SELECTION, GROWTH RATES AND SEASONAL VARIATION OF PROTEIN AND LIPIDS IN CHANNEL CATFISH *ICTALURUS PUNCTATUS* (RAFINESQUE)

by

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INTRODUCTION

In recent years considerable interest has been shown in the commercial production of fresh-water fishes. One species that has received attention is the channel catfish (Ictalurus punctatus, Rafinesque). Johnson (1959) stated that fish "farming" has not been profitable in North America because an extensive development of commercial fishing of wild fresh-water and marine populations has provided an adequate amount to supply domestic demands. Bennett (1962) stated fisheries of the Great Lakes and coastal marine waters have out-produced those of inland waters to the extent that commercial operations in inland waters are much reduced except for catfishes, which he stated always have a ready market.

Growing channel catfish to marketable size by supplemental feeding of dry pelleted feeds was reported by Swingle (1958). Further investigations on supplemental feeding of channel catfish in ponds was carried out by Tiemeier (1962). Since then research facilities have been constructed below Tuttle Creek Reservoir near Manhattan, Kansas chiefly for experimentation on channel catfish. The facilities are known as the Tuttle Creek Fisheries Research Laboratory and consist of 28, ¼-acre earthen ponds, along with a smaller observation pond and a metal building housing maintenance equipment and research facilities. The ponds were lined with polyethylene plastic to provide more uniform experimental units.

Research has progressed at a rapid rate since completion of the facilities with the major emphasis being on supplemental feed requirements of channel catfish. The effect of diets containing two energy and two protein levels on the growth of fingerling channel catfish was reported by Tiemeier et al. (1965). Deyoe and Tiemeier (1966) reported excellent growth of fingerling channel catfish using a pelleted feed containing only five percent animal protein.

In conjunction with supplemental feeding experiments other factors have been investigated. Selection for a faster growing channel catfish was started during the summer of 1964. During the summer of 1965 fingerlings selected from the 1964 selection experiment were compared in growth rate with small fish from the 1964 supplemental feeding program. These fish stocked on an equal number basis were then compared with ponds stocked with an equal biomass of large and small channel catfish in the same pond. Two ponds were then stocked with large fish on an equal number basis to compare with ponds stocked with both small and large fish.

In the spring of 1965 a study was initiated to determine the seasonal variations of fat and protein in channel catfish. Major purposes of the studies were to determine the deposition of these factors during the feeding period, and their reduction during the non-feeding period of winter. During the winter fish were also kept in tanks in the laboratory at Kansas State University to determine the effect of a higher temperature on fat and protein metabolism during starvation.

LITERATURE REVIEW

Selection

From reviewing the literature it was evident that few, if any, selection studies have been conducted on channel catfish. Numerous reports on the propagation of channel catfish can be found in the literature (Morris, 1939; Doze, 1925; Davis, 1953; Mobley, 1931; Toole, 1951; Brown, 1942; Canfield, 1947; Lenz, 1947; Snow, 1962; Clemens et al., 1957). Doze (1925) tried to breed a spineless channel catfish which he called a "muley" channel catfish.

He clipped the pectoral spines of the brood stock and hoped this would be transmitted genetically after several generations of clipping. Needless to say his experiment was a failure.

Work on the controlled spawning of channel catfish with the use of human gonadotropic hormones has been conducted by Riggs and Sneed (1959). By using this method to induce spawning many problems of selective breeding programs will be overcome. Other work on this aspect has also been done by Clemens and Sneed (1957) and Riggs (1958) with favorable results on the number of channel catfish fry produced from aquaria spawned fish.

Hickling (1962) mentioned that genetic or selective breeding studies have been conducted chiefly on the carp and trout families. Selective breeding of fishes had its beginning in China before the year 1500 A.D. where the selective breeding of goldfish was started (Smith, 1924). In the United States it was not until the 1900's that selective breeding of fish gained momentum, but it has not kept pace with the breeding practices of domestic animals and plants (Davis, 1931). Although work in the field of fish genetics has not received the attention it should, some work was started as early as 1919.

Embody and Hayford (1925) conducted experiments on brook trout (<u>Salvelinus fontinalis</u>) and by selective breeding increased their resistance to furunculosis and increased the growth rate of experimental fish. Also an increase in rate of growth, earlier maturation, and greater egg production was achieved (Hayford and Embody, 1930). Davis (1931, 1935) conducted experiments on improving trout brood stock and the genetic effects on the spawning of trout. Davis (1953) discussed the selective breeding of trout and selective breeding of bass. His outlook on the selective breeding of bass was not as favorable as it was for trout.

Lewis (1944) reported increased egg production and earlier maturity due to selective breeding of trout. Millenbach (1950) found egg production and rate of growth in trout were reduced even though selected fish matured earlier. Carbine (1953) and Ratledge and Cornell (1953) reported on attempts to breed a non-migratory strain of rainbow trout. Wolf (1954) conducted experiments with positive results on disease resistant strains of trout. Donaldson and Olson (1957) discussed breeding experiments conducted on rainbow trout for 23 years which have improved growth rates, age at maturity, resistance to disease, tolerance to warm water, and egg production. Ehlinger (1964) following closely the methods used by Embody and Hayford (1925) conducted studies to develop disease resistant brook trout.

Alkhunis (1956) reported Russian investigators have experimented on improving the breed of carp. The largest selective breeding program now in progress on improving the carp is being conducted in Israel. Numerous articles on their methods, problems, and results have been published, (Moav and Wohlfarth, 1960; Moav, et al., 1960; Wohlfarth et al., 1961; Moav and Wohlfarth, 1962; Wohlfarth et al., 1963; Wohlfarth et al., 1964; Moav et al., 1964; Wohlfarth et al., 1965, and Yashouv, 1965).

Growth Rates

Tiemeier (1966) reported growth rates of channel catfish fed supplemental diets in Kansas farm ponds. In two farm ponds stocked at 500 fish per acre, Age Class 0 fish weighed 3.8 and 3.9 grams, and Age Class I fish weighed 98 and 66 grams with both groups being weighed in the fall. Weights for Age Class II fish weighed in the fall were 337 and 317 grams in the two ponds. In another pond stocked at 1250 fingerling fish per acre, weight in the fall of Age Class I fish was 159 grams and Age Class II fish weighed 345 grams.

In a fourth pond stocked at 534 fingerling fish per acre the weight in the fall of Age Class 0 fish was 3.6 grams, Age Class I, 75 grams, and Age Class II, 181 grams. In five farm ponds the average weight of Age Class I fish was 83.60 grams, and in four ponds the average weight for Age Class II fish was 331.28 grams.

In a study by Tiemeier et al., (1965) Age Class I channel catfish that weighed 8.0 grams in the spring increased their weight to 73.50 grams by the fall. These results were obtained from 16 experimental ponds stocked at 12,000 fish per acre.

Swingle (1958) by supplemental feeding, and fertilizing ponds obtained an increase in weight from 3.86 grams to 304.18 grams during a 200 day feeding period. These were presumably Age Class I channel catfish and were stocked in the spring at rates of 1000 to 5000 fish per acre. For channel catfish stocked during the late summer and early fall the growth rate was from 16.34 grams to 367.74 grams. The number of days in this experiment were over 390, with six ponds being stocked at 1000 to 2000 fish per acre.

Nail (1962) found channel catfish gained from 33.20 grams to 82.52 grams in 73 days, while determining their protein requirement. The fish were held in metal troughs during the experiment.

Variation of Protein and Fat

Vinogradov (1953) stated that of 20000 or so known species of fishes only 350 to 400, mostly marine species, have been subjected to chemical analyses. Many of the values that are available have been obtained from analyses of one or a few fish. Atwater (1892) performed extensive and careful analyses of fifty-three species of fish, but considered his work only the beginning, because of the small number of fishes sampled.

Ingalls et al. (1950) in a study of the nutritive value of fishes from Michigan waters, found protein varied from 14.10 to 22.10 percent in the following nine species of fish, atlantic herring (Clupea h. harengus), white suckers (Catastomus commersonii), carp (Cyprinus carpio), burbot (Lota lota), smelt (Osmerus mordax), lake trout (Salvelinus namaycush), whitefish (Coregonus clupeaformis), yellow perch (Perca flavescens), and walleye pike (Stizostedion vitreum). Burbot contained the least protein and yellow perch and walleye pike the largest amount of protein per gram of fresh fish tissue. These variations in total protein were related to moisture and fat content of the fish tissue. Total protein content of the fish tended to be less in species having a high fat content. Fat content of the nine species varied widely with whitefish, trout and carp having a high fat content. Moisture in the nine species varied from 82.60 to 69.20 percent, with lower readings recorded in fat fish and higher readings in lean fish.

Wood et al. (1957) while doing a nutritional study of ten salmonoid fishes found fish reared under artificial conditions consistently showed marked differences in body composition in comparison with wild salmonoids. Protein was lower and lipid values were higher for hatchery fish than wild fish of the same species and age. Protein values showed a variation of 10 percent in both groups, but the maximum and minimum were higher for wild fish. Fat in hatchery reared salmonoids ranged from 15.10 to 28.70 percent. In wild salmonoids fat ranged from 11.10 to 18.60 percent.

Buhler and Halver (1961) gave values for chinook salmon (Oncorhynchus tshawytscha) while conducting an investigation on their carbohydrate requirement. Moisture ranged from 81 to 77 percent; protein on a dry basis ranged from 55.60 to 72.10 percent, and fat on a dry basis ranged from 36.60 to 18.70 percent.

Phillips et al. (1958) made a comparison of hatchery and wild brook trout (Salvelinus fontinalis) and hatchery brown trout (Salmo trutta). The moisture in wild brook trout was 71.50 percent, protein 21.20 percent, and fat 3.40 percent. Analyses of hatchery brook trout of comparable size and age showed a moisture content of 71.20 percent, protein 17.30 percent, and fat 6.50 percent. Values for the hatchery reared brown trout were moisture 68.60 percent, protein 21.20 percent, and fat 6.30 percent.

