THE EFFECT OF PROTEINS IN DIFFERENT FOODS ON THE GROWTH OF FISH

by

BERNICE LUCILLE HARPER

A. B., Kalamazoo College, 1929

A THESIS

submitted in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

KANSAS STATE AGRICULTURAL COLLEGE

1930

TABLE OF CONTENTS

INTRODUCTION

This problem has been undertaken to determine a cheap and suitable protein supplement and protein substitute for beef liver in the diet of the spotted channel catfish Ictalurus punctatus (Rafinesque) and the common goldfish Carassius auratus (Linnaeus).

Since protein is the major constituent of the blood, of the muscles, and of the organs it is a vital factor in the diet of fish. Liver has been used by the fish culturists at many of the hatcheries to supply the requisite dietary protein. The cost of liver is probably the greatest single item in the total cost of rearing fingerlings to the adult stage. An effective substitute or supplement for

liver is highly desirable from the economic standpoint.

To determine the economy, the cost of supplementary and substitute foods must be compared with the cost of raw liver.

The production of healthy bodies and the rate of growth have been used by fish culturists as the criteria for the suitability of the food for the fish. This method has been used in this experiment.

REVIEW OF LITERATURE

James (1928) has calculated 270,000 dollars to represent the fixed charge of the annual feed bill on fish cultural operations in this country.

Efficiency experts have advised fish culturists that economical and effective administration of any activity must be based upon a reduction of all fixed charge to an absolute minimum.

When fish rearing was first started every hatchery used liver for feeding purposes. It was cheap and the results obtained were adequate. Since the nutritional value of liver in the human diet has been recognized it has become too expensive to include in the diet of large numbers of fish.

The sportsmen have stimulated the demand for fish. In consequence, fish culturists have extended their small beginning to one of a vast enterprise in making hatcheries adequate to supply the demand for fish in the streams and lakes of this country.

Experiments at Harvard, Yale, and Rochester in feeding liver to experimental animals, chiefly rats and dogs, have shown a marked virtue in their product. Young animals grew at a rate far in excess of what was formerly considered normal. Rats will do this when only 5 or 10 per cent of the diet is liver.

Experimental work on fish nutrition has been done chiefly with trout and bass at the fish hatcheries. McCay, Bing, and Dilley (1927) found that trout needed a protein level of over 10 per cent for normal growth, but that the addition of over 25 per cent had no effect upon the rate of growth.

McCay and Dilley in a later paper (1927) state that young trout require a factor in raw liver that is apparently none of the vitamins. They call it factor H. These workers found factor H to be present in a limited amount in milk which has been dried by the spray process.

In their experiments with trout (1927) they found that an amount of raw liver, as small as 5 per cent of the ration

exerts a marked influence upon the growth produced by feeding dried skimmed milk.

Titcomb, Cobb, Crowell, and McCay (1928) in experiments with trout found that milk alone would permit good growth for only a limited time. Combined with meat, however, it has been very successful over a period of sixteen months.

These workers found dry buttermilk to be as good as dry skim milk for trout feed.

Thomas (1909) has given to meat, milk, and fish protein biological values approximating 100 and to peas a value of 88.

More recent determinations of the biological values of proteins have in general indicated smaller differences between animal and vegetable proteins than the results of Thomas.

The work of Osborne and Mendel (1919) assigned to cereal proteins values much nearer those of animal proteins than the work of Thomas.

Davis (1927) found in experiments on trout that the use of cereals in the diet is objectionable. Not only are the starches undigested but when present in any considerable amount they must necessarily prevent the fish from obtaining sufficient quantities of protein and fat for optimum growth.

Bing (1926) and Davis (1927) in substituting a vegetable food for liver in the form of cooked soybeans which are characterized by a high percentage of protein which closely resembles animal protein in structure found that beans did not produce growth equivalent to that produced by raw liver. When used in combination with beef liver in all cases there was produced a much slower growth than on beef liver.

Yet all the commercial fish breeders in Colorado, and there are numbers of them, use steam cooked beans. With these beans they use lungs rather than cooked liver.

McCollum, Simmonds, and Parsons (1918) in their report on the dietary properties of the pea have attributed unusually high values to legume seeds, especially beans and peas, with respect to their quality of proteins and content of fat soluble A. From this data one would conclude that the pea is dietetically unique among seeds in these respects.

These workers found the legumes to be deficient in chlorine, calcium, and sodium. In the experimental diet on rats 25 per cent consisted of cooked dried peas and the remaining per cent of pure food stuffs and butter fat to furnish fat soluble A. The peas were cooked under pressure one and one-fourth hours. The rats grew to full adult size at the normal rate. The minimum amounts they believe to be from 5 to 25 per cent.

Johns (1921) found that the digestibility of proteins were reported to be much improved by cooking. The value of these proteins in growth experiments on rats in large part depended upon whether or not the proteins were cooked.

Davis (1927) found a difference in food requirements as to species. Beneficial results were obtained when cod-liver oil and yeast were added to the diet of rainbow trout. The brook trout on the other hand failed to show any benefit from the addition of these substances. It seems that each species of fish presents an individual problem.

The Kansas State Fish Hatchery at Pratt is one of the few hatcheries of the world engaged in the rearing of the spotted channel catfish. The experimental field of artificial diets for these carniverous fish is relatively new.

There is but little reference in scientific literature to experimental work done in the field of artificial diets for the common goldfish. Goldfish are fed commercial food which has not been analyzed for its content of the growth producing factors.

Schneberger (Manuscript, 1929) and Alexander (Manuscript, 1929), working on vitamin requirements, worked out artificial diets for the common goldfish and catfish. The result of their work was reported by M. E. Jewell before the Zoology Section of the American Association for the Advancement of Science at Des Moines in December, 1929.

METHODS

In this experiment the fish used were the common colored goldfish Carassius auratus (Linnaeus) and the spotted channel catfish Ictalurus punctatus (Rafinesque). The goldfish were obtained from the Grassyfork Fish Hatcheries at Martinsville, Indiana. The catfish were supplied by the Kansas State Fish Hatchery at Pratt. All of the fish were of spring (1929) hatching.

The fish were kept in wooden troughs in the basement of Fairchild Hall. The troughs were six feet long, one foot wide, and one foot deep. Water flowed in from a faucet at one end, and out at the other through a pipe inserted near the bottom. The water was from the Kansas State Agricultural College supply and was kept at a depth of about eight or nine inches in each trough.

In each of the four troughs were four galvanized wire baskets. Each of the two baskets nearest the inlet contained twenty-five catfish. Similarly, each of the two baskets toward the outlet contained twenty-five goldfish. The baskets in each trough were designated from the inlet to the outlet by the letters A, B, C, and D.

At the beginning of the experiment on October 20, 1930, the fish were measured and placed in the baskets so that the A's in troughs 4, 5, 6, and 7 had the same average

length. Likewise, each of the other baskets, B, C, and D, had the same average lengths in troughs 4, 5, 6, and 7.

