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NOTES ON THE USE OF SUPPLEMENTS FOR FRESH MEAT IN THE PROPAGATION OF BROOK, RAINBOW AND BROWN TROUT IN MICHIGAN[1]

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[1] Contribution from the Institute for Fisheries Research. This is a portion of the thesis to be submitted toward the requirements of the degree of Doctor of Philosophy in the Department of Zoology at Michigan State College.

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ABSTRACT

Brook (*Salvelinus f. fontinalis*), rainbow (*Salmo gairdnerii irideus*), and brown trout (*Salmo trutta*) fingerlings were fed diets in which fresh meats were supplemented with dry animal and plant meals. Ten diets were employed including one of pure sheep liver for comparison.

Trout fed diets that contained dry meals were reared at a lower cost per pound of trout (except in one case among the rainbow trout) than the controls.

The mortality among the trout that received sheep liver plus dry meals in the diet was generally about as low (in some instances lower) than that of the controls, whereas the loss among those that

received trimmed pork "melts" (spleen from which fat has been trimmed) in the diet could in no case be compared favorably with the losses among the other trout. An epidemic of ulcer disease was most severe among the fish which were fed pork "melts."

Pure sheep liver yielded the greatest increase in weight among brook and rainbow trout. Among the brown trout two of the diets that contained dry meals produced better growth than did pure sheep liver.

The best conversion of food ("as purchased" basis) into body tissue was obtained from some of the diets containing dry meals.

INTRODUCTION

For many years Michigan has been engaged in the artificial propagation of trout to be planted in the public waters of the state. This enterprise has grown to such proportions that the cost of rearing trout in the hatcheries has become a large item of expense. With a view toward reducing this cost the experiments described in this paper were carried out.

It is not necessary to present an extensive survey of the work of other investigators in the field of trout nutrition since excellent reviews have been published by McCay (1937a and 1937b).

Because fresh liver was a rather satisfactory food conducive to the growth of young trout it has been almost the only food used in the artificial propagation of trout in Michigan's hatcheries and rearing stations. Until recently liver was a relatively inexpensive by-product of the meat-packing industry. However, the price of fresh liver has increased materially during the past few years and consequently the cost of rearing trout on this food has also increased. The purpose of these experiments, therefore, was to find some means whereby the cost of rearing trout could be reduced by supplementing the expensive fresh liver with less expensive materials. Similar studies that involved relatively fewer numbers of trout have been made by Titcomb, Cobb, Crowell and McCay (1928); McCay (1933); and McCay and Tunison (1934, 1935). In these studies dried animal and plant meals were used with success. In fact, diets containing dry meals gave better growth in some instances than did fresh liver alone. Some of the diets used in the present study were quite similar in composition to diets used elsewhere. However, nearly every rearing station may be considered to have its own set of conditions and its own problems with regard to factors involved in the rearing of trout, so that any study made applies directly to local conditions and only indirectly to conditions elsewhere.

With this in mind, experiments were set up, taking advantage of the findings of other investigators. The experiments were designed in general to be of a rather practical nature, consequently hatchery methods and routine were duplicated as nearly as possible. Larger numbers of fish were used in these experiments than are usually employed in similar nutrition studies; thus the experiment was transferred from a purely laboratory basis to a semi-production basis.

METHODS AND RESULTS

When this study was begun 96,000 brook trout fingerlings, 31,528 rainbow trout fingerlings, and 50,490 brown trout fingerlings were employed. The investigation included twelve two-week periods (except Period 2 which was only one week) extending from April 13, 1937 to September 21, 1937.[2]

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[2] On September 21, 1937, some of the trout were removed to raceways at the state fish hatchery, Benton Harbor, Michigan, where they were

continued on their respective diets for another six months. The results of the continuation of this study at Benton Harbor will be reported elsewhere at a later date.

The experiments were carried on at the Wolf Lake State Fish Hatchery located 10 miles west of Kalamazoo, Michigan, on Highway M-43. The water supply for the hatchery comes from an underground spring which has a flow of approximately 1,200 gallons per minute. The clear water flows into an open pond which was formed by building a dam across the stream valley, thereby making the pond about 100 yards long, 30 yards wide, and about 18 feet deep. A large number of brook trout had been placed in this pond at an early date, long before the hatchery was erected. Several times during the summer of 1937 specimens from this pond were examined and no evidence of external parasites or of any disease was discovered. Very few organisms such as small crustaceans, small insects or worms entered the hatchery troughs. Only after very severe rains did any quantity of silt enter the troughs and this amount was so small that it cleared up almost immediately.

In the hatchery the water temperature was approximately 40° to 50°F. during the colder months, and about 50° to 60°F. during the warmer months. Several determinations of dissolved oxygen, free carbon dioxide, and the pH of the water were made during the summer of 1937. The lowest concentration of dissolved oxygen found was 6.7 p.p.m. at 7:00 a.m. and the greatest was 9.9 p.p.m. near midnight. It was noted that in rainy weather the values for dissolved oxygen were about 1 p.p.m. lower than the above values. The lowest value obtained for free carbon dioxide was 1.8 and the highest value 3.24 p.p.m. The amount of free carbon dioxide was usually low when the dissolved oxygen content was high. The pH of the water was usually about 7.7; the minimum value, except during rainy weather, was 7.5 and the maximum value 8.1.

Standard hatchery troughs, located indoors, having a capacity of about 37 gallons, were used. About 5.8 gallons of water per minute flowed through each trough, except while the trout were small, when the flow was less.

A beam balance, sensitive to within 1 gram, having a capacity of 20 kilograms, was placed in the hatchery for the purpose of weighing fish at two-week intervals. The food for the fishes was weighed in small aluminum pans on a torsion balance of 4.5 kilogram capacity which was sensitive to one-fifth of a gram. The amount of food given to the fish each day was determined by the difference in weight of the food in the pan in the morning and the amount left in the pan at the end of the day. Possible error resulting from evaporation was considered negligible since the amount of food left in the pan at the end of each day was usually very small.

Since this study was to be of a practical nature, the composition and cost of diets were based on the weight of the material "as purchased" during the time of the experiment rather than on a dry weight basis which is in some cases more applicable in studies pertaining primarily to the nutrition of trout. Table 1 is a compilation of the composition and cost of the diets used in 1937.

