RESULTS OF FURTHER EXPERIMENTS ON REARING LARGEMOUTH BASS FINGERLINGS UNDER CONTROLLED CONDITIONS [1]

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ABSTRACT

Experiments on rearing largemouth bass fingerlings to a size of 4-6 inches total length in rearing troughs and tanks are described.

Fingerling fish 1.5-3.0 inches in length which had been started in earthern ponds on natural food were trained to take artificial food employing ground fresh or frozen fish as a starting diet. Following the initial training period the fish were fed a prepared ration composed of varying amounts of frozen fish or beef liver mixed with a dry trout food.

Data on survival, growth, food conversion and special problems encountered are presented. The rate of growth appeared to be slower in the controlled environment than had been observed in ponds. A six to ten-fold increase in weight was measured in two different years for a feeding period of 73-120 days.

Survival and food conversion was better in troughs (69 percent survival, conversion 2.6) than in concrete tanks (39 percent survival, conversion 3.3), but more than five times as many fish could be cared for with the same amount of labor in tanks than was possible in troughs. Also, the fish were more readily trained to take artificial food in tanks than in troughs.

The author feels that the results obtained are promising enough to warrant further research on this method of bass culture.

INTRODUCTION

The possibility of an increased need for largemouth bass fingerlings (*Micropterus salmoides*, Lac.) of a larger size than that readily grown in quantity in conventional rearing ponds has motivated a reexamination of the feasibility of rearing this species in a controlled environment such as a trough or raceway. In states such as Alabama where farm ponds are numerous, an active program of management assistance for farm pond owners by management biologists has already increased the demand for fingerling bass 4-9 inches in length for corrective restocking of ponds crowded with small bluegills or other forage species. Availability of bass of this size would permit a more widespread utilization of the predator species restocking technique in pond management work.

Up to now, little success has been reported in rearing largemouth bass fingerlings under controlled conditions. Scattered references in the early fish cultural literature describe efforts to propagate and rear bass in a manner similar to that now used for trout. The most significant evidence as to the relative difficulty of using such a procedure successfully or economically is the fact that at present, the rearing pond method employing natural foods is the universal type of culture presently practiced by both federal and state hatcheries. Production is mainly limited to fingerlings smaller than two inches total length because of the difficulty of economically rearing larger size bass in ponds.

Controlled propagation is possible as has been demonstrated in Wisconsin by Sprecher (1938), where brood fish were hand-stripped, the eggs incubated in jars and the fry then reared under pond conditions. More recently the State of Virginia and the federal fish hatchery at San Marcos, Texas, were reported to have reared largemouth bass in a controlled environment on artificial food although no published reports of the work have been noted.

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In a preliminary attempt to rear largemouth bass in troughs, Snow (1960) was able to induce small bass of one and one-half to three inches total length to feed upon ground fresh fish. Appreciable growth was obtained for a group of 1,000 fish cultured, but mortality was high (54.4 percent) and the rate of growth was slow. It appeared from this preliminary experiment that, while the black bass could be grown successfully under controlled conditions, much improvement would be needed to make the practice feasible.

Experimental Methods

For the first experiment the initial rearing unit consisted of a series of eight metal troughs 14" x 8" x 8' supplied with pond water at a rate of 1-2 gallons per minute. The water supply came from an unfertilized 0.8-acre pond that was devoid of fish and which received a flow of well water estimated to be about 80 gallons per minute. The water contained little animal life which could be utilized by the bass as food according to two samplings during the course of the experiment.

Largemouth bass fingerlings which had been spawned in ponds and reared to a size of about two and one-fourth inches in total length and a weight of 1.5 grams each were used as test animals. The number of fish at the start was 1,470. They were hand sorted into eight lots after a preliminary conditioning period of several days. Lots were composed of uniform sized fish so that cannibalism would be difficult. One lot was designated to receive the "non feeders," those individuals which were slow to learn to take the food presented. This lot was given extra attention in order to induce as many fish as possible to take food.

Initially the food consisted of frozen carp passed several times through a food grinder equipped with a 3/16-inch plate. Bits of the ground fish were dropped or flicked with the fingers into the part of the trough where the fish were concentrated. After a nine-day preliminary conditioning or training period, the diet was changed to a mixture of 80 percent ground carp and 20 percent fine fry size commercial trout feed. This was prepared by grinding the carp and then mixing in the dry feed by hand.