Two average lengths of catfish were used. Basket A contained fish ranging from 47 to 53 millimeters, making an average length of 50.52; basket B ranging from 54 to 63 millimeters, making an average length of 56.68.

Likewise, two average lengths of goldfish were used. Basket C contained fish ranging from 34 to 37 millimeters, making an average length of 35.24; basket D ranging from 37 to 40, making an average length of 38.04.

A torsion balance with accuracy to 0.2 gram was used to weigh the fish. The fish of each basket were weighed together in a wet cloth sack. The water was wrung out of the upper part which was folded back over the wet part. The bag without the fish was weighed and the difference between the two weights taken as the weight of the fish.

This method was improved upon in January. A glass crystalizing dish partly filled with water and containing a small wire basket which fitted in the jar was placed on the scales which were then balanced. In preparation for weighing the fish, the wire basket was taken out of the water and the water was allowed to drain off in a continuous stream until drops began to fall. Three drops were allowed to fall back into the dish. The basket was then placed in a pan and the fish emptied, after being measured, into it.

Again the water was allowed to drain off until three drops fell and the basket with the goldfish was transferred to the dish with water. The fish were then weighed. The basket was removed as before and dipped into a 1 to 2000 part solution of copper sulphate in distilled water. They were treated for two minutes and transferred at once into the basket in the trough. They were thus handled as little as possible. A back weight was made on the wire basket each time but with practice it was found that the error was less than 0.1 gram, which was less than the accuracy of the balance.

The fish were measured once a month and weighed each week. Handling of the fish in weighing tended to weaken and make them more susceptible to disease. The interval between weighing was then changed to two weeks. From January the fish were weighed once a month when measured. The distance from the most anterior point to the base of the caudal fin, measured with a pair of dividers, was considered the length of the fish. This was accomplished by holding the fish in a wet towel while measuring.

Since this required considerable time a machine was perfected whereby the fish could be measured by dropping them in a small glass trough; the nose of the fish against a block at a stationary point; a sliding pointer to indicate the length on a millimeter rule.

Since the catfish could not be measured by this method because of the lateral spines it was only used in measuring the goldfish.

The fungus growth of the fish was controlled, to some extent, by siphoning the waste material from the tanks each day and scrubbing the troughs and cages once a week. It was later thought more adequate to thoroughly clean the tanks every two days.

The fish were fed twice daily. The amount varied according to the consumption of the fish in each trough. In all cases they were fed all that they would eat. Petri dishes were used as food containers.

The following ingredients were used to make the basic mash:

Oatmeal	79 grams
Crisco	5 grams
Hogan's salt mixture	3 grams
Yeast	10 grams
Grapefruit	10 cc.
Codliver oil	4 cc.
Water	190 cc.

The following diets were used in the experiment. The number of the diet corresponds to the number of the trough.

Diet Number 4 - 60 gm. of mash
40 gm. of raw liver

Diet Number 5 - 60 gm. of mash
5 gm. of ground raw liver
17.5 gm. of buttermilk powder

Diet Number 6 - 60 gm. of mash
20 gm. of buttermilk powder

Diet Number 7 - 60 gm. of mash
33.2 gm. of pea meal

Diet Number 4 was used as the control diet; Diet Number 5 as the supplement diet; and Diets Number 6 and 7 as the substitute diets.

The protein of the oatmeal was used to supplement the proteins added to the mash. Crisco was used as a source of fat, Hogan's salt mixture for the necessary salts and minerals in proper proportions, yeast for vitamin B and G, grapefruit juice for vitamin C, and codliver oil for vitamins A and D.

The oatmeal, crisco, salt mixture, and water were cooked. To this cooked preparation was added the grapefruit juice, codliver oil and yeast.

For Diet 4 the meat was ground fine and thoroughly mixed with the mash so that the constituent parts could not be picked out by the fish.

In Diet 5, 24 cc. of water was used to form a thick paste of the mash, ground raw liver, and buttermilk powder.

In Diet 6, 26 cc. of water was used with the buttermilk powder and mash to make a thick paste.

In Diet 7, split peas were ground fine. To this meal was added enough water to make a solution which was autoclaved one and one-fourth hours. It was then mixed with

the mash.

On February 13, due to high mortality, the goldfish of each of the troughs 6 and 7 were combined and placed in the baskets C. Twenty-five fish which had been fed three months on an adequate diet (basic mash plus 20 per cent of ground liver and green vegetation) were weighed and measured and placed in trough 7D. In trough 6D were placed twenty-five goldfish weighed and measured which had been fed on rice flakes (Farona).

DISCUSSION

Data were obtained from eight groups of twenty-five catfish and eight groups of twenty-five goldfish from October 20 to May 3.

The rate of growth is the best means available at the present time for evaluating a given food stuff. This has been accomplished in this experiment by weighing and measuring the fish.

Table I gives the average gain in lengths of the A and B groups taken together. Table II gives the average gain in length for each group. The lengths of the fish that died between the dates of measuring were subtracted each month from the total length to secure an average of the living fish at the next time of measuring. This eliminated the

Table I. Catfish and Goldfish Lengths.

Troughs	Oct. 20	Nov. 17	Dec. 14	Jan. 11	Feb. 8	Mar. 7	Apr. 4	May 3	Average gain (mms.)	Average gain per cent
4 A and B	53.56	55.56	55.55	55.7	56.22	56.18	56.90	57.49	3.93	7.2
C and D	36.62	40.32	42.12	44.68	47.00	49.54	53.17	60.08	23.4	64
5 A and B	53.6	54.66	55.16	54.99	55.93	57.01	56.69	57.87	4.27	8
C and D	36.64	39.24	40.78	43.72	44.22	45.88	47.69	51.69	15.05	41
6 A and B	53.6	54.27	54.81	55.74	55.63	56.09	57.08	57.74	4.14	8
C and D	36.64	38.5	39.45	42.55	43.33	43.25	46.00	47.20	10.56	29
7 A and B	53.6	54.22	54.52	54.56	55.44	55.68	55.25	55.64	2.04	4
C and D	36.64	37.73	38.55	39.05	40.23	40.66	41.60	43.50	6.86	18

Table II. Goldfish and Catfish Lengths.

