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Life History of the Banded Pygmy Sunfish,
Elassoma zonatum
Jordan (Pisces: Centrarchidae),
in Western Kentucky

Stephen J. Walsh and Brooks M. Burr

number eight

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Description, Biology and Distribution of the Spotfin Chub, *Hybopsis monacha*, a Threatened Cyprinid Fish of the Tennessee River Drainage

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ABSTRACT: Jenkins, Robert E. and Noel Burkhead, 1984. Description, biology and distribution of the spotfin chub, *Hybopsis monacha*. Bulletin Alabama Museum of Natural History, Number 8:1-30, 6 tables, 7 figs. Anatomy and color of the distinctive spotfin chub, *Hybopsis monacha* (Cope), are described in detail for the first time. This species currently is in the subgenus *Erimystax*, but *Erimonax* may warrant resurrection as a subgenus for its sole reception. The following appear to be closely linked phylogenetically: *H. monacha*, *Erimystax* s. s., additional eclectic species and species-groups presently in *Hybopsis*, the genus *Phenacobius*, and the subgenus *Cyprinella* of *Notropis*.

Major food items of *H. monacha* are benthic immature insects, primarily Diptera. Maximum longevity is about three years, maximum known size 89.5 mm SL; males attain larger size than females. Spawning probably extends from May into August. Number of ripe ova present in females at one time (150-800; 0.8-1.4 mm diameter) increases with size of female, but may greatly underestimate fecundity in one spawning season if *H. monacha* is a fractional spawner.

Hybopsis monacha typically inhabits medium to large, relatively clean, warm streams. It is closely associated with riffles and runs with various largely unsilted substrate types. During the past 100 years, it was generally rare or uncommon.

The spotfin chub is endemic to the Tennessee River drainage, in which it had a wide range: five states, four physiographic provinces, and 12 tributary systems. It has disappeared from most of this range, being extant and localized in only four systems: Little Tennessee, North Carolina; Duck and Emory, Tennessee; and North Fork Holston, Tennessee and Virginia. Probable or possible reasons for reduction or extirpation of populations include impoundments, cold tailwaters, channelization, pollution, turbidity, siltation, stream renovation by ichthyocide, localized intensive collecting, and interspecific competition. The spotfin chub merits protection status of Threatened nationally, as designated in 1977.

Introduction

The spotfin chub, *Hybopsis monacha* (Cope), is a small cyprinid fish, poorly known until recently. Currently, it is placed in the subgenus *Erimystax*, but its exact relationships to this and other species-groups of eastern minnows are unclear. Cope (1868) thought it had solitary habits, but the specific epithet connoting monastic is appropriate only to its occurrence as generally localized, small populations. The nuptial male of brilliant blue body and blue and white fins has been seen rarely.

Hybopsis monacha is endemic to the Tennessee River drainage of Alabama, Georgia, North Carolina, Tennessee,

and Virginia. Its original range includes varied upland-montane habitats in four physiographic provinces comprising 12 tributary systems: Blue Ridge (French Broad River and Little Tennessee River systems), Ridge and Valley (Clinch River, Powell River, North and South forks of Holston River, and Chickamauga Creek systems), Cumberland Plateau (Emory River and Whites Creek systems), and Interior Low Plateaus (Shoal Creek, Little Bear Creek, and Duck River systems). However, since 1960 *H. monacha* is known only from the Duck, Little Tennessee, Emory and North Fork Holston systems, North Carolina, Tennessee and Virginia. Based on its wide extirpation, and

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on localization and vulnerability of the extant populations, it has been designated as a Threatened species nationally since 1977.

With recognition of wide decline of *H. monacha*, Jenkins was contracted in 1975 by the Office of Endangered Species, U.S. Fish and Wildlife Service, to perform a study of morphology, life history, habitat, and distribution. The data were used in brief accounts of the species (Jenkins and Burkhead, 1980; Jenkins and Musick, 1980; Starnes and Etnier, 1980; Parker and Dixon, 1981), and as a basis for granting it protection status. In 1981, we performed further work for the U.S. Fish and Wildlife Service to determine the current status of populations of *H. monacha* and to supplement previous life history work.

Here presented is a detailed account of historical and current biogeography from museum specimens, ecological data files, and our fieldwork through 1982. This was greatly enhanced by major contributions of collection data by numerous ichthyologists, several with special interest in *H. monacha*. Additionally, the first detailed description of the species is given, and its complex phylogenetic relationships are discussed on the basis of continuing study by Jenkins.

A critical feature of this study is presentation of geochronographic figures. These depict, for single rivers or river systems with extant populations, the past and current distribution of the species, give numbers of specimens captured by specific collection sites, and summarize numbers of collections that did and did not include the species. In so doing, we attempted, and at least closely approached, a review of the entire history of ichthyological survey in the streams treated. Inclusion with the maps of data indicating apparent absence of the species ("negative" data) provides an aspect of the historical record often needed but missing or lightly treated in similar studies. We regard the maps as a valid starting point for future studies of the same species (and to have application in study of associated species). Investigators would not need to repeat the tedious and pitfall-replete process of regathering and resynthesizing the original data, which are highly scattered, often esoteric, and largely unpublished.

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The extent of geographical and historical coverage of this report would have been unapproachable without the interest and aid of numerous colleagues, several of whom frequently provided data.

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Special recognition is due the following. James P. Beets and Robert P. Smith provided detailed notes on joint observations in Emory River. Edward Crittenden, recent retiree of the USFWS, Gatlinburg, provided his unpublished survey report on the Little Tennessee system, gave background on his Emory system survey, and collected Whites Creek for us; all these efforts were specifically for *H. monacha*. Bruce H. Bauer transmitted Crittenden's Emory data to us. Richard B. Eager, formerly TVA, now USFWS, provided specimens and his unpublished report on *H. monacha* in Little Tennessee River, and transmitted information on Franklin Dam. David A. Etnier sent a report on survey of the Little Tennessee system for *H. monacha*, and kept us abreast by unpublished reports of all his collections made in Tennessee since 1967 and of two study sessions on early TVA collections at the UMMZ. For these considerable efforts, we also acknowledge Etnier's students Bruce H. Bauer, James P. Beets, John L. Harris, David L. Nieland, and Wayne C. Starnes. We thank Richard G. Biggins, USFWS, Asheville, for a copy of the Chickamauga survey report by Etnier, Bauer and Andrew G. Haines, UT. Joseph C. Freeman provided vast data from ichthyofaunal study of North Fork Holston River by the TVA. Richard L. Hill, Virginia State Water Control Board, apprised us of water quality and recent fish kills in the North Fork Holston. William H. Redmond, UT, had printout made for us of *H. monacha* records in the TVA Natural Heritage Program data bank. J. Frank McKinney, USNM, aided in specimen photography.

The following significantly aided us in fieldwork: Robert L. Dudley, Mark D. Gibson, William H. Haxo, Stephen P. McIninch, Roanoke College students; and Diane J. Jenkins.

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Methods

External, sensory, and trophic anatomy. — Lengths of specimens are expressed as mm SL (standard length), measured to the nearest 0.1 mm with needlepoint dial calipers, or as size classes of 2 mm SL. Measurements of body parts were read to the nearest 0.1 mm, except for basal diameters of tubercles and brain dimensions, which were measured under a binocular microscope with dial calipers to the nearest 0.05 mm. Standard methods (Hubbs and Lagler, 1958) generally were used for counts and measurements of body parts, but some of our methods warrant qualification when alternative methods may be in common practice or implied by Hubbs and Lagler. Head and postorbital lengths were measured to the bony posterior margin of the operculum. Snout and postorbital lengths were taken from the bony orbital rim. Orbit length and interorbit width were measured from the fleshy orbital rim. Upper lip length includes the anterior expansion of the lip and excludes the barbel. Nuptial tuberculation, the cephalic lateral line system and cutaneous taste buds were examined under strong light with a binocular microscope and compressed air. Snelson (1972) was followed for terminology of the lateral line system. Gill raker counts are of the total, including rudiments, on the outer portion of the first right arch. The intestine and swim bladder were extracted for measurement.

Food. — Diet was determined from contents of the first descending section of the intestine. Percent fullness of this section was visually estimated.

Aging. — Attempts to age specimens by recognition of annuli on scales often resulted in great uncertainty. Usually 6–10 scales were removed from the dorsolateral area below the dorsal fin. For 56 specimens, scales were mounted between glass slides. For 28 additional specimens, scales were placed in a watch glass with alcohol. Scales were examined under a 30x stereomicroscope and/or a 100x microprojector. Attempts to age many problematic specimens were made during well separated periods, to allow a fresh opinion each time, but no clear advantage was gained.

For some specimens, regarded as aged with some certainty, periods of rapid or slow growth were recognized by groups of widely or closely spaced circuli (each group with four to many circuli) in the lateral and posterior fields, and/or by cutting over of one to three lateral field circuli. However, for many other specimens, adjacent similarly spaced circuli numbered only two or three, rendering it highly uncertain that a full period of rapid or slow growth for the year was indicated. In some of these specimens, posi-

tion of a putative annulus often varied distinctly among the scales. The first annulus generally was the least distinct or unrecognizable annulus. Of 84 specimens we attempted to age by scales, 36 were deemed unageable, and 48 were aged with some certainty. Hereafter the latter are termed "scale-aged" specimens. We did not back-calculate lengths of scale-aged specimens because a single circulus marking an annulus often was unrecognizable (particularly at the first annulus), and because of potential bias from using a subsample that in this case was particularly selective.

Length frequency also presented unsolved problems in aging individual specimens and recognition of a general growth pattern. The composite of 317 specimens (Table 3) from throughout the species range, the vast majority from extant populations, did not clearly identify age groups, despite separate analysis of the sexes and only moderate latitudinal/altitudinal range. Separate frequency distributions for the Little Tennessee, Emory, and North Fork Holston populations did not enhance aging due to smaller samples and possible year-class differences in growth. Apparent protraction of the spawning season also probably adversely affected length frequency analysis.

In the Age and Growth section, age groups are recognized on combination of the pooled length frequency and the 48 scale-aged specimens, with emphasis on the latter.

Reproductive parameters. — Specimens were sexed by examination of gonads or, for some nuptial males, by presence of well-developed tubercles. Size of gonads was recorded as minute, small, medium, large, or very large, by comparison with maximum gonad size of the respective sex. GSI refers to gonosomatic index, calculated by total weight of both ovaries divided by eviscerated body weight X 1000. Weights were determined after blotting, to the nearest 1 mg for ovaries and to the nearest 10 mg for bodies, with a Mettler analytic balance. Numbers of Class I ova were determined by direct count from both ovaries. Numbers of Class II ova were estimated by counting a total of 125–200 ova of classes I and II from each specimen, subsampled from different areas of the ovaries, to determine the ratio of Class II to Class I in the pooled subsamples of the specimen; the ratio was then multiplied by the total number of Class I ova in that specimen. Ova diameters were measured with an ocular micrometer in a stereomicroscope. Ten randomly selected ova of each class from seven specimens were measured, to the nearest 0.1 mm for Classes I and II, nearest 0.05 mm for Class III.

Substrate. — Size ranges in cm of certain substrate types mentioned herein are: pea or small gravel, 0.3–3.0; medium gravel, 3–5; large gravel, 5–8; small rubble, 8–15; medium rubble, 15–22; large rubble, 22–30; boulder, greater than 30.

Geochronographic figures: data base, collecting methods, and interpretation. — These figures are maps showing loca-

tions, years, numbers of collections, and results of collecting in rivers with three of the extant populations (Figs. 5-7). Collection sites generally are 0.1-0.4 km length. The center of each site usually is located to the nearest 0.1 Rkm (River kilometer). A few sites were located approximately, generally when distance/bearing descriptors and site names given by the collector disagreed slightly. In such cases, the most likely site was chosen. A few localities shown as one actually comprise 1-3 separate sites whose centers are usually 0.5 km apart at most. For USGS/TVA topographic quadrangles that omit North Fork Holston River mileages, we determined these with a map measurer using checkpoints provided by the TVA; some of these may be slightly inaccurate. In a few cases the number of specimens is approximate; this occurs for specimens released without careful count or those observed instream. In instances when a range of number of specimens was given to us, the low estimate was used. Locality data for all records are given under Materials. Data for collections lacking *H. monacha* are available from Jenkins.

Interpretation of qualitative (presence/absence) and quantitative (number/density) catch results, particularly for determination of stability or changes in distribution and abundance, should include consideration of objectives, technique, and intensity of collecting. These in turn may be affected by substrate, turbidity, and discharge and by habitat preferences of target species. We did not sample by electroshocker or ichthyocide when turbidity would have reduced specimen capture. High discharge from heavy rains caused us to abort collecting trips. However, under favorable conditions, we believe that for *H. monacha*, one intensive collection by either seine, shocker, or ichthyocide at a site generally provides adequate qualitative information, i.e. the species is either present or absent (or uncollected but extremely rare, virtually absent). Most collections made by seine and shocker since 1970 in the upper Little Tennessee, Emory, and North Fork Holston were aimed particularly, often solely, at securing *H. monacha* by expending greater effort in its preferred habitat, or they involved chemical treatment (rotenone or creosol of fairly large areas, sodium cyanide in small, swift areas). Several sites in the above rivers have been sampled often, lending greater strength to qualitative results. Further, although some sites were sampled only once or twice, generally these were near more frequently worked sites. Data from low sampling intensity tended to be consistent with those from high intensity, and combination of data from both intensities usually yielded a clear pattern for 10-20 km river sections concerned.

Seining often is criticized as yielding too little or invalid qualitative and quantitative data. Many collections treated herein were made by seine, virtually all of those from the 1800s to 1950, and many of ours since 1970. We think the seine yielded adequate qualitative data in most situations. We emphasize that seining effectiveness is greatly enhanced by knowledge of specific habitat associations and by good execution of techniques appropriate for these habitats.

Population of *H. monacha* in North Fork Holston River are often centered at major areas of gravel in or near swift current. Such relatively smooth surfaced substrate is readily sweep-seined. An indication of our apparent effectiveness is depletion by seining of *H. monacha* at North Fork Holston Rkm 10.1 and 41.2. Also, at North Fork Holston Rkm 3.2, we first surveyed a wide area by snorkeling, locating only two juveniles at one spot of rough bottom; immediately subsequent seining of the entire snorkeled area took one juvenile from the exact spot where the two were sighted.

The prevalent methods used in the Little Tennessee and Emory were electroshocking and ichthyocide, probably more effective methods therein than seining because of higher frequency of large rubble and boulder than in the North Fork Holston. In the latter, most of our 1981 collections and all of our 1982 collections were by shocker. Kick-seining, of course, yields useful results for benthic fishes among large substrate and was employed in much of our work.