The amount of dry feed was gradually changed from 20 percent to 60 percent of the mixture. Also at the start of the third feeding period (July 17) the fish portion was changed from frozen carp to frozen "ocean perch" fillets of the type sold in grocery stores for human consumption. Preparation consisted of grinding the fish, mixing the meat and dry feed by hand and then running the mixture through the grinder equipped with a 3/16-inch plate. A semi-solid moist pellet was produced by this procedure which greatly facilitated feeding the test animals.

During the first seven feeding periods the bass were fed five times daily on what they would readily clean up and it was assumed that they would not utilize particles which had sunk to the bottom of the trough. Later observation indicated that either this was an incorrect assumption or that the habits of the fish changed, as small amounts of feed were eaten between feeding periods as the experiment progressed. After a pelleted mixture was developed, the food retained its form for a longer time. As a result, and because bottom feeding was occurring, a rate of three percent of the body weight of the fish per day was supplied to the troughs in two feedings with no effort being made to get the small fish to feed as the particles settled to the bottom. This level of feed appeared to be about the right amount of the mixture being supplied. One exception was a trough of larger fish which contained less than a hundred fish. They were more nervous and apparently did not feed as heavily because of the small number and large size. This lot would only clean up about two percent of their body weight per day.

The experiment lasted for a period of 73 days. This time was divided into nine feeding periods of seven days each except for one of 10 and one of 14 days duration. The fish were weighed, counted and sorted at the end of each feeding period. Weights were taken on torsion balances to the nearest gram. Sorting was done by hand although it appeared that a sorting box or fish grader could have been used to an advantage. The daily ration was weighed on a laboratory balance sensitive to 0.02 gram. Any dead fish were weighed on the same type balances and the weight added to the weight of the lot at the end of the feeding period for the purpose of determining gain and food conversion.

Water temperature was obtained by means of a recording thermometer located at the point where the supply entered the pipeline from the pond. The average temperature for each feeding period along with the range is shown in Table 1.

Table 1. Water temperatures of trough supply for nine feeding periods

Period	Minimum	Maximum	Mean
6/30-7/ 6	25.0	28.8	26.9
7/ 7-7/16	23.5	28.5	26.3
7/17-7/23	24.6	29.2	26.8
7/24-7/30	26.2	30.2	27.8
7/31-8/ 6	25.6	29.0	27.1
8/ 7-8/13	23.8	28.4	26.1
8/14-8/20	24.8	27.4	25.9
8/21-8/28	23.0	25.2	24.3
8/29-9/11	23.6	27.0	25.4

Unobserved losses which appeared to be caused by predation of wild animals influenced a decision to move the experiment into the fish holding house at the end of the third feeding period. The water supply and trough size was the same as at the first location but light conditions were much better for feeding. The move, along with trough covers which were installed several weeks later, eliminated most of the unseen losses.

The troughs were cleaned daily. Disease control consisted of the routine application of pyridylmercuric acetate as a prolonged treatment of 2 ppm for one hour or 4 ppm for 30 minutes. Normally two treatments on successive days were given each week. When losses which were thought to be caused by disease increased, the number of treatments was increased to three per week.

Discussion of Results of the Trough Experiment

The results of this experiment along with the experience of our previous work and some later efforts with another group of 700 fish indicate that the largemouth bass fingerlings one and one-half inches or larger can readily be trained to take artificial food, provided that the feed suits their taste. Ground fish and a mixture of ground fish and dry trout feed have been acceptable feeds. In limited trials the bass rejected dry pelleted feed although we have fed such material successfully to larger bass which had first been trained to feed on ground fish.

The pattern of feeding behavior was similar for the three experiments mentioned. At first the small fish made no effort to feed when the particles were offered. After the fourth or fifth feeding a few individuals would take the food into their mouths but would then eject it. By the seventh or eighth feeding, some fish would swallow the food they took and others would be following the example of the early feeders. After the third day of training a sizeable number of bass were swallowing the food offered. Additional fish learned to eat for a period of 2-3 weeks although most of the fish which learned to eat artificial feed did so during the first two weeks of training.

Not all of the bass observed in this study had the ability or inclination to accept the form of food offered. In the preliminary work mentioned above (Snow, 1960), 60-65 percent of one group learned to feed. In this experiment the percentage was much higher, with only 110 fish of 1,470 (7.5 percent), dying from apparent starvation. In a group of 654 fish given training later in the season, 46 percent were feeding after one week, with 13.5 percent learning to take feed the following three weeks. However, this lot of fish was older than any which had been trained previously and had been on natural food about two months longer than those described above.

Three to four weeks were required for the "non-feeders" to starve to death, but the last ten days of existence was generally spent in a listless, inactive condition when it was impossible to interest them in food.