Another study on chemical composition of brook trout reared in a hatchery (Phillips et al. 1960) gave values in the spring of 76.80 percent moisture, 4.57 percent fat and 13.33 percent protein. Fall hatchery trout had 75.70 percent moisture, 5.70 percent fat and 14.08 percent protein. Phillips et al., (1963) investigated effects of different temperature levels on the growth of brook trout. Trout maintained at water temperatures of 47° F. had 75.82 percent moisture, 5.02 percent fat, and 14.03 percent protein, while those at 51° F. had 76.77 percent moisture, 4.12 percent fat and 13.80 percent protein.

Gerking (1952) found utilization of food for growth was influenced by the age of fish and rate of feeding. While carrying out this study the chemical compositions of longear sunfish (Lepomis megalotis) and green sunfish (Lepomis cyanellus) were determined. Moisture and protein of longear sunfish varied only three percent while moisture content of green sunfish varied eight percent and protein 11 percent. In a similar study the chemical composition of the bluegill was determined by Gerking (1955). Analyses were made on fish collected during the spring and fall, with the fat, protein, and moisture showing little variation. Readings for the fall showed 74.10 percent moisture, 3.03 percent fat and a protein level of 16.55 percent. During the spring the values were 74.10 percent moisture, 2.33 percent fat, and 16.07 percent protein.

Pearse (1925) obtained variations in results of chemical analyses of brook trout made at different seasons and on different age groups. Beginning with the ovarian eggs, the water content showed an increase from 61 to 83 percent during the first six months of development. After the first year percentage of water remained fairly constant at about 75 percent. Protein decreased during the first year and then maintained an average of about 18.80 percent. Fat varied between 1.68 and 7.80 percent with fluctuations being correlated with the seasons of the year. During the first year of development fat decreased during the summer and increased in the autumn, but in succeeding seasons fat always increased in the summer and decreased in the winter. Pearse (1925) also conducted chemical analyses of the yellow perch with seasonal variations of fat being obtained. In adult perch, water and protein remain fairly constant throughout the year, but fat varied from 1.50 percent in the winter to slightly above five percent in the summer.

Also included in the study by Pearse (1925) were the effects of starvation and body composition on largemouth bass (Micropterus salmoides) and pumkinseed (Lepomis gibbosus). Comparisons were made with wild fish from Lake Mendota and fish held in laboratory tanks with water from the lake running through them. Fat decreased markedly in starved fish and increased in fish that were allowed to feed, but no fish showed a reduction in fat to less than 0.42 percent of their body weight. Protein decreased slightly in starved fish while ash increased. Moisture content of fed fish was lower than of starved fish.

Nail (1962) conducted a study on protein requirements, and made chemical analyses of the channel catfish. The average values obtained in the spring were 76.99 percent moisture, 1.76 percent fat, and 14.59 percent protein; in the fall 73.53 percent moisture, 5.93 percent fat, and 14.31 percent protein readings were obtained. Fat varied about four percent; moisture varied three percent and protein remained constant throughout the summer. Age Class I fish used during these experiments were six to seven inches in length, and weighed 30 grams in the spring and over 100 grams in the fall.

Heper and Chervinski (1965) made analyses of carp bodies and their inner parts. Carp bodies had a moisture content of 68.80 percent, 12.23 percent fat, and 14.70 percent protein. Inner parts had a moisture content of 73.45 percent, 8.05 percent fat, and 14.53 percent protein.

One of the more comprehensive studies on the chemical composition of fish was conducted by Atwater (1892). From 1880 to 1890 he analyzed many species of American food fishes. In some instances his analyses were based on only a single individual, although in many cases several individuals were analyzed. Most analyses were based only on the edible portion of the fish with all bone, skin, and other unedible parts removed from the fish. The values he obtained are too numerous to enumerate.

Eschmeyer and Phillips (1965) have recently conducted a comprehensive study of the fat content of siscowet (Salvelinus n. siscowet) and lake trout from Lake Superior. Seasonal fluctuations of fat and variation related length were obtained. Their analyses showed a range in fat content of 32.50 to 88.80 percent in siscowets and 6.60 to 62.30 percent in lake trout. Protein readings were not obtained in their study.

In his preliminary report on the chemical composition of fish, Stansby (1954) discussed various inadequacies of past studies and the lack of data from fresh-water species. In the second report written by Thurston et al. (1959) the chemical composition of 21 fresh-water species were given. Determinations were made on fillets only, with bone and skin removed. One fish that is closely related to the channel catfish on which determinations were made was the black bullhead (Ictalurus m. melas). Moisture ranged from 79 to 83.10 percent; fat ranged from 0.80 to 4.40 percent and protein ranged from 15.80 to 16.70 percent in the fillets analyzed.

Brown (1957) reported 80 percent as the average water content of fish flesh. Extreme values of 53 and 89 percent have been reported for certain species of fishes taken at various seasons and from different localities. Values for protein were 14 to 23 percent of wet weight. Lagler (1962) stated water and fat content varied inversely and fat content may vary from place to place in the same fish.

METHODS AND MATERIALS

Selection

Channel catfish used in the selection study were obtained from the Kansas Forestry Fish and Game Commission's State Hatchery located at Pratt, Kansas. Fertilized eggs from the six earliest spawns were collected and hatched. After hatching, fry were transported from Pratt to the Tuttle Creek Fisheries Research Laboratory in plastic bags filled with water and oxygen. Upon arrival on June 9, 1964 fish were placed in six separate and polyethylene lined 1/6-acre ponds. Each of six ponds were stocked with 12 ounces of fry estimated at 10,000. Ponds stocked were Nos. 2, 5, 7, 16, 23, and 28.

The fry were fed twice daily, seven days a week throughout the summer at 7 AM and 3 PM. Feed consisted of a formulated feed mixed by the Kansas State University Department of Flour and Feed Milling. Two different formulas, Z-13 and Z-7 were fed during the summer. Feed Z-13 was in crumblized form and was used as the starter feed, while Z-7 was in a pellet form and was fed after August 25, 1964. Both feeds Z-7 and Z-13 contained 35 percent protein and 1050 kilocalories of energy per pound of feed. Feed was fed on a volume basis rather than a specific amount of weight. The volume varied from 1/3 of a gallon to 1½ gallons per feeding by the conclusion of the experiment. The feed was increased gradually after every weighing period with a total of 2825 pounds being used, or 471 pounds per pond. Feeding ceased on Sept. 28, 1964 after which the ponds were drained and the fish removed.

The six ponds were first seined with a minnow seine on July 1, 1964. This was not considered a sampling period since the fry were not weighed on this date. On 21 July, 25 fry from each pond were weighed and after this date ponds were sampled at two-week intervals. During the first two sample periods only 25 fish, in groups of five, were weighed with the sample being increased to 50 fish on August 31. On the same date the use of the minnow seine was discontinued and a larger ½-inch mesh seine 8 by 40 feet was employed for the sampling.

On 20 August, 1020 fry were removed from ponds Nos. 16 and 28 and stocked in ponds Nos. 18 and 20. The purpose being to eliminate the possibility of crowding and to observe the effect, if any, this would have on growth rate as compared to the initial ponds stocked at a higher rate.

Growth Rates

During the spring of 1965 the especially large fingerling obtained from the selection experiment of 1964 were divided equally and placed in ponds Nos. 4 and 20. Pond No. 4 received 179 fish having an average weight of 39.79 grams. Pond No. 20 was stocked with 179 fish with an average weight of 36.15 grams. Because many fingerlings from the 1964 selection experiment had died during the winter, only Age Class II fish were available for comparison with the select group. The smallest fingerling from the 1964 supplemental feeding experiment were used for comparison with large Age Class I fingerling. The Age Class II fingerling were stocked in ponds Nos. 8 and 12 at a rate of 179 fish per pond which was equal to the stocking rate of the select group. Average weight for fish in pond No. 8 was 61.30 grams and in pond No. 12 was 60.90 grams.

The experiment was carried further by stocking two ponds Nos. 3 and 10, with 179 large fish from the 1964 supplemental feeding program. The purpose was to compare the growth rates of large and small fish and to provide a check for the last phase of the experiment. The large fish in ponds Nos. 3 and 10 averaged 91.90 and 76.10 grams. The last phase of the experiment consisted of stocking an equal biomass of large and small fish in the same pond. Equal weights (7.5 pounds) of both large and small fish were stocked in pond Nos. 2 and 6. Pond No. 2 was stocked with 35 large fish with an average weight of 97.30 grams and 67 small fish with an average weight of 51.50 grams. Pond No. 6 was stocked with 31 large fish and 66 small fish with average weights of 109 and 51.60 grams.

After the last pond was stocked on April 27, 1965 fish were fed six days a week at a rate of 4 percent of their body weight. The feed used was Z-14 which contained 25 percent protein and an energy-to-protein ratio of 30-to-1. The amount of feed was adjusted after every biweekly weighing period to the 4 percent level, except for the last two-week period, when it was reduced to three percent.

The ponds were sampled at two-week intervals from June 7 through August 30, after which the ponds were drained and fish removed. Samples were obtained by using an 8 by 40 foot, ½-inch mesh seine. Sample size consisted of 10 fish from each pond, except for ponds Nos. 2 and 6 where 10 large and 10 small fish were sampled for each pond.

Mortality of the select fish in ponds Nos. 4 and 20 necessitated removing the fish on May 15, 1965. Approximately 92 fish were recovered from pond No. 4 and 150 fish from pond No. 20. Upon inspection, it was determined that fish were infected with Cyclochaeta domerguei and the Henneguya exiles. Upon removal fish were placed in stainless steel tanks and treated with a 1:4000 solution of formalin for one hour as recommended by Davis (1953), with ½ teaspoon of antibiotic (aureomycin) also being added to each tank. The fish were treated three separate times and were restocked on May 18, 1965 with the remaining fish (206) being placed in pond No. 4. The average weight at stocking was 35 grams.

Variation of Protein and Fat

Channel catfish used in experiments to determine seasonal variations of protein and fat were Age Class II fish and had been used in 1964 supplemental feeding experiments. The fish were also part of the 1965 experiment to test the differences between expanded and pelleted feed. Ponds Nos. 1 and 18 were each stocked with 850 fish which had been overwintered in a farm pond. Fish in both ponds were fed formula feed Z-14 which contained 25 percent protein and 850 kilocalories per pound of feed, at 4 percent of their body weight. The only difference being one feed was expanded the other in pellet form.

