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REPORT NO. 410

WOLF LAKE TROUT FEEDING EXPERIMENTS -- 1936*

During 1935 some feeding experiments were conducted at the Wolf Lake Fish Hatchery in which only brook trout were used. The primary purpose of this first work was to acquaint the investigators with the technique of fish cultural procedure, and to find some point of departure for further studies on the problem of finding a means of reducing the cost of feeding trout in Michigan's hatcheries.

The purpose of the feeding during the 1936 season was primarily to discover to what extent fresh meat in the diet of trout might be replaced by less expensive dry meals, and still maintain satisfactory growth. Previous experiments by workers in other states had shown that dry meals could be used satisfactorily in hatchery feeding, and it was reasonable to believe that the same would be true here. This report will present the conditions under which this experimental work was conducted, the materials and equipment used, and the results obtained. Of greatest importance in this study is a comparison of the costs of rearing unit weights of trout in good nutritional condition.

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* The writer wishes to acknowledge assistance in this study as follows: Dr. Louis Wolf assisted in planning and directed the work; Professor J. W. Stack and Dr. C. A. Hoppert of Michigan State College also assisted in planning the experiments and furnished valuable advice during their progress and in the preparation of this report; Mr. J. G. Marks, Superintendent of Fisheries Operations, in Charge of Wolf Lake Hatchery, supplied facilities for the work and gave much valuable assistance in the practical aspects of the experiments.

The facilities of the Wolf Lake Hatchery were again used for the experimental studies, which were started July 8 and terminated September 11, 1936. This period was not as long as would have been desirable, but even so, a comparison of the nutritional worth of these diets did appear. At the start of the feeding tests 20,800 brown trout fingerlings weighing about 1500 grams (54 oz.) per thousand were divided into 26 standard hatchery troughs, 800 in each. Fresh spring water whose temperature ranged from 50° to 60° F. (10° to 15° C.) flowed into each trough through a screen so that natural food was excluded.

In the experiment each of the thirteen diets were given to two troughs of fish. Table I shows the composition of each diet and the "as purchased" cost per pound. The costs of the diets are calculated from the purchase price of small quantities of the components, as quoted at the first of the summer, 1936.

The diets consisting only of moist foods (fresh meats and "Balto") were ground to a size suitable for the fish and fed by placing small quantities at intervals along the trough. In preparation of the diets containing dry meals, the meal portions were first thoroughly mixed in large quantities and stored in vermin-proof cans. The ground fresh meats were added to the meal mixtures and allowed to stand in a refrigerator for about 12 hours before feeding. Covered glass jars were very satisfactory for the storage of the meat-meal mixtures. Since fresh meat was received twice each week, the food stood in the refrigerator for from 12 to 60 hours, portions being taken out each day for feeding. In most cases a small quantity of water was added to facilitate mixing the rations since it is almost impossible to get a thorough mixture if the ratio of dry meal to meat is high. Also it is necessary to have the mixture of a consistency which is not too dry nor too wet in order to permit the trout to ingest it readily, and to avoid waste. When ready for feeding, these mixtures were all of very nearly

the same consistency. Table I shows the amount of water added to each diet. It may be stated here that diet J, the only one containing oatmeal (18.2%), was readily mixed with what seemed at first to be too much water; but after standing in the refrigerator for 12 hours the mixture had become stiff enough to handle nicely in feeding. In fact, this mixture had the best consistency for feeding of all the diets used in 1936.

The fish received all the food they would consume in two twenty-minute periods each day, six days per week. It is customary at the hatchery to omit feeding on Sunday, so on one day each week no food was offered at all. The amount of food administered each day is recorded, and the totals for each period are shown in Table II on an "as purchased" basis, correction being made for those diets to which water was added during preparation.

A daily record of mortality is kept so that the number of fish in each trough is known for any time, except for an occasional trout that may leap from his trough into one adjacent or onto the floor. Any dead fish are removed each morning so that the mortality figures really account for the day and night preceding. Table III shows the mortality record for this season's study. Under most conditions the mortality figures can be used as a fairly good index as to the value of a diet. It will be noticed in this experiment that the foods which resulted in poor growth also resulted in high mortality.