As was noted previously (Snow, 1960), cannibalism was not a factor in the losses sustained. Sorting or grading the bass into lots of uniform size discouraged predation during the early stage of training. After the bass learned to take artificial feed they seemingly were less inclined to attempt to prey upon other fish. Only three instances of cannibalism were observed in this experiment, all occurring when small size fish jumped into a trough containing bass considerably larger. In two of these instances the larger fish regurgitated the swallowed individual during the excitement of trough cleaning. The hand fed fish did not lose their instinct to feed on live food as is indicated by the fact that several selected artificially fed bass having an average weight of 28 grams were placed in a pond containing small bluegills. After being in the pond about four months during the fall and winter the fish averaged 212 grams, an increase in weight of more than 650 percent!

The test animals never fed well during midday hours while in outside troughs or late in the afternoon when in the holding house tanks. It appeared that the shadow of the attendant caused so much excitement that feeding activity was impossible. At other times the fish were unexplainably nervous and would not feed even when no shadows were thrown. It was thought that night disturbances by wild animals may have been partly the cause of such behavior but definite information was never obtained regarding it. Later developments suggest that this excitability may have been an early syndrome of vitamin deficiency.

The rate of growth of the group of fish was steady, although never up to the rate observed under pond conditions of rearing where abundant natural food existed. Table 2 shows how the fish increased in weight during the progress of the experiment. From an average size of 1.63 grams initially, they grew to an average weight of 10.42 grams in 73 days. The rate of growth was far from uniform, however, as might be expected. Under more natural conditions a grading process of large fish consuming small ones would eliminate most of the smaller individuals within a short period of time. Figure 1 illustrates the discrepancy in rate of growth between individuals as well as the emaciated condition resulting from a failure to accept the artificial food.

The most rapid growth occurred during the second and third feeding periods. Several factors probably influenced this. The diet contained more ground fish during these periods, the fish were smaller and less crowded and no disease conditions were in evidence.

Detailed information on trough lots is given in Table 3 which illustrates the uniformity of response between the various lots. Except for Lot 5 which was the trough of "non-feeders," and isolated instances where heavy unobserved losses occurred, the response of the various trough lots to the care given was remarkably uniform. Little variation in percent of weight gained per day and food conversion was noted which suggests that predictable results could be obtained if the operation were repeated.

As can be noted from the data in Table 2, average food conversions were excellent, ranging from a low of 1.8 to a high of 3.4 for the entire group. The lowest conversion obtained was a "C" value of 1.4 in Lot 4 for the period August 15 to August 21. A number of instances were noted where the conversion value was lower than 2.0. As might be expected, the "C" value decreased as the amount of meat in the ration decreased. With an 80-20 mixture, food conversion averaged 3.4 for seven lots with a range of 3.0-3.9. A mixture containing 60 percent fish to 40 percent dry feed gave a seven-lot average "C" value of 2.9 and a range of 2.6-3.2. When the mixture was changed to 40-60, conversion averaged 1.8 with a range of 1.6-2.7. For this period the values were 1.8, 1.7, 1.7, 2.7, 1.6, 1.7 and 2.0 for the seven trough lots.

Although the value for food conversion decreased with the increase in the proportion of dry feed contained in the ration, the rate of gain decreased following the change to a 40-60 meat-dry feed mixture. The

Table 2. Response of a group of 1,470 largemouth bass fingerlings to trough rearing on artificial feed

Date inventoried	No. of fish	Total weight in grams	Average weight in grams	Gain in weight [1]	Food Supplied grams	Food conversion	Daily Gain [2] in wt.	Losses during period	Mean water temperatures
6/30 (start)	1,470	2,397	1.63	——	——	—	—	—	—
7/ 7	1,404	3,114	2.22	794.3	2,762.6	3.5	4.7	66	26.9
7/17	1,268	4,453	3.51	1,468.0	4,279.1	2.9	6.6	136	26.3
7/24	1,209	5,431	4.49	1,060.0	1,912.2	1.8	2.9	59	26.8
7/31	1,164	6,544	5.62	1,155.7	2,614.0	2.3	3.1	45	27.8
8/ 7	1,065	6,804	6.39	472.5	1,316.0	2.8	1.0	99	27.1
8/14	1,059	7,362	6.95	585.5	1,485.0	2.5	1.2	6	26.1
8/21	1,047	8,216	7.85	854.2	1,651.5	1.9	1.7	12	25.9
8/28	1,042	8,927	8.57	799.0	1,774.0	2.2	1.4	5	24.3
9/11	1,014	10,569	10.42	1,847.4	3,787.0	2.0	1.3	28	25.4

1. Includes weight in grams of living fish at end of feeding period plus weight of observed mortality or loss during the period. Includes grading losses discarded prior to starting new feeding period.
2. Obtained by dividing gain in weight by starting weight and then dividing by number of days in feeding period.
3. Total losses were cataloged as follows: Starvation — 110; Disease — 20: Jumping from trough — 77; Unknown causes — 159; Grading — 87: Cannibalism — 3.