The first sample of 12 fish was collected at the beginning of the feeding period on April 22, 1965. The second sample was collected on June 7, after which samples were collected at biweekly intervals until August 30, when feeding terminated. All samples during the feeding period were collected from pond No. 1. On Sept. 17, 1965 approximately 160 fish were moved from pond No. 1 to a small observation pond to facilitate sampling during the winter months.

On the same date 120 fish from pond No. 1 were moved into the laboratory, in Fairchild Hall, on the campus of Kansas State University. These fish were placed in two oval (2 ft. X 2 ft. X 6 ft.) stock tanks of 156 gallon capacity. Each tank was equipped with a number five, 110 volt "Mino Saver" agitator. During the first week water in the tanks was changed occasionally with dechlorinated water from a charcoal filter located in another laboratory. After the first week a charcoal filter was installed which furnished a continual supply of fresh dechlorinated water to each tank.

Because of an oversight, standpipes in the two tanks had not been securely fastened and during the second night fish in one tank knocked the standpipe over allowing the water to drain from the tank. All but one fish in this tank were lost due to suffocation. The remaining fish were then divided between the two tanks with 30 fish in each tank. On Feb. 14, 1966 all the remaining fish were again placed in one tank.

At each sampling date 12 fish were collected from the observation pond but only six were collected from the indoor tanks because fish had suffocated in one tank. After collection, fish were weighed individually and the weights recorded. After weighing each fish, the liver and viscera were removed and weighed separately, with the gall bladder being discarded from the sample. Upon removal of the liver and viscera from the fish the disemboweled bodies were again weighed. The 12 livers and 12 viscera or six livers and six viscera were then combined to form one sample each. Fish bodies were grouped in twos making a total of six samples, or three samples for fish held inside. Samples were then placed in a freezer and frozen.

After freezing, samples were chopped into chunks about one inch square using a butcher knife and mallot. These chunks were then ground in a Waring Blendor using isopropyl alcohol as a mixing media, and to facilitate drying. The blended solutions were placed in tared evaporating dishes and desiccated in an oven for 24 hours at 110° C. Upon removal from the oven, the dishes were again weighed and the amount of moisture present in the sample calculated. Dry samples were then ground, using a mortar and pestle, to form a homogenous mixture.

Fat determinations were made following the procedure in the Methods of Analysis of the Association of Official Agricultural Chemists, 1960 edition. Soxhlet continuous extracting apparatus and acetone as the extractant were used. Protein determinations were made using the Kjeldahl method and the results were multiplied by a standard factor of 6.025 which is suggested by Love (1957).

RESULTS

Selection Experiments

When the fry ponds were first checked with a minnow seine on July 1, 1964, numerous fish were obtained in all ponds except pond No. 7. In two seine hauls in pond No. 7 only six fish were caught along with numerous dragonfly larvae, and a few tadpoles. Fish in pond No. 7 were in excellent condition and somewhat larger than those in the other ponds. Seine hauls in the other ponds produced fish all about 1½ inches long, with numerous tadpoles being present in most ponds.

Ponds were again sampled with a minnow seine on the July 21, 1964 with the average weight of 25 fish being recorded. The average weights of the fish for this and following sample dates can be found in Table 1. Fish in all ponds except ponds Nos. 5 and 7 had average weights ranging from 2.32

to 2.72 grams. Fish in pond No. 7 averaged 9.00 grams, while those in pond No. 5 averaged 3.52 grams. These differences, noted during the first sample period, increased throughout the summer. Fish in ponds Nos. 2, 16, 23, and 28 never had a range, among themselves, greater than 1 gram. Fish in pond No. 5 were 1.35 times as heavy as fish in ponds Nos. 2, 16, 23, and 28, at the first sampling period; this increased to 1.68 times as great when the ponds were drained. Fish in pond No. 7 were 3.46 times heavier at the first sampling period and 5.22 times heavier at the final weighing, than fish in ponds Nos. 2, 16, 23, and 28. Fish in pond No. 7 were 2.56 times heavier than those in pond No. 5 at the first weighing period with this increasing to 3.11 by the end of the summer. Average weights for the different ponds at the end of the experiment can be found in Table 1. An analysis of variance indicated the weight differences were significant ($P=0.01$).

Feed Z-13 was in crumblized form and much of it would float, and on July 11, 1964 fry in ponds Nos. 16, 23, and 28 were observed feeding near the surface of the water. This feeding near the surface was later noted in all ponds, with several hundred fry per pond swimming about feeding shortly after the feed had been placed in the water. The fry would swim about in a zig-zag fashion feeding with their mouths and barbels breaking the surface of the water. When feed Z-7, which was in a pellet form, was fed to the fry they stopped feeding on the surface.

On August 20, 1964, 1020 fry from ponds Nos. 16 and 28 were transferred to both ponds 18 and 20. Ponds Nos. 18 and 20 had never been stocked with fish and had just been relined with plastic. The average weight of fish stocked in pond No. 18 was 5.41 grams and 6.02 grams for those stocked in pond No. 20. On the previous sampling date fish in pond No. 16 averaged

Table 1. Weight in grams of channel catfish fry at various sampling dates, and number of fish recovered from an initial stocking of 12 ounces of fry in six ponds.

Pond	Weighing Dates						No. of fish recovered. Sept. 28, 1965
	July 21	Aug. 5	Aug. 18	Aug. 31	Sept. 14	Sept. 28	
2	2.68	4.24	5.40	6.52	8.78	7.90	12,787
5	3.52	6.63	8.32	12.44	13.10	13.88	6,064
7	9.00	21.60	30.90	33.40	42.40	43.10	352
16	2.32	4.68	5.70	7.62	9.70	7.82	9,898
23	2.72	4.86	6.24	8.42	8.18	8.66	11,231
28	2.68	4.68	5.36	6.82	9.10	8.60	8,250
Fry removed from ponds Nos. 28 and 16 on August 20, 1964 and transferred to ponds Nos. 18 and 20.							
18(16)-stocked 1020			5.41	8.06	13.20	14.60	1,016
20(28)-stocked 1020			6.02	9.16	15.20	15.66	997

5.70 grams and fry in pond No. 28 averaged 5.36 grams. From August 20, 1964 to Sept. 28, 1964, fry in pond No. 18 increased in weight to 14.60 grams as compared to 7.82 grams for those remaining in pond No. 16. The weight of fry from pond No. 20 increased from 6.12 to 15.66 grams while fry in pond No. 28 had a final average weight of 8.60 grams. An analysis of variance indicated the weight differences were significant (P=0.05). A gain in weight was noted in all ponds during the summer from one sample date to the next. From Sept. 14, 1964 until Sept. 28, 1964 a loss of weight or a small gain in weight was recorded in all ponds.

When all ponds were drained, it was discovered that ponds Nos. 2, 16, 23, and 28 contained between 8000 to 13000 fish (Table 1). Pond No. 5 contained slightly more than 6000 fish but pond No. 7 contained only 352 fingerling. Survival of fish stocked in pond No. 18 was 99 percent and in pond No. 20, 98 percent. Upon removal, fish from pond No. 7 were placed in pond No. 1 and overwintered. Approximately 5000 of the other larger fingerlings were placed in pond No. 3. The remaining fish were returned to the Kansas Forestry Fish and Game Commission for stocking in lakes and reservoirs. All fish placed in pond No. 3 became diseased and those in pond No. 1 became infected with *Cyclochaeta* and *Henneguya* after they were restocked in the spring of 1965.

Growth Rates

The select fingerling from the 1964 experiment, after being treated and restocked in pond No. 4, had a gain in weight from 35 to 251 grams (Table 3). Small fish in ponds Nos. 8 and 12 had an average gain of 321.30 and 336.10 grams, with an initial weight difference of 0.4 grams, the smallest fish having been in pond No. 12. Small fish stocked in ponds Nos. 2 and 6 had an

Table 2. Number of fish stocked per pond, stocking rates per acre, number of fish recovered, survival, conversion rates, and production rates per acre of Age Class I and II fish.

Pond[1]	Number of fish stocked	Stocking rates per acre	No. of fish recovered	Percent survival	Conversion	Lb. gain per acre
			Age Class I			
4 small	205	1427	204	99	1.94	
			Age Class II			
2 large	35	715	35	100	2.07*	669*
2 small	67		66	97		
	102		100	98*		
6 large	31	675	31	100	2.04*	679*
6 small	66		66	100		
	97		97	100*	2.06*	674*
3 large	179	915	154	86	2.64	763
10 large	179	1247	178	99	2.69	1020
	358		332	93*	2.66*	891*
8 small	179	1247	179	100	2.35	883
12 small	179	1247	179	100	2.25	923
	358		358	100*	2.30*	903*

[1]Ponds were stocked with small (Age Class I), large (Age Class II), or a combination of these sizes of fish.

*Represent means.

average gain of 381.5 and 415.4 grams respectively, with an initial weight difference of 0.1 gram (Table 3).

Large fish in ponds Nos. 3 and 10 had an average gain of 455.1 and 373.9 grams. The difference in initial stocking weights was 15.8 grams. Large fish in ponds Nos. 2 and 6 had an average gain of 539.7 and 544.0 grams, the initial difference in stocking weight was 11.70 grams (Table 3). Survival of fish in all ponds except No. 3 was excellent (Table 2).

The total gain for all large fish and all small fish was nearly identical (Table 3). But the percentage gain for all small fish was greater than for large fish, 652 as compared to 489 percent (Table 3). Wohlfarth et al. (1965) noted in carp progenies that for every 1 gram initial weight difference a 3 or 4 gram difference in final weight was obtained. Large fish in ponds Nos. 3 and 10, and small fish in ponds Nos. 8 and 12, had an initial difference of 45.8 grams, and a final weight difference of 217 grams. For every one gram initial difference, a 4.74 gram weight difference was obtained in final weight. The difference for large and small fish stocked together indicated a final difference of 3.78 grams for every 1 gram initial difference (Table 3). Conversion rates (lbs. feed required to produce a lb. of fish) for fish in ponds Nos. 2 and 6 were better than for either large or small fish stocked separately, 2.06 as compared to 2.66 and 2.30 (Table 2).

