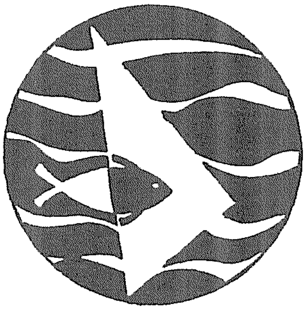
FAO Fisheries Synopsis No. 115

FIR/S115
SAST - Largemouth Bass - 1,70(10)014,02



SYNOPSIS OF BIOLOGICAL DATA ON THE LARGEMOUTH BASS

Micopterus salmoides (Lacepède) 1802

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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(Distribution restricted)

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Micropterus salmoides (Lacepède) 1802

Prepared by

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PREPARATION OF THIS SYNOPSIS

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This work is dedicated to all the fishery scientists who have contributed the thousands of man years of research upon which this manuscript is based.

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Synopsis. Biological data. Freshwater fish. Taxonomy. Identification keys. Vernacular names. Morphology (organisms). Geographical distribution. Hybridization. Sexual reproduction. Life cycle. Development (biological). Autecology. Population characteristics. Inland fisheries. Fishing gear. Fishing grounds. Fishery regulations. Habitat improvement. Stocking (organisms). Fish culture. Freshwater aquaculture. Micropterus salmoides.

CONTENTS

1 IDENTITY

1.1 *Nomenclature*

1.11 Valid name

Current name: *Micropterus salmoides* (Lacepède)
Original combination: *Labrus salmoides*
(Lacepède): Lacepède, 1802, Histoire
naturelle des poissons. Vol. 4. Plassan,
Paris, 716-8, Pl. 5, Fig. 2.

1.12 Objective synonymy

There are no junior objective synonyms of the name.

1.13 Etymology

Micropterus = small or short fin, a mutilated second dorsal fin led Lacepède to believe there was a small fin between it and the caudal fin; *salmoides* = trout-like.

1.2 *Taxonomy*

1.21 Affinities (after Berg, 1947)

- Suprageneric

Phylum Vertebrata
 Subphylum Craniata
  Superclass Gnathostomata
   Series Pisces
    Class Teleostomi
     Subclass Actinopterygii
      Order Perciformes
       Suborder Percoidei
        Family Centrarchidae

- Generic

Micropterus Lacepède, 1802, Histoire naturelle des poissons. Vol. 4. Plassan, Paris. Type *M. dolomieui*.

- Subjective generic synonyms

Micropterus Lacepède, 1802 (*M. dolomieui*. Lacepède)
Calliurus Rafinesque, 1820 (*C. punctulatus* Rafinesque)
Aplites Rafinesque, 1820 (*Lepomis pallidus* Rafinesque)
Nemocampsis Rafinesque, 1820 (*Lepomis flexuolaris* Rafinesque)
Dioplites Rafinesque, 1820 (*Lepomis salmonea* Rafinesque)
Aplesion Rafinesque, 1820 (*Etheostoma calliura* Rafinesque)
Huro Cuvier and Valenciennes, 1828 (*H. nigricans* Cuvier and Valenciennes)
Grystes Cuvier and Valenciennes, 1829 (*Labrus salmoides* Rafinesque)

The generic concept adopted here is that of Hubbs and Bailey, 1940, a revision of the black basses (*Micropterus* and *Huro*), with descriptions of four new forms. Misc. Publ., Univ. Mich., Mus. Zool. 48: 7-51.

Common characteristics include the following: spinous and soft-rayed portions of the dorsal fin united into one; villiform teeth on palatines and ectopterygoids, but none on entopterygoids, present or absent on glossohyal; rigid bifid opercle with lower lobe much longer than upper, especially in adult; large mouth, maxillary extending at least to below centre of pupil; well developed supramaxillary; entire preopercle; 31-33 vertebrae: 14-15 precaudal vertebrae (rarely 13-16); 55-81 scales along lateral line; 9-20 scale rows on cheek; 9-11 dorsal spines; 3 anal spines (very rarely 2 or 4); 6 branchiostegals (very rarely 7); anal base less than half dorsal base; moderately compressed, elongated body; branched pyloric caeca.

- Specific

Labrus salmoides (Lacepède, 1802). (Type locality: rivers near Charleston, South Carolina, U.S.A.).

Lacepède described it solely on the basis of the manuscript communication and drawings furnished to him by M. Bosc.

Probably the oldest preserved specimen of the largemouth bass is in the Museum d'Histoire Naturelle in Paris. This specimen from the state of Florida was described by LeSueur in 1822 and named *Cichla floridana*.

Diagnosis characters modified from Pfleiger (1968) and Hubbs and Bailey (1940) are as follows: mouth large, upper jaw extending far behind back of eye in fish more than 15 cm in length; midside with a dark horizontal strip; tail fin of young two-coloured rather than three-coloured; hind part of fin darker than base; pyloric caeca mostly befid near base; spinous dorsal nearly separate; outline of spinous dorsal strongly convex, length of shortest dorsal spine near notch less than half length of longest spine (Fig. 1).

- Some subjective synonymy

Labrus salmoides Lacepède, 1802; placed in synonymy by Jordan, 1880, and Hubbs and Bailey, 1940. Reasons discussed.

Cichla floridana LeSueur, 1822; *Huro nigricans* Cuvier, in Cuvier and Valenciennes, 1828; *Grystes nobilis* Agassiz, 1854; *Gruystes nuecensis* Baird and Girard, 1854; *Grystes megostoma* Garlick, 1857; placed in synonymy in Hubbs and Bailey, 1940. Reasons discussed.

Aplites salmoides ?; placed in synonymy by Hubbs, 1926. Reasons discussed.

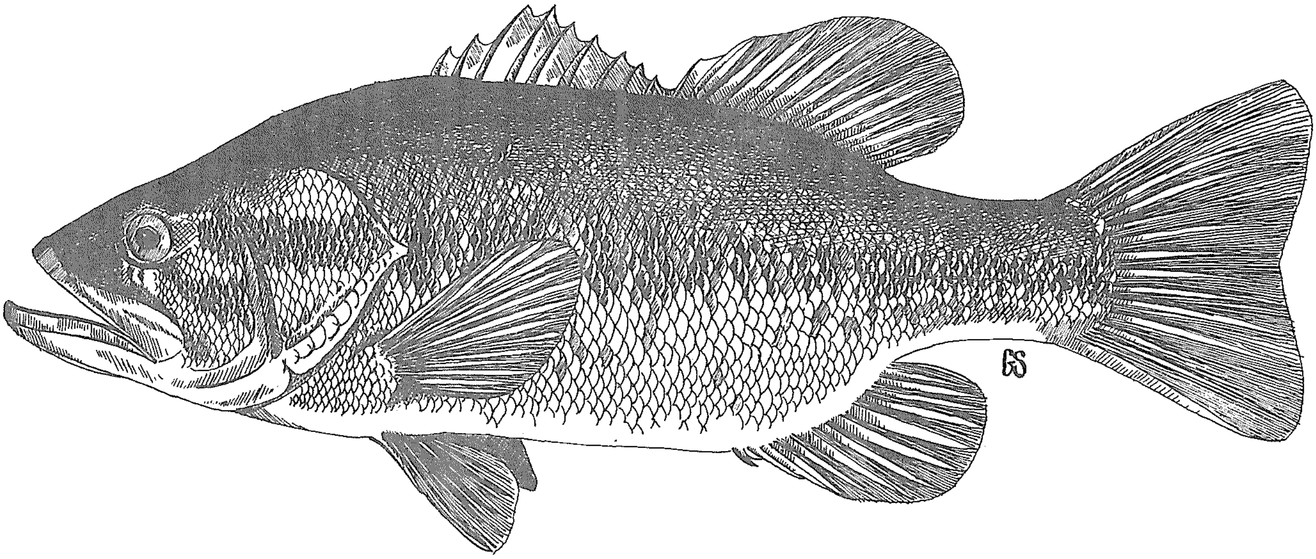
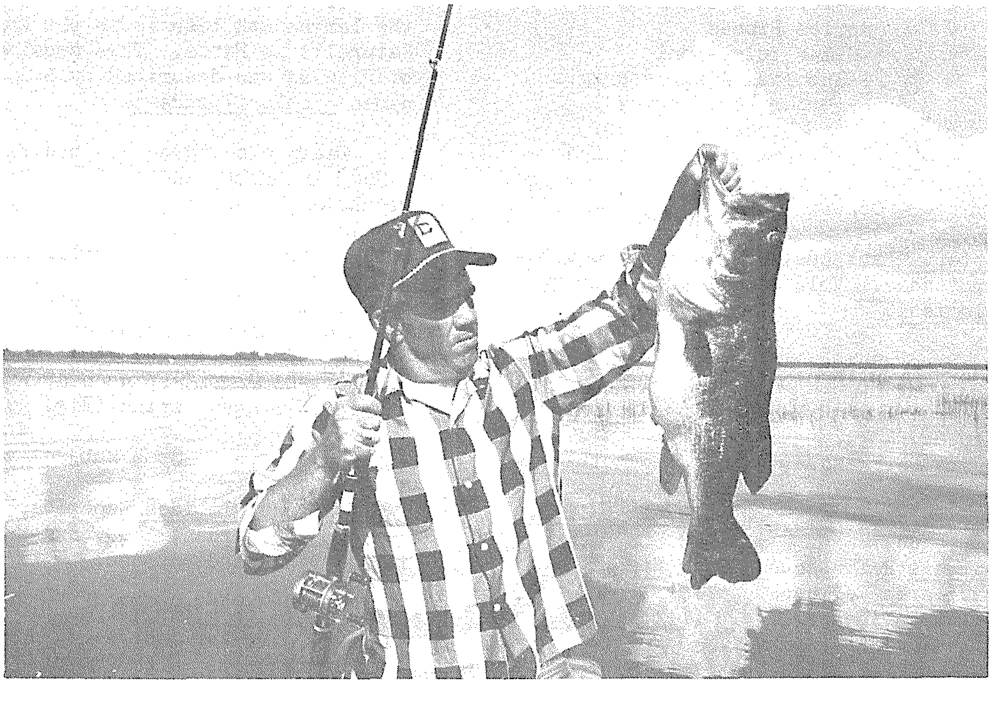


Fig. 1 a) Micropterus salmoides



b) A 5 kg largemouth bass caught in a shallow Florida lake
(photograph courtesy of Steve Wunderly)

Huro salmoides Lacepède, 1802; placed in synonymy by Hubbs and Lagler, 1941. Reasons discussed.

Pikea sericea Fowler, 1938; placed in synonymy by Robins and Böhlke, 1960. Reasons discussed.

Artificial key to the species of *Micropterus* (after Robbins and McCrimmon, 1974).

1a. Dorsal fin deeply notched, shortest posterior spine less than half length of longest spine; anal and soft-dorsal fins scaleless; scales on cheeks large, in 9-12 rows . . . . Largemouth bass - *Micropterus salmoides* (Lacepède)

1b. Dorsal fin slightly notched, shortest posterior spine more than half the length of longest spine; anal and soft-dorsal fins with small scales between rays near fin-bases; scales on cheeks minute, in more than 12 rows 2

2a. Dorsal soft-rays usually 13-15 . . . . Smallmouth bass - *Micropterus dolomieui* (Lacepède)

2b. Dorsal soft-rays usually 12 3

3a. In young, well developed vertical bars on either side of body with a poorly developed lateral band; adults more boldly striped longitudinally, from the ventrolateral region up over the sides; found only in the rivers and reservoirs of central Texas . . . Guadalupe bass - *Micropterus treculi* (Vaillant and Bocourt)

3b. Young with poorly developed or faded vertical dark bars, and modified into light-centred rhombs on the caudal penduncle; adults, with little distinct colour pattern on sides; lateral band missing or faint in both adults and young; in the streams and rivers of the southeastern Appalachians . . . . *Micropterus coosae* Hubbs and Bailey

3c. Sides with a series of dark blotches, often fused to form a dark lateral band and with a basicaudal spot and patches of lighter blotches above the lateral line 4

4a. Basicaudal spot small and not prominent, ventrolateral region light in colour with no blotching . . . . Spotted bass - *Micropterus punctulatus* (Rafinesque)

4b. Basicaudal spot large and prominent; ventrolateral region, cheeks and breast turquoise blue in life with some blotching on the cheeks, on the sides and below the lateral line; found only in the region in and near the Suwannee River in northern Florida . . . Suwanee bass - *Micropterus notius* Bailey and Hubbs.

1.22 Taxonomic status

This is a well defined species by morphological and breeding data. The species is polytypic.

1.23 Subspecies

First described by Hubbs and Bailey (1949).

M. s. floridanus (LeSueur). Originally found in fresh waters of peninsular Florida.

M. s. salmoides (Lacepède). Originally found in fresh waters of the lower Great Lakes drainage, middle Mississippi River system south to Gulf Coast, Florida, and north to the coastal watersheds in Georgia, South Carolina, North Carolina and Virginia.

Various methods have been used to separate these two subspecies (Table I). In areas of integradation hybrids have intermediate characteristics. In intensively fished warm waters, such as in California where both subspecies have been stocked, the trend in meristic characteristics after a number of generations is toward the southern subspecies (Bottroff, 1967) (see 2.42).

1.24 Standard common names, vernacular names

It is impossible to list common and vernacular names in use in all countries.

Country	Names
Australia	Black bass, freshwater perch, gippoland perch
Austria	Forellembarsch, perche truitée
Canada	Largemouth bass, many of those names that are used in the U.S.A., achigan à grande bouche
Czechoslovakia	Okounek pstrukový, ostračka
France	Black-bass à grande bouche, perche-truite
Germany	Forellembarsch, grossmauliger forellenbarsch
Hungary	Fekete sügér, pisztrangsügér
Italy	Persico trota, boccalone
Mexico	Tucha de patzcuaro, robalo fino, corvina negra, black bass, huro y otros
Netherlands	Florellenbaars
Poland	Weilkogebowy, bas weilkogebowy
Portugal	Black-bass, perca americana, perca-trucha, boca grande, robalo-negro, achigã

TABLE I

Methods used in separating the southern subspecies (M. s. floridanus) from the northern subspecies (M. s. salmoides)[a]

	floridanus	salmoides	Reference
Scale counts[b]	137.9(129-145)[c]	125.0(116-132)	Bailey and Hubbs (1949)
(as above)	136.8(135-141)	125.9(124-130)	Buchanan (1968)
Number of pyloric caeca	----	24.0(20-33)	Applegate (1966)
(as above)	36.8(26-53)	23.2(13-35)	Buchanan (1968)
(as above)	39.0(30-47)	22.7(13-29)	Addison and Spencer (1972)
(as above)	F_1 progeny 28.0(17-41)		(as above)
Number of abdominal vertebrae	14	15	Bryan (1969)

[a] For isozyme methods see 1.33
[b] Average of the sum of the 5 meristic scale counts given in Table II
[c] Range in parentheses

Country	Names
United States	Largemouth bass, black bass, green bass, Oswego bass, slough bass, lake bass, bigmouth, bucket mouth, southern largemouth, northern largemouth, Florida bass, largemouth black bass, straw bass, bayou bass, moss bass, grass bass, marsh bass, trout, green trout, welchman, chub (primarily from Jordan and Evermann, 1969 ed.)

1.3 Morphology

1.31 External morphology
(for description of spawn, larvae and adolescents, see 3.17, 3.22, 3.23; also see sexuality, 3.11)

In addition to those morphological characteristics listed in Table I and 1.23, others are listed in Tables II and III. The southern subspecies tends to have more scales than the northern subspecies.

Unlike salmoides and floridanus in the rest of its range, largemouth bass in the southwestern extremity of its range in North America have a high incidence of glossohyal teeth (Bailey and Hubbs, 1949).

Ratios for total length to standard length decline from 1.236 at 50-69 mm to 1.174 at over 450 mm (Stroud, 1948). In general, length-weight regression slopes are above 3.0 but there are many exceptions in the literature. The relationship between mouth width and total length are given by Lawrence (1958) as follows:

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 $M = -29.41 + 0.1961\ L$, $s = 4.32$
500-599 mm $M = -56.36 + 0.2477\ L$, $s = 5.95$

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

1.32 Cytomorphology

Robert (1964) found 46 diploid chromosomes in testis cell culture, but Baker (1956) reported 48 from non-cultured testicular material.

1.33 Protein specificity

Fish with greater amounts of low mobility blood protein are thought to be in general more pollution-tolerant. The serum of 9 largemouth bass averaged 7.8 g of mobil protein per 100 g of sample protein (Bouck and Ball, 1967). In experimental fish subjected to diurnal oxygen pulses, there occurred an increase in low mobility proteins in the blood (Bouck and Ball, 1965).

A combination of hybridization, immunochemical, and electrophoretic analyses revealed that the largemouth bass possess three homopolymeric lactate dehydrogenase (LDH) isozymes, A_4, B_4 and E_4. The E_4 retinal-specific homotetramer isozyme is the product of a distant nuclear gene (E locus) on an autosomal chromosome. This E gene appears to segregate independently of the gene for supernatant malate dehydrogenase (MDH) (Whitt et al., 1971). The interspecific F_1 hybrid between the largemouth and smallmouth bass (M. dolomieui) exhibits 5 eye-specific isozymes formed by the random association of two parental types of E subunits (Whitt, Miller and Shaklee, 1973).

TABLE II

Range of scale counts in North American populations of largemouth bass

Subspecies	Location	Bodies of water sampled	LLS	ALLS	BLLS	CPS	CS[a]	Reference
salmoides	Arkansas	8	58–68	7–9	13–18	24–32	8–13	Buchanan (1967)[b]
	California	21	56–70	6–9	13–19	23–30		Bottroff (1968)
	Ill., Mich.	2	59–69	7–9	14–17	24–30	9–13	Bailey and Hubbs (1949)
	Alabama	2	60–68	7–9	14–17	24–28	9–12	(as above)
	Florida	2	58–68	7–8	14–16	25–27	9–11	(as above)
	S. Carolina	1	59–69	7–9	14–17	24–29	9–12	(as above)
	Indiana	2	61–71	7–9	13–16	26–28	9–12	Frey (1951)
	Ohio	1	57–68	7–10	21–17			Hart (1952)
	Tennessee	1	58–64					(as above)
floridanus	California	8	62–79	6–10	14–20	24–32		Bottroff (1968)
	Florida	4	65–77	7–11	14–23	24–34	10–14	Buchanan (1967)[b]
	Florida		65–75	7–10	16–18	27–32	10–14	Bailey and Hubbs (1949)
	Florida							
	normal fish	1	57–77	8–11	14–17			Hart (1952)
	stunted fish	1	64–70	7–10	14–16			(as above)
Intergrades	California	6	58–78	6–10	13–19	24–31		Bottroff (1967)
	Florida	1	57–68	6–8	12–16	25–30	9–12	Buchanan (1967)[b]

[a] LLS = lateral line scales; ALLS = scales above lateral line; BLLS = scales below lateral line; CPS = scales around caudal peduncle; CS = cheek scales

[b] And personal communication with Buchanan

TABLE III

Range of vertebrae, spine and ray counts in North American populations of largemouth bass

Subspecies	Location	V	DS	DR	AS	AR	PR[a]	Reference
salmoides	Ohio	30–32	–	12–14				Hart (1952)
	Ohio River	30–33						Bryan (1969)
	–	–	–	11–14	3	10–12	13–17	Hubbs and Bailey (1940)
	Indiana	–	8–10	12–14	2–3	11–12	14–15	Frey (1951)
floridanus	Florida	–	9–11	12–14	3	10–12	14–16	Bailey and Hubbs (1949)
	Ohio	30–32						Hart (1952)
	Florida, Calif.	32						Bryan (1969)

[a] V = vertebrae; DS = dorsal spines; DR = dorsal rays; AS = anal spines; AR = anal rays; PR = pectoral rays

Supernatant MDH isozymes (as visualized by starch gel electrophoresis) consist of two homodimers AA and BB, and a heterodimer AB, which are encoded by two distinct gene loci. When an interspecific F_1 hybrid is formed between the largemouth and smallmouth bass a unique MDH heterodimer isozyme composed of one subunit of each parental type is generated. The inheritance of alleles at the MDH-B locus is consistent with a single Mendelian autosomal locus (Wheat et al., 1971).

Isocitrate dehydrogenase (IDH) activity is highest in the liver. It is encoded at a single locus and is not sexed linked. The IDH phenotype is exhibited as a single band on electrophoretic analysis. The F_1 hybrid tissues possess three dimeric isozyme bands, the fast smallmouth bass isozyme, the slow largemouth bass isozyme, and the intermediate hybrid band, presumably a heteropolymer composed of parental subunits. When male F_1 largemouth bass x smallmouth bass are back crossed with a female LMB, there appears to be rapid elimination of their heterozygous progeny in pond populations. When these offspring are placed in plastic pools, where cannibalism is the main source of mortality, the heterozygotes are no longer subject to adverse selection. The progeny of this cross exhibited a strong correlation between increased heterozygosity and increased rate of growth. In the reciprocal backcross there were no significant differences between heterozygous and homozygous individuals as far as survival or growth rates are concerned in either the pond or plastic pool environment. These differences between the reciprocal crosses may be related to maternal cytoplasmic effects on development (Wheat, Childers and Whitt, 1974).

The Florida subspecies, northern subspecies and their integrades can be differentiated by MDH and tetrazolium oxidase isozymic differences. The northern subspecies is polymorphic for the malate dehydrogenase-B isozyme. Individuals are classified phenotypically as S/S, S/F, or F/F with S representing the more slowly migrating allelic isozyme and F representing the more rapidly migrating band. All individuals of the Florida subspecies analysed have been monomorphic for the fast MDH-B band. The Florida subspecies is polymorphic for tetrozolium oxidase and can be classified phenotypically as F/F, F/S, or S/S. All northern largemouth analysed have been monomorphic for fast tetrazolium oxidase isozyme. F_1 hybrids exhibited gene frequencies for both enzyme loci which were intermediate between those of their parental subspecies populations (Childers and Whitt, 1974).

Agglutination of erythrocytes from the northern and southern subspecies to rabbit antiserum indicated immunological differences between the fish examined, but few were characteristic of one or the other subspecies (Miller, 1965).

Scale homografts were rejected within 30 days at 15-18°C (Reid and Triplett, 1968).

1.34 Ageing

Ageing of bass by counting the number of annuli on the scales is an approximation at best (Thompson, 1965; LaFaunce, 1965; Eschmeyer and Jones, 1941). The scale method proved 80% accurate in ageing 0-2 year old Alabama bass (Prather, 1967), and 94% accurate in 0-4 year old Texas bass (Prentice and Whiteside, 1974). To obtain this degree of accuracy required multiple readings. However, in an Iowa study the second reading by the same individual agreed on only 64% of 239 bass (Thompson, 1965). In the U.S.A. annulus formation has been reported from April up to and including August (Benson, 1959; Zweiacker, 1972; Cross, 1951; Manning, 1951; Morgan, 1958; Stroud, 1948). In general it occurs later in the northern portion of the bass's range, in larger fish, and in slower-growing fish.

1.35 Osteology

Largemouth bass have acellular bone. Osteocytes are completely absent from the matrix and apparently are not present during any ontological stage. Except for the long bones of the branchial arch system which show epiphyseal growth, bass bones grow only by apposition. Four basic types of bone formation are recognized. Achondral ossification is characteristic of most cranium bones, parachondra ossification is primarily found in the neurocranium, perichondral ossification is characteristic in most of the cartilage bone, and endochondral ossification is found in the vertebrae (Al-Saadi, 1962).

1.36 Blood

Some of the known parameters for largemouth bass blood other than those listed in Table IV are as follows: oxygen capacity 42-86 cc/l, lactic acid 28-270 mg% (Denyes and Joseph, 1956); Na^+ 128-198 meg/l, K^+ 0.6-8.2 meg/l, Cl^- 95-127 meg/l, total plasma cholesterol 90-680 mg/100 ml (Hunn and Robinson, 1966); length x width of red blood cell 10.0-6.8 µ, length x width of red blood cell nucleus 5.8-3.1 µ (Coburn, 1970; Smith et al., 1952).

Chew (1969) found that the range of serum calcium in male and female bass was 10-24 (120 male fish) versus 11-32 (88 female fish) mg/100 ml. In both males and females the calcium value increased during the spawning season, but the increase was much greater in the females.

2 DISTRIBUTION

2.1 Total area

See 1.23 for original distribution. Due to introductions by man the largemouth bass occurs in

TABLE IV

Hematological characteristics of largemouth bass

Red blood cells (no. x 10^6/ml)	Hemoglobin (g/100 ml)	Hematocrit (%)		Serum protein (mg/ml)		Reference
		male	female	male	female	
1.47-1.74	5.3-7.0	21-33 both sexes		-	-	Coburn (1970)
1.72-1.48	5.5-12.3	-		-	-	Denyes and Joseph (1956)
-	9.8-13.2	-		-	-	Hiestand (1951)
-	5.8-8.5	-		-	-	Hunn and Robinson (1966)
-	-	35-62	26-49	-	-	Steucke and Atherton (1965)
-	-	24-27 sex ?		-	-	Schoettger and Julin (1966)
-	-	44.4[a]	45.4[a]	7.8[a]	4.2[a]	McCraren (1974)
-	-	41.4[b]	42.4[b]	8.6[b]	9.4[b]	(as above)
-	-	31	42	-	-	Smitherman (1965)

[a] Bass fed Oregon Moist Pellets (see 7.52)
[b] Bass fed natural food

fresh waters of many countries and provinces (Fig. 2). The following distribution, date of initial stocking and original source is primarily from Robbins and McCrimmon (1974) (Table V).