Two types of quantitative information derive from numbers of specimens in a collection: general or relative abundance (compared with associated species, or with other efforts for target species alone) and population density. Estimates of the latter for *H. monacha* resulting from random community sampling generally have little significance because of its distinct tendency to localize. Density estimates are treated under Distribution, Emory system.

Abundance descriptors used herein, from numbers captured or seen while snorkeling, are rare (1-4 specimens), uncommon (5-10), and common. These interpretations are fairly firm for some North Fork Holston sites because we tended to equalize efforts at specific sites (each generally worked 1-2 h, some on 4-8 dates). We made similar interpretations of most recent data by others because we are aware of their collecting strategies.

For pertinent background and documentation of collecting efforts, we review under Distribution major or otherwise important collecting programs, with indication of methods when known. These and additional collections from three of the four systems with extant populations are summarized in Figs. 5-7.

Materials

A virtually complete record of capture, repository or release, or observation is given. Institutional acronyms are under Acknowledgements. NMB and REJ prefix our field numbers, with which series are identified at Roanoke College. RC denotes series at Roanoke College not collected by us. Number of specimens (in parentheses) follows the catalog or field number, or acronym. For more than one number in parentheses, the first is of extant specimens, the others released or observed specimens, as indicated. Brackets signify all specimens were released or observed. Asterisk denotes extant specimens not examined by us. Notation "nonextant" refers to specimens, none examined by us, that

apparently no longer exist. All specimens indicated as unexamined, released, observed, or nonextant are regarded as competently identified. The few misidentifications of this distinctive species that have occurred were resolved.

The 841 total specimens (96 collections and/or observations) comprise 333 extant, examined by us (part or all of 55 series); 199 extant, unexamined (part or all of 36 series); ca. 63 released (part or all of 12 collections); ca. 113 observed (6 sessions); and ca. 133 unlocated, probably nonextant (forming part of 1, all of 4 collections). Numbers taken in two additional nonextant collections are unknown.

Within each tributary system, collections are listed in sequence progressing upstream, all main river sites first. Collections from the same site are listed in chronological order. Nonoriginal locality data, except for conversions to metric, are bracketed. For collectors, generally only party leader or agency is given.

Duck River System. *Tennessee:* LEWIS COUNTY: NLU 39464 (4*) Buffalo River 0.4 km below to 0.4 km above Grinders Creek mouth, 8-9 April 1978, Douglas. UMMZ 105181-105182 (3) Grinders Creek at TVA site 579, 41SE, 42NE, 50SW [6.4 airkm NW of Napier], 24 May 1937, TVA.

Little Bear Creek System. *Alabama:* COLBERT COUNTY: UMMZ 132502 (1) Little Bear Creek at TVA site 620 [5.6 airkm SW of Tuscumbia], 19 November 1937, TVA.

Shoal Creek System. *Alabama:* LAUDERDALE COUNTY: UMMZ 192582 (orig. Indiana Univ. 4787) (1), USNM 36664 (2) Shoal Creek at [probably near] Florence, 1884, Gilbert, Swain.

Chickamauga Creek System. *Georgia:* CATOOSA COUNTY: (nonextant) [South] Chickamauga Creek at Ringgold, summer 1877, Jordan.

Little Tennessee River System. *Tennessee:* MONROE COUNTY: UMMZ 113292 (1) Citico Creek near mouth, 16.1 km E of Madisonville, 11 November 1936, Holloway. UMMZ 165598 (1) Citico Creek 10 miles above mouth, near Tellico Plains, 16 September 1940, Holloway. *BLOUNT COUNTY:* UMMZ 129466 (37) Abrams Creek ca. 1.6 km above mouth, ca. 0.4 km above and below Panther Creek mouth, 6 September 1937, Hubbs. UMMZ 163294 (1) Abrams Creek near Panther Creek mouth, 31 March 1941, Hubbs. UMMZ 163280 (3), UMMZ 163280S (1* cleared, stained) Abrams Creek at Happy Valley, ca. halfway between mouth and falls, 31 March 1941, Hubbs. KFW (32) Abrams Creek within ichthyocided zone, below falls, 9 June 1957, Whitney. *North Carolina:* SWAIN COUNTY: UMMZ 131474(2) Tuckasee River at Noland Creek mouth, 29 June 1940, Hubbs. Little Tennessee River: RC (4, 4 rel.) Rkm ca. 144.4, vic. end of Co. Rt. 1125, including Halls Ford, 0.5 km below Sawmill Creek, near or just within upper arm of Fontana Reservoir, 6 November 1975, Eager. (TVA 68.16, 1* specimen, from this site on "12" November 1975 probably is one of the "released" specimens, misdated). RC (4) same site as preceding, 26 November 1975, Eager. UT 44.1424 (1*) same site as preceding, 8 July 1977, Etnier. UF 26374 (1*) same site as preceding, 1 October 1977, Etnier. RC (1) Rkm 154.9, 50 m above Rattlesnake Creek mouth, 10 April 1980, Crittenden. UT 44.1424 (1*) Rkm 156.1, along Co. Rt. 1113, at swinging bridge, 1 October 1977, Etnier. *MACON COUNTY:* Little Tennessee River: UF 24085 (2*) Rkm 159.3, along Co. Rt. 1113 near county line, 7 July 1977, Etnier. UT 44.1110 (3*, 3 rel.) Rkm 160.9 near Stiles, vic. Lost Creek Bridge, between Rts. 28 and 1370, ca. 2.9 km above Co. line, 6 November 1975, Eager. TVA (2*) same site as preceding, 25 November 1975, Eager. UF 26423 (1*) same site as preceding, 8 July 1977, Etnier. TVA 68.15 (1*, 1 rel.) Rkm 170.6, Coggins Bend, access via Welch Farm, ca. 0.8 km above Rose Creek mouth, 6 November 1975, Eager. RC (2) same site as preceding, 25 November 1975, Eager. NCSM 6894 (1*) Rkm ca. 177.0, Rt 28 bridge near Iotla, just below Iotla Creek, 6 November 1975, Eager.

French Broad River System. *North Carolina:* MADISON COUNTY: USNM 40499 (1) Spring Creek at Hot Springs, 13-14 August 1888, Jordan. *BUNCOMBE COUNTY:* UMMZ 192584 (orig. Indiana Univ. 8132) (2) Swannanoa River at railroad station to ca. 3.2 km above, near Asheville, 15, 17 August 1888, Jordan.

Whites Creek System. *Tennessee:* RHEA-ROANE COUNTY LINE: USNM 190644 (7) Whites Creek 1.6 airkm SW of Glen Alice, 29 August 1959, Taylor.

Emory River System. *Tennessee:* **Emory River:** ROANE COUNTY: UMMZ (44*), UMMZ (16), UMMZ 157704 (2) Rkm ca. 20.9, vic. Avery Branch mouth, 12-13 October 1941, TVA. *MORGAN COUNTY:* UT 44.189 (2) Rkm ca. 29.0, at Oakdale, 16 October 1967, Etnier. UT 44.563 (4) Rkm 35.1, at Hall Bridge near Camp Austin, 4 September 1968, TVA. TVA 68.8 (6*) same site as preceding, 11 December 1974, TVA. UT (2*) same site as preceding, 6 November 1975, Etnier. BHB (6*) same site as preceding, 18 August 1981, Crittenden. UF 15919 (4) Rkm ca. 44.2-46.0, near Nemo Bridge between mouths of Obed River and Island Creek, SW of Wartburg, 12 June 1968, Etnier. UT 44.564 (36 plus 11 nonextant) same site as preceding, 16 August 1968, TVA. (1 nonextant) same site as preceding, 5 August 1969, Etnier. UT 44.552 (21) same site as preceding, 6 August 1970, Etnier. UT 44.1031 (19*) same site as preceding, 8 May 1974, UT students. UT 44.1092 (23*) and WCS 265-01 (8*) same site as preceding, 24 July 1974, Starnes. TTU (38), AU 12167 (1*) same site as preceding, 14 and/or 19 September 1974, Riddle. [2 obs.] same site as preceding, 10 December 1974, Saylor. TVA 68.7 (1*) same site as preceding, 12 December 1974, Saylor. UAIC 4897.02 (11*) same site as preceding, 6 June 1975, Boschung. AU 11026 (24*) same site as preceding, 27 August 1975, Ramsey. [ca. 80 obs.] same site as preceding, 15 August 1979, Beets, Smith. NMB 601 (9, ca. 20 obs.) same site as preceding, 10 August 1981, Burkhead. BHB 887 (4*), UT 2377 (4*) same site as preceding, 19-20 August 1981, Crittenden.

Emory River tributaries. *Tennessee:* *MORGAN COUNTY:* USFWS (2*) Island Creek just above mouth in Emory River, 23 August 1979, Smith. (27 nonextant?) Obed River, tributary of Emory River, Rkm 0.6, fide Riddle (1975), 1974, Riddle. AU 11449 (2*) Obed River, Rkm 15.0, at Daddys Creek mouth, 3 July 1974, Riddle. UT 44.2359 (3*) Clear Creek, tributary of Obed River, Rkm 2.3, at Lilly Bridge, 7 August 1981, Crittenden. TTU (4), AU 11474 (1*) Clear Creek, Rkm 6.4, at Jett Bridge, Rt 4252, 27 June 1974, Riddle. UT 44.2361 (2*) same site as preceding, 5 August 1981, Crittenden. (89 nonextant) Clear Creek, Rkm 14.2, at Waltman Ford Bridge, White Creek mouth, August 1968, TVA. UT 44.2360 (3*) same site as preceding, 6 August 1981, Crittenden. UT 44.2363 (2* and 1 hybrid) Daddys Creek, tributary of Obed River, Rkm 0.0-0.5, 16 July 1981, Crittenden. (5 nonextant?) Daddys Creek, Rkm 0.3, 1974, Riddle. TTU (2*) Daddys Creek, Rkm ca. 3.9, near Devil's Breakfast Table in Catoosa Wildlife Management Area, 16 November 1979, Abbott. UT 44.2378 (3*) same site as preceding, 20 August 1981, Crittenden. UT 44.2362 (1*) Daddys Creek, Rkm ca. 5.6, unnumbered Co. Rt. at Cumberland-Morgan Co. line, 28 July 1981, Crittenden.

Clinch River System. *Tennessee:* *CLAIBORNE-UNION COUNTY LINE:* USNM 117361 (1) Clinch River at Walkers Ford, [Rkm ca. 203], 12 October 1893, Evermann. *CLAIBORNE COUNTY:* (nonextant) Ball Creek near Tazewell, 12 October 1893, Evermann.

Powell River System. *Tennessee:* *CLAIBORNE COUNTY:* USNM 70581 (2) Indian Creek near Cumberland Gap, 17 October 1893, Gurley.

North Fork Holston River System. *North Fork Holston River:* *Tennessee:* *HAWKINS COUNTY LINE:* UMNH 17606 (orig. VPI 554) (4) Rkm 0.3-1.2, near Sullivan Rt 11 bridge, 12 June 1954, Ross. USNM 177657 (orig. VPI 558) (1) same site as preceding, 9 July 1954, Ross. CU 46397 (2) same site as preceding, 9 August 1963, Zorach. TVA 68.21 (2*) same site as preceding, 23 August 1977, TVA. USNM 231355 (orig. REJ 701) (1, 1 obs.) Rkm 3.2, 0.5 km. below Sensabaugh Branch mouth, 26 August 1975, Jenkins. CU 50382 (orig. VPI 559) (1) Rkm 7.5, Cloud Ford, above bridge on Cleveland-Morrison City Road, 9 July 1954, Ross. *Virginia:* *SCOTT COUNTY:* REJ 376 (7) Rkm 10.1, Click Island, 1 August 1970, Jenkins. TVA 68.6 (1*) same

site as preceding, 13 March 1972, TVA. TVA 68.27 (1*) same site as preceding, 21 April 1976, TVA. (1 rel.) same site as preceding, May 1981, TVA. REJ 568 (1) Rkm 37.7, Holston Mill along Co. Rt 689, 4 June 1972, Jenkins. REJ 931 (1) same site as preceding, 18 June 1981, Jenkins. REJ 552 (18) Rkm 41.2, island off Blue Springs Branch mouth, along Co. Rt 689, 16 May 1972, Jenkins. REJ 569 (10) same site as preceding, 4 June 1972, Jenkins. TU 96409 (orig. REJ 668) (3) same site as preceding, 20 May 1974, Jenkins. USNM 231356 (orig. REJ 707) (2) same site as preceding, 27 August 1975, Jenkins. REJ 928 (2, 2 rel.) same site as preceding, 17 June 1981, Jenkins. REJ 947 (1, 1 rel., 4 obs.) same site as preceding, 19 May 1982, Jenkins. REJ 948 [1 rel.] Rkm 45.9, along Co. Rt 689, 0.5 km above Cove Cr. mouth, 19 May 1982, Jenkins. WASHINGTON COUNTY: NMB 614 (3, 7 rel.) Rkm 59.2, island off Co. Rt 615, 0.7 airm S of Jct. Co. Rts 614-615, near Mendota, 14 August 1981, Burkhead. REJ 949 (2, 1 rel.) Rkm 62.9, Co. Rt 614 bridge at Mendota, 19 May 1982, Jenkins. NMB 613 (6, 16 rel.) Rkm 68.2, Hobbs Ford off Co. Rt 614, 1.6 airm E of Mendota, 14 August 1981, Burkhead. REJ 950 (1, 20 Rel.) same site as preceding, 20 May 1982, Jenkins. NMB 612 (3, 6 obs.) Rkm 71.6, Fleenor Mill Ford off Co. Rt 614, 3.9 airm ENE of Mendota, 14 August 1981, Burkhead. REJ 951 (4, 6 rel.) same site as preceding, 20 May 1982, Jenkins. SMYTH COUNTY: ANSP 2036-2040 (5 syntypes) Rkm ca. 132, vic. of Saltville; see Types section, October 1867, Cope. USNM 40475 (3) same site as preceding, or nearby, 9 August 1888, Jordan. ANSP 74181 (1) Rkm 142.6, at Co. Rt 633 bridge 5.8 km. E of Saltville, 21 June-4 July 1954.

South Fork Holston River System. Tennessee: SULLIVAN COUNTY: UMMZ 157561 (3) South Fork Holston River 0.4 km above South Holston Dam site, 23 September 1947, Bailey. Formerly UMMZ 157534, exchanged (2*) South Fork Holston River near Fish Dam Creek mouth, 3.2 km ENE of dam site, 22 September 1947, Bailey. UMMZ 159595 (3) South Fork Holston River 1.6 km below state line, 23 September 1947, Bailey. UMMZ 157506 (1) Jacob Creek, tributary of South Fork Holston River, from mouth to ca. 200 m upstream, 20 September 1947, Bailey.