In this work growth was measured only in terms of the wet weight of the fish, which is taken every two weeks on a platform balance of fifty pounds capacity. All the fish in the trough are weighed each time and the weight per hundred calculated. This type of balance is not as sensitive as might be desired, but considering the factors which make for inaccuracy on more sensitive balances, the weights taken here seem to be as good as any.

From the figures for both increase in weight of the fish for any period and the amount of food fed for that period, a food conversion factor has been calculated by the following formula:

$$\text{Food Conversion Factor} = \frac{\text{Wt. of Food Fed Per 100 Fish}}{\text{Increase in Weight Per 100 Fish}}$$

or

$$\text{F.C.F.} = \frac{\text{Wt. of Food Fed}}{.01 \times \text{Average No. Fish During Period} \times \text{Increase Weight Per 100}}$$

The F.C.F. is the amount of food that produces a unit weight of trout. Table IV shows the food conversion factors for each trough by periods and the average for the ten weeks of the experiment. Table III shows the average number of fish during any period.

By multiplying the price per unit weight of the food by the F.C.F. it is possible to calculate the cost of rearing a unit weight of trout. Table V shows the F.C.F. per diet and the cost for rearing a unit weight of trout during the extent of the experiment. Table VI is a bar chart comparing food conversion factors for each diet; and Table VII is a bar chart comparing costs of rearing unit weights of trout.

No "condition factor" was calculated since only weight was taken as a measure of growth. However, observations were made and recorded as to the behavior and appearance of the fish, and thus the general condition of the trout was approximately determined. Table V includes this information classified in four groups with no well defined limits: poor, fair, good, and excellent. The fish which appeared in poor condition were at the same time those which grew poorly and among which mortality was high.

An examination of Table VII shows that for the duration of the experiment, it cost less to raise a pound of fingerling brown trout on diet F than on any other; diets G and H were not far behind. Diets D, E, K, J, and I seem to form another group in which the cost of rearing a pound

of trout is a little greater. On diets L, M, C, B, and A the cost is approximately two to three times as great as on diet F. Since the chief concern in this work is to find the cheapest satisfactory diet for rearing trout fingerlings in the hatchery, these last named diets, L, M, C, B, and A, can immediately be considered unsatisfactory because of cost, although fish in excellent condition were reared on both diets A and B.

An examination of Table V shows that diets G, H, I, and K produced trout in poor or only fair condition, and, except for one trough receiving diet K, also resulted in a mortality figure greater than the average. Considering these facts, it seems wise to regard them as unsatisfactory.

This leaves for consideration diets D, E, F, and J. Fish in apparently excellent condition were reared on diets D and F, with a comparatively low mortality. The fish reared on diets E and J were in good condition but hardly equal to those receiving diets D and F. It must be remembered, however, that the condition of the fish was determined in this experiment only by observation, and that the degree of difference between good and excellent is not necessarily great. The trout receiving diet J suffered an increased mortality near the end of the experiment, and it is impossible to say whether or not this might have continued longer. As has been mentioned previously, diet J is of a consistency which is quite easily prepared and is not likely to be wasted in feeding. Although diet E resulted in very low mortality, and its preparation requires only that it be put through a food chopper, it is so mushy that there is likely to be a great deal of waste. Such waste might be avoided by the addition of some dry ingredient, preferably one with some binding quality.

This happens to be the case with diet F, which is composed of 75% trimmed hog melts plus 25% of a dry meal mixture* made of equal parts of fish meal, cottonseed meal, and roller process skim milk powder. Diet D, composed of 50% sheep liver plus 50% of the dry meal mixture XX, produced excellent fish, and had a mortality figure almost as low as diet F; but to rear a pound of trout on diet D cost about 30% more than with diet F.