Fresh meats were obtained from meat packing houses located in nearby cities. This material was brought into the hatchery early in the morning, ground to the desired size in the meat grinder and stored in an electric refrigerator. Under normal conditions this meat was used within three days. At the Wolf Lake hatchery the fish were ordinarily allowed to fast one day each week and this practice was

TABLE 1. COMPOSITION AND COST OF DIETS "AS PURCHASED," 1937

Ingredients	Cost per pound	Percentage composition of diet Nos.									
		2	4	6	17	18	19	20	21	22	23
Fresh sheep liver	$0.0850	100.0	50.0	...	50.0	30.0	50.0	50.0	...	...	...
Fresh pork "melts" (trimmed)	0.0350	...	...	75.0	...	...	...	...	75.0	60.0	75.0
Vacuum white fish meal	0.0300	...	16.7	8.3	13.3	20.0	...	...	5.0	10.0	...
Cottonseed meal	0.0240	...	16.7	8.3	13.3	20.0	...	13.3	5.0	10.0	...
Oatmeal	0.0304	...	...	...	10.0	10.0	30.0	10.0	10.0	10.0	...
Skim milk powder, roller process	0.0560	...	16.7	8.3	13.3	20.0	20.0	13.3	5.0	10.0	...
Dog biscuits #20	0.0515	...	...	...	...	...	...	...	...	...	25.0
Grasshopper meal	0.1000	...	...	...	...	...	...	13.3	...	...	...
Water (shown as per cent by weight of rest of diet)		...	33.3	...	33.3	50.0	33.3	33.3	...	25.0	11.1
Cost per pound before May 31 (Periods 1 to 4)		$0.0850	0.0608	0.0354	0.0602	0.0505	0.0628	0.0695	0.0348	0.0350	0.0391
Cost per pound after June 1[1] (Periods 5 to 12)		0.0850	0.0608	0.0504	0.0602	0.0505	0.0628	0.0695	0.0498	0.0470	0.0541

[1] After June 1 the price of pork "melts" was increased from $0.035 to $0.055 per pound.

followed in this experiment. The hatcheryman generally prepares ground meat by mixing a certain amount of water with it until the meat particles are separated, and the resultant thin, soupy mixture is distributed in the troughs with a spoon. This method results in considerable waste. In this feeding study the liver when fed alone was placed into the troughs in chunks without the addition of water in the same condition as it came from the grinding machine. The consistency of the meat thus compares somewhat with that of the meat-meal mixtures which were used in the experimental feeding. In the preparation of diets containing meat and dry meal, the meal preparations were made in advance by mixing the proper proportion of the various kinds of meal and storing them in large cans. Rations of meat and meal, sufficient for three days, were then mixed and stored in the refrigerator until used. This mixture was kept in storage for twelve hours before it was fed to the trout to allow sufficient time for the meat juices to be absorbed by the dry meal and, therefore, prevent them from being washed down the drain at feeding time. In most of the diets there was not sufficient moisture in the meat to make a feeding mixture of suitable consistency. It was necessary, therefore, to add some water. This water was added to the meat first and then the dry meal stirred into the soupy mixture of meat and water. In order to reduce all of the feeding mixtures to the same consistency it was necessary to try several different quantities of water until the proper amounts were determined. The amount of water that was added to the diets to bring about a suitable feeding mixture is shown in Table 1. The amount of water is stipulated in per cent of the weight of the meat and meal mixture. For instance when preparing Diet 4, 33.3 pounds of water were added to 100 pounds of the meat-meal mixture. The added water, therefore, made up 25 per cent of the final mixture, but was equal to 33.3 per cent of the rest of the diet. When determining the amount of food used by the trout each day a correction was made for this water so that the amounts of food eaten appear comparable on an "as purchased" basis. This method of preparation of food is essentially the same as that used at the Cortland Experimental Hatchery, New York (McCay and Tunison, 1935).

The usual hatchery routine was followed as nearly as possible so that when the hatchery fish were fed once per day the experimental fish were fed once; when the hatchery fish were fed twice a day, the experimental fish were fed twice a day. Many trout culturists recommend feeding only an amount equal to a certain per cent of the body weight of the trout each day, claiming that this method results in better food conversion. However, in this experiment the practice of offering all that the fish would eat at each feeding was followed. At first the fish were given an amount which was probably less than they would eat. If after fifteen minutes all the food had been consumed, more was given until the fish refused to eat. An ideal method would be to put into the trough the precise amount the fish would eat. However, it was difficult to know the exact quantity that would be consumed, so a slight excess of food usually was allowed to remain in the trough. From experience one learned quickly the amount of food that the fish probably would eat during the course of the day. A slightly larger amount, therefore, was weighed into the pan and taken into the hatchery room.

The food mixtures were of about the consistency of freshly ground liver, sometimes slightly more firm, and were placed in the trough in large chunks, several to each trough so that each fish probably had an equal opportunity in obtaining food. After a short time the fish became accustomed to feeding in this manner and vigorously attacked the chunks of food. The hatcheryman has claimed that with this method the fish do not have an equal opportunity to feed, that the big fish monopolize the food and prevent the small fish from obtaining a sufficient amount to eat, and points out as evidence the great range in size that is found among the fish so fed. It is true, the range in size of the trout of these experiments was greater than that of fish in the production troughs, but I believe that the difference was not due to the method of feeding but to the removal of the smaller fish from the foot of the production trough when it was necessary to reduce crowding. Such thinning tends toward uniformity in the size of the fish. In the experimental work no selection of this sort took place. Every sample removed from the trough was taken at random so that no particular size group was removed or remained. This practice resulted in a wide range of sizes. Observations made at the time of feeding indicate that each fish had about an equal opportunity to feed adequately.

The prices for the dry meals are computed as of April 1, 1937, the time at which they were purchased (Table 1). Some fluctuations in price occurred during the term of the experiment, but these changes were ignored. The price of pork "melts" was increased after June 1 from $0.035 to $0.055 per pound, and this change in price was recognized in the cost figures of the experiment. The price quoted on grasshoppers in the present study could, no doubt, be materially reduced if these insects were collected locally in sufficient quantities. In the event of a decreased cost Diet 20 could be given favorable consideration since the mortality among the trout given this diet was low and the growth fair.[3]

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[3] With regard to the use of grasshoppers as food for hatchery trout, the only reference found so far is contained in the discussion following a paper published by Titcomb, Cobb, Crowell and McCay, (1928).