Hybopsis monacha (Cope)

Spotfin Chub

Figs. 1-3

Cope (1868) described the spotfin chub as *Ceraticthys monachus* from an unspecified number of specimens seined in October 1867 with W.A. Stuart. The five syntypes found by Fowler (1924) and us are subadult to adult, 52-79 mm SL, in fair condition. Orthography of the specific epithet was clarified by Hubbs and Crowe (1956).

The types are from North Fork Holston River, Virginia, the locality being the vicinity of Saltville located in Smyth County just above the Washington County line. Cope (1868) stated that the species occurs in the channel of the Holston in Washington County, but stated he collected in Saltville, and often seined "...for some miles at a time." We arbitrarily plotted the type locality, and the second Saltville area record (Jordan, 1889), at Saltville (Fig. 7: Rkm 131.9).

Description

Diagnosis. — Body elongate, slightly compressed; eye small, lateral; mouth inferior, upper lip expanded anteriorly; terminal labial barbel minute or absent; teeth 4-4; scales moderately small, lateral line 52-62; anal rays 8; caudal spot with distinctive shape; posterior part of dorsal fin with dark area or moderate amount of melanin in membranes; no blot-

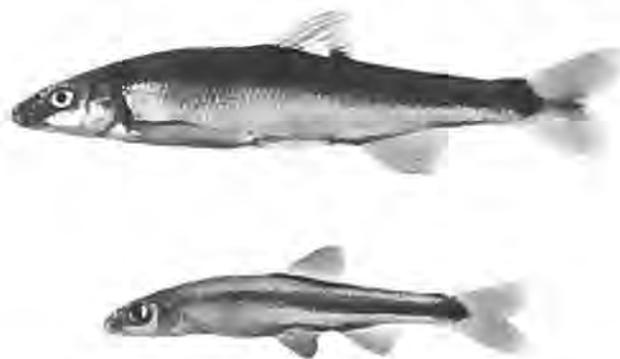


Fig. 1. *Hybopsis monacha*: Upper - tuberculate male 74 mm SL taken 4 June 1972 (REJ 569). Lower - juvenile male 44 mm SL taken 16 May 1972 (REJ 552). Both from North Fork Holston River.

ches or speckling on body. Nuptial male with medium to large, antrorse tubercles on most of head dorsum; smaller tubercles on front and side of snout; body with iridescent blue prominent above lateral line; fins blue with white margins.

External morphology. — Morphometry: Physiognomy of head and body and form and location of fins are shown in Fig. 1. Proportional measurements (Table 1) show slight but significant sexual dimorphism only in lengths of the dorsal, anal and pelvic fins (longer in males) and predorsal and postdorsal lengths (dorsal fin inserted more anterior in males). It is surprising that a significant difference was not found in pectoral fin length (expected longer in males), as this fin is tuberculate only in males and probably used to aid in maintenance of contact with females during the spawning act. The probability of a significant difference between the sexes in pectoral length was less than 0.1 but not less than 0.05. The juveniles in the measured sample may have reduced the pectoral fin difference of adults. Sexual dimorphism in position of the dorsal fin insertion in certain other American cyprinids was found by Snelson (1972), Hubbs et al. (1974), and Snelson and Pflieger (1975).

Scale counts: Lateral line 53 (in 1 specimen), 54(2), 55(5), 56(4), 57(5), 58(3), 59(3), 60(4), 61(2), \bar{x} = 57.2 (range of 52-62 given by Hubbs and Crowe, 1956). Rows across back 15(2), 16(2), 17(20), 18(2), 19(3), \bar{x} = 17.1. Rows across belly 13(5), 14(9), 15(12), 16(1), 17(1), \bar{x} = 14.5. Circumferential rows (last 2 counts + 2) 30(1), 31(1), 32(5), 33(8), 34(9), 35(1), 36(3), 38(1), \bar{x} = 33.5. Predorsal rows crossing mid-dorsum 24(3), 25(4), 26(11), 27(3), 28(1), \bar{x} = 25.7. Caudal peduncle 15(2), 16(7), 17(12), 18(6), 20(1), \bar{x} = 16.9. Breast squamation (% scaled area) 10-100, \bar{x} = 48. Scale radii only in posterior field; counts from 38 total scales from upper body beneath dorsal fin of 5 specimens 50-77, \bar{x} = 65 mm SL: primary radii 3-11, \bar{x} = 4.7, secondary radii 0-6, \bar{x} = 2.1, total radii 3-12, \bar{x} = 6.9; larger specimens tended to have higher counts.

Fin ray counts: Pectoral 13(3), 14(13), 15(10), 16(1),

Table 1. Proportional measurements (expressed in thousandths of SL) of well preserved larger juveniles and adults of *Hybopsis monacha*: 9 females 46-78, \bar{x} =62.7 mm SL; 13 males 48-76, \bar{x} =65.6 mm SL. Student's t-test was used to test the significance between means. Levels of probability (P) greater than 0.05 were considered not significant (ns).

Character	Sex	Range	x	SD	t value	P
Head length	F	213-234	228	0.60	1.632	ns
	M	216-235	223	0.68		
Head depth	F	131-141	138	0.60	0.607	ns
	M	133-145	139	0.35		
Head width	F	112-129	120	0.55	1.167	ns
	M	108-128	117	0.52		
Snout length	F	75-84	79	0.32	1.027	ns
	M	73-89	81	0.50		
Postorbital	F	80-94	88	0.45	0.766	ns
	M	79-99	90	0.56		
Orbit length	F	39-60	51	0.67	0.892	ns
	M	40-54	49	0.43		
Upper lip length	F	58-67	63	0.46	0.109	ns
	M	60-68	63	0.23		
Gape width	F	46-62	52	0.51	1.710	ns
	M	46-65	56	0.53		
Interorbital width	F	69-83	74	0.46	0.320	ns
	M	69-82	75	0.36		
Caudal peduncle length	F	182-239	206	1.57	0.056	ns
	M	194-218	206	0.83		
Caudal peduncle depth	F	78-92	84	0.41	1.750	ns
	M	81-101	88	0.53		
Dorsal fin length	F*	164-193	175	1.03	3.335	0.01
	M**	177-194	186	0.53		
Anal fin length	F*	129-161	144	1.06	3.348	0.01
	M**	146-169	159	0.93		
Pectoral fin length	F*	139-170	158	1.10	1.994	ns
	M**	151-177	166	0.75		
Pelvic fin length	F	128-151	138	0.070	2.824	0.02
	M	138-153	145	0.38		
Body depth	F	151-219	190	2.16	0.101	ns
	M	175-221	191	1.25		
Body width	F	114-153	131	1.36	1.958	ns
	M	116-136	123	0.65		
Predorsal length	F	515-543	526	0.87	2.557	0.02
	M	493-529	516	0.99		
Postdorsal length	F	476-510	494	1.13	2.518	0.05
	M	494-528	506	0.95		
Prepelvic length	F	471-499	492	0.92	1.298	ns
	M	474-505	487	0.98		
Preanal length	F	673-718	698	1.39	1.170	ns
	M**	682-712	692	0.85		

*8 specimens; **12 specimens

\bar{x} = 14.3. Pelvic 8-8(27), 8[left]-7(2), 9-8(1), \bar{x} = 16.0. Anal 7(2), 8(35), \bar{x} = 8.0. Dorsal 8(32). Branched caudal 17(24).

Nuptial tuberculation: twenty-eight highly tuberculate males, 60-89, \bar{x} = 73.2 mm SL (KFW, Abrams Cr.; REJ 569, 950, North Fork Holston R.; UF 15918, Emory R.), were examined. Fig. 2 is of a male with basically typical distribution of head tubercles; its head dorsum tubercles are larger, less crowded and fewer than in most specimens. Distribution of cephalic tubercles (and range of tubercle counts of

11 specimens) are: head dorsum from internasal region to occiput (58-142); anterior snout (38-64); sides of snout, over lachrymal bone (12-41); jaw rami and lower cheek with a few tubercles in some specimens (0-5, 0-6 respectively). Total head tubercles range 112-244, \bar{x} = 183; the figured specimen has 118. Larger specimens tend to have higher counts, resembling certain species of *Notropis* (*Cyprinella*) in Gibbs (1963:Fig. 2, upper two specimens). A narrow to broad (Fig. 2) hiatus occurs between internasal and anterior snout tubercles in most specimens; in some specimens, generally those with relatively high tubercle numbers, the area of the hiatus has tubercles spaced about equally as in the internasal region. Size of most head tubercles is medium-small to medium-large (compared with cyprinids in general), basal diameter of largest ones 0.9% SL. Tubercle size tends to be smallest, and density greatest, on the snout tip. Some specimens with relatively few, less crowded tubercles on the dorsum behind the snout have suggestion of alignment of many of those tubercles into two rows, each slightly lateral to the midline (as on left side in Fig. 2); no specimens have a straight row. (See also description of small, weakly tuberculate specimens, below.) Most dorsum and lateral snout tubercles are antrorse, except supraorbitally where tubercle tips more frequently curve laterad; most on the snout tip are erect.

The body, although most roughened, is weakly tuberculate. Its tubercles are generally very small to minute; they tend to be more widely distributed in larger specimens. Most specimens have moderate to low density of tubercles in most dorsal and lateral areas and relatively few tubercles on the belly. The anterior nape tends to be the most heavily tuberculate area, with tubercles scattered over all exposed scale fields; a few tubercles approach the size of smaller head tubercles. Elsewhere tubercles tend to occur only marginally and submarginally on scales. The midlateral body tends to be more tuberculate than the upper body except for the nape. When tubercles are present on the lower half of the caudal peduncle, they tend to be slightly larger than those on the upper half. Firm, pronouncedly thickened, probably keratinized epidermis extends over the scales in the ventrolateral area from the pectoral to caudal fin. Thickening increases toward the posterior margin of each scale, effecting a rough surface. Thickening is greatest over the urosome, where in peak development the surface of each scale is further roughened by 3-10 longitudinal ridges apparently of the same tissue as general epidermal thickening. Some specimens with pronounced urosomal skin thickening apparently lack tubercles in that area; the function of tubercles probably is served by elevation of skin at scale margins and surface ridging.

On the pectoral fin, small tubercles occur along most of the dorsal surface of ray 1 and succeeding 7-10 rays; they are arranged uniserially (except biserial at proximal ray fork), and number 1-2 per ray segment. Tips are curved posteriad or medioposteriad when the fin is abducted 90°.

Pelvic fin tubercles are minute and occur on the dorsal surface of rays, from ray 2 through 4-8. No other fins are tuberculate.

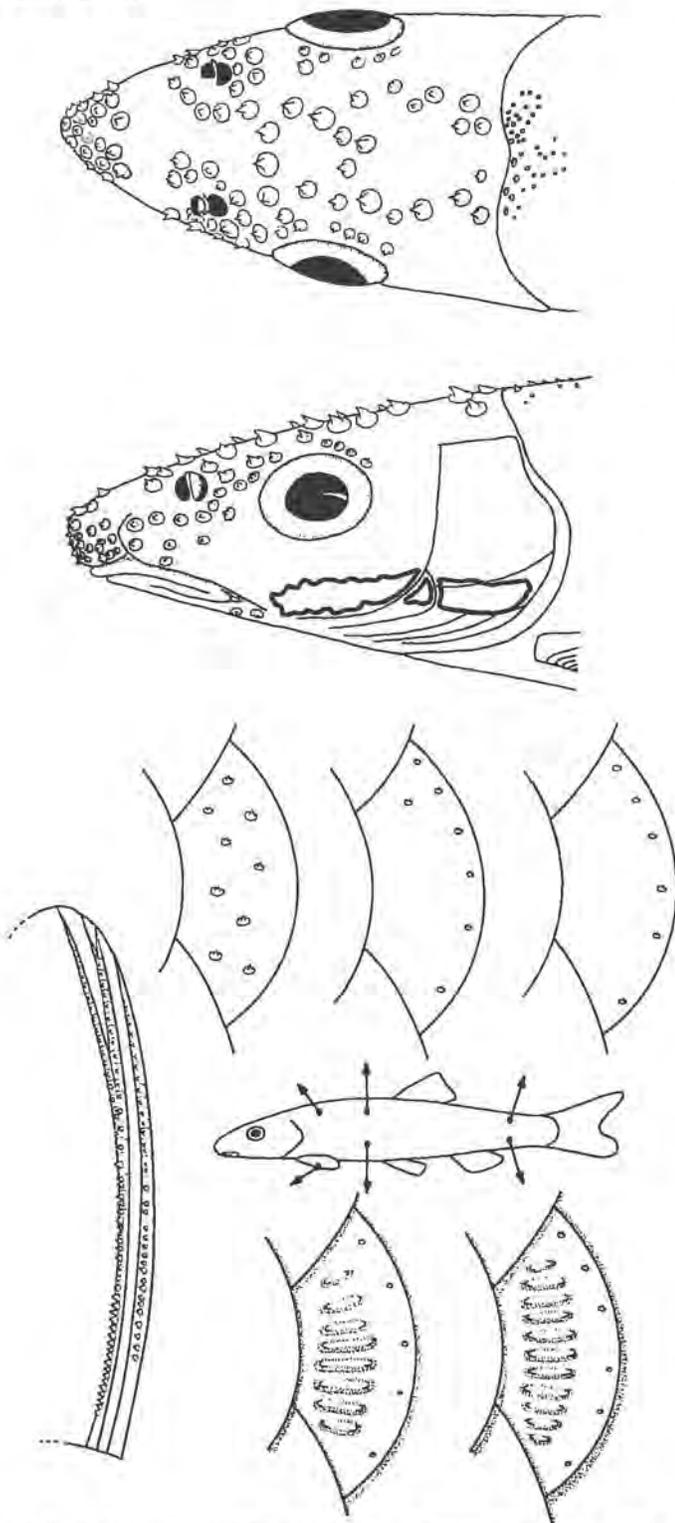


Fig. 2. Highly tuberculate males of *Hybopsis monacha*. Dorsal and lateral head from same specimen as in Fig. 1, upper. Bold outline on lower side of head indicates location of nuptial pad. Tuberculation of representative scales and dorsal surface of first two pectoral fin rays based on composite of specimens in KFW series from Abrams Creek, 9 June 1957.

A nuptial cheek pad is present in two males (REJ 569, UF 15918). It is a pale, flat, smooth surfaced (under 10X magnification) area of firm (not hard), possibly keratinized tissue on the lower cheek and operculum (Fig. 2). The pad is only moderately developed in one male (74 mm, REJ 569) compared with nuptial males of other species of the subgenus *Erimystax* and the genus *Phenacobius* and is barely discernible on another male (72 mm, UF 15918). Oddly, all 25 Abrams Creek tuberculate males appear to lack the pad, although it is hinted in one of the larger. It is absent in the 89 mm North Fork Holston male (REJ 950), which on the lower cheeks has 6 tubercles on one side, 11 on the other. The pad probably increases friction between spawning individuals, and may be a contact pad.