Diet F, therefore, seems to be the logical winner in this race for the "least expensive, satisfactory" diet for rearing brown trout fingerlings in the hatchery.

There are other considerations which must be brought out at this point. Unequal fluctuations in the prices of the components of the diets can have pronounced effects on the cost of rearing a unit weight of trout. For instance if the increased demand for hog melts caused an increase in the price of that product (now $0.035 per pound) so that it should reach $0.055 per pound it would cost just as much to rear a pound of trout on diet F as on diet D.

From this it appears that one of the most important disclosures that can be made from this study is the food conversion factor, which for a given set of conditions should remain quite constant. With the food conversion factors established one needs only to know the prices of the rations to compute the cost of rearing trout. Then as prices change one can change the proportions of the components of the diet in order to get the best growth for the money.

It is practically impossible to control the many factors which influence food conversion, principally the variability in nutritive value of the constituents of the diets and the biologic variation among experimental animals. However, the food conversion factor should serve as a fairly good index to the nutritive value of any food mixture, all other conditions being approximately equal.

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* Dry Meal Mixture XX.

Referring to Table VI it is noticeable that diet D was converted into trout flesh more completely than any of the others. Diet A ranks second when the food conversion factor is considered, but unfortunately it was the least satisfactory from the standpoint of cost of rearing unit weights of trout. Next in order of nutritive worth are diets H, F, G, and J, with B and C close behind. Diets L and M made a rather poor showing, with some rather inexplicable losses of trout as shown in Table III. One trough on diet K also exhibited a peculiar mortality record. In this connection the location of the six troughs which received those three diets may have had some effect upon both mortality and growth. A study of the possible influence of the location of these troughs, especially with reference to light, is planned for the coming season.

Evidently the feeding method used with diet I is not very successful with that particular combination of ingredients. Dry Meal Mixture XX, to which reference has already been made (page 6), does not have a great deal of binding power, so it may be that there is quite a loss during feeding. However, these trout were offered as much as they would eat, and yet were in poor condition from shortly after the start of the experiment until the end. Also their mortality was the greatest of any.

It is interesting to note that diet A upholds the usual contention of the fish culturist: that beef liver is better than sheep liver. In this experiment the food conversion factor for beef liver was 2.815, whereas that for sheep liver (diet B) was 4.004; that of hog melts (diet E) was 4.828. When certain meals are added to the meats, there seems to be a tendency for the food conversion factors to be reduced in most cases. Examples of this are diets D, F, G and H.

The addition of "Balto" to sheep liver, as in diet C, has very little effect upon the food conversion factor, but does reduce the cost of producing a unit weight of trout, with hardly any noticeable difference in the condition of the fish.

From the data obtained under the conditions described here, a diet composed of 75% trimmed pork melts, 8.3% cottonseed meal, 8.3% roller process skim milk powder, and 8.3% fish meal produced unit weights of brown trout fingerlings at the least cost. These trout were in excellent condition, every bit as good as those receiving beef liver (considered as controls).

A diet of 50% sheep liver, 16.7% cottonseed meal, 16.7% skim milk powder, roller process, and 16.7% fish meal produced more pounds of trout per pound of food fed than any other diet. Also it is evident that there is a better conversion of the food when the fresh meats are supplemented by some dry meals.

Very likely a slight modification of the proportion of the percentage of meat in diet F will bring about an even better food conversion factor.