Protein and Fat

Percentages in this text on the seasonal variation of protein and fat content of fish outside are on a wet basis. On a wet basis, values for the various factors (protein, fat, moisture) are actual percentage composition of the entire component (liver, viscera, bodies, or entire fish). A

Table 3. Stocking and recovery weights in grams and gains of Age Class I and II fish.

Pond[1]	Stocking weight[2]		Recovery weight[2]		Average[2] gain	Total[2] gain	Percent gain
	Average	Total	Average	Total			
			Age Class I				
4 small[3]	35.00	7,210	251	51,455	216.00	44,280	614
			Age Class II				
2 large	97.30	3,405	637	22,295	539.70	18,890	555
2 small	51.50	3,405	433	28,145	381.50	24,740	727
Total		6,810		50,440		43,630	641*
6 large	109.00	3,405	653	20,243	544.00	16,838	495
6 small	51.60	3,405	467	30,822	415.40	27,417	805
Total		6,810		51,065		44,255	650*
3 large	91.90	16,456	547	84,238	455.00	67,782	412
10 large	76.10	13,620	450	80,100	373.90	66,480	488
Total		30,076		164,338		134,262	446*
8 small	61.30	10,980	383	68,557	321.30	57,577	524
12 small	60.90	10,896	397	71,063	336.10	60,667	552
Total		21,876		139,620		117,744	538*

[1]Ponds were stocked with small, large or a combination of various sizes of fish.

[2]Weights in grams.

[3]Age Class I fish.

*Represent means.

comparison of percentages on a dry basis and average weights for various components are given in Table 4. Results from the starvation of fish kept inside are also based on wet percentages. A comparison of values on a wet and dry basis from fish kept inside and outside are given in Tables 5, 6, and 7. The following results were obtained from 168 moisture, 336 protein and 336 fat determinations on 240 Age Class II channel catfish.

Seasonal variations in moisture content of livers varied from a high of 82 percent in the spring of 1965 to a low of 71.20 percent on July 5, 1965 (Plate 4, Fig. 1). A general increase in moisture was noted after the low reading in July to a level of 81.60 percent on Dec. 30, 1965. During the remaining winter and early spring, values near 80 percent were recorded.

The lowest moisture reading occurred with the highest fat level (8.92 percent) in livers recorded during the year (Plate 4, Fig. 1). The lowest fat reading was recorded with both the highest moisture content of 82 percent and a moisture content of 75 percent. The fat level at both moisture levels was approximately 3.50 percent. Values throughout the remainder of the year showed less variation ranging between 4 and 6 percent at different times of the year and at different moisture levels (Plate 4, Fig. 1).

The lowest protein content in the livers was obtained at the end of the feeding period on Aug. 30, 1965 (Plate 4, Fig. 1). The protein increased to 13.20 percent on Sept. 30, 1965 with the same reading being recorded on Oct. 30, 1965. Protein was maximal at 16.14 percent on Nov. 30, 1965, after which it remained stable at approximately 11 percent for the remainder of the winter and spring (Plate 4, Fig. 1). Protein values during the previous summer showed an increase from 9.29 percent on June 21, 1965 to 11.89 percent on July 19, 1965 and decreased to a low of 7.21 percent on Aug. 30, 1965 (Plate 4, Fig. 1). Livers were too small to obtain protein readings

Table 4. Percent composition (dry basis), and average weights in grams of various components of channel catfish held in an outdoor pool.

Sampling date	Average weight of bodies in grams	Bodies		Average weight of livers in grams	Livers		Average weight of viscera in grams	Viscera	
		Percent fat	Percent protein		Percent fat	Percent protein		Percent fat	Percent protein
22 April	67.91	22.86	56.71	1.18	19.51	---	4.47	30.88	61.80
7 June	93.52	27.29	54.91	2.67	16.99	---	7.65	47.50	50.24
21 June	119.45	30.85	52.47	3.82	18.97	36.78	9.92	46.80	44.31
5 July	145.94	32.65	49.61	5.41	30.98	34.34	12.95	55.54	36.46
19 July	164.54	34.56	50.67	4.22	22.90	48.55	17.95	58.18	31.06
2 Aug.	178.63	33.96	50.46	4.59	23.22	42.08	17.19	57.51	31.06
16 Aug.	204.44	34.72	49.18	5.92	18.96	38.90	18.63	69.61	26.39
30 Aug.	229.56	35.27	50.81	4.46	13.75	28.83	19.06	62.86	32.45
30 Sept.	248.80	31.53	52.36	2.86	21.73	57.24	16.37	48.79	45.37
30 Oct.	232.09	28.40	55.54	3.12	21.55	65.61	14.03	38.52	55.12
30 Nov.	216.58	28.31	55.44	2.97	22.26	60.53	13.82	42.68	51.20
30 Dec.	201.93	29.27	69.20	3.12	21.73	54.42	12.68	46.16	72.36
2 Feb.	204.29	26.42	66.54	2.90	19.76	59.11	11.46	41.63	67.63
1 March	209.00	29.64	69.42	3.15	22.68	54.59	13.45	46.67	72.29
31 March	248.53	25.44	66.23	3.37	21.40	52.17	16.24	30.02	59.72
2 May	185.67	21.78	64.51	2.17	21.96	53.95	12.12	28.24	57.45

Table 5. Average weights in grams, percent fat, protein, and moisture of fish bodies from fish held outside compared with bodies from fish held inside.

Sampling Date		Average weight of bodies in grams	Dry basis percent fat	Dry basis percent protein	Wet basis percent water	Wet basis percent fat	Wet basis percent protein
30 Sept.	0	248.80	31.53	52.36	71.90	8.84	14.63
	I	213.25	30.92	53.85	72.10	8.64	15.02
30 Oct.	0	232.09	28.40	55.54	73.80	7.45	14.55
	I	200.83	27.71	55.01	72.50	7.62	15.13
30 Nov.	0	216.58	28.31	55.44	74.10	7.35	14.38
	I	194.85	23.27	58.62	74.50	5.94	14.95
30 Dec.	0	201.93	29.27	69.20	73.22	7.84	18.53
	I	181.27	19.04	64.30	76.50	4.52	15.12
2 Feb.	0	204.29	26.42	66.54	74.60	6.75	16.91
	I	196.38	8.97	57.78	79.16	1.90	12.04
1 Mar.	0	209.00	29.64	69.42	73.57	7.85	18.35
	I	245.25	8.35	58.12	80.85	1.62	11.13
31 Mar.	0	248.53	25.44	66.23	74.00	6.46	17.22
	I	206.13	6.50	56.93	82.12	1.20	10.18
2 May	0	185.67	21.78	64.51	75.80	5.32	15.61
	I	167.62	4.15	60.74	83.71	.69	9.89

Table 6. Average weight in grams, percent fat, protein and moisture of fish viscera from fish held outside compared with viscera from fish held inside.

Sampling Date		Average weight of viscera in grams	Dry basis Percent fat	Dry basis Percent protein	Wet basis Percent water	Wet basis Percent fat	Wet basis Percent protein
30 Sept.	0	16.37	48.79	45.37	68.90	15.24	14.11
	I	13.94	55.04	36.46	68.25	17.48	11.58
30 Oct.	0	14.03	38.52	55.12	76.30	9.80	13.07
	I	10.65	44.32	56.18	75.60	10.82	13.72
30 Nov.	0	13.82	42.68	51.20	75.60	10.40	12.48
	I	8.11	32.57	63.39	72.60	8.92	17.37
30 Dec.	0	12.68	46.16	72.36	74.10	11.95	18.74
	I	9.10	22.99	52.60	81.50	4.25	9.73
2 Feb.	0	11.46	41.63	67.63	76.10	9.95	16.16
	I	10.97	15.61	44.07	83.95	2.51	7.07
1 Mar.	0	13.45	46.67	72.29	76.50	10.97	16.99
	I	13.80	10.71	41.30	83.80	1.74	6.69
31 Mar.	0	16.24	30.02	59.72	79.00	6.31	12.54
	I	10.32	9.16	43.88	83.40	1.52	7.28
2 May	0	12.12	28.24	57.45	79.99	5.65	11.50
	I	8.95	10.78	41.00	82.90	1.85	7.02

Table 7. Average weights in grams, percent fat, protein and moisture of fish liver from fish held outside compared with liver from fish held inside.

Sampling Date		Average weight of livers in grams	Dry basis Percent fat	Dry basis Percent protein	Percent water	Wet basis Percent fat	Percent protein
30 Sept.	0	2.86	21.73	57.24	76.90	5.01	13.20
	I	2.53	23.38	69.75	81.82	4.25	12.68
30 Oct.	0	3.12	21.55	65.61	79.70	4.37	13.30
	I	1.81	23.70	65.08	79.70	4.83	13.21
30 Nov.	0	2.97	22.26	60.53	73.30	5.93	16.14
	I	1.83	22.16	67.42	77.30	5.04	15.34
30 Dec.	0	3.12	21.73	54.42	81.60	4.00	10.02
	I	1.55	30.85	58.72	79.03	6.45	12.21
2 Feb.	0	2.90	19.76	59.11	80.20	3.91	11.70
	I	1.85	20.62	-----	77.90	4.56	-----
1 Mar.	0	3.15	22.68	54.59	80.20	4.49	10.81
	I	2.47	20.77	55.08	80.40	4.07	10.80
31 Mar.	0	3.37	21.40	52.17	79.30	4.43	10.80
	I	1.54	21.25	-----	78.50	4.57	-----
2 May	0	2.17	21.96	53.95	79.80	4.43	10.89
	I	1.16	17.46	-----	79.90	3.50	-----

during the first two sample periods in the spring of 1965.

The seasonal variation of the fat and moisture content of the viscera indicated these factors were inversely related. Lowest moisture readings of 62 percent occurred with the highest fat level of 26.45 percent, both on Aug. 16, 1965. Highest moisture content of 79.99 percent and the lowest fat readings of 5.65 percent were recorded on May 2, 1966. This compared with a 77.20 percent moisture and a 7.11 percent fat reading the previous spring of 1965 (Plate 3, Fig. 1).