Other large, apparently adult size, males and females, and some smaller which may be large immatures or have just matured (taken from spring to mid-summer, sometimes with highly tuberculate males), have weakly developed tuberculation. Their tubercles are small or, in most specimens, minute (possibly in "bud" stage, Lachner and Jenkins, 1971) on the head, anterior nape and, present only in larger males, minute on pectoral and pelvic fins. A nuptial pad and coloration were not detected on any. These males tend to have better developed tuberculation than females of similar size with which they were collected. Some adults of both sexes taken in later summer and fall have obvious, somewhat keratinized buds or old tubercle cores on the head. Smaller specimens tend to have fewer head tubercles than larger specimens, and often most of their dorsum tubercles are arranged into 2 or 4 longitudinal rows.

Sensory and trophic anatomy. — The form of the dorsal surface of the brain of species of *Hybopsis* was studied by Davis and Miller (1967), but they lacked *H. monacha*. Compared with data and figures by Davis and Miller, *H. monacha* has a large cerebellum and optic lobes and small facial and vagal lobes (Fig. 3), adapting it for maneuverability and placing it in the "sight feeder" group, although the orbit is small. Brain proportions (thousandths of total brain length) of one specimen (REJ 522) 65 mm SL, total brain length 7.45 mm are: forebrain length 336, width 134; total optic width 523; cerebellum length 282, width 282; facial lobe length 107, width 121; vagal lobe length 161, width 67, total vagal width 215; rhomboid fossa length 80, width 101.

Lateral line on body complete, uninterrupted. Preoperculo-mandibular (PM) and supraorbital (SO) canals always incomplete. Pore counts from 15 adults: infraorbital (IO), including common pore, when rarely present, at infraorbital-supratemporal (ST) junction) 11(1), 12(4), 13(4), 15(1), 11+2(1), 8+2+3(1), 11+3(1), 5+5+2+3(1), 9+5+2(1); PM 7(1), 8(1), 2+5(2), 3+5(10), 3+6(1); SO 8(12), 9(3); ST 5(11), 3+3(1), 4+1(1), 1+2+2(1), 1+2+2+1(1). Canal locations, pore sizes, and canaliculus lengths are as described and illustrated from three specimens by Reno (1969b), with the following modifications. Often the third

IO canaliculus is slightly shorter and joins the IO slightly posterior to the position figured by Reno. Often the cephalic lateralis dips moderately ventrad from the IO-ST junction, not from above the posterior end of the opercle.

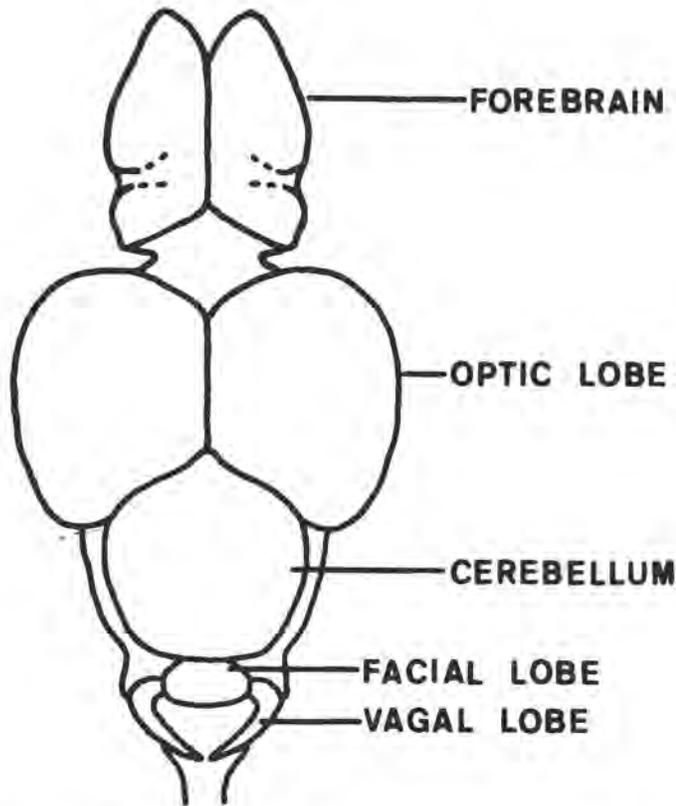


Fig. 3. Dorsal view of brain of *Hybopsis monacha*, 64.9 mm SL (REJ 522), North Fork Holston River.

The mouth is distinctly inferior. The lips are thick and heavily papillose; the central portion of the upper lip is extended anteriorly. The barbel generally is only a minute, tapered extension or nub on the posterior end of the lip symphysis. Infrequently it is separated by a cleft and excised or clearly pendant from the lips (Reno, 1969b: fig. 10, ventral view). No specimens have more than one barbel on a side, and often there is no trace of a barbel on one or both sides. Cutaneous taste buds are obvious only on the ventral surface of the head and barbel, where they are densely distributed. The rugose area of moderate to large buds depicted with stipple by Reno (1969b:750) should have included the lower edge of the snout and isthmus.

Gill rakers 5(2), 6(6), 7(3), 8(3), 9(1), $\bar{x} = 6.7$; upper rakers short, acute; lowers rudimentary, blunt. Pharyngeal teeth 4-4 in the 10 specimens studied. Fowler (1924) gave the dental formulae of syntypes as 4-4, rarely 5-4. Our examination of the 5 syntypes showed all have 4-4 teeth. All teeth hooked at tip in some specimens. With wear, teeth apparently lose hooks and become acutely tipped, the tips grading basad into a smooth, flat grinding surface. Some teeth, possibly only when recently ankylosed, have serrations along

the lower portion of the inner curve of hooks and on a flange slightly below, where the grinding surface develops. Thickness of teeth and arch and length of the upper and lower edentulous processes are moderate. As is typical of cyprinids, a true stomach is apparently absent in *H. monacha*; the bile duct enters the alimentary canal just posterior to the esophagus. The intestine is short and S-shape, unwhorled. In 8 adults 53-72, $\bar{x} = 62$ mm SL, the ascending section is only 8.2-17.5, $\bar{x} = 13.8\%$ SL, and total intestinal length is 55.3-77.9, $\bar{x} = 68.4\%$ SL. The inner lining of the intestine has folds arranged in a herringbone-like pattern. The peritoneum is medium brown to partly silvery (melanophores not contiguous), usually light brown.

Other internal characters. — Gas bladder large, two chambered; total length 28.4-31.8, $\bar{x} = 29.9\%$ SL, posterior chamber length 18.9-20.6, $\bar{x} = 19.6\%$ SL, in 8 adults with abdominal cavity length 38.5-47.6, $\bar{x} = 42.8\%$ SL. Peritoneal tunic (Rosen and Greenwood, 1970) covers anterior chamber. Pneumatic duct uncoiled, attached to anterior portion of posterior chamber. Bladder lacks spiral markings, striations, and intrinsic or extrinsic muscles.

Post-Weberian vertebrae (subtraction of 4 from counts in Jenkins and Lachner, 1971) 37(3), 38(15), 39(1), $\bar{x} = 37.9$.

Coloration. — In life: Hand held nonnuptial adult males, adult females and juveniles are pale to medium green or dusky grey above the lateral line, silvery on the lower sides. An iridescent stripe of green, sometimes with gold suffusion, occurs middorsally and one on each side dorsolaterally. The dorsal spot is obvious and black in large specimens. The black caudal spot is obvious in juveniles, but not as predominant as when preserved; in large specimens the spot tends to be partly masked by silvery. When observed underwater, the ground colors of juveniles and small adults appears medium grey throughout the body, and the iridescent stripes on the upper body and dark dorsal and caudal spots are obvious.

Nuptial color is shown in photographs by Jenkins (Deacon et al., 1979) and W.C. Starnes (Parker and Dixon, 1980). The respective specimens are 74 mm taken 4 June from North Fork Holston River and 76 mm, 24 July, Emory River. The blue color of the former specimen had faded markedly in 15 min. between placement in formalin and photographing, and the slide was underexposed. The 76 mm specimen may have lost some blue prior to photographing.

The 74 mm male was deep metallic turquoise to royal blue on the body from the dorsolateral area to about the lateral line, from occiput to tail, and over the entire caudal base. Contrasting with the upper body, an iridescent blue wash extended from the lateral line to the ventrolateral area and was present on some belly scales. The dorsum was iridescent greenish. An iridescent oblique dark blue bar occurred just behind the head. On the head a band of blue, more brilliant than on the upper body, extended along the dorsal

margin of the operculum. The dorsal fin spot was blue. With rapid fading of the blue in formalin, the back became darker green and the mid and lower sides a lustrous silvery white.

All fins had satiny white distally, least in the pectoral (margin only) and caudal (tips only), best developed in the pelvics and anal, which had a broad white marginal band and white extending proximad along anterior rays. Tubercles were whitish.

A 72 mm nuptial male taken 12 June from Emory River was described (D.A. Etnier, C.R. Gilbert, pers. comm., 1968) as having an iridescent deep sky blue upper body and silvery lower body; no blue or milky colors were noted in the fins.

The probable peak nuptial color was seen in one of the largest known males, 89 mm from the North Fork Holston on 20 May 1982. Although bluish did not extend below mid-side, most of the upper body was iridescent aqua to turquoise, changing rapidly to steel blue in formalin. The dorsum was brownish olive when the living specimen was viewed from directly above, but bluish when observed laterally. All fins had satiny turquoise, with some golden glints, distributed throughout the pelvic, anal and dorsal, mostly along the first three rays and margin of the pectoral, and narrowly margining the caudal. Upon death turquoise disappeared from the fins, revealing satiny white in the same areas.

An additional color pattern, possibly developed only during courtship/spawning, was seen in aggressive tuberculate males on 15 August in Emory River (underwater observation by J.P. Beets, in litt.). Two large whitish zones occurred on the anterior half of the body, extending from the lower sides to the dorsolateral area. Between and posterior to the zones, the body was blue. The whitish zones were most distinct dorsolaterally, where the remainder of the body was deepest blue, rendering males highly obvious. This pattern was obvious in the 89 mm male in life; it faded rapidly in formalin, remaining slightly developed in the alcoholic specimen due to differential intensity of melanophore pigmentation. It is slightly developed in a few of the 25 highly tuberculate preserved males from Abrams Creek on 9 June. It is faintly suggested in the preserved 74 mm male (Fig. 1) but was not detected in life.

As indicated under Reproduction, some small mature males may lack blue color during the spawning season. Females lacked nuptial color.

In preservative: The head and body are dark above, pale below (Fig. 1). Scales above the lateral line are marked, evidently in larger specimens, moderately obviously in small specimens, by a smoothly curved intensification of melanophores parallel and submarginal to the rounded posterior margins of scales. Thus the dorsolateral area lacks the diamond-shape pattern of pigmentation characteristic of many *Notropis* (*Cyprinella*) species. The lateral stripe on the posterior half of the body is centered along the horizontal myoseptum, but the stripe is prominent usually only below

this myoseptum. In adults, which have a darker back than juveniles, the upper edge of the stripe is less discrete (often indistinct) than in juveniles. Frequently the stripe is interrupted by a narrow, pale, obliquely oriented line over each transverse myoseptum. On the anterior body of adults the stripe generally is poorly developed or absent; occasionally it is quite dusky with the darkest portion centered just above the horizontal myoseptum. The anterior portion of the stripe is usually faint in juveniles, which typically have a narrow dark line over the horizontal myoseptum. Just above and below each lateral line pore on the anterior body is a small area of slight intensification of pigment. A middorsal stripe is well developed from head to tail, widest before the dorsal fin.

The caudal spot is particularly diagnostic. It is prominent in young, juveniles and smaller adults, but occasionally it is broadly connected with the lateral stripe in large specimens with a dark stripe; the adult male in Fig. 1 has a well developed, distinct spot. In young and small juveniles the spot usually is disconnected from the lateral stripe. The spot has two contiguous components, one over caudal base musculature, one in the area of the basal exposed portion of the medial 3-4 caudal rays. The anterior, larger component usually is round or oval, the longest axis vertical. On caudal rays generally it is quadrate or subtriangular, the apex anterior. The two components are nearly disconnected in young and small juveniles. In large juveniles and small adults the components generally are moderately to broadly connected, and the dark area often appears somewhat bell shaped. Large adults normally have the components completely connected, and the dark area is ovoid or amorphous.

The size and intensity of the dorsal fin spot correlates positively with body length, as in many cyprinids and shown for *Notropis* (*Cyprinella*) by Gibbs (1975b) and for total fin pigmentation in *Notropis* (*Lythrurus*) by Snelson (1972). The spot is best developed in nuptial males and is obvious in other large males and females. It is formed by concentration of melanophores in membranes between the last 3 rays and between the forks of each ray, and centered mid-third of the length of the rays. Melanophores are sparse in the central portion of the membranes between the medial rays, and absent in anterior membranes (except lining rays). Some nuptial males have a clear "window" in the basal part of the dorsal fin, effected by a nearly pigmentless area below and slightly anterior to the spot, thus highlighting the spot. Young and small juveniles have relatively few melanophores in the posterior membranes; hence, they lack a definitive spot.

Relationships

Hybopsis monacha is a distinctive species, described once and never synonymized. Due to its distinctiveness and because critically important nuptial color and tuberculation were long unknown, its relationships have been unclear. It was described in the genus *Ceratichthys* Baird, in which most

barbeled chubs were sometimes placed during the 1800's. It has generally been placed in *Erimystax* Jordan, which at times was recognized as a genus, and essentially since 1956 as a subgenus of *Hybopsis* Agassiz. Jordan (1924) described *Erimonax* as a genus for the sole reception of *H. monacha*, but was not followed. Reviews of the taxonomic and nomenclatural history of *Hybopsis* are by Reno (1969a), Clemmer (1971) and Lachner and Jenkins (1971).

Evidence of close relationship of *H. monacha* to the other four species of *Erimystax* (*sensu stricto*, type species *Hybopsis dissimilis*, including *H. cahni*, *H. insignis*, *H. x-punctata*) is their sharing of two distinctive, probably apomorphic character states: nuptial pad and anteromedial upper lip expansion. Additionally the five species have a terminal labial barbel. As indicated by Jenkins and Lachner (1971), these five species are phylogenetically linked to *Hybopsis* (*Hybopsis*) *storeriana*, *H. (Platygio) gracilis*, *H. (Macrhybopsis) gelida*, and the five species of suckermouth minnows, genus *Phenacobius*. All of these also develop a nuptial pad and, except for *Phenacobius*, terminal labial barbels. *Phenacobius* also has an upper lip expansion. The large majority of these fishes are elongate, live in moderate to swift currents, and are adapted for benthic feeding.