In a personal communication from Mr. W. M. Keil of the U. S. Forest Service the writer was informed that in feeding trials conducted about 1910 a diet composed of beef liver plus pressed locust or grasshopper from Argentina was found unsatisfactory and caused increased mortality if the grasshoppers constituted more than about 33 per cent of the mixture. A noticeable increase in mortality did not occur among the fish that received a diet containing less than 33 per cent grasshoppers as compared to the fish in the control lot which were fed only beef liver. In growth the controls surpassed the fish whose diet included pressed grasshoppers. Because beef liver was still an inexpensive article at this time, no further experiments were conducted.

At the end of each two-week period the figures of total weight of food placed in each trough were reduced, by means of correction factors, to include only the weight of the food before water was added. Consequently the computed food conversion factors refer only to the food as purchased.

The food conversion factor for a given length of time is the ratio of the amount of food fed to the increase in weight. These quantitative figures are usually expressed in grams. The formula employed in this study may be stated as follows:

$$\text{F. C. F.} = \frac{\text{grams of food given per thousand fish}}{\text{increment in weight in grams per thousand fish}}$$

The food fed per thousand fish was obtained as follows:

$$\frac{\text{Total food given}}{\text{Average number of fish fed during period}} \times 1{,}000$$

The mean of the number at the start and the number at the end of the period was taken as the average number of fish during a given period.

Table 2 contains the average food conversion factors for the first four periods (April 13 to June 1) for all three species, for the last two periods (June 1 to June 29) for the brook trout and the last eight periods (June 1 to September 21) for the rainbow and brown trout. The table also shows the cost of food to rear one pound of trout based on the work done during 1937. The figures on the price of food per pound are shown in the last two rows of Table 1. The food conversion factors are among the most important data disclosed in this kind of study since from the price of the ingredients of a diet and the food conversion factor for that diet one may readily compute the cost to rear a pound of trout on the diet chosen by multiplying the conversion factor by the cost per pound of the diet. The cost of the ingredients of a diet vary from time to time. Although the food conversion factors are by no means fixed values, they are probably rather constant all other factors being equal.

The trout employed in this feeding experiment had been feeding for about six weeks before the experiment started. They had been fed chiefly fresh beef liver which was supplemented as time went on with increasing amounts of fresh sheep liver so that for about ten days before they were transferred to the experimental diets the trout had been receiving only sheep liver.

The brook trout were divided equally according to weight and put into twenty standard hatchery troughs. Similarly the rainbow trout were divided and placed in ten troughs, and the brown trout in ten troughs. Thus at the beginning of the experiments there were about 4,805 brook trout per trough, 3,153 rainbow trout per trough, and 5,059 brown trout per trough. The average weights per thousand fish of these three species were 377.5 grams, 360.4 grams, and 225.4 grams respectively.

TABLE 2. SUMMARY OF FOOD CONVERSION FACTORS, AND COST OF FOOD TO REAR ONE POUND OF TROUT

Diet No.	Average food conversion factor			Cost of food[2] to rear one pound of trout		
	Periods 1 to 4	Periods 5 to 12[1]	Periods 1 to 12[1]	Periods 1 to 4	Periods 5 to 12[1]	Periods 1 to 12[1]
			Brook Trout			
2	2.573	4.468	3.204	$0.2187	$0.3798	$0.2723
4	2.423	3.288	2.711	0.1473	0.1999	0.1648
6	2.981	4.123	3.362	0.1055	0.2078	0.1396
17	2.651	3.361	2.887	0.1596	0.2023	0.1738
18	2.606	3.491	2.900	0.1316	0.1763	0.1465
19	3.848	4.072	3.924	0.2417	0.2557	0.2464
20	2.765	3.651	3.060	0.1922	0.2537	0.2127
21	3.176	4.558	3.637	0.1105	0.2270	0.1493
22	3.176	4.422	3.591	0.1112	0.2078	0.1434
23	4.165	5.144	4.491	0.1628	0.2783	0.2013
Average	3.036	4.058	3.377	0.1581	0.2389	0.1850
			Rainbow Trout			
2	3.084	3.938	3.652	0.2621	0.3347	0.3104
4	3.020	3.811	3.547	0.1836	0.2317	0.2157
6	3.606	5.231	4.639	0.1273	0.2636	0.2182
17	3.190	3.937	3.688	0.1920	0.2370	0.2220
18	3.314	3.854	3.673	0.1674	0.1946	0.1855
19	4.804	5.318	5.146	0.3017	0.3340	0.3232
20	3.993	3.913	3.939	0.2775	0.2720	0.2738
21	4.673	6.191	5.684	0.1626	0.3083	0.2597
22	3.853	6.238	5.442	0.1349	0.2932	0.2404
23	4.834	6.441	5.905	0.1890	0.3485	0.2953
Average	3.837	4.887	4.537	0.1998	0.2818	0.2574
			Brown Trout			
2	3.845	4.462	4.256	0.3268	0.3793	0.3618
4	3.479	3.890	3.753	0.2115	0.2365	0.2282
6	4.314	4.544	4.467	0.1527	0.2290	0.2036
17	3.401	3.886	3.724	0.2047	0.2339	0.2242
18	3.578	3.969	3.838	0.1807	0.2004	0.1938
19	5.226	5.200	5.208	0.3282	0.3266	0.3271
20	4.255	4.166	4.195	0.2957	0.2895	0.2916
21	4.654	5.262	5.059	0.1620	0.2620	0.2287
22	4.220	5.199	4.872	0.1477	0.2444	0.2122
23	4.330	6.660	5.883	0.1693	0.3603	0.2966
Average	4.130	4.724	4.526	0.2197	0.2762	0.2568

[1] Brook trout experiment was discontinued at end of Period 6. "Periods" for this species therefore are 5 to 6 and 1 to 6 instead of 5 to 12 and 1 to 12.

[2] The cost per pound of food is shown for the various diets in the last two rows of Table 1.