INSTITUTE FOR FISHERIES RESEARCH

By: J. T. Wilkinson
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Table 1

Composition and Cost of Diets "As Purchased," 1936

INGREDIENTS	COST PER POUND	COMPOSITION OF DIETS IN PARTS PER HUNDRED												
		A	B	C	D	E	F	G	H	I*	J	K	L	M
Beef Liver	$0.1400	100.0	...	...	...	...	...	...	...	...	...	...	...	...
Sheep Liver	.0900	...	100.0	66.7	50.0	...	...	...	...	...	...	...	...	...
Pork Melts (trimmed)	.0350	...	...	...	...	100.0	75.0	50.0	25.0	34.0	25.0	50.0	70.0	25.0
"Balto"	.0600	...	...	33.3	...	...	...	...	...	...	...	...	...	...
Fish Meal	.0225	...	...	...	16.7	...	8.3	16.7	25.0	22.0	...	15.0	6.7	21.7
Cottonseed Meal	.0160	...	...	...	16.7	...	8.3	16.7	25.0	22.0	10.9	25.0	6.7	21.7
Skim Milk Powder, Roller	.0800	...	...	...	16.7	...	8.3	16.7	25.0	22.0	...	10.0	6.7	21.7
Skim Milk Powder, Spray	.0940	...	...	...	...	...	...	...	...	...	18.2	...	...	...
Oatmeal	.0340	...	...	...	...	...	...	...	...	...	18.2	...	...	...
Alfalfa Meal	.0150	...	...	...	...	...	...	...	...	...	3.6	...	10.0	10.0
Yeast (N'western)	.2000	...	...	...	...	...	...	...	...	...	3.6	...	...	...
Cod Liver Oil	.2000	...	...	...	...	...	...	...	...	...	2.2	...	...	...
Meat Scrap	.0260	...	...	...	...	...	...	...	...	...	18.2	...	...	...
Cost per pound		$0.1400	.0900	.0800	.0648	.0350	.0361	.0373	.0384	.0380	.0487	.0329	.0340	.0360
Cost per Kilo		$0.3086	.1984	.1764	.1428	.0772	.0796	.0822	.0846	.0837	.1117	.0725	.0749	.0793
Water**		...	...	...	25.00	...	...	25.00	42.85	66.67	42.85	25.00	11.10	66.67

* The Trout on Diet I received only fresh melts on one day per week, and only the dry meal portion of the diet on the five other feeding days. The proportions, therefore, were computed at the end of the entire ten week feeding period. The amount of water added in this case is based only on the weight of dry meals.

** Amount of water added to diet to assure suitable consistency for feeding; shown as per cent by weight of the rest of the diet.

Table II

Grams of Food Fed Each Period

Trough	Period 1 July 5-19	2 July 19 Aug. 2	3 Aug. 2-15	4 Aug. 16-30	5 Aug. 30 Sept. 12	Total	Diet
1	1025	1290	1737	1851	2611	8514	A
2	991	1297	1797	1855	1959	7899	B
3	996	1521	2182	2377	2803	9879	C
4	836	1164	1586	1994	2167	7747	D
5	1051	1527	2134	2585	2721	10018	E
6	943	1334	1950	2288	2827	9342	F
7	931	1174	1664	1965	1937	7671	G
8	839	1000	1246	1425	1729	6239	H
9	848	999	1283	1107	1327	5564	I
10	870	1083	1194	1469	1773	6389	J
11	1000	1277	1778	1974	2676	8705	A
12	993	1353	1824	2017	2624	8811	B
13	970	1568	1887	2303	2416	9144	C
14	856	1150	1615	1859	2132	7612	D
15	1060	1557	2127	2624	2652	10020	E
16	975	1348	1881	2298	2675	9177	F
17	875	1138	1528	1606	1815	6962	G
18	813	1005	1067	1226	1506	5617	H
19	782	959	1288	1196	1257	5482	I
20	840	1101	1308	1457	1724	6430	J
33	1002	1127	1578	1653	1732	7092	K
34	949	1280	1483	1323	1800	6835	L
35	780	910	1224	1211	1367	5492	M
36	1064	1194	1722	1905	1816	7701	K
37	937	1143	1541	1366	2069	7056	L
38	769	897	1159	1174	1350	5349	M
Total	23995	31396	41783	46108	53465	196747	

Table III

Mortality Record Showing Loss, Mean Number of Fish During Each Period, and Average Mean Number of Fish During Entire Period