Hybopsis monacha appears to be most closely allied to *Cyprinella*, one of the largest subgenera (ca. 25 species) of *Notropis*, by possessing several diagnostic features of *Cyprinella* (in part, Gibbs, 1957a): cephalic dorsum tubercles anterior and tending to align in longitudinal rows; hiatus present between snout and internasal tubercles; lower urosome with tubercles larger than adjacent body areas, or with distinctive keratinization; pectoral fin tubercles uniserial, first ray tuberculate; distinctive head physiognomy; white in fins and iridescent blue upper body color of nuptial males; blackened posterior dorsal fin membranes. The only known hybrid of *H. monacha* involved a species of *Cyprinella* (Reproduction section).

Features of *H. monacha* in which it diverges from *Erimystax s.s.* and/or *Cyprinella* are small size of eye and scales, distinctive shape of caudal spot, and anal ray count of 8 (7 in all species of *Erimystax s.s.*, 8-11 in *Cyprinella*). Although *H. monacha* lacks the diamond-patterned scale coloration typical of *Cyprinella*, this is also absent in some *Cyprinella* species.

Pending further study of the *Hybopsis* - *Notropis* complex, particularly the barbeled *H. (Hybopsis) labrosa* species-group which also probably is closely related to *Cyprinella* (Jenkins and Lachner, 1980), *Erimonax* may warrant resurrection to at least subgeneric level for sole reception of *H. monacha*. We leave *H. monacha* in *Erimystax* until conclusions are firm. Regardless of taxonomic rank, *H. monacha* seems phylogenetically linked, in an undetermined way, to two large, complex groups of eastern American minnows - shiners (*Notropis*) and certain non-nestbuilding barbeled "chubs" (*Hybopsis*).

Diet and Feeding Behavior

Food of 39 specimens collected during daylight is summarized in Table 2. The diet comprises a relatively non-diverse assemblage of virtually entirely immature aquatic insects. Of the 2539 insect items found, 89.8% were dipterans. The bulk were midge larvae (48.0% of total insects, some in cases) and pupae (0.4%) and blackfly larvae (41.0%) and pupae (0.1%); all other dipterans were crane fly larvae, *Antocha* (0.4%). Mayfly larvae were commonly taken, forming 6.8% of total items. Of these, *Baetisca* and heptageniids were rarely taken; the remainder (6.2% of total items) were tiny baetids, probably *Baetis* and/or *Pseudocloeon*, and unidentifiable genera probably at least largely baetids. At least most insects unidentified to order (1.5%) probably also were baetids. The following orders formed small portions of the diet: Trichoptera 1.6% of total items (some hydroptilids in purse cases); Lepidoptera 0.2% (all *Parargyractis*); Plecoptera 0.08%; Coleoptera 0.04%; all were larvae except one of the 40 trichopterans was a pupa.

Dipterans dominated gut contents of most specimens oc-

Table 2. Food contents of first descending section of intestine of *Hybopsis monacha*. Total insect items = 2539. Total fish sample 39 specimens: 23 small specimens, ranging 27-48, \bar{x} = 38.2 mm SL; 16 large specimens, 51-87, \bar{x} = 63.6 mm. River systems subsamples: 11 from North Fork Holston River, 20 Emory system, 7 Little Tennessee River, 1 Abrams Creek. Number of specimens by month: 1 in April, 2 May, 5 June, 1 July, 17 August, 7 September, 6 November. Omitted are 6 specimens (5 from Little Tennessee in November) that lacked insects and Algae.

Items	% of total insect items	No. spms. with item		Range		\bar{x} both sizes
		Small fish	Large fish	Small fish	Large fish	
Insecta, undet.	1.5	7	6	1-12	2-33	7.1
Ephemeroptera, undet.	5.0	8	8	1-17	1-26	10.6
Baetidae	1.2	1	6	1	1-23	6.5
Heptageniidae, undet.	0.3	1	3	3	1-3	2.3
<i>Epeorus</i>	0.2	0	1	0	3	3.0
<i>Stenonema</i>	0.04	0	1	0	1	1.0
Baetiscidae, <i>Baetisca</i>	0.1	1	1	1	1	1.0
Plecoptera, undet.	0.04	0	1	0	14	14.0
<i>Taeniopteryx</i>	0.04	1	0	100	0	100.0
Trichoptera, undet.	1.0	6	10	1-8	0.4-67	14.8
Hydropsychidae	0.2	0	3	0	2-14	6.0
Hydroptilidae	0.4	0	5	0	0.4-67	14.7
Lepidoptera, <i>Parargyractis</i>	0.2	0	3	0	0.2-1	0.7
Coleoptera, undet.	0.04	0	1	0	1	1.0
Diptera, Tipulidae, <i>Antocha</i>	0.4	0	4	0	0.4-3	1.6
Chironomidae	48.4	20	15	1-100	4-81	61.9
Simuliidae	41.0	13	10	2-100	15-96	37.6
Nematoda	—	0	1	—	—	—
Filamentous Algae	—	2	0	—	—	—
Detritus	—	4	2	—	—	—
Sand, mica	—	5	2	—	—	—

asionally, usually in specimens with few items, mayflies and caddisflies were found in moderate percentages, and one specimen had consumed only a stonefly.

Insect choices were essentially uniform in the four river systems sampled. Analysis of diet by subdivision of fish into two size groups (Table 2; small fish group includes one or few young, mostly juveniles; large fish group composed of subadults and adults) indicates that small and large fish have similar preferences. Number of insect items in large fish (2-460, \bar{x} = 115 items) was generally greater than in small fish (1-96, \bar{x} = 39). The somewhat greater taxonomic diversity of items consumed by large fish probably reflects greater food intake due to larger gut capacity, and possibly a wider range of foraging habitat, including current swifter than that typically occupied by small fish.

Insects consumed were generally minute, usually 1 mm or less. Large midge and blackfly larvae were rare. Most mayfly larvae seemed to be early instars. The notable exception was one stonefly larva, *Taeniopteryx* nearly of emergence size, the only item eaten, and occupying 30% of anterior gut lumen of a 37 mm specimen. The generally much larger number of items taken by large fish also indicates that large fish generally do not select larger insects than do small fish. An average difference in size of insects consumed by large and small fish was not discerned by observation of gut contents.

Non-insect items were rarely found. One adult had one nematode, possibly parasitic. Filamentous algae was taken by only two juveniles, both in a November collection from Little Tennessee River; the algae filled 10% of gut volume in one specimen, 40% in the other. Detritus, other than probable shredded midge larvae cases, was recognized in only six specimens (three from Little Tennessee River in November), forming 5-80%, \bar{x} = 28% of gut volume. Sand, one to several grains, occurred in only seven specimens, four from Little Tennessee River in November. Two of the latter also had a few mica flakes, the only specimens in which mica was found. All of these items, certainly the inorganic matter, may have been consumed incidentally while foraging for insects.

Regarding seasonality, the data are largely from the warmer half of the year. In 32 specimens taken from mid May to mid September (Table 2), volume of insects was 10-100%, \bar{x} = 71% of anterior gut space. Only one additional specimen (July) from this period lacked food. Some distinct differences occurred with specimens collected from Little Tennessee River during colder months, mid April (1 specimen) and early to late November (10). The April specimen, a large adult, had the gut only 5% full (two insects). Of the November specimens, only five had insects, total of nine items composing 1-30%, \bar{x} = 12% of gut volume. Three of these specimens also consumed algae, detritus and/or inorganic materials, composing an additional 1-50%, \bar{x} = 26% of gut volume. Two other specimens had only detritus and/or inorganic matter, the sum of which

was trace-10% of gut volume. The remaining three specimens lacked material in the anterior gut. Food intake probably is generally low throughout the range during colder times. From snorkeling during December 1974 in Emory River, C.F. Saylor (pers. comm.) found *H. monacha* to be under and among large rubble and boulder, not in swift current; they were very sluggish in the cold water. The differences, particularly consumption of inorganic matter by the November Little Tennessee specimens, may relate to reduced chub activity and insect availability, the latter possibly effected by both low temperature (this is the highest altitude population) and heavy sand-mica deposition.

The following are observations of feeding habitat and behavior, all but the first instance by snorkeling.

Abrams Creek, 13 Sept. 1937, C.L. Hubbs (fieldnotes M37-917 at UMMZ): "Under and about flat boulders of riffles; observed sliding over bottoms, feeding on rock surface with inferior mouth."

North Fork Holston River, Rkm 41.2, 1700-1730 h, 20 May 1974, Burkhead, Jenkins: Two adults and one or two juveniles were in a gravel run, 0.3-1.0 m depth. They almost always remained very close to substrate, more frequently than closely associated benthic feeding *Hybopsis dissimilis*, and moved about less rapidly than most other species. Generally they picked at the upper surface of gravel, apparently feeding on material indistinguishable to observers. Often one fish mouthed branched algae. Once one made an apparent feeding movement about 10 cm above bottom. Common associates were *H. dissimilis*, *Notropis galacturus*, *N. rubellus* and *Notropis* sp. (sawfin shiner).

North Fork Holston River, Rkm 3.2, 1420-1500 h, 26 Aug. 1975, Jenkins, Dudley: In a run floored largely with bedrock, two juveniles were seen briefly near a school of shiners. The latter were feeding actively in midwater on material dislodged by our wading. The spotfin chubs remained at or near the bottom, and their probable feeding movements were slow compared to the shiners.

Emory River, Nemo Bridge, 10 Aug. 1981, 1305-1410 h, Burkhead: Two small groups and a few isolated specimens, totaling ca. 20 probable juveniles, were watched. Some were over small gravel, some among boulders, all slightly silted at most, in depths of 0.3-0.6 m and slow to moderate current. All chubs were in close association with the substrate, usually only a few cm above. Most were feeding, only from substrate, by lateral movements of the head.

Emory River, Nemo Bridge, 15 Aug. 1979, 1000-1700 h, Beets, Smith (in litt.): Approximately 1.6 km of river was intensely searched and only about 80 *H. monacha* were seen. None were observed in several large, heavily silted pools nor at the Obed River mouth in an area of swift current and large rubble and boulder, which virtually lacked small substrate particles. Most chubs were sighted in the area just above the pool which extends under the bridge. Some young and/or small juveniles were feeding at large bedrock shelves in quiet water, ca. 1 m deep, just below a shoal. Others were feeding nearby on large, flat smooth-surfaced rocks beside the stream bank in 0.1-0.2 m depths. Rocks were coated with a thin film of algae or sediments, but appeared cleaner than those in the pool proper. The chubs were in small, loose groups; they remained very close to and continuously picked from the substrate. They exhibited no territoriality and were commonly associated with young *Notropis coccogenis*. About 20-30 adults, including females and highly colored, tuberculate males, and several juveniles were concentrated a short distance above the juveniles, in midstream of a riffle-run area of bedrock, boulder, rubble and small patches of gravel; depths were 0.2-0.6 m. When not feeding, most chubs swam individually up in the water column with other cyprinids, particularly *N. coccogenis* and *N. leuciodus*. These were generally above the near-benthic level occupied by *Camptostoma anomalum* and *Nocomis micropogon*. Often they darted from midwater to feed at the substrate for periods varying from

a few picks to nearly continuous picking. Once an adult male swam rapidly to the surface of a boulder to briefly tug a probable caddisfly larva, then quickly resumed midwater position. Chubs generally fed with the body very close to the substrate, at angles of ca. 10-20%, unlike the shiners whose bodies were at higher angles to the substrate. Feeding was restricted to the bottom; chubs were not observed taking particles in the water column, not even those stirred up by hand from the substrate. Some adults exhibited territoriality, treated under Reproduction.

In summary, *H. monacha* is an insectivore and, as indicated by instream observations, diet and trophic morphology, it feeds benthically in areas of slow to swift current and varied substrate but only slight siltation at most. Deep drift may be taken occasionally; no terrestrial forms were found, suggesting that midwater and higher drift is not often sought. It is a diurnal feeder; it may also feed nocturnally but no data are available. The general absence of detritus and inorganic material in the gut indicates *H. monacha* is a sight feeder and/or an efficient taste-sorter of insects from other material in the oropharyngeal cavity. It seems morphologically equipped to detect food by taste and sight. The dash by one specimen to take a benthic organism indicated ability to visually detect food. The relatively high frequency of algae, detritus and sand/mica

in early winter Little Tennessee specimens may be due to different feeding habits in cold water and/or to lower quality of habitat, with an overload of such materials.

Age and Growth

Problems of age determination by scales and composite length frequency (Table 3) are treated in the Methods section. We make frequent reference below to position of many of the 48 scale-aged specimens in the frequency distribution. For convenience, we often use the term age for age group. Young are age 0 specimens taken in the calendar year they hatched. Subsequent age groups begin at January 1.

Four age groups (0-III) were found. Young first appeared in August collections and ranged 19-37 mm, the latter scale-aged from a November collection.

Age I specimens ranged 20-48 mm through May, 27-50 mm in June, 27-59 mm in August (27 mm and 30 mm based on one and two scale-aged specimens respectively; 59 based on one scale-aged specimen), 34-60 mm in September, and 41-62 mm in October-November. The apparent separation within this age group around 49-50 mm in August-September is judged artifactual based on three specimens, 53, 58, and 59 mm, scale-aged as age I, and on the overall frequency distribution.

Table 3. Length frequency by month and sex of 317 specimens of *Hybopsis monacha* from throughout its range. (unsex = unsexed)

SL ₁ mm	Mar.	Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.	
	un- sex F	M		un- sex M	F	un- sex M	F	M	F	un- sex M	F	un- sex M	F	un- sex M	F	M	F
89-88				1		1											1
87-86		1				1											1
85-84						1											
83-82						4											1
81-80						3					1						
79-78						4					1			1			
77-76					1	3	1				1						
75-74						3	1						1				
73-72					1	5			1		1				3		
71-70						1					1	1		1	1		
69-68						1	4				2		2				
67-66						2	1		1			1	1		2		
65-64					2	3					1		1	1	1		
63-62						2	1				2		1				
61-60						1					1	1	2	4	1	1	
59-58	1										3	2	1	4	2		
57-56						2	1				4	1	1	5			
55-54					1	3	1				2		1	4	1		
53-52	1				1	1	4				1	4	1	3	1	1	2
51-50						1					3	3	1		2		1
49-48					1	2	1				1	1	2		2		
47-46	1				2						1	1	2	6	4	1	1
45-44					3		1				1		3	4			1
43-42					1						2	1	1	5			1
41-40						1					1	5	1	3	3		1
39-38						2					3	1	2	4			
37-36					1	1		1			3	1	3	2		1	1
35-34					1			1			1	6	3	2	2	1	
33-32							2				3	3				1	2
31-30					1	1		3			1	2	3				1
29-28					1			1			2	1	1	1			
27-26							1					1			1		
25-24											3				1		
23-22					1						2						
21-20	1																
19														1			

Age II and III specimens show considerable overlap in length based largely on the following scale-aged specimens. Three of age II ranged 55–65 mm in May; minimum size was 56 mm in June, 67 mm in August; maximum size was 89 mm in May, 88 mm in June, 89 mm in November. The smallest of age III were 72 mm in May, 76 mm in August; the largest were 77 mm in May, 86 mm in June, 80 mm in August. The greater overlap in length of age II and III specimens, compared with age I and II, suggests that age III specimens grow relatively slowly. The latest month of capture of age III specimens (two males, one female) was August, hence maximum longevity is about three years.