The troughs in the hatchery were arranged in two rows. Each trough in the lower row received its supply of water from the outlet of the trough in the upper row. The arrangement of troughs of fish receiving the ten different diets was such that the diet numbers occurred in the same order in each of four groups of ten troughs in the upper row. A duplicate arrangement existed in the lower row, and, therefore, the diet given to the fish in an upper trough was the same diet as that given to the fish in the lower trough which received its water supply from the trough above. It was possible for some food to pass from an upper to a lower trough. However, the quantity of food which could have passed into a lower trough was insignificant when compared with the amount consumed by the fish.

At the end of Period 2 (May 4) the trout by weight were transferred from each trough and placed into other troughs which had become available. Thus the number of troughs occupied by each group was doubled but no reduction in numbers of trout occurred at this transfer. It was necessary to remove at intervals some fish from the experimental lots to avoid crowding. Although the results are based on the number of fish in the various lots, these reductions were made on the basis of weight since counting such large numbers of fish was impossible with the amount of help available. Therefore, whenever these "thinnings" were made, enough fish were removed so that an equal weight of fish remained in each trough. The weight of fish that remained was then converted to numbers by means of the known number per kilogram at that time.

It was intended at the start that the thinnings would be made at regular intervals, but due to conditions beyond the control of the investigator it was inconvenient to do so, with the result that the removals were made whenever possible, but always at the end of a period.

Reduction in numbers did occur, therefore, at the end of Period 3 (May 18) and at the end of Period 6 (June 29). At each time the weights of fish per trough were equalized (for each of the three species). The entire lot of brook trout was removed from the hatchery at the end of the sixth period because of an epidemic of ulcer disease.

Immediately after the brook trout had been removed (they had occupied the forty troughs in the upper row) the experiments with rainbow and brown trout were expanded to include the space previously occupied by the brook trout, thus placing twenty troughs of rainbow and twenty troughs of brown trout in the upper row with a similar arrangement in the lower row. The redistribution of the rainbow and brown trout does not vitiate the conclusions reached with respect to the relative values of the diets although such redistribution did in all probability influence the growth rate and mortality.

At intervals of two weeks all of the fish in each trough were transferred to a wire basket. The basket of fish was then lifted from the water and allowed to drain until the steady flow broke into drops. At this point the basket of fish was placed in a bucket of water on the balance and the weight of the fish computed. The total number of fish in each trough being known, the weight per thousand was readily calculated. The weight obtained in the above manner is commonly called the "wet weight" which includes some water computed by Embody (1937) to equal about 5.99 per cent of the "wet weight." By weighing the entire lot no error resulted from sampling, and considerable time was saved because the fish did not have to be counted. Occasional checks were made in order to be certain that an accurate record was being kept of the number of fish in each trough. The average weight in grams per thousand fish at the end of each period is shown in Table 3 for each diet and each species.

TABLE 3. RATE OF GROWTH

Diet No.	Grams per thousand trout: On April 13, 1937	At end of period Nos.: 1	2	3	4	5	6	7	8	9	10	11	12
							Brook trout						
2	377.5	625	847	1,317	2,048	2,720	3,970	...	...	...	...	...	...
4	377.5	545	670	1,126	1,866	2,676	3,663	...	...	...	...	...	...
6	377.5	604	736	1,210	1,864	2,579	3,564	...	...	...	...	...	...
17	377.5	547	647	1,050	1,659	2,377	3,304	...	...	...	...	...	...
18	377.5	506	599	956	1,440	1,969	2,666	...	...	...	...	...	...
19	377.5	471	535	821	1,246	1,777	2,395	...	...	...	...	...	...
20	377.5	542	632	1,005	1,691	2,349	3,149	...	...	...	...	...	...
21	377.5	550	678	1,076	1,715	2,374	3,259	...	...	...	...	...	...
22	377.5	525	632	979	1,474	2,105	2,813	...	...	...	...	...	...
23	377.5	510	580	882	1,226	1,656	2,346	...	...	...	...	...	...
Average	377.5	542	656	1,042	1,623	2,258	3,113	...	...	...	...	...	...
							Rainbow Trout						
2	348	521	689	1,076	1,670	2,293	3,041	4,132	5,871	7,908	10,503	12,762	15,097
4	351	552	661	1,010	1,490	1,983	2,429	3,299	4,504	6,164	8,020	9,873	11,672
6	327	523	681	915	1,337	1,735	2,099	2,858	3,710	4,911	6,316	7,711	9,130
17	371	541	652	1,029	1,577	2,105	2,626	3,541	4,799	6,452	8,461	10,162	12,095
18	363	504	589	907	1,387	1,804	2,258	3,023	3,974	5,176	6,553	8,269	9,719
19	384	489	580	813	1,158	1,536	1,991	2,560	3,300	4,274	5,418	6,413	7,356
20	359	501	579	845	1,286	1,765	2,260	3,188	4,239	5,737	7,451	9,020	10,485
21	379	542	632	915	1,319	1,684	2,109	2,781	3,636	4,677	5,722	6,704	7,685
22	362	547	653	942	1,344	1,707	2,019	2,606	3,340	4,148	4,117	6,212	7,126
23	359	493	587	812	1,138	1,495	1,908	2,568	3,340	4,289	5,488	6,524	7,443
Average	360	521	630	926	1,371	1,811	2,274	3,056	4,071	5,374	6,905	8,365	9,781
							Brown Trout						
2	222	342	411	612	847	1,061	1,387	1,960	2,660	3,255	3,989	4,741	5,518
4	223	317	363	542	775	983	1,258	1,695	2,358	3,068	3,985	4,823	5,646
6	202	318	362	522	703	927	1,170	1,572	2,109	2,866	3,771	4,849	5,752
17	214	308	363	538	740	923	1,193	1,684	2,276	2,962	3,684	4,376	5,267
18	232	316	365	546	701	873	1,077	1,433	1,881	2,379	2,949	3,776	4,606
19	242	307	373	467	628	816	1,003	1,335	1,742	2,183	2,706	3,170	3,889
20	244	327	373	502	689	921	1,148	1,564	2,120	2,830	3,568	4,439	5,089
21	214	308	349	513	710	904	1,133	1,522	1,971	2,568	3,193	3,902	4,824
22	237	320	371	538	766	960	1,215	1,614	2,143	2,865	3,498	4,278	5,202
23	224	324	366	532	729	844	1,086	1,438	1,993	2,355	3,158	4,423	5,373
Average	225	318	370	531	729	921	1,167	1,582	2,125	2,733	3,450	4,278	5,117

The bar charts of Figures 1, 2, and 3 are based on the data in Table 3.