The largemouth bass has been introduced (date in parentheses) unsuccessfully or has disappeared from the following countries: Canal Zone (1917); Nicaragua (1959-60); Venezuela (1935?); Malawi (1937); Mozambique (1947); Tunisia (1966); Zaire (1945); Zambia (1944?); Mauritius (1949); Cyprus (1971); Denmark (1901); Finland (1893); The Netherlands (1884); Norway (1887); Sweden (1885-90); Yugoslavia (1914); Poland (1883); Guam (1963).

2.2 Differential distribution

2.21 Spawn, larvae and juveniles (see 2.22, 3.16, 3.22)

2.22 Adults

The adult male largemouth bass guards the nest and fry. In general the juveniles tend to stay along the shoreline in shallower, more protected areas than do the adults.

2.3 Determinants of distribution changes (see 3.32 (Table VII) for O_2, pH, temperature, salinity and turbidity tolerances)

Successful introductions into constant temperature areas such as Central America and Africa plus reproduction in constant temperature springs (see 3.16) in Florida have refuted the idea that a clear annual cycle of temperature is required for spawning. Failure of introductions can be attributed to cold temperature (but not to hot), fast current or predation by native species.

2.4 Hybridization

2.41 Hybrids; frequency of hybridization; species with which hybridization occurs; methods of hybridization

Hybridization readily occurs between the two subspecies. In their native range no unequivocal natural interspecific hybrid has been found. Childers (1975) reports that 30-50 largemouth bass x bluegill hybrids were caught in the Puu Kaele reservoir on the island of Kauai, Hawaii. Hybrids have not been produced by isolation methods. However, by striping and in some cases hormone injections both interspecific and intergeneric hybrids have been produced (Table VI).

2.42 Influence of natural hybridization in ecology and morphology

After ten years of natural hybridization between the two subspecies in the heavily fished warm waters of some Californian lakes, the meristic characteristics of the bass populations have shifted toward those of the southern subspecies (Bottroff, 1967).

Meristic characteristics of interspecific F_1 hybrids were found to be intermediate in 11 out of 17 characters (West and Hester, 1966).

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Largemouth bass are heterosexual. Functional sex reversal or functional hermaphroditism does not

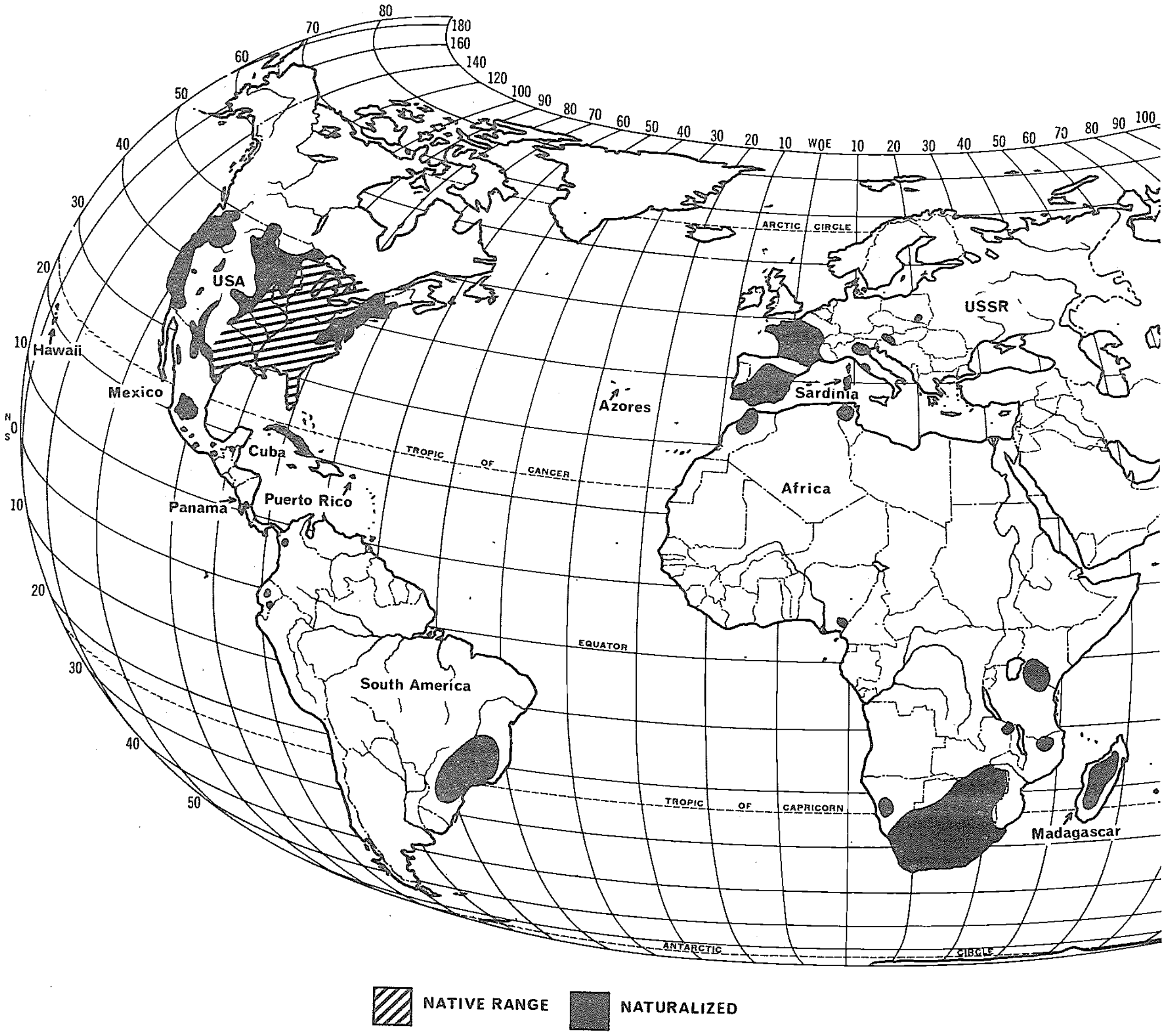


Fig. 2 World distribution of the largemouth bass except for Japan and the Phillipines (after Robbins and McCrimmon, 1974)

TABLE V

Present day distribution of the largemouth bass (primarily after Robbins and McCrimmon, 1974)

Country	Year of first introduction	Original source	Regular stocking programme in at least some waters	Status		Regulations
				sport fish	commercial or food fish	
U.S.A.	Native	–	Yes	Yes	No	See 6.11
Canada	Native introduced	U.S.A.	Yes	Yes	No	Length, season and numerical limit in certain waters
Mexico	Native introduced (1898)	U.S.A.	Yes	Yes	Yes	20 cm minimum, no season, limit 5 per day
Brazil	1926	–	Yes	Yes	–	–
Columbia	1956	U.S.A.	No	–	–	–
Costa Rica	–	U.S.A.?	No	Yes	No	None
Cuba	1915	U.S.A.	Yes	Yes	Yes	–
Ecuador	1960	U.S.A.	–	–	–	None
Guatemala	–	U.S.A.	No	Yes	Yes	–
Honduras	1955	U.S.A.	No	Yes	–	–
Panama	1935	U.S.A.	No	–	–	–
Puerto Rico	1915	U.S.A.	Yes	Yes	Yes	None
Botswana	1938	Swaziland	–	–	–	–
Cameroun	1956	France	No	–	–	–
Kenya	1929	Europe	Yes	Yes	Yes	–
Lesotho	1937	Swaziland	No	–	–	–
Madagascar	1951	France	Yes	Yes	Yes	None
Morocco	1934	France	Yes	Yes	–	–
Rhodesia	1932	Cape Province	Yes	Yes	Yes	–
South Africa	1928	The Netherlands	Yes	Yes	Yes	–
Swaziland	1933	Cape Province	No	Yes	–	Permit required
Tanzania	1956?	Kenya	No	Yes	Yes	–
Tunisia	1966	Morocco	Yes	–	–	–
Uganda	1960	Kenya	No	Yes	Yes	None
Azores	1898	U.S.A.	No	Yes	No	–
Austria	1885	Germany	No	Yes	No	–
Belgium	1885–90	Germany	No	–	–	–
British Isles	1879	U.S.A.	No	Yes	No	–
Czechoslovakia	1885–90	Germany	No		–	–
France	1877	U.S.A.	No	Yes	–	–
Germany – Fed. Rep.	1885	Ger. Dem. Rep.	No	No	Culture only	None
Hungary	1885–90	Germany	No	Rare	Rare	–
Italy	1886–90	Germany	Yes	–	Yes	–
Spain	1955–56	France	Yes	Yes	No	–
Switzerland	1885–90	Germany	No	Yes	No	–
U.S.S.R.	1885–90	Germany	–	–	Yes	–
Japan	1925	U.S.A.?	No	Yes	No	Angling only
Philippines	1907	U.S.A.	No	–	–	–

TABLE VI

Success of various laboratory induced interspecific and intergeneric crosses[a]

Hybrid cross Female	x	Male	Hatch as a % of controls	F_1 fry produced (5 cm)	F_1s fertile
Lepomis macrochirus		*Micropterus salmoides*	9	No	No
L. gulosus		*M. salmoides*	71	Yes	-
Pomoxis nigromaculatus		*M. salmoides*	1	No	No
Ambloplites rupestris		*M. salmoides*	0	No	No
M. salmoides		*P. nigromaculatus*	1	No	No
M. salmoides		*L. macrochirus*	66	Yes	-
M. salmoides		*L. gulosus*	104	Yes	No
M. salmoides		*A. rupestris*	1	Yes	-
M. salmoides		*A. rupestris*	High	No	-
M. salmoides		*M. dolomieui*	90	Yes	Yes
M. salmoides		*L. cyanellus*	High	Yes	-
M. salmoides		*L. microlophus*	High	No	-
M. dolomieui		*M. salmoides*	High	Yes	-

[a] Table was compiled from the following papers: West and Hester, 1966; Hester, 1970; West, 1970; Whitt *et al.*, 1971; Tyus, 1969; Childers, 1968; and from personal communication with E. Hester and B. Childers

occur. However, James (1946a) reported the abnormal occurrence of both testicular and ovarian tissue in the gonads of several largemouth bass.

Externally bass greater than 35 cm in total length can be sexed correctly 92 percent of the time by looking at the scaleless area surrounding and immediately adjacent to the urogenital opening (Parker, 1971). In the male this area is nearly circular in shape while in the female it is elliptical or pear-shaped.

Internally largemouth bass may be sexed with an otoscope (Driscoll, 1969). Male bass tend to have a higher hematocrit value than female bass, but the values overlap. Steucke and Atherton (1965) found that 1 in every 7 male bass possessed a hematocrit value below the established average of 42.7, while 1 in every 6 females had a value above this average value.

3.12 Maturity

Sexual maturity is more related to size than to age. Female bass reach maturity when approximately 25 cm in total length (200 g), while males may be mature at 22 cm (160 g) (James, 1942; Bennett, 1948; Moorman, 1957; Holvik, 1970). Fast-growing bass in tropical or subtropical regions may reach maturity in 8 months to 1 year, whereas slow-growing bass or those found in the northern portion of their range may require 3 to 5 years to sexually mature (Regier, 1963; Moorman, 1957; Stocek and McCrimmon, 1965; Erdman, 1972; Fehlmann, 1930).

3.13 Mating

Promiscuous, see 3.16.

3.14 Fertilization

External.

3.15 Gonads

Johnston (1951) found that germ cells segregate and differentiate in the early blastopore stage. Migration by amoeboid movement of the germ cells to the gonadal primordia begins 37 hours after fertilization and requires 16-18 hours. Sex appears to be determined by the chromosomal makeup of the fertilized egg. Between 2 and 3 cm of length undifferentiated gonadal sex exist. Sex is microscopically distinguished in females from 3 to 4 cm in length. Females larger than 4 cm can be sexed by gross dissection. In males sex is microscopically distinguishable at 4 cm and by gross dissection at 5-6 cm.

The ovaries of largemouth bass are paired bilobed, elongated nearly circular in cross section, and have been reported to make up as much as 7-10 percent of the body weight (James, 1942; Chew, 1974). The lumen of the ovary is continuous with the oviduct (Stevens, 1970).

James (1946b) divided the process of oogensis into the following five stages. Egg diameters are from Kelley (1962) who used bass from Maine. Based on diameters of fertilized eggs (see 3.17) these values may be too small for larger or more rapidly growing bass.

Stage 1: Youngest oocytes - Numerous small irregular oocytes, containing a round or slightly oval nucleus filling most of the cell, "lampbrush" chromosomes are present in the largest oocytes of this stage, follicular membrane composed of a layer of flat cells.

Stage 2: Vacuolization of the cytoplasm - Oocytes characterized by small vacuoles in the peripheral cytoplasm and the absence of yolk material, most abundant in mature but redeveloping ovaries, diameters of the largest from 0.34-0.48 mm, follicular membrane composed of two layers of flattened cells, nucleus oval with numerous nucleoli close to its membrane.

Stage 3: Beginning of yolk deposition - Yolk present but still transparent, diameter of largest 0.45-0.75 mm, most abundant in ovaries in advanced stages of redevelopment, follicular membrane composed of small round cells with a distinct nucleus outside and a clearly defined homogeneous zona radiata on the inside.

Stage 4: Mature ova - Diameters of 0.75-1.56 mm with abundant yolk which almost fills the oocytes and renders them opaque, the fully ripened oocyte contains a distinct yellow oil globule 0.34-0.54 mm in diameter, vitelline membrane present, zona radiata with radial stations, nucleus located at one pole. Mature ova constitute the bulk of the ovary.

Stage 5: Resorption - Oocytes characterized by being enlarged and distorted. Disintegration is rapid. Stevens (1970) reports both follicular and extra-follicular resorption.

The process of maturation is described by Stevens (1970), as follows: "During final maturation of bass oocytes just prior to ovulation, multiple oil globules appear and gradually coalesce to form one large globule. This globule then changes in shape from oval to round and seems to rise from the interior of the egg to the surface. During this process the egg increases in volume and changes from opaque to translucent".

Oocytes of an individual occur in more than one stage of maturity. Stevens (1970) reported what he considered to be multiple or "mini-ovulations". However, Wilbur and Langford (1974) pointed out the possibility that the second ovulations reported by Stevens could be carryovers of the initial ovulation.

In 11 separate studies cited by K. Carlander (in manuscript material from "Handbook of freshwater fisheries", Vol. 2) and Bishop (1968) from various places in the United States the ovaries of female bass contained 2 000-145 000 eggs (2 000-176 000/kg). Some of this variation may be due to the methods used in counting the eggs. The average number of eggs remaining in the "spent" ovaries of 1.3 kg females was 103 680 per fish (Bishop, 1968).

James (1942, 1946b) describes the testes and their developmental stages. The testes are elongated organs in the posterior-dorsal part of the body cavity, lying against the ventral wall of the swim bladder. They are fused posteriorly and a duct leads to the urogenital opening. Anteriorly they are connected to the swimbladder with two mesorchia. Each testis is covered with connective tissue that extends into the testes on the ventral side.

Stage 1: Immature testis - Lobules containing many spermatogonial cells. Each spherical spermatogonium contains a small round central nucleus.

Stage 2: Poorly developed testis - Prominent strands of connective tissue around the lobules. Each lobule has spermatogonial cells near the periphery and a large lumen surrounded by spermatogonial cysts undergoing the early stages of spermatogenesis.

Stage 3: Enlarged testis - Cysts of spermatogonial cells near periphery of lobule, primary and secondary spermatocytes, and spermatids near interior.

Stage 4: Spawning condition testis - Very few spermatogonial cells. Testis appears swollen with the ducts and the lobules filled with spermatozoa resembling small oval lobes.

Stage 5: Partly spent testis - As milt is extruded the ducts and lobules decrease in size. Some sperm remains.

Stage 6: Completely spent testis - Testis contains few spermatozoa, but denudation of the lobes is rare. Lobes are mostly filled with spermatogonial cells.

3.16 Spawning
(for effect of age on spawning see 3.31 and 7.2)

Male largemouth bass build a nest in the spring when the water temperature reaches 15-24°C (Kramer and Smith, 1962; Swingle, 1956). However, in a constant temperature spring (22°C) in Florida bass spawning still appears to be chiefly limited to spring and summer (Caldwell *et al.*, 1957). Thus other factors, such as length of day, must control the spawning cycle. Swingle (1956) reports occasional autumn spawning in Alabama, when the water temperature drops to 20-24°C. These may have been young fish just reaching sexual maturity. Females tend to spawn once a year. However, the spawning act may be prolonged and they may lay their eggs in more than one nest (Lamkin, 1901).

In the southern portion of its range the spawning season of the bass tends to be more prolonged than in the northern portion. In southern Florida spawning starts when the water "cools" to about 16°C in mid-December to mid-January, peaks in February, and stops in April or May (27°C). In marshes with cooler water, spawning may continue into July (Clugston, 1966). In Illinois bass spawn after the water "warms" in the spring from May to end-June (Bennett, 1954) and in Ontario from late May to early June Stocek and McCrimmon, 1965).

In a 1 120 ha reservoir receiving thermal effluent averaging 10°C above ambient Bennett and Gibbons (1975) found earlier attainment of maximum gonadal size and the presence of significantly larger juvenile bass in the heated area. Data were inconclusive as to whether or not spawning was advanced by at least some bass in the heated area. The reproductive period started in March and continued through April in both heated and non-heated areas.

In California, the Florida subspecies reached the peak of spawning two weeks before the northern subspecies in the same lake, but there was considerable overlap in spawning (Hunsaker and Crawford, 1964).

Preparatory to spawning the male bass selects a nest site, usually in water from 0.33 to 1.33 m in depth. The author has observed male bass guarding nests from 15 cm to 5.5 m in depth. Nests may be constructed almost anywhere in a lake, but it is not unusual for them to be grouped on certain shorelines or in specific coves (Miller and Kramer, 1971) that are warmest and provide protection from excess wind action which can destroy nests. The nests are often constructed to take advantage of the protection offered by rocks, stumps or slopes (Miller and Kramer, 1971). Bass nests are spaced 2 m or more apart (Carr, 1942) unless some obstruction prevents the guarding males from seeing each other (Breder, 1936).

The male bass places his head in the centre of the nest and sweeps debris out in front of him. He then returns and with his head in the middle of the nest pivots around in a circle (Carr, 1942). Thus the radius of the nest tends to be approximately the length of the bass. The male may remove large material with its mouth (Eddy and Surber, 1947). Almost any substrate may be used as a nest site from rock to organic debris. Nests built on hard substrate are shallower than those built on soft substrate. Bass nests in Lake Mead consisted of 2.5 percent rubble, 31 percent coarse gravel, 41 percent fine gravel, 16 percent sand, 7 percent silt and 0.2 percent organic debris (Allan and Romero, 1975).

With regard to mating, Chew (1974), Reighard (1906), Breder (1936) and Carr (1942) all agree on the following points:

"1. The male leaves repeatedly after nest construction in search of a ripe female.
2. Males can attract only ripe females to the nests by their aggressive courting behaviour, which includes rapid and vivid colour pattern changes.
3. Male and female return to the nest and circle slowly.
4. The male then stimulates the female by physical contact such as nipping, butting or pushing. At this time, the colour pattern of both becomes more definite and vivid.
5. Spawning begins with both fish over the nest, side by side, and each tilted laterally so their vents are close.
6. Egg and sperm emission are accompanied by violent jerks or shudders of the body. Each time the shudders occur, eggs are omitted, fertilized, and sink slowly into the nest.
7. Spawning takes place over a prolonged period. Carr (1942) counted six spawning spasms within a period of 30 minutes for one pair.
8. Spawning ceases when the female, instead of floating and resting, moves slowly away from the nest.
9. The male will usually follow her for a short distance and then return to the nest to assume guardianship."

A male bass may entice more than one female bass to lay her eggs in his nest. Also, a single female bass may not lay all of her eggs in the same nest (Lamkin, 1901). Successful bass nests have been reported to contain 5 000-43 000 eggs (Snow, 1971; Kramer and Smith, 1962).

Some bass lay their eggs during midday, but most spawning occurs at night near dusk or dawn (Carr, 1942; Kelley, 1962; Reighard, 1906). After the eggs are fertilized, they settle to the bottom of the nest and adhere to the substrate. The male bass fans the eggs and guards the nest against predators such as the bluegill sunfish Lepomis macrochirus. Slow moving organisms such as snails, dragonfly larvae and aquatic beetles are often ignored by the guarding bass (Shealy, 1971). This is true even in the case of the snail Viviparus georgianus, which eats the eggs (Eckblad and Shealy, 1972). Certain species of fishes, such as the golden shiner (Notemigonus crysoleucas) and the lake chubsucker (Erimyzon sucetta), are allowed to lay their eggs in bass nests (Kramer and Smith, 1960a; Carr, 1942). The male bass fans and protects these eggs along with his own.

Male bass do not eat when they are guarding the nest or fry. They will "mouth" a fish, crayfish, or artificial bait and move it out of the nest. The male bass continues to guard the young fish for several weeks after they hatch.

Since interspecific and intergeneric crosses are physiologically possible (see 2.4), yet do not occur in the bass normal range, behavioural and temporal isolation between species is essentially complete. Hybridization between the two subspecies is common.

3.17 Spawn

Fertilized eggs are yellow to orange, spherical (1.4–1.8 mm in diameter), semiopaque, contain one large oil globule (0.5–0.7 mm in diameter), adhesive and demersal (Meyer, 1970; Carr, 1942; Chew, 1974). The diameter of the egg increases with the size of female (Merriner, 1971). The eggs lie with the oil globule up, and water-harden within 15 min. Eggs are covered with a thin (0.025 mm), flexible membrane, over the zona radiata (vitelline membrane). The perivitelline space is about 0.05 mm and filled with a colourless fluid.

Bass sperm have an ovoid head approximately 2 microns long, with a tail 20 microns long (Carr, 1942). The spermatozoa are viable for only a minute or so after they are shed.

3.2 Pre-adult phase

3.21 Embryonic phase

At 10, 18 and 28°C the eggs hatch in 317, 55 and 49 h respectively (Badenhuizen, 1969; Merriner, 1971). Chew (1974) describes embryonic development at 22.2°C as follows:

1.25 h – 2 to 4 cell stage
2.25 h – 16 cell stage
3.25 h – blastula
5.25 h – blastoderm beginning to spread over yolk
7.25 h – blastoderm spreading rapidly over yolk
14.00 h – gastrulation, blastopore open
15.00 h – gastrula, blastopore open
21.50 h – early embryo, blastopore closed
31.50 h – embryo, myomeres forming, head developing
37.00 h – late embryo
45.50 h – first hatching
60.00 h – yolk sac larvae
77.00 h – yolk sac larvae
82.50 h – yolk sac larvae, head no longer deflected over yolk, mouth opening
167.00 h – yolk sac larvae, beginning free swimming, yolk reabsorbing, pigmentation of head region, mouth fully formed.

Considering the variation in experimental temperatures, the stages agree closely with those of Badenhuizen (1969), Merriner (1971), Johnston (1951), Laurence (1969) and the more detailed description given by Carr (1942).

3.22 Larvae phase

At hatching the pre-larvae are 3–5.5 mm in total length (Carr, 1942; Johnston, 1953; Meyer, 1970). If there are sticks or gravel in the nest the almost colourless fry settle among them for several days. According to Reighard (1906) at first the larvae move by rocking from side to side on the yolk sac. After several days they are able to rest on the ventral surface of their yolk sac, where a sticky cap is present. Reighard (1906) comments that the function of this cap is to keep the larvae from sinking into the bottom ooze. The larvae can "right" themselves and rise from the nest only after the swimbladder begins to inflate (Johnston, 1953). Even though a pneumatic duct exists in 3–8 mm larvae they do not have to gulp air to fill their swimbladder. The initial gas which fills the swimbladder appears to be derived from vacuolated columnar cells found in the ventral epithelium of the swimbladder (Johnston, 1953).

Growth rate of pre-larvae is correlated ($r = 0.885$, 1 percent level) with water temperature (Kramer and Smith, 1960b). Laurence (1969) reported that at 20°C the mouth forms in 192 h after fertilization, the larva is free-swimming after 240 h, and the yolk sac is absorbed in 312 h. This agrees with the observations of Chew (1974), Carr (1942), Lamkin (1901), and Kramer and Smith (1962).

Fry must eat within 6 days after becoming free-swimming or they will die (Laurence, 1971a). At normal developmental temperatures the larvae have enough energy in the yolk to provide for all metabolic processes for a short period following the initiation of feeding. However, only 74 percent of the larvae Laurence (1969) looked at obtained food within the critical period. The cause of non-feeding was not determined. Fed fry, 1–7 days after becoming free-swimming, are more active than non-fed fry. Fed larvae can attain a sustained swimming velocity of 4.0 cm/sec while starved larvae attain a velocity of only 1.5 cm/sec (Laurence, 1972).

