGANISM	No. of species	No. of individuals	Volume in c.c.	Per cent of total volume
EPHEMEROPTERA (Mayflies)				
Ephemerella invaria - N	1	12	trace	trace
Baetis vagans - N	1	3	trace	trace
TRICHOPTERA (Caddisflies)				
Rhyacophila sp. - L	1	1	trace	trace
Hydropsyche sparna - L	1	1	trace	trace
DIPTERA (Midges, flies, etc.)				
Tipulidae - L	1	1	trace	trace
Chironomus modestus - L	1	91	0.125	62.5
Chironomidae - L	2	78	0.025	12.5
All above "traces" combined:			0.025	12.5
Totals	8	187	0.200	100.0

Table 5

Stream bottom sample, one square foot, taken from Diversion Section I-B in 4 to 5 inches of water over fine to moderate gravel.

January 24, 1941, 8:30 a.m. Air -3°F.; water 33°F. Snowing.

ORGANISM	No. of species	Number of individuals	Volume in c.c.	Per cent of total volume
ANNELIDA (Aquatic worms)				
Tubificidae	1	1	trace	trace
EPHEMEROPTERA (Mayflies)				
Paraleptophlebia mollis - N	1	1	trace	trace
Ephemerella invaria - N	1	15	0.025	2.7
Baetis vagans - N	1	278	0.225	24.3
PLECOPTERA (Stoneflies)				
Leuctra tenuis - N	1	4	0.025	2.7
Allocapnia torontoensis - N	1	15	0.025	2.7
Isoperla sp.	1	1	trace	trace
TRICHOPTERA (Caddisflies)				
Mystrophora americana - L	1	3	trace	trace
Rhyacophila sp. - L	1	4	0.050	5.4
Chimarrha aterrima - L	1	1	trace	trace
Hydropsyche sparna - L	1	1	trace	trace
DIPTERA (Midges, black flies, etc.)				
Rhaphidolabis sp. - L	1	2	trace	trace
Chironomus modestus - L	1	80	0.300	32.5
Chironomus modestus - P	1	14	0.100	10.8
Chironomidae - L	3	172	0.025	2.7
Simulium sp. - L	1	108	0.150	16.2
HYDRACARINA (Water mites)	1	1	trace	trace
Totals	19	701	0.925	100.0

Table 6

Square-foot bottom sample taken from Diversion Section I-B in 6 to 7 inches of water over mixture of sand and coarse gravel.

January 27, 1941, 9:00 a.m. Air 18°F.; water 36°F. Cloudy.

ORGANISM	No. of species	Number of individuals	Volume in c.c.	Per cent of total volume
ANNELIDA (Aquatic worms)				
Lumbricidae	1	1	0.050	3.8
Tubificidae	1	7	0.025	1.9
Hirudinea	1	1	0.125	9.4
MALACOSTRACA (Shrimp)				
Hyalella sp.	1	1	trace	trace
EPHEMEROPTERA (Mayflies)				
Ephemerella invaria - N	1	9	0.025	1.9
Baetis vagans - N	1	242	0.200	15.1
PLECOPTERA (Stoneflies)				
Leuctra tenuis - N	1	8	trace	trace
Allocapnia torontoensis - N	1	23	0.050	3.8
Nemoura sp. - N	1	10	0.025	1.9
COLEOPTERA (Water beetles)				
Stenelmis sp. - L	1	1	trace	trace
TRICHOPTERA (Caddisflies)				
Rhyacophila sp. - L	1	6	0.050	3.8
Hydropsyche sparna - L	1	1	0.025	1.9
DIPTERA (Midges, flies, etc.)				
Rhaphidolabis sp. - L	1	2	0.025	1.9
Chironomus modestus - L	1	75	0.300	22.6
Chironomus modestus - P	1	31	0.175	13.2
Chironomidae - L	2	487	0.150	11.3
Ceratopogonidae - L	1	1	trace	trace
Simulium sp.	1	93	0.100	7.5
Totals	19	999	1.325	100.0

Table 7

Square-foot bottom sample taken from Diversion Section I-B in 6 inches of water over sand to moderate gravel.

February 4, 1941, 8:30 a.m. Air 10°F.; water 34°F. Clear.

ORGANISM	No. of species	Number of individuals	Volume in c.c.	Per cent of total volume
TURBELLARIA (Free-living flatworms)				
Planariidae	1	1	trace	trace
ANNELIDA (Aquatic worms)				
Tubificidae	1	1	trace	trace
MALACOSTRACA (Freshwater shrimp)				
Gammarus sp.	1	2	0.025	1.6
EPHEMEROPTERA (Mayflies)				
Ephemerella invaria - N	1	23	0.025	1.6
Baetis vagans - N	1	699	0.450	28.5
PLECOPTERA (Stoneflies)				
Leuctra tenuis - N	1	7		
Allocapnia torontoensis - N	1	10		
Nemoura sp. - N	1	20	0.050	3.2
Isoperla sp. - N	1	1		
Isogenus frontalis - N	1	1	0.075	4.7
TRICHOPTERA (Caddisflies)				
Rhyacophila sp. - L	1	6	0.050	3.2
Hydropsyche sparna - L	1	2	0.050	3.2
DIPTERA (Midges, blackflies, etc.)				
Rhaphidolabis sp. - L	1	3	trace	trace
Chironomus modestus - L	1	49	0.225	14.3
Chironomus modestus - P	1	70	0.225	14.3
Chironomidae - L	3	590	0.200	12.7
Ceratopogonidae - L	2	3	trace	trace
Simulium sp. - L	1	142	0.200	12.7
HYDRACARINA (Water mites)	1	5	trace	trace
Totals	21	1,535	1.575	100.0