Presented at Mich. Acad. Sci., Arts and Letters Meetings, March 22-24, 1956, but not submitted for publication.

Original: Fish Division
Education-Game
Inst. for Fish Res.
D. S. Shetter
J. W. Leonard
C. T. Yoder
R. J. Ellis

INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES
MICHIGAN DEPARTMENT OF CONSERVATION
COOPERATING WITH THE
UNIVERSITY OF MICHIGAN

Gerald P. Cooper
XXXXXXXXXXXXXX PH.D.
DIRECTOR

ADDRESS
UNIVERSITY MUSEUMS ANNEX
ANN ARBOR, MICHIGAN

January 16, 1957

Report No. 1501

COMPARATIVE FOOD VALUE OF NATURAL TROUT-FOOD ORGANISMS AS EXHIBITED IN THE GROWTH OF TROUT

By

Robert J. Ellis

Introduction

The purpose of this study was to determine whether or not differences exist in the efficiency with which various kinds of food organisms are converted to fish flesh. Such data will aid in assessing the value as fish food of the bottom fauna produced by the stream environment.

Since this investigation was exploratory in character, little attention was given to statistical design. Considerable emphasis was placed upon standardizing procedures for collecting food organisms, measuring food intake and measuring growth increments of fish. This work was conducted from April 10 to September 10, 1950 at the Hunt Creek Fisheries Experiment Station, Lewiston, Michigan.

Methods and Equipment

The fish used were brook trout from the state fish hatchery at Grayling, Michigan. At the beginning of feeding experiments these fish ranged from 128 to 156 millimeters in total length. Fish were held in a hatchery trough which had been divided into 10 covered compartments (12 by 18 by 6 inches in dimension) by installing transverse, screen partitions. Water was obtained from the spring which supplies the station laboratory. Since this source was known to be low in dissolved oxygen, an aerating system was installed which raised the dissolved oxygen content to near the saturation level. Daily records of water temperatures were obtained from a maximum-minimum thermometer located at the lower end of the trough. The maximum daily temperature change was 4° F.; during the experimental period the range was from 47° to 52° F.

A prepared hatchery ration was first used as a control diet, but during the early feeding trials it was noted that considerable leaching occurred when this finely ground food was introduced into the water. Its use was further restricted by the fish's habit of taking this food into the mouth and then forcibly ejecting it into the water, where it formed a milky cloud until dissipated by the current. Raw pork liver, cut into rectangular pieces of a size easily ingested by the fish, was substituted for the hatchery ration. Liver leached somewhat but probably little more than the natural food organisms. Fresh pork liver was obtained weekly and kept frozen until needed.

The natural foods used were those which could be collected easily: nymphs of the burrowing mayfly *Hexagenia*; stonefly nymphs of the family Perlidae; and larvae of the fish fly, *Nigronia*.

The *Hexagenia* were obtained from Fuller Creek and East Fish Lake, Montmorency County; most of the remaining organisms were taken from the North Branch of the Au Sable River near Lovells, Crawford County. Small numbers of insects were taken from Hunt Creek, Montmorency County. Insects were collected with a fine-mesh scap net and transported to the laboratory in a pail. In the laboratory they were placed in a screen-bottomed box which floated in a tank of flowing, aerated spring water.

At first the trout were fed by dropping the living organisms onto the surface of the water. Later trout became accustomed to hand feeding and would take organisms from forceps held above or below the water surface. Liver was fed in the same manner as living organisms. To facilitate ingestion, larger food organisms were broken into two parts before feeding.

The quantity of materials fed was determined volumetrically. In measuring volume, organisms were first blotted on filter paper to remove free surface moisture and then were dropped into a 15 milliliter centrifuge tube which contained a known volume of water. The water volume displaced by the organisms was estimated to the nearest 0.025 milliliter. In calculating the various indices used in this paper it has been assumed that the weight of one milliliter of food is one gram. Other workers have found this conversion to be approximately correct for aquatic insects (Ball, 1948) and measurements of raw pork liver indicated a specific gravity of 1.08.

Fish were fed all they would eat twice a day (7:30 a.m. and 4:00 p.m.), for 5 1/2 consecutive days. There was no further feeding until after the fish were measured on the seventh day. The elapse of 24 hours between feeding and weighing avoided loss of food by regurgitation during handling and also probably minimized differences in weight arising from variations in quantity of food ingested at the last feeding.

Weekly measurements were made of the weight and total length of each fish. Fish were anesthetized in an aqueous solution of ether, and the surface moisture was removed by filter paper before they were weighed. This handling seemed to have no ill effects upon the fish.