During daylight hours at 20°C small fry pass food through their stomach in approximately 3 h. The number of minutes required during daylight hours for 10–16 day old, actively feeding fry to evacuate their stomach contents is expressed by the linear regression equation: $y = 354.63 - 10.41x$, where x = water temperature from 17 to 23°C. The time for non-actively feeding fry is given by the formula: $y = 638.459 + 18.097x$ (Laurence, 1971a). Fry 2–8 days after becoming free-swimming do not appear to feed at night. They conserve energy by settling to the bottom and reducing their digestive and metabolic rates (Laurence, 1971b). The author is unable to determine when the transfer to night feeding takes place.

Larvae bass less than 10 mm in total length eat primarily copepods, cladocerans and rotifers

(Rogers, 1968; Mullan and Applegate, 1970; DeRyke, 1923; Emig, 1966; Turner and Kraatz, 1920; Kramer and Smith, 1960b). Bass investigate a forage organism for a second or so before consuming it.

Kramer and Smith (1960b) gave the length-weight relationship of 3.0-6.0 mm larvae as $\text{Log } W = -3.79828 + 1.34337 \text{ Log } L$, and 6.4-11.9 mm larvae as $\text{Log } W = -5.80130 + 3.89555 \text{ Log } L$.

3.23 Adolescent phase

Both male and female bass reach the adolescent phase by 40 mm of total length. Kramer and Smith (1960b) gave the length-weight relationship of fish from 12 to 80 mm in total length as $\text{Log } W = -4.79809 + 2.96211 \text{ Log } L$. They did not find differential growth between males and females. Growth did not correlate with the amount of food in the stomach but growth was positively correlated with the ratio of large to small organisms found in the stomach. In their study Kramer and Smith (1960b) found the differences in relative condition factor (Kn) between geographic areas in a single year were directly related to weight of stomach contents, while differences in condition among years within an area were inversely related to abundance of bass fingerlings.

Different investigators have reported bass to switch from a microcrustacean diet to an insect diet at various lengths as follows: 25-35 mm (Rogers, 1967), 22-75 mm (Marcy, 1953), 30-50 mm (Turner and Kraatz, 1920), 40 mm (Mullan and Applegate, 1970; DeRyke, 1923; Miller and Kramer, 1971), 50 mm (Kramer and Smith, 1962; Applegate et al., 1967) or 70 mm (MacCammon et al., 1964). Bass over 50 mm tend to eat fish (Miller and Kramer, 1971; Kramer and Smith, 1962). Kramer and Smith (1960b) concluded that bass remain in broods for 26-31 days (approximately 32 mm) before dispersing.

Ramsey and Smitherman (1971) gave a key for separating juvenile largemouth bass from other Micropterus. Young largemouth bass (16-30 mm) have more than 20 pyloric caeca compared to 13 or less in spotted bass (M. punctatus) (Applegate, 1966).

3.3 Adult phase

3.31 Longevity

It is not possible to cite a single value for the average life expectancy of bass after they reach maturity. However, most populations contain 6 and 7 year old fish. There is an unproven but general feeling among biologists that fast-growing bass do not live as long as slow-growing bass.

The largemouth bass tends to live longer in the northern portion than the southern portion of its range (K. Carlander in manuscript material from "Handbook of freshwater fisheries", Vol. 2). They have been reported to live for 15 years in Wisconsin and 11 years in Louisiana (Bennett, 1937). Evidently male bass do not live as long as female bass (Padfield, 1951). Thus as a year class becomes older, the percentage of males decreases. There is some indication that in California waters the southern subspecies lives longer than the northern subspecies (Smith, 1971).

3.32 Hardiness

In general, largemouth bass's tolerance to handling and physical-chemical conditions are intermediate between salmon-shad and cyprinids-ictaluridis (Table VII). Using normal precautions they can be kept in covered aquaria.

3.33 Competitors

In its native range the largemouth bass dominates the spawning grounds and competition for spawning area is minimal. It spawns before any of the other centrarchids except for the crappie (Pomxis spp.) and smallmouth bass. Some cyprinids are not temporally or spatially isolated (see 3.16), but they do not seem to interfere with bass spawning.

Most piscivorous fishes such as the crappie, walleye (Stizostedion vitreum), northern pike (Esox lucius), channel catfish (Ictalurus punctatus), white bass (Morone crysops), and striped bass (M. saxatilis), characids, and some chichids eat the same species of forage organisms that the bass does. However, criteria to measure the degree of competition have not been satisfactorily established.

3.34 Predators
(for predators on eggs and young see 3.16, 4.31)

Except for man there are no significant predators of adult largemouth bass in its native range. In North America few fishes are capable of eating adult largemouth bass. Northern pike, muskellunge (Esox masquinongy), striped bass, or very large largemouth bass are some of the exceptions. Change or control of density or size composition of adult largemouth bass caused by predation has not been documented.

3.35 Parasites, diseases, injuries and abnormalities
(see 4.42 and 7.6)

- Parasites and diseases

The following list of parasites found in the largemouth bass is from Hoffman (1967) unless otherwise noted.

Protozoa

- Chilodonella cyprini (Moroff)
- Henneguya mictospora (Kudo)
- Ichthyophthirius multifilis (first described from France, 1876, but its origin is unknown)
- Myxobolus inornatus Fish, 1939
- Myxobolus sp. Butschli
- Myxosoma cartilaginis Hoffman, Putz, and Dunbar, 1965
- Scyphidia micropteri Surber, 1940
- S. tholiformis Surber, 1942
- Trichodina domerguei (Wallengren)
- T. fultoni Davis, 1947
- T. myakkae (Mueller, 1937)
- T. nigra Lom, 1961
- T. pediculus (Müller, 1786); Ehrb., 1838

Trematoda

- Acolpenteron ureteroecetes Fischthal and Allison, 1940
- Actinocleidus fusiformis (Mueller, 1934); Mueller, 1937
- A. micropteri (?)
- Azygia angusticauda (Stafford, 1904); Manter, 1926
- A. loossii Marshall and Gilbert, 1905
- A. micropteri (MacCallum, 1921)
- A. tereticolle Leidy, 1851
- Bucephaloides pusillus (Syn. (Stafford, 1904) Bucephaloides pusillus)
- Bunodera cornuta (Osborn, 1903)
- Caecincola parvulus Marshall and Gilbert, 1905
- C. wakullata sp. n., See Premvati (1967)
- Clavunculus bursatus (Mueller, 1936); Mizelle et al., 1956 (Syn. Actinocleidus b.)
- C. unguis (Mizelle and Cronin, 1943); Mizelle et al., 1956
- *Clinostomum marginatum (Rud., 1819)
- *Crassiphiala ambloplitis (?)
- Crepidostomum cooperi Hopkins, 1931
- C. cronutum (Osborn, 1903); Stafford, 1904
- C. ictaluri (Surber, 1928)
- Crepidostomum sp. Braum, 1900
- Cryptogonimus chyli Osborn, 1910
- *Diplostomulum scheuringi Hughes, 1929
- *Diplostomulum sp. Hughes, 1929
- Gyrodactylus macrochiri Hoffman and Putz, 1964
- Leuceruthrus micropteri Marshall and Gilbert, 1905
- Microphallus opacus (Ward, 1894); Ward, 1901
- Multigonotylus micropteri gen et sp. n., See Premvati (1967)
- *Neascus sp. Hughes, 1927
- Neochasmus umbellus Van Cleave and Mueller, 1932
- Phyllodistomum lohrenzi (Loewen, 1935)
- P. pearsii Holl, 1929
- Pisciamphostoma stunkardi (Holl, 1929); Yamaguti (1953)
- *Posthodiplostomum minimum (MacCallum, 1921)
- Proterometra macrostoma Horsefall, 1933
- Rhipidocotyle papillosum (Woodhead, 1929)
- R. septpapillata Krull, 1934
- Sanguinicola huronis Fischthal, 1949
- *Tetracotyle sp. Faust (1918); Hughes (1928)
- Urocleidus dispar (Mueller, 1936); Mizelle and Hughes, 1938 (Syn. Onchoclidus d., Haplocleidus d.)
- U. furcatus (Mueller, 1937); Mizelle and Hughes, 1938 (Syn. Haplocleidus f.)
- U. principalis (Mizelle, 1936); Mizelle and Hughes, 1938 (Syn. Onchocleidus p., O. contortus)
- *Uvulifer ambloplitis (Hughes, 1927); Dubois, 1938

Cestoda

- Abothrium crassum (?)
- Bothriocephalus claviceps (Goeze, 1782); Rud., 1810
- **B. cuspidatus Cooper, 1917
- Hymenolepis sp. Bangham (1951)
- Ophiovalipora minuta See Norman (1971)
- Philometra nodulosa Thomas, 1929
- *Proteocephalus ambloplitis (Leidy, 1887); Benedict, 1900
- P. fluviatilis Bangham, 1925
- P. pearsei LaRue, 1914
- Proteocephalus sp. Weinland, 1858
- *Triaenophorus nodulosus Pallas, 1760

Nematoda

- Camallanus oxycephalus Ward and Magath, 1917
- **Camallanus sp. Railliet and Henry, 1915
- Capillaria catenata Van Cleave and Mueller, 1932
- Contracaecum brachyurum (Ward and Magath, 1917)
- *C. spiculigurum (Rud., 1819)
- *Contracaecum sp. Railliet and Henry, 1912
- Dacnistoides ctylophora Ward and Magath, 1916
- Dioctophyma sp. Cyllet - Maygret, 1802
- Goegia See Gaines, Ware and Rogers (1973).
- Philometra cylindracea Ward and Magath, 1916
- Philometra nodulosa Thomas, 1929 (Syn. Icthyonema)
- Rhabdochona decaturensis Gustafon, 1949; See Spall (1968)
- Spinitectus carolini Holl, 1928
- S. gracilis Ward and Magath, 1916
- Sprioxys sp. Schneider, 1866

Acanthocephala

- Echinorhynchus salmonis Müller, 1784
- *Leptorhynchoides thecatus (Linton, 1891); Kostylew, 1924
- Neoechinorhynchus cylindratua (Van Cleave, 1913); Van Cleave, 1919
- Pomphorhynchus bullocolli (Linkins, 1919); Van Cleave, 1919

Hirudinea

- Illinobdella moorei (Meyer, 1940); Meyer, 1946 (Syn. Myzobdella m.)
- Illinobdella sp. Meyer, 1940
- Piscicola punctate (Verrill, 1871)
- Placobdella montifera Moore, 1912

Mollusca

- Glochidia
  - Lampsilis radiata (Gmelin); See Tedla and Fernando (1969)

TABLE VII

Effects of various physical-chemical paremeters on largemouth bass

Parameter	Comments	Reference
Antimycin A	24 h EC_0 = 0.2 ppb, EC_{100} = 1.3 ppb for 1.8-2.9 g fish	Walker, Lennon and Berger (1964)
	5 ppb will kill all bass in most pond treatments	Berger, Lennon and Hoggan (1969)
Aqualin	24 h TLm 0.183 mg/l at 22°C 96 h TLm 0.160 mg/l	Louder and McCoy (1963)
Bay 73WP71	In 48 h 0% mortality at 0.1 mg/l; 100% at 0.25 mg/l	
Bayer 73	95% LC_{50} confidence interval at 24 h = 0.099-0.124; 48 h = 0.087-0.109; 96 h = 0.076 at 17°C for 4 cm bass	Marking and Hogan (1967)
Delrad (dehydroabietylamine acetate)	Minimum lethal dose 0.65 mg/l	Lawrence (1958)
Denuron-TCA	24 h EC_{10} = 4.2 mg/l; 24 h EC_{50} = 7.4 mg/l for 10 cm bass	Walker (1964)
3-2 Dibrom-Malathion	48 h TLm = 0.10 mg/l at 22°C with 5-10 cm fish	Hoff and Westman (1965)
Di-N,n, dimethylococamine salt of 3,6-endohexahydrophthalic acid	96 h LD_{50} = 0.14 mg/l	Walker (1962)
Diquist	24 h TLm = 24 mg/l; 48 h TLm = 11 mg/l; 96 h TLm = 7.8 mg/l	Surber and Pickering (1962)
Diquist dibromide	96 h TLm = 60 mg/l	Shealy and Shiflet (1969)
Di Sodium Endothal	96 h LD_{50} = 120 mg/l	Walker (1962)
Endosulfin EC 2	0.05 mg/l 100% mortality in 24 h	Mulla, St. Amant and Anderson (1967)
Endothal	24 h TLm greater than 560 mg/l; 48 h TLm = 320 mg/l; 96 h TLm = 200 mg/l	Surber and Pickering (1962)
Isobornyl thiocyanoacetate	100% mortality with 0.7 mg/l at 25°C; 100% mortality with 0.8 mg/l at 10°C	Lewis (1968)
Monurone-TCA	24 h EC_{50} = 2.7 mg/l for 10 cm bass	Walker (1964)
Oxygen	Bass are not adapted for survival in oxygen-depleted waters	Lewis (1970)
	No mortality at 250% saturation	Wiebe and McGavock (1932)
	No mortality when moved from 7.3 to 41 mg/l or from 40 to 5.6 mg/l	Wiebe (1931)
	Avoids 1.5 mg/l or less	Whitmore, Warren and Doudoroff (1960)
	Critical level when acclimated 0.82, 0.83, 1.20 mg/l at 25, 30 and 35°C respectively. When not acclimated the critical level of oxygen occurs at 0.92, 1.19 and 1.14 mg/l	Moss and Scott (1961)
	Growth only 60-75% as rapid at 4 mg/l as at 8 mg/l. Diel fluctuations also also impaired growth	Stewart, Schumway and Doudoroff (1967)

TABLE VII continued

Parameter	Comments	Reference
Oxygen	Hatching success reduced at 2.0, 2.1, 2.8 mg/l at 15, 20 and 25°C respectively. At oxygen levels less than 1 mg/l prehatching survival increased with mechanical movement of eggs, but at hatching mechanically moved eggs died at all oxygen levels tested	Dudley and Eipper (1975)
pH	50+ percent mortality below 4.2 and above 10.4	Swingle (1961)
	24 LD_{50} at pH = 11.0 for small and large bass	Swingle (1962)
	Bass survive a change in pH from 9.5 to 6.1 and from 6.1 to 9.5	Wiebe (1931)
	No reproduction at pH below 5.0 or above 10.0	Swingle (1949b)
Picloram (4-amino-3,5,6-Trachloropicolinic acid)	24 h TLm = 19.7 mg/l at 23°C; 48 h TLm = 13.1 mg/l at 23°C	Kenaga (1969)
Quinaldine	95% LC_{50} range for 24 h 8.8-11.3 mg/l; for 96 h 7.7-10.5 mg/l	Marking (1969)
Rotenone formulations		
Pro Noxfish	24 h LD_{50} = 0.081 mg/l at 22°C	Hester (1960)
Noxfish	24 h LD_{50} = 0.147 mg/l at 22°C	
Powdered	24 h LD_{50} = 0.164 mg/l at 22°C	
Salinity	11-13% sea water low reproduction 9-10% sea water high reproduction	Martin (1959)
	Adults are common in 12.4% of sea water	Schwartz (1964)
	Adults can withstand 25% sea water but may cease feeding	Wollitz (1962)
	Eggs hatch at 20% sea water but not 30% 96 h TLm = 38% of sea water for 35-41 mm fry	Tebo and McCoy (1964)
Silt	Visible adverse behavioural reaction at 20 000 mg/l	Wallen (1951)
Simizine	96 h LD_{50} = 45 mg/l	Walker (1964)
Sodium cyanide	Bass are less sensitive than carp, *Cyprinus carpio*	Bridges (1958)
	At 0.1 mg/l NaCn killed gizzard shad, *Dorosoma cepedianum* but not bass	Huish (1958)
Temperature	Bass can withstand a wide range of temperatures if acclimated, but handling below 4.5°C and above 25.5°C is detrimental	Wilson (1950)
TFM	1-1.8 mg/l killed less than 25%	Marking *et al.* (1970)
Turbidity	Direct lethal effect caused by gill filament clogging at an average concentration of 101 000 mg/l	

Crustacea
Achtheres micropteri Wright, 1882
Argulus appendiculosus Wilson, 1907
A. flavescens Wilson, 1916
A. mississippiensis Wilson (1914); See Norman (1971)
Ergasilus caeruleus Wilson, 1911
E. centrarchidarum Wright, 1882
E. nigritis (nigratus) Wilson, 1916
E. lizae Kroyer 1863; See Kelly and Allison (1963)
Ergasilis sp. Nordmann, 1832
Lernaea anomala Wilson, 1917
L. cruciata (LeSueur, 1824)
L. cyprinacea Linnaeus, 1761

Fungi
Saprolegnia spp.
Branchiomyces sanguinis See Meyer and Robinson, 1973

Virus
Lymphocystis See Weissenberg (1945)

Bacteria
Aeromonas liquifaciens See Brauhn and Ray (1970)
Flexibacter columnaris (Syn. *Cryptophaga c.*, *Chondrococcus c.*) See Isom (1960)
Staphylococcus spidermis See Brauhn and Ray (1970)
Pseudomonas spp.

Arthropoda
Sebekia oxycephala (Diesing) Savabon, 1922; See Dukes, Shealy and Rogers (1971)

* Larval form
** Immature

Ordinarily parasitic infections of bass are relatively light and do not cause mortality. Only a few parasites such as *Ichthyopthirius multifilis*, *Chondrococcus columnaris* and *Lampsilis radiata* have been reported to cause epizootics of subadult and adult bass in natural populations (Allison and Kelley, 1963; Isom, 1960; Telda and Fernando, 1969). *Saprolegnia* spp. has been reported to kill eggs (see 3.21). See 7.6 for parasite control in culture situations.

The metacercaria of *Clinostomum marginatum* (yellow grub) is not harmful if eaten by humans but the fish flesh is aesthetically unpleasing when heavily infected (Taber, 1972). The plerocercoid of the bass tapeworm *Proteocephalus ambloplitis* may reduce fertility of largemouth bass (Mraz and Cooper, 1957). When bass are introduced into trout waters the plerocercoid may infect the trout (Becker and Brunson, 1968).

The modes of transmittal may be direct as in the case of bacteria and many protozoan parasites, or indirect as in the case of trematodes and cestodes. The copepod, *Cyclops*, and the amphipod, *Hyalella knickerbocker*, are the source of infection of *P. ambloplitis* (Bangham, 1927).

– Injuries and abnormalities

No regularly occurring abnormalities have been reported in the largemouth bass. However, Reid (1951) reported a fibroma type, Mawdesley-Thomas (1975) a melanoma type, and Mawdesley-Thomas (1972) a lipoma type neoplasm on the side of a bass. James (1946a) has reported ovatestes. A double-mouth adult bass was cited by Herman, Holtman and O'Donnell (1947) and Allen and Neil (1953) noted a zanthic bass.

Artificially induced hybrids are frequently abnormal and die (Table VI). Under experimental conditions vertebrae injury has been caused by electric shock (Spencer, 1967). Dudley (1969) and Dudley and Eipper (1975) reported that embryos held under low oxygen were frequently abnormal. White blindness frequently occurs in bass that are fed on horse liver (Allison, 1951).

3.4 Nutrition and growth

3.41 Feeding

Like many predatory fishes, the bass has a large mouth and a large, well developed, elastic stomach. It does not bite off chunks of food, but rather swallows a whole organism. According to Lawrence (1958) a bass can swallow a fish whose maximum depth is equal to the mouth width of the bass (see 1.31).

If available, the size of forage that bass eat increases with bass size (Rogers, 1968; Lewis *et al.*, 1974; Snow, 1971; Schneider, 1971; Turner and Kraatz, 1920). There is some evidence that when feeding on small forage items food intake is calorically controlled. When bass were fed bullfrog tadpoles (*Rana catesbeiana*) or green sunfish (*Lepomis cyanellus*) *ad libitum* they consumed on a daily basis 7.9% of their body weight in tadpoles and 4.3% of their body weight in green sunfish. This corresponded to 0.023 kcal/g body weight/day of tadpoles and 0.025 kcal/g body weight/day of green sunfish (Kirk, 1967). As temperature decreases the size of forage organisms consumed by bass decreases (Wright, 1970).

Lewis *et al.* (1961) and Lewis and Helms (1964) found that bass in small tanks preferred golden shiners to other forage. However, in small ponds bullfrog tadpoles, crayfish, young black bullheads (*Ictalurus melas*) and green sunfish were preferred in that order. They suggested that the difference in food preference was due to the increased mobility of shiners and other fishes, which made them less vulnerable in the pond situation. Thus selectivity of food may be influenced by the vulnerability of the prey species present. To date all properties which constitute "vulnerability" have not been defined. However, Lagler and DeRoth (1952) concluded that bass are a more effective predator on prey with a terete body shape than those with a strongly compressed form. Goodyear (1972) reported that if a prey species behaves unnaturally, predation by bass with increase.

The bass exhibits at least two types of feeding behaviour (Vanderhorst, 1967). In the "hunger" motivated type the bass goes through a fairly lengthy series of preparatory movements which involves a rocking motion of the body, and flaring the gill covers. When bass exhibit this behaviour, forage fish show a marked escape response. A second type of feeding behaviour is reflex-like strike response (Lewis et al., 1961). Characteristically orientation and positioning occurs before the attack. Nyberg (1971) found that the distance from the prey at which the final attack was initiated was greatest when the bass was travelling toward the prey at a high velocity. Attacks initiated at a distance greater than one fourth the length of the bass's head usually failed. Once the jaws begin to open the sequential movement is stereotype. Bass either "over swim" their prey, suck them in or both. Crayfish were swallowed tail first in 97 percent of the cases and gizzard shad (Dorosoma cepedianum) headfirst in 66 percent (Zweiacker, 1972).

The bass is not a continuous feeder. When stomachs are collected from the wild by electrofishing it is common for approximately 50 percent of them to be empty (Zweiacker and Summerfelt, 1974; Dubets, 1954; Lewis et al., 1974). Bass feed both at night and during the day. Our experiments show they are capable of feeding on bluegill sunfish and growing in complete darkness at clay turbidities of at least 140 JTU. A midmorning and afternoon period of increased feeding activity has been indicated by Zweiacker and Summerfelt (1974), but this phenomenon needs further investigation.

Lewis et al. (1974) reported that once a gizzard shad is ingested, the bass characteristically does not eat again for approximately 40 h. This apparently does not hold true when small forage fishes or crayfishes are being utilized (Snow, 1971; Lewis et al., 1974).

Bass do not feed when they are spawning (see 3.16), or at water temperatures above 37°C or below 5°C (Markus, 1932). Even though small bass tend to feed more at lower temperatures than large bass (Markus, 1932), all sizes of bass tend to feed very little during the winter at northern latitudes (Keast, 1968). They consume approximately three times as much food at 20°C as at 10°C (Hathaway, 1927).

Bass stop feeding when dissolved oxygen approaches 1 mg/l (Snow, 1961). See 3.22 for nonfeeding of larval bass and 3.32 for effect of salinity on feeding.

3.42 Food

The enzyme complement of the bass limits the type of food it can utilize. The pyloric caeca are sources of trypsin and lipase. Protein is absorbed primarily in the stomach and fat in the intestine (Beamish, 1972). The enzymes associated with carbohydrate break-down, such as amylase, maltase, lactase and invertase, are not found in bass (Sarbahi, 1951).

Emig (1966) and K. Carlander (in manuscript material from "Handbook of freshwater fisheries", Vol. 2) have summarized many of the numerous reports on the food organisms eaten by largemouth bass. See 3.22 and 3.23 for feeding of larvae and subadult bass. In general, adult bass eat fishes and crayfishes. However, just about every macro-organism which is found in fresh water has been found in the stomach of bass.

Lewis et al. (1974) reported food intake values as high as 25 percent of body weight for 90 g bass, but the average for 90-450 g, 450-900 g 900+ g bass was 9.2, 7.6 and 3.0 percent respectively.

There is a positive curvalinear relationship between temperature and digestion rate (Table VIII). These values are similar to those reported by Seaburg and Moyle (1964), Hunt (1960), Markus (1932), and Beamish (1972).

Markus (1932) found no difference in the digestive rate of 45 g versus 175 g bass and Beamish (1972) found no difference in the digestive rate of digestive efficiency of 7 g versus 91 g bass. Larger meals within the range of 2-8 percent of body rate require longer to digest, but the absorption efficiencies of protein-N, lipid, or energy do not differ significantly (Beamish, 1972).

