A LABORATORY STUDY OF NATURAL FOOD CONVERSION AND GROWTH RATES OF LARGEMOUTH AND SMALLMOUTH BLACK BASS

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This is to certify that the

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A LABORATORY STUDY OF NATURAL FOOD CONVERSION AND GROWTH RATES OF LARGEMOUTH AND SMALLMOUTH BLACK BASS

By

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

INTRODUCTION

It has been previously demonstrated that growth rate is an important factor in the life history studies of fishes (tester, 1932), and that ultimate fish yields depend upon the availability of food and the efficiency of its transformation into the various fish body tissues. An experimental method of providing maximum yields consists of providing maximum food availability by the use of shortened food chains, which eventually leads to consideration of the efficiency of food conversion (Swingle, 1949). Food conversion factors are obtained by dividing the weight of food consumed by the amount of gain in body weight, and prove useful in evaluating yields, since they establish a relationship between the amount of food ingested and the increase in body weight of individual fish fed.

In order to add in some small measure to the existing knowledge concerning food conversion and fish growth, the present study was designed to test the efficiency of conversion and growth rates of 21 smallmouth bass, *Micropterus dolomieu dolomieu*, and five largemouth bass, *Micropterus salmoides salmoides*, fed twice daily on known weights of forage fishes in the laboratory.

Previous Studies

The current literature contains few comprehensive reports concerning food conversion studies, although some workers have accomplished notable work in this respect. Thompson (1941) found an average conversion factor of 2.5 for twenty largemouth bass ranging in size from fin-

gerlings to one pound in weight, fed live minnows at an average temperature of 70 degrees fahrenheit in individual aquaria. For simplicity, conversion values for bass of all sizes were adjusted to those of ten-inch bass. He stated that maximum food conversions were obtained by feeding from 3.5 to 4.0 percent of the initial body weight daily, and that food was utilized less efficiently when larger amounts were fed. This suggests that greatest efficiency of food conversion may be attained at submaximum levels of feeding. Earlier, Kingsbury (1934) estimated that about nine pounds of food were required to produce one pound of bass at an average temperature of 70 degrees fahrenheit, using a variety of artificial foods. In a later study, Kingsbury and Royce (1935) reported that young bass fingerlings held in hatching troughs required about fifteen percent of their body weight daily in order to convert food to flesh, varying with temperature and the type of diet. Prather (1951), by selecting annually from fast-growing individuals for brood stock over a six-year period, was able to produce fast-growing yearling bass that converted an average of 2.06 pounds of live forage fishes to one pound of body weight. The bass were fed twice weekly in outdoor cement aquaria twelve feet in diameter and two feet in depth. During the first year of the study, fish were fed from .5 to 9.5 percent of their initial body weight daily, but since it was found that those individuals fed at the highest rate were unable to consume all the food given them, he fed five percent of initial body weight daily in later experiments. An average conversion factor of about four was found by Lagler and Kruse (1953) in an experiment with four largemouth bass and three smallmouth bass held in individual aquaria placed out-of-doors and supplied with running water from a nearby lake. The bass were given an average two-day diet of three species of live forage fish for a period of about four weeks.

METHODOLOGY AND PROCEDURES

The experimental work was conducted in the fisheries laboratory of the Fisheries and Wildlife Department at Michigan State College in East Lansing, Michigan. The feeding program was carried on over a period of fourteen weeks, beginning on December 1, 1953 and ending March 9, 1954. For the study, a total of 26 fish were used, 21 smallmouth bass and five largemouth bass collected by the use of an electric shocking apparatus from the Red Cedar and Looking Glass Rivers near East Lansing. No attempt was made to collect any particular size or age class for the experiment.

Captured bass were placed in individual glass-sided aquaria in the laboratory, and were fed approximately all the live food they would consume for one week previous to the initial weight and length determinations. Weights of forage species fed during this adjustment period were not recorded.

