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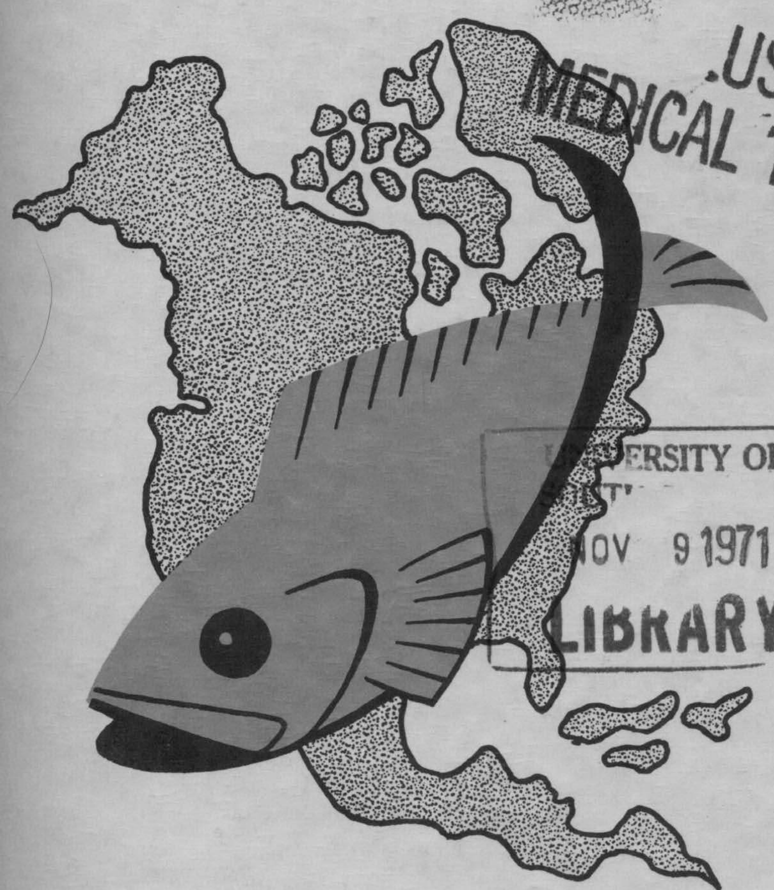

The Centennial Volume

Volume 100 Number 4
October 1971
Published Quarterly

THE AMERICAN FISHERIES SOCIETY

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Published at Lawrence, Kansas 66044. Second Class Postage paid at Lawrence, Kansas.

Price per copy: $3.75

PRINTED BY ALLEN PRESS, INC., LAWRENCE, KANSAS

29 October 1971

Biology of the Fallfish, *Semotilus corporalis* (Pisces, Cyprinidae)[1]

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ABSTRACT

The biology of fallfish, *Semotilus corporalis*, was studied in Massachusetts. Back calculated age and growth data from eight different populations are compared. The computed TL–SR equation is $L = 18.00 + 1.010\ S$. Fish from the Quabbin Reservoir attained a maximum age of X+. Males attained sexual maturity when III+, females at IV+. Spawning occurred from late April to June when the water temperature reached 14.4 C. Unfertilized egg diameter is $2.16 \pm .09$ mm and the water hardened egg diameter $2.70 \pm .07$ mm. Eggs hatched 138–144 hours after fertilization in a constant water bath of 17.0 ± 0.5 C. Newly hatched larvae are $6.82 \pm .32$ mm TL. Early larval development and scale formation are described. The fecundity–weight relationship is $F = 159.1 + 26.4\ W$. Fallfish are omnivorous based on stomach content (algae, fish, aquatic and terrestrial insects, and crayfish).

INTRODUCTION

Fallfish, *Semotilus corporalis* (Mitchill), are found in the Lake Ontario and Superior drainages, the James Bay region, the northern St. Lawrence tributaries, and east of the Appalachians as far south as Virginia (Hubbs and Lagler, 1958).

General life history observations for *S. corporalis* are summarized by Adams and Hankinson (1928) and more recently by Mansueti and Hardy (1967). This largest native cyprinid east of the Rockies attains a maximum total length of at least 508 mm (Shoemaker, 1945). Because of their large size and active behavior, they provide considerable sport fishing in some areas.

My four-year study provides initial data on embryology, larval development, pre-juvenile appearance, and back calculated age and growth determinations. Comparisons are made with other life history aspects already described in the literature.