3.43 Growth rate

The growth rate of largemouth bass is variable. Usually they grow faster in a new lake than in an old lake (Figs.3 and 4). In established populations their growth rate is usually faster in large bodies of water than small ones (Fig. 4). At the end of 1 year a largemouth bass may be 5-35 cm in length. This variation appears to be better correlated with

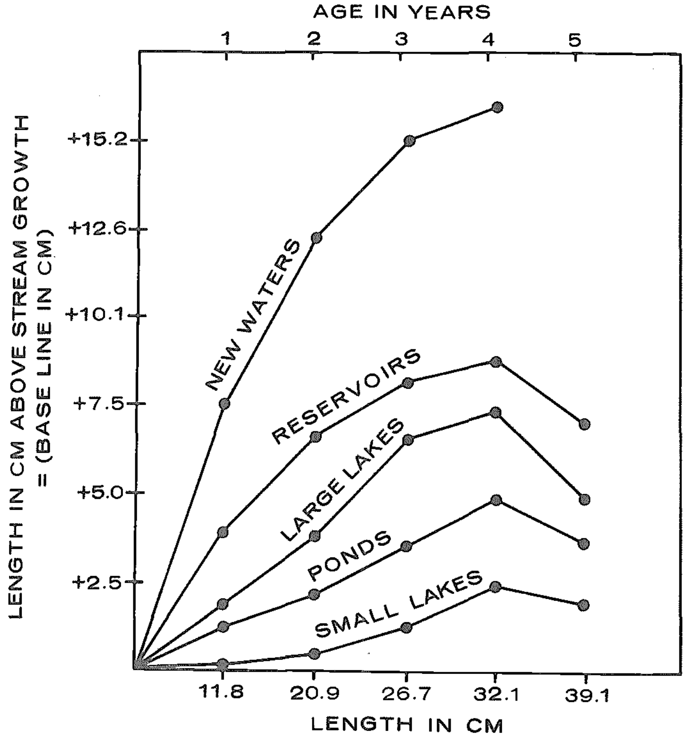


Fig. 3 Growth of largemouth bass in Oklahoma lakes above growth in streams (growth in streams = base) (after Jenkins and Hall, 1953)

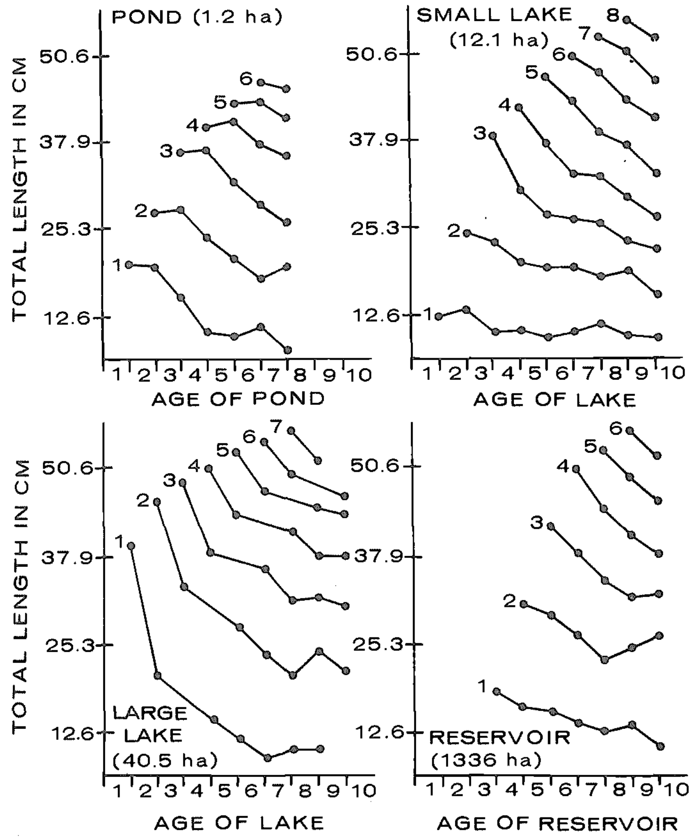


Fig. 4 History of annual growth of largemouth bass following impoundment of bodies of water in Oklahoma (after Jenkins and Hall, 1953)

TABLE VIII

Effect of water temperature on the digestive rate of 25-27 cm bass (after Molnár and Tolg, 1962)

Temperature (°C)	5	10	15	20	25
Time to empty stomach (hours)	110	50	37	24	19
Standard deviation (hours)	12.9	6.9	8.3	4.2	2.2

density and food supply than with digestive function or temperature. When bass have been fed fish flesh, conversion rates of 2.5-5.6 have been reported (Snow, 1962; Thompson, 1941; Prather, 1951).

If a forage population is made up of only large organisms, small bass may be underfed. However, Lewis et al. (1974) reported another situation in which large bass were less well nourished than small bass. They found that when bass feed on large organisms they characteristically eat only one. Under such conditions, if the forage is fairly uniform in size and both large and small bass utilize it, the daily food intake of the small bass as a percentage of its body weight can be high, while that for the large bass is low.

Reviewing data from K. Carlander (manuscript material from "Handbook of freshwater fisheries", Vol. 2), one finds that in general the northern subspecies tends to grow larger in the southern than in the northern portion of its range.

Even though several researchers have investigated the relative growth rates of the northern and southern subspecies of the largemouth bass (Clugston, 1964; Smith, 1971; Addison and Spencer, 1972), the evidence indicating differences in rate of growth is inconclusive. In Californian waters there is some indication that larger specimens of the southern subspecies occur because it is harder to catch and lives longer than the northern subspecies (Smith, 1971). In cold climates the southern subspecies does not appear to survive as well as the northern subspecies (Stevenson, 1972).

The literature on the relative growth of male and female bass is contradictory. Pardue and Hester (1967) reported that up to 0.3 kg the males are heavier than females. Padfield (1951) found that females up to 6 years old are slightly longer than males of the same age. Other investigators have reported no difference in growth rate between the sexes (Kramer and Smith, 1960a; Hill, 1939; Roseberry, 1952; Thompson and Bennett, 1949; Eschmeyer, 1940; Stroud, 1948; Beckman, 1949).

In most studies the body-scale relationship was shown to be a straight line through the zero intercept (K. Carlander, manuscript material from "Handbook of freshwater fisheries", Vol. 2). However, a Frazer type correction has been used in many studies, for example, Cross (1951), Zweiacker (1972), Thompson (1964), LaFaunce, Kinsey and Chadwick (1964), Manning (1951), Elder and Lewis (1955), and Carter (1967).

Scale formation is at 18-26 mm (Stroud, 1948; Klavano, 1958). Scales from above the lateral line gave lower calculated lengths than scales from below the lateral line (Klavano, 1958).

The approximate relationship between total length (TL), standard length (SL) and fork length (FL) is TL = 1.22 SL up to a TL of 200 mm, TL = 1.215 SL up to 380 mm, and TL = 1.21 SL over 380 mm, and that TL = 1.08 fork length (K. Carlander, manuscript material from "Handbook of freshwater fisheries", Vol. 2). Bennett (1971) states that bass between 12.6 and 37.9 cm in total length, and coefficient of condition K (based on total length in cm, and weight in grams) of 0.97-1.25 denotes fish in poor flesh, 1.27-1.52 fish of average plumpness, and 1.55-1.80 a very fat fish. However, Buck and Thoits (1970) have demonstrated that the fastest growth rates of bass were not always accompanied by the highest condition factor.

3.44 Metabolism

- Metabolic rates

Primarily due to differences in the thermal, handling and feeding history of experimental fish as well as differences in experimental design, there is considerable variation in the reported oxygen uptake of largemouth bass (Table IX). Beamish (1970) determined the effect of swimming speed, weight and temperature on oxygen consumption (Table X). The logarithm of oxygen consumption for a given swimming speed and temperature increased linearly with the logarithm of weight. Regression slopes were considerably less than 1. For a given swimming speed oxygen consumption increased linearly with temperature from 10°C to 34°C.

TABLE IX

Oxygen consumption of largemouth bass

Size (g)	Temperature (C)	Standard ($mgO_2/kg/h$)	Active ($mgO_2/kg/h$)	Reference
38-50	17.8-19.3	65 ± 2.3 SE[a]	-	Clausen (1936)
4.7-23.9	25	89-156 SE 0.002-0.005	-	Moss and Scott (1961)
12.2-22.6	30	101-129 SE 0.002-0.005	-	(as above)
62.7-97.6	35	112-150 SE 0.002-0.003	-	(as above)
6-10	5	38	48	Johnson and Charlton (1960)
6-10	12	130	198	(as above)
6-10	17	134	250	(as above)
6-10	22	185	303	(as above)
6-10	29	320	450	(as above)
150	10	80	187	Beamish (1970)
150	15	97	257	(as above)
150	20	120	345	(as above)
150	25	127	375	(as above)
150	30	170	540	(as above)
150	34	178	533	(as above)
1.6	20	-	456-750	MacLeod (1967)
11.8	22-24	-	720 individually	Parker (1973)
11.8	22-24	-	710 grouped	(as above)

[a] SE = standard error

Active oxygen consumption increased linearly with weight for each temperature when expressed on a logarithmic grid. Equations for the regressions are from Beamish (1970) except where noted.

(°C)
10 $\log Y = -0.6681 \pm 0.9725 \log X$
15 $\log Y = -0.5590 \pm 0.9855 \log X$
20 $\log Y = -0.0417 \pm 0.8068 \log X$
25 $\log Y = -0.2411 \pm 0.9190 \log X$
25 $\log Y = -1.2140 \pm 0.7980 \log X$ (O'Hara, 1966)
30 $\log Y = -0.0143 \pm 0.8836 \log X$
34 $\log Y = -0.1336 \pm 0.9358 \log X$

Oxygen consumption of largemouth bass was not altered when the concentration of oxygen was increased to 150 percent saturation.

Energy available for swimming, termed metabolic scope of activity, is calculated by subtraction of standard from active oxygen consumption. According to Beamish (1970) the scope of activity increased with temperature from 10 to 30°C and decreased from 30 to 34°C.

Laurence (1969) has determined the oxygen consumption of individual eggs and larva bass (Table XI).

In general small bass have a higher per gram oxygen requirement than do large bass (O'Hara, 1966). However, Moss and Scott (1961) found that bass between 15 g and 50 g showed no change in standard metabolic rate with increased size, but below 15 g metabolic rate varied inversely with weight. O'Hara (1966) reported that tissue respiration does not change with size of fish when they are larger than 50 g (2.8 µl/mg dry/h). Bass less than 10 g had a lower respiration ratio (2.0 µl/mg dry/h). Moss and Scott also noted no daily endogenous rhythmus in standard oxygen consumption of non-fed fish. However, Clausen (1933, 1936) stated that daily standard oxygen consumption peaked at 06.00 and 21.00 h.

Active metabolism for individual and grouped 11.8 g bass was found to be the same (Parker, 1973; Table VII).

The routine oxygen consumption of largemouth bass decreased from 8.53 ± 1.55 95% CI to 2.70 ± 0.36 95% CI mg O_2/h after 144 h of food deprivation. The mathematical relationship between routine oxygen consumption and time of food deprivation is $Y_i = a + be^{CX_i}$ where X_i is the time of deprivation in hours, $a = 2.97$, $b = 5.73$ and $C = -0.0367$ ($\leqslant R^2 = 1.04$) (Glass, 1968)

Denyes and Joseph (1956) found no relationship between oxygen content of branchial blood and water temperatore or oxygen concentration in the water. Oxygen concentration in the blood ranged from 5.70 to 28.75 cc/l.

Fuhrman et al. (1944) found that when log Oo_2 of excised bass brain is plotted as a function of temperature, the curve is a straight line with a positive slope over the range 10-35°C. There is

TABLE X

The relationship between weight (X in g) and oxygen consumption (Y in mg/h) at different swimming speeds and temperatures (after Beamish, 1970)

Acclimation temperature (°C)	Swimming speed (cm/s)[a]	Total length (cm)		Weight (g)		Regression	Correlation coefficient	95% confidence interval of slope
		mean	SD[b]	mean	SD			
10	30	22.1	3.5	164.1	73.5	$\log Y = -0.1137 + 0.6557 \log X$	0.694	0.0418
15	30	22.5	4.0	164.6	81.2	$\log Y = 0.0926 + 0.6056 \log X$	0.908	0.0120
15	40	23.3	3.5	180.6	73.4	$\log Y = 0.1894 + 0.6014 \log X$	0.822	0.0854
15	50	24.8	2.7	208.9	62.3	$\log Y = 0.1936 + 0.6264 \log X$	0.865	0.0224
20	30	19.7	3.7	130.9	75.5	$\log Y = 0.0867 + 0.6471 \log X$	0.910	0.0214
20	40	19.7	3.7	130.9	75.5	$\log Y = 0.2695 + 0.6007 \log X$	0.854	0.0281
25	30	20.0	5.1	118.1	82.6	$\log Y = -0.0594 + 0.7475 \log X$	0.941	0.0288
25	40	20.0	5.1	118.1	82.6	$\log Y = 0.0785 + 0.6908 \log X$	0.938	0.1091
30	30	22.4	3.1	152.5	64.5	$\log Y = 0.2000 + 0.6593 \log X$	0.790	0.0270
30	40	22.4	3.1	152.5	64.5	$\log Y = 0.4798 + 0.5580 \log X$	0.740	0.0289
30	50	22.4	3.1	152.5	64.5	$\log Y = 0.4263 + 0.6217 \log X$	0.759	0.0290
34	30	21.2	3.0	125.0	60.3	$\log Y = 0.1338 + 0.7062 \log X$	0.548	0.0430
34	40	21.4	3.0	128.8	62.3	$\log Y = 0.2920 + 0.6484 \log X$	0.700	0.0390

[a] Johnson and Charlton (1960) reported cruising speed of 6–10 g largemouth bass to be 9.6, 22.3, 24.3, 41.5 and 20.5 cm/s at 5, 12, 17, 22 and 29°C respectively

[b] SD = standard deviation

TABLE XI

Average oxygen consumption per 24 hours of a single largemouth bass egg and larva at 19 ± 0.5°C (after Laurence, 1969)

Time interval after fertilization (h)		Oxygen consumed (µl)
0-24		0.057
24-48		0.519
48-72		0.725
72-96	(hatching)	1.915
96-120		1.478
120-144		1.256
144-168		1.314
168-192	(mouth formed)	2.059
192-216		1.822
216-240	(free-swimming)	2.688
240-264		1.911
264-288		3.071
288-312	(yolk absorbed)	2.970

a sharp decline at 40°C. Brain acetylcholinesterase in inhibited *in vivo* by organic phosphorus insecticides (Weiss, 1961).

- Maintenance

Niimi and Beamish (1974) investigated changes in growth and proximate body composition of largemouth bass of 8-150 g, between 18°C and 30°C. They found that:

> "... for most weight, growth of fish was highest at 25°C, and lowest in fish at 18°C. This was attributed in part to a higher satiation feeding level at 25°C. For a fixed level of feeding, growth rate was highest for fish held at 18°C.
>
> Lipid content increased with feeding level and was highest at 18°C. Moisture content varied inversely with lipid content. Protein and ash content did not vary appreciably with temperature, body weight, or feeding level.
>
> Maintenance requirement of bass, expressed as grams per day, was about twice that lost during food deprivation, but only slightly different when expressed as dilocalories per day.
>
> Standard metabolism accounted for 50% of intake energy near maintenance, but only 10% at the satiation feeding level. Growth requirements increased from zero at maintenance to 40% of intake energy at satiation feeding".

Beamish (1974) found that apparent specific dynamic action (SDA) rose curvilinearly with ration size. For a fixed feeding rate as a percent of body weight per day, apparent SDA increased curvilinearly with the weight of bass. Apparent SDA expressed did not differ significantly with weight of fish or meal size (SDA ± SD was 14.9 ± 4.19% of the energy ingested). With swimming speeds from 1.4 to 2.5 BL/s, their was no difference in apparent SDA of similar size bass fed a ration of 4 percent body weight/day.

In bass fed on emerald shiners (*Notropis atherinoides*) Beamish (1972) estimated faecal energy loss to be 10.4 percent of the ingested energy. Non-faecal loss was calculated at 7.9 percent of ingested energy (Niimi and Beamish, 1974). Thus metabolizable energy in bass represents 81.7 percent of that consumed and apparent SDA accounts for 14.2 percent of the metabolizable energy (Beamish, 1974).

- Carbohydrate and steroid

In exercised bass liver glycogen decreased by 35 percent at 20°C and 83 percent at 5°C. Muscle glycogen also decreased with exercise. Blood glucose in exercised fish increased more at 20°C than at 5°C. Muscle glycogen of unexercised fish decreased with temperature. Blood glucose in unexercised fish was lower at 20°C than at 5°C. With exercise, blood lactic acid increased more at 5°C than 20°C (Dean and Goodnight, 1964).

Blondin *et al.* (1966) demonstrated that sterol biosynthesis in bass follows the same metabolic pathway as has been demonstrated for mammals. Thus in vivo 2-C^{14}-mevalonic acid served as a precursor to lipid materials in the liver. Addition of cofactors are not necessary with liver homogenates but additional ATP and NADPH did increase incorporation. Squalene, lanosterol and cholesterol were identified as metabolites of mevalonic acid and 7-dehydrocholesterol was converted to cholesterol.

- Endocrine systems and hormones (for osmotic tolerances see Table VII)

Ovulation in largemouth bass was induced by injection of bass pituitary gland, HCG, LH, FSH, growth hormone and prolactin (Stevens, 1970). The possibility exists that LH occurred as a contaminate in all of the preparations.

Due to the deep-seated position of the pituitary gland in the largemouth bass, hypophysectomized individuals died. Female bass treated with Methallibure (I.C.I. 33828) did not ovulate (Stevens, 1970).

Bass produced more milt after injection of 4 000-8 000 IU of HCG/kg than did non-injected bass (Wilbur and Langford, 1974).

For induced spawning of largemouth bass with hormones see 7.4.

3.5 Behaviour
(for feeding behaviour see 3.41, for reproduction behaviour see 3.13, 3.21)

When both a large and small bass are placed in an aquarium the large fish usually becomes dominate.

3.51 Migration and local movement

Recapture of previously marked fish in large lakes has yielded some information on movement of bass. Rawstron (1967) found that the majority of bass moved 1.1 km. In a study by Hancock (1956) bass averaged 1.6 km of movement between captures. Averages of 6.4 km were found by Eschmeyer (1942) and Dequine and Hall (1950). Schumacher and Eschmeyer (1942) found that 90 percent of the recovered bass had moved 25.6 km in 1 year.

Some authors working on lakes less than 20 ha have reported home ranges of approximately 100 m (Lewis and Flickinger, 1967; Warden and Lorio, 1975). Lewis and Flickinger (1967) calculated that 1.2 percent of the bass population was on the shoreline at any one time (except when spawning), therefore 150 m of shoreline was available per bass. If the entire population had been on the shoreline only 1.25 m would have been available for each bass. The considerable variations in the reported distances that bass move would be explained if, as proposed by Fetterolf (1952), there are two populations of bass, one that "wanders" and one that stays in a given area. A shifting type of "home range" as found by Warden (1973) would also explain many of the above results.

In the spring, when bass are moving into the shallow water to spawn and the entire adult population is on the shoreline, large numbers move out of lakes over weirs and spillways (Lewis, Heidinger and Konikoff, 1968; Clark, 1942; Louder, 1958; Elser, 1961). Most of the escapement takes place during the crepuscular period (Lewis, Heidinger and Konikoff, 1968).

During the winter bass tend to move into the warm water discharge of electrical power generating plants. In many cases this can result in excellent sport fishing (Gibbons et al., 1972). Warden (1973) found at temperatures above 27°C that diurnal movement decreased and nocturnal movement increased, at temperatures below 10°C all movement decreased.

3.52 Schooling
(for schooling of fry see 3.23)

Observing the escape of fish over spillways, Lewis, Heidinger and Konikoff (1968) reported that the fish aggregated in the current at the lip of the spillway before escapement. They also may school and move long distances when chasing such forage fish as the threadfin shad (Dorosoma petenense).

At the present time separate stocks of bass are not recognized in the reservoir habitat.

In the classical sense of the term bass aggregate in the warm water behind electrical power generating plants (see 3.51), and in coves where they spawn (see 3.16). When water temperatures drop below 10°C in large main stream reservoirs in North America, bass tend to move into the open water of the reservoir. They aggregate over 30-60 m water at depths of at least 10 m. Usually they are associated with brush; for example, tree tops. However, some bass can be found in shallow waters all year (Cady, 1945). It is becoming evident that bass should be considered an aggregating fish rather than a strictly solitary fish.

Artificial reefs or shelters have been successfully used to attract bass (Rodenheffer, 1940, 1941, 1945) for a number of years. Crumpton and Wilbur (1974) found a significant ($P = 0.05$, $t = 3.051$) increase (1.7 times) in catch rate when experienced anglers fished artificial structures versus natural structures.

3.53 Responses to stimuli
(see Table VII, 3.44, 3.51, 3.52, 5.42)

- Environmental stimuli

Largemouth bass have been captured at depths of 23 m (Cady, 1945).

Thermal preferences in the field have been reported as 26-28°C by Dendy (1946) while laboratory thermal preferences of 30-32°C are reported by Ferguson (1958) citing Fry (MS. 1950).

The largemouth bass can distinguish different wave lengths of light (Brown, 1937) but the exact wave lengths that they can detect at various intensities has not been determined. Both rods and cones are present. The cones are in patterns of single and double. No new elements are added with age (Shafer, 1900).

Cummings (1968) postulates that the specific pattern of diurnal variation in swimming activity in bass under natural conditions contains three components: (a) direct response to illumination; (b) a deep-seated, phase-non-labile, 24 hour fluctuation, apparently due to a response to subtle geophysical variations; (c) a phase-labile component which has the tendency to repeat on successive days the pattern imposed during the previous 2 or 3 days.

Nothing is known about the bass' ability to detect sound, but since they do not possess a Weberian apparatus one would suspect they could detect frequencies from 500 to 3 000 Hz with their inner ear.

The acoustico-lateralis system of the largemouth bass has been described by Branson and Moore (1962). There are 11 infraorbital canaliculi and 12 preoperculomandibular pores. The lachrynal neuromasts are of moderate size but shallower than in other Micropterus. The number of supporting cells in relation to sensory elements is 57:23.

The anatomy of the largemouth bass olfactory organs has been described by Eaton (1956). Seven epithelial folds radiate, propeller-like, from a region approximately under the anterior naris. At the posterior end of the nasal sac are found apertures of two accessory pouches, one extends mediad, the other ventro-laterad. The olfactory nerve passes back within the wall that separates the two apertures. Alarm substance(s) have not been demonstrated in the largemouth bass.

- Artificial stimuli

Schools of larval largemouth bass can be displaced by a moving 60-150 W incandescent light source. A point source of light is most effective. Young bass tend to prefer a higher illumination than adult bass, but adult bass also display positive phototaxis. Angling under a light is not as effective in turbid water as it is in clear water. Bass appear to be most active under a light from twilight until 2 hours after nightfall and during the last hour of darkness before dawn (Fore, 1969).

- Electrical
(see 3.54)

Capture by electrofishing with a 2 500 W 60 Hz alternating current does not sterilize the bass (Elder, 1954). Bass held between electrodes spaced 4.7 cm apart were not killed with a 5 min exposure to 3 phase, 180 Hz, 3.1 amp 230 V alternating current (Spencer, 1967).

For a given power output alternating current covers a larger effective area than direct current (Novotny and Preigel, 1974). As the pulse rate of direct current is increased, the power requirement to stun the fish decreases (Novotny and Preigel, 1974; Edwards and Higgins, 1973). Large bass are easier to stun than small bass. Evidently the voltage drop across the fish is very important. With alternating current a drop of 1-2 V/2.53 cm is required.

3.54 Learning

Bass do not learn to do a task as quickly as bluegill sunfish (Lepomis macrochirus). In a single hooking avoidance test, isolated bass made more errors than bluegill (Witt, 1949). Radabaugh (1970) tested the relative learning ability of bass and bluegill for three simple tasks. The performance of the bluegill was far superior to that of the bass. Neither Farabee (1970) nor Radabaugh (1970) found any difference between the learning ability of the male versus the female bass. Individual bass do not have equal learning abilities. A high percentage of the bass used by Radabaugh never mastered any of the three learning tasks. Also, some bass never learn to utilize artificial feed (Snow, 1964; Lewis, Heidinger and Konikoff, 1969).

4 POPULATION

4.1 Structure

4.11 Sex ratio

The sex ratio of fish less than 5 years old has been reported to be approximately 1:1 (Cross, 1951). However, Bryant and Houser (1971) reported the female to male ratio up to 6 years of age to be 1:4, 1:2, 1:5, 2:3, 2:7 and 6:0 respectively. Very old specimens are usually females (see 3.31). At any given time there are usually more males than females on the spawning grounds (see 3.16).

4.12 Age composition
(see maturity 3.12; longevity 3.31)

The majority of bass both by number and weight in a population which has completed at least one generation cycle is less than 5 years old (Table XII).