Moisture in the viscera decreased from a high reading in spring to a low on Aug. 16, 1965, after which it increased until the last sample was collected on May 2, 1966. Fat increased as the moisture decreased throughout the summer, then decreased as the moisture increased throughout the winter (Plate 3, Fig. 1).

Protein content of the viscera decreased from 14.12 percent on April 22, 1965 to approximately 10 percent by the end of the feeding period (Plate 3, Fig. 1). On the first sampling date after feeding stopped, protein had again increased to 14 percent, followed by an increase to 18.74 percent on Dec. 30, 1965. Protein then dropped to 11.50 percent by May 2, 1966.

In the fish bodies the lowest moisture reading occurred with the highest fat level of 10.46 percent. High moisture readings of 74.80 and 75.80 percent were obtained in the spring of 1965 and 1966. These high moisture readings occurred simultaneously with the lowest fat readings of 5.78 and 5.32 percent. Moisture decreased from a high reading in spring to a low on Aug. 16, 1965 (Plate 2, Fig. 1), which occurred with the low reading obtained from the viscera (Plate 3, Fig. 1). After Aug. 12, 1965 there was a gradual increase to the maximum moisture content in the spring.

For fish kept outside protein values for the bodies remained constant at slightly over 14.00 percent from April 22, 1965 to Dec. 30, 1965 after which it increased to 18.57 percent (Plate 2, Fig. 1). After Dec. 30, 1965 protein varied between 18 percent and 15.61 percent which was recorded on May 2, 1966 (Plate 2, Fig. 1).

Upon combining all three factors from the three body components, moisture content for the entire fish was maximal on April 22, 1965 and May 2, 1966. During the spring of 1965 moisture was 75.05 percent and during the following spring 75.03 percent. Moisture gradually decreased during the summer until a low of 70.10 percent was noted on Aug. 16, 1965. After this date moisture increased to a high of 75.03 percent in the spring of 1966 (Plate 1, Fig. 1).

Fat in the entire fish varied from a low of 5.83 percent on April 22, 1965 to a high of 11.61 percent on Aug. 16, 1965. Fat then decreased to a low of 5.84 percent on May 2, 1966. Fat and moisture were again inversely related as was evident in the body and viscera separately (Plate 1, Fig. 1).

Protein in the entire fish was stable from April 22, 1965 to Nov. 30, 1965 varying from 14.59 to 13.54 percent with a range of 1.05 percent. On Dec. 30, 1965 a high of 18.14 percent protein was recorded. This decreased to 16.67 percent on Feb. 2, 1966 and increased to 17.80 percent on March 1, 1966 (Plate 1, Fig. 1). On March 31, 1966 protein decreased to 16.86 percent and continued to decrease until a reading of 14.25 percent was reached on May 2, 1966.

For fish held inside, moisture content of the liver was irregular with a high of 81.82 percent on Sept. 30, 1965. Moisture then decreased to 77.30 percent on Nov. 30, 1965, increased to 79.03 percent on Dec. 30, 1965 and then decreased to 77.90 percent on Feb. 2, 1966. On March 1, 1966, 80.40

percent moisture was recorded. This decreased to 78.50 percent on March 31, 1966 and increased to 79.90 percent on May 2, 1966 (Plate 4, Fig. 2). The fat content of the liver on Sept. 30, 1965 was 4.25 percent and increased to 6.45 percent on Dec. 30, 1965. After this date, fat in the liver decreased to a low of 3.50 percent on May 2, 1966 (Plate 4, Fig. 2).

Protein readings were obtained only on five sample dates because livers were small. Protein on Sept. 30, 1965 was 12.68 percent and increased to 15.34 percent by Nov. 30, 1965. Protein then decreased to 12.21 percent on Dec. 30, 1965 and the last reading obtained on March 1, 1965 showed a 10.80 percent protein content (Plate 4, Fig. 2).

Moisture content for the viscera from fish kept inside showed a general increase from a low of 68.25 percent to a high of 83.95 percent reached on Feb. 2, 1966. Thereafter a slight decrease in moisture to 82.90 percent on May 2, 1966 was noted (Plate 3, Fig. 2). Fat content of the viscera decreased from a high of 17.48 percent on Sept. 30, 1965 to a low of 1.52 percent on March 31, 1966. The May 2, 1966 reading was 1.85 percent (Plate 3, Fig. 2). Protein content of the viscera was irregular with an 11.58 percent reading being obtained on Sept. 30, 1965. This increased to 17.37 percent on Nov. 30, 1965 and decreased to 7.02 percent reading on May 2, 1966 (Plate 3, Fig. 2).

For fish kept inside, moisture content of the bodies showed an increase from a low of 72.10 percent on Sept. 30, 1965 to a high of 83.71 percent on May 2, 1966. At the same time, fat had a high reading of 8.64 percent on Sept. 30, 1965, decreasing to a low of 0.69 percent by May 2, 1966 (Plate 2, Fig. 2). Protein remained stable at approximately 15 percent from Sept. 30, 1965 until Dec. 30, 1965. Thereafter it decreased from 15.12 percent to a low of 9.89 percent on May 2, 1966 (Plate 2, Fig. 2).

From a low of 71.97 percent on Sept. 30, 1965 moisture in the entire fish, for those kept inside, increased to a high of 83.66 percent on May 2, 1966 (Plate 1, Fig. 2). Fat content in the entire fish decreased from a high of 9.13 percent on Sept. 30, 1965 to a low of 0.77 percent on May 2, 1966 (Plate 1, Fig. 2). Protein remained at approximately 15 percent from Sept. 30, 1965 until Dec. 30, 1965, for fish kept inside. By Feb. 2, 1966 protein had decreased to 11.77 percent and continued to decrease to a low of 9.76 percent on May 2, 1966 (Plate 1, Fig. 2).

DISCUSSION

Selection Experiments

Results of selection from six individual spawns showed a significant difference (P=0.01) in growth rates. Survival rates of fish in various ponds also was significantly different. Number of fish recovered from the various ponds ranged from 352 to 12,787. Although growth of fish in ponds Nos. 7 and 5 was significantly greater than those in ponds Nos. 2, 16, 23, and 28, the difference in number cast a doubt on their genetic superiority.

Effect of survival on growth rates is further supported by growth rates of fry in ponds Nos. 18 and 20 which were significantly different (P=0.05) in growth rates from the original ponds. Therefore, it would seem the major factor affecting growth rates in this experiment was survival. Although the fry were over-fed, crowding and competition may have reduced the availability of food for fry in ponds with larger numbers of fish. A stocking rate of 12 ounces of newly hatched fry would have to be considered too great for a pond 0.1436 surface acre in size.

Rate of growth in all ponds was greater than those reported by Tiemeier _et al_. (1965) and Tiemeier (1966), and Swingle (1958) for Age Class 0 fish.

Average weights for Age Class 0 fish used in their studies were between 3 and 4 grams compared to 7.82 grams for the smallest fish in this experiment. Tiemeier (1966) reported the weights of fed and non-fed Age Class 0 channel catfish from Kansas farm ponds. The average for fed fish was 3.8 grams and average weight of non-fed fish was 5.0 grams. The final weight (43.10 grams) of fish in pond No. 7 was so large that any comparison with fry from the other spawns would be difficult. Therefore, it was decided to keep the fish from pond No. 7 for the following years experiment.

Rates of Growth in Populations of Fish of Various Sizes

Ponds containing large fish and ponds containing only small fish produced more pounds of fish per acre than did individual ponds containing an equal biomass of both large and small fish. Large fish in ponds Nos. 3 and 10 had 763 and 1020 pounds of gain per acre, while small fish in ponds Nos. 8 and 12 had 883 and 923 pounds of gain per acre (Table 2). In comparison small and large fish stocked together in ponds Nos. 2 and 6 had 669 and 679 pounds of gain per acre (Table 2). The difference in pounds gained per acre can be attributed to the difference in stocking rate per acre (Table 2). Ponds containing only large or small fish were stocked at a higher rate than were ponds stocked on an equal weight basis of both large and small fish. This influence of stocking rate on production has also been reported by Swingle (1958), Hickling (1962), Tiemeier (1957) and Simco and Cross (1966).

Stocking an equal biomass of large and small fish in the same pond has shown a significant difference (P=0.05) in growth rates compared with large and small fish stocked in separate ponds (Table 2). Furthermore, ponds containing mixed sizes of large and small fish had a greater percentage gain and lower conversion rate than fish in ponds stocked with large and small fish (Table 2). At the conclusion of the experiment a 4.74 grams difference was noted for every 1 gram initial weight difference between large and small fish stocked in individual ponds. The final weight difference for large and small fish stocked together on an equal weight basis was only 3.79 grams. This smaller difference would indicate that in ponds containing both large and small sizes of fish, small fish grew faster than small fish stocked separately. When an equal biomass of large and small fish were stocked the smaller fish were able to compete more efficiently with the large fish because of greater numbers.

The major factor in controlling growth rates would not be size of the fish but rather the stocking rate. If the goal of production is larger fish, rather than an increase in pounds of fish per acre, a reduction in stocking rate would be necessary. This factor was evident in the selection experiment where a poor survival rate produced a small stocking rate and large fish. Where survival was good, production per acre was increased but smaller fish were produced.

Tiemeier (1966) gave the average weight of Age Class II channel catfish raised in Kansas farm ponds and given supplemental feed as 384 grams. Age Class II channel catfish in this study averaged 496 grams. Small fish averaged 420 grams and large fish averaged 572 grams (Table 2). For Age Class I fish fed supplemental diets in Kansas farm ponds the average weights were 115 grams. At the end of the feeding period select Age Class I fish in this study weighed 251 grams. The large difference between the two groups of fish can be attributed to the initial size (35 grams) of the Age Class I fingerlings used in this experiment. In the spring the average size of Age Class I fingerlings reported by Tiemeier (1966) was 11 grams.