MATERIALS AND METHODS

Age and growth determinations are based on 910 specimens preserved in 10% formalin (Table 1). I employed this procedure: recorded total length to the nearest millimeter and weight to the nearest tenth of a gram, and removed scales from above the lateral line below the posterior of the dorsal fin. Scales, mounted between two microscope slides, were examined with an Eberbach projector (43×). Pertinent data were transferred to data processing cards and these determinations made by the CDC 3600 computer at the University of Massachusetts: calculated total length at scale formation ("a" value), length–weight equation, condition factor, and age-growth back calculation. An analysis of covariance, conducted on the length–weight data, determined if the regression coefficients and/or the adjusted means were significantly different between collections.

Additional specimens were collected by electro-fishing from the Mill River (315), Amherst, Massachusetts to document the seasonal feeding pattern, and from the West Branch of the Swift River (35), New Salem, Massachusetts by trap nets for embryological and fecundity studies. Trap net sets near the West Branch stream mouth completely blocked the spawning migration.

Fish were collected in the field and stripped eggs fertilized by the "wet" method. Eggs were then taken to the fisheries laboratory at the University, placed in a water bath at a constant temperature of 17.0 C, and the embryological stages recorded. Larvae were stained with alizarin red S to determine the scale pattern.

[1] This is contribution Number 21 of the Massachusetts Cooperative Fishery Unit jointly supported by the U. S. Bureau of Sport Fisheries and Wildlife, the Massachusetts Division of Fisheries and Game, the Massachusetts Division of Marine Fisheries, and the University of Massachusetts.

TABLE 1.—*Sampling location, date, gear and number of fallfish collected*

Location and date	Gear	Number of specimens
Cannan River, New Brunswick August 1953	Seine—hook and line	68
Connecticut River, Massachusetts May 1965	Fyke net	135
Quabbin Reservoir, Massachusetts September 1965	Fyke net	87
Mill River, Massachusetts August 1970	Rotenone	191
Millers River, Massachusetts September 1967	Rotenone	107
Kettle Creek, Pennsylvania July 1967	Electro-shocker	101
Yellow Creek, Pennsylvania July 1967	Electro-shocker	98
Winooski River, Vermont August 1967	Electro-shocker	123
	TOTAL	910

Ovaries were removed from preserved specimens and this procedure used to determine fecundity: 100 eggs each taken from the posterior, middle, and anterior portion of the paired ovaries, weighed and the data expanded for the whole ovary (Lehman, 1953). I used a graduated ocular microscope to determine mean egg diameter.

RESULTS AND DISCUSSION

Age and Growth

Some fallfish scales are peaked in the anterior field; others are flattened and oval. These flattened scales, initially used to compute a correction factor ("a" value), had a low correlation coefficient (0.455) and were consequently not used. The mathematical relationship between total length and scale radius using "peaked" scales was computed: $L + 18.00 + 1.010\ S$ where L = total length of fish in mm and S = scale length $43 \times$ in mm. The correlation coefficient for this relationship was 0.976. Fish lengths at the formation of each annulus were calculated by a computer program (Mawson and Reed, 1970) using the 18.0 mm "a" value. Back-calculated age and growth data are not available for *S. corporalis*. Therefore, I analyzed growth differences between collections (Table 2). The New Brunswick growth rate is the slowest, reflecting a short growing season. Quabbin Reservoir fallfish, the only collection from a lentic habitat, exhibited the best growth. The growth rates in the other collections are intermediate and showed only minor differences. Males exceeded the females in growth by age IV+.

TABLE 2.—*Back calculated total length in millimeters for fallfish, using a correction factor (a) of 18.0 mm and the number of fish in parentheses*