The per cent increase in weight of fish for the entire term of the experiment is shown in Table 4.

Weight alone is not a satisfactory measure of the growth of an animal. Length measurements as well as measurements of individual parts of the body are sometimes necessary for an adequate knowledge of the progress of growth. The practice of determining growth by weight only is customary in Michigan's hatcheries, and for that reason only weights were used in this experiment.

It was usually necessary to remove from the troughs the accumulated refuse and the sediment which came in with the water supply. Thus at the beginning and at the end of each day a small brush was used to remove these materials from the sides and bottom of the trough. This cleaning was done very carefully so that none of the fish were injured.

At the time of the morning "clean-up" the number of dead fish if any was recorded. Dead fish were removed from the troughs and examined to determine, if possible, the cause of death. The percentage of fish lost during a period was determined by dividing the number lost by the number present at the start of the period. Table 4 summarizes the losses which occurred during the various periods of this experiment. The mortality record is very important in a nutrition experiment, since it is a good index of the value of a diet. Figures 4, 5 and 6 compare the losses that occurred on each diet.

Disease caused a great part of the mortality throughout the experimbnt. The occurrence of ulcer disease among the brook trout was somewhat sporadic though usually when one lot of fish receiving a given diet became infected the remaining lots receiving that diet soon showed the symptoms. The brook trout receiving Diet 18 did not appear to be

Figure 1. (At right.) Growth in weight of brook trout on various diets during each feeding period. Plotted on semi-logarithmic scale.

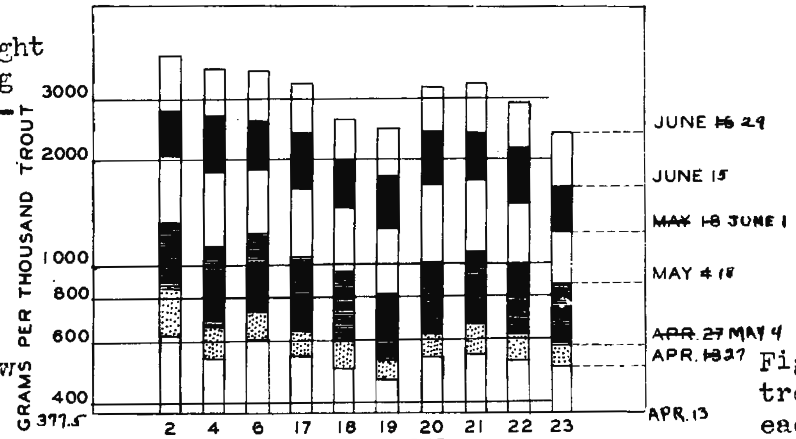

Figure 1

Figure 2. (Below.) Growth of rainbow trout on various diets during each feeding period. Plotted on semi-logarithmic scale.

Figure 3. (Below.) Growth of brown trout on various diets during each feeding period. Plotted on semi-logarithmic scale.

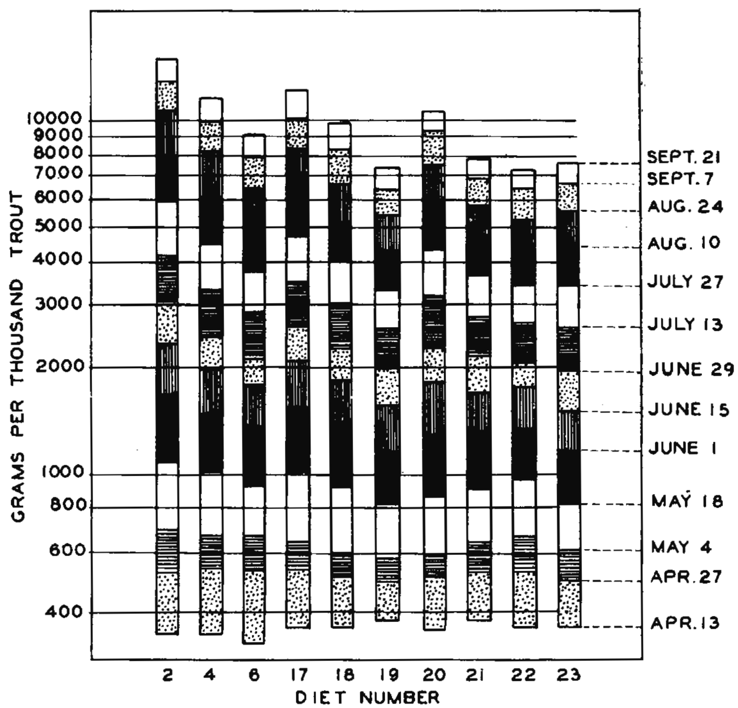

Figure 2

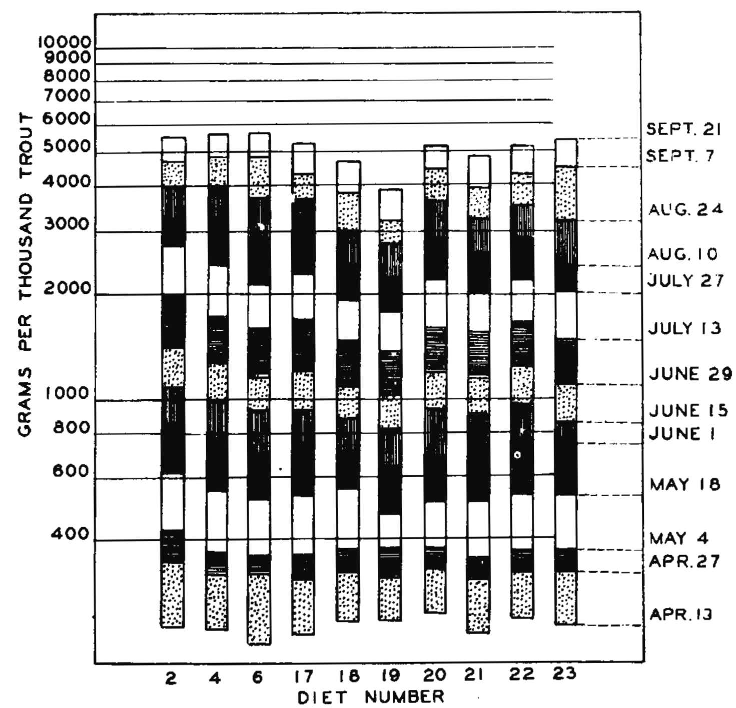

Figure 3

Figure 5. (At right.) Rainbow trout mortality. Bars represent per cent of fish lost each period numbering from left to right. Period 2 was just half as long as the other periods.