Trough	Periods															Common Mean*	Diet
	July 5 to 19			July 19-Aug. 2			Aug. 2 to 16			Aug. 16 to 30			Aug. 30-Sept. 11			Sept. 11	
	Start	Loss	Mean	Start	Loss	Mean	Start	Loss	Mean	Start	Loss	Mean	Start	Loss	Mean	Start	
1	800	4	798	796	0	796	796	0	796	796	1	796	795	1	795	794	798	A
2	800	3	798	797	1	796	796	0	796	796	2	795	794	1	794	793	796	B
3	800	3	798	797	0	797	797	0	797	797	2	796	795	2	794	793	798	C
4	800	4	798	796	1	796	795	2	794	793	1	793	792	1	792	791	795	D
5	800	0	800	800	0	800	800	2	799	798	1	798	797	1	796	796	799	E
6	800	1	800	799	4	797	795	0	795	795	0	795	795	0	795	795	796	F
7	800	11	795	789	3	788	786	5	783	781	6	778	775	9	770	766	783	G
8	800	11	795	789	5	787	784	5	782	779	16	771	763	40	743	723	776	H
9	800	4	798	796	0	796	796	9	791	787	115	730	672	35	655	637	754	I
10	800	5	797	795	2	794	793	4	791	789	6	786	783	12	777	771	789	J
11	800	1	800	799	2	798	797	0	797	797	3	795	794	1	794	793	797	A
12	800	0	800	800	4	798	796	1	796	795	5	793	790	3	788	787	795	B
13	800	5	797	795	5	793	790	0	790	790	2	789	788	3	787	785	791	C
14	800	10	795	790	4	788	786	2	785	784	2	783	782	5	780	777	786	D
15	800	4	798	796	4	794	792	4	790	788	2	787	786	13	780	773	790	E
16	800	5	797	795	0	795	795	1	794	794	3	792	791	6	788	785	793	F
17	800	2	799	798	6	795	792	12	786	780	67	747	713	48	689	665	763	G
18	800	6	797	794	3	792	791	8	787	783	86	740	697	83	655	614	754	H
19	800	3	798	797	6	794	791	154	714	637	75	600	562	6	559	556	693	I
20	800	7	796	793	2	792	791	4	790	787	12	781	775	18	766	757	785	J
33	800	2	799	798	1	798	797	1	796	796	31	780	765	102	714	663	777	K
34	800	4	798	796	3	795	793	33	777	760	151	690	609	52	583	557	729	L
35	800	3	798	797	1	796	796	0	796	796	34	779	762	183	670	579	768	M
36	800	6	797	794	6	791	788	0	788	788	5	785	783	3	782	780	789	K
37	800	2	799	798	1	798	797	2	796	795	6	792	789	5	787	784	794	L
38	800	6	797	794	3	792	791	8	787	783	6	780	777	20	767	757	785	M
Total	20800	112	...	20688	67	...	20621	257	...	20364	640	...	19724	653	...	19071	780	

* Mean number of fish during the ten week period, computed by dividing the summation of the means of each period by the number of periods.

Table IV

Food Conversion Factors by Periods

Trough	Period 1	2	3	4	5	Mean	Diet
1	2.733	2.382	2.661	3.101	3.284	2.832	A
2	1.749	4.071	3.701	3.590	9.489	4.520	B
3	3.782	2.272	3.466	4.895	4.836	3.850	C
4	2.381	1.720	2.407	3.143	3.463	2.623	D
5	5.255	2.982	4.173	5.999	5.604	4.803	E
6	2.807	2.202	3.270	5.330	3.995	3.521	F
7	5.855	1.862	2.624	4.141	3.494	3.595	G
8	(21.107)	1.873	3.064	4.298	2.938	3.055*	H
9	(∝)	5.020	5.232	6.893	3.493	5.159*	I
10	4.198	2.393	4.440	3.526	2.783	3.468	J
11	1.786	3.903	2.323	2.624	3.337	2.798	A
12	2.535	1.971	3.055	4.239	5.644	3.488	B
13	3.289	2.709	4.507	5.307	5.203	4.203	C
14	3.167	1.536	2.365	2.931	2.706	2.541	D
15	6.038	2.482	4.019	5.378	6.296	4.353	E
16	3.058	2.261	3.702	4.396	4.090	3.501	F
17	4.380	2.309	3.136	4.300	4.390	3.703	G
18	3.091	2.488	3.228	7.203	3.593	3.921	H
19	6.533	4.026	(30.075)	3.437	4.164	4.540*	I
20	5.554	1.931	3.010	4.909	3.517	3.780	J
33	5.700	2.615	4.310	9.528	6.556	5.742	K
34	7.928	5.552	11.227	6.612	7.130	7.700	L
35	(∝)	7.621	7.322	(155.456)	(∝)	7.472*	M
36	4.944	2.435	4.047	6.386	4.466	4.456	K
37	(29.318)	3.581	6.050	10.780	6.918	6.832*	L
38	10.721	6.292	7.363	11.578	8.800	8.951	M
Mean	4.431	3.096	4.188	5.382	4.311	4.458	