To minimize losses due to disease all the fish were treated for one hour with a 1:4,000 solution of formalin and for one minute with a 1:10,000 solution of malachite green-oxalate (Allison, 1950).

Despite several such prophylactic treatments many fish died. Some deaths were apparently caused by fungus, Saprolegnia, and fin rot, Gyrodactyloidea, but all fish that died had refused to eat for considerable periods before death.

Observations on Behavior During Experiments

When two trout were placed together in a larger trough compartment (dimensions, 12 by 36 by 6 inches), it was observed that within about two days one of the fish had become dominant and the other submissive. The dominant fish was light in color, moved freely about the compartment and ate the food placed in the trough. The other fish was dark in color, remained in one corner of the compartment and did not eat. Since the trout were exposed to similar light conditions, this difference in color is difficult to explain. When the dominant fish from two groups were placed together in hopes of preventing establishment of a nip order, the two fish began to fight fiercely and a hierarchy was again established. The failure of all attempts to prevent such an order from being established made it necessary to use only one fish per compartment.

A trout placed in the experimental trough for the first time would generally refuse food for an initial period of two or three days. If the fish failed to eat for ten or twelve days, it could be expected to die. Two exceptions to this rule may be mentioned. In one case, four fish suddenly refused to eat although they had been feeding on Hexagenia nymphs for more than two weeks. Hexagenia were offered regularly for two weeks but were not taken. During this period one of the fish died and all lost weight. After two weeks the three remaining fish began eating again. A second exception was a brook trout which refused food for more than six weeks. During this period its weight decreased from 16 grams to 13 grams.

This fish finally resumed feeding and fed well for the duration of the experiment.

Results

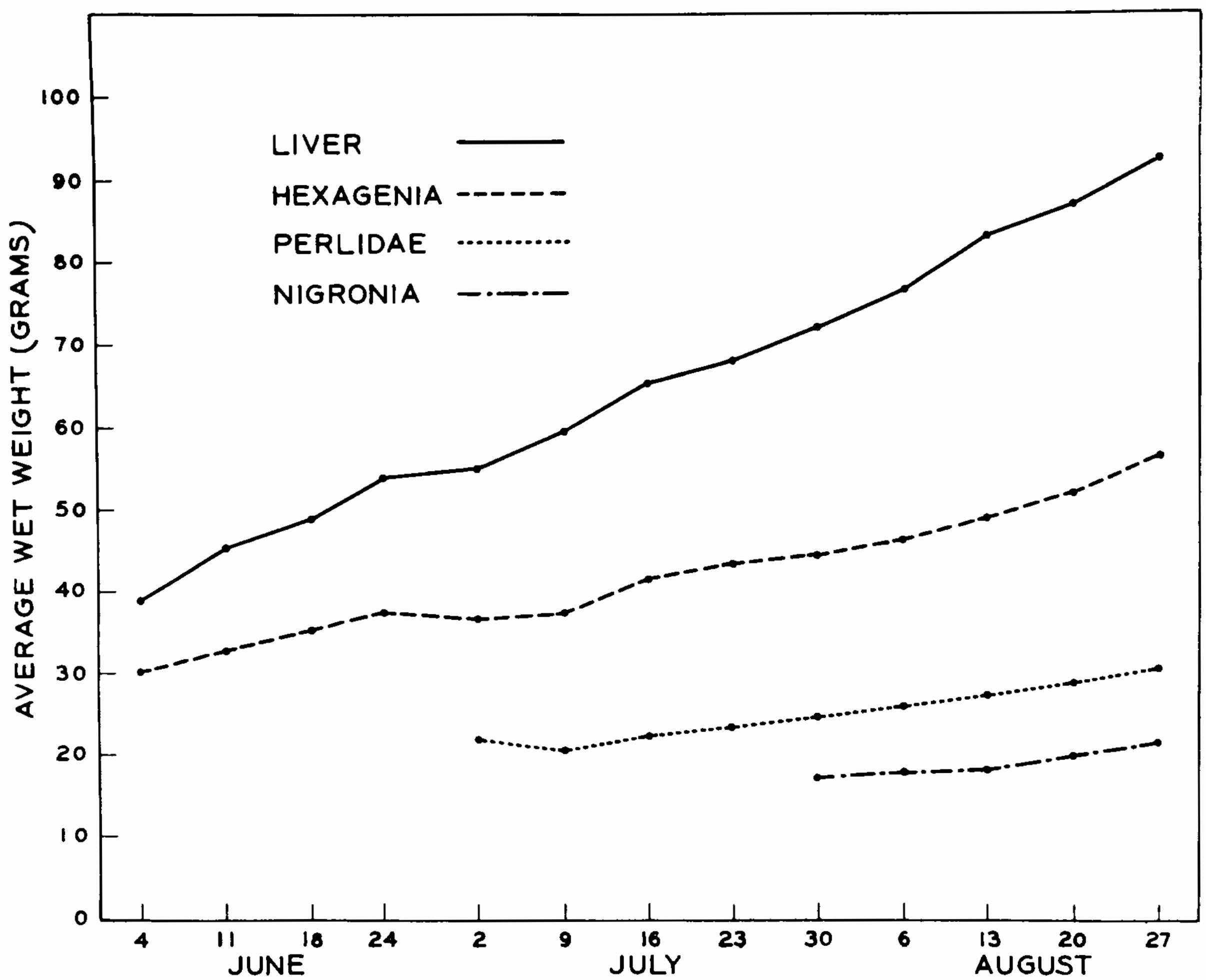
Although the temperature variation in the feeding trough was small (47° to 52° F.), the food consumption was very regular (Fig. 1), and the average weight of each group increased steadily (Fig. 2), the specific growth rate changed erratically (Table 1). For fish on a liver diet the values for two successive weeks showed a divergence as great as 17 percentage points (weekly values of 23.0 and 6.0 percent) and the total range for the 12-week period was 0.0 to 23.0 percent. For fish on a *Hexagenia* diet the values which showed the greatest difference during successive weeks were 5.1 and -7.8 percent; the range during the 12-week period was -7.8 to 15.4 percent.