Figure 4. (Below.) Brook trout mortality. Bars represent per cent of fish lost each period numbering from left to right. Period 2 was just half as long as the other periods.

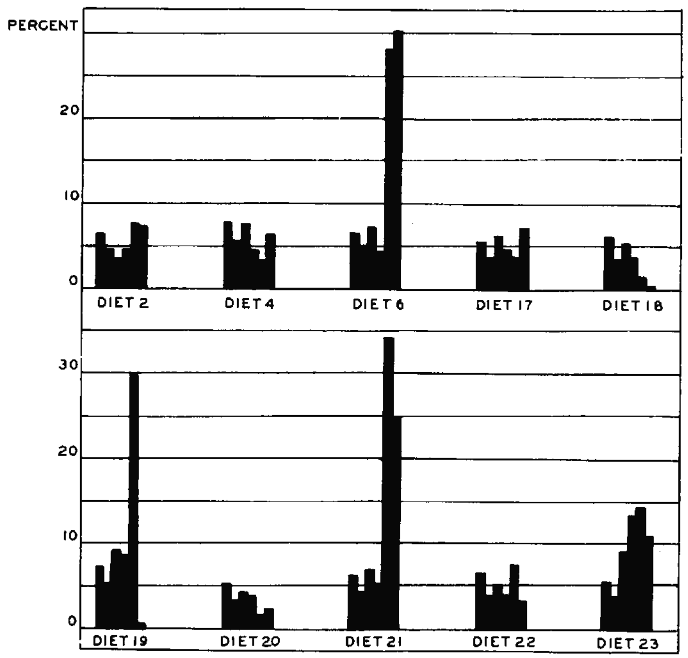

Figure 4

Figure 6. (At right.) Brown trout mortality. Bars represent per cent of fish lost each period numbering from left to right. Period 2 was just half as long as the other periods.