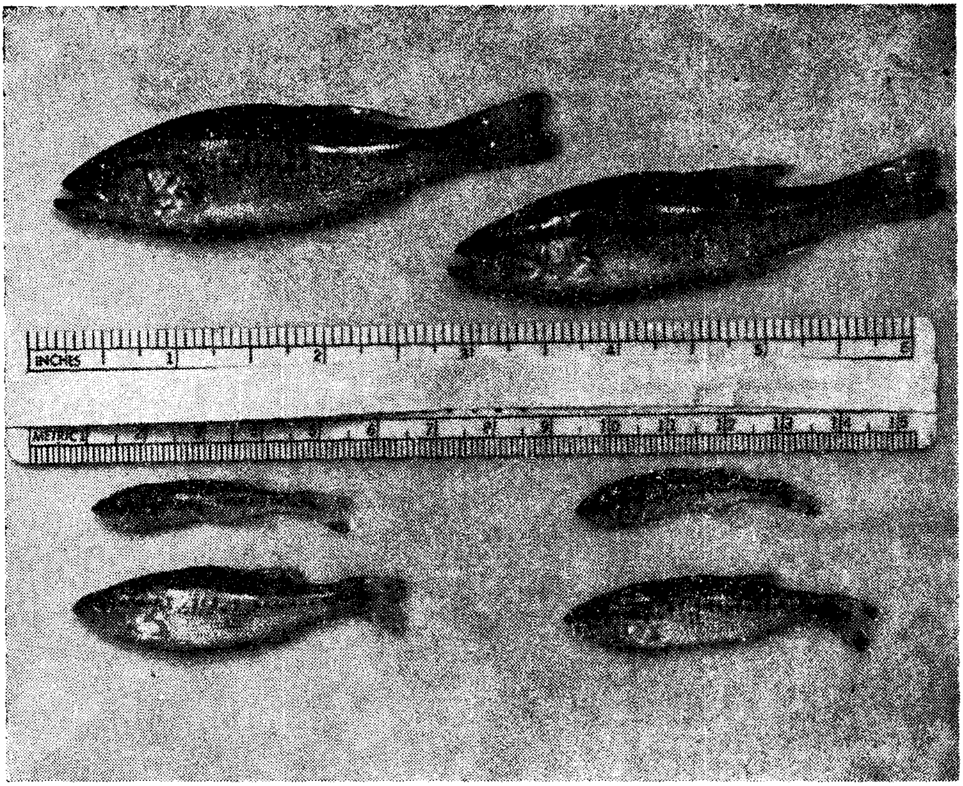

Figure 1. Variation in growth of trough-reared bass. Top fish are fast growing, bottom ones are slow growing, while center fish failed to learn to take the artificial ration and are in an advanced stage of malnutrition.

Table 3. Growth data of trough lots for one feeding period [1]

Lot No.	No. Fish Start	No. Fish End	Weight [2] Start	Weight End	Gain [3]	Food supplied	Con-version	Per Cent Weight increase/day
1	261	261	572	908	336	885.0	2.6	5.9
2	114	114	407	603	196	558.0	2.8	4.8
3	276	258	410	633	223	664.7	3.0	5.4
4	142	143	278	420	142	451.3	3.2	5.1
5[4]	105	64	124	84	15	140.6	9.4	1.2
6	204	199	531	752	221	654.3	3.0	4.2
7	163	161	320	470	150	450.0	3.0	4.7
8	69	68	398	583	185	475.2	2.6	4.6

1. Duration of feeding period 10 days.
2. All weights are in grams.
3. Gain in starting weight minus end weight plus weight of observed losses. Unobserved losses were as follows: 18 in Lot 3; 5 in Lot 6; 1 in Lot 7 and 2 in Lot 8. Gain in number in Lot 4 was due to counting error or fish jumping from adjoining trough.
4. This lot was composed of individual fish that were slow to learn to take artificial food. Loss from starvation was heavy during this period.

percent gain in weight was highest during the second feeding period (6.6 percent), but dropped to around 1.0-1.7 percent the latter part of the experiment. However, other factors than the ration probably were instrumental in slowing down the rate of growth.