Area	Sex	Age in years 1	2	3	4	5	6	7	8	9	10
Quabbin Reservoir, Massachusetts		45 (87)	71 (87)	142 (87)	188 (71)	245 (60)	197 (44)	349 (18)	407 (7)	450 (5)	462 (2)
Connecticut River, Massachusetts		45 (135)	69 (135)	133 (119)	176 (110)	207 (90)	243 (57)	281 (31)	330 (5)		
Cannan River, New Brunswick		38 (67)	62 (67)	98 (58)	132 (38)	161 (21)	190 (15)	218 (7)	238 (1)		
Kettle Creek, Pennsylvania		42 (101)	63 (101)	102 (95)	143 (73)	179 (46)	217 (21)	272 (9)			
Winooski River, Vermont		41 (123)	66 (123)	107 (93)	150 (32)	189 (17)	237 (3)	275 (1)			
Yellow Creek, Pennsylvania		44 (98)	68 (48)	123 (19)	170 (11)	210 (5)	240 (2)				
Mill River, Massachusetts	♂	43 (86)	67 (73)	130 (66)	164 (52)	194 (27)	227 (11)				
	♀	44 (77)	68 (64)	131 (59)	152 (38)	180 (21)	212 (6)				
Millers River, Massachusetts		41 (107)	66 (107)	111 (94)	150 (59)						

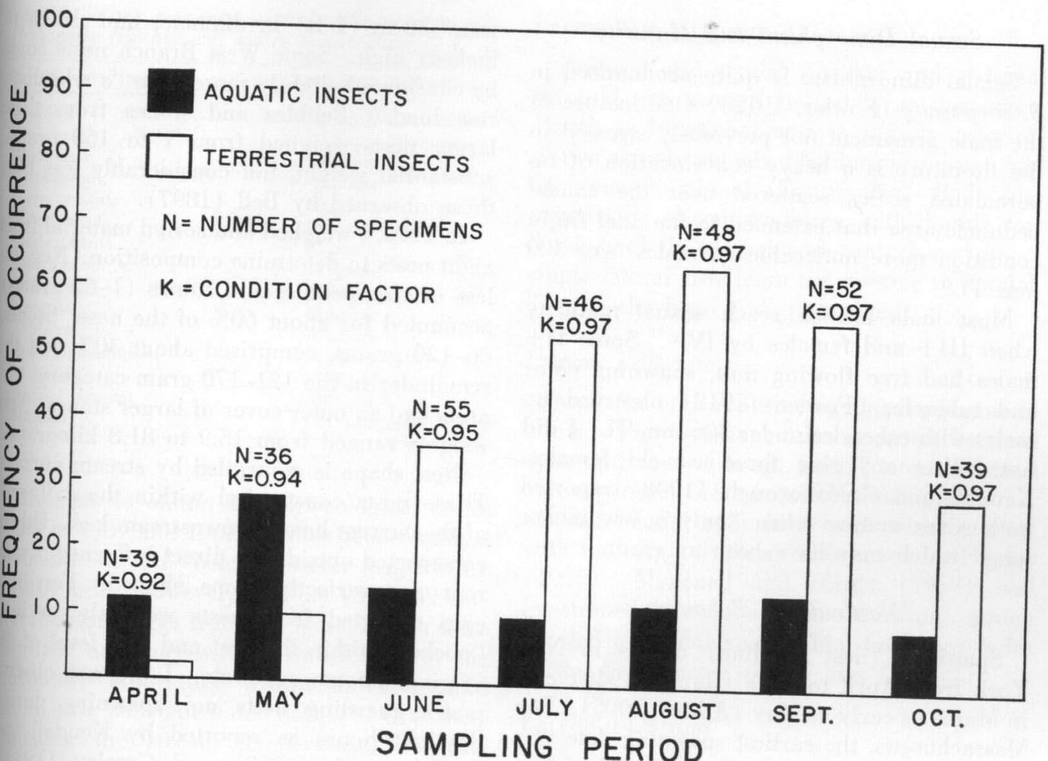

FIGURE 1.—Seasonal diet and condition factor for fallfish collected in 1967 from the Mill River, Amherst, Massachusetts.

Length–weight Relationships and Condition Factor

The New Brunswick collection was not used in the length–weight determination because of its extensive time in preservative. Calculated length–weight relationships for the other collections had "b" values (slopes) that approached or slightly exceeded the cube of length (Table 3). The regression coefficients for the length–weight relationship using analysis of covariance (Steel and Torrie, 1960) showed significant differences between all collections at the 5% probability level. Since the seven samples are drawn from varied environments, such variation is not considered unusual. Magnin (1964) reported a length–weight relationship for fallfish in Quebec as log W = -4.063 + 2.698 log FL.

The condition factor for each collection reflects general well-being and good robustness. In addition, data from the Mill River (April–October, 1967) showed only minor variation in condition (Figure 1).

