

ESTIMATED SIZES OF VARIOUS FORAGE FISHES LARGEMOUTH BASS CAN SWALLOW*

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Since the development of pond management techniques using bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) as the basic components of the fish population, numerous questions have arisen concerning the sizes of fish that a bass of a given size can swallow. For example, when a pond is checked for balance (Swingle, 1956) and found to have an overcrowded population, a knowledge of the sizes of bass that should be present to harvest the existing crop of smaller bluegills or other species would probably be of considerable value. Also, to determine the Y/C ratio between bass and small forage fishes (Swingle, 1950), it is necessary to know the sizes of forage fishes available as food to each inch-group of bass. This was pointed out by Swingle (1950, p. 28): "Since the 'C' (carnivorous) species can eat only sizes that they are able to gulp and swallow, the maximum depth . . . of 'F' (forage) species would appear to be the only dimension of importance to the fishes in a population."

To determine the size of fish a bass can eat, it was necessary to observe how a bass normally swallows a fish. In field observations the bass usually took the fish into its mouth head first. When a fish was taken sidewise or tail first, the bass spit out the fish, and at the same time flipped it so that it could be recaptured head first. Once the fish was head first in the mouth of the bass, it was rotated 90 degrees from its vertical axis and then swallowed. The position of a forage fish in the mouth of a bass ready to be swallowed is illustrated in Figure 1.

After observing bass feeding, it was postulated that some structure located in the pectoral region of the body must limit the size of a fish that could be swallowed by an individual. Dissection revealed that the cleithrum bones were the relatively non-flexible structures regulating the size of an object that might pass through the esophagus of the bass. Top and side views of these limiting bony structures in the largemouth bass are shown in *x*-ray photographs, Figures 2 and 3. It will be noted that bluegill, whose maximum depth of body (Figure 4) equals the mouth width (Figure 5) of the bass, can be swallowed. It is also evident from these *x*-rays that the horizontal capacity of the esophagus is slightly greater than the vertical capacity. Thus, with fish whose maximum depth of body approaches their maximum width of body, the vertical capacity of the esophagus may be a critical measurement. In this study are considered only those species of forage fishes whose maximum depth of body is much greater than their maximum width of body.

The assumption that a largemouth bass can swallow a fish whose maximum depth of body is equal to the mouth width of the bass was checked in aquarium feeding tests in the laboratory. A total of 29 bass, ranging in total length from 155 to 290 millimeters and with mouth widths from 15 to 33 millimeters, was used in this series of tests. During the 4.5 months that the tests were in progress, the bass were offered bluegills, golden shiners, and goldfish whose total length and maximum depth of body had been determined.

It was found that bass swallowed a considerable number of forage fishes whose maximum depth of body was equal to or slightly greater than the mouth width of the bass. Also, it was observed that if bass had a choice of smaller fish, these were eaten in preference to sizes approaching the mouth width measurement. While this study did not establish the maximum sizes of forage fish that a bass could swallow, it appeared that a bass seldom fed upon fishes with maximum depths of body greater than its mouth-width measurement.

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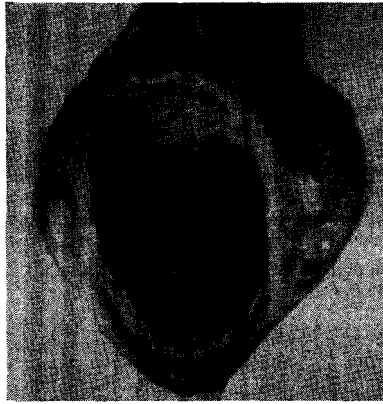


Figure 1



Figure 2



Figure 3



Figure 4

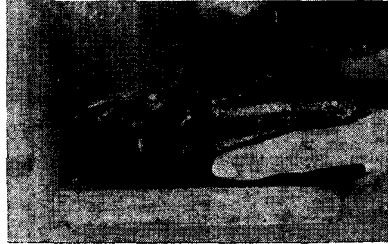


Figure 5

If it is assumed that a bass can swallow a forage fish whose maximum depth of body is equal to the mouth width of the bass, this relationship may be expressed symbolically as follows:

$$M = D$$

bass forage

The linear relationships between total length and mouth width and total length and maximum depth of body for largemouth bass were determined from 1,699 individuals collected from 39 populations and ranging in size from 31 to 595 millimeters in total length. The mean mouth widths, maximum depths of body, and weights for each inch-group of total length for largemouth bass are given in Table I.