* Data enclosed in parentheses disregarded in computing mean F.C.F. for ten week period.

Table V

Food Cost Per Unit for Rearing Fingerling Brown Trout from July 8 to September 12, 1936,* at Wolf Lake Fish Hatchery, Van Buren County, Michigan

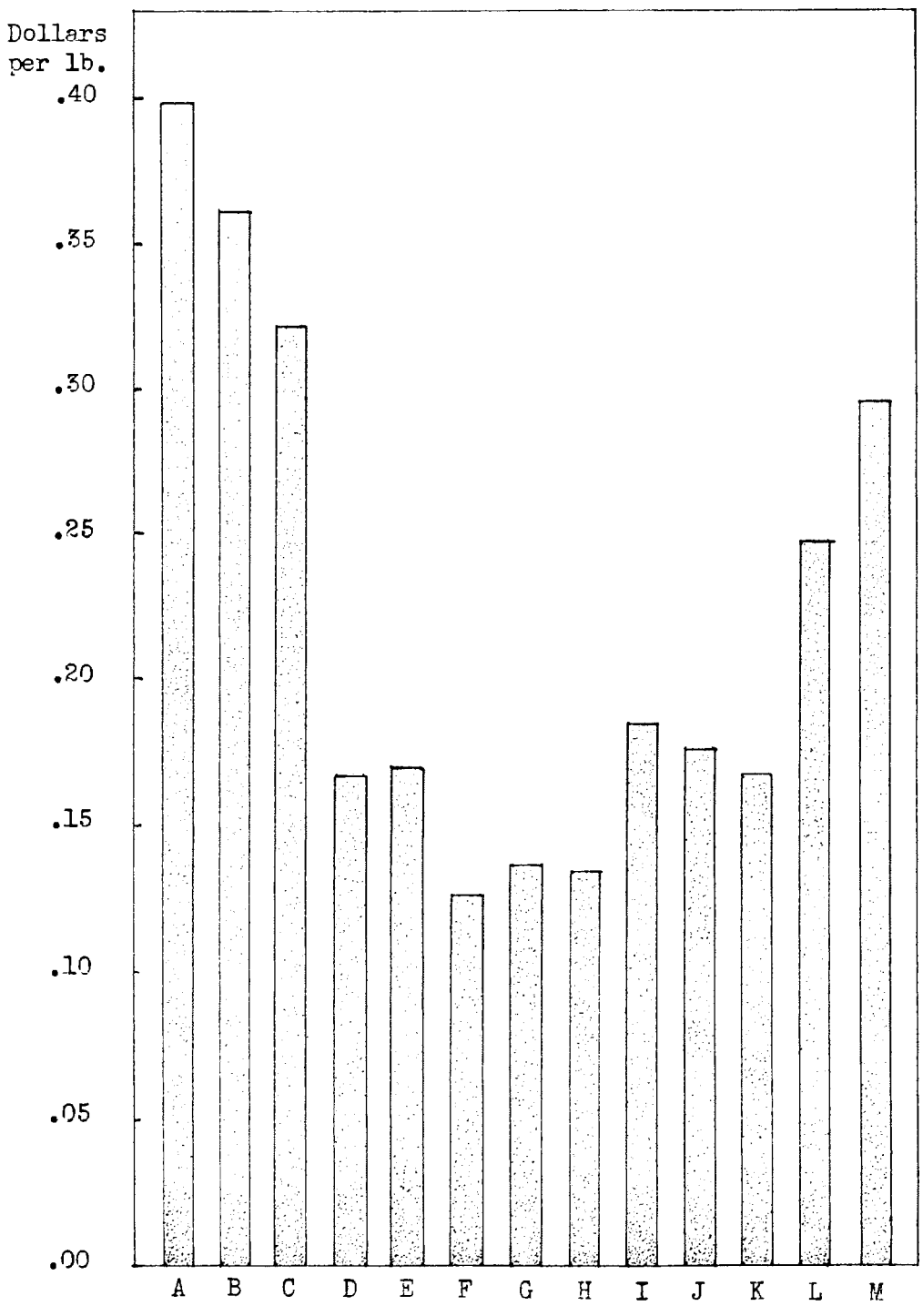
Diet	Trough	Food Conversion Factor	Average FCF for Diet	Price of Diet		Food Cost for Rearing		Average Cost to Rear		Condition
				Per Kilo	Per Pound	1 Kilo	1 Pound	1 Kilo	1 Pound	
A	1	2.832	2.815	$0.3086	$0.1400	$0.3740	$0.3965	$0.8693	$0.3991	Excellent
	11	2.798				.8635	.3917			
B	2	4.520	4.004	.1948	.0900	.8805	.4068	.7800	.3604	Excellent
	12	3.488				.6795	.3139			
C	3	3.850	4.027	.1764	.0800	.6791	.3080	.7103	.3221	Good
	13	4.203				.7414	.3362			
D	4	2.623	2.582	.1428	.0648	.3746	.1700	.3638	.1674	Excellent
	14	2.541				.3629	.1647			
E	5	4.303	4.328	.0772	.0350	.3708	.1681	.3778	.1690	Good