TABLE 3.—*Length-weight relationship and condition factor from seven fallfish populations. W = weight in grams; L = total length in millimeters*

Area	Condition	L-W relationship	r
Millers River, Massachusetts	1.02	Log W – 4.9884 + 2.998 Log L	.989
Quabbin Reservoir, Massachusetts	1.01	Log W – 5.3642 + 3.138 Log L	.980
Connecticut River, Massachusetts	1.03	Log W – 5.1162 + 2.988 Log L	.988
Mill River, Massachusetts	1.06	Log W – 5.3361 + 3.150 Log L	.997
Yellow Creek, Pennsylvania	1.04	Log W – 4.9505 + 2.979 Log L	.996
Kettle Creek, Pennsylvania	1.04	Log W – 5.2905 + 3.135 Log L	.996
Winooski River, Vermont	1.16	Log W – 5.3289 + 3.179 Log L	.992

Sexual Dimorphism and Maturity

Sexual dimorphism is quite pronounced in *S. corporalis* (Fowler, 1912). One feature of the male armament not previously stressed in the literature is a heavy concentration of tuberculated scales scattered over the caudal peduncle area that extended to the anal fin, a condition more noticeable on males over 300 mm TL.

Most male fallfish reach sexual maturity when III+ and females by IV+. Some II+ males had free flowing milt, spawning color and tubercles. Fowler (1912) observed no males with tubercles under 305 mm TL. I did not collect any ripe three-year-old females. Kendall and Goldsborough (1908) reported both sexes mature when "only a few inches long" which may have been an error.

Nestbuilding Behavior

Spawning (nest building) occurs in New York from April to June (Raney, 1949) and in Maine as early as May (Atkins, 1905). For Massachusetts, the earliest spawning date was April 27, 1967 in the Mill River and the latest on June 10, 1968 in the West Branch of the Swift River. Nest construction never occurred in either stream until the water temperature reached 14.4 C. Local climatic conditions produced two nest building periods each spring. Spawning ceased for several weeks when cold weather caused the water temperature to fall below 14.4 C. In addition, trap net catches in the West Branch declined and did not increase again until the water temperature reached 14.4 C.

Nest size varies from "3 to 6 feet in diameter and from 12 to 24 inches in height," (Wilson, 1907; Mansueti and Hardy, 1967). In addition, Bell (1897) observed fallfish depositing stones from an "ounce to a pound in weight" and these nests contained from a "wheelbarrow load to 4 or 5 tons each."

Nests observed in the two Massachusetts study streams indicated less ambitious activities but still represented an enormous expenditure of energy. The largest nest, measured in the West Branch, was 1.21 m (4 ft) in diameter and .58 mm (22 inches) high. Smaller nests, also containing eggs, in the Mill River were .30 m (1 ft) in diameter and .10 m (4 inches) high. Some West Branch nests could be considered slightly more than "a wheelbarrow load." Pebbles and stones from these larger nests weighed from 1 to 168 grams, substantial weight, but considerably less than those observed by Bell (1897).

In 1970, I weighed and sorted material from eight nests to determine composition. Regardless of size, pebbles and stones (1–65 grams) accounted for about 60% of the nest. Stones, 66–120 grams, comprised about 30% and the remainder in the 121–170 gram category. All nests had an outer cover of larger stones. Nest weights ranged from 15.9 to 81.8 kilograms.

Nest shape is controlled by stream current. Those nests constructed within the influence of the current have a downstream keel. Others constructed outside the direct influence of current are perfectly dome shaped. Fertilized eggs collected from nests were always in a "pocket" within the nest and at a level of the original stream substrate. I did not observe males guarding nests nor spawning during daylight hours as reported by Kendall and Goldsborough (1908) and Greeley (1933). Some white sucker, *Catostomus commersoni*, eggs collected from the nests are considered a "drift" product. However, the common shiner, *Notropis cornutus*, and the blacknose dace, *Rhinichthys atratulus*, did use these nests as spawning sites. In contrast, nests of the hornyhead chub, *Hybopsis biguttata*, and the river chub, *Hybopsis micropogon*, are utilized by many fish species (Lachner, 1952).

Embryology

Fallfish eggs have been described as nonadhesive (Atkins, 1905) and adhesive (Shoemaker, 1945). I believe both of these observations are correct: unfertilized eggs are nonadhesive and fertilized eggs do adhere to the substrate. Such a condition is beneficial to the species. Unfertilized eggs, washed away by the current, cannot endanger the nest's "fertilized egg pocket" environment. One hundred unfertilized eggs had a mean diameter of 2.16 ± .09 mm and the same number of water hardened eggs a mean diameter of 2.70 ± .07 mm.