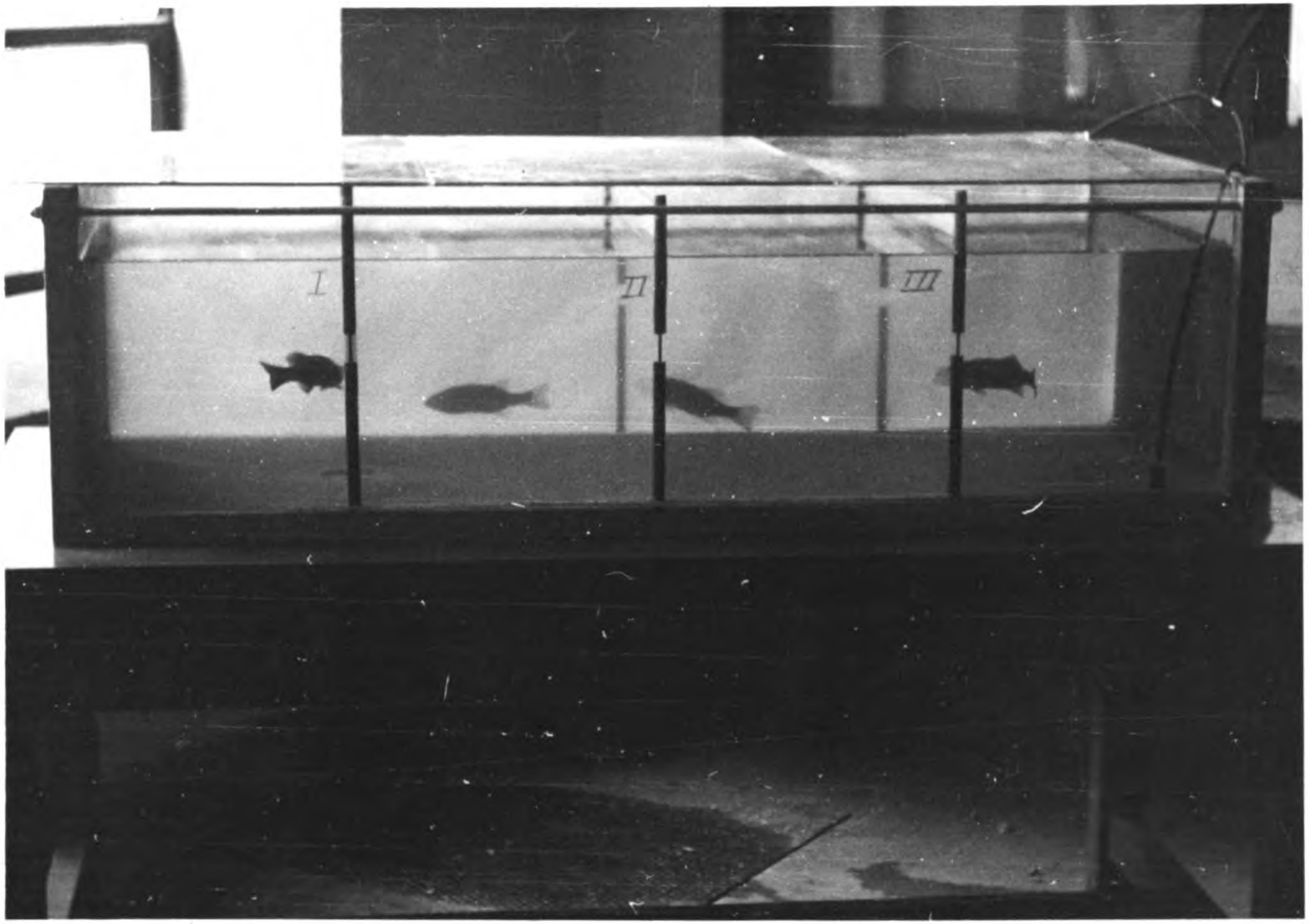
Aquaria

Four of the aquaria used had a capacity of about fifty gallons, and were divided by glass spacers into four approximately equal compartments of about 12½ gallons (see Fig. I). Four smaller aquaria were divided into two compartments of about 14 gallons each. The largest bass in the sample was placed in a large museum-type display aquarium with a capacity of slightly over 100 gallons.