Maximum length of *H. monacha* was thought to be ca. 77 mm SL. (Jenkins and Musick, 1980), based on study through summer 1975. More recent acquisitions from Abrams Creek (1957 collection), Little Tennessee River, Clear Creek of Emory system and North Fork Holston River have significantly larger specimens. Size attained in these populations seems about equal. All four produced males in the 85–89 mm range (about equal numbers of ages II and III). The largest known specimen is a male 89.5 mm (92.5 mm SL freshly preserved, R.B. Eager, pers. comm.) of age II taken in November from Little Tennessee River.

The six largest females range 70–77.7 mm SL, the three aged being age III. The data suggest that longevity of the sexes is about equal, and that males grow faster, attaining larger size. Males generally are larger than females in many highly sexually dimorphic/dichromatic cyprinids, notably at least most species of *Cyprinella*.

Reproduction

Sex ratio of all age groups combined was 128 males: 120 females. The data exclude 32 specimens (29 males) taken by massive poisoning of Abrams Creek; selective preservation of colorful tuberculate males apparently occurred.

Age at attainment of maturity was determined only from scale-aged specimens. Only males with well developed nuptial tuberculation (and coloration if known) were regarded mature. Such males are all those of age III and some of those of age II. All 28 highly tuberculate (aged and unaged) males studied are relatively large, 60–89 mm, $\bar{x} = 73.2$ mm. It is possible that most or all age II and some age I males mature before or in the spawning period, but do not exhibit obvious sexual dimorphism and hence may not be recognized as mature. This is based on some medium size males, 45–59 mm, with tubercles in an early developmental (or possibly postnuptial) stages. Recent maturation would be difficult, at best, to detect by size of testes, as most large nuptial male *H. monacha* have small testes. Gale and Gale (1977) found that some spawning males of *Notropis (Cyprinella) pilopterus* lack observable tubercles and have only slight nuptial color.

Mature females are those with mature ova. All age II and III specimens taken May–August were mature (3 and 7 scale-aged specimens, respectively). The two other large females

(75, 76 mm, at least age II based on length) taken during the spawning season were also mature. These 12 specimens ranged 67–77 mm, $\bar{x} = 71.3$ mm. Many specimens of 35–47 mm (probable age I) taken mid-May to early June were immature, as were many of 40–59 mm (probable age I) taken in mid-August. However, three other mid-August specimens, 53, 57, 58 mm, scale-aged as age I, had many mature ova, indicating that some females mature around the end of their first full year of life. Other small, 55–66 mm, mature unaged (age I and/or II) females were gravid during mid-June to early August.

The extent of the spawning period was estimated from dates of capture or observation of apparently reproductive males (highly tuberculate, nuptial color) and females (ovaries large, some ova mature). Dates for males range 20 May–15 August, females 16 May–14 August. Hence the spawning period appears to be protracted, possibly mid-May to mid-August. Unsuitable conditions such as turbidity may interrupt spawning during this general period.

Hybopsis monacha may be a fractional, crevice spawner. All seven species of *Cyprinella* whose reproduction is known (Outten, 1958; Wallace and Ramsey, 1981 and references therein) spawn partly or entirely in crevices of rocks, logs and other cover. Evidence of crevice spawning is the only known hybrid involving the spotfin chub: one specimen of *H. monacha* x *Notropis (Cyprinella) galacturus* from Daddys Creek (Burkhead and Bauer, 1983). The latter is a crevice spawner (Outten, 1958). For adequately studied species of *Cyprinella*, multiple or fractional spawning is typical, with some females spawning up to 11–12 times over three months (Gale and Gale, 1977; Gale and Buynak, 1978). Advantages of fractional spawning (increased fecundity) and crevice spawning (localization and protection of eggs from predation, mechanical damage and siltation) were discussed by Gale and Gale (1977).

Three classes of ova are recognized in preserved adults from the spawning period (Table 4). Class I ova are opaque, yellow or pale orange, and 0.8–1.4 mm in diameter. Class II ova are opaque, white or slightly yellowish, and 0.4–0.8 mm. Class III ova are translucent and 0.09–0.2 mm. Class I ova are apparently mature. Some of the Class II approached apparent maturity and may have matured during the current spawning period. Class II ova were 3.3–5.0 times more numerous than Class I ova. Class III ova were not counted, but appeared much more numerous than Class II ova. Ova of all classes seemed evenly intermixed throughout ovaries.

Numbers of Class I and II ova increased markedly with increase in female size. Numbers of Class I ova per female (157–791) may not adequately indicate fecundity because of possible spawning prior to capture. Further, counts of Class I ova present at one time in a female may grossly underestimate fecundity over a spawning season if *H. monacha* is a fractional spawner. Total Class I and II ova at the start of the spawning season may be a better index

Table 4. Reproductive parameters of seven female *Hybopsis monacha*, from N. Fk. Holston River (May, August) and Abrams creek (June). GSI = gonosomatic index. Ova classes (Roman) head right side five columns.

Date	Age group	SL, mm	Body wt., g, evis.	GSI	No. ova		Diameter, mm		10 ova, x,		Range	
					I	II	I	II	III			
May 16	III	77	4.4	—	791	—	—	—	—	—	—	
	III	72	3.2	—	589	—	—	—	—	—	—	
June 9	II	69	3.1	—	408	1120	1.03,	.9-1.2	.53,	.4-.7	.12,	.1-.2
	II	69	3.0	125	425	1145	1.08,	.9-1.3	.48,	.2-.7	.12,	.1-.2
	II	68	3.4	147	403	2029	1.26,	1.2-1.4	.56,	.5-.8	.09,	.1-.2
Aug. 14	I	57	1.9	—	170	739	1.22,	.9-1.4	.69,	.6-.8	.09,	.05-.13
	I	53	1.6	—	157	522	1.01,	.8-1.2	.60,	.5-.7	.09,	.05-.15

of fecundity for this species.

Possible reproductive behavior was observed in Emory River at Nemo bridge in afternoon of 15 August 1979 (Beets and Smith, in litt.). Highly colored, tuberculate males and adult females were associated in a riffle-run area with structurally diverse habitat, including large and small rocks. Both sexes often fed during the period. Males were loosely aggregated and exhibited aggressive behavior toward other cyprinid species by rapid chases.

Parasites

The only ectoparasites found were blackspot metacercariae of strigeid trematodes. These were rarely hosted, and when spots were found they almost always numbered one or two per fish; the largest number noted was five. Examination of the first descending section of the intestine of 43 specimens revealed only one minute nematode, possibly nonparasitic.

Habitat

Certain habitat parameters of the 24 stream sections in 12 tributary systems historically occupied by *H. monacha* are given in Table 5. All records are from freely flowing sections, some later impounded. Occupation of lentic habitat is very unlikely due to its habitat preference. Elevations are 200-600 m, gradients moderate to moderately high. Its range extends across the Blue Ridge gradient barrier (Gilbert, 1980) into the upper Little Tennessee and French Broad systems. Water is moderately soft to moderately hard. Stream temperatures in summer are generally warm (diurnal maxima greater than ca. 20 C); some populations in maxima of 18-20 C may be thermally limited. Submersed macrophytes are absent or, occasionally, scant to abundant; the spotfin chub does not appear to be closely associated with higher plants, although often it is found along bars with stands of emergent water willow, *Justicia*, and occasionally near or among submerged pondweed, *Potamogeton*.

The large majority of records are from medium to large streams, average widths of occupied sections ca. 15-0 m. Most records from smaller streams are within a few km of

the mouth in much larger ones, and may represent forays of individuals, or populations largely reliant upon recruitment from main rivers. If the latter were untrue, more tributary populations would likely have survived modification of main rivers. No records are from Tennessee River or lower sections of its largest major tributaries (Duck, Elk, Hiwassee, Little Tennessee, French Broad, Holston and Clinch rivers). However, prior to impoundment and other changes of these large rivers, only generally scant collecting efforts were made for small, benthic, rheophilic fishes (in part, Etnier et al., 1979).

Stream sections inhabited have riffles, runs and pools, with *H. monacha* nearly always found during warmer times in or near moderate to swift current, depth usually 0.3-1 m. Young and juveniles tend to occupy slower current than adults, although much overlap seems typical. During mid-winter, adults tend to inhabit slower current than in warm seasons (C.F. Saylor, pers. comm.). Common substrates (Table 5) in populated sections are silt, gravel, rubble, boulder and bedrock; occasionally small amounts of sand are present. The spotfin chub occupies all these substrates, but apparently only where siltation is slight at most. Jenkins and Musick (1980) stated that *H. monacha* shows a strong proclivity for large areas of small (pea) to medium gravel in North Fork Holston River. Of 89 specimens, taken or observed in this river during 1970-1981 by Burkhead and Jenkins, about 55 were over small-medium gravel; most of the remainder were from uniform or mixed coarse sand, large gravel, rubble, boulder and bedrock. However, the disproportionate numbers of chubs found on gravel bars and flats may relate partly to our preference and ease of seining over gravel. In the North Fork during 1982, with approximately equal electrofishing effort in gravel, rubble and small boulder, we took 41 chubs: ca. 15 from large gravel, 17 in large gravel-small rubble mix, 4 from rubble, 5 among rubble-boulder. No streams are known to have been typically turbid when occupied by *H. monacha*, although many become quite turbid from intense precipitation.

Descriptions of feeding habitat, comprised in that described above, are given under Feeding. Although Cope (1868)

Table 5. Habitat parameters of all specific stream sections with record of *Hybopsis monacha*, with years populations are known. Numbers of specimens without parentheses refer to those with at least partial habitat data; those in parentheses lack original habitat data (although in most cases they are from stream sections of the former category). Bracketed habitat data were not originally associated with records and may be incomplete, as are some originally associated data. ? = estimate of width without observation of stream, or data unknown. Substrate types defined under Methods: Sd sand, Gr gravel, Ru rubble, Bo boulder, Bd bedrock; dominate type(s) italicized when known; siltation excluded here, treated in text.

System	Stream	Year(s)	No. of Specimens	Width, m	Substrate:		Source
					General	Capture/Obs.	
Duck	Buffalo	1978	4	[20-30]	Sd Gr <i>Ru</i> [Bo] <i>Bd</i>	?	Douglas [Anon., 1973]
	Grinders	1937	3	7	<i>Bd</i>	?	UMMZ
Lit. Bear	Lit. Bear	1973	1	3-6	Gr Rb	?	UMMZ
Shoal	Shoal	1884	3	[20-40]	Gr Rb	?	Gilbert, 1891 [Williams, Howell]
Chickamauga	S. Chickamauga	1887	(''abt.'')	[30-40]	[Sd Gr Bo]	?	Jordan and Brayton, 1878 [Etnier et al., 1981.]
Lit. Tennessee	Citico	1936 1940	2	[4-10]	[Gr <i>Rb</i> <i>Bo</i> <i>Bd</i>]	?	[Bauer et al., 1983]
	Abrams	1937-1957	42(32)	10-12	Sd Gr <i>Rb</i> <i>Bo</i> <i>Bd</i>	Rb Bo	UMMZ; Lennon and Parker, 1959
	Tuckasegee	1940	2	60	Gr Bo <i>Bd</i>	Gr	UMMZ
	Lit. Tennessee	1975-1980	29(4)	75-100	Sd Gr <i>Rb</i> <i>Bo</i> <i>Bd</i>	Sd Gr Bo <i>Bd</i>	Eager, Crittenden, Etnier, NMB
French Broad	Spring	1888	1	[8-12]	[Sd Gr <i>Rb</i> <i>Bo</i> <i>Bd</i>]	?	Jordan, 1889 [REJ]
	Swannanoa	1888	2	[?15-30]	Gr Rb	?	Jordan, 1889 [REJ]
Whites	Whites	1959	7	15-30	Rb Bo <i>Bd</i>	Rb Bo	USNM
Emory	Emory	1941-1981	174(225)	10-40	Sd Gr Ru <i>Bo</i> <i>Bd</i>	Gr Ru Bo <i>Bd</i>	Anon., 1970; Beets, Crittenden, NMB
	Island	1979	2	Small	?	?	Smith
	Obed	1968-1974	29	[20-25]	Sd Gr <i>Ru</i> <i>Bo</i>	?	[Anon., 1970; Crittenden]
	Clear	1968-1981	94(8)	15-30	Sd Gr <i>Ru</i> <i>Bo</i> <i>Bd</i>	?	Anon., 1970; Crittenden
	Daddys	1974-1981	3(10)	5-15	Gr <i>Ru</i> <i>Bo</i> <i>Bd</i>	?	Crittenden [Anon., 1970]
Clinch	Clinch	1893	1	[?40-70]	[Gr] Ru Bo <i>Bd</i>	?	Evermann and Hildebrand, 1916 [REJ]
	Ball	1893	?	[Small]	?	?	Evermann and Hildebrand, 1916 [REJ]
Powell	Indian	1893	2	[10-15]	Gr Ru Bo <i>Bd</i>	?	Evermann and Hildebrand, 1916 [REJ]
N. Fk. Holston	low. N. Fk. Holston	1954-1982	130(13)	20-40	Sd Gr Ru Bo <i>Bd</i>	Sd Gr Ru Bo	REJ, NMB
	up. N. Fk. Holston	1867-1954	4(5)	[25-35]	[Gr <i>Ru</i> <i>Bo</i> <i>Bd</i>]	?	Cope, 1868; Jordan, 1889; Patrick 1961 [REJ]
S. Fk. Holston	S. Fk. Holston	1947-1949	8	45-90	Sd Gr Ru Bo <i>Bd</i>	?	UMMZ
	Jacob	1947	1	2-6	Gr <i>Ru</i> <i>Bd</i>	?	UMMZ

thought *H. monacha* had solitary habits, it was commonly observed in small, loose to tight aggregations. Often 2-4 specimens were captured per short seine haul, and none taken in most other parts of a locality, suggesting localization.