TABLE 4.—*Time sequence, after fertilization, in fallfish early life history; water temperature 17 C*

Developmental stage	Time after fertilization
Two-cell	2 hours–45 minutes
Four-cell	3 hours–30 minutes
Eight-cell	4 hours
Sixteen-cell	5 hours
Early blastula	10 hours
Late blastula	19 hours
Early gastula	25 hours
Late gastula	31 hours
Yolk plug	42 hours
Neurula	45 hours
Optic vesicle	50 hours
Body pigmentation	63 hours
Motility	70–75 hours
Retinal pigment	105–111 hours
Hatching	138–144 hours

Attempts to obtain an embryological series failed in 1967 and 1968 because of mechanical problems in the constant-water-temperature control unit. However, on May 29, 1969 several thousand eggs from the West Branch were fertilized and successfully transferred to the University laboratory within an hour and placed in a constant-water bath (17 C ± 0.5) matching the stream temperature. At this temperature the eggs hatched within 139–144 hours after fertilization (Table 4). Egg samples were taken at the various developmental stages and the time recorded. Development is typical of bony fishes with pigmentation meroblastic and disc-shaped.

Atkins (1905) hatched eggs in 7–9 days in water temperatures "being from 54½° to 63½° F., averaging under 60° F" that may have favored the lower temperatures range based on my data.

Larvae and Prejuveniles

Newly hatched larvae were preserved in 5% formalin and 182 specimens measured: mean, 6.82 ± .32 mm TL. Larvae are almost devoid of chromatophores with only a light scattering on the head (Figure 2a). The pectoral buds are absent and the caudal fin not defined. The yolk-sac stage persists for 5 days at the constant water temperature of 17.0 C. Most larvae absorbed their yolk by 9.0 mm TL and had already ingested food. Use of the constantwater bath was then discontinued and the water temperature reached room temperature (20-24 C).

Larvae 9.0–10.0 mm

Pectoral and caudal fin rays and a dorsal fin fold are present in larvae at this stage. Mouth is functional and is slightly inferior. A two-chambered air bladder is present and the anus functional (Figure 2b). Body pigmentation: chromatophores, with double row down both the dorsal and ventral surface; a single lateral row from the opercle to caudal. Top of the head well pigmented.

Larvae 12.0 mm

Anal fin fold appears; caudal fin begins to notch. Pigmentation: more dense between eyes and top of head, lateral row darkened and a general increase of chromatophores. A distinct caudal spot is present which agrees with the original observation made by Fowler (1945). Mansueti and Hardy (1967) had questioned Fowler's line drawing which showed a caudal spot. This dark spot fades as the fish reaches 65–75 mm TL.

Larvae 14.0 mm

Anal fin fully developed with rays; pelvic fin buds appear. Pigmentation: lateral stripe very dark, caudal spot enlarged, ventral row reduced to an area between anus and caudal, dorsal body surface with more pigment.

Larvae 18.0 mm

All fins fully developed. Pigmentation of caudal spot, ventral stripe, dorsal surface, and head continues. Mouth position adult-like: terminal and somewhat oblique (Figure 2c).

Scale Formation

Larvae (13 mm +) were periodically removed from the aquaria and placed in alizarin red to determine size and pattern of scale formation. Scale platelets are first observed on 18 mm larvae as a narrow band on the caudal peduncle (Figure 3). Scales spread anteriorly along the narrow dark lateral stripe until the larvae reached 23 mm. By this size, the caudal peduncle is almost covered with scales which have spread dorsal-ventrally from the lateral band. By 26 mm, most larvae are about 60% scaled. The last area to be covered with scales is located between the dorsal fin base and