Troughs		Oct. 20	Nov. 17	Dec. 14	Jan. 11	Feb. 8	Mar. 7	Apr. 4	May 3	Average gain (mms.)	Average gain
4	A	50.44	52.6	52.5	52.2	52.82	52.81	53.06	53.73	3.29	6.5
	B	56.68	58.52	58.6	59.20	59.62	59.55	60.75	61.25	4.57	8.0
	C	35.2	39.36	41.00	43.52	45.30	48.00	52.31	59.08	23.88	68.0
	D	38.04	41.28	43.25	45.87	48.71	51.08	54.04	61.08	23.04	60.0
5	A	50.52	51.48	51.87	51.96	52.72	53.55	53.38	54.62	4.1	8.0
	B	56.68	57.84	58.45	58.02	59.15	60.47	60.00	61.12	4.44	8.0
	C	35.24	37.84	39.27	41.54	43.31	45.07	47.12	51.75	16.51	47.0
	D	38.04	40.65	42.29	45.90	45.13	46.69	48.27	51.63	13.59	36.0
6	A	50.62	51.43	51.75	52.75	52.58	53.05	53.44	54.06	3.54	7.0
	B	56.68	57.12	57.87	58.74	58.69	59.13	60.72	61.43	4.75	8.4
	C	35.24	36.74	37.50	41.00	41.80				6.56[3]	18[3]
	D	38.04	40.26	41.40	44.00	44.87[1]				6.83[3]	17[3]
	New fish in basket D, February 14					35.55[2]	38.75	40.50	44.75	9.2	25
7	A	50.52	51.16	51.83	51.50	52.27	52.70	52.20	52.70	2.18	4.0
	B	56.68	57.28	57.21	57.62	58.61	58.66	58.32	58.58	1.9	3.3
	C	35.24	36.41	36.00	37.83	38.20				2.96[3]	12[3]
	D	38.04	39.06	40.10	40.28	41.71[1]				3.67[3]	9[3]
	New fish in basket D, February 14					37.10[2]				4.53	12

[1] D united with C, see Table I.

[2] New fish in D, February 14.

[3] Represents gain to February 8.

error in length caused by the death of larger or smaller fish.

Table III gives the average gain in weight of the A and B groups taken together and the B and D groups taken together. Table IV gives the average weight of each group.

Figure 1 was made from Table I; figures 2a and 2b from Table II; figure 3 from Table III; figures 4a and 4b from Table IV.

In the tables and figures the average length of the surviving fish has been used.

The percent of protein (N x 6.25) present in the different foods by an analysis made by the Chemistry Department of the Kansas State Agricultural College was as follows:

Diet 4 - 11.25

Diet 5 - 10.31

Diet 6 - 9.50

Diet 7 - 5.25

The supplement and substitute foods showed an economy in cost in comparison with liver of 78 per cent in Diet 5, 82 per cent in Diet 6, 90 per cent in Diet 7. This is based only upon the costs of the food mixed.

The average growths in length of the C and D goldfish are shown in Table I, figure 1. All the goldfish show an average increase in length. The goldfish of groups 4 and 5 having meat in the diet show greater gains than the substi-

Table III. Catfish and Goldfish Weights

Troughs	Nov. 2	Nov.17	Dec.14	Jan.11	Feb. 8	Mar.7	Apr. 4	May 3	Gain (Grams)	Gain per cent
4 A and B	2.4	2.2	2.5	2.6	2.5	2.7	2.6	3.0	.55	22
C and D	2.2	2.3	2.9	3.7	4.4	5.4	6.6	9.0	6.75	309
5 A and B	2.4	2.5	2.6	2.6	2.7	2.8	3.0	3.1	.63	24
C and D	2.1	2.3	2.7	3.1	3.1	4.2	4.6	5.6	3.47	169
6 A and B	2.3	2.2	2.5	2.5	2.5	2.7	2.8	3.0	.75	31
C and D	2.2	2.3	2.6	2.8	3.1	3.2	3.0	4.2	2.0	91
7 A and B	2.1	2.1	2.2	2.2	2.3	2.2	2.3	2.4	.3	14
C and D	2.0	2.0	2.2	2.1	2.3	2.5	2.6	3.05	1.05	52

Table IV. Catfish and Goldfish Weights

Troughs		Nov. 2	Nov.17	Dec.14	Jan.11	Feb. 8	Mar. 7	Apr. 4	May 3	Average gain in grams	Average gain in per cent
4	A	2.1	2.1	3.0	3.0	2.0	2.5	2.2	2.6	.5	23
	B	2.8	2.4	2.1	2.3	3.0	3.0	3.1	3.4	.6	21
	C	2.1	2.0	2.8	3.4	4.1	5.2	6.5	9.0	6.9	328
	D	2.4	2.7	3.1	4.0	4.8	5.7	6.7	9.0	6.6	291
5	A	2.1	2.2	2.2	2.2	2.3	2.3	2.4	2.4	.27	13
	B	2.8	2.9	3.0	3.0	3.2	3.3	3.6	3.8	1.0	35
	C	1.9	2.2	2.5	2.9	2.5	4.0	4.8	5.75	3.85	202
	D	2.3	2.6	3.0	3.4	3.8	4.5	4.4	5.45	3.1	137.
6	A	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	.5	26
	B	2.7	2.5	2.9	3.0	2.9	3.2	3.4	3.7	1.0	37
	C	1.9	2.0	2.4	2.5	2.9	[1]			1.0[3]	52[3]
	D	2.5	2.6	2.9	3.2	3.4	[2]			.9[3]	36[3]
		New fish added					2.2	2.7	4.0	1.8	81
7	A	1.8	1.8	1.9	1.9	2.0	1.9	2.0	2.1	.3	16
	B	2.5	2.5	2.5	2.5	2.6	2.6	2.6	2.8	.3	12
	C	1.8	1.8	1.9	2.0	2.0	[1]			.2[3]	11[3]
	D	2.3	2.2	2.5	2.2	2.7	[2]			.4[3]	18[3]
		New fish added					2.1	2.5	2.6	.5	23

[1] D united with C, see Table III.

[2] New fish in D, February 14.

[3] Represents gain to February 8.

tute foods of groups 6 and 7. Group 4 shows an average gain of 64 per cent which is the greatest gain of all the groups.

The average length of group 5, fed on buttermilk powder and meat parallels that of group 4, fed on the raw liver, to January 11. From this time to May 3 the curve drops to a lower level.

Group 6 parallels the growth of group 5 until February 8 when it drops off.

Over a period of three or four months the supplementary and substitute foods seem to be adequate although under that of the controls. This seems to indicate that over a long period of time the diets containing meat are the most effective for goldfish.

The average length of the goldfish of group 7 shows a flat curve with no great increase in length from month to month.

In feeding the fish it was observed that the fish of group 4 ate more than those of the remaining groups. The cooked pea meal was eaten sparingly by the fish of group 7 during the first few months. At no time did they consume as much food as the fish of the other groups.

The resistance to disease was low among the goldfish fed on the substitute foods. Here also was a greater mortality. These fish seemed unable to counteract the disease

even after treatment with copper sulphate or weak salt water as did the fish fed on the ground liver and the supplement diet. The color and general appearance of the fish having meat in the diet was much better than those on the substitute foods.

Dry buttermilk was used to supplement the liver since some workers have attributed to it special virtues. It contains approximately the constituents of skim milk which has been used as a supplement for liver. The gain on this diet in group 5 was only 45 per cent of the gain of group 4.

The buttermilk powder as a substitute showed the highest mortality of all the groups. The surviving fish were those having the largest and healthiest appearance. The gain in this group was 45 per cent of the gain of group 4. This would seem to indicate that there is a growth factor in liver not present in buttermilk powder.