Distribution, Abundance and Population Status

Hybopsis monacha is known from 12 upland or montane tributary systems located widely in the Tennessee River drainage, most in the upper half (Fig. 4). Populations in apparently only four systems are extant (in part, Figs. 5-7). Generally the species was rare or uncommon (Table 5), probably relating to decline in availability of, and localization at, preferred habitat. Recently it was found to be common only at few sites in Emory and North Fork Holston rivers. It was reported abundant only in South Chickamauga Creek in 1877 (Jordan and Brayton, 1878). Although their specimens were not found, the identification is probably correct as Jordan and Brayton reported the other species with which *H. monacha* would likely be confused.

Reviewed here and in Tables 5 and 6 are distribution within and status of populations and habitat of the tributary systems, with comments on certain associated, sensitive or localized species. Year of dam closures, filling of reservoirs,

and associated parameters are from Anon. (1940, 1949, 1963, 1964a, b), Louder and Baker (1966) and Fitz (1968).

Duck River System. — Extreme localization and tenacity may apply to the spotfin chub in this large lower Tennessee River tributary system, western Tennessee. Only two records are known, from a small area, with a major hiatus between years of capture. Three specimens were taken in middle Grinders Creek, a small Buffalo River tributary, in 1937 by the TVA. Four specimens were caught in Buffalo River at Grinders Creek mouth in 1978 by N.H. Douglas. *Hybopsis monacha* has been very rare at the latter. Douglas (pers. comm.) made an intensive collection there once each year from 1970-1981, totaling some 50,000 fishes. The site also was worked by D.A. Etnier in 1970, the TVA in 1971 (Anon., 1973), and W.C. Starnes in 1977. Other one-time records from there for the entire Duck system are of *Nocomis micropogon* (UT) and *Ammocrypta vivax* (Starnes et al., 1977). Douglas also seined lower Grinders Creek several times but did not find *H. monacha*.

The spotfin chub may be localized within the Buffalo sub-system of the Duck, based on absence from 58 additional collections from throughout it during 1937-1981 (TVA, UMMZ file; Anon., 1973; Etnier, Feeman, in litt.; UAIC).

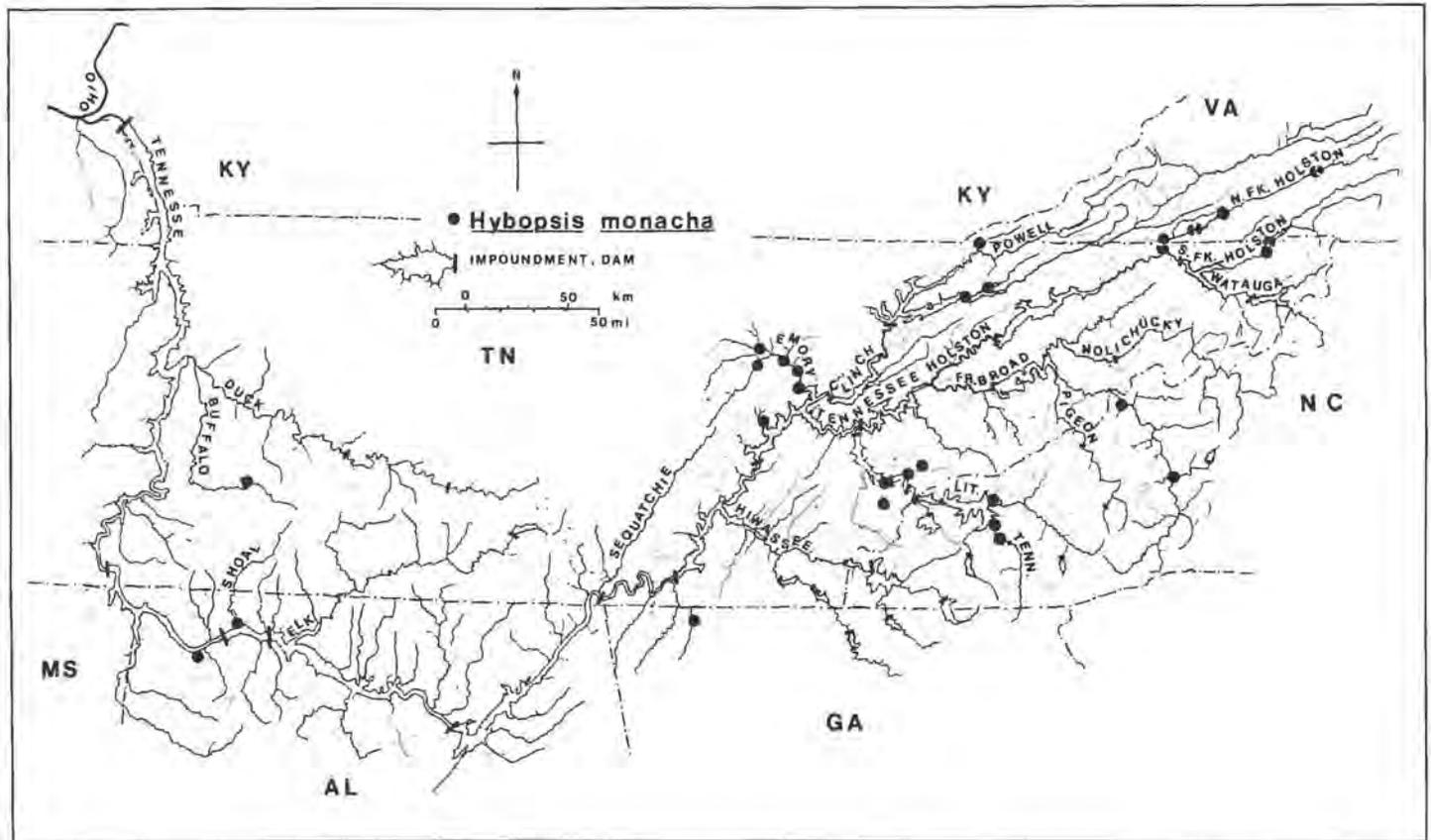


Fig. 4. Distribution of *Hybopsis monacha*, showing all known extant and extirpated populations. Some dots cover more than one record locality. Records from three of four extant populations are shown in detail in Figs. 5-7.

However, only ca. 12 of these are from the ca. 160 km of main channel below Grinders Creek. Buffalo River lacks impoundment and it and its tributaries are typically clean, clear and of varied substrate. Isom and Yokely (1968) and Starnes et al. (1977) opined that Buffalo River is essentially pristine, and Anon. (1973) stated it is considered one of the most unspoiled rivers in the Southeast. Isom and Yokely (1968) found its mussel fauna in poor condition, and speculated a cause to be changes in the fish fauna of the lowermost reach induced by embayment of Tennessee River. However, the subsystem still has moderately high species richness and diversity of fishes (in part, Anon., 1973). *Hybopsis monacha* may be temperature limited by numerous high volume, cool springs in the system.

The puzzling apparent absence of *H. monacha* from the much larger Duck subsystem casts doubt upon its possible wider occurrence in the Buffalo. It is absent from over 350 collections from throughout the Duck subsystem, many from Duck River proper (Anon., 1975; Nieland, 1979; J.C. Feeman, pers. comm., 1981). Habitat quality and diversity in the subsystem appear to remain high, and Duck River sustains the most speciose ichthyofauna in the Tennessee drainage (Etnier and Jenkins, 1980), perhaps the most diverse in North America. It includes relict populations of *Noturus stanauli* and *Etheostoma tippecanoe*.

Hybopsis monacha may never have been particularly successful in the Duck system. Many natural differences are known between the upland faunas of the lower and upper Tennessee drainage (summary for fishes, Jenkins et al., 1972; bivalve mollusks, Ortmann, 1925, van der Schalie, 1939, and Stansbery, 1964; crayfishes, Hobbs, 1969).

Little Bear Creek System. — The single specimen was taken in the lower part of this small northwestern Alabama stream in 1937 during preimpoundment survey of the southern bend region of Tennessee River. The only change of which we are aware that may affect the stream is impoundment, at its mouth, of Tennessee River by Pickwick Dam in 1938. Apparently the creek has not been recollected. The population may have been supported by recruitment from a hypothetical one in the Muscle Shoals section of Tennessee River, a former extensive haven of rheophilic life whose preimpoundment fish fauna is virtually unknown.

Shoal Creek System. — Three specimens represent the single record from lower Shoal Creek, Alabama in 1884 by Gilbert (1891), who regarded *H. monacha* as rare and had sampled other western tributaries of the southern bend. The system was widely surveyed over the past 20 years (Wagers, 1974). Although the lower 10 miles were impounded by

Table 6. Length (km) of stream sections with extant populations (probable discontinuities between record sites included), and anthropogenic and natural limiting factors (some only suspected) on all known populations of *Hybopsis monacha*. "Indirect" impacts are on stream sections receiving populated tributaries (some of the former also were or remain populated). Impacts: 1 impoundment, 2 cold tailwater, 3 channelization, 4 siltation and/or coal fine sedimentation, 5 pollution (inorganic and/or organic), 6 population renovation, 7 localized collecting, 8 natural cool temperature, 9 small stream size. Impact may not refer to all parts of occupied section.

System	Stream	Length	Impact:	
			Direct	Indirect
Duck	Buffalo	1	78	—
	Grinders	—	78,79	78
Lit. Bear	Lit. Bear	—	79	1
Shoal	Shoal	—	1	1
Chickamauga	S. Chickamauga	—	1,3,4,5	1
Lit. Tennessee	Citico	—	8,79	1,2
	Abrams	—	1,6,8	1,2
	Tuckasegee	—	1,4,5,78	1,4,5,78
	Lit. Tennessee	33	1,2,4,5,78	—
French Broad	Spring	—	75,78,79	4,5
	Swannanoa	—	4,5	4,5
Whites	Whites	—	1	1
Emory	Emory	25	1,4,5	1
	Island	0.2	79	4,5
	Obed	15	4,5	4,5
	Clear	14	4,5	4,5
	Daddys	6	4,5	4,5
Clinch	Clinch	—	1,2,4,5	1
	Ball	—	79	1
Powell	Indian	—	4	4
N. Fk. Holston	low. N. Fk. Holston	72	4,5,7	4,5
	up. N. Fk. Holston	—	4	4,5
S. Fk. Holston	S. Fk. Holston	—	1,2	4,5
	Jacob	—	1,78,9	1

Wilson Dam in 1924, the mainstream above is of size that probably would support *H. monacha* and has stretches of clean gravel and rubble (W.M. Howell, J.D. Williams, pers. comm.). Wagers (1974) considered the lower section of the watershed, in Alabama, to be in good condition (contrasting with some upper parts, in Tennessee).

All Alabama populations of *H. monacha* were regarded as extirpated by Ramsey (1976). Some streams in the bend region have been or are scheduled for channelization (Ramsey et al., 1972). The ichthyofauna of the bend region (in part, Armstrong and Williams, 1971) is somewhat transitional between the lower and upper Tennessee faunas. *Hybopsis monacha* is known only from the western part of the bend, and the populations may have been marginal, as in the Duck.

Hybopsis monacha probably populated the eastern sector of the bend region, perhaps more so than the western. Although recent survey of the former found two relict species, *Notropis* sp., the palezone shiner of upper Tennessee affinity, and the snail darter, *Percina tanasi* (R.G. Biggins,

J.C. Feeman, pers. comm.), earlier sampling was much less than that of the western part, insufficient to locate the then probably receding spotfin chub.

Chickamauga Creek System. — This system was collected once during 1877, in South Chickamauga Creek at Ringgold, by Jordan and Brayton (1878), yielding the sole *H. monacha* record for the system and Georgia. It was said to be abundant. Some springs and West Chickamauga Creek were sampled in 1893 by Evermann and Hildebrand (1916), who took the only record from the latter of *Phenacobius uranops* and *Noturus flavipinnis* (Taylor, 1969). The system was sparsely collected, often at springs, beginning about 1960, and extensively surveyed in 1979-1980 by Etnier et al. (1981), who reviewed most previous collections. Recently *Notropis ariommus* (Gilbert, 1969), *P. uranops* and the snail darter (Etnier et al., 1981) were discovered in South Chickamauga Creek at or below Ringgold. However, *H. monacha*, *N. flavipinnis*, and the extinct *Lagochila lacera*, the latter also taken only by Jordan and Brayton, apparently have not persisted. From description by Etnier et al. (1981), stream size (becoming a medium size river at Ringgold) and substrate (except for siltation) of lower South Chickamauga Creek seem appropriate for *H. monacha*. However, the extreme lower section in Tennessee is impounded or partly leveed and channelized. This portion and the section in Georgia up to about Ringgold has a history of heavy floods, siltation and domestic and industrial pollution (Anon., 1964c; Etnier et al., 1981).

Little Tennessee River System. — A population is extant in the upper section of only one of the four streams that yielded records. Lower Little Tennessee River is treated first as it bears on the extirpated populations of two of its tributaries in Tennessee.

Lower Little Tennessee River: At least part of the lower 80 km of Little Tennessee River in Tennessee probably supported *H. monacha* prior to impoundments. Suitable structural habitat appeared to have been present based on Kingman et al. (1900), Etnier (1976), Starnes (1977) and Hickman and Fitz (1978). However, other than probable gamefish sampling, we know of only one early collection, from Rkm ca. 60 in 1937 by Hubbs (UMMZ file). This was below the two earliest constructed dams, Calderwood at Rkm 71 (filled in 1930), Cheoah at Rkm 80 (1919). Some warmwater fishes were taken in the 1937 collection, and although Calderwood reservoir had typically warmwater habitat at the time (Dendy and Stroud, 1949), maximum temperature in the river below may have declined somewhat as both reservoirs were deep. River temperature below Calderwood was greatly lowered by operation of Fontana Dam, the highest east of the Mississippi River, at Rkm 96.5 in North Carolina (closed in 1944). Water released from Fontana passed relatively quickly through Cheoah and thence Calderwood reservoirs as thick density currents,

highest temperature 20 C, generally much lower, and sometimes with very low oxygen content (Dendy and Stroud, 1949). Chilhowee Dam, built at Rkm 53 (closed in 1957), effected a 92 km series of impoundments that further extended cold tailwaters. The upper section of the lower freely flowing 53 km was sampled five times in 1964, not showing a typical warmwater riverine fauna (Etnier, in litt.). Etnier (1976) indicated that the lowermost 32 km was unsampled until 1973, when *P. tanasi* was discovered, and had a predominance of warmwater fishes. Collections reported by Hickman and Fitz (1978) indicated a somewhat depauperate warmwater fauna, and R.B. Eager (in litt.), who was involved in the TVA study, stated that the lower Little Tennessee was sparsely populated, with numbers of fishes largely restricted to areas of tributary mouths. Temperature was depressed far down the river, not exceeding 20 C at Rkm ca. 11 (Hickman and Fitz, 1978). Virtually the remainder of lower Little Tennessee River was impounded by Tellico Dam in 1979.