Variation of Protein and Fat

Vinogradov (1953) stated that few fishes had been chemically analyzed. Reports on seasonal variations of effects of starvation on the chemical composition of fishes are rare. In this study, Age Class II channel catfish were analyzed for protein and fat content. Furthermore, seasonal variations of these factors plus the effect of starvation, at a higher than normal winter temperature, were obtained.

On each of 16 sampling dates for fish held outside 12 fish were collected and chemically analyzed. Eight moisture determinations were made at each sampling date, six on the grouped fish bodies, and one each on the combined livers and combined viscera. Sixteen fat and 16 protein determinations were made on each sampling date with 12 being made on the grouped fish bodies and two each on the combined livers and combined viscera. During the starvation period from August 30, 1965 to May 2, 1966 these fish were held in an outside pond with an average water temperature of 48° F.

For fish kept inside, six fish were collected at each sampling date and chemically analyzed. At each sampling period five moisture determinations were made, three on the grouped fish bodies, and one each on the combined livers and combined viscera. Ten fat and ten protein determinations were made, six on the grouped fish bodies and two each on the combined livers and combined viscera. These fish were starved the same length of time as fish kept outside, but at a higher water temperature (70° F.).

Pearse (1925) found percentage of water and protein remained stable in brook trout and yellow perch after the first year of development. In channel catfish, the percentage of water fluctuated between 75 percent in the spring to 70 percent at the end of the feeding period. Percent protein increased during the winter to 18.14 percent, while during the remainder of the year it ranged between 13.54 and 14.59 percent. Pearse (1925) also found that fat in brook trout varied from 1.68 to 7.80 percent and in yellow perch from 1.50 to slightly over 5 percent during the summer. Fat in the channel catfish varied from 5.83 percent in the spring to a high of 11.61 percent at the end of the feeding period, an increase of 100 percent.

The largest variation in fat occurred in the viscera where fat increased from a low of 7.11 percent on April 22, 1965 to a high of 26.45 percent on August 16, 1965. In the livers and bodies, fat varied only five percent from the low to the high readings. Moisture in the viscera varied as much as 15 percent during the year while in the livers it varied 10 percent during the year. High moisture readings occurred in the spring while low readings occurred during the summer.

Moisture in the fish body varied 5.10 percent from 70.70 to 75.80 percent. Fat varied 5.14 percent, from 5.32 to 10.46 percent. Although these variations are smaller than those for the liver and viscera they represented 90 percent of the entire fish, while liver and viscera represent two and seven percent respectively of the entire fish.

Fish held in the laboratory at 70° F. for 244 days had a 12 percent increase in moisture while fish kept in an outdoor pool had a three percent increase during the same period. Moisture levels for both groups were 72 percent on the first sampling date after starvation started. This difference in moisture can be correlated to the difference in fat content of the entire fish. Fish kept outside lost approximately three percent of their fat while fish kept inside lost over eight percent of their fat. Not only did the fish held inside lose more fat, they also had a decrease of protein, while fish kept outside had an increased percentage of protein. Pearse (1925) also reported a loss of body protein in starved fish.

During the summer the average gain for Age Class II channel catfish fed supplemental diets in Kansas farm ponds was 265 percent (Tiemeier, 1966). In comparison fish in pond No. 1 had a 285 percent gain in weight during the summer. The fish in the farm ponds were fed a diet containing 35 percent protein at 5 percent of their body weight. Fish in this experiment were fed a diet containing only 25 percent protein and fed at a rate of 4 percent of the body weight. Stocking rates of fish in farm ponds were less than 1600 fish per acre, in all ponds, while fish in pond No. 1 were stocked at a rate of 4345 fish per acre.

Although fish kept in farm ponds had access to some natural food and were stocked at a lower rate than fish in pond No. 1 their percent gain was less than for fish in pond No. 1. Several factors could be responsible for the difference in gain, water temperature, diets or difference in genetic growth potential of the fish.

Tiemeier (1966) found in Kansas farm ponds fingerling channel catfish stocked in the spring, and given supplemental feed during the summer achieved the most gain in weight (94.8 percent) by September 1. After Sept. 1, only a slight gain or loss in weight was noted. Data by Tiemeier (1966) showed that channel catfish not fed a supplemental diet achieved 71.2 percent of their gain in weight from spring to fall. Only 27.8 percent of the gain in weight of channel catfish was obtained from fall to spring. Channel catfish were seined in early June and again in late August or early September.

During the course of the feeding period fish were fed a diet which contained 25 percent protein and 850 kilocalories per pound. The average conversion rate for these fish was 2.64, and 2244 kilocalories were required to produce a pound of fish. The grams of protein required to produce one pound of fish were 300 grams, or 1170 kilocalories. Kilocalories of protein and fat were calculated using values given by Phillips and Brockway (1959) of 3.9 kilocalories per gram of protein and 8.0 kilocalories per gram of fat. Of this amount only 258 kilocalories were deposited as protein per pound of fish produced. Therefore, 33.92 kilocalories were required to produce 1 gram of fish protein. The amount of fat deposited (52.80 grams) per pound of fish produced was 422 kilocalories, requiring 42.50 kilocalories per gram of fat produced. The amount of protein and fat deposited (680 kilocalories) when subtracted from the total amount of kilocalories fed (2244) indicated the fish required 1564 kilocalories as energy for every pound of fish produced. The gross efficiency coefficient (calories of flesh divided by calories of feed X 100)of the feed was 30.30 percent using the formula given by Lagler (1962).

Of the 1170 kilocalories of protein required to produce a pound of gain, only 258 kilocalories were deposited as protein, leaving 912 kilocalories either used for energy or stored as fat. During the same period 422 kilocalories of fat were deposited per pound of gain. Of the total amount of energy (1564 kilocalories) required to produce a pound of fish, over one-half was provided by protein in the diet. From this it would appear that the amount of protein in the diet could be reduced and a different form of energy substituted.

Phillips et al. (1966) investigating the use of calorie sources by brook trout found food fat had a sparing action on food protein. Three diets containing different protein levels and calories per pound of feed were used in the study. All diets contained 25 percent each of beef liver and beef spleen. The remainder of each diet consisted of one of three dry meal mixtures. The first diet contained 27.3 percent protein and 724 kilocalories per pound of feed, the second diet contained 598 kilocalories and 23 percent protein, and the third diet contained 18.3 percent protein and 464 kilocalories per pound of feed.

At these different levels of protein, and calories the diet with the highest protein content produced the best growth. Corn oil was then added to the low protein diets raising their calorie content to that of the high protein diet. Results then showed low protein diets produced the same amount of growth as the high protein diet when the calorie content in the diets were equal.

Chemical analyses of the brook trout showed that when diets had unequal amounts of calories per pound of feed, the diet with the highest protein level produced the highest level of body fat (20.6 percent). When corn oil was added, those diets receiving the oil produced the highest level of body fat, approximately 26 percent.

Heper and Chervinsiki (1965) chemically analyzed carp fed various supplemental diets. They found carp fed a pelleted feed containing 30 percent protein had less fat than carp fed grain sorghum containing 20 percent protein. Fish fed on pellets contained only 4.9 to 7.6 percent fat as compared to 17.4 to 18.0 percent fat in fish fed milocorn. They also found that the amount of protein in the diet effected yield after the stocking rate was increased beyond a certain "critical" point. A possible explanation was that low protein diets could not supply enough protein to keep certain amino acids at a sufficient level to produce good growth.

Phillips and Brockway (1959) conducted experiments on brook trout using diets containing different protein and energy levels. A diet that contained 25.7 percent protein and 653 kilocalories of energy had the best conversion rate of 2.5. With this diet 1,632 kilocalories were required to produce a pound of fish, and of this amount 279 kilocalories were deposited as protein, 200 kilocalories as fat, and 1,153 kilocalories being required for energy per pound of fish produced. In a second diet, the conversion rate was poorer (2.9) but the kilocalories per pound of feed were lower (486) as was the percent protein (19.3). At the conversion rate of 2.9, 1409 kilocalories were required to produce a pound of fish. Of this amount 279 kilocalories were deposited as protein and 203 kilocalories as fat, and 927 kilocalories were required as energy to produce a pound of fish.

Phillips and Brockway (1959) concluded that higher protein levels increased the metabolic rate of fish. The higher levels of protein required more kilocalories of energy to produce a pound of fish because excess protein was either burned for energy or deposited as fat and not increasing fish protein. In my study only 22 percent of the available protein was deposited as protein and the remainder was either used for energy or stored as fat.

During the feeding period the channel catfish gained 5.78 percent fat per pound of gain, an amount of fat equal to 210 kilocalories of energy. The maximum amount of fat present in the entire fish was equal to 417 kilocalories of energy. Of this amount, fish bodies contained 335.50 kilocalories, viscera 77.2 kilocalories, and livers 4.38 kilocalories of energy in the form of fat. During the starvation period of 244 days the fish kept outside lost 5.77 percent of their fat per pound of fish, or 210 kilocalories, which is the same amount gained during the feeding period. The amount lost per day during starvation was one half the amount stored per day during the summer. The difference in the amount lost per day compared to the amount stored per day resulted from a reduced metabolic rate at the cooler temperature. The bodies lost 70 percent, viscera 28 percent and livers 2 percent of the fat present at the beginning of starvation.

Fish kept inside in tanks lost 8.36 percent of their fat or 303.6

kilocalories of energy per pound of fish. Fish kept inside also had a reduction in the amount of protein. During the final 123 days of starvation the fish lost 5.03 percent of their protein or 89.04 kilocalories of protein energy. For fish held inside there was a different rate of fat lost in the three components compared to fish kept in the outside pool. For fish held inside the bodies supplied 80 percent of the energy, viscera 19 percent and livers only 1 percent of the energy required for the maintainence of the fish. The total amount of energy lost by fish kept inside was 393 kilocalories which was 183 kilocalories more than for fish held outside. Fish starved at the higher temperature required 8.30 kilocalories more energy for every 1 degree difference in temperature during the period of starvation.

Because the liver comprised only a small percentage of the body weight its importance as a storage vessel for fat was minor. Throughout the year livers averaged 1.78 percent of the live body weight for fish held outside. Percentages were different for winter and summer. Average weight of livers for fish taken during summer was 2.46 percent, while during the winter livers averaged 1.28 percent of the body weight. For fish held inside in tanks the average was even smaller at 1.01 percent of body weight.