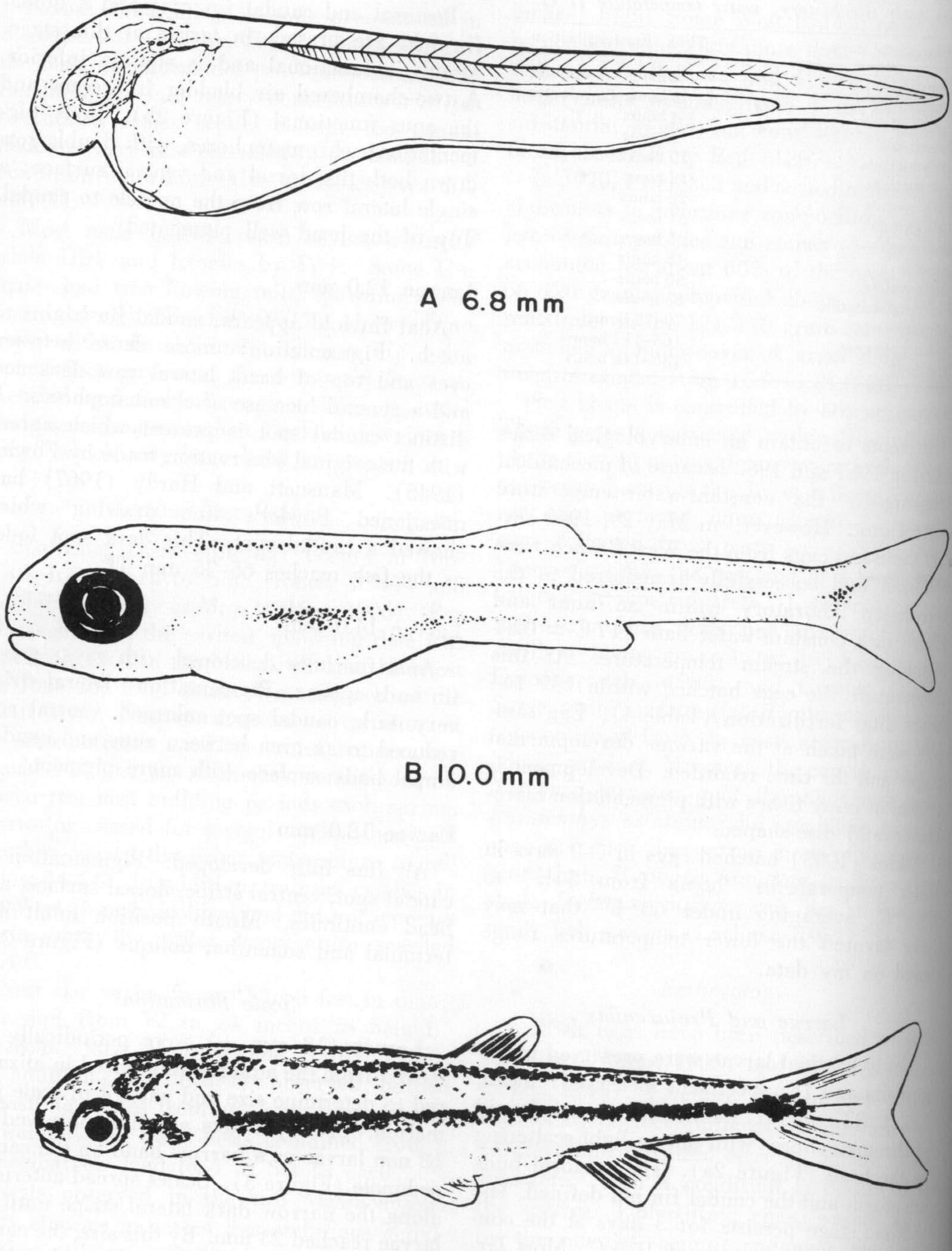

FIGURE 2.—Larval development of fallfish (drawn from live specimens).