Although buttermilk powder alone is not an effective diet it may be enhanced by its use as a supplement to liver.

Although the pea meal was thoroughly mixed with the mash the pea meal material was discarded by the fish. This fine material left in this trough (7) did not appear in the other troughs.

The gain of the goldfish fed on pea meal was 28 per cent of the gain of group 4. This would seem to indicate that there is some necessary factor for growth present in

liver which is not found in pea meal.

The average growth of all the catfish (A - B) are shown in Table I, figure 1.

The catfish of group 4 show a greater gain the first four months than the other groups. During the remaining three months of the experiment the average gain of groups 5 and 6 exceeded the average gain in growth of group 4. It was observed that the catfish fed on the meat diet did not eat readily. At times much of the food was left in the basket. This would seem to indicate that the supplement diet of group 5 and the substitute diet of dry buttermilk of group 6 would be adequate over a long period of time. Some meat is necessary in the diet since group 6 does not gain as much as group 5 which has some meat in the diet.

The catfish fed on pea meal show a slow rather steady gain. Unlike the goldfish, the catfish ate greedily of the pea meal. As soon as it was placed in the basket the catfish would come from the dark corners to eat. They acted as if they were starved and ate ravenously of the pea meal.

The catfish of group 7 felt soft in comparison with the firmness of the bodies of those of groups 4 and 5.

The mortality of the groups in the four troughs averaged about the same. Thus, the catfish will live and grow on all of the diets used in this experiment.

The comparative average growths in length of the small and large goldfish are shown in Table III, figures 2a and 2 2b. In comparison with the larger goldfish of D groups, those of the smaller goldfish of C groups show a greater average gain in all the troughs. This would indicate that the smaller goldfish grow more rapidly than the larger.

The goldfish growth curves of figures 2a and 2b are approximately the same with the exception of group 5, figure 2b, which closely approximates group 4 until January 11 and then drops away. This may have been due to the death of the small fish making the gains of the large fish appear less.

The comparative average growths in length of the small and large catfish are shown in Table II, figures 2a and 2b.

The large catfish of B groups gained more than the small catfish of A groups, with the exception of trough 7 where the gain was greater in the A group. This may be accounted for by the apparent rapid gain the first month which may have been due to the loss of twelve catfish which were not measured. Thus, the average length of the surviving fish could not be calculated.

The average weights of the A and B and the C and D goldfish and catfish are shown in Table III, figure 3. The average weights of the A catfish and C goldfish are shown in Table IV, figure 4a. The average weights of the B cat-

fish and D goldfish are shown in Table IV, figure 4b.

Since the data on the weights of the fish were obtained collectively, i.e., by weighing the fish of each basket together the comparative weights are not as accurate as the lengths which were made individually. The weights may have been influenced by some of the fish becoming gravid thereby increasing the weight making fluctuations in the average gains. The amount of food eaten by the fish previous to weighing may have affected the weight to some extent.

The goldfish of group 4 showed an average gain in weight of 6.75 grams; those of group 5 a gain of 3.47 grams; those of group 6 a gain of 2.0 grams; those of group 7 a gain of 1.05 grams.

Using weight as a criterion for a healthy body this shows that the bodies of the goldfish of group 4 are much healthier than those of the other groups.

Group 4 exceeds the other groups in weight more than in length. Group 4 shows a gain in length of 55 per cent over that of group 5 and a gain in weight of 95 per cent over group 5.

This seems to indicate that the supplement and substitute foods for the goldfish produce skeletal development which is not accompanied by as great deposition of fat as the raw liver.

The catfish of group 4 showed an average gain in weight of 22 per cent; those of group 5 a gain of 24 per cent; those of group 6 a gain of 31 per cent; those of group 7 a gain of 14 per cent.

The catfish of groups 5 and 6 showed greater average gains in weight than those of group 4. This would correlate the results found in length. Over a long period of time a 40 per cent liver diet is not as conducive to growth as a substitute diet of buttermilk or buttermilk with 6 per cent liver.

The fish placed in basket 6D on February 14 showed a gain of 9.2 millimeters in the following three months. This was 50 per cent greater gain than the fish placed in 7D at the same time. The lesser growth of these fish on pea meal agrees with the results of the goldfish in these same troughs previous to February 14.

These fish show a greater rate of growth from February 14 to May 3 than did fish fed on the same diet from October 20 to January 11. This seems to indicate that the rate of metabolism is greater in the spring.

SUMMARY

1. This experiment has been conducted with 200 catfish to determine the comparative value of the protein of ground raw liver, buttermilk powder as a supplement to liver,

buttermilk powder, and pea meal.

2. The experiment was conducted over a period of eight months.

3. Goldfish make better growth in both length and weight on the diet containing raw liver.

4. Dry buttermilk as a supplement to raw liver in the goldfish diet shows a gain somewhat under the diet containing raw liver.

5. Dry buttermilk and pea meal are not conducive to growth of goldfish.

6. This experiment shows indications of a factor present in beef liver conducive to growth.

7. Forty per cent raw liver in the diet of catfish is not effective over a long period of time.

8. The catfish show that the supplement diet containing 6 per cent ground raw liver and 15 per cent dry buttermilk, and the substitute diet containing 25 per cent dry buttermilk are more effective than the diet of 40 per cent raw liver.

9. The substitute foods showed an economy in cost of 78 per cent in diet 5, 82 per cent in diet 6, and 90 per cent in diet 7.

ACKNOWLEDGMENTS

This problem was started under the direction of Dr. Minna E. Jewell and completed under the direction of Dr. E. J. Wimmer, both of the Zoology Department of the Kansas State Agricultural College. The author wishes to thank the following for assistance in this experiment: Mr. Alva Clapp of the State Fish and Game Commission for the catfish used; Dr. Jewell in planning the experiment and the diets; and Dr. E. J. Wimmer for the valuable aid in perfecting a machine for the measurement of the goldfish.

BIBLIOGRAPHY

Baugham, R. H.
1927. Disease of fish in Ohio hatcheries.
Trans. Amer. Fisheries Soc., 57:223-231.

Belding, D. L.
1927. Epidemics among fish, occurrence favoring conditions, course and remedy.
Trans. Amer. Fisheries Soc., 57:217-227.

Bing, F. C.
1927. A progress report upon feeding experiments with brook trout fingerlings at the Connecticut State Fish Hatchery.
Trans. Amer. Fisheries Soc., 57:266-280.

Cobb, E. W.
1928. Feeding with clams, meat, etc.
Trans. Amer. Fisheries Soc., 58:224-227.

Davis, H. S.
1927. Some results of feeding experiments with trout fingerlings.
Trans. Amer. Fisheries Soc., 57:281-285.

Doze, J. B.
1925. The barbed trout of Kansas.
Trans. Amer. Fisheries Soc., 55:167-183.