It had appeared from previous work that a "space factor" existed for largemouth bass fingerlings being reared in troughs that would limit the weight of fish which could be carried per trough to a level much below that which is used for other species such as trout or channel catfish. A number of density levels were employed during the course of this experiment which provided more data on how many bass a trough of given size will accommodate for reasonable growth rates. Rates of from 62 to 645 grams of fish per cubic foot of trough were used. Within these limits there appeared to be no significant influence from crowding, however, it seemed that the fish fed better at the moderate to heavy rates of stocking due possibly to the greater degree of competition for the food supplied. At lighter densities the fish were more nervous, apparently gaining a feeling of security in numbers.

Jumping was more prevalent as the fish grew larger and skin infections, probably caused by crowding, were a problem. The fish were held in the rearing troughs 4-6 weeks longer than they should have been had normal fish cultural procedures been followed. Fish four inches in length held in a rearing trough containing six inches of water obviously are not growing under ideal conditions.

Losses from disease were insignificant. However, effects assumed to be caused by disease were obvious on three occasions during the course of the experiment. In early August during the fifth and sixth feeding periods, the entire group of bass stopped feeding normally although the symptom was more noticeable in some troughs than in others. The average rate of growth was reduced by two-thirds and some lots practically stopped feeding for several days. Examination of specimens by a fish disease technician did not reveal the cause of the trouble. Coincident with the reduced food intake was a change in personnel caring for the fish and this fact may have been primarily responsible for the upset rather than disease. There was no marked change in food conversion values as a result of the upset, due to the fact that the fish were being fed the amount they would clean up at this time, thus the amount of food provided was reduced when consumption decreased.

As the fish grew and became progressively more crowded in the troughs, trouble was experienced with a disease that appeared to be caused by bacterium tentatively identified as belonging to the genus *Pseudomonas*. Affected fish developed diseased areas on the head or around the fins. The areas increased rapidly and resulted in the death of the fish within three days. Epidemic conditions did not develop and the spread of the disease may have been checked by changing the frequency of PMA treatments from two to three per week.

During the last two feeding periods still another abnormality occurred which appeared to be a diseased condition. A few fish in practically all lots showed symptoms of whirling and loss of equilibrium, darkened color indicative of blindness, cessation of feeding, spinal curvature and partial paralysis. Examination of the fish by disease technicians and by the Eastern and Western Fish Disease Laboratories failed to reveal the causative organism if any. The same symptoms had been observed in an earlier experiment by Snow (1960) who thought at the time that the symptoms were produced by a nutritional deficiency. Only a small percentage of the group of fish was affected and the disease did not develop in epidemic form. As can be surmised from the low mortality attributed to disease (4.4 percent), the experiment was relatively free from trouble of this type.

Probably the greatest difficulty was experienced from the fish jumping out of the troughs. It was known that 16.9 percent of all losses resulted from this cause. Most of the unseen losses (34.9 percent) are thought to have occurred from jumping also. To keep bass of this size in troughs, it appeared that a tight cover should be provided which would only be removed for cleaning the troughs. Even then, precautions should be taken to avoid mixing of fish in adjoining troughs.

1962 Experiments

Further work along the lines described above was carried on in 1962 to confirm earlier findings and to improve cultural techniques. Except for one lot of fingerlings, the trough environment inside the fish holding house was employed for starting and rearing the fingerlings for a period of 30-45 days. Later, a substantial number of fish were moved to a spiral raceway similar to one described by Sneed and Cozort (1959) for observation of growth under conditions where more space was available. The water supply was the same as was employed the previous year. The diet was similar except that frozen "ocean perch" was the meat fed throughout the experiment except in a special instance discussed later.

Due primarily to the quality of the small fingerlings available for inclusion in the experiment, results were less satisfactory than for the previous experiment. Three developments of significance resulted from the 1962 study which will be discussed.

The diseased condition described previously which was characterized by blindness, deterioration of mandibular structures, debilitation, partial or complete paralysis and finally death appeared after about eighty days on the experimental ration. Consideration of available information led to the hypothesis that the condition was a result of vitamin B_1 (thiamine) deficiency. Use of either fresh or canned fish in the diet of trout resulted in B_1 avitaminosis according to Schneberger (1941) and Wolf (1942). Earlier work by Deutsch and Hasler (1934) demonstrated the presence of a B_1 destroying enzyme, thiaminase, in many species of freshwater fishes. Reportedly the enzyme was less common among marine species but our experience suggests a high level in frozen "ocean perch," as symptoms of avitaminosis were mere prevalent when an all "ocean perch" diet was fed than was the case when the diet included frozen carp or fresh bluegill flesh.