TABLE XII

Structure of mature bass populations

Reservoir (U.S.A.)	% by number in each year class								Reference
	1	2	3	4	5	6	7		
Wappapella, MO	33	27	14	6	5	10	5		Anderson (1974)
Clearwater, MO	44	41	15	1	-	-	-		(as above)
Lake Carl Blackwell, OK	39	22	16	11	8	3	1		Summerfelt (1975)
Third Sister, MI	49	4	21	18	4	3	1		Brown and Ball (1943)
	% by weight in each year class							Total kg/ha	
	1	2	3	4	5	6	7		
Beaver, AR	10	51	26	5	3	3	1	10.5	Calculated from Bryant and Houser (1971)
Bull Shoals, AR	8	29	16	18	14	10	3	14.4	(as above)
Third Sister, MI	2	2	21	39	15	13	8	14.2	Brown and Ball (1943)

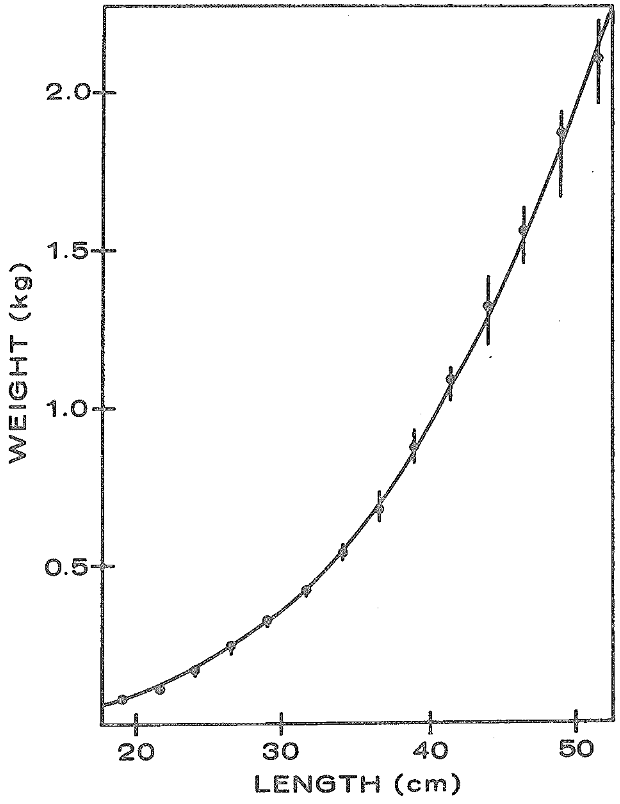


Fig. 5 Average length-weight relationship for largemouth bass. Vertical lines represent the central 50 percent range (after Anderson, 1975)

TABLE XIII

Age and growth of largemouth bass

Locality	Total length in mm at each annulus										Reference
	1	2	3	4	5	6	7	8	9	10	
U.S.A.											
AR (Ft. Smith Lake)	94	190	269	325	391	498					Trenary (1958)
CA (Folsom Lake)	152	284	351	399	434	465					Tharratt (1966)
CA (Sutherland Lake)	178	312	391	447	495						LaFaunce, Kinsey and Chadwick (1964)
IA (18 ponds)	132	231	310	355	363						Moorman (1957)
IL (average)	160	229	295	343	401	442	480	503	516	526	Lopinot (1967)
KY (farm ponds)	147	254	356	399	442	480	526	556			Smith, Kirkwood and Hall (1955)
KY (lakes)	150	292	368	396	483						Tompkins and Carter (1951)
LA (Idlewild Lake)	218	267	287	351	388	498					Muncy (1966)
MO (state-wide)	109	218	292	335	353						Purkett (1958)
MN (average)	99	157	292	350	389	414	429				Mraz, Kimiotek and Frankenberger (1961)
MT (farm ponds)	53	160	260	270							Brown and Thoreson (1952)
NC -	203	274	323	381	429	483	526	561	584	610	Raver and Cornell (1951)
OH (average)	89	178	257	318	368	409	450	480	503		Evans (1948)
OK (average)	140	246	318	378	434	472	505	531	574		Jenkins and Hall (1953)
OR (farm ponds)	66	141	214	250	260						Klavano (1958)
RI (average)	76	162	236	300	366	396	424	460			Saila and Horton (1957)
VA (Back Bay)	130	274	358	404	452	503	541	554			Roseberry (1951)
WI (average)	84	188	267	318	356	384	414				Mraz, Kimiotek and Frankenberger (1961)
N. America (unweighted mean)	119	216	288	345	392	432	467	495	510	528	Carlander[a]
Ontario, Canada (average)	170	221	287	320	348	391	426	450	457	490	Scott and Crossman (1973)
S. Africa	262	356	386	421							Thompson (1939)
France near Paradet	40mm	200g	400g	750g	1125mm						Wurtz-Arlet (1952)

[a] K. Carlander in manuscript material from "Handbook of freshwater fisheries", Vol. 2

In North America the largemouth bass is considered a sport fish. Thus in most waters it is legally caught only on hook and line, primarily on artificial baits or live minnows. Little published information exists on the landings of largemouth bass in those countries where commercial fishing takes place.

The largemouth bass first appears in the creel at approximately 18 cm (2-4 years). However, in many areas both length and numerical limits are applied (see 6.11).

4.13 Size composition
(for maturity see 3.12; longevity 3.31; length and weight relationships for larva 3.22; for adolescent phase 3.23; size at first capture 4.12)

By comparing the age composition of various populations (Table XII) with the total length of bass at various ages (Table XIII), one finds that the majority of bass in a population are less than 35 cm in total length. Hayne, Hall and Nichols (1967) poisoned a 50 ha arm of a large reservoir and found 44 percent of bass to be between 2 and 10 cm, 42 percent between 12 and 23 cm and 14 percent larger than 23 cm.

K. Carlander in manuscript from "Handbook of freshwater fisheries", Vol. 2, has compiled extensive data on the length-weight relationship of bass. Anderson (1975) summarized and plotted these data (Fig. 5).

The average length-weight relationships for bass in Alabama are given in Table XIV.

4.2 Abundance and density (of populations)

4.21 Average abundance

Population densities of 120-240 adult fish/ha represent "strong" bass populations. As the density increases above 240/ha the possibility of a stunted population of 20-25 cm fish increases. "Weak" populations typically consist of relatively few large individuals (Heidinger, 1975).

4.22 Changes in abundance

For a short time after the spawning season larval bass occur at densities of several hundred or more per ha, but in the presence of an established fish population the number is drastically reduced within a month. However, because of their small size little change in biomass occurs.

TABLE XIV

Length-weight relationships of largemouth bass from Alabama (after Swingle, 1965)

Total length (cm)	Number of fish	Range in weight (g)	Average empirical weight (g)	Calculated weights[a/] Standard (g)	Calculated weights[a/] Polynomial (g)	Coefficient of condition (K)
5.1	190	1-7	2	2	3	1.55
7.6	1 083	2-14	6	6	6	1.39
10.2	1 554	3-29	12	14	14	1.19
12.7	1 283	14-6	25	26	27	1.23
15.2	839	16-91	45	45	45	1.28
17.8	391	23-141	77	73	77	1.39
20.3	234	86-181	109	104	113	1.32
22.9	202	91-227	150	150	159	1.26
25.4	208	136-340	209	204	213	1.29
27.9	119	227-635	308	290	327	1.63
30.5	121	113-572	395	386	372	1.50
33.0	70	363-626	490	494	467	1.37
35.6	66	408-907	612	626	608	1.37
38.1	33	544-1 021	758	776	789	1.38
40.6	27	794-1 134	934	953	993	1.39
43.2	25	907-1 402	1 193	1 157	1 225	1.49
45.7	13	907-1 724	1 452	1 384	1 470	1.51
48.3	7	1 361-2 041	1 678	1 642	1 724	1.50
50.8	4	1 729-2 676	2 159	1 932	1 978	1.65
53.3	3	2 268-2 914	2 522	2 259	2 223	1.66

[a/] The standard calculated weights are from equations of the form $W = aL^b$ and polynomial calculated weights are from equations of the form $W = b_0 + b_1 L + b_2 L^2 + b_3 L^3$

TABLE XV

Standing crop of largemouth bass in selected bodies of water

Locality	Sampling method	number/ha	kg/ha	Reference
166 ponds from Florida to Canada	various	395(208-830)[a]	62.9(0.3-173.7)	Carlander (1955)
Ridge Lake, IL	average of 9 drainings over a 21 year period		44.8(30.3-56.0)	Bennett (1971)
Avg. 170 reservoirs U.S.A.	various		10.0(0.1-59.4)	Jenkins (1975)
Cuban lakes	cove sampling	1 505(267-2 744)	92.0(56-129)	Holvik (1970)
30 Oklahoma ponds	various		49.0(2-359)	Jenkins (1957)
12 Ohio ponds	various	472(250-1 668)	69.0(35-119)	Morgan (1958)
9 balanced KY ponds	various		49.0	Turner (1960)
9 unbalanced KY ponds	various		41.0	(as above)
14 midwestern U.S.A. ponds	various	602(3-3 203)	39.0(3-107)	Hackney (1975)

[a] Range

4.23 Average density

Some average densities are shown in Table XV. Additional data are given by K. Carlander in manuscript material for "Handbook of freshwater fisheries", Vol. 2. It will be noted that standing crops are relatively low. This is not surprising in view of the fact that the adult largemouth bass occupies a high trophic level.

Jenkins (1975) examined the correlations between the standing crop of largemouth bass and the standing crops of other fishes in U.S.A. reservoirs. He found a negative correlation (P = 0.20) for longnose gar (*Lepisosteus osseus*) and smallmouth bass a positive correlation ($P > 0.05$) for black crappie, spotted gar (*L. productus*), spotted bass (*Micropterus punctulatus*), white crappie (*Pomoxis annularis*), white bass, gizzard shad, topminnows (*Fundulus* spp.), bluegill, warmouth, longear sunfish (*Lepomis megalotis*), channel catfish (*Ictalurus punctatus*), bullheads (*Ictalurus* spp.), carp (*Cyprinus carpio*), blue catfish (*I. furcatus*), bigmouth buffalo (*Ictiobus cyprinella*). Green sunfish were positively correlated at the $P > 0.20$.

In comparison to standing crop, the literature contains very few values of production or surplus production. High standing crops do not necessarily correlate with high production or surplus production in either fished or unfished populations (Cooper, Hidu and Anderson, 1963; Cooper, Wagner and Krantz, 1971; Houser and Rainwater, 1975; Zweiacker and Brown, 1971; Schneider, 1971).

In a new 1.1 ha pond in Pennsylvania, Cooper, Hidu and Anderson (1963) calculated an annual surplus production of 57 kg/ha in 1959 and 85 kg/ha in 1961. In a 4.0 ha Pennsylvania lake annual surplus production over a 6 year period averaged 6.3 kg/ha (-16.0 to 29.4) (Cooper, Wagner and Krantz, 1971).

Annual production of age I and older bass in Gunnel Fork Cove of Bull Shoals Lake, Arkansas from 1969 to 1973 ranged from 1.8 to 14.4 kg/ha. In Slate Gap Cove of Beaver Lake, Arkansas from 1968 to 1973 annual production of age I and older bass ranged from 2.9 to 35.5 kg/ha (Houser and Rainwater, 1975).

4.24 Changes in density (see 4.22; for catch per unit effort see 5.41)

When a new lake in the United States is opened up to fishing it is not uncommon for fishermen to remove 70 percent of the bass within 6 months (Graham, 1974). In Missouri's public fishing lakes (8-83 ha) with 22-94 trips/ha an average of 40 percent (27-69 percent) of the bass were harvested within the first 4 days.

A widely recognized phenomenon in reservoir bass populations is a very strong population for the first 3-10 years and then a drastic reduction in growth rate (Figs. 3 and 4), standing crop and yield. Various causes have been postulated including increased parasitism, lack of reproduction, overfishing, predation and depletion of nutrients. Lewis (1967) believes that the change in abundance of vulnerable food organisms leads to the decrease in bass populations. The cause(s) of this change has not been completely delineated.

4.3 Natality and recruitment

4.31 Reproduction rates

Bass tend to have a spawning season limited to less than 2 months a year (see 3.16). In culture ponds Bishop (1968) showed that 1.3 kg females produced an averaged 40 500 fry/female. Relative fecundity appears to be directly related to condition and size of fish. Changes in viability of eggs with increasing age of females has not been documented (see 7.2).

4.32 Factors affecting reproduction

Swingle (1956) reported a spawning repressive factor that he believed prevented eggs from being laid. A sudden drop in water temperature does not in itself kill bass eggs. It does cause the male to desert the nest and in most cases the eggs are eaten or will be destroyed by Saprolegnia. Evidently the fanning action of the male is necessary for egg survival (Kelley, 1968; Miller, 1970; Jurgens and Brown, 1954). Removal of the male bass from the nest by angling or other means usually results in mortality of the eggs or newly hatched fry. Ordinarily an uninjured released male bass will return to his nest (Kramer and Smith, 1962).

The hatch of bass eggs in a suitable habitat may exceed 80 percent (Miller and Kramer, 1971; Snow, 1971). The success of the male bass in guarding the nest depends upon the physical placement of the nest, his ferocity and the number of predators, especially other centrarchids in North America (also see 4.33).

4.33 Recruitment

As is the case with many other species of fishes, year class strength of largemouth bass is determined within the first month (Kramer and Smith, 1962). Miller and Kramer (1971) found that the mean number of bass per seine haul after brood dispersal could be used as an index to year class strength. All factors that affect reproduction (see 4.32) affect recruitment.

The introduction of largemouth bass has failed in a number of countries (see 2.1). In South Africa Clarias gariepinus and Barbus anoplus appear to be detrimental (Robbins and McCrimmon, 1974). In Costa Rica the introduction of largemouth bass has failed in rivers containing Cichlasoma dovii (Robbins and McCrimmon, 1974). Bass have been stocked in large reservoirs in Rhodesia. Downstream movement of these fish appears to be limited by the large number of tiger fish Hydrocynus vittatus that are found below the dams (Jubb, 1967).

No correlation has been found between size of spawning stock and recruitment (Summerfelt, 1975; von Geldern, 1971; Kramer and Smith, 1962; Mraz and Cooper, 1957; Mraz, Kimiotek and Frankenberger, 1961; Saila and Horton, 1957; Schneider, 1971). However, because of intraspecific predation there is little recruitment of adolescent fish in small lakes which are overcrowded with 15-25 cm bass.

High recruitment has been correlated with high water levels especially when there is a flooding of new vegetation for several months after spawning occurs (Aggus and Elliot, 1975 r = 0.91; Bross, 1967; Jackson, 1957; Keith, 1975; von Geldern, 1971; Wegener and Williams, 1974). Negative correlations have been found when the high water levels occurred because of cold run off water produced by snow melting in mountain areas. High, especially cold, water may cause a delay in bass spawning, thus allowing the threadfin shad to spawn before the bass, resulting in direct competition for zooplankton between shad and young bass (von Geldern and Mitchell, 1975).

4.4 Mortality and morbidity

4.41 Mortality rates

Swingle (1951) and Brown (1951) stocked a total of 89 new or renovated ponds with bass fry and usually fry of other species. Survival averaged 70 percent (19-100 percent) to age I. Ball and Tait (1952) reported 60 percent survival to age II of stocked fingerlings and Johnson and McCrimmon (1967) reported 42 percent.

Regier (1963) determined the mean survival rates for approximately 1 cm bass stocked in bass-golden shiner ponds to be 83 percent/year for the first 2.3 years and 94 percent/year for the next 2.7 years. Corresponding estimates for bass in bass-bluegill ponds were about 80 percent/year for the first 5 years.

As can be seen from Table XVI the annual mortality rates of bass populations are quite variable. Except where noted mortality rates are for age I and older. Under increasing fishing pressure fishing mortality tends to increase and natural mortality decrease (Table XVII).

Zweiacker and Brown (1971) found higher mortalities of age I, VI and VII bass than age II, III and IV bass. Houser and Rainwater (1975) calculated higher mortalities of age II and III bass than older fish. Bennett (1971) calculated natural mortality of 1-3, 3-5, 5-6, 7-8 and 8+ year old bass to be 33, 13, 15, 39 and 73 percent respectively.

4.42 Factors causing or affecting mortality
(see 4.31 for mortality of eggs and 3.2 for mortality of pre-adults)

Mortality of largemouth bass has been attributed to pollutants (see Table VII), diseases (see 3.35), oxygen depletion due to ice cover (Johnson, 1965), and predators including man. A unique source of mortality is electrical power generating plants. Subadult bass are intrained and impinged by the water required for cooling these units. At present the degree of harm incurred by the bass population due to these units has not been clearly defined.

Holbrook (1975) summarizes the results of initial and delayed mortalities of bass caught in 25 tournaments (see 5.41). Initial mortality in all 25 of these tournaments averaged 21 percent (2-61 percent). Delayed mortality was determined after 8 tournaments and averaged 12 percent (2-36 percent). High mortalities were associated

TABLE XVI

Annual mortality of largemouth bass in various bodies of water

Locality	Year	Mortality (%)			Reference
		Fishing	Natural	Total	
Clear Lake, CA	-	20	36	56	Kimsey (1957)
Sutherland Reservoir, CA	1956	20	48	68	LaFaunce, Kinsey and Chadwick (1964)
(as above)	1957	40	38	78	(as above)
(as above)	1958	47	26	73	(as above)
(as above)	1959	35	20	55	(as above)
(as above)	1960	48	35	83	(as above)
Sugarloaf Lake, MI	-	26	44	70	Cooper and Latta (1954)
Gladstone Lake, MN	1957-1958	14	47	61	Maloney, Schupp and Scidmore (1962)
Whitmore Lake, MI	-	22	20	42	Cooper and Schafer (1954)
Brown's Lake, WI	-	24	12	12	Mraz and Threinen (1957)
Ridge Lake, IL	1941-1963	35-40	25-30	5-11	Bennett (1971)
New York ponds (no fishing)	-	-	20	20	Regier (1963)
Cuba	-	-	-	76-89	Holvik (1970)
Folsom Lake, CA	-	40	49	89	Rawstron (1967)

TABLE XVII

Harvest, mortality and catch statistics for largemouth bass in Merle Collins Reservoir (407 ha) (after Rawstron and Hashagen, 1972)

Year	No. anglers	Angler hours	Annual catch (no.)	No. bass per hour	Mean weight (g)	Mortality (%)		
						Fishing	Natural	Total
1965	3 410	13 007	3 447	0.27	127	36	56	92
1966	5 118	17 376	5 407	0.31	91	45	26	71
1967	8 194	27 801	7 682	0.28	172	62	24	86
1968	10 118	39 930	3 582	0.10	245	65	11	76
1969	11 756	48 222	2 300	0.05	380	65	21	86
1970	11 170	52 860	1 937	0.04	458	-	-	-

with high water temperature. Plumb, Gaines and Jennings (1974) concluded that injections of oxytetracycline did not reduce delayed mortality. May (1973) found that 67 percent of the bass that had swallowed the hook died versus 7 percent that were hooked in the mouth.

4.43 Factors affecting morbidity (for wild populations see 3.35; for cultured see 7.6)

4.44 Relation of morbidity to mortality rates

Due to the young state of fishery science, parasitic infection has not been correlated with mortality unless an obvious epizootic has occurred. We do not know, for example, if a heavy bass tapeworm infection increases the mortality rate of the largemouth bass.

4.5 Dynamics of population (as a whole)

Very few mathematical models dealing with largemouth bass populations have been published and even fewer have been tested. Mathematically either the dynamic pool model approach of Beverton and Holt (1957) or the logistic model (Schaefer, 1954) could be used to describe bass populations. Of the two, the logistic is much simpler in that it only requires catch and effort data. However, Jensen (1974) has shown that numbers and biomass do not act concordantly in Kostitzin (1939), Lotka (1956) or Volterra (1928) competition equations unless average individual biomass is constant. In bass populations it is not constant, thus the logistic approach can be criticized on this point.

Lackey, Powers and Zuboy (1975) have tested a simulation model (STOCKS) on a multispecies lake fishery. This is a stochatic model which emphasizes dynamic interrelationships among bluegill, black crappie and largemouth bass. In this model, analogous processes are not defined; rather, distributions are generated about some expected value for the vital statistics. The output is in terms of yield (catch). With the current sophistication the model at best predicts trends (Fig. 6).

Gasaway (1971) has proposed a model to estimate the costs of sustained stocking of largemouth bass fingerlings or yearlings in reservoirs. The necessary parameters are cost of fingerlings or yearlings, growth rate, annual mortality until the year class comes into the fishery, and exploitation rate after entry into the fishery. The effects of stocking on the existing bass population is not considered.

In order to appreciate some of the more important factors that affect standing crop (stock) Hackney (1974) has stated a simplistic model based on biomass of food available, annual mortality, assimilation of food and average metabolism. His model is as follows: B (biomass of bass possible) = biomass of food x percent assimilated ÷ requirements for metabolism as a percentage of the ichthyomass/day throughout the year + percent annual mortality.

Anderson (1975) considers annual mortality to be extremely important in terms of optimum yield. By using average age-weight data, assuming no natural mortality, no change in growth rate or recruitment, a standing crop of 56 kg/ha and 50 or 80 percent total mortality, he generates the data shown in Table XVIII. The quality points column shown in the Table is based on a mathematical relationship in which a 4.5 kg bass has twice the value of ten 0.45 kg bass. The use of quality points reflects the status of the largemouth bass as a sport fish in the U.S.A. and is an attempt to deal with optimum yield rather than maximum sustained yield.

Latta (1975) used Paulik and Bayliff's (1967) computer programme, which is based on Ricker's model of equilibrium yield per unit of recruitment, to predict the greatest potential yield (Table XIX) with various size limits and exploitation rates. The yield was positively correlated with exploitation rate and maximum at 70 percent exploitation with a 30 cm minimum size limit. Latta (1975) obtained good agreement with this model on 3 out of 4 lakes in Michigan. Apparently the change in growth or mortality due to increase in numbers of bass in these three cases was minimal.

Swingle (1950) from empirical observations in ponds described biomass ratios of predators (bass) to prey in balanced and unbalanced populations (Table XX). According to Swingle's definition of balance,

> "the interrelationships in fish populations are satisfactory if the populations yield, year after year, crops of harvestable fish that are satisfactory in amount when the basic fertilities of the bodies of water containing these populations are considered".

Based on the results of his 1950 study, Swingle (1956) devised a method of analysis which

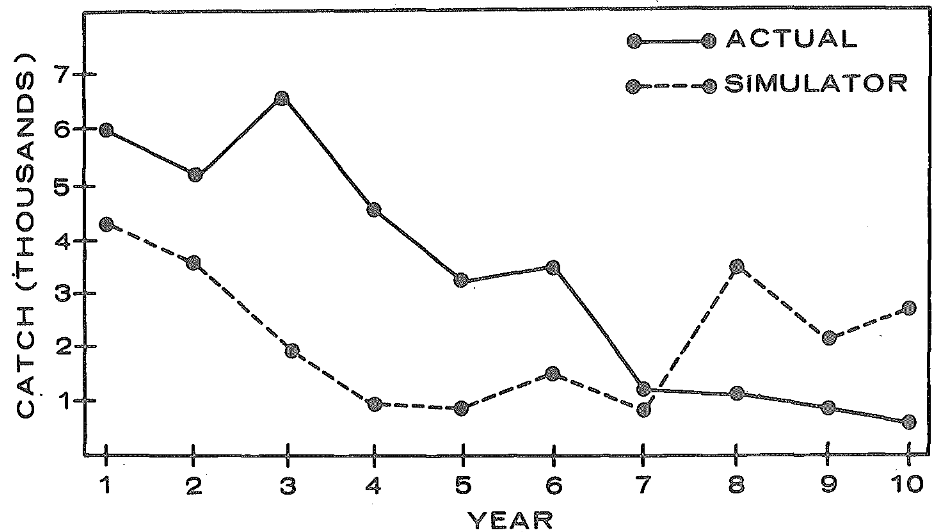


Fig. 6 Predicted yield of multispecies simulation model STOCKS as opposed to actual yield (after Lackey, Powers and Zuboy, 1975).

TABLE XVIII

Harvest and quality of bass fishing at 50 and 80 percent total annual mortality (after Anderson, 1975)

Average/fish		50 percent mortality						80 percent mortality		
		Harvest/ha			Catch and release/ha			Harvest/ha		
Weight (kg)	Quality[a] points	No.	Weight (kg)	Quality points	No.	Weight (kg)	Quality points	No.	Weight (kg)	Quality points
0.34	1.0	29.6	10.08	29.65	17.8	6.00	8.90	47.4	16.08	47.06
0.59	2.8	14.8	8.72	41.51	8.9	5.21	10.29	9.4	5.55	25.98
0.87	4.1	7.4	6.46	30.39	4.4	3.85	9.07	2.5	2.15	10.05
1.19	6.0	3.7	4.42	22.24	2.2	2.60	6.62	-	-	-
1.53	8.2	2.0	3.06	16.31	1.0	1.47	3.92	-	-	-
1.69	9.5	1.7	2.94	16.31	-	-	-	-	-	-
	TOTAL	59.2	35.68	156.41	34.3	19.13	38.80	59.3	23.78	83.09

[a] Quality points are based on a mathematical relationship in which a 4.5 kg bass has twice the value of ten 0.45 kg bass

TABLE XIX

Yield in kg (per 453 kg of young bass recruited) of largemouth bass at four rates of exploitation and various minimum size limits (after Latta, 1975)

Minimum size limit (cm)	Approximate annual rate of exploitation			
	0.20 (½F)[a]	0.35 (1F)	0.55 (2F)	0.70 (3F)
20	1 112	1 276	1 282	1 317
25	1 119	1 425	1 632	1 812
30	994	1 359	1 670	1 912
35	565	879	1 266	1 117
40	332	540	825	1 065
45	75	130	213	282

[a] Instantaneous fishing mortality F = 0.581

TABLE XX

Biomass ratio of bluegill and largemouth bass (after Swingle, 1950)

Ratio[a]	Range	Range of balance	Most desirable range
A_t	0-90.0	33.00-90.0	60-85
Y/C	0.02-16.0	0.02- 5.0	1-3
F/C	0.06-65.0	1.40-10.0	3.6
E[b]	3.10-41.6	9.10-41.6	14-25
A_F	1.20-99.6	18.20-99.6	60-80
I_F	0.00-100.0	0.00-41.4	-
S_F	0.40-95.5	0.40-80.0	15-40

[a] A_t = biomass of catchable fish/total biomass
Y/C = biomass of forage fish small enough to be eaten by average size predator/biomass of predators
F/C = biomass of forage fish/biomass of predators
E = biomass of bass/total biomass
A_F = biomass of large size forage/total biomass of forage
I_F = biomass of intermediate size forage/total biomass of forage
S_F = biomass of small size forage/total biomass of forage

[b] For two species only

does not require a representative biomass sample of the total fish populations. His method can be used in ponds during the second summer after they have been stocked with bluegills and largemouth bass or in older ponds that contain these species. The procedure involves making several shoreline hauls with a 16 m minnow seine. Swingle's interpretation is as follows:

I. No young bass present:

  A. Many newly-hatched bluegills, no (or very few) intermediate bluegills. (Bass overcrowded, temporary unbalance.)

  B. No recent hatch of bluegills, many intermediates. (Unbalanced, bluegills overcrowded, insufficient bass.)

  C. Same as above, plus many tadpoles and/or minnows. (Unbalance, no bass or extremely few bass.)

  D. No recent hatch of bluegills, few intermediates. (Unbalanced, due to crowding by other species, e.g., catfish, shad.)

  E. No recent hatch of bluegills, no intermediates. (Water too cold for spawning (less than 18°C); too saline; or too heavily laden with silt.)