The equations developed from these data to estimate mouth widths of largemouth bass are as follows:

Total Length

Less Than 100 mm.	$M = 1.88 + 0.0775 L,$	$s = 0.69$
100 - 199 mm.	$M = -1.88 + 0.1113 L,$	$s = 1.94$
200 - 299 mm.	$M = -5.16 + 0.1289 L,$	$s = 2.92$
300 - 399 mm.	$M = -7.96 + 0.1371 L,$	$s = 4.37$
400 - 499 mm.	$M = -29.41 + 0.1961 L,$	$s = 4.32$
500 - 595 mm.	$M = -56.36 + 0.2477 L,$	$s = 5.95$

Where M is mouth width in millimeters, L is total length in millimeters, and s is the standard deviation from regression.

The mean maximum depths of body and weights for each inch-group of various forage fishes are given for bluegill (Table II); redear, *Lepomis microlophus* (Table III); geern sunfish, *Lepomis cyanellus* (Table IV); golden shiner, *Notemigonus crysoleucas* (Table V); goldfish, *Carassius auratus* (Table VI); and gizzard shad, *Dorosoma cepedianum* (Table VII).

TABLE I

MEAN MAXIMUM DEPTHS OF BODY, MOUTH WIDTHS, AND WEIGHTS FOR LARGEMOUTH BASS IN GIVEN INCH-GROUPS

Total Length Inch- Group	Mean Mm.	Mean Maximum Depth of Body		Mean Mouth Width		Mean Weight	
		Inches	Mm.	Inches	Mm.	Pounds	Grams
1	34.5	0.27	7.0	0.17	4.4	0.0033	1.5
2	51.0	0.40	10.2	0.22	5.7	0.0051	2.3
3	72.9	0.57	14.5	0.29	7.6	0.0115	5.2
4	99.7	0.76	19.4	0.37	9.6	0.0236	10.7
5	127.4	1.03	26.2	0.48	12.4	0.0493	22.4
6	151.4	1.22	31.1	0.58	14.8	0.1029	46.7
7	179.2	1.49	38.0	0.70	17.9	0.1482	67.3
8	202.5	1.72	43.9	0.82	21.0	0.2152	97.7
9	229.1	1.99	50.7	0.97	24.7	0.3282	149.0
10	253.4	2.17	55.3	1.02	26.1	0.4533	205.8
11	279.0	2.51	64.0	1.20	30.7	0.6035	274.0
12	302.3	2.81	71.5	1.35	34.4	0.8627	391.7
13	334.9	3.11	79.0	1.52	38.8	1.140	517.6
14	356.2	3.32	84.5	1.60	40.7	1.380	626.6
15	379.6	3.60	91.6	1.72	43.7	1.759	798.6
16	406.3	4.04	102.7	1.97	50.2	2.242	1,017.9
17	429.7	4.28	108.9	2.16	54.9	2.678	1,216.0
18	456.7	4.68	118.9	2.34	59.6	3.459	1,570.5
19	487.1	5.12	130.2	2.64	67.3	4.284	1,945.1
20	507.0	5.15	130.9	2.72	69.2	4.606	2,091.1
21	534.8	5.79	147.2	2.99	76.0	5.793	2,629.8
22	561.1	5.87	149.2	3.28	83.4	6.395	2,903.4
23	583.0	5.98	152.0	3.44	87.4	7.164	3,252.6

TABLE II
MEAN MAXIMUM DEPTHS OF BODY AND WEIGHTS OF BLUEGILL
IN GIVEN INCH-GROUPS

Inch-Group	Total Length		Mean Maximum Depth of Body		Mean Weight	
	Mean	Mm.	Inches	Mm.	Pounds	Grams
1	31.8		0.28	7.1	0.0009	0.41
2	49.1		0.55	14.1	0.0043	1.96
3	74.6		0.93	23.7	0.0152	6.91
4	101.8		1.35	34.4	0.0402	18.2
5	126.6		1.75	44.6	0.078	35.2
6	152.3		2.14	54.6	0.118	63.3
7	176.2		2.56	65.4	0.235	106.5
8	201.4		3.06	78.1	0.368	166.9