	15	4.353				.3747	.1699			
F	6	3.521	3.511	.0796	.0361	.2803	.1271	.2795	.1268	Excellent
	16	3.501				.2787	.1264			
G	7	3.595	3.649	.0822	.0373	.2953	.1341	.2999	.1361	Fair
	17	3.703				.3044	.1381			
H	8	3.055*	3.488	.0846	.0384	.2585	.1173	.2951	.1340	Fair
	18	3.921				.3317	.1506			
I	9	5.159*	4.350	.0837	.0380	.4318	.1960	.4059	.1843	Poor
	19	4.540*				.3800	.1725			
J	10	3.468	3.624	.1117	.0487	.3874	.1689	.4048	.1765	Good
	20	3.780				.4222	.1841			
K	33	5.742	5.094	.0725	.0329	.4163	.1889	.3697	.1678	Fair
	36	4.456				.3231	.1466			
L	34	7.700	7.266	.0749	.0340	.5767	.2618	.5442	.2471	Fair
	37	6.832*				.5117	.2323			
M	35	7.472*	8.212	.0793	.0360	.5925	.2690	.6512	.2956	Poor
	38	8.951				.7098	.3222			
Mean			4.458					.4890	.2220	
Median			4.004					.4048	.1765	

* See Table IV: some erratic data disregarded in computing these factors.