Finks, A. J., Carol, O., Johns
1921. Nutritive value of the proteins of lima bean, Phaseolus linatus.
Amer. Jour. Physiol., 54:205-208.

Hoagland, R.
1926. Nutritive value of protein in liver.
Jour. Ag. Res., 32:1025-1040.

James, M. C.
1928. More about food for fish.
Trans. Amer. Fisheries Soc., 58:168-172.

McCay, C. M.
1927. Goals in nutrition.
Trans. Amer. Fisheries Soc., 57:261-265.

McCay, C. M., Dilley, W. E.
1927. Factor H in nutrition of trout.
Trans. Amer. Fisheries Soc., 57:250-260.

McCay, C. M., Bing, F. C., Dilley, W. S.
1927. The effect of variations in vitamins, protein, fat and mineral matter in the diet upon the growth and mortality of eastern brook trout.
Trans. Amer. Fisheries Soc., 57:240-280.

McCollum, E. V, Simmonds, N., Parsons, H. T.
1918. Dietary properties of the pea.
Jour. Biol. Chem., 37:287-303.

Mellen, F.
1919. Various foods for fish, comparative cost of.
Trans. Amer. Fisheries Soc., 48:78-86.

Mitchell, H. H.
1922. The place of proteins in the diet in the light of the newer nutrition.
Amer. Jour. Pub. Health, 13:17-23.

Osborne, T. B.
1924. The vegetable proteins.
pp. 95-121, figs. 9, 2nd ed.
Longmans Green and Co., London.

Titcomb, J. W., Cobb, E. W., Crowell, M. F., McCay, C. M.
1928. Nutritional requirements and growth rates of brook trout.
Trans. Amer. Fisheries Soc., 58:205-232.

Titcomb, J. W.
1926. Feeding beans and meat, comparative observations on.
Trans. Amer. Fisheries Soc., 56:130-134.

Waterman, F. C., Johns, C. O.
1921. The effect of cooking on digestibility of phaseolin.
Amer. Jour. Biol. Chem., 46:9-17.

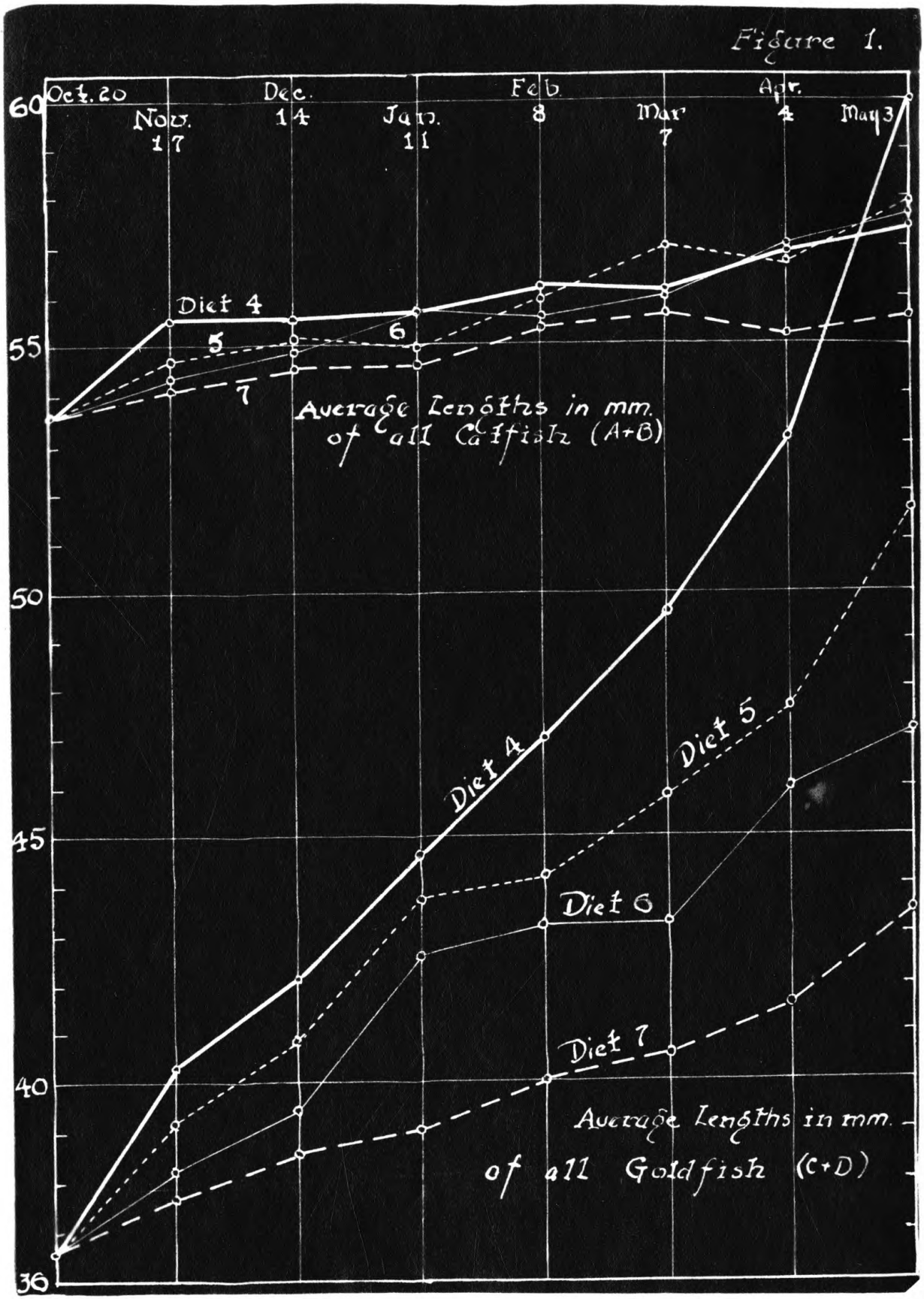
Figure 1.
Oct. 20
Nov. 17
Dec. 14
Jan. 11
Feb. 8
Mar 7
Apr. 4
May 3
60
55
50
45
40
36
Diet 4
5
6
7
Average Lengths in mm. of all Catfish (A+B)
Diet 4
Diet 5
Diet 6
Diet 7
Average Lengths in mm. of all Goldfish (C+D)