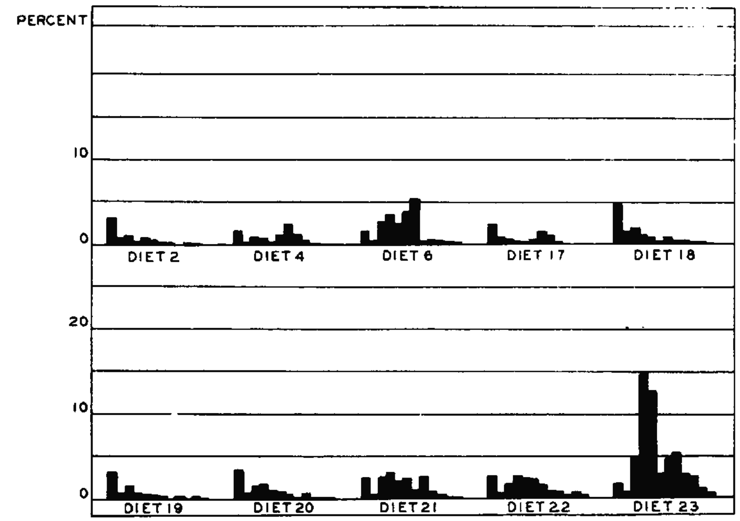

Figure 5

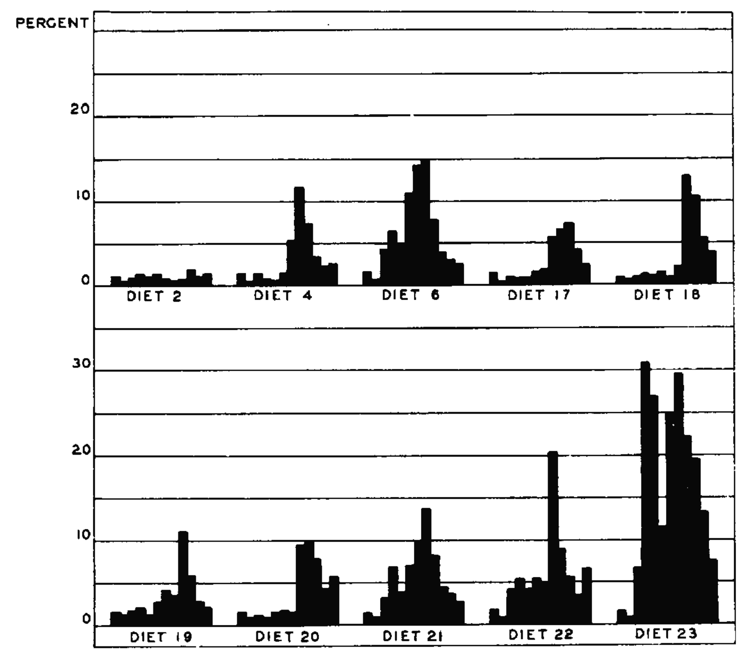

Figure 6

TABLE 4. SUMMARY AND INDEX FIGURES OF GROWTH,
MORTALITY, FOOD CONVERSION, AND COST OF FOOD TO REAR ONE POUND OF TROUT

Diet No.	Per cent increase in weight	Index[1]	Average per cent mortality[2]	Index	Average food conversion factor[3]	Index	Cost of food to rear one pound of trout	Index
			Brook Trout					
2	952	100	5.78	100	3.204	100	$0.2723	100
4	870	91	5.94	103	2.711	85	0.1648	61
6	844	89	13.72	237	3.362	105	0.1396	51
17	775	81	5.24	91	2.887	90	0.1738	64
18	606	64	3.52	61	2.900	91	0.1465	54
19	534	56	8.72	151	3.924	122	0.2464	90
20	734	77	3.55	61	3.060	96	0.2127	78
21	763	80	13.73	238	3.637	114	0.1493	55
22	645	68	5.20	90	3.591	112	0.1434	53
23	521	55	9.63	167	4.491	140	0.2013	74
Mean (11 weeks)			7.50		3.377		0.1850	
			Rainbow Trout					
2	4,088	100	0.67	100	3.652	100	0.3104	100
4	3,139	77	0.81	121	3.547	97	0.2157	69
6	2,433	60	1.71	255	4.689	128	0.2182	70
17	3,255	80	0.64	96	3.688	101	0.2220	72
18	2,596	64	0.92	137	3.673	101	0.1855	60
19	1,941	47	0.66	99	5.146	141	0.3232	104
20	2,809	69	0.80	119	3.939	108	0.2738	88
21	2,032	50	1.41	210	5.684	156	0.2597	84
22	1,877	46	1.34	200	5.442	149	0.2404	77
23	1,965	48	4.45	664	5.905	162	0.2953	95
Mean (23 weeks)			1.32		4.537		0.2574	
			Brown Trout					
2	2,348	100	1.00	100	4.256	100	0.3618	100
4	2,405	102	3.11	311	3.753	88	0.2282	63
6	2,452	104	6.15	615	4.467	105	0.2036	56
17	2,237	95	2.73	273	3.724	88	0.2242	62
18	1,943	83	3.43	343	3.838	90	0.1938	54
19	1,625	69	3.27	327	5.208	122	0.3271	90
20	2,158	92	3.73	373	4.195	99	0.2916	81
21	2,040	87	5.39	539	5.059	119	0.2287	63
22	2,208	94	5.83	583	4.872	114	0.2122	59
23	2,284	97	16.09	1609	5.883	138	0.2966	82
Mean (23 weeks)			5.07		4.526		0.2568	

[1] The value of the control (Diet 2) is considered as 100. In the index figures pertaining to per cent increase in weight a value of less than 100 means poorer growth. In the index figures pertaining to average per cent mortality, average food conversion factor, and cost of food to rear one pound of trout a value less than 100 means respectively lower mortality, lower food conversion factor (better conversion of food into body weight), and lower cost of food to rear one pound of trout.

[2] Average per cent mortality is the average of the per cent of trout lost each period.

[3] Average food conversion factor is the average of the food conversion factors for each period.

subject to ulcer disease at any time. Those fish whose diets contained pork "melts" (Nos. 6, 21, 22 and 23) seemed unable to withstand the disease--in nearly every lot on each of these diets there was a heavy mortality.[4] Thirty-minute treatments with a 1:75,000 solution of potassium permanganate at intervals of about forty-eight hours were of no avail.

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[4] It would be unjust, however, without more complete evidence to blame the pork "melts" for this heavy mortality from ulcer disease since pork "melts" have been used successfully in trout diets and since many of the groups not receiving this food, notably those fed Diet 19, were also affected. It was unlikely that disease was spread from trough to trough since such precautionary measures as rinsing brushes and other implements used in handling the trout in strong solutions of potassium permanganate, copper sulfate or lysol were taken at all times.

Gyrodactylus sp. occurred occasionally among the fish, but at no time was it allowed to grow to epidemic proportions. A twenty-minute treatment in a 1:75,000 solution of potassium permanganate apparently was effective in controlling these parasites. The use of the chemical had no visible harmful effect upon the trout, and probably did not materially affect the final results of the feeding experiment.

DISCUSSION

It would be unwise to attempt to evaluate definitely the various diets on the basis of the data presented here. Some of the combinations will bear further study before they can be recommended; others deserve further trial before being condemned. The tabular data probably portray better than words the results of the experiment. However, in conclusion a few statements are warranted regarding the relative worth of the diets employed in this study.

Perhaps the most logical approach in selecting the best diets in this study is to eliminate at once all those diets which show the least promise of rearing fish at low cost. The diets which survive the elimination with regard to cost should be further selected in regard to the mortality and growth resulting from these diets. We shall assume for the time being that the brook trout were not under observation for a long enough period and that the ulcer disease was a disturbing factor, and begin the elimination of diets in the rainbow and brown trout experiments. If the results with the brook trout agree with those of the other two species they may perhaps be accepted also.

From Table 4 it is easy to see that among the rainbows all but Diets 4, 6, 17, and 18 should be eliminated when cost alone is considered. It must be remembered that for sixteen of the twenty-three weeks the price of pork "melts" was $0.055 per pound whereas for the first seven weeks the price was $0.035 per pound. However, an examination of the food conversion factors (Table 2) discloses the fact that unless the price of "melts" is relatively low it cannot successfully compete with sheep liver as a portion of the diet.

The mortality record (Table 5) indicates that only those diets that contained liver should be retained. This then eliminates Diet 6 from the four chosen on the basis of lowest cost, leaving Diets 4, 17, and 18. If we now examine the growth record (Table 4) for these three we find that Diets 4 and 17 rank second and third among the rainbows as compared with fifth place for Diet 18, or about 20 per cent better growth