Since the diet of the experimental bass included a substantial amount of frozen fish and was ordinarily prepared and stored several days in advance of use, it seemed logical to assume that symptoms described were caused by a thiamine deficiency.

This hypothesis was tested by dividing thirteen lots of affected fish and providing a ration which had been fortified with sources of vitamin B_1 for half while leaving half on the unfortified ration. After a period of three weeks, the average number of obviously affected survivors ranged from 16 to 80 percent more in the control lots than in those receiving food fortified with vitamin B_1. In another test, severely affected individuals which had stopped feeding were injected with doses of either thiamine hydrochloride or a commercial vitamin mixture. Noticeable improvement occurred within 48 hours, and fish receiving a single injection recovered to the point where they would again accept food.

These results indicated that the prolonged feeding of a ration containing substantial amounts of frozen "ocean perch" resulted in avitaminosis from the lack of vitamin B_1.

After a preliminary training period of 30-45 days, several lots of fingerling bass were moved to a spiral raceway to evaluate this more spacious environment as a rearing facility. The quantity of fish available was limited so compartments were installed to restrict the fish to a limited area. At stocking rates ranging from about 0.1 pound to 0.6 pound per cubic foot, the fish fed well and behaved normally until the nutritional deficiency described above began to affect an appreciable number.

One lot of 1,746 fingerlings which numbered 153 per pound at the start was given preliminary training in taking artificial food in a conventional concrete holding house tank. Dimensions of the tank were length 9.5 feet, width 2.5 feet, water depth 25 inches. Capacity in cubic feet was about 49.5. A flow of 3-5 gallons of water per minute was maintained. During a 35-day period 67 percent of the fish learned to feed. Losses amounted to 5.5 percent of the number at the start.

After being moved into the spiral raceway, additional individual fish learned to eat the ground frozen fish being used as a starting ration. Although it was not possible to obtain an accurate record of the number learning to feed, the percentage did not appear to be as high as had been obtained in troughs in 1961. However, the number of fish in the lot was more than three times greater than that which seemed to be the maximum for starting in the rearing troughs. Since the time required for training the fish to feed was about the same in the tank as in the trough, a threefold increase in efficiency appeared possible.

1963 Experiment

The objectives of the work in 1963 included testing the use of holding tanks as a rearing environment, a time study of the methods employed in the operation, and testing measures designed to eliminate the avitaminosis encountered in previous work.

The technique followed in 1961-62 was modified in several ways. Conventional concrete holding tanks were employed as rearing units. These tanks were the same size previously described containing 49.5 cubic feet of water. Six lots of pond started fingerling fish ranging in size from 910 to 180 per pound were included. They were stocked in the tanks at rates of from 1,600 to 2,700 fish per tank. Ground frozen "ocean perch" or ground cull brood bass flesh was used as a starting ration, but was replaced by the pelleted ration containing 70 percent dry commercial trout feed and 30 percent "frozen ocean perch" as soon as feeding commenced and noticeable growth occurred. Also, a purified diet containing 28 percent protein was prepared following the directions of Dupree[1] and fed two days weekly in an attempt to offset the effect of the thiaminase in the frozen fish. Some fish rejected the purified diet when it was substituted for ground fish, but most of the amount fed was eaten. Seven lots totaling 15,984 fish which weighed 45.7 pounds were included in the experiment.

As is generally the case when a different procedure is attempted, unforeseen occurrences took a heavy toll. One tank was a complete loss when the water leaked out while a disease treatment was being applied. The smaller size fish escaped in unknown numbers by moving around loosely fitting tank screens before an effective seal was developed. An outbreak of columnaris disease developed in three lots and caused extensive losses before control was achieved.

Because of the difficulties mentioned, survival data are not considered to be indicative of the success of the tank rearing procedure if compared to that obtained in 1961 employing troughs.

However, of the 15,984 fish started, 6,300 (39.4 percent) were on hand when a final inventory was made on September 6. A 123.27-pound increase in weight was measured for the 112-day period. Growth was encouraging in instances where disease was not prevalent. Length of the fish at the end of the experiment varied from three to 7.5 inches. Sorting the survivors into inch groups revealed the following production.

Length 2.6 - 3.5 inches —	1,551 fish	weight 19.46	pounds
Length 3.6 - 4.5 inches —	3,420 fish	weight 85.25	pounds
Length 4.6 - 5.5 inches —	1,171 fish	weight 49.94	pounds
Length 5.6 - 7.5 inches —	158 fish	weight 14.35	pounds
Total	6,300	169.00	

After the bass had been trained to consume the artificial ration, growth was consistent in lots not affected by disease even though the gain was not spectacular. During the first eight weeks, the lots were weighed and graded every two weeks. As more uniformity was achieved, the need for grading lessened, so the fifth feeding period was 28 days duration, while the sixth and seventh were 14 days in length.