Spacers used were of double-strength glass plates cut about one-quarter-inch less than the inside width of the aquarium and high enough

FIGURE 1

FIGURE 1



Photograph showing aquarium set-up used in the feeding study.

so that approximately two inches of the plate extended above the water level. Installation of spacers was accomplished by placing short lengths of 1/8-inch rubber tubing over the edges and forcing them into position. Some space was left between lengths of tubing to allow oxygen diffusion to all compartments of the aquarium (Fig. I). By the use of these glass spacers, cannibalism was prevented, no marking of fish was necessary, and bass could be fed and observed individually. Double-strength glass plates were used to cover all aquaria.

Aquaria were filled to capacity with tap water (assumed to be chlorinated) and aerated for 24 hours before bass were introduced. One aerator was placed in an end compartment of each aquarium. It was assumed that by using tap water, little if any plankton would be available for food. Consequently, no plankton measurements were deemed necessary. Water was added only when needed to keep aquaria filled to capacity, and once each week, excrement and accumulated materials were removed by siphoning with a short length of hose to prevent putrefaction.

Weight and Length Determinations

Individual bass were weighed and measured at the beginning of the experiment, three times during its course, and again at its conclusion. Forage species were weighed in water to the nearest .1 gram, and excess water was allowed to drain off before weighing. Bass were weighed in the same manner as the forage species, but were first anesthetized by immersing in a one percent solution (by weight) of ethyl ether until loss of equilibrium was apparent. The length of time fish were allowed to remain in the solution varied with the size of the fish, although generally, about thirty seconds was found sufficient to make them un-

stable enough to handle easily. Length measurements were made to the nearest millimeter by the use of a home-made fish measuring board.

Forage Fish and Feeding

Bass were fed live forage fishes twice daily, at about 7:30 A.M. and 5:30 P.M. Dead forage fish and those not consumed by the subsequent feeding time were removed, weighed and subtracted from the record. Temperature in degrees Fahrenheit was recorded during each feeding period from a chemical thermometer placed in each aquarium.

Cement tanks in the laboratory were used as holding tanks for forage species. Included among forage species were Eucalia inconstans, Pimephales promelas, Lepomis machrochirus, Notropis heterolepis, Notropis atherinoides, Chrosomus eos, Notemigonus crysoleucas auratus and Notropis cornutus.

Treatment of Diseased Fish

During the course of the study, it became necessary to treat two of the smallmouth bass for fin rot and three for fungus. Individuals infected with fin rot, apparently a bacterial infection for which the causative organism has not yet been isolated in pure culture (Davis,1953), were treated by immersing in a three percent NaCl solution for about fifteen minutes; the treatment was administered daily for one week. Both of the fish treated for the disease showed marked improvement after five of the salt treatments, and effected fins showed new growth in about 10 days.

For treatment of the fungus (Saprolegnia) a 1:10,000 solution of malachite green oxalate was made by diluting .38 grams of malachite green lustrous crystal into one gallon of water, and infected fish were immersed in the solution for about two minutes. After three treatments spaced two days apart, the effected individuals showed improvement, and in two weeks the fungus had completely disappeared.

Statistical Methods

Statistical procedures used in calculating differences in mean weight gains were those presented by Snedecor (1950), and all computations were made on a computing machine. Analyses of data by statistical methods were made only on order to simplify interpretation of data.