TABLE 5. MORTALITY IN PER CENT LOST DURING EACH TWO-WEEK PERIOD

Diet No.	Period 1	2[1]	3	4	5	6	7	8	9	10	11	12	Average: Four periods	Average: Twelve periods[2]
							Brook Trout							
2	6.55	4.83	3.60	4.62	7.62	7.43	....	....	....	....	....	....	4.90	5.78
4	7.99	5.73	7.53	4.79	3.30	6.31	....	....	....	....	....	....	6.51	5.94
6	6.63	5.13	7.26	4.58	28.21	30.50[3]	....	....	....	....	....	....	5.90	13.72
17	5.59	3.81	6.24	4.72	3.92	7.15	....	....	....	....	....	....	5.09	5.24
18	6.13	3.54	5.54	3.86	1.44	0.63	....	....	....	....	....	....	4.77	3.52
19	7.32	5.33	9.11	8.91	20.93	0.73[3]	....	....	....	....	....	....	7.67	8.72
20	5.27	3.47	4.32	3.99	1.84	2.43	....	....	....	....	....	....	4.26	3.55
21	6.14	4.47	6.95	5.49	34.36	25.00[3]	....	....	....	....	....	....	5.76	13.73
22	6.68	4.06	5.37	4.17	7.65	3.29	....	....	....	....	....	....	5.07	5.20
23	5.74	3.94	9.11	13.40	14.53	11.04	....	....	....	....	....	....	8.05	9.63
Average	6.40	4.43	6.50	5.85	12.38	9.45	....	....	....	....	....	....	5.80	7.50
							Rainbow Trout							
2	3.19	0.89	1.02	0.45	0.84	0.56	0.31	0.25	0.06	0.25	0.19	0.00	1.39	0.67
4	1.64	0.28	0.95	0.92	0.48	1.10	2.37	1.19	0.47	0.21	0.05	0.00	0.95	0.81
6	1.44	0.29	2.59	3.29	2.43	3.71	5.20	0.42	0.50	0.37	0.14	0.09	1.90	1.71
17	2.26	0.87	0.71	0.47	0.27	0.58	1.42	0.94	0.11	0.00	0.00	0.00	1.08	0.64
18	4.52	1.54	1.84	0.90	0.60	0.25	0.52	0.24	0.24	0.19	0.19	0.00	2.20	0.92
19	3.19	0.74	1.55	0.75	0.61	0.51	0.28	0.04	0.20	0.00	0.05	0.00	1.56	0.66
20	3.23	0.62	1.35	1.50	0.98	0.86	0.38	0.19	0.38	0.05	0.05	0.00	1.68	0.80
21	2.21	0.34	2.30	2.91	2.02	2.18	1.01	2.35	0.86	0.32	0.18	0.18	1.94	1.41
22	2.55	0.59	1.61	2.58	2.27	2.25	1.59	0.89	0.69	0.35	0.43	0.31	1.83	1.34
23	1.55	0.57	4.69	14.67	12.57	2.91	4.50	5.06	2.74	2.45	1.09	0.61	5.37	4.45
Average	2.56	0.67	1.87	2.84	2.16	1.42	1.79	1.11	0.63	0.42	0.24	0.12	1.99	1.32
							Brown Trout							
2	1.00	0.42	0.80	1.17	1.03	1.24	0.83	0.52	0.73	1.97	1.12	1.16	0.85	1.00
4	1.29	0.46	1.10	0.77	0.73	1.38	5.12	11.45	7.21	3.26	2.16	2.38	0.91	3.11
6	1.41	0.67	4.16	6.27	4.69	10.66	14.08	14.62	7.87	3.92	2.96	2.51	3.13	6.15
17	1.21	0.27	0.90	0.87	0.89	1.41	1.82	5.58	6.49	7.05	4.07	2.24	0.81	2.73
18	0.86	0.54	0.98	1.19	1.06	1.33	0.89	2.06	12.76	10.24	5.49	3.82	0.89	3.43
19	1.53	1.32	1.60	1.94	1.18	2.57	4.04	3.58	10.90	5.86	2.64	2.04	1.60	3.27
20	1.23	0.61	0.97	0.98	1.34	1.53	1.52	9.37	9.63	7.89	4.17	5.51	0.95	3.73
21	1.20	0.88	3.09	6.72	3.81	6.94	9.76	13.52	8.08	4.53	3.55	2.61	2.97	5.39
22	1.63	0.76	4.09	5.27	4.06	5.26	4.83	20.11	8.95	5.40	3.34	6.34	2.94	5.83
23	1.27	0.74	6.42	30.71	26.75	11.31	24.95	29.24	22.00	19.22	13.07	7.44	9.79	16.09
Average	1.26	0.65	2.41	5.59	4.55	4.36	6.78	11.01	9.46	6.93	4.26	3.60	2.46	5.07

[1] Period 2 is only one week long; other periods are two weeks.

[2] Only six periods for brook trout.

[3] These figures based on the mortality of only two troughs on each of the three diets; the mortality had been so heavy among the fish in the other two troughs that too small a number of fish was left to feed satisfactorily.

than Diet 18. It now becomes necessary to make a choice between cost and growth. If the chief aim is to grow larger fish, then Diets 4 and 17 must be chosen. Diet 17 had the lowest mortality record for the rainbows, ranked second in growth, but fourth in cost--(only slightly more expensive than Diet 4). Diet 18, however, enabled the fish to be reared at a cost about 15 per cent less than Diets 4 and 17. The mortality record of Diet 18 was low even though it ranked sixth; and the fish appeared in good condition.

Turning to the brown trout, from the standpoint of cost, Diets 2, 19, 20, and 23 can be eliminated immediately; the mortality record of Diet 6, ranking ninth, is somewhat high and this diet should therefore be eliminated also. However, Diet 6 yielded the best growth and was second lowest from the standpoint of cost. The high mortality on Diet 6 occurred during Periods 6, 7, and 8 (Table 5) and then receded.[5]

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[5] When evaluating a diet in terms of the mortality of the trout that received the diet, one must consider the age of the trout at the time the mortality occurred. Obviously, the longer a trout has been confined and fed the greater is the loss in dollars and cents when death ensues. Early mortality, therefore, does not entail as large a financial loss as late mortality. From the data obtained during this experiment it is hoped that an equation for evaluating mortality may be derived, which considers the total cost of the trout at the time of death.

Diets 4 and 17 are not far behind Diet 6 in cost and growth and both have very low mortality records. Diets 4 and 17 can be recommended from the standpoint of low mortality and good growth and Diet 18 from the standpoint of low mortality and low cost. Diet 6 was effective in producing good growth of brown trout at a low cost, but accompanied by relatively high mortality.

Trout can be reared more cheaply, and with a mortality record almost as low, on Diets 4, 6, 17, and 18 than on the sheep liver diet fed to the controls (Diet 2). In general, trout reared on sheep liver present excellent growth and low mortality records, but the cost of this diet is about twice that of the other satisfactory diets.

Results of the rainbow and brown trout experiments are comparable to those with the brook trout in that Diet 18 again provided low cost fish, this time in third place. Diet 18 was associated with the lowest mortality record, with Diet 20 a very close second. Although Diet 6 provided good growth at low cost, its high mortality record disqualifies it.

It is concluded on the basis of this study that the diets containing pork "melts" are least desirable because of the heavy mortality. Unless the price of "melts" is relatively low, the cost to rear a pound of trout on diets that contain "melts" will not compare favorably with that of the diets that contain sheep liver. Diet 18 was outstanding when cost to rear trout was considered; Diets 4 and 17 were best when low mortality and good growth accompanied by relatively low cost were desired; and Diet 6 produced good growth at low cost in the brown trout, but with rather high mortality.

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