Food conversion was measured for six of the feeding periods (Table 4). Values of individual lots ranged from 1.55 to 11.36 with a value of 3.26 being measured for all lots during the entire experiment. While

[1] Dupree, H. K., Purified experimental diets for channel catfish nutritional research. In Manuscript.

Table 4. Survival and growth of bass fingerlings in concrete tanks

Date inventoried	Number of fish[1]	Total weight in pounds	Number per pound	Gain in weight pounds	Pounds food supplied	Food con-version	Observed loss	Water temperature deg. C.
Start	15,984	45.73	349	——	——	—	——	———
6/14	11,509	62.19	185	16.46	108.60	6.6	1,543	25.0
6/28	——	84.66	—	22.47	53.65	2.4	1,056	25.2
7/12	——	98.09	—	13.43	52.19	3.9	1,830[2]	25.6
8/ 9	6,814	137.71	49	39.62	107.13	2.7	968	24.3-23.0[3]
8/23	6,667	156.26	43	18.55	40.22	2.2	147	23.0
9/ 6	6,300	169.00	37	12.74	39.71	3.1	74	23.0
Total				123.27	401.50	3.3	5,618	

1. Estimated on basis of sample counts and total weight except on 6/14 and 9/6 when count was made.
2. 1203 lost when tank accidentally drained during disease treatment.
3. Well water substituted for pond source 10 days after period began.

the values obtained in the tank environment were somewhat higher than those where the trough was used, they compare more favorably when it is considered that the weight of dead fish was not added to the end weight as was done in the 1961 data. Since the 1963 work was being done under production conditions it was felt that weight of fish dying during the experiment should not be included in the conversion computation as they were unavailable for stocking. Conversions of about 2.5 seemed to be a normal occurrence with the ration fed and a lower value could be expected if the fish were feeding well and the rate of mortality was low. Data presented in Tables 4 and 5 are indicative of the rate of food consumption, rate of growth and conversion.

The reservoir pond became unsatisfactory for use as a water supply on July 22 because of decomposing aquatic vegetation. Well water having a temperature of about 23°C was substituted for the remainder of the experiment. Food intake decreased slightly because of the lower temperature but the food conversions probably were also lowered although it was not possible to measure the effect of the change.

The data in Table 5 illustrate a substantial mortality in lots T-12 and T-14 which appeared to be caused mainly by disease. As this approached epidemic levels, several steps were taken to combat the loss. The environmental temperature was lowered by changing the water supply as has been mentioned. This also provided a clean supply, free of organic debris. Aureomycin at a rate of 3 grams per 100 pounds of fish per day was incorporated into the ration for one week and then repeated after an interval of one week. Symptoms of avitaminosis appeared in spite of the inclusion of a vitamin-fortified ration two days each week, so liver was substituted for the frozen "ocean perch" on July 19. Following these changes losses were reduced to a marked extent, particularly in the larger fish. As an example, Lot T-16 showed a mortality of five fish in 56 days. In T-9, four fish were lost in 28 days while mortality in T-11 was three fish over the same period. During the last two weeks of the experiment, 74 fish were lost out of the eight-lot complement of more than 6,300 fish. These losses appeared to be caused mainly by individuals which failed to make the change from the fish-dry trout feed ration to that of liver-dry trout feed. Many showed symptoms of avitaminosis as indicated by deformity and deterioration of the mandibular structures, inflamed nodules along the posterior portion of the mandible and a noticeable loss of flesh indicative of the early stages of malnutrition. These symptoms were not paralleled to the thiamine deficiency described previously except for the deterioration of the mandible area.

The fingerling bass appeared to be more easily trained to take the starting ration in tanks than in the shallower troughs. They were less nervous, possibly due to the greater volume and depth of water, and accepted food in a shorter length of time. The increased water depth was a factor in the ease of training as the food particles were in view longer as they sank slowly to the bottom. The larger volume of water made possible the inclusion of more fish in each lot. Within the

Table 5. Food consumption, growth and mortality for a 28-day feeding period

Lot Number	Number in Lot	Observed mortality	Initial weight[1]	Food consumption	Gain in weight	Conversion
T- 7	1,144	13	15.46	19.51	7.17	2.7
T- 8	588	20	11.92	12.76	5.30	2.4
T- 9	514	45	12.10	12.00	4.65	2.6
T-11	953	27	12.06	13.57	8.06	1.7
T-12	2,226	674	12.23	17.10	2.55	6.7
T-14	1,458	174	14.95	14.36	5.11	2.8
T-15	691	10	10.83	10.34	3.36	3.1
T-16	284	5	8.54	7.49	3.42	2.2
Total	7,858	968	98.09	107.13	39.62	2.7

1. All weights are in pounds.

numerical limits employed (1,600-3,000 per tank) no difference in ease of training was apparent. Tanks could be fed, cleaned or treated for disease in about the same amount of time required for the troughs. Since 5-6 times as many fish could be started in the tanks as in a trough environment, this finding was a major improvement in reducing the time requirements of the process.