TABLE VII

PLOT SHOWING COST PER POUND OF REARING BROWN TROUT

BARS REPRESENT COST OF REARING ONE POUND OF BROWN TROUT
IN THIS EXPERIMENT

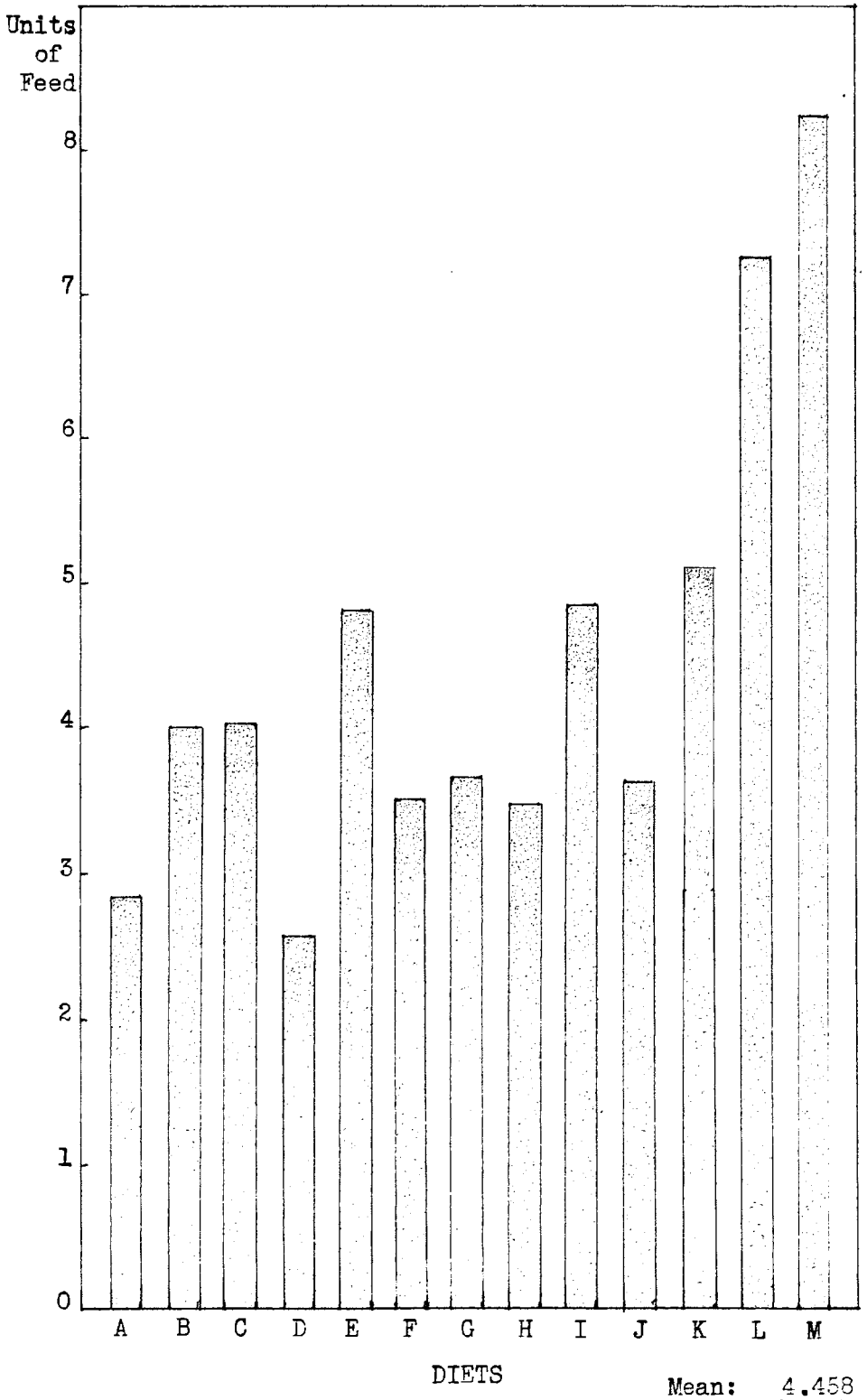


Mean: .2220
Median: .1765

TABLE VI

PLOT OF CONVERSION FACTORS FOR BROWN TROUT

BARS REPRESENT UNIT WEIGHTS OF FOOD REQUIRED TO REAR ONE UNIT WEIGHT OF BROWN TROUT IN THIS EXPERIMENT



Mean: 4.458
Median: 4.004