Considering the small amount of fat stored in the liver (4.63 percent yearly average) and the small fluctuation during starvation (0.58 percent) liver fat cannot be considered a major factor in providing energy for the fish during starvation. There was a decrease in the amount of protein during starvation (2.31 percent) which could account for the decrease in percent of live-body weight.

Livers from fish held inside had an average fat content of 4.65 percent during starvation while fish held outside had a 4.57 percent average during the same period. There was also a decrease of protein in the livers for fish held inside. The difference between the last reading obtained on March 1, 1966 and the Sept. 30, 1965 reading was 1.88 percent.

Judd and Cross (1966) noticed fish fed artificial diets developed discrete pallid blotches in their livers, and the livers of these fish seemed enlarged and friable. Tiemeier (1966) studied channel catfish in Kansas farm ponds and noted fat fish frequently had larger and more yellowish livers than thin fish. During the course of this experiment it was noted that some, not all, of the livers had pallid blotches, but none of the livers seemed enlarged or friable. Judd and Cross (1966) also noted a relationship between the mean liver-weight to fish-weight and the amount of tissue-damage in the liver. Liver-weight to fish-weight ratio changed during the year in my experiment.

Judd and Cross (1966) also noted that tissue damage was correlated with carbohydrate content of the feed. Because carbohydrate is either used for energy, stored temporarily as glycogen, or converted into fat (Nail 1962) the only possible source of damage from carbohydrates would be due to the abundance of glycogen. The highest fat level recorded in the liver was only 8.90 percent and this was recorded on one sample date. Possible causes of the tissue damage suggested by Judd and Cross (1966) are low oxygen level or rapid fluctuations in oxygen-content of the water, coupled with high temperature inhibiting fat metabolism, or excessive accumulations of glycogen. However, there is a high incidence of these pallid blotches in wild fish, and it seems to have no effect on fish growth and survival.

The appearance of starved fish kept in indoor tanks and outdoor pools remained good throughout the period of starvation. Some fish kept inside developed rough fins probably caused by other fish nipping them while in the confinement of the tanks. At the end of the experiment one small fish, starved inside, had the appearance of starvation with the bones of the head and ribs being evident underneath the skin. After a starvation period of approximately 244 days, fish kept inside had a relative plumpness using the Coefficient of Condition (R) that ranged from a low of 0.86 to a high of 1.15. Tiemeier (1966) considered any (R) values below 1.20 as poor for populations of farm pond channel catfish weighed and measured during the summer months.

On April 19, 1966 eight fish, no longer needed for the chemical analyses, were placed in a separate tank and fed beef and turkey liver to May 25, 1966. From an initial weight of 1289 grams for the eight fish, they increased to 1743 grams at a conversion rate of 3.44. At the initial feeding, fish did not feed on the liver for several minutes, but at subsequent feedings they immediately fed after the liver was dropped into the water. After the last sample was collected, fish that remained in the other tank were also fed. Liver was taken by these fish within a matter of seconds after it was dropped into the water. There was no mortality of fish fed after starvation even though as much as a pound of liver was placed in the tank at one time.

Adelman et al. (1955) starved brook trout for seven months during the winter at a water temperature of 9.5 C. The brook trout were graded according to size into three different groups of 40 fish in each group. Of the smallest fish (9 cm) 70 percent died, as compared to 10 and 25 percent of the larger fish 14 cm. and 19 cm., respectively. After this starvation period the surviving brook trout were fed at different levels and those allowed an unrestricted amount of feed died, while those fed a restricted ration survived and resumed normal growth. In comparison, none of the channel catfish used during my experiment died from starvation, even though they were starved for a longer period than were the brook trout. Furthermore, none of the fish starved at the higher temperature were lost, and none were lost when fed after starvation.

SUMMARY

Results of selection experiments conducted on six individual channel catfish spawns showed a significant difference (P=0.01) in rate of growth. Survival of fish in various ponds was also significantly different ranging from 352 to 12,787 fish recovered. Low survival was obtained from fish in ponds Nos. 7 and 5, but growth of fish in these two ponds was significantly greater than those in ponds Nos. 2, 16, 23, and 28.

Fry from two of the initial ponds (16 & 28) were stocked in two separate and previously empty ponds (18 & 20). Results showed that transferred fry had a significant increase in growth compared to the original ponds (P=0.05). Because fish in pond No. 7 were large (43.10 grams) they were selected for the following years experiment.

During the summer of 1965 growth rates of large fingerlings from the 1964 selection experiment were compared with small fish from the 1964 supplemental feeding program. After the 1964 selected fingerlings were stocked in the spring of 1965 they became infected with Cyclochaeta domerguei and Henneguya exiles. Fish were removed from the ponds and treated with formalin and aureomycin. Those fish surviving were placed in pond No. 4.

The experiment was also designed to compare growth rates of various sizes and treatments of Age Class II fish. Two ponds (3 & 10) were stocked with 179 large fish, and two ponds (2 & 6) were stocked with an equal biomass (7.5 pounds) of large and small fish in the same pond.

Results from this experiment showed ponds containing large and small fish had a poorer conversion rate, and lower average percent gain than ponds stocked with both sizes of fish on an equal weight basis. Ponds which contained either large fish or small fish did produce more pounds per acre than ponds with mixed

sizes of fish. There was a significant difference ($P=0.10$) in growth of the various treatments, with growth rates of mixed sizes of fish being greater than for fish in ponds with either large or small fish.

From April 22, 1965 to May 2, 1966, 240 channel catfish were analyzed for moisture, protein and fat content. During the feeding period from June 7, 1965 to Aug. 30, 1965 samples were collected at biweekly intervals with 12 fish being collected at each sampling date. From Aug. 30, 1965 until May 2, 1966 samples were collected at monthly intervals with 12 fish being collected at each sampling date. During the winter fish were also kept in our laboratory at a water temperature of 70° F. These fish were also sampled at monthly intervals from Aug. 30, 1965 to May 2, 1966, only six fish were collected at each date.

Chemical analyses of channel catfish held outside showed a seasonal variation in content of moisture, fat, and protein. Percentages of moisture and fat showed a negative correlation, when one factor was maximal the other was minimal. Moisture content was maximal in the spring, and minimal at the end of the feeding period for the entire fish. Fat was minimal during the spring and maximal at the end of the feeding period. Protein of the entire fish remained stable during the late spring, summer, and early winter at approximately 14 percent. During late winter and early spring the percentage of protein increased to 18 percent for a short time, then dropped to 14.80 percent by May 2, 1966.

Channel catfish held in the laboratory showed marked differences in chemical composition when compared to fish held in an outdoor pool. Fish held in tanks had a 12 percent increase in moisture, eight percent decrease in fat, while fish held outside had a three percent increase in moisture and three percent decrease in fat. Not only did the fish maintained in the laboratory lose more fat, they also had a decrease in protein while fish kept outside had an increased percentage of protein.

During the feeding period fish required 2244 kilocalories to produce a pound of fish. Total amount of protein necessary to produce a pound of catfish was 300 grams or 1170 kilocalories, and of this amount 278 kilocalories were deposited as protein. A total of 1564 kilocalories were used for energy to produce a pound of fish. The amount of fat deposited per pound of fish produced was 422 kilocalories. Calculations showed the gross efficiency of the feed was 30.30 percent. From this study it was evident that the majority of the protein contained in the feed was either used for energy or deposited as fat. A study on carp has shown that a low protein diet deposited more fat than a high protein diet.

During the starvation period fish kept in an outdoor pool subject to normal winter temperatures lost exactly the same amount of fat they had gained during the feeding period (210 kilocalories). Of this amount lost, 70 percent was supplied from fat in the fish body or fish muscle. Fish held inside in tanks at a temperature of 70° F. lost 392 kilocalories of energy, losing both fat and protein. Of this amount, 80 percent was supplied by the fish bodies or fish muscle.

Because liver comprised only a small percentage of the body weight its importance as a storage vessel for fat was minor. During the starvation period the liver provided only two percent of the total energy required by fish held in an outdoor pool. For fish held inside in tanks, the liver provided only one percent of the energy required by the fish.

The appearance of starved fish kept in indoor tanks, and outdoor pools, remained good throughout the period of starvation. There was no mortality of fish during the period of starvation, and after starvation, when fish were fed.

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Recognition is also accorded to the author's wife, Raeann, for encouragement during the course of these studies, and for editing the thesis.

EXPLANATION OF PLATE I.

Fig. 1. Percentage moisture, protein, and fat content of channel catfish, held in an outdoor pond from April 22, 1965 to May 2, 1966. Fish were fed from April 22, to Aug. 30, and starved from Aug. 30, 1965 to May 2, 1966. Percentages are on a wet basis.

Fig. 2. Percentage moisture, protein and fat content of channel catfish, held in tanks, in the laboratory from Sept. 17, 1965 to May 2, 1966. Fish were starved from Aug. 30, 1965 to May 2, 1966. Percentages are on a wet basis.

PLATE I

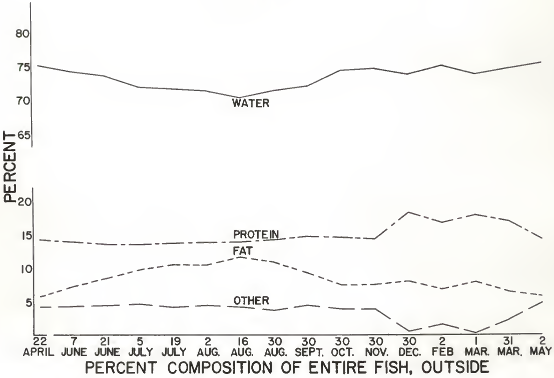

Figure 1.

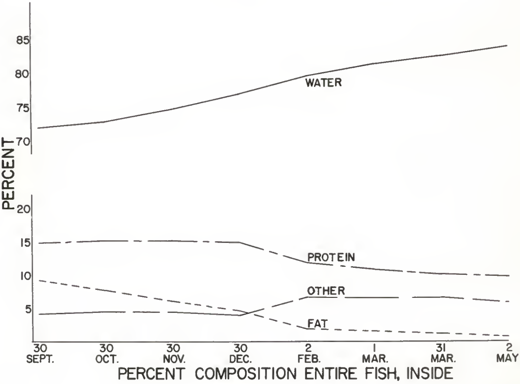

Figure 2.