II. Young bass present:

  A. Many newly-hatched bluegills and some intermediates present. (Pond in balance and producing fish in proportion to its fertility.)

  B. Many newly-hatched bluegills and no intermediates. (Temporary balance, but bass overcrowded.)

  C. No recent hatch of bluegills.

    1. Few intermediate bluegills. (Pond overcrowded after bass-spawning period. Usually due to pond's being fertilized last year, unfertilized in current year. Sometimes due to overcrowding by other species which reached a competitive size in late spring or summer, e.g., gizzard shad.)

    2. No intermediate bluegills. (Bluegills absent from pond or unable to reproduce. Water too cold for spawning (less than 26°C) or too saline (salinity 0.5 °/oo or higher).)

    3. No intermediate bluegills, many newly-hatched green sunfish. (Pond probably stocked with green sunfish instead of bluegill.)

    4. Many intermediate bluegills. (Unbalance, same as I-B but less badly overcrowded by bluegills.)

4.6 The population in the community and the ecosystem

Much of this subject is dealt with in other sections of this synopsis. When 8-15 cm Atlantic salmon (Salmo salar) were stocked in the presence of bass, a sample of the bass demonstrated that 25 percent of them had salmon in their stomachs (Warner, 1972). Similarly, when rainbow trout (Salmo gairdneri) were stocked to maintain a "two-storey" fish population, 49, 82 and 91 percent of the 40, 42 and 45 cm bass contained trout. They averaged 5 trout per bass. It was concluded that a trout of at least 25 cm in length is required to avoid heavy loss due to predation (Keith and Barkley, 1971). Predation by bass on stocked rainbow trout has also been reported in Ontario by Stocek and McCrimmon (1965) and in Oregon by Bond (1948).

5 EXPLOITATION

5.1 Fishing equipment

5.11 Gear

In North America bass are taken for sport, primarily by angling. Early anglers used a cane pole with a large live minnow as bait. One of the first artificial lures was a bug-like object made of deer hair. The Seminole Indians of Florida used lures like these as early as 1700. Other North American Indians used floating lures carved from cedar (Logendyke, 1953). Most of the small floating lures were later used as fly rod lures. This type of fishing is now referred to as "bug fishing". The development of a reel holding 50-75 m of line attached to a relatively short, steel or bamboo rod, together with the development of larger and heavier lures was the basis for the present bait casting method of fishing. Although originally developed for catching largemouth bass, this method is now used in fishing for almost every sport fish (Lincoln, 1953). Over the years, bait casting equipment (rod, reel, line and lure) has been continually improved. Today, bait casting reels are light-weight, freespooling and equipped with automatic drags, anti-backlash devices, and level-wind pickup. While the early lines were braided silk, and later nylon, they are now clear or fluorescent monofilament nylon, with a breaking strength of 3-14 kg. Rods have evolved from solid wood, split bamboo and steel, to glassfibre. and finally to high density graphite rods with ceramic or Teflon(R) line guides.

TABLE XXI

Effectiveness of fishing methods used for largemouth bass

Capture	Location	Year	Number/h	Yield kg/ha/year	Reference
Flag gillnet (see Table XXII)					
Yo-Yo	32 lakes in LA	-	0.001	-	Davidson, Posey and Hoenke (1968)
Spearfishing	Lake Mead, NV	1969-1970	0.72	-	Lockard (1971)
(as above)	Nebish Lake, WI	1967	0.28	-	Kempinger (1968)
Trawl (midwater)	Douglas Reservoir, TN	-	0.66 per haul (10 min?)		Hayne, Hall and Nichols (1967)
Hook and Line	46 national bass tournaments[a]	1967-1974	average 0.33 (0.05-1.00)[b]		Hollbrook (1975)
(as above)	National average of 85 U.S.A. reservoirs	-	0.17	6.1	Jenkins and Morais (1971) and personal communication with Jenkins
(as above)	3 fertilized ponds, IL	1947-1952	average 0.26 (0.06-1.21)	13.6 (1.12-33.6)	Hansen *et al.* (1960)
(as above)	3 unfertilized ponds, IL	1947-1952	average 0.29 (0.09-0.56)	12.8 (3.4-37.0)	(as above)
(as above)	11 lakes, AL	-	-	32.8 (10.1-67.2)	Byrd and Moss (1957)
(as above)	Gladstone, MN	1952-1958	-	3.2 (2.1-4.7)[c]	Maloney, Schupp and Scidmore (1962)
(as above)	Mozoe Dam, Rhodesia	-	-	(1 100 kg total)	Toots (1970)
(as above)	Cleveland Dam, Rhodesia	-	-	(65-140 kg total)	(as above)
Electrofishing	6.2 ha lake, IL	1% of population per trip around the lake			Lewis and Flickinger (1967)

[a] Primarily largemouth bass

[b] Range

[c] Fishing pressure of 91 h/ha/year

Concurrent with the development of bait-casting equipment, spinning equipment has been improved and become popular. In general, it permits the use of lightweight lures and is relatively trouble-free as regards the line becoming tangled on the reel. The evolvement of lures has in part been based on a better understanding of the behaviour of the largemouth bass.

One of the earliest commercially available artificial baits was a cigar-shaped design made by Jim Heddon in Michigan. This and similar designs were surface fishing lures. Subsequently lures were developed that can be used at various depths below the surface. In recent years one of the most successful lures has been the plastic worm. It is not easily snagged on underwater obstructions and can be fished at any depth. Furthermore, it is probable that the plastic worm, being soft, avoids the possibility of the lure being as readily rejected by the fish. Various accessory devices have also come into use. Thus in the last ten years the availability of relatively inexpensive sonar sounding devices which detect bottom contours, and even fish, have led to the highly productive method of fishing known as "structure" fishing. Devices for detection of temperature and oxygen values at various depths are also being used.

Probably more bass are caught with minnows, spinner baits and artificial plastic than with all other baits combined. Snow (1971) found that 75 percent of the bass were caught on artificial lures, despite the fact that 50 percent of the fishing was with natural bait.

Even though hook and line methods are most popular, many other methods have been used to capture bass. Spearfishing with SCUBA has been legalized in a few lakes in the U.S.A. (Kempinger, 1968; Lockard, Wood and Allan, 1971). Relatively few bass are caught on trot lines. Yo-Yo fishing also takes relatively few bass (Table XXI). Yo-Yos are automatic spring-loaded devices equipped with a line and a hook that when triggered by the pull of a fish automatically set the hook and play the fish. These are legal in many states in the U.S.A.

Entanglement gear such as trammel nets and gillnets and maze gear such as hoop nets, or wing nets will also capture bass (see 5.41 and Table XXI), but in general their efficiencies are rather low (Starrett and Barnickol, 1955; Vasey, 1972; Buck and Cross, 1952; Grinstead and Gomez, 1972; Bennett and Brown, 1969) (Tables XXII, XXIII, XXIV). Trawls are also inefficient in the capture of bass (Hayne, Hall and Nichols, 1967; Bonn, 1967). In fish management it is often desirable to harvest commercially species such as carp, buffalo (Ictiobus spp.), and other non-game fish without capturing bass.

In fishery research work electrical fishing equipment, seines and fish toxicants are commonly used to sample largemouth bass populations (see 5.44). Electrofishing equipment used in the U.S.A. usually consists of a gasoline powered, 60 or 180 Hz, single or three-phase, alternating current generator of 2 500-3 500 W output, while in Europe direct current units of similar wattage are more popular.

5.12 Boats

Many bass were and still are caught from shore, but boat fishing is very popular and has undergone tremendous change in the last 15 years. Wooden row boats were initially used, while aluminium and fibreglass boats are now the most popular. In the mid-sixties the average boat was 3-4.5 m long, powered by an outboard motor of 18 hp or less.

TABLE XXII

Efficiency of experimental flag gillnets in capturing largemouth bass. Each net consisted of seven 25 m panels 2.6 m deep (after Lambou, 1962)

Bar size (mm)	Total length bass Mean (mm)	Range (mm)	Total caught[a] (number)	Number per net-day[b]
25	295	190-470	3	0.05
38	325	241-508	15	0.23
51	381	343-559	14	0.21
64	455	406-533	7	0.12
76	472	432-521	3	0.05
88	0	-	0	0.0
114	0	-	0	0.0

a/ Total of 70 net-days
b/ Net-day = 1 experimental net set for 24 hours

TABLE XXIII

Selectivity of gill and trammel nets for largemouth bass

	Bar mesh (mm)										
	13	19	24	32	38	44	51	63	76	89	101 + 129
					Johnson, Rinne and Mincbley, 1970						
Number/30.4 m/24 h											
Roosevelt Lake, AR	0.3	1.2	1.3	1.6	-	2.1	0.8 (0.3)a/	0	0.1	-	0.1
Appace Lake, AR	0.1	0.7	0.9	1.6	-	1.5	0.6 (0.6)a/	0	0.1	-	0.0
					Bennett and Brown, 1969						
Number/30.4 m/24 h					0.17	-	0.06	0.02	0.02	0.07	0.02
Weight(g)/30.4 m/24 h					150	-	86	37	24	181	58
					Buck and Cross, 1952						
Number/30.4 m/24 h			4.7	-	0.27	-	0.36	0			
Length range (cm)			16-22	-	26-29	-	33-35	0			

a/ Catch in parentheses for a 30.4 m trammel net fished 24 hours. Outer mesh 254 mm, inner mesh 51 mm

TABLE XXIV

Efficiency of trap nets in capturing largemouth bass

Net description	Number bass caught/ 24 h set	Size range (cm)	Reference
1.1 m diameter, 3 m length, 3 m wings, 18 m lead-nylon	2.5	15-42	Buck and Cross (1952)
1.1 m diameter, 3 m length, 3 m wings, 18 m lead-wire	1.4	17-44	(as above)

Fig. 7 Well equipped high-speed bass boat complete with echosounder, anchors, padded seats, electric trolling motor and aerated live well (photo courtesy of Steve Wunderly)

Today many bass boats are 5-6 m long, powered by 80-150 hp motors. They are capable of attaining speeds of 70 km/h. Two factors have contributed to the increase in size and weight of bass boats: the increased number of large reservoirs have made the larger, heavier bass boats more desirable, while the electric trolling motor has made their use in bass fishing practical. A well equipped bass boat (Fig. 7) has an echosounder, winch-operated anchors, padded pedistal seats, 12-24 V electric trolling motor (used for positioning the boat), an aerated live well, oxygen meter, light meter and thermister.

5.2 Fishing areas

5.21 General geographic distribution (for geographic distribution see 2.1)

The largemouth bass is fished in all waters where it occurs.

5.22 Geographic ranges (see 2.1)

5.23 Depth ranges

Largemouth bass have been caught at depths of at least 25 m (Cady, 1945). In the many eutrophic lakes inhabited by bass the absence of oxygen in deep water limits their vertical distribution.

5.24 Conditions of the grounds

Two factors have increased the area which the largemouth bass now occupies. One has been the introduction of bass into other countries from North America, and the other has been the construction throughout the world of new reservoirs.

A number of events have decreased bass habitat. Stream and river channelization, which results in silting of backwater areas, has destroyed bass habitat. Municipal and industrial pollution has degraded water quality in many parts of the world. In the U.S.A. from 1960 to 1972 over 144 million fish were reported killed in 4 200 incidents (Mackenthum, 1972). The number of bass was not given.

5.3 Fishing seasons

5.31 General pattern of season(s) (see 5.41)

Except where prohibited by law (6.12), bass are caught all year round. However, peak effort and catches characteristically occur in the spring (Lagler and DeRoth, 1952; Snow, 1971).

5.32 Dates of beginning, peak and end of season(s) (see 6.12)

5.33 Variations in date or duration of season (see 5.41, 6.11, 6.12)

5.4 Fishing operations and results

5.41 Effort and intensity

Heidinger (1975) cites 295 references that contain information on catch per unit effort by hook and line and 169 references that contain information on catch/unit effort by other methods than hook and line. Selected values are given in Tables XXI, XXII, XXIII, and XXIV.

Catches of between 1 and 2 fish/h over at least a 12 month period have been documented only a few times (Hansen et al., 1960; Trautman, 1941). It has been estimated that 126 legal-size bass/ha would be needed to provide an average catch of 1 bass/h (Lagler and DeRoth, 1952).

In the past few years there has been an upsurge of interest in bass fishing stimulated by bass clubs and groups such as the Bass Anglers Sportsman Society (BASS). An outgrowth of these organizations has been the proliferation of bass fishing tournaments (Lorenzen and Heidinger, 1973). An even more recent outgrowth of this interest in the largemouth bass was the establishment in 1974 of the Bass Research Foundation (BRF).

The growing number and commercialization of bass fishing tournaments has generated some concern among anglers and fishery managers about the effect of these tournaments on bass populations. In most tournaments efforts are made to release the bass alive after weighing. At the present time it appears that the large national tournaments do not overfish bass populations (Holbrook, 1975). In most reservoirs, large national fishing tournaments have accounted for less than 4 percent of the total yearly harvest of bass by all fishermen. National tournament fishermen catch bass at a slightly faster rate than do nontournament anglers (Table XXI), but like ordinary fishermen the "pros" seldom catch a legal limit. Tournament caught bass are typically small (average 0.84 kg) females (61 percent) (Holbrook, 1975). Because of the large number of bass caught (approximately 1 000) in a relatively short period (usually 3 days), bass tournaments offer the opportunity to investigate population size, movement, etc.

5.42 Selectivity

Colour, mesh size and construction affect the selectivity of entanglement and maze devices. Of 9 colours of gillnets used (red, orange, yellow, green, blue, violet, brown, black, clear monofilament), yellow caught the most large bass and red the fewest (Jester, 1973). Flag gillnets of larger than 76 mm bar mesh capture very few bass (Table XXII). Both gillnets and trap nets capture relatively few bass and are size selective (Tables XXIII, XXIV).

5.43 Catches (see 5.41 and Table XXI)

Jenkins (1967), using multiple regression analysis to investigate the influence of environmental factors on standing crop and harvest of fishes in U.S.A. reservoirs, determined the following:

1. An increase in total dissolved solids correlates with an increase in standing crop and sport fish yield;
2. An increase in reservoir age correlates with an increase in clupeid crop and commercial harvest, a decrease in sport fish harvest and little change in standing crop;
3. An increase in storage ratio correlates with a decrease in standing crop and commercial harvest and an increase in sport harvest;
4. An increase in reservoir area correlates with a decrease in sport harvest (due to decrease in effort/unit area);
5. An increase in mean depth correlates with a decrease in total standing crop, sport harvest, and commercial harvest;
6. An increase in shoreline development correlates with an increase in standing crop and sport fish harvest, but a decrease in commercial harvest.

For yield/ha/year by hook and line see Table XXI.

5.44 Sampling and marking

Reported information on bass populations exhibits considerable variation. A portion of this variation is due to sampling error rather than biological variation. Validity of various methods used to estimate some parameters are summarized in Table XXV. One of the most comprehensive studies on the bias associated with rotenone-sampling of coves was reported by Hayne, Hall and Nichols (1967) (Table XXVI). Cove samples tended to overestimate Swingle's F/C ratio. Barry (1967) found rotenone sampling provided a better estimate of standing crop, but electrofishing gave a better estimate of the relative abundance of various species.

TABLE XXV

Validity of various types of population estimates

Lake area (ha)	Sampling method	Mark and recovery formula estimate: Schnable Number	Schnable Weight (kg)	Krumholz (1944) Number	Petersen Number	Rotenone Number	Rotenone Weight (kg)	Population obtained by draining: Number	Weight (kg)	Reference
3.5	Electrofishing	304			469			604		Swingle et al. (1966)
2.5	Seine (40 x 5 m)			180				221		Hundley (1954)
16.0	Seine	64	28					17	17	Elkin (1955)
0.3	Seine				57			59		Carlander and Moorman (1956)
396.0	Seine (650 x 5 m) (13 hauls)	16 (10–26)[a]	9 (4–18)					29	30	Threinen (1956)
36.0	Rotenone cove sample					171	30	71	24	Barry (1967)
200.0	(as above)					62	12	11	10	(as above)
10.0	Fyke net			51				159		Krumholz (1944)

[a] Range

TABLE XXVI

Validity of cove rotenone samples as an estimate of numbers and weight of young (2.5–10.2 cm), intermediate (12.7–20.3 cm), and harvestable (>22.9 cm) size bass in a 46.5 ha arm of Douglas reservoir, Tennessee (after Hayne, Hall and Nichols, 1967)

	Outer 5 coves (1.2–1.6 ha)	Inner 5 coves (0.8 ha)	2 ha cove	Minor 9 coves (0.2–0.8 ha)	All 20 coves	Shoreline	Open water	Grand total
No/ha	168	296	217	274	237	178	116	158
Kg/ha	13	14	13	17	14	13	16	16

Bias[a] of numerical estimates at various sampling sites and its level of statistical significance[b]

Young				Intermediate				Harvestable				Total				
0.8 ha	1.2 ha	2 ha	shore-line	0.8 ha	1.2 ha	2 ha	shore-line	0.8 ha	1.2 ha	2 ha	shore-line	0.8 ha	1.2 ha	2 ha	minor cove	shore-line
***	*	***		*				*		*		***		***	***	
2.81	1.25	1.86	1.29	1.30	0.94	1.08	1.06	0.55	0.75	0.69	0.71	1.87	1.05	1.37	1.61	1.12

Bias[a] of weight estimates at various sampling sites and its level of statistical significance[b]

Young				Intermediate				Harvestable				Total				
***	*	***						*		*						
2.72	1.25	1.82	1.35	1.22	0.87	1.01	0.94	0.53	0.76	0.68	0.75	0.89	0.82	0.86	1.01	0.85

[a] Bias = Number or weight of bass found in a given sampling site divided by total number or weight in all samples

[b] * = $0.05<p\leq0.20$ ** = $0.01<p\leq0.05$ *** = $p\leq0.01$

Buck and Thoits (1965) used a seine that covered 90 percent of the water to obtain a series of Petersen mark and recovery estimates on three 0.4 ha ponds. The ponds were then drained. For all groups of bass, the average percentage of error was 28.1. When restricted to fish older than age 0, the average percentage of error was 19.8. The principal source of error was the recapture of too many marked fish. Underestimations exceeded overestimations by rates of 46 to 16.

Ordinarily not all bass are recovered by draining or poisoning. Swingle et al. (1965) recovered 71 percent of the marked fish in a small pond. Henley (1967) used SCUBA to determine the sampling error for 11 cove rotenone samplings (0.4-0.6 ha). After 3 days an average of 84 percent of the bass floated to the surface and were recovered.

Under most conditions mark and recovery estimates tend to underestimate both weight and number of bass. In the presence of extremely low population densities the method appears to overestimate the population (Lewis, Summerfelt and Bender, 1962). Total estimates are always lower than the sum of size-class estimates. Cove samples tend to overestimate the numbers of subadult bass (Table XXVI).

Because of their selectivity, creel data, entanglement devices and maze devices do not give reliable information on population structure (Tables XXVII, XXVIII). The validity of creel census data depends upon reporting of marked fish by fishermen. Exploitation rates based on such data may vary considerably for a given population due to the non-reporting of tags. In two studies in California waters failure to report was approximately 40 percent (Rawstron, 1971, 1972); in a similar study in Massachusetts, failure to report was 25 percent (Stroud and Bitzer, 1955).

Numerous marks and tags have been used on largemouth bass. Fin clipping was one of the first methods used for marking largemouth bass; as is the case of all marking or tagging, the question arises as to the effect of the procedure on the fish. Ricker (1949) concluded that young-of-the-year bass 4.8 cm long with one fin removed suffered twice the natural mortality of unmarked fish, but bass larger than 13 cm in total length were not subject to differential mortality. Meehean (1940) found that after 5 weeks, pelvic, dorsal or pectoral fin clips on fingerling bass were not discernable. However, Eipper and Forney (1965) reported that when the distal half of the pectoral fin of 15-18 cm bass was removed, even though the fin regenerated, a permanent thickening or bending of the rays was evident. This was not

TABLE XXVII

Comparison of population structure based on fyke net and poisoning on a 4 ha lake (after Krumholz, 1944)

Total length of bass (mm)	Fyke net		Poison	
	Number	%	Number	%
51-100	3	12	21	12
101-150	5	20	26	14
151-200	13	52	38	21
201-250	4	16	82	45
251-300	-	-	11	6
301-350	-	-	4	2

TABLE XXVIII

Comparison of largemouth bass population structure by weight and number using various sampling methods

Lake area (ha)	Gillnet		Cove rotenone		Hook and line		Draining		Reference
	Number %	Weight %	Number %	Weight %	Number %	Weight %	Number %	Weight %	
36	27	45	1.7(3)[a]	18(3)	5.5	17.4	1.6	12.4	Sandow (1971)
15			3.0(1)	22(1)	32.3	45.5	1.2	16.0	Barry (1967)
81			1.4(1)	4(1)	3.7	22.9	0.5	3.3	(as above)

[a] Number of coves sampled in parentheses

TABLE XXIX

Retention time of various tags used for marking largemouth bass

Tag type	Tag location	Duration of study (months)	Retention (%)	Reference
Spaghetti[a]	Below and behind dorsal	24	17	White and Beamish (1972)
Frazer[a]	(as above)	24	17	(as above)
Atkins	Below posterior base of soft dorsal	7	10	Latapie (1968)
Petersen disc	Midway between spiny dorsal and lateral line below middle	7	0	(as above)
Spaghetti	Same as Atkins	7	5	(as above)
Strap	Opercle upper edge	7	0	(as above)
Dart	Midway between spiny dorsal and lateral line below middle	7	5	(as above)
Strap	Premaxillary or maxillary	1	30	(as above)
Disc dangler[b] (modified Atkins)	2 wires below posterior base of soft dorsal	24	100	Kimsey (1956)
Petersen disc	2.5 cm below dorsal[c]	1.3	53	Kirkland (1963)
Petersen disc	3 scales anterior to origin of caudal ray[c]	1.3	85	(as above)

[a] Used monofilament: 2 people can apply 30 tags/h

[b] For every 5 cm increase in fork length there is a 25 mm increase in width. Thus for a 23 cm bass in California waters 2 year's growth are required before pressure is placed on the bones. Tantalum wire was best since it aided in immobilizing the tag

[c] Tag was attached with a stainless steel pin

TABLE XXX

Percentage retention time of various Floy$^{(R)}$ dart tags on adult bass (after Wilbur and Duchrow, 1973 except where noted)

Tag type	Time (months)	Colour		
		orange	green	brown
FD-67	3	58	62	63
FD-67	3	78		
FD-67 (standard)	3	47		
FD-67 C	3	75		
FD-68 D	3	88		
FD-68 B a/	1	51		

a/ after Moody (1974)

true when the anal fin was clipped. Fin clipping does not appear to affect growth (Ricker, 1949). Follis (1972) used air injected (120-140 psi) fluorescent particles (50-350 microns) to mass mark 6-13 cm bass. These fish were 100 percent identifiable after 12 months and 80 percent after 30 months. Carlson and Shealy (1972) used 85 Sr to mark bass eggs and fry. Fry 1-7 days after hatching took up more Sr than did eggs. Marked fry could be detected for several months. Pritchard (1972) cold branded (-80°C) 100 mm bass. The brands were 100 percent identifiable after 10 months, but mortality was 67 percent versus 43 percent for controls.

Many types of tags have been used on largemouth bass with varying results (Table XXIX). Huish and Copeland (1963) found no difference in the percentage return of strap tags versus Petersen tags. White and Beamish (1972) found no difference in return ($p>0.05$) of spaghetti tags versus Frazer tags. However, strap tags attached to the mouth area interfered with growth (Tebo, 1957; Wegener, 1966). Fish marked with anchor tags had a 30 percent loss and 61 percent mortality after 10 months.