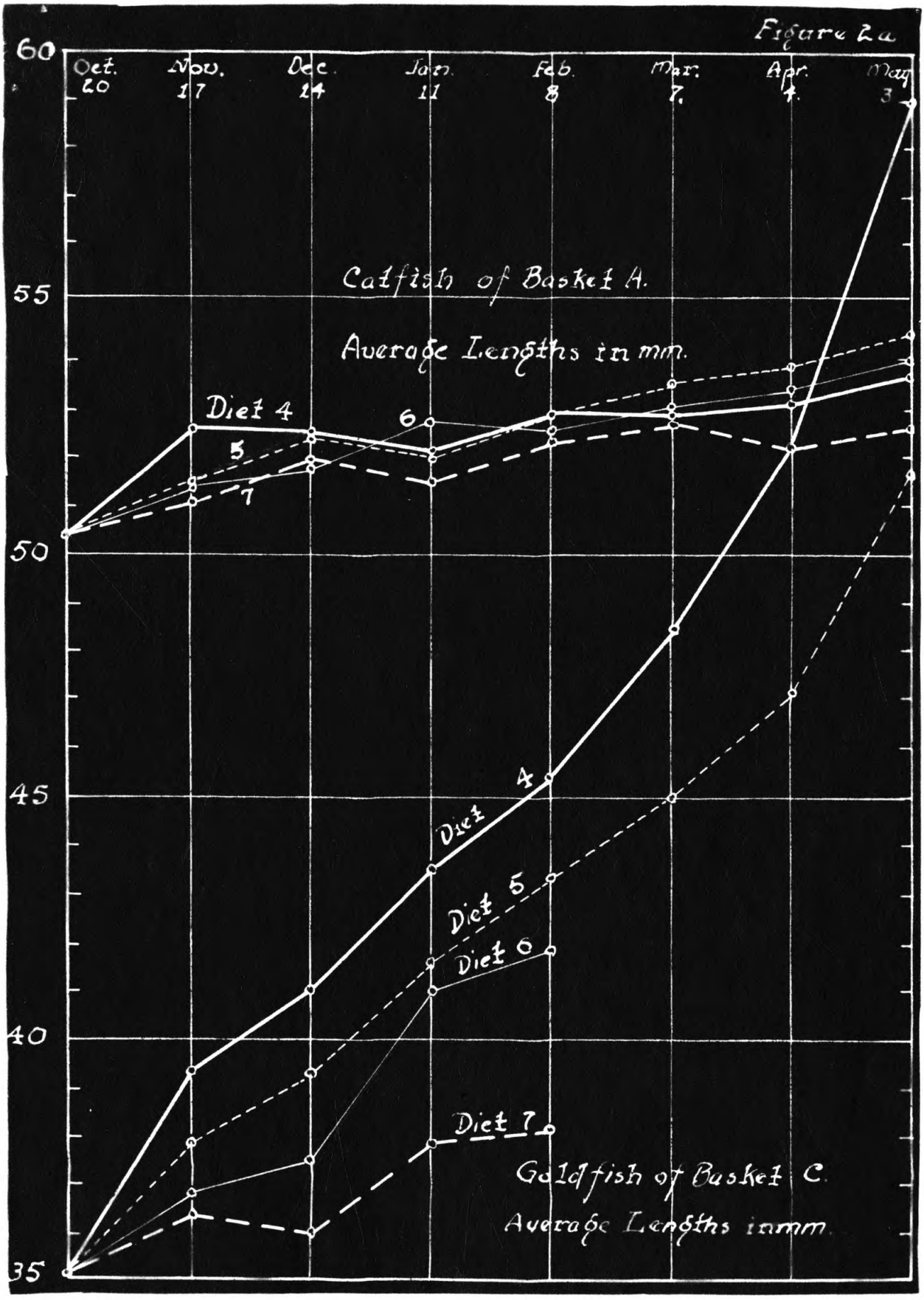
Figure 2a
60
55
50
45
40
35
Oct. 20
Nov. 17
Dec. 14
Jan. 11
Feb. 8
Mar. 7.
Apr. 4.
May 3
Catfish of Basket A.
Average Lengths in mm.
Diet 4
5
6
7
Diet 4
Diet 5
Diet 6
Diet 7
Goldfish of Basket C.
Average Lengths in mm.

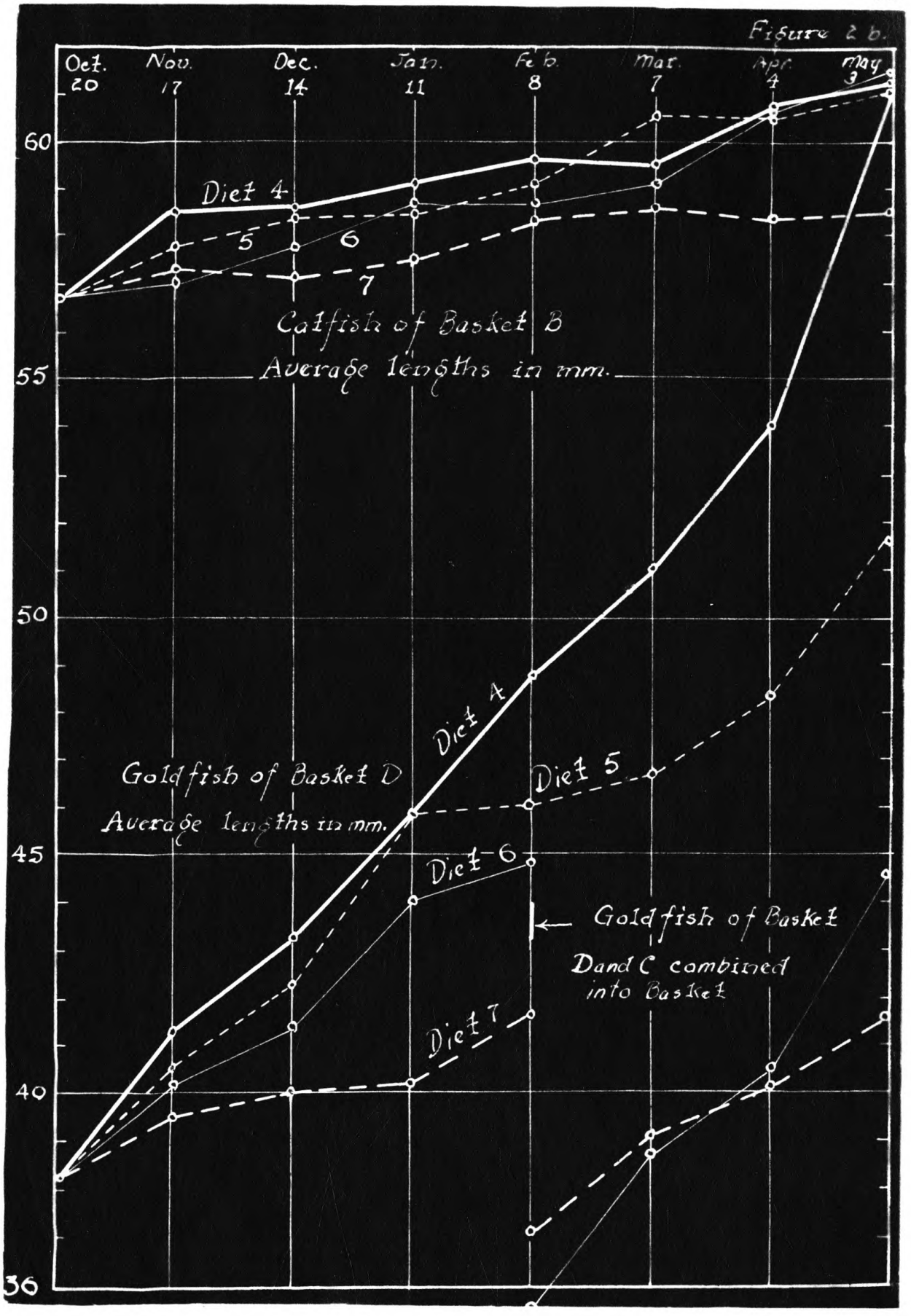
Figure 2 b.
Oct. 20
Nov. 17
Dec. 14
Jan. 11
Feb. 8
Mar. 7
Apr. 4
May 3
60
55
50
45
40
36
Diet 4
5
6
7
Catfish of Basket B
Average lengths in mm.
Goldfish of Basket D
Average lengths in mm.
Diet 4
Diet 5
Diet 6
Diet 7
Goldfish of Basket
D and C combined
into Basket