TABLE III
MEAN MAXIMUM DEPTHS OF BODY AND WEIGHTS OF REDEAR SUNFISH
IN GIVEN INCH-GROUPS

Inch-Group	Total Length		Mean Maximum Depth of Body		Mean Weight	
	Mean	Mm.	Inches	Mm.	Pounds	Grams
2	56.7		0.69	17.7	0.0060	2.7
3	77.5		1.04	26.4	0.0208	9.4
4	102.3		1.32	33.7	0.043	19.3
5	125.2		1.67	42.8	0.077	34.9
6	144.3		1.88	48.0	0.121	55.0
7	180.2		2.28	58.2	0.242	109.8
8	206.0		2.76	70.4	0.385	174.5

TABLE IV
MEAN MAXIMUM DEPTHS OF BODY AND WEIGHTS OF GREEN SUNFISH
IN GIVEN INCH-GROUPS

Inch-Group	Total Length		Mean Maximum Depth of Body		Mean Weight	
	Mean	Mm.	Inches	Mm.	Pounds	Grams
1	31.8		0.27	8.8	0.0016	0.72
2	52.5		0.60	15.3	0.0054	2.45
3	73.7		0.89	22.6	0.0161	7.29
4	99.3		1.25	31.9	0.045	20.3
5	127.6		1.71	43.6	0.104	47.3
6	149.0		2.04	51.9	0.166	75.3
7	181.0		2.59	66.0	0.258	117.0

TABLE V
MEAN MAXIMUM DEPTHS OF BODY AND WEIGHTS OF GOLDEN SHINER
IN GIVEN INCH-GROUPS

Inch-Group	Total Length		Mean Maximum Depth of Body		Mean Weight	
	Mean	Mm.	Inches	Mm.	Pounds	Grams
2	55.9		0.47	11.9	0.0051	2.3
3	76.3		0.55	14.0	0.0088	4.0
4	92.8		0.80	20.3	0.0172	8.8
5	126.8		1.15	29.4	0.0519	23.5
6	151.5		1.39	35.4	0.076	34.3
7	176.7		1.69	43.1	0.133	60.2
8	200.5		1.96	50.0	0.172	78.0

TABLE VI
MEAN MAXIMUM DEPTHS OF BODY AND WEIGHTS OF GOLDFISH
IN GIVEN INCH-GROUPS

Inch-Group	Total Length		Mean Maximum Depth of Body		Mean Weight	
	Inch	Mm.	Inches	Mm.	Pounds	Grams
1		35.0	0.31	8.0	0.0013	0.6
2		55.4	0.50	12.7	0.0055	2.5
3		75.4	0.98	25.0	0.0249	11.3
4		101.0	1.11	28.3	0.041	18.4
5		119.4	1.28	32.6	0.051	22.9

TABLE VII
MEAN MAXIMUM DEPTHS OF BODY AND WEIGHTS OF GIZZARD SHAD
IN GIVEN INCH-GROUPS

Inch-Group	Total Length		Mean Maximum Depth of Body		Mean Weight	
	Inch	Mm.	Inches	Mm.	Pounds	Grams
2		59.7	0.52	13.2	0.0044	2.0
3		73.4	0.70	17.8	0.0090	4.1
4		105.1	1.09	27.6	0.0270	12.3
5		127.1	1.31	33.3	0.0421	19.1
6		146.6	1.57	39.8	0.0651	29.6
7		175.0	1.90	48.3	0.128	57.9
8		207.4	2.24	57.0	0.204	92.6
9		226.4	2.46	62.5	0.250	113.9
10		257.3	2.96	75.8	0.408	185.2
11		279.3	3.17	80.4	0.499	226.7
12		304.0	3.53	89.6	0.685	310.8
13		330.0	3.93	100.0	0.969	440.0

The equations for forage species relating their total lengths to their maximum depths of body were as follows:

Bluegills	$L = 19.10 + 2.3925 D,$	$s = 11.75$
Redear	$L = 6.06 + 2.8917 D,$	$s = 7.38$
Green Sunfish	$L = 11.70 + 2.6859 D,$	$s = 4.96$
Golden Shiner	$L = 18.30 + 3.8876 D,$	$s = 7.19$
Goldfish	$L = 22.09 + 2.5992 D,$	$s = 10.29$
Gizzard Shad	$L = 15.63 + 3.4050 D,$	$s = 10.18$

Where L is total length in millimeters, D is maximum depth of body in millimeters, and s is the standard deviation of regression.