Other workers have followed the growth of individual trout under laboratory conditions. Brown (1946) observed erratic changes in the specific growth rates of brown trout similar to those observed here. These trout were reared at a constant temperature of 52.7° F. on a diet of minced liver and meat. Surber (1935) presented data which show similar erratic fluctuations in the specific growth rates of brook trout which were increasing in weight regularly. These fish were fed *Gammarus fasciatus* and maintained at 54° F.

Various other aspects of the results of the feeding experiment are summarized in Table 2.

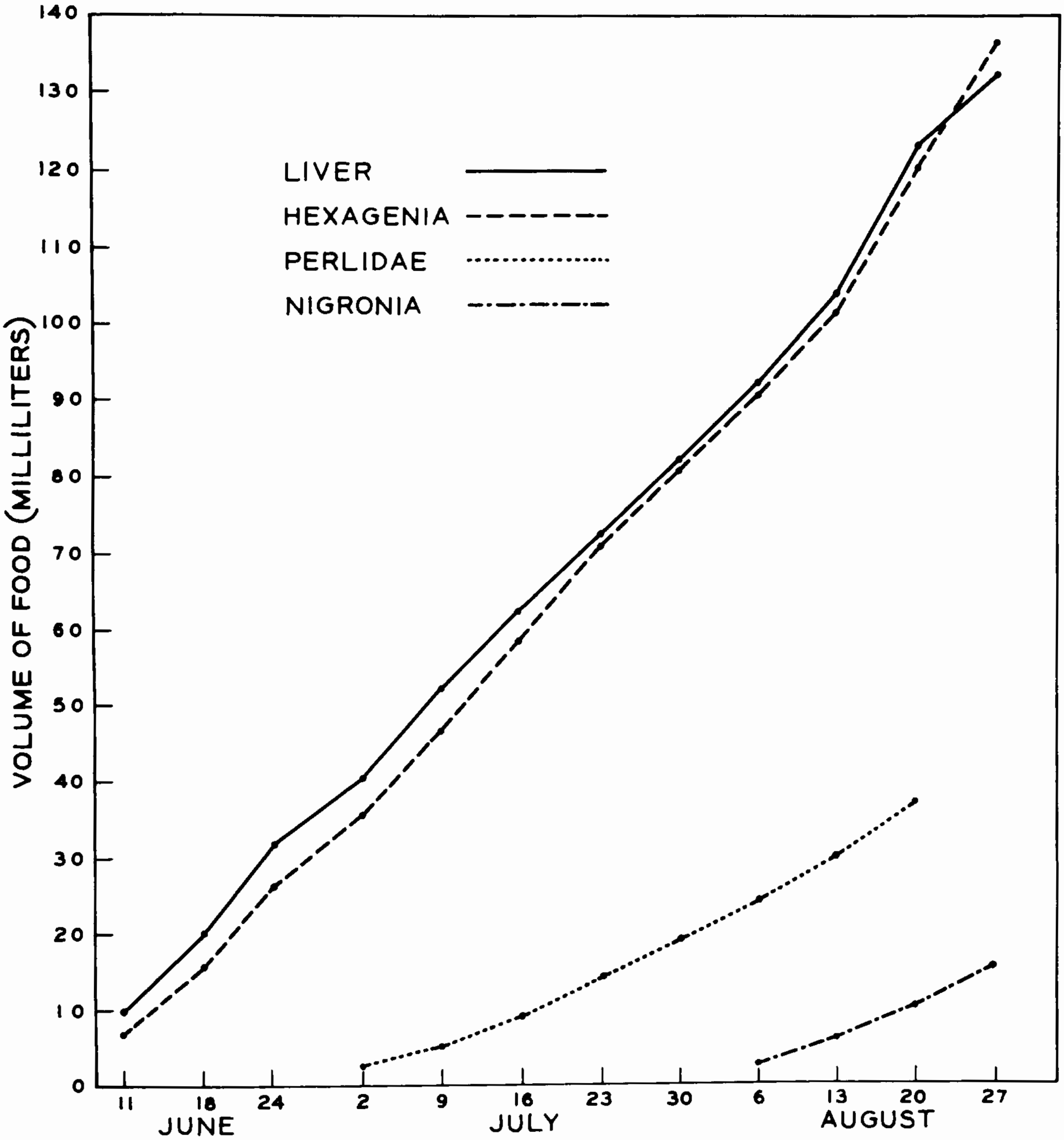
During the experimental period, the coefficient of condition increased for all four groups of fish (Item 4, Table 2). All condition factors were within the range given by Shetter and Leonard (1943) for wild brook trout in Hunt Creek.