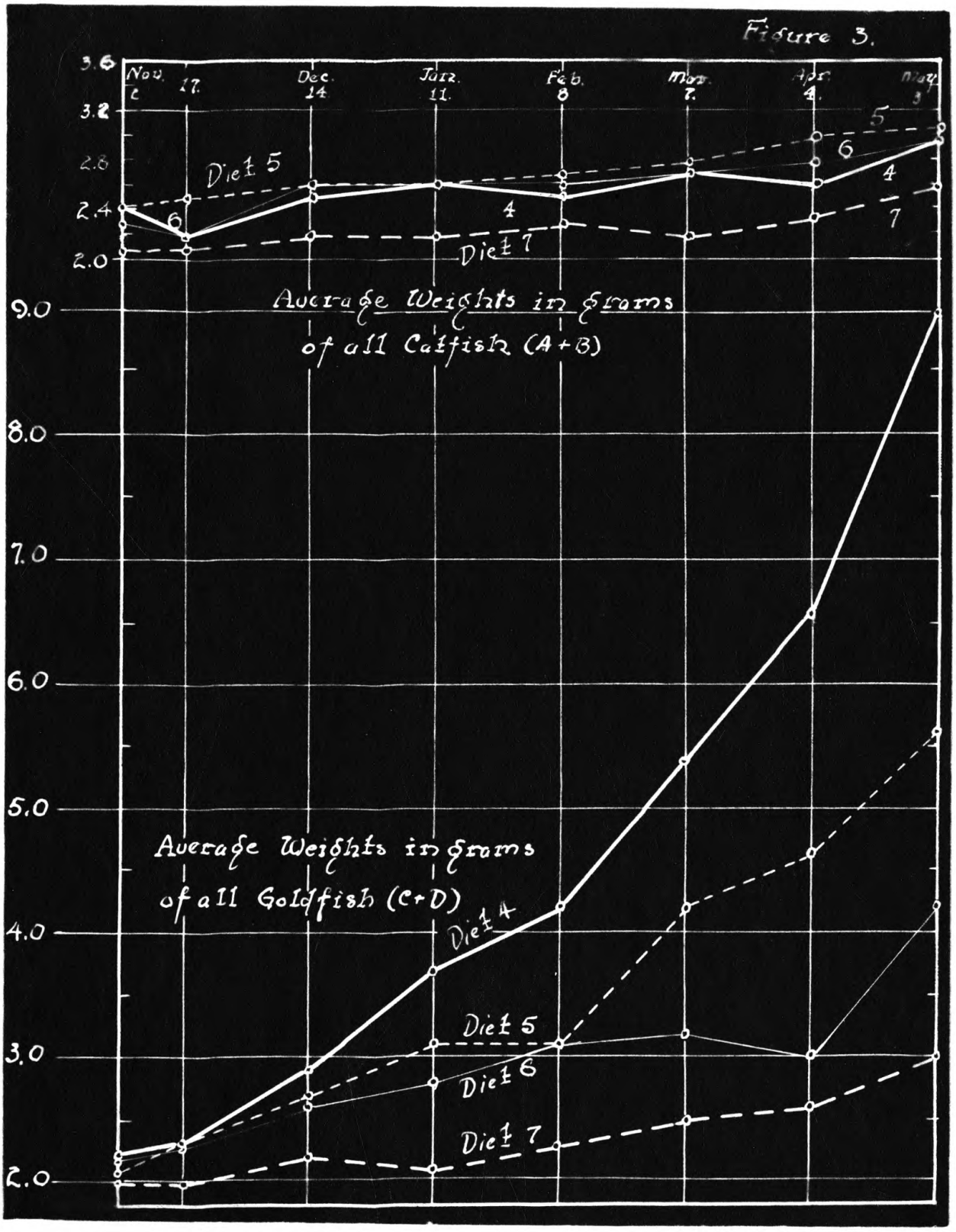
Figure 3.
Nov. 2
17.
Dec. 14
Jan. 11.
Feb. 8
Mar. 7.
Apr. 4.
May 3
3.6
3.2
2.8
2.4
2.0
Diet 5
Diet 7
Average Weights in grams of all Catfish (A+B)
9.0
8.0
7.0
6.0
5.0
Average Weights in grams of all Goldfish (C+D)
4.0
3.0
2.0
Diet 4
Diet 5
Diet 6
Diet 7