While largemouth bass are not usually classed as a forage species, large bass do eat smaller bass. The equations relating total length to maximum depth of body for bass are:

Total Length		
Less Than 100 mm.	$L = -0.04 + 4.9919 D,$	$s = 3.23$
100 - 199 mm.	$L = 31.50 + 3.8790 D,$	$s = 7.34$
200 - 299 mm.	$L = 95.30 + 2.9056 D,$	$s = 11.34$
300 - 399 mm.	$L = 175.20 + 2.1186 D,$	$s = 18.38$
400 - 499 mm.	$L = 238.10 + 1.7434 D,$	$s = 16.61$
500 - 595 mm.	$L = 407.50 + 0.9446 D,$	$s = 22.84$

Where L is total length in millimeters, D is maximum depth of body in millimeters, and s is standard deviation of regression.

The estimated total lengths of each of these species that can be swallowed by bass of a given total length are given in Table VIII. Thus, a fisheries biologist is provided with another tool that may be used experimentally in correcting overcrowded fish populations. That is, he can determine by seining the species and sizes of fish that are overcrowding the pond, and from Table VIII estimate the minimum size of bass that when added should correct this condition.

TABLE VIII

ESTIMATED SIZES OF FORAGE FISHES LARGEMOUTH BASS CAN SWALLOW

Bass		Total Length of Forage Fish						
Total Length Inches	Mouth Width Mm.	Bass Inches	Bluegill Inches	Redear Inches	Green Sunfish Inches	Golden Shiner Inches	Goldfish Inches	Gizzard Shad Inches
1.5	4.8	0.94	...	...	...	...	...	...
2.5	6.8	1.34	1.40	1.02	1.40	1.77	1.57	1.53
3.5	8.8	1.73	1.58	1.24	1.60	2.06	1.77	1.79
4.5	10.8	2.13	1.77	1.47	1.81	2.37	1.98	2.06
5.5	13.7	2.68	2.04	1.80	2.12	2.82	2.27	2.45
6.5	16.5	3.23	2.30	2.11	2.42	3.24	2.56	2.82
7.5	19.3	3.78	2.57	2.43	2.71	3.67	2.84	3.19
8.5	22.7	4.72	2.89	2.82	3.07	4.19	3.19	3.66
9.5	25.9	5.19	3.19	3.19	3.41	4.69	3.52	4.09
10.5	29.3	5.71	3.51	3.57	3.77	5.20	3.86	4.54
11.5	32.5	6.22	3.81	3.94	4.11	5.69	4.19	4.97
12.5	35.5	6.65	4.09	4.27	4.43	6.15	4.50	5.37
13.5	39.1	7.20	4.43	4.69	4.80	6.70	4.87	5.85
14.5	42.5	7.72	4.76	5.07	5.16	7.22	5.22	6.31
15.5	46.1	9.02	5.09	5.48	5.54	7.77	5.58	6.79
16.5	52.8	9.80	5.72	6.25	6.26	8.80	6.27	7.69
17.5	57.7	10.35	6.19	6.81	6.78	9.55	6.78	8.35
18.5	62.8	10.94	6.67	7.39	7.31	10.33	7.30	9.04
19.5	67.7	11.50	7.30	7.95	7.83	11.08	7.80	9.69
20.5	72.7	11.73	7.60	...	8.36	11.85	...	10.36
21.5	78.9	13.46	8.18	...	9.02	...	...	11.19
22.5	85.1	13.98	8.77	...	...	...	...	12.02
23.5	91.5	14.53	...	...	...	...	...	12.89

There are further applications of these relationships as they apply to the study of population dynamics. This information along with detailed information concerning how the equations used in this paper were derived will be presented in later publications.

SUMMARY

From measurements of 1,699 individuals equations were developed to estimate the mouth width from total length of largemouth bass (*Micropterus salmoides*). It was found that the most accurate estimates were linear equations that covered total length in 100-millimeter intervals. In addition, the mean mouth widths, maximum depths of body, and weights for each inch-group of total length were tabulated.

Equations were also developed for estimating the total length from the maximum depth of body of the following species: largemouth bass, bluegill (*Lepomis macrochirus*), redbreast (*Lepomis microlophus*), green sunfish (*Lepomis cyanellus*), golden shiner (*Notemigonus crysoleucas*), goldfish (*Carassius auratus*), and gizzard shad (*Dorosoma cepedianum*). The mean maximum depths of body and weights for each inch-group of total length for the latter six species were also tabulated.

It was shown in aquarium tests that bass will swallow readily forage fishes whose maximum depths of body are equal to the mouth widths of the bass. From the aforementioned equations, the estimated sizes of the various species of fish a bass of a given total length can swallow were calculated. These estimates are tabulated for each total length inch-group of bass.

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