Figure 1.--Average weight of fish fed different diets.



LIVER
HEXAGENIA
PERLIDAE
NIGRONIA
AVERAGE WET WEIGHT (GRAMS)
0
10
20
30
40
50
60
70
80
90
100
4
11
18
24
2
9
16
23
30
6
13
20
27
JUNE
JULY
AUGUST

Figure 2.--Cumulative volume of food consumed during feeding experiment. Each point shows the average volume of food eaten by two fish.



LIVER
HEXAGENIA
PERLIDAE
NIGRONIA
VOLUME OF FOOD (MILLILITERS)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
11
18
24
JUNE
2
9
16
23
30
JULY
6
13
20
27
AUGUST

Table 1.--Specific growth rates[1] (as percentage weight per week) of individual brook trout fed two diets

Diet	Fish	Week 1	2	3	4	5	6	7	8	9	10	11	12
Liver	a	10.0	15.0	9.9	3.7	7.0	3.3	10.8	2.9	5.6	6.5	3.7	5.9
	b	23.0	6.0	9.5	0.0	8.7	11.0	1.5	8.4	6.5	10.0	1.1	9.6
Hexagenia	a	15.4	8.2	5.1	-7.8	3.5	9.8	2.3	2.2	4.3	6.2	3.9	9.2
	b	6.9	9.5	5.9	0.0	2.8	10.5	7.2	2.3	4.5	6.3	5.9	7.4

[1] $G = \dfrac{\log_e W_T - \log_e W_t}{T - t} \times 100$

where G = specific growth rate, W_T = weight at time T.

W_t = weight at time t, and T is later than t.

The time was measured in weeks, so that the specific growth rate is expressed as percentage weight per week.

Table 2.--Results of feeding experiments. Figures given below are average results for the two test fish used with each diet

Item	Diet			
	Liver	Hexagenia	Perlidae	Nigronia
1. Duration of experiment (days)	84	84	56	28
2. Weight of fish (grams)				
Initial	39.0	32.5	22.0	17.0
Final	98.5	53.5	29.5	21.5
3. Total ration for experiment (milliliters)	132.8	136.2	37.9	14.9
4. Condition factor (K) [1]				
Initial	1.46	1.25	1.22	1.13
Final	1.68	1.52	1.41	1.25
5. Daily ration ÷ body weight (percent) [2]	3.3	5.0	3.6	3.5
6. Avg. daily growth ÷ average body weight (percent) [3]	1.04	0.58	0.52	0.82
7. Food conversion efficiency (percent) [4]	44.8	15.4	19.8	30.1
8. Ration ÷ growth (food conversion factor) [5]	2.2	6.5	5.0	3.3
9. Comparative food value (percent) [6]	100	34.4	44.2	67.4

1/ $K = \frac{\text{Weight in grams} \times 100{,}000}{(\text{Standard length in millimeters})^3}$

2 $\frac{\text{Weight of ration for the week (grams)} \div \text{number of feeding days}}{\text{Weight of fish at the beginning of the week (grams)}} \times 100$

3 $\frac{\text{Total increase in weight (grams)} \div \text{length of experiment}}{\text{Average weight (grams)}}$

4 $\frac{\text{Gain in weight (grams)} \times 100}{\text{Weight of food consumed (grams)}}$

5 $\frac{\text{Weight of food consumed (grams)}}{\text{Increase in weight (grams)}}$

6 $\frac{\text{Food conversion efficiency of test diet}}{\text{Food conversion efficiency of liver}}$

The average daily ration for each group of fish (expressed as percentage of the fish's body weight) computed on a weekly basis, ranged from 3.3 percent for the liver-fed group to 5.0 percent for the *Hexagenia*-fed group (Item 5 Table 2). The average ration for each feeding day for all groups of fish was 3.8 percent of the body weight.