PRESENTATION AND ANALYSIS OF DATA

Food Conversion

Water temperature during the experiment ranged from 67 to 77 degrees fahrenheit, with an average temperature of 70.3 degrees for the 14-week period. The conversion factor for both bass species was found to be 5.6, with that for smallmouth bass 5.63 (Table 1) and that for the largemouth bass 3.81 (Table 2). The average value for the entire sample closely coincides with the ratio of five to one as used by several German workers and suggested by Richardson (1921) for fish living primarily on animal food. Individual bass varied considerably in the ability to convert food to flesh, as was indicated by conversions ranging from 2.14 to 15.33 (Tables 1 and 2).

The application of the regression formula (Snedecor, 1950) to initial weights and food conversion rates of 16 smallmouth bass studied (those treated for diseases were ignored in the calculation) supports the ~~fact~~ view that larger fish utilize more food in maintaining the body and thus are less able to convert food to flesh. Although the "t" test is not significant for the data presented, the sample estimate cannot be ignored, since there is evidence to support some relation between the initial body weight and food conversion. Conversion rates, therefore, can be partially predictable, each gram increase in initial body weight corresponding to an increase of .0025 in the food conversion rate of smallmouth bass in the sample. The use of the regression formula may lead to predictions of conversions for larger populations, and may be

TABLE 1

WEIGHT DATA AND FOOD CONVERSION FOR 21 SMALLMOUTH BASS

Initial Wt. (grams)	Final Wt. (grams)	Total Wt. gain (grams)	Amount of food given (grams)	Conversion factor
4	24	20	52	2.60
5	25	20	56	2.80
8	22	14	51	3.64
13	33	20	82	4.10
22	33	11	89	8.09*
22	57	35	107	4.03
24	31	7	31	4.43
26	33	7	55	7.86
31	46	15	79	5.27
34	49	15	98	6.53
39	45	6	92	15.33*
39	66	27	120	4.44
40	55	15	98	6.53
55	98	43	112	2.60
56	84	38	154	5.50
60	113	53	198	3.74
87	117	30	237	7.90*
94	121	27	252	9.33*
111	144	33	121	3.67
112	177	65	309	4,75
119	140	21	283	13.48*

Average food conversion factor: 5.63

* Denotes conversion factors for fish treated for diseases.

TABLE 2

WEIGHT DATA AND FOOD CONVERSION FOR FIVE LARGEMOUTH BASS

Initial Wt. (grams)	Terminal Wt. (grams)	Total Wt. gain (Gm)	Amount of food given (grams)	Conversion factor
464	526	62	409	6.59
27	38	11	63	5.73
22	72	50	107	2.14
20	75	55	129	2.34
19	44	25	57	2.28

Average food conversion factor: 3.81

valuable in studies aimed at determining amounts of food utilized by fish for maintaining the body. Undoubtedly this sample was too small to yield a valid regression coefficient. However, the method may prove to be of considerable value when large samples are involved.

The average food consumption for all bass studied was 4.3 percent of the initial body weight daily. This value is only slightly higher than the optimum rate of feeding suggested by Thompson (1941). Results of the present study indicated that most efficient conversions were obtained by feeding from five to about thirteen percent of the initial weight daily (Table 4).

Weight Gains

In comparisons of weight gains between the two bass species, it was evident that significant weight gains occurred (Table 3), with the largemouth bass showing greater weight gains than smallmouth bass. Total weight gains for individual bass ranged from seven to 62 grams (Tables 1 and 2). The largest weight gain for one individual, as compared to initial body weight, was shown by the smallest bass in the sample. This fish gained five times its starting weight during the 14-week period.