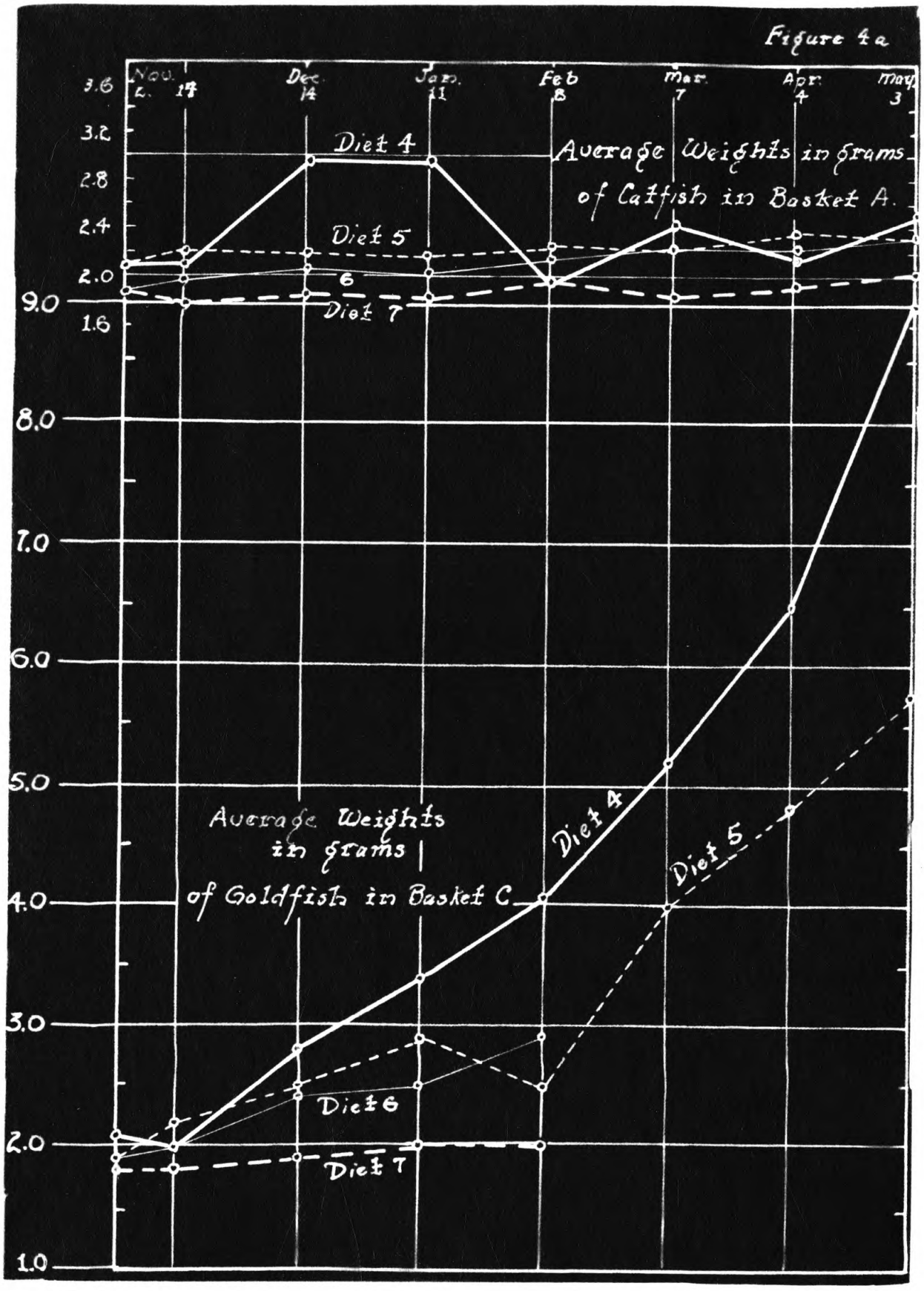
Figure 4a
Nov. 14
Dec. 14
Jan. 11
Feb 8
Mar. 7
Apr. 4
May 3
3.6
3.2
2.8
2.4
2.0
9.0
1.6
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Diet 4
Diet 5
6
Diet 7
Average Weights in grams of Catfish in Basket A.
Average Weights in grams of Goldfish in Basket C
Diet 4
Diet 5
Diet 6
Diet 7

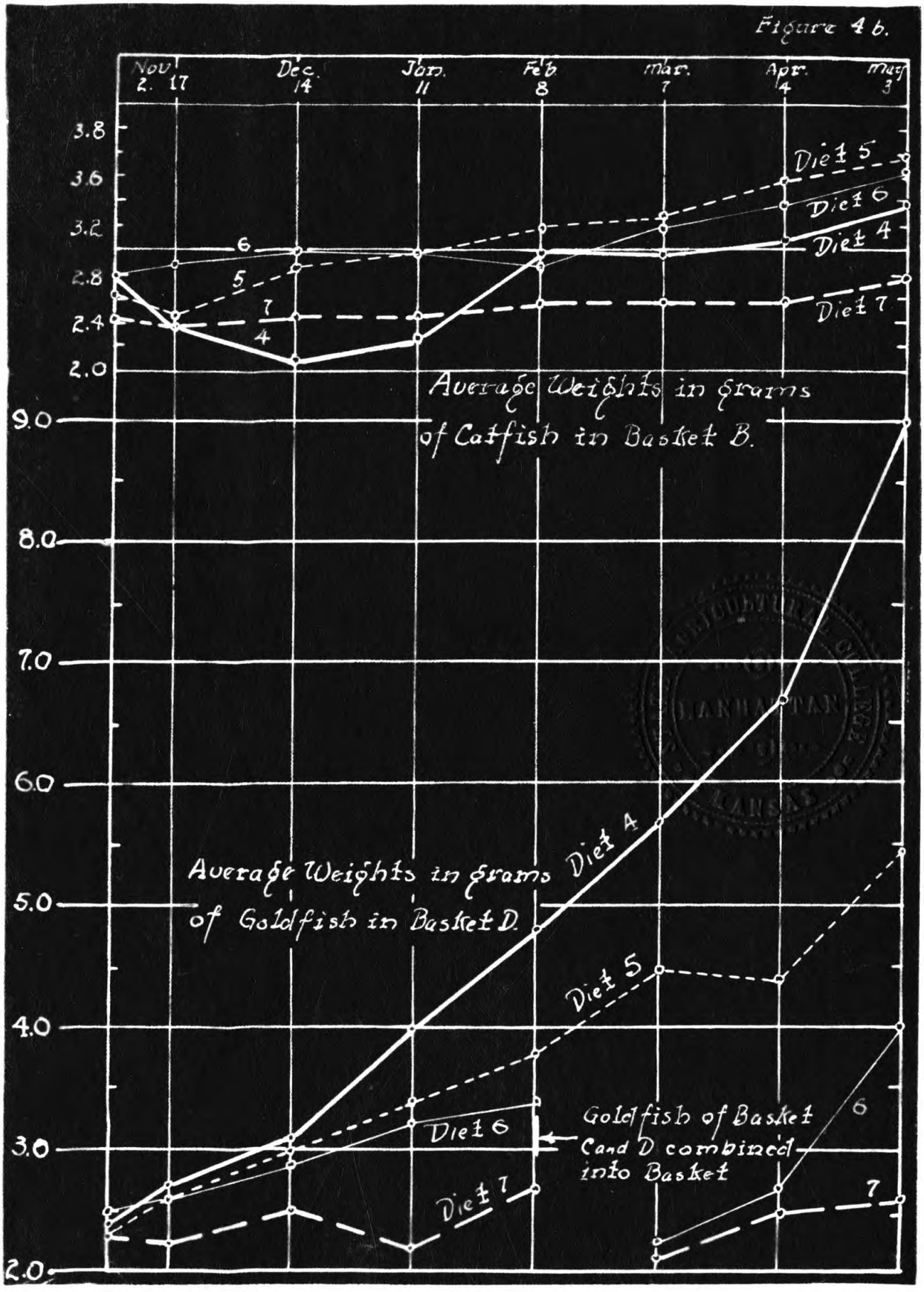
Figure 4 b.
Nov 2. 17
Dec. 14
Jan. 11
Feb 8
Mar. 7
Apr. 4
May 3
3.8
3.6
3.2
2.8
2.4
2.0
Diet 5
Diet 6
Diet 4
Diet 7
6
5
7
4
Average Weights in grams of Catfish in Basket B.
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
Average Weights in grams of Goldfish in Basket D.
Diet 4
Diet 5
Diet 6
Diet 7
Goldfish of Basket C and D combined into Basket
6
7