More cannibalism occurred in the tanks, particularly in the lots where cannibals were present at the time the lot was incorporated into the experiment. Use of a mechanical grader was necessary because of the number of fish involved. A commercial model adjustable bar grader was employed because it was available and inflicted little damage to the fish being processed. Efficiency of the device was not great enough to prevent some small fish from remaining with the larger ones, making cannibalism possible. As had been observed in earlier work, cannibalism virtually ceased as the fish learned to take artificial feed and were graded to a uniform size within lots.

The density of fish in the tanks never approached the maximum 1961 trough level of 645 grams (1.4 pounds) per cubic foot. The maximum density per tank at the end of the experiment was 0.54 pounds per cubic foot while the minimum density was about 0.31 pound per cubic foot. No difference in rate of gain was discernable at the maximum and minimum rates, as the poorest conversion occurred at the heaviest rate while the next highest conversion was observed in the tanks having the least density.

Discussion of Results

The work on controlled rearing of largemouth bass to date suggests that the method has promise as a production technique. However, a great deal of research is indicated before a final evaluation can be made.

Use of fish reared in a controlled environment for corrective restocking should be compared to pond reared fish of a comparable size. During the course of such research, cost of producing fish in controlled and uncontrolled environments could be compared and evaluated. Further research in nutrition and diet improvement must be accomplished. Concurrent with research on nutrition, existing recommendations for disease control in cold-water species could be tested on largemouth bass and modified as needed. Also, additional study of carrying capacity and optimum water temperatures is indicated. Testing of both ponds and raceways as rearing environments after the fish have been trained to feed on the artificial ration should be included in further research. An increase in operational efficiency and a corresponding reduction in production costs should occur when mass production is instituted. A further reduction in production costs may possibly be achieved by the development of a more suitable ration. The possibility of mechanization of parts of the operation is promising enough to warrant study and might reduce production costs.

A genetical approach to developing a strain more readily trained and adapted to the controlled environment is indicated. Other desirable characteristics might also be included in such breeding work, since trained fish could be readily cultured in a smaller space than pond reared individuals; a limiting factor which has precluded work in improving hatchery brood stocks up until now.

The data obtained in this experiment indicate that the largemouth bass can be satisfactorily reared in troughs or tanks in numbers great enough to make possible the research suggested above. Efficient utilization of the ration employed shows the bass to be at least as effective as coldwater species in converting food to fish flesh. Further study along the lines mentioned above seems indicated by the results to date.

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PHYSICAL AND BIOCHEMICAL CHANGES IN FEEDS DURING PROCESSING

W. H. Hastings [1]

ABSTRACT

Materials used for feeding fish may be subjected to drying, freezing, grinding, radiation, hard pelleting and expansion pelleting. During these processes, physical and chemical changes occur due to inherent enzymes, contamination by microorganisms, oxygen, temperature, pressure and ionization of molecules. These changes are not reflected in the gross composition of the major nutrient classes (protein, fat, carbohydrate, ash), but in the intrinsic nutrients, organic additives and digestibility. Experimental work showed the hard pelleting process to be destructive to added enzymes.

INTRODUCTION

Any attempt to supply fish with feed, except as natural food, involves processing. Culled animals, animal by-products, cereal grains, vegetables and their by-products may be ground, steamed, frozen, thawed, mixed, dried and pelleted. Following a combination of these treatments, feeds are thrown into ponds on the assumption that they are a contribution to the well-being of fish.

To be satisfactory as feed, materials fed to fish must be available, acceptable and nutritious. The purpose of processing is to accomplish these objectives economically. It is conceivable that the attainment of one objective is detrimental to another.

As feeds are harvested, processed and stored, they may be subjected to autolysis, putrefaction, air, light, heat, pressure and radiation. Each leaves its mark on the nutritive properties of a feed and also on its ability for autolytic digestion. The original value may be so greatly altered during the interim between harvest and feeding, that an appropriate question would be, "What nutrient quality can be expected in fish feeds?"

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