EXPLANATION OF PLATE II.

Fig. 1. Percentage of moisture, protein, and fat in bodies of channel catfish held in an outdoor pond from April 22, 1965 to May 2, 1966. Fish were fed from April 22, 1965 to Aug. 30, 1965 and starved from Aug. 30, 1965 to May 2, 1966. Percentages are on a wet basis.

Fig. 2. Percentage of moisture, protein and fat in fish bodies of channel catfish held in tanks, in the laboratory from Sept. 17, 1965 to May 2, 1966. Fish were starved from Aug. 30, 1965 to May 2, 1966. Percentages are on a wet basis.

PLATE II

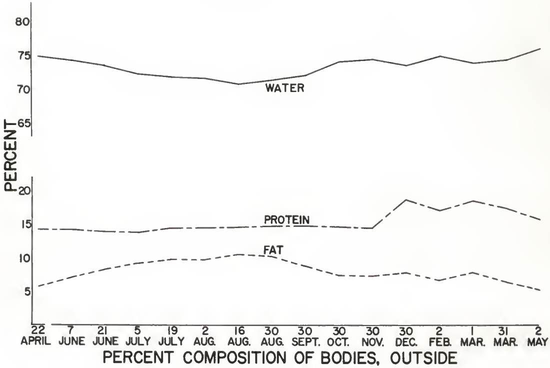

Figure 1.

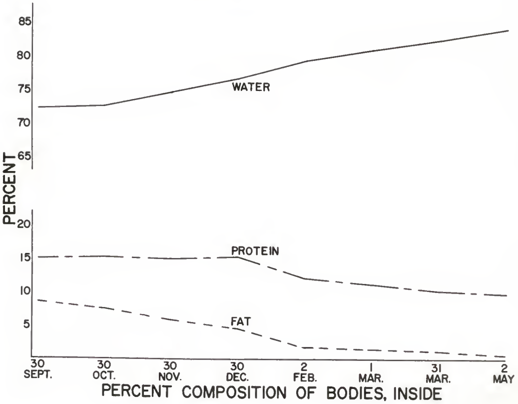

Figure 2.

EXPLANATION OF PLATE III.

Fig. 1. Percentage of moisture, protein, and fat content in viscera of channel catfish held in an outdoor pond from April 22, 1965 to May 2, 1966. Fish were fed from April 22, 1965 to Aug. 30, 1965 and starved from Aug. 30, 1965 to May 2, 1966. Percentages are on a wet basis.

Fig. 2. Percentage of moisture, protein, and fat content in viscera of channel catfish held in tanks, in the laboratory from Sept. 17, 1965 to May 2, 1966. Fish were starved from Aug. 30, 1965 to May 2, 1966. Percentages are on a wet basis.

PLATE III

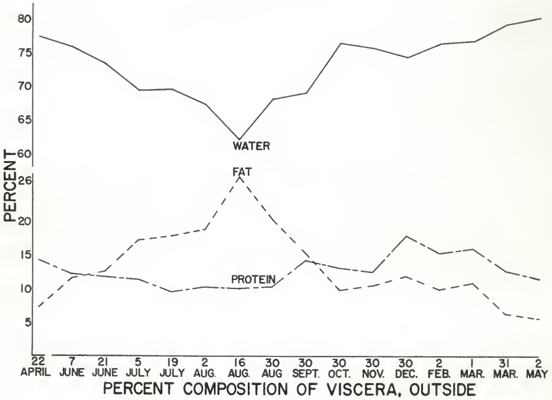

Figure 1.

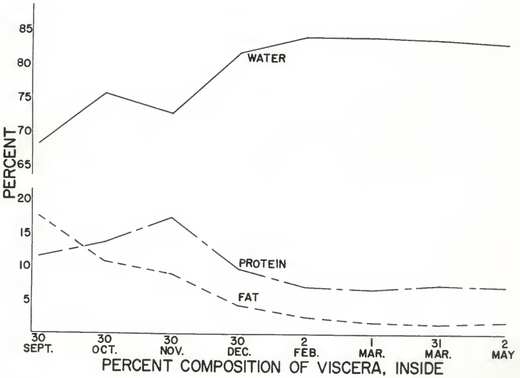

Figure 2.

EXPLANATION OF PLATE IV.

Fig. 1. Percentage of moisture, protein, and fat content in livers of channel catfish held in an outdoor pond from April 22, 1965 to May 2, 1966. Fish were fed from April 22, 1965 to Aug. 30, 1965 and starved from Aug. 30, 1965 to May 2, 1966. Percentages are on a wet basis.

Fig. 2. Percentage of moisture, protein and fat content in livers of channel catfish held in tanks, in the laboratory from Sept. 17, 1965 to May 2, 1966. Fish were starved from Aug. 30, 1965 to May 2, 1966. Percentages are on a wet basis.

PLATE IV

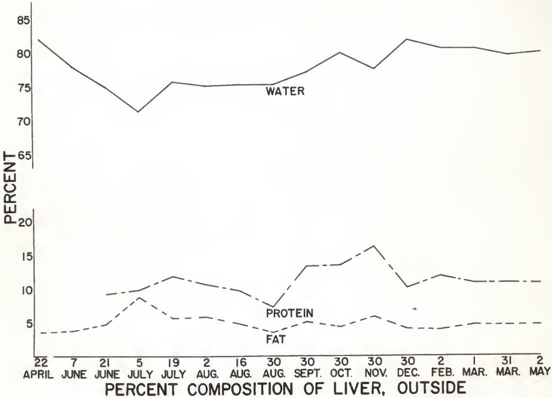

Figure 1.

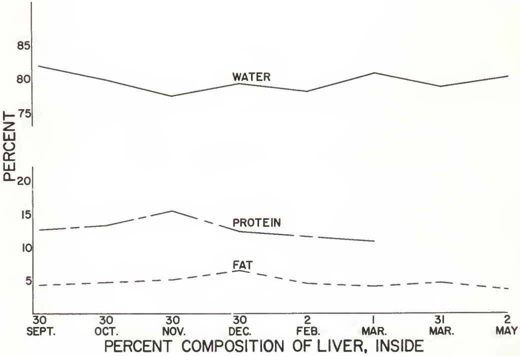

Figure 2.

SELECTION, GROWTH RATES AND SEASONAL VARIATION OF PROTEIN AND LIPIDS IN CHANNEL CATFISH, *ICTALURUS PUNCTATUS* (RAFINESQUE)

by

VICTOR CHARLES SUPPES

B. S., Fort Hays Kansas State College, 1962

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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Manhattan, Kansas

1967

Selection of channel catfish for a faster growth rate was conducted during the summer of 1964. The six earliest spawns were collected and hatched at the Kansas Forestry Fish and Game Commission Hatchery at Pratt, Kansas. From these six spawns, 12 ounces of fry were stocked in six ponds at the Tuttle Creek Fisheries Research Laboratory. These ponds were maintained at a 0.1436 surface acre of water and were lined with polyethylene plastic.

Poor survival was obtained in pond No. 7, and pond No. 5 had only 60 percent survival of the estimated stocked fish. Survival was excellent in four remaining ponds. Fish in pond No. 7 were the largest (43.10 grams), while fish in pond No. 5 weighed 13.88 grams. Growth of fish in the other four ponds ranged from 7.82 to 8.66 grams.

Suspecting poor survival in some ponds, fry from two of the initial ponds with poor growth were stocked in two separate and previously empty ponds. Results showed that transferred fry had a significant increase in growth compared to the original ponds (P=0.05). Because of the large size (43.10 grams) of the fish in pond No. 7 they were selected for the following years experiment. During the summer of 1965 growth rates of large fingerling from the 1964 selection experiment were compared with small fish from the 1964 experimental feeding program.

After the 1964 fingerlings were stocked in the spring of 1965 they became infected with (Cyclochaeta domerguei) and the myxosporidian (Henneguya exiles) and had to be removed from the ponds and treated. Because of the heavy loss of fish, all those surviving were placed in one pond.

An experiment was designed to compare growth rates of various sizes and treatments of Age Class II fish. Two ponds were stocked with 179 large and two ponds were stocked with 179 small fish. An additional two ponds were stocked with an equal biomass (7.5 pounds) of large and small fish in the same pond.

Results from this experiment showed ponds containing only large or small fish had a poorer conversion rate, and lower average percent gain than ponds stocked with both sizes of fish on an equal weight basis. Ponds which contained either large fish or small fish did produce more pounds per acre than ponds with mixed sizes of fish. There was a significant difference ($P=0.10$) in growth of the various treatments, with growth of mixed sizes of fish being greater than for fish in ponds with either large or small fish.

Chemical analyses of channel catfish showed a seasonal variation of moisture, fat, and protein content. Amount of moisture, and amount of fat showed a negative correlation. When one factor was maximal the other was minimal. Moisture content was maximal in the spring, and minimal at the end of the feeding period in the entire fish. Fat was minimal during the spring and maximal at the end of the feeding period. Protein of the entire fish remained stable during the late spring, summer, and early winter at approximately 15 percent. During late winter and early spring the percentage of protein increased to 18 percent for a short time, then dropped to 14.80 percent by May 2, 1966.

During the feeding period, fish required 2244 kilocalories to produce a pound of fish. Total amount of protein necessary to produce a pound of catfish was 300 grams or 1170 kilocalories, of this amount 278 kilocalories were deposited as protein. A total of 1564 kilocalories were used for energy to produce a pound of fish.

During the starvation period fish kept in an outdoor pool subjected to normal winter temperatures lost exactly the same amount of fat they had gained during the feeding period (210 kilocalories). Of the amount lost, 70 percent was supplied from fat in the fish body, or fish muscle. Fish held inside, in tanks, and at a temperature of 70 F lost 392 kilocalories of energy, losing both fat and protein. Of this amount, 80 percent was supplied by the fish bodies, or fish muscle.