The use of different Floy$^{(R)}$ dart tags has resulted in differences in length of time the tags are retained (Table XXX). In many cases the anchor was not pulled out of the fish, but the plastic tubing was pulled off the anchor attachment. Ten cm bass will rapidly shed Floy$^{(R)}$ tag FTF-69 (R. Amick, personal communication).

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (legislative) measures

6.11 Limitation or reduction of total catch

The Black Bass Act was passed by the United States legislature in 1926. This law prevented the interstate transport of black bass for sale. Since that time all states have legislated against the sale of black bass which are caught in the wild, thus assuring their status as a sport fish.

In the U.S.A. in 1974, three states had a 23-cm, seven a 25 cm, and four a 30 cm minimum size limit. In addition, fourteen states have a minimum size limit, from 25 to 45 cm, on certain waters. Creel limits average 9 (5-25) bass per day. Thirty-four states have a continuous season, while eight states have a special season; most of these regulations protect the bass from angling during spawning (Fox, 1975). Regulations in a number of other countries are given in Table I.

Quota limits are used on relatively few lakes. The State of Alabama attempts to limit the annual yield of largemouth bass in its State-owned public fishing lakes (13) to 35 percent of the standing crop. Only trophy size bass of at least 2.3 kg are allowed to be creeled after the quota has been reached (Powell, 1975).

6.12 Protection of portions of population (see for season limits and for length limits)

Minimum length limits of 253-306 mm are being applied in a number of areas (see 6.11). In studies of length limits by Choate (1970), Martin et al. (1964) and Prosser (1973) no beneficial effects were demonstrated for the bass population nor was there evidence of improvement in size composition of the bluegill population. Ming and McDonald (1975) attributed these results to a lack of a strong year class of bass in the population before the length limit was established. However, Schneider (1971) found no change in the largemouth bass population in a 55 ha Michigan lake which was closed to fishing for 5 years. In a Missouri lake (97 ha) which had been heavily fished, a 306 mm length limit on largemouth bass increased the catch rate (Ming and McDonald, 1975). Gulish (1970) and Sheridan (1962) found an increased harvest of larger bluegill, but no appreciable change in harvest in bass after a size limit was applied.

Length limits of 354-404 mm are currently under investigation in the U.S.A.

Several methods besides length limits, creel limits, closed season and quotas have been investigated in an attempt to reduce the initial large harvest of bass (see 4.24) after opening (2-3 years after stocking) of a new lake. An initial 16 day catch and release period (286 h/ha) did not reduce the opening week catch, in that 40 percent of the adult population was removed in the first 4 days with 93 h/ha of effort (Redmond, 1974). Allowing the lake to be fished immediately after stocking led to an overabundance of bluegill within 3 years. A midwinter opening was also unsuccessful (Redmond, 1974). By not allowing approximately 40-90 percent of the area of a new lake to be fished, the initial 40-70 percent harvest of bass is spread out over several months instead of 1 or 2 weeks (Redmond, 1974; Hill and Shell, 1975).

6.2 Control or alteration of physical features of the environment

6.21 Regulation of flow

The maximum current velocity acceptable at the intake of electrical power generating plants is currently under investigation. At the present time no flow regulations are enforced.

6.22 Control of water levels (for benefits in recruitment see 4.33; for aquatic weed control see 6.41)

Control of water levels is an important management tool, but desirable water levels for bass may conflict with flood control projects, hydroelectric generating requirements, or waterfowl management needs.

6.23 Control of erosion and silting

In most cases control of erosion and silting involves planting the watershed with suitable vegetation, riprapping the shoreline, and fencing cattle from the water. Colloidal clay can be settled by adding gypsum or organic material such as chopped hay (Bennett, 1971). Even though bass can feed in turbid water (see 3.41), high turbidity limits primary and secondary production thus reducing standing crops and growth rate of bass (Buck, 1956) and adversely affects spawning.

6.24 Fishways at artificial and natural obstructions

Schafer and Greagan (1958) reported 540 bass going up the Lake Chicot, Louisiana, fishway in 1955, and 270 in 1956.

6.25 Fish screens

Because of the escape of bass and other fishes over spillways (see 3.51), screening is recommended (Lewis, Heidinger and Konikoff, 1968). At the present time a practical screen for large reservoirs has not been developed and tested. The escape of fish from lakes and reservoirs is one of the most serious problems in inland fish management at this time.

6.26 Improvement of spawning grounds (for improvement in culture situations see 7.3)

Natural spawning grounds have seldom been successfully improved except by controlling water levels (see 4.33). Vogele and Rainwater (1975) found that largemouth bass preferentially ($P>0.20$) nested near brush shelters especially early in the spawning season. James (1936) used 500 floating bass nests (0.8 cm x 10 cm wooden frame filled with rocks) in a reservoir subject to violent water level fluctuations. He noted heavy utilization, but the contribution to the year class was not determined.

6.27 Habitat improvement

Various types of habitat improvements have been made. In farm ponds it is desirable to fence cattle from the pond to prevent erosion and excess turbidity. Protection of the watershed by plants is also desirable. Some acid stripmine waters have been neutralized with lime or by running water through them from a well buffered source.

Numerous attempts have been made to destratify lakes (Toetz, Wilhm and Summerfelt, 1972), but changes in bass populations have not been documented.

The effect on catch rate of leaving standing timber in new lakes has been investigated in several studies (Table XXXI). In general there is a greater harvest per ha in the timbered areas because of increased fishing effort.

It is extremely difficult to maintain population balance (see 4.5 for definition) in small ponds. Hooper (1970) determined balance in 33 Alabama ponds ranging in size from 0.07 to 0.10 ha. He found only 7 in balance after 2 years. Hooper (1970), citing Kelley, reported 68 percent of the ponds larger than 0.10 ha were in balance after 2 years. However, Hooper and Reeves (1975) found only 5 of 40 (0.20-0.40 ha) to be in balance after 2 years. These ponds had been stocked with the recommended 2 470 bream (bluegill and redear) and 247 bass/ha.

6.3 Control or alteration of chemical features of the environment

6.31 Water pollution control

In the U.S.A. with the establishment of state and federal environment protection agencies, minimum water quality standards have been set and are being enforced by fines. One problem has been to establish a monetary value for largemouth bass.

TABLE XXXI

Harvest of largemouth bass from cleared and non-cleared areas of a lake

Lake	Standing timber			Cleared area			Reference
	Catch rate		Angling effort (%)	Catch rate		Angling effort (%)	
	No./h	kg/h		No./h	kg/h		
Lake CA (2 884 ha)[a]	0.17[b] (0.15-0.18)[d]		75	0.25 (0.16-0.33)		25	Bartholomew (1972)
Bussy Lake[c] LA (891 ha)	0.71 (0.45-0.97)	0.39 (0.33-0.48)	50-90	0.73 (0.47-1.00)	0.41 (0.28-0.51)	50-100	Davis and Hughes (1971)

[a] Timbered area 2.5 ha or 0.26%
[b] Average of 3 years
[c] Approximately 17 km of timber in bands 91-137 m wide
[d] Range

The Southern Division of the American Fisheries Society recommended the following values be used for recovery of damages from pollution-caused bass kills in the southeast (Sherry, 1971):

Length (cm)	Value U.S.$	Length (cm)	Value U.S.$
2.53	0.20	17.71	1.00
5.06	0.25	20.24	1.25
7.59	0.35	22.77	1.50
10.12	0.50	25.30	1.75
12.65	0.65	27.83	2.00
15.18	0.75	30.36	2.25

Bass larger than 454 g (approximately 30 cm) were valued at U.S.$ 5.00/kg. Similar values were placed on bass by the State of Illinois Department of Conservation (Lopinot, 1971). However, based on angler expenditures, Bennett and Durham (1951) estimated bass to be worth U.S.$ 19.12/kg.

6.32 Salinity control

No information available.

6.33 Artificial fertilization of waters

Hooper (1975) briefly reviewed the use of inorganic fertilizers to increase bass production. Based primarily on the work of Swingle at Auburn University, Auburn, Alabama, Hooper concluded that commercial fertilizer mixtures of 8-8-2 (112 kg/ha/year) can be used to increase production of fish in new ponds. The catch of largemouth bass from relatively infertile ponds stocked with a combination of bass and bluegill more than doubled as a result of fertilization. Ponds which have been fertilized 3-5 years with 8-8-2 can then be maintained with phosphate only (16.8 kg/ha/year tripple superphosphate), thus reducing the cost by approximately 70 percent.

6.4 Control or alteration of biological features of the environment

6.41 Control of aquatic vegetation

The largemouth bass often occupies waters which support a luxurious growth of aquatic vegetation. It is likely that in many cases this vegetation serves as a substrate for larval insects or other food organisms utilized by the bass. Also, the vegetation may serve as a refuge area and ensure survival of the young bass. Aquatic weed control is practised, however, in an attempt to improve bass fishing. Weed control serves to eliminate the refuge area for small fishes and makes them more susceptible to capture by the bass, and to improve accessibility to fishing grounds. Methods of control of aquatic vegetation include the use of herbicides, fertilization, mechanical removal, water level manipulation, and attempts at biological control.

6.42 Introduction of fish foods (plant, invertebrate, forage fishes)

With a few exceptions, invertebrates or plants have not been introduced to increase the yield of largemouth bass. The bluegill sunfish is the species most commonly stocked in combination with the largemouth and as forage for it. This practice is used particularly in small ponds and lakes. In recent years the threadfin shad has been widely used in large reservoirs as forage for largemouth bass.

Range (1971) found no increase in growth rate of 1, 2 and 3 year old bass within 2 years after threadfin shad were introduced into Dale Hollow (12 540 ha), Tennessee. Numerical change or population structure changes were not investigated. The threadfin shad was introduced into Lake Havasu, California in 1954. All age groups of bass showed improved growth (Kimsey, Hagy and McCammon, 1957). Similar trends were found after threadfin were introduced into Lake Nacimiento, California (von Geldrin and Mitchell, 1975). However, Miller (1971) concluded that threadfin in Pine Flat Lake, California decreased the growth of 1 year old bass. A mail survey of state agencies (von Geldrin and Mitchell, 1975) concluded that the threadfin shad is a desirable forage fish for bass (also see 4.33).

Atherina mochon was introduced as forage in Sardinia (Cottiglia, 1968). In Kenya, *Tilapia nigra* was added for forage (Harrison, 1936). McCaig and Mullan (1960) found no change in the bass population in a 10 117 ha Mississippi lake after the introduction of smelt (*Osmerus mordax*).

In the late sixties *Tilapia aurea* were inadvertently introduced into Lake Trinidad, a power plant cooling reservoir in Texas. Recruitment of the northern largemouth bass ceased and annual stocking of the Florida subspecies since 1972 has failed to result in successful spawns. In spite of high survival and rapid growth of the stocked bass, tilapia densities of 2 240 kg/ha were reported (Noble, Germany and Hall, 1975).

6.43 Control of parasites and diseases

Because of the expense, very little parasite or disease control has been attempted except under culture situations (see 7.6).

6.44 Control of predation and competition

Fish toxicants, traps, seines and electrofishing have all been used in an attempt to change population composition. Dense populations of bluegill exhibit slow growth, subcatchable size, and may prevent bass recruitment. Many attempts have been made to either reduce or eliminate these populations especially in ponds and small lakes. Complete renovation with rotenone has in general been the most successful.

TABLE XXXII

Effects of complete or partial removal of fish on the remaining fish population

Lake and location	Removal method	Fish removed	Comments	Reference
14 lakes, MI	Seine	109 kg/ha for 25 years, primarily carp and brown bullheads	No effect on rough fish population or on total pounds of game fish	Moyle, Kuehan and Burrows (1949)
Bass lake, IN (648 ha)	Seine	99 kg/ha of carp, suckers and buffalo	Water cleared; average catch of bass/seine haul increased from 0.1 to 0.6	Ricker and Gottschalk (1941)
Lake Chautauqua, IL (1 442 ha)	Traps	Avg. 93 kg/ha for 5 years, primarily buffalo, carp and shad	Removal of approximately 20% of total standing crop of rough fish did not change standing crop of bass population	Starrett and Fritz (1965)
Flora Lake, WI (16.6 ha)	Traps	Rough fish for 5 years	No change in growth rate of bass but standing crop increased from 4.3 to 6.8 kg/ha and yield increased from 15.4 kg in 1952 to 66 kg in 1955	Parker (1958)
Oklahoma Lake (6.9 ha)		2-19% of total standing crop for 4 years, primarily bluegill and black bullheads	No change in bass	Houser and Grinstead (1962)
Lake Hollingsworth, FL (144 ha)	Seine	270 kg/ha in 2 years (gizzard shad and brown bullheads 96%) pre-standing crop 168-336 kg/ha	Number of bass increased from 2.7/ha to 114/ha; growth rate also increased	Ware (1971)
225 IL ponds (average 0.5 ha)	Rotenone average 2.3 ppm	Incomplete removal in 31% of ponds	Ponds tended to be over-populated with small or undesirable fish in 5 years	Lopinot (1970)
Lake Blackshear, OK (3 300 ha)	Rotenone 0.1 ppm	Gizzard shad reduced from 60% to 15% of total standing crop	Shad and bass population reached pretreatment levels within 5 years	Zeller and Wyatt (1967)
Clear Lake, LA (46 ha)	Seine	257 kg/ha 90% gizzard shad over 2 year period	Harvest of bass increased during the following 5 years	Lambou and Stern (1959)
Mediana Lake, TX	Drawdown and rotenone	Primarily gizzard shad	Increase in condition, numbers and growth during following 2-3 years	Dietz and Jurgens (1963)
3 lakes, MI (52-90 ha)	Antimycin (1.0-1.25 µg/l)	10-90% of the bluegill	Did not affect bass	Lincoln and Smith (1974)

However, these ponds often become unbalanced (for definition of balance see 4.5) again within 5 years.

Removal of a portion of a fish population has met with varying success (Table XXXII). Hackney (1974) has shown that assuming that food supply remains constant, 70 percent of the bluegill (by numbers) would have to be removed to increase the average length of bluegill from 10 cm to 15 cm. Thus it does not seem feasible to remove sufficient bluegill by electrofishing (Spencer, 1967), by trapping or by destroying their nest. Balance in ponds was obtained with several shoreline applications of rotenone by Hooper and Crance (1960), Swingle (1954), and Smith, White and Hooper (1975).

The use of rotenone for the selective reduction of overcrowded fish populations in bodies of water from 0.4 to 12 141 ha spread rapidly during the fifties. Pond treatments were intended primarily to reduce overcrowded sunfish populations, but in large bodies of water the target species also included gizzard shad, carp, drum (Aplodinotus grunniens), and catostomids, as well as other species. Marked improvement in bass reproduction occurred in many waters (Burress, 1975). However, the benefits lasted only 2-5 years and did not justify the cost (Burress, 1975; Stroud and Martin, 1968). By 1965 this management technique had become restricted to small bodies of water (Jenkins, 1970; Burress, 1975). Bennett (1971) recommends thinning before bass spawning season or immediately after bluegill spawning season. Swingle, Prather and Lawrence (1953) recommend supplemental stocking of bass fingerlings following poisoning.

Antimycin was introduced in the late sixties and has partly replaced rotenone. It is less toxic to bass than to other centrarchids and is effective in cool water, but is ineffective at high pH.

For a recent review of reclamation of ponds, lakes and streams with rotenone and antimycin see Lennon et al. (1970) and Schnick (1974a and 1974b).

6.45 Population manipulation

"Super predators" such as the muskellunge (Gammon and Hasler, 1965) have been added to existing bass populations containing excessive numbers of slow-growing forage fishes. In most cases no change in bass or forage fish populations have been documented. At present in the U.S.A. striped bass are being stocked in many of the large reservoirs in an attempt to utilize the large gizzard shad populations. Changes in the bass populations due to the introduction of striped bass have not been clearly demonstrated.

Lake drawdown has been demonstrated to increase the vulnerability of forage fishes and increase feeding activity of bass (Heman, Campbell and Redmond, 1969; Bennett, 1962). Heman, Campbell and Redmond (1969) found an increase in bass growth rate after a drawdown. However, when weak bass populations are present at the time of a lake drawdown, mathematical computation demonstrates that little change in the weight of the forage fish population can be expected as a result of bass predation. Pierce, Frey and Yawn (1964) made similar findings for 15 Alabama lakes. Probably of more importance is the possibility of development of a strong year class of bass when the lake refills, as was found by Hulsey (1957) and Bennett, Adkins and Childers (1969). Wegener and Williams (1974) reported the effects of a drawdown on Lake Tohopekaliga, Florida, where 50 percent of the lake bottom was exposed for nearly 6 months (Table XXXIII).

6.5 Artificial stocking

6.51 Maintenance stocking

Unless preceded by at least partial renovation, maintenance stocking of fry or fingerling largemouth

TABLE XXXIII

Largemouth bass standing crop in Lake Tohopekaliga, Florida (9 186 ha), before and after a 6 month drawdown of 50% of surface area (after Wegner and Williams, 1974)

	Before drawdown		After drawdown[a]				
	Spring 1970	Autumn 1970	Autumn 1971	Spring 1972	Autumn 1972	Spring 1973	Autumn 1973
			Number/ha				
Littoral	215	168	264	1 268	724	111	277
Limnetic	79	17	12	72	44	25	25
			Kg/ha				
Littoral	53	38	39	56	72	28	54
Limnetic	8	9	4	3	3	3	7

[a] Spring 1971

bass has been ineffective in reducing overcrowded forage fish populations (Clark, 1964; Kempinger, 1969; Lagler and DeRoth, 1952; Viosca, 1945; McKay, 1960; Jackson, 1958; Swingle, 1945; Carlander and Moorman, 1957).

Fieldhouse (1971) stocked 1 350 3 cm bass in a 62 ha lake. Over the following 3 years they constituted 42 percent, 36 percent and 18 percent of that year class respectively.

Fast (1966) stocked bass ranging in size from fingerling to fish 0.7 kg in weight in El Capitán Reservoir, California. Few of the small fish survived, but 56 percent of the large bass were caught by the end of the second year.

Stroud and Bitzer (1955) estimated 65 percent survival for adult bass salvaged from closed water supplies and restocked in public waters. They estimated that 11 percent of these fish were ultimately caught.

In general, because of culture limitations, large numbers of bass greater than 3 cm in length have not been available for use in research or management.

6.52 Transplantation; introduction (for world wide introduction and distribution see 2.1 and Table V)

6.53 Stocking combinations (ponds) (for introduction of forage fishes into large reservoirs see 6.42)

The use of various stocking combinations has usually been limited to small lakes. Dillard and Novinger (1975) and Wenger (1972) have recently reviewed the U.S.A. literature concerning largemouth bass stocking techniques.

In the U.S.A. during the early 1900s it was believed that poor fishing was caused by a lack of fish and could be corrected by stocking fry. H.S. Swingle was one of the first investigators to demonstrate that in small ponds at least, poor fishing was strongly correlated with an overabundance of small and intermediate size forage fish (especially bluegill) or largemouth bass. Much research has been undertaken to develop stocking combinations which maintain a balanced (see 4.5) population.

The stocking combinations for small lakes currently recommended by 17 state agencies in the U.S.A. are given in Table XXXIV. The bass-bluegill combination has been most frequently used. However, many experimental stocking combinations have been tried and some of these are listed in Table XXXV. Note that most of these studies are limited to the 1 or 2 year period following stocking.

Monospecific stockings of bass in Illinois ponds resulted in standing crops as high as or higher than bass stocked in combination with other species. Growth rate, however, was slower (Buck and Thoits, 1970). Monospecific stockings of bass in Alabama ponds also resulted in reduced growth (Swingle and Smith, 1943). Monospecific stockings of bass in 4 Oregon ponds resulted in growth rates superior to those in 9 comparable ponds stocked with bass-bluegill (Bond _et al._, 1958). In Canadian ponds Johnson and McCrimmon (1967) found a smaller weight gain in bass-bluegill ponds (adult bluegill stocked) than bass alone (362 g after 3 years). Of the various combinations they investigated, bass-golden shiner combinations exhibited the poorest growth. Swingle (1949) and Ball (1952) found a faster growth rate when golden shiners were stocked with bass than when bass were stocked with bluegill, but they used fingerling bluegill rather than adults. Ball and Tait (1952) reported that when bass were stocked with fingerling bluegill, at age 2+ they had attained a length of 21 cm; when stocked with adult bluegill, at age 2+ they had reached 27 cm.

Some forage species such as the fathead minnow (_Pimephales promelas_) (Elrod, 1971; Ball and Ford, 1953) and _Gambusia_ (Swingle, 1949) are eliminated after a few years when bass are present. Some species are reduced but not eliminated after the introduction of bass. In general, Swingle (1960) found that after 1 year when 93-896 bass fry were stocked with _Tilapia mossambica_ or _T. nilotica_ (subsequently identified as _T. aurea_), the number of tilapia per ha was reduced by 50-75 percent and the A_T value increased.

Regier (1966) stocked 1 000 golden shiners and 247 fingerling bass/ha in 0.06-0.21 ha New York ponds with the results shown in Table XXXVI. Five years after stocking, most of the shiner populations were eliminated or reduced to a standing crop of less than 17 kg/ha.

Bass and channel catfish are often stocked together in small ponds. Little difference in bass yield was noted between fed and unfed fish populations (Table XXXVII). With 0.9 kg bass present in a pond approximately 19 cm channel catfish must be stocked to avoid elimination of the catfish by the bass (Krummrich and Heidinger, 1973).

F_1 hybrid sunfish, predominately male, have been used to prevent excess reproduction and overcrowding in ponds. In a 0.4 ha pond, Childers and Bennett (1967) stocked 417 fingerling bass, 8 male redear and 3 female green sunfish. During a 6 year period, mean fishing effort was 519 (82-771) h/ha/year and the average bass yield was 75 (4-118) kg/ha/year. Harvest of hybrids averaged 136 (12-323) kg/ha/year. At the end of 6 years the standing crop of bass was 117 kg/ha plus 20 kg/ha of hybrids.

TABLE XXXIV

Species combinations and numbers per ha currently recommended by several states for stocking ponds (after Dillard and Novinger, 1975)

State (U.S.A.)	Stocking recommendation[a/][b/][c/]
Alabama	247 LMB spring after 2 471 BG(85%) and RE(15%) preceding autumn and winter; unfertilized ½ density
Arkansas	247 LMB, 500 to 1 236 to 2 471 BG and RE, all same autumn; flexible by fertility and availability of fish
Georgia	247 LMB spring after 2 471 BG(80%) and RE(20%) preceding autumn and winter; unfertilized ½ density
Illinois	124 to 247 LMB with 500 to 1 236 to 2 471 BG, RE or BG(70%) and RE(30%); all same autumn or LMB spring after sunfish preceding autumn; rate adjusted according to fertility
Indiana	494 LMB with 2 471 BG, or BG(70%) and RE(30%); all same autumn
Iowa	247 LMB spring after 2 471 BG preceding autumn
Kansas	247 LMB spring after 247 BG preceding autumn
Kentucky	296 LMB spring after 988 BG preceding autumn
Michigan	247 LMB with 1 236 BG all late summer; or 494 LMB with 2 471 to 4 942 GSH or FHM stocked when available
Missouri	242 LMB spring after 1 236 BG preceding autumn
Nebraska	247 LMB with 1 236 BG all same autumn
New York	247 LMB late summer after 988 GSH early summer, or 247 LMB with 2 471 BG all same autumn, or 371 LMB alone
Ohio	247 LMB June with 1 236 BG late summer same year, or 247 LMB alone
Oklahoma	247 LMB with 247 BG all together May to September when available, or LMB spring after BG preceding autumn
Tennessee	247 LMB spring after 1 853 BG, or BG(75%) and RE(25%) preceding autumn; unfertilized 185 LMB and 1 236 sunfish
Texas	247 LMB spring alone, or after 247 hybrid RE x GS or WM preceding autumn
Wisconsin	247 LMB summer alone, or with 988 GSH or FHM

[a/] LMB = Largemouth bass, BG = Bluegill, RE = Redear sunfish, GS = Green sunfish, GSH = Golden shiner, FHM = Fathead minnow, WM = Warmouth

[b/] Channel catfish may be included except in Alabama and New York

[c/] All states recommend fry or fingerlings except golden shiners and fathead minnows which are stocked as adults

TABLE XXXV

Results of experimental stocking combinations in small lakes. (Except where noted standing crops were obtained by draining.)