Growth Rates

Instantaneous rates, expressed as the natural or Naperian logarithms of the simple quotients obtained by dividing the terminal or final weights by the starting or initial weights of bass studied, were selected to represent relative growth rates (in weight) of fish in the sample. The relationship is expressed by the formula $i = \text{Log}_e\ Y_t/Y_o$ where i is the

TABLE 3

SUMMARY OF STATISTICS FOR COMPARISON OF MEAN WEIGHT GAINS BETWEEN LARGEMOUTH AND SMALLMOUTH BASS

Species	Number observed	Degrees freedom	Mean Wt. gain (grams)	Sum of squares
Smb[1]	21	20	24.4	595.36
Lmb[2]	5	4	40.6	1648.36
		Sum = 24	Difference = 16.2	Sum = 2243.72

Pooled variance = 2243.72/24 = 93.48

Standard deviation from mean $= \sqrt{\frac{93.48\ (21\quad 5)}{(21)\ (5)}} = 4.81$

$t = 16.2/4.81 = 3.37^{*}$

[1] Denotes smallmouth bass.

[2] Denotes largemouth bass.

TABLE 4

COMPARISON OF FEEDING RATES TO INSTANTANEOUS GROWTH RATES OF LARGEMOUTH AND SMALLMOUTH BASS

Species	Initial Wt. (grams)	Terminal Wt. (grams)	No. of days in period	% of initial body Wt. fed Ea. day	% of initial body Wt. gained Ea. day	Instantaneous rate of growth in Wt. per day
Lmb[1]	19	44	98	3.1	1.43	.00857
"	20	75	98	6.6	2.80	.01349
"	22	72	98	5.0	2.30	.01209
"	27	38	63	6.9	1.16	.00542
"	464	526	62	2.0	.31	.00183
Smb[2]	4	24	98	13.3	5.10	.01828
"	5	25	98	11.4	4.10	.01642
"	8	22	98	6.5	1.78	.01032
"	13	33	98	6.4	1.50	.00951
"	22	57	98	6.5	1.60	.00971
"	24	31	52	2.0	.45	.00492
"	22	33	98	4.1	.51	.00414*
"	26	33	98	2.2	.28	.00243
"	31	46	98	2.6	.49	.00403
"	34	49	98	2.9	.44	.00373
"	39	66	98	3.1	.70	.00537
"	39	45	98	2.4	.15	.00146*
"	40	55	98	2.5	.38	.00325
"	55	98	98	2.1	.79	.00589
"	56	84	98	2.8	.51	.00414
"	60	113	98	3.4	.89	.00789
"	87	117	98	2.8	.35	.00302*
"	94	121	98	2.7	.29	.00258*
"	111	144	34	3.2	.87	.00792
"	112	177	98	2.8	.59	.00467
"	119	140	98	2.4	.18	.00166*

[1] Denotes largemouth bass; [2] Denotes smallmouth bass.

* Denotes instantaneous growth rates of bass treated for diseases during the study.

instantaneous rate, Y_t is the terminal weight and Y_o is the starting or initial weight at the beginning of the study. The values for i were divided by the number of days in the total feeding period to give daily instantaneous rates. These rates have been used previously to some extent for studying mortality rates of fishes, e.g., Ricker, 1948.

Instantaneous rates of growth in weight between individual bass and between the two species were variable (Table 4), although in general, largemouth bass showed higher rates than smallmouth bass. The average daily rate for all bass was .00658. Smallest growth rates were those shown by diseased fish, and the highest were shown by the smallest individuals in the sample (Table 4).

Length Gains

The average gain in total length for all bass in the sample was found to be about .3 millimeters daily. The smaller individuals of both species showed the greatest increases in length (Table 5), while the largest bass in the sample showed no gain in length during the feeding study. Smaller bass were evidently able to convert food more readily to increases in length since they required less food to maintain the body.