The average daily growth for each group (expressed as a percentage of the average body weight) for the entire period ranged from 0.52 percent for the Perlidae-fed group to 1.04 percent for the liver-fed group (Item 6, Table 2). The average daily growth for all groups was 0.74 percent.

The food conversion efficiency (the percentage of the weight of food which was converted to fish flesh) ranged from 15.4 percent for *Hexagenia* to 44.8 percent for liver (Item 7, Table 2). The food conversion factors (Item 8, Table 2) are the reciprocals of the food conversion efficiencies.

Food conversion efficiencies have also been expressed as percentages of the efficiency of pork liver. This gives a comparative index, for each test food which is referred to as "comparative food value" (Item 9, Table 2).

As the fish in the present study were allowed to eat all they wanted twice each day, the average ration for each feeding day is probably close to the fish's feeding capacities under the experimental conditions. The daily ration expressed as percentages of the fish's body weight was 3.3 percent for the liver fed fish, while the groups fed insects had an average of 4.0 percent. These results are comparable to the findings of Pentelow (1939) and Surber (1935). Both of these authors kept *Gammarus* constantly available to trout. At comparable temperatures and using fish of about the same size as in the present experiments Pentelow found a daily consumption of 2.3 percent for brown trout and Surber found a ration amounting to 5.4 percent of the fish's weight for brook trout.

The average food conversion efficiency computed from Pentelow's data is 18 percent and Surber's data yield an efficiency of 17 percent. Such close agreement is remarkable considering the differences in experimental temperature (Pentelow, 41° to 64° F. and Surber 54° F.) and bearing in mind that these authors used different species of fish. The average efficiency of conversion of the insects fed in the present study was 21.4 percent.

The average daily growth of the groups fed insects in the present study was 0.64 percent of the fish's body weight, which is about 50 percent greater than the value of 0.42 percent of Pentelow and equal to the 0.65-percent figure which Surber's data yield. These differences and similarities in growth are consistent with the food consumption and food conversion efficiencies of each experiment.

Of the three kinds of insects used as food, Nigronia was converted most efficiently to fish flesh. The Perlidae were second in efficiency and Hexagenia was utilized least efficiently. These limited observations might suggest that from the standpoint of trout nutrition, Nigronia and perlids are more desirable than Hexagenia in stream environments. However, an important factor--the relative availability of these organisms to fish in the stream--has not been evaluated. Also, since Nigronia and perlids are carnivorous (in contrast to Hexagenia), they probably compete with trout to some extent for invertebrate food. Invertebrates probably are utilized more efficiently in the food chain if they are eaten directly by fish rather than first being utilized by intermediate consumers (Nigronia and perlids). Hence from the standpoint of food-cycle dynamics Nigronia and the Perlidae may be less desirable than Hexagenia.

Literature Cited

Allison, Leonard N.

1950. Common diseases of fish in Michigan. Institute for Fisheries Research, Michigan Department of Conservation, Misc. Publ. No. 5, 27 pp.

Ball, Robert C.

1948. Relationship between available fish food, feeding habits of fish and total fish production in a Michigan lake. Mich. State College Agricultural Experiment Station, Tech. Bull. 206, 59 pp.

Brown, Margaret E.

1946. The growth of brown trout (Salmo trutta Linn.). II. The growth of two-year-old trout at a constant temperature of 11.5° C. Jour. Exp. Biol., 22: 130-144.

Pentelow, F. T. K.

1939. The relation between growth and food consumption in the brown trout (Salmo trutta). Jour. Exp. Biol., 16: 446-473.

Shetter, David S. and Justin W. Leonard

1943. A population study of a limited area in a northern Michigan trout stream, September, 1940. Trans. Amer. Fish. Soc., 72 (1942): 35-51.

Surber, Eugene W.

1935. Trout feeding experiments with natural food (Gammarus fasciatus). Trans. Amer. Fish. Soc., 65: 300-304.

INSTITUTE FOR FISHERIES RESEARCH

Robert J. Ellis

Approved by: G. P. Cooper

Typed by: J. M. Lederer