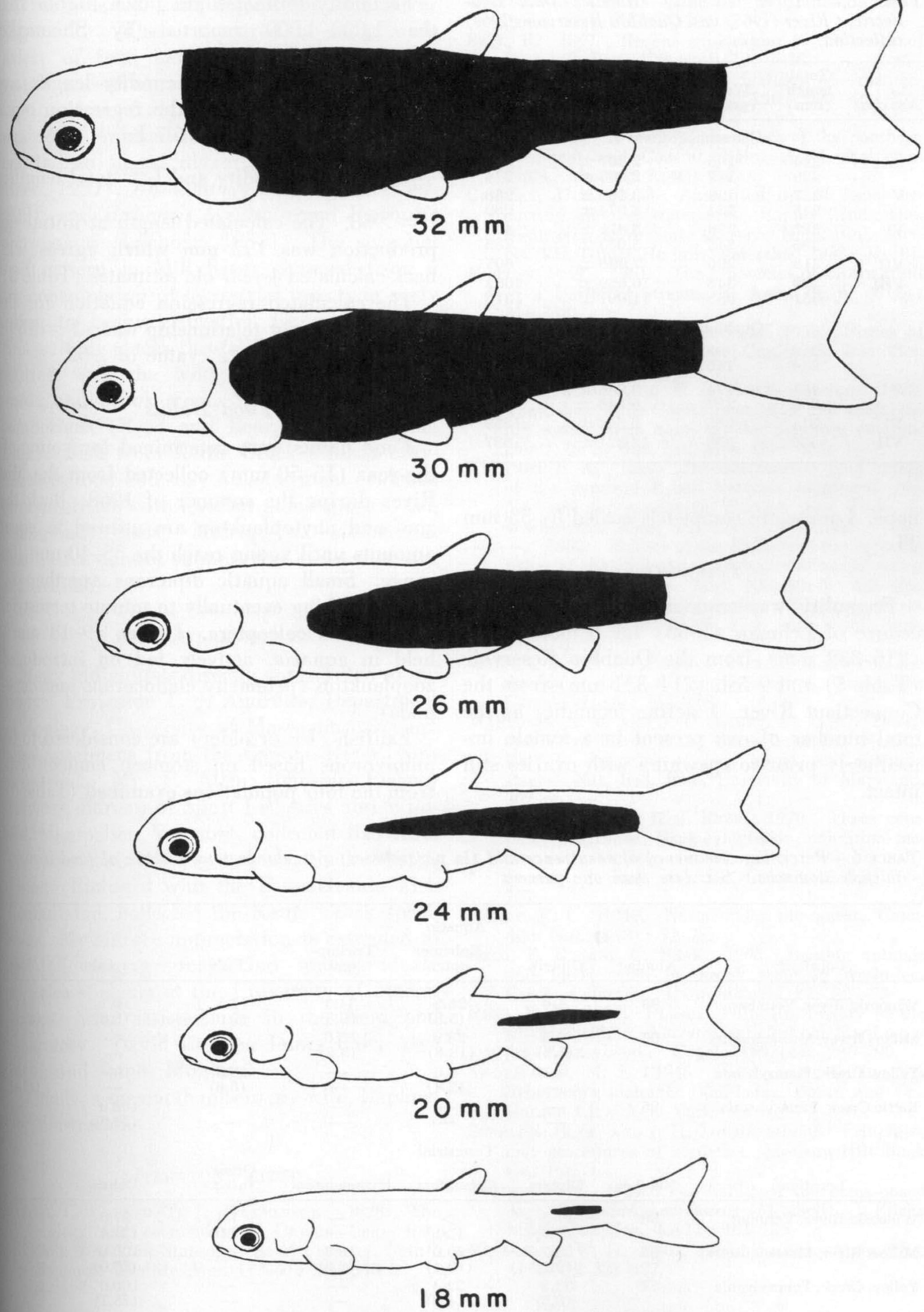

FIGURE 3.—Fallfish scale pattern (indicated in black).

TABLE 5.—*Fallfish fecundity estimates from Connecticut River (1965) and Quabbin Reservoir (1968) collection*

Age class	Total length (mm)	Weight (grams)	Mean	Standard deviation
		Connecticut River		
IV	214	105	2,307 ±	285
	229	117	2,883 ±	274
V	237	129	3,369 ±	258
	245	134	4,074 ±	289
VI	287	230	5,811 ±	406
	295	245	5,633 ±	782
VII	318	296	7,998 ±	605
VIII	329	348	10,659 ±	1052
	331	358	11,091 ±	1318
		Quabbin Reservoir		
IV	216	98	2,099 ±	426
	244	146	4,160 ±	289
V	251	174	3,966 ±	581
	289	227	5,846 ±	345
VI	311	365	9,504 ±	1652
VII	332	378	12,321 ±	1387

nape. Larvae are completely scaled by 33 mm TL.

Fecundity

Fecundity was enumerated using the procedure of Lehman (1953) for 6 mature fish (216–332 mm) from the Quabbin Reservoir (Table 5) and 9 fish (214–331 mm) from the Connecticut River. I define fecundity as the total number of ova present in a female immediately prior to spawning with ovaries still intact.