Effect of Size of Prey on Feeding

It was quite evident from observations made during the feeding study that the size of the prey item is an important factor to consider in studying food conversions and growth rates. A similar conclusion was reached by Lagler and Kruse, 1953. The larger bass consistently refused small prey items, and often would not feed until larger forage

TABLE 5

LENGTH DATA BY SPECIES FOR 26 BASS STUDIED

Species	Initial length (mm)	Terminal length (mm)	Length gain (mm)	Daily length gain (mm)	Number of days for length gain
Lmb[1]	117	177	60	.61	98
"	121	174	53	.54	98
"	124	134	10	.16	63
"	133	151	18	.18	98
"	312	312	0	.00	62
Smb[2]	83	127	44	.44	98
"	84	126	42	.43	98
"	84	120	36	.36	98
"	109	149	40	.42	98
"	130	170	40	.42	98
"	123	139	16	.28	52
"	127	141	14	.14	98
"	127	147	20	.20	98
"	137	156	19	.19	98
"	142	156	14	.14	98
"	146	168	22	.22	98
"	150	174	24	.24	98
"	152	160	8	.08	98
"	160	185	25	.26	98
"	167	202	35	.35	98
"	169	207	38	.38	98
"	185	211	26	.26	98
"	191	210	19	.19	98
"	192	220	28	.28	98
"	202	207	5	.15	34
"	212	243	31	.32	98

[1] Denotes largemouth bass.

[2] Denotes smallmouth bass.

All lengths given are based on total length.

species were offered. For this reason, some selection of forage species was made during feeding, and prey items were given that seemed, subjectively, to be most readily consumed by the individual fed.

Effect of Diseases on Growth and Food Conversion

Although none of the bass were lost due to disease, and all of the treated fish recovered, the results of the study reveal that there was a noticeable effect upon the ability of these individuals to convert food to flesh. A statistical analysis of weight gains between diseased and presumably healthy smallmouth bass indicated that mean weight gains were significantly less among diseased bass (Table 6). It could be concluded that most of the food ingested by diseased fish was necessarily used in maintaining the body, or that conversion of food into the various body cells was inhibited in some manner by effects of the disease, even though it may have been slight. Conversion factors for diseased fish ranged from 7.90 to 15.33 (Table 1), with a mean value of 10.82 as contrasted with a mean of 4.53 for disease-free smallmouth bass.

Instantaneous growth rates for diseased fish were generally less than for presumably healthy individuals. It seems probable that similar reduced rates of growth or conversion ability may account for some of the variation in growth of fishes of the same species among natural populations.

Observations made of diseased bass would seem to indicate, superficially, that when fish begin to feed well, they are apparently able to build up a higher resistance to diseases.

TABLE 6

SUMMARY OF STATISTICS FOR COMPARISON OF MEAN WEIGHT GAINS FOR DISEASED AND DISEASE-FREE SMALLMOUTH BASS

	Number observed	Degrees freedom	Mean Wt. gains (grams)	Sum of squares
Disease-free	16	15	26.06	679.12
Diseased	5	4	19.00	361.00
	Sum =	19	Difference = 7.06	Sum = 1040.12

Pooled variance = 1040.12/19 = 5.47

Standard deviation from mean $= \sqrt{\frac{5.47\ (16 \quad 5)}{(16)(5)}} = 1.22$

$t = 7.06/1.22 = 5.79$**

SUMMARY

A laboratory study based on data from 21 smallmouth bass and five largemouth bass fed twice daily on known weights of live forage fishes clearly indicated considerable variability in instantaneous growth rates (in weight) and food conversions among individual bass as well as between the two species.

At an average aquarium temperature of 70.3 degrees fahrenheit, the food conversion factor for both bass species averaged 5.6, with that for smallmouth bass 5.63 and that for largemouth bass 3.81.

The most efficient food conversions were attained by bass fed from five to about 13 percent of their initial body weight daily.

Smallmouth bass suffering from diseases evidently required more food to maintain the body and were less able to convert food to flesh than healthy individuals of the same species.

The application of the regression formula to data for presumably healthy smallmouth bass shows some evidence to support a relation between initial body weight and food conversion rate. The regression method may prove to be of considerable value in predicting food conversions and in determining the amount of food utilized for body maintenance by fishes.

Largemouth bass showed greater mean weight gains than smallmouth bass, and fish treated for diseases showed a lower mean weight gain than presumably healthy individuals.

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