Combination (number/ha in parentheses)	Pond area (ha)	Duration of study (year)	Standing crop of bass kg/ha	U.S.A. location	Reference
Bass only	0.28	1.5?	70[a]	OR	Isaac and Bond (1963)
Bass only (618 fry)	1.02	1.5	106	TX	Brown (1951)
Bass only (988 fry)	1.02	1.1	86	TX	(as above)
Bass only (495 fry)	1.02	1.1	56	TX	(as above)
Bass only (247 fry)[b]	–	4	37	AL	Swingle (1952)
Bass only (247 fry)	–	1	30	AL	Swingle (1951)
Bass only (247 fry)	–	1	45	AL	(as above)
Bass only (59 adults + 247 fingerlings)[c]	7.28	2	54	IL	Bennett (1954)
Bass (4 adults)[d]	3(.4)	1-3	80(24-142)[e]	IL	Buck and Thoits (1970)
Bass (4 adults)[f]	3(.4)	1-3	57(24-94)	IL	(as above)
Bass (494 fry) + goldfish (494 adults)[g]	0.10	1	58	AL	Swingle (1949)
Bass (494 fry) + golden shiners (494 adults)[g]	0.10	1	83	AL	(as above)
Bass (494 fry) + gizzard shad (68 adults)[g]	0.10	1	119	AL	(as above)
Bass (494 fingerlings) + goldfish (494 adults)[g]	0.10	1	190	AL	(as above)
Bass (494 fingerlings) + golden shiners (494 adults)[g]	0.10	1	132	AL	(as above)
Bass (247 fry) + Gambusia (692 adults)[g]	0.10	1	170[h]	AL	(as above)
Bass (371 fingerlings) + golden shiners (4 942 adults) + fathead minnows (2 471 adults)	Avg. of a number of ponds	1.5	398[i]	MI	Ball and Ford (1953)

[a] Schnabel estimate

[b] Yield averages 47 kg/ha/year for last 3 years

[c] 524 h/ha with a yield of 17 kg/ha

[d] Not cropped

[e] Range

[f] Cropped

[g] Forage stocked 1 year before bass

[h] Gambusia (Gambusia affinis) eliminated

[i] Fatheads eliminated

TABLE XXXVI

Standing crop and harvest in kg/ha of largemouth bass stocked with golden shiners in New York ponds[a] (after Regier, 1963)

Pond number	Year 1	Year 2		Year 3		Year 4		Year 5
	Standing crop	Standing crop	Harvest	Standing crop	Harvest	Standing crop	Harvest	Standing crop
1	129	169	11	144	45	138	6	132
2	25	65	28	77	17	96	45	113
3	35	49	17	130	45	150	0	166
4	16	70	0	85	11	99	0	185
5	52	86	0	104	0	150	39	126
6	43	68	39	104	22	140	50	112

[a] Zero harvest values are due to no fishing effort

TABLE XXXVII

Average yield in kg/ha of bass and channel catfish in fed and non-fed Alabama farm ponds (after Crance and McBay, 1966)

Stocking rate of channel catfish[a] (number/ha)	Number of ponds	Total area of pond (ha)	Angling per ha (h)	First year harvest		Second year harvest	
				bass	channel catfish	bass	channel catfish
1 236	11	13.6	174	8.7	62	–	–
1 236	8	8.7	104	–	–	5.0	37
4 942[b]	5	3.0	2 165	12.2	753		
4 942[b]	2	1.2	682	–	–	5.2	463
7 413[b]	6	7.1	2 649	4.4	597		
7 413[b]	5	3.9	1 384	–	–	3.1	587

[a] All ponds stocked with 247 bass fingerlings/ha

[b] Fish fed commercial diet

TABLE XXXVIII

Potential stocking combinations using hybrid sunfish and largemouth bass

ENVIRONMENTAL SITUATION NO. 1

Pond 0.3 ha or more in size, contains no fish (new or reclaimed by poisoning), and wild fishes have no access. Overflow or spillway screened from 1 March to 1 July.

Stocking Recommendation No. 1

Species	Size (mm)	Fish/ha	
		fed	not fed
Largemouth bass	50–76	185	124
Bluegill x green sunfish F_1 hybrid	50–102	3 706	741
Redear x green sunfish F_1 hybrid	50–102	1 236	494
Channel catfish	76–102	1 236	247
Fathead minnow	adult	2 471	2 471

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Fishing can be started during the second summer after stocking. In the autumn following stocking and each autumn or spring thereafter, add the following:

Bluegill x green sunfish F_1 hybrid	102 and above	1 236	494
Redear x green sunfish F_1 hybrid	102	371	247
Channel catfish	152–203	494	124

Stocking Recommendation No. 2

Species	Size (mm)	Fish/ha
		not fed
Male redear	adult	12
Female green sunfish	adult	12
Largemouth bass	50–76	185

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In the third or fourth year repeat sunfish stocking. These fish will not readily utilize artificial feed.

ENVIRONMENTAL SITUATION NO. 2

Pond less than 0.3 ha in size, contains no fish (new or reclaimed by poisoning), and wild fishes have no access. Overflow or spillway screened from 1 March to 1 July.

Stocking Recommendation No. 1

Species	Size (mm)	Fish/ha
		not fed
Redear x green sunfish F_1 hybrid	50–76	1 979
Largemouth bass	50–76	185

Stocking Recommendation No. 2

Species	Size (mm)	Fish/ha
		fed
Bluegill x green sunfish F_1 hybrid	50–76	7 413
Largemouth bass	50–76	185

Based on preliminary work, Lewis and Heidinger (1973) have recommended further evaluation of the stocking combinations shown in Table XXXVIII.

7 POND FISH CULTURE

7.1 Use of cultured fish

At the present time most of the cultured largemouth bass are used for stocking. More than 42 million largemouth bass fingerlings were produced in U.S.A. federal and state fish hatcheries during 1967 (Snow, 1969). Usually when they are raised as a food fish, bass are used in polyculture schemes to prevent overpopulation by large forage organisms. As a frozen food product, bass can be kept for long periods because of the low fat content (Mraz, Kimiotek and Frankenberger, 1961). However, Snow and Lovell (1974) found that bass fed on OMP (see 7.2) had good texture and appearance, but were inferior in flavour to bass fed on forage fish. Chatfield (1940) reported the chemical composition of bass to be 980 cal/kg with 26.6 percent protein, 1.8 percent fat, 1.2 percent ash and 76.7 percent water. The dressed weight of largemouth bass is 44 percent of its whole body weight (Mraz, Kimiotek and Frankenberger, 1961). Goodyear and Boyd (1972) found that the elemental composition of bass did not vary with size and listed the various values as follows:

Element	Approximate g/100 g dry weight
Nitrogen	11.5
Phosphorus	3.8
Sulphur	1.0
Calcium	6.5
Potassium	1.4
Sodium	0.4
Magnesium	0.2
	mg dry weight
Iron	34
Manganese	5
Zinc	48
Copper	6

7.2 Procurement and maintenance of stock

Largemouth bass have been propagated since the late 1800s (Arnold and Isaac, 1882). Mature bass are either captured from the wild prior to spring spawning, or they are held in hatchery ponds. Initially they were maintained on fresh beef heart, liver or live forage fish such as goldfish (Carassius auratus) (Wiebe, 1935). Snow (1971a) found no difference in fecundity of age I, II and III largemouth bass raised on Oregon Moist Pellets (OMP) (Hublou, 1963) as compared to those raised on a natural diet. Bass fed OMP averaged 84 400 (43 400-125 800) ova/kg. Hatching success for these eggs ranged from 2.3 to 92 percent as opposed to 35 to 97 percent for bass fed on natural food. Five year old bass appear to be equal or superior to 1-4 year old bass in egg production. The number of eggs produced on a number/kg basis is less for age I bass than for older fish (Snow, 1973).

Snow (1970) estimated annual loss of brood fish to be 10-30 percent. Brood bass larger than 2 kg are difficult to handle, thus he recommends replacing 25-33 percent of the brood fish annually. Malformed individuals should be culled.

The brood bass must be fed well in the late summer and autumn before spring spawning. In order to ensure the development of a large egg mass, the brood fish should gain 50-100 percent of their body weight annually (Snow, 1970).

7.3 Genetic selection of stock

The present author knows of no coefficients of hereditability for any desirable culture traits in largemouth bass. Bass that have been held under hatchery conditions for several generations appear to learn to accept artificial feed better. In fish from the wild, Snow (1971b) concluded 60-65 percent acceptance of OMP to be normal, whereas 90-95 percent of bass from his hatchery strain accepted the feed. Similarly, Flickinger and Langlois (1975) found they could train 91 percent of the fry produced by their hatchery brood fish, but only 58 percent of those produced from Lake St. Clair brood fish could be trained.

Prather (1951) selectively bred bass for better food conversion on natural forage. Initial food conversion averaged 7.3 SD ± 1.12; after 5 generations of selection the average was 3.4 SD ± 0.26.

7.4 Induced spawning
(see endocrine systems and hormones 3.44)

During the spawning season, Wilbur and Langford (1974) injected 50 male bass and 106 female bass with 4 000 IU of human chorionic gonadotropin (HCG)/kg. Milt production was increased or maintained in 80 percent of the males and 63 percent of the females ovulated. Ninety percent of the females which ovulated required only one injection. Most females ovulated within 48 h after injection. Ovulated eggs, if not stripped and fertilized, became nonviable within 12 to 16 h after ovulation. HCG concentrations greater than 4 000 IU did not increase ovulation. The author confirmed Stevens' (1966) findings.

By holding brood fish in indoor tanks at 17°C, spawning was delayed several months (Brauhn, Holz and Anderson, 1972). Carlson (1973) raised bass

TABLE XXXIX

Production of 15–20 mm largemouth bass fry in fertilized spawning ponds

Hatchery	Pond area (ha)	No. of ponds	Brood fish/ ha	Brood fish size (kg)	Production/ha	Reference
Jasper, TX	–	1	–	–	336 000	Wiebe (1935)
(as above)	0.12	1	370[a]	2.3	867 000	(as above)
(as above)	0.12	1	370[a]	1.8	470 000	(as above)
(as above)	0.08	1	556[a]	1.0	478 000	(as above)
(as above)	0.12	1	436[a]	0.8	314 000	(as above)
Tishomingo, OK	0.30–0.68	4	235–1 100[a]	–	average 179 000 (146 000–240 000)[d]	Topel (1949)
San Marcos, TX	0.50	1	91[b]	–	567 000	Bishop (1968)
(as above)	0.40	1	99[c]	–	636 000	(as above)
Gatliff, KY	0.60	1	203	0.3–1.2	950 000	Clark (1950)

a/ Sex ratio approximately 1:1
b/ 2:1 males to females
c/ 3:1 males to females
d/ Range

at 10°C in tanks. When subjected to increasing length of day or a continuous 12 h day, the fish spawned on nylon mats when the water temperature was raised to 20°C. At this temperature spawning took place within 39 days, in December, January, February, March, June and July. Hormones were not used.

7.5 Culture methods

7.51 Extensive

Brood fish are placed in recently filled ponds which are free of wild fish. Production of 15–20 mm fry commonly exceeds 500 000/ha (Table XXXIX). Fry are either left in the spawning ponds or they are moved to rearing ponds. The rearing ponds are usually fertilized to produce a zooplankton bloom. Ordinarily if a pond is used for spawning, it is not fertilized. Rogers (1968) found that in culture ponds bass less than 15 mm in length ate primarily copepods and cladocerans while larger fish ate mostly midge larvae. There is considerable variation in the number of fingerlings produced; however, standing crops of 100 kg/ha are common (Table XL). Much of the variation in these results is due to cannibalism. Because of cannibalism, it is biologically and economically difficult to produce bass larger than 8 cm at practical population densities by the extensive method of culture. Marzolf (1954) stocked 9 clean ponds with 2 470–8 650 fry/ha. After 2 years the standing crop averaged 80 (49–171) kg/ha of 17 cm fish. Survival averaged 32 (9–75) percent. Our laboratory has used nursery ponds to produce 25 cm bass. Production records for this work are shown in Table XLI. Yields averaged 368 fish/ha. Species of forage fish which appear to be well suited for propagation as bass food include goldfish, European carp, fathead minnow, golden shiner, and Tilapia spp. (Snow, 1970).

7.52 Intensive

The intensive method of raising largemouth bass involves training them to accept artificial feed. The following procedure for intensively raising largemouth bass was developed by Jack Snow at the Marion, Alabama, National Fish Hatchery (Snow, 1970, 1971b, 1975).

A. Well fed male and female brood fish (see 7.2) are maintained in separate ponds for several weeks following normal time of spawning in order to avoid loss of eggs due to sudden drops in temperature.

B. Only ripe brood fish are moved into the unfertilized spawning pond (185 small or 94 large brood fish/ha). A stocking ratio of 3 males to 2 females is recommended.

C. Spawning may be on natural substrate, but a nylon spawning mat can be used (Chastain and Snow, 1966). The number of fry produced/ha should range from 250 000 to 370 000.

   a. If no spawning mats are used the eggs are allowed to hatch and the 10–15 mm fry are moved to nursery ponds by trapping or seining. They are graded and stocked 123 000–185 000 fry/ha) in nursery ponds which have been fertilized to produce large numbers of zooplankters. Before stocking, the fish may be treated for disease (see 7.6). In approximately 30 days the bass will reach 30–40 mm with 75–90 percent survival and a total standing crop of 84–100 kg/ha. Some selected production values are given in Table XL.

TABLE XL

Production of fingerling largemouth bass in fertilized rearing ponds stocked with 15–20 mm fry (except where footnoted) and fed on naturally occuring invertebrates or forage fish. Range in parentheses

Hatchery (U.S.A.)	Pond area (ha)	No. of ponds	Stocked/ha	Average % survival	Harvest[a]		Production kg/ha	Days approx.	Reference
					mm	number/kg			
Natchitoches, LA	–	19	42 000–50 000	38(3–62)[b]	–	approx. 220	–	90	Meehean (1940)
Marion, AL[c]	–	5	50 000	38(3–74)	–	approx. 220	–	100	(as above)
Welaka, FL	0.8	5	37 000	74(48–86)	–	approx. 220	average 110 (82–197)	–	(as above)
Welaka, FL[d]	0.8	3	37 000	43(6–68)	–	approx. 183	–	–	(as above)
Fairport, IA	1.2	1	50 000	33	–	–	–	–	Wiebe (1935)
Tupelo, MI	1.2	1	19 000	31	–	–	–	–	(as above)
Lonoke, AK[e/][f]	0.3	11	11 600	86(57–103)	57–144	–	–	120	Hogan (1933)
Lonoke, AK[g]	0.3	8	7 300–11 600	94(86–100)	82–108	–	–	120	(as above)
Lonoke, AK[d]	avg. 1.6 (0.7–2.8)	13	25 000–35 000	44(15–68)	76–126	–	–	210	(as above)
Hebron, OH	0.4	7	124 000	38(12–86)	30–134	–	average 75 (48–109)	–	Morgan (1960)
Marion, AL	0.04–0.2	10	12 000–40 000	71(61–84)	–	average 202 (134–317)	average 112 (69–177)	46	Snow (1970)

[a] 51 mm fish average 579/kg, 76 mm fish average 191/kg (Meehean, 1940)
[b] Range
[c] Stocked with 123–240 adult bluegill/ha
[d] Stocked with forage minnows
[e] Ponds not fertilized
[f] Stocked fish averaged 32 mm
[g] Stocked with 32–63 mm fish

TABLE XLI

Largemouth bass harvest from nursery ponds on the Crab Orchard National Wildlife Refuge, Williamson County, Illinois, in the winter of 1974-1975[a/]

Pond number	Area (ha)	Number of fingerlings stocked	Number harvested	Recovery %	Size TL (cm)
1	0.8	600	227	38	20-28
2	1.2	500	367	73	18-28
3	1.0	550	197	36	25-30
4	2.2	1 400	980	70	18-30
5	4.9	2 400	1 924	80	15-25
6	1.7	900	363	40	20-30

a/ All ponds were renovated in the spring of 1974 with rotenone and stocked with adult golden shiners, fathead minnows and lake chubsuckers at a rate of 5 kg/ha of each plus 5 pairs of adult threadfin shad/ha

b. Many types of substrates can be used for a spawning mat. These include nylon, conservation webbing, rock, and Spanish moss. A mat size of 7 cm x 15 cm is sufficient (Chastain and Snow, 1966). At the stocking rate for brood fish given above, 77 mats/ha should be used. The mats are most effective in ponds having a silt or mud bottom. Some success has been obtained in transferring the mats with eggs to a rearing pond and allowing the eggs to hatch (Chastain and Snow, 1966). Carlson (1973) hatched bass eggs on a mat in tanks with running water. If this method is used it is probably desirable to use a porous spawning substrate such as Spanish moss and to elevate the mat at least 10 cm off the bottom of the pond, tank or raceway (F. Leteux, personal communication).

The eggs can be washed from the nylon mat and incubated in Downing type hatching jars (Chastain and Snow, 1966) or a Heath Vertical Incubator (Snow, 1973). An 8 l/min flush is required. Snow (1973) obtained 2 714 000 eggs from 563 brood fish in seven 0.04 ha brood ponds. Approximately 22 percent of the eggs were not fertilized, but total hatching success was 58 percent.

If a Heath Incubator is used, a fine mesh screen is necessary. A standard tray will hold approximately 50 000 eggs. The eggs should be washed and cleaned of debris before being placed in the incubator. They can be enumerated by the settled volume method. Snow (1973) found 1 ml (settled volume) equaled 281 eggs.

If the eggs are to be removed, the spawning mats should be checked each morning. If eggs are too old when separated, the stress of removal causes premature hatching. At a water temperature of 19°C the mats should be moved on the second day, at 19-22°C the day following observation, and at temperatures above 23°C the afternoon of the day observed. The mats should be moved in a tub of water (Snow, 1973).

Fry should be stocked in nursery ponds at 100 000-200 000/ha. Snow (1970) has found that enumeration by the pan comparison method is 90 percent accurate.

D. Regardless of the culture method used, after the fish reach 30-40 mm in the nursery ponds they are seined, graded, treated for disease and transferred to tanks or raceways to be trained to accept artificial food (non-living). Very poor survival (usually less than 10 percent) is attained when one attempts to train 10-25 mm bass to accept artificial food (Snow, 1960). Apparently a moist pellet is required. One of the best commercially prepared feeds for training bass is the Oregon Moist Pellet (OMP) (Snow, 1968a; Hublou, 1963). However, this type of pellet must be stored frozen. Bass can be trained to feed on ground fish, beef liver, etc., or a mixture of ground fish and artificial food. Care must be taken to prevent thaimine deficiency (Snow, 1965).

In order to train bass they must be concentrated. Snow (1975) recommends training for 10-14 days in tanks stocked at 0.07-0.18 kg/28.3 l. However, Flickinger and Langlois (1975) have trained at densities of 1.36 kg/28.3 l with 91 percent of the bass learning to accept the food. Typically within 14 days 65-75 percent of the bass will learn to take the artificial feed.

TABLE XLII

Production of fingerling largemouth bass on artificial feed in rearing ponds stocked with 38–51 mm bass

Hatchery	Pond area (ha)	Number ponds	Number stocked/ha	Recovery %	Production kg/ha	Number/kg	Food conversion	Days stocked	Reference
Marion, AL[a]	0.03–0.28	8	32 300–75 300	avg. 75 (58–93)	1 223–2 661	13.9–22.7	2.50–3.67	100	Snow (1971b)
Marion, AL[b]	0.04	20	27 400–73 900	avg. 78 (53–98)	2 107–4 990	avg. 11.1 (6.4–19.6)	1.43–1.85	100	(as above)
Marion, AL[c]	0.04–0.44	14	26 800–66 700	avg. 80 (55–112)	2 230–8 011	avg. 9.4 (7.0–12.1)	1.13–1.59	100	(as above)
Marion, AL[d]	0.04–0.20	10	12 400–53 800	avg. 56 (39–87)	925–2 564	avg. 13.2 (7.3–18.3)	3.7–5.7	81–97	Snow (1968b)
Inks Dam, TX[c]	0.10–0.36	3	22 200–48 300	74–84	3 227–6 339	5.1–6.4	avg. 1.22	148	McCraren (1974)
Ft. Worth, TX[c]	0.20–0.26	3	20 200–39 500	40–75	1 508–5 880	5.1–5.3	avg. 1.37	130	(as above)
Tishomingo, OK[c]	0.32	2	15 400–30 900	52–55	560–894	14.3–18.9	avg. 3.57	99–150	(as above)

[a] Fed ground fish mixed with trout food (50/50 or 60/40)
[b] Fed OMP – Oregon Moist Pellet (Hublou, 1963)
[c] Fed OMP + floating trout feed
[d] Fed mixture of 10% trout feed + 10% beef liver + 80% ground fish

TABLE XLIII

Treatments for control of various parasites of bass under hatchery conditions. (Except where footnoted these are recommendations by the author cited and no experimental data were presented)

Parasite or disease	Chemical	Treatment	Reference
Haemorrhagic septicemia	Oxytetracycline	Inject 50-75 mg active/kg bass	Snow (1970)
Prophylactic	(as above)	In food 3 g/45 kg fish/day for 7-10 days before moving	Snow (1971a) McCraren (1974)
(as above)	Acriflavine	2 ppm when transporting	Snow (1971b)
Prophylactic for fungus	(as above)	Bass eggs 50 ppm for 15 min	Snow (1973)
(as above)	Phridylmercuric actetate	Bass fry 2 ppm for 1 h	Snow (1961)
(as above)	Formalin	Bass fry 1:4 000 for 1 h	(as above)
(as above)	Potassium permanganate	Bass fry 10 ppm for 30-60 min	(as above)
(as above)	Simazine	11.2 kg/ha preflooded spawning pool	Snow (1975)
Trichodina	Formalin	In pond 25 ppm	Snow (1973)
Flexibacter	Acriflavine	5 ppm 4 h or 2 ppm continuous	Snow (1970)
(as above)	Sodium chloride	1% for 5-6 h	Nelson, Bowker and Robinson (1974)
(as above)	Combiotic	8 ppm 24 h	(as above)
(as above)	Copper sulfate	1-2 ppm for 1 h	(as above)
Bacteria	Potassium permanganate	2 ppm in pond	McCraren (1974)
(as above)	Copper sulfate	0.5 ppm in pond	(as above)
External protozoa or fungi	Sodium chloride	1% for 6 h	Nelson, Bowker and Robinson (1974)
Proteocephalus ambloplitis	Kamla	200 mg/0.45 kg for 3 days orally	Snow (1970)
Corallobothrium or *Alloglossidium*	Di-n-butyl	150 mg/kg for 7 days orally	Allison (1957)
Tadpole shrimp *Apus* fairy shrimp *Streptocephalus*	Dylox	0.25 ppm in pond	Hornbeck, White and Meyer (1966)
Aeromonas	Acriflavine	Bass eggs 500-700 ppm for 15 min	Wright and Snow (1975)
(as above)	Betadine (150 ppm active I_2)	Bass eggs 100 ppm for 15 min	(as above)
(as above)	Wescodyne (150 ppm active I_2)	Bass eggs 100 ppm for 15 min	(as above)
(as above)	Merthiolate	Bass eggs 750 ppm for 15 min	(as above)

Feeding is initiated the day after the fish are stocked in the training tank. A 16–24 mm pellet is fed at 1–2 h intervals during the daylight hours. The daily ration should be about 15 percent of body weight of the fish. Cannibalism is not a problem at this time but the effect of attempted cannibalism needs further investigation. Nelson, Bowker and Robinson (1974) noted increased training success with water temperatures near 26°C (76 percent) against lower temperatures (30 percent). Waste material must be siphoned from the bottom of the training tank daily, and sufficient freshwater flush must be used to maintain good water quality.

E. The trained fish can be stocked in raceways, tanks, cages or ponds. Snow (1965) raised bass in troughs at densities of 645 g/28.3 l. This was equivalent to 113 g/l/min flush with a turnover rate of 3–7 h. Nelson, Bowker and Robinson (1974) maintained bass at 336 g/28.3 l with a 28 l/min flush and a turnover rate of 48 min. The fish were graded to reduce cannibalism, survival was 33 percent.

Snow and Wright (1975) stocked 302–404 fish (11.5 cm, 15 g) in 0.66 m^3 cages having a mesh size of either 0.64 cm or 1.27 cm. These fish were fed on OMP for 2 months. Survival was 98–99 percent with food conversions of 1.46–2.41. The maximum loading was 39 kg/cage. Growth was similar to bass stocked in open ponds at 50 000/ha.

The procedure which has been best evaluated is to stock the trained bass in ponds at 25 000–50 000/ha (Table XLII). Since food is supplied, production often exceeds 2 000 kg/ha. The fish are fed at 15 percent of body weight for several weeks, after which the rate is dropped to 5 percent for one month followed by a 3 percent rate. Pellet size should be increased as the fish grow. Oxygen depletion frequently occurs when feeding rates exceed 20 kg/ha (Snow, 1971). In fish larger than 27 cm food conversion is typically in the order of 3.0 (Snow, 1975; Lewis, Heidinger and Konikoff, 1969).

7.6 Disease and parasite control

A number of chemicals and procedures for treatment are recommended in the literature (Table XLIII), but there are few studies which give both qualitative and quantitative data.

7.7 Harvest

Fry are harvested with a fine mesh seine or a fry trap. Hayford (1948), Severson (1963) and Snow (1970) described fry trap designs and use. In general, the bass tend to swim around the spawning pond in a school. Guides made of screen, glass, or plexiglass divert the bass into the V-shaped trap entrance. The trap may have an opening at both ends. A flow of water through the trap enhances its effectiveness. The trap may also be used by directing the flow of water through it, in which case the fish are concentrated and directed into the trap as a result of their response to the flowing water.

Largemouth bass fingerlings are harvested with a seine.

7.8 Transport

Bass should be held for 24 h after harvesting before being transported. It is preferable to transfer bass at water temperatures of 15°C or less. Snow (1970) recommends hauling densities of 0.06–0.12 kg/l of water. McCraren (1974) has transported bass at 0.25 kg/l of water for up to 11 h.

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