Fecundity estimates are much higher than the 1,000–4,000 reported by Shoemaker (1945).

The relationship of fecundity–length was linear and expressed by the regression equation: $F = 14{,}913.3 + 76.7\ L$

where F = fecundity and L = total length: $r = .958$. The calculated length at initial egg production was 192 mm which agrees with back-calculated 4-year old estimates (Table 2).

The calculated regression equation for the fecundity–weight relationship was: $F = 159.1 + 26.4\ W$ with an "r" value of .962.

Food Habits

Food habits were determined for young-of-the-year (15–50 mm) collected from the Mill River during the summer of 1968. Both the zoo- and phytoplankton are utilized in equal amounts until young reach the 35–40 mm size range. Small aquatic dipterans are then selected, shifting eventually to minute terrestrial diptera and coleoptera. Larvae (9–18 mm), held in aquaria, actively fed on introduced zooplankton (primarily cladocerans and copepods).

Fallfish (I+ or older) are considered to be omnivorous based on stomach content data from the four populations examined (Table 6)

TABLE 6.—*Percentage frequency of occurrence and (in parentheses) percentage total volume of food items in fallfish stomachs. >= less than one percent*

Location	Number	Aquatic Diptera	Aquatic Ephemeroptera	Aquatic Trichoptera	Aquatic Fish	Aquatic Crayfish	Aquatic Algae
Winooski River, Vermont	99	1.0 (>)	26.3 (5.8)	34.3 (9.3)	11.1 (9.6)	10.1 (8.6)	64.6 (39.8)
Millers River, Massachusetts	95	2.2 (1.8)	28.9 (13.8)	15.6 (5.2)	— —	— —	53.3 (30.9)
Yellow Creek, Pennsylvania	71	— —	5.6 (2.4)	— —	8.5 (6.8)	— —	76.1 (42.4)
Kettle Creek, Pennsylvania	95	— —	— —	— —	— —	100.0 (14.3)	— —

Location	Number	Terrestrial Diptera	Terrestrial Coleoptera	Terrestrial Hymenoptera	Terrestrial Other Insecta	Debris
Winooski River, Vermont	99	17.2 (3.4)	> (>)	— —	7.1 (1.9)	97.0 (21.4)
Millers River, Massachusetts	95	26.7 (9.1)	20.0 (10.4)	6.7 (3.8)	— —	100.0 (25.0)
Yellow Creek, Pennsylvania	71	33.8 (8.5)	32.4 (14.8)	— —	— —	100.0 (25.1)
Kettle Creek, Pennsylvania	95	1.1 (>)	78.9 (56.3)	33.7 (26.3)	— —	3.2 (3.0)

and the seasonal sampling of the Mill River (Figure 1). There appeared to be a wide variety of food items ingested: algae, fish, aquatic and terrestrial insects, and crayfishes.

Utilization of algae by *S. corporalis* is not considered unusual since other cyprinids are reported to ingest algae: *Notropis rubellus* (Reed, 1957), *Rhinichthys atratulus* (Traver, 1929), and *Hybopsis biguttata* and *Hybopsis micropogon* (Lachner, 1950). The seasonal food pattern in Mill River changed from a low consumption of terrestrial insects in early spring to heavy utilization by mid-summer. This pattern places the fallfish in direct competition with the wild brown trout, *Salmo trutta*, and brook trout, *Salvelinus fontinalis*, populations (Reed and Bear, 1966; Horton, 1961). Fish from Kettle Creek utilized crayfishes as food and may be additional evidence of competition with another game species, *i.e.*, smallmouth bass, *Micropterus dolomieui*. Qualitative data to support this conclusion are not available.

ACKNOWLEDGMENTS

Many individuals directly contributed to my study: Professor T. J. Andrews, Department of Zoology, University of Massachusetts, supplied specimens from the Cannan River, New Brunswick; Mr. F. Allen Johnson, Fishery Services, Bureau of Sport Fisheries and Wildlife, Montpelier, Vermont, collected fish from the Winooski River; and Mr. Jack Miller, Fishery Biologist with the Pennsylvania Fish Commission, collected the Kettle Creek specimens. My sincere appreciation is extended to the following graduate and undergraduate fisheries students at the University of Massachusetts who assisted me in the field and laboratory: David Crestin, James Fair, Alan Maki, and James Moulton.

Finally, a special thanks to my wife, Daphne, for illustrations.

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