Citico Creek: This lower Little Tennessee tributary yielded one specimen in 1936 near the mouth, and one in 1940 from its middle section. It is entirely within Cherokee National Forest, Tennessee, and has remained in good condition (Bauer et al., 1983). Its fauna and that of neighboring tributaries are well known from collections made in 1969-mid 1970's (Etnier, Crittenden, in litt.). More recently, *Noturus baileyi*, formerly believed extinct, *N. flavipinnis* and the duskytail darter, *Etheostoma (Catonotus) sp.*, were discovered in lower Citico Creek (Bauer et al., 1983; Etnier, pers. comm.). Middle Citico is trout water and may have been marginal, too cool and small, for *H. monacha*. Only lower Citico may have provided preferred habitat, but because of longevity of good conditions and apparent current absence of *H. monacha* therein, we suspect the population was at least partly reliant on a hypothetical one in lower Little Tennessee River. Although the Little Tennessee was freely flowing at the Citico Creek mouth until 1979, it was a cold tailwater since at least 1944.

Abrams Creek: Spotfin chubs populated at least the lower, warmer half of the lower 23.5 km, below Abrams Falls, of this Great Smoky Mountains National Park, Tennessee stream. It was taken in three of four collections from below the falls in 1937 and 1941, the negative result from near the falls. It was next (and last) taken at an unknown site(s) below the falls in 1957 (KFW series misidentified as *Notropis stigmaturus* [= *venustus*] by Lennon and Parker, 1959). We do not know the stream to have been worked by an ichthyologist during 1942-1956.

The stretch ca. 1.0-1.8 km above the mouth was described in 1937 by C.L. Hubbs (UMMZ file) as long pools and long riffles, substrates mud, sand, gravel, boulders and bedrock, water "exceptionally clear and not easily roiled." At ca. 12 km above the mouth, it was nearly all rapids with small amounts of sand and mud. The lower 23.5 km was characterized (Lennon and Parker, 1959) as short cascades

and very long, deep pools; water clear, slightly brown, and soft. Descriptions by Hubbs and the latter differ somewhat, suggesting varied physical features; all agreed regarding water clarity. The chub population of the lower creek was probably resident: the stream is slightly larger and probably warmer than nearby Citico Creek; the 1957 collection postdates by 13 years cooling of Little Tennessee River with closure of Fontana Dam.

Hybopsis monacha was regarded as common in Great Smoky Mountains National Park by Lennon (1962). Although he used the 1937 and 1941 records (KFW series still misidentified), the statement is at least partly erroneous as Abrams Creek had supported the only known Park population. Spotfin chubs may have been only locally common in lower Abrams Creek. Although 37 specimens were taken near the mouth in 1937, the sampling effort spanned ca. 0.8 km. and 5.5 h. Only five specimens were caught in 1941, one near the mouth, and four about halfway to the falls. Results of the extensive ichthyocidal treatment in 1957 are inconclusive regarding abundance. Only 3233 specimens, including 2237 game and food fishes, from the lower 23.5 km were "checked" (Lennon and Parker, 1959); nuptial *H. monacha* apparently were selectively preserved (Reproduction section).

The spotfin chub apparently was extirpated from Abrams Creek in 1957 by rotenone treatment of the stream from the falls to the mouth and of many tributaries. The "reclamation" was intended to reduce competition of nongame and warmwater sport fishes with introduced trout, an action difficult to reconcile with Park policy of preservation of native biota. Although Abrams Creek remains in good condition, and many native species have reestablished naturally (Miller, 1968; Bauer et al., 1983) its populations of *N. baileyi*, *Percina burtoni*, *Etheostoma blennioides* and duskytail darter vanished with *H. monacha*. Impoundment of the lower four km of Abrams Creek by Chilhowee Dam in 1957 (and prior and later impoundment of Little Tennessee River) sealed their fate.

Upper Little Tennessee River system: Fig. 5 shows 41 and 42 collections, respectively, from 18 and 12 sites in upper Little Tennessee River and its largest tributary, Tuckasegee River, North Carolina. Early or major surveys are reviewed first. Their tributaries also have been surveyed extensively.

In 1930, J.S. Gutsell surveyed Tuckasegee River and tributaries; the actual number of collections is unknown. Hildebrand (1932) reported the collections and mentioned six sites on the main river; we considered that one collection was made at each. During 1937-1940, C.L. Hubbs and/or TVA personnel collected two sites in upper Little Tennessee River that now are impounded, and three sites in Tuckasegee River, two of which are inundated. In 1947, J.R. Bailey made a fishery survey, including two and three collections, respectively from Little Tennessee and Tuckasegee rivers. In 1961, a North Carolina Wildlife

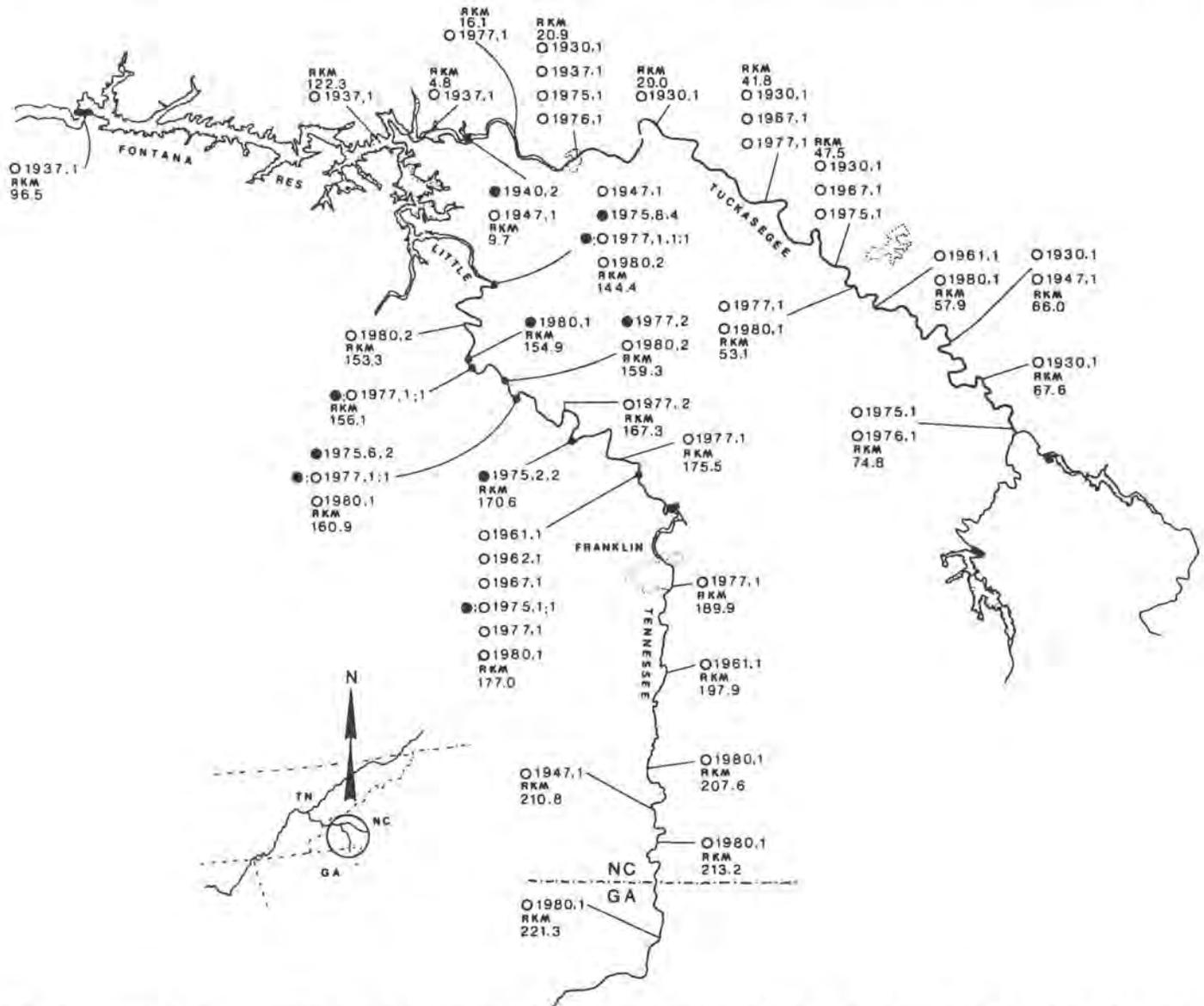


Fig. 5. Geochronography of *Hybopsis monacha* in Little Tennessee and Tuckasegee rivers, North Carolina. Map shows all collections known from their main channels from Fontana Dam up to headwaters (except for one collection each from three unspecified lower and middle Tuckasegee sites in 1975). Collections from reservoir area were made prior to impoundment. Solid dots on rivers indicate capture sites, but not necessarily extant subpopulations. Offriver data are: year of collection(s), preceded by (1) solid dot if *H. monacha* taken, (2) open circle if not taken; following the year are: (3) number of specimens taken, if any (if specimens were taken more than once in a year, the number of specimens in each collection is given separately, hence indicating the number of collections yielding specimens), and lastly (4) the number of collections not yielding specimens (this number is separated by a semicolon from number of specimens).

Resources Commission crew poisoned 60 stations, two in Little Tennessee River, three in Tuckasegee River (Messer and Ratledge, 1963). In 1969, a TVA crew creosoted 19 sites, all in tributaries (Anon., 1971). In November 1975 R.B. Eager and TVA crew kick-seined four Little Tennessee River sites, on two occasions at each site, yielding the first specimens of *H. monacha* from the river proper. During 1975–1976, Eager or other TVA biologists made one or two collections from each of three places (plus one collection each from three unspecified sites) on Tuckasegee River and two collections in Cullasaja River, a major Little Tennessee

River tributary. Upon discovery of *H. monacha* in the first 1975 collection, the subsequent TVA collections were particularly aimed for this species. During 1977, in a survey for *H. monacha*, D.A. Etnier made 19 collections, including 13 from Little Tennessee River and three from Tuckasegee River, by seine, electrofisher or ichthyocide. Burkhead worked on 14 of these collections. For a status assessment of *H. monacha*, E. Crittenden, USFWS, made a broad survey of the system during summers of 1978–1980. The inhouse report is confusing regarding number of collections; apparently 64 were made, including 10 from the Little Ten-

nessee, two from Tuckasegee and eight from Cullaseja rivers. The year of collection is unavailable for all collections except the one in which *H. monacha* was taken, in 1980; the year of all collections is given as 1980 in Fig. 5. Methods were kick-seine or electrofisher. R.B. Eager worked with Crittenden on several days. Fish identifications were verified by Etnier or others at the University of Tennessee.

Tuckasegee River: The two spotfin chubs from this river are from the Noland Creek mouth in 1940. The demise of the lower river population was spelled in 1945 by filling of Fontana Reservoir. However, *H. monacha* probably had previously declined widely as it was not taken in other preimpoundment collections, and never above the reservoir. The river has a history of marked pollution (Hildebrand, 1932; Messer and Ratledge, 1963; Anon., 1971) and its lower section is considerably silted.

Upper Little Tennessee River: The reach of Little Tennessee River, North Carolina, inhabited by *H. monacha* spans ca. 32.5 km, from the markedly fluctuating head of Fontana Reservoir to near Franklin Dam just below the town of Franklin (Fig. 5). Within this section, *H. monacha* was found at seven sites since 1975 and generally was rare; the most taken at one time was eight. Three once-sampled sites yielded no specimens. The population may have long been tenuous. It was not taken in four collections in 1947–1967 from the currently occupied section nor earlier in three preimpoundment collections. Varied success is suggested at some localities during 1975–1981. The section above Franklin was searched sparsely but specifically for *H. monacha* with negative results, indicating enclosure of the population by two impoundments.

Several factors beset the biota. Much of the substrate is covered with mobile fine sand and mica, the former found commonly only in the gut of Little Tennessee specimens, the latter appearing only therein. Messer and Ratledge (1963) stated that the river below Franklin is a turbid stream, with heavy sedimentation emanating widely from farming, mining and other sources, and it carries domestic and industrial pollution from the Franklin area and industrial pollution from Georgia. The *H. monacha* population may also be thermally limited; it occupies the altitudinal extreme for the species (520–600m), where temperature maxima may normally be 18–20 C (Messer and Ragledge, 1963).

Regarding Franklin Dam, the following is from correspondence in 1976 from an official of Nantahala Power and Light Company, Franklin, to R.B. Eager. The dam was constructed in 1925 at Rkm 182, impounds ca. 4.5 km of the Little Tennessee to form Lake Emory, and generates electrical power. Most of the reservoir usually is fully sedimented, hence much of the incoming alluvial load passes through turbines and floodgates. It was estimated that if the reservoir was fully desilted, it would refill in less than five years. Since the reservoir is not used for storage, it is lowered only for maintenance such as clearance of plant intake racks by sluicing. This is done once within one to two

year periods, at no set schedule but generally during low river stage, usually in fall. (At such times the reservoir is drained and at least the lower part of its main channel flushed to near base level, with heavy sediment load released below, fide J. Davies, North Carolina Wildlife Resources Commission, pers. comm., 1982).

The dam may have varied impacts related to timing and intensity of sediment passage. It may have been a primary factor in persistence below of *H. monacha*. Its formation of a sedimentation basin (although generally ineffective) would be beneficial particularly during the spring-summer spawning period. However, a major load released then and at other times probably would cause population reduction, and could be devastating at least locally. Despite uncertainty regarding relative effects of lake drainage, general siltation and pollution from and above Franklin, it seems didactic that only one spotfin chub was caught in the total of eight collections from the two sites nearest Franklin.

French Broad River System. — The lower reach of two widely separate tributaries in the Blue Ridge, North Carolina yielded three specimens in 1888 to Jordan (1889), who regarded *H. monacha* as uncommon. He described the lower Swannanoa and Spring Creek sites as clear. In 1972 we found the lower 100 m of Spring Creek to be very clear and have scant siltation. Lower Swannanoa River, in the populous Asheville area, now is heavily silted and received domestic and industrial pollution (Richardson et al., 1963). Although lower Spring Creek seemed in good physical condition in 1972, it was somewhat small for *H. monacha*, and fish species richness was low (10 species). It may periodically receive contaminants from the town of Hot Springs. French Broad River was heavily polluted from Brevard, just above the Swannanoa mouth, to the Tennessee state line, just below the Spring Creek mouth (Richardson et al., 1963).

Whites Creek System. — The single series was taken in 1959 at the foot of Cumberland Plateau Escarpment, Tennessee (just below Emory River mouth, Fig. 4). Although only seven spotfin chubs were caught, W.R. Taylor (USNM file) regarded it as common based on difficult seining conditions and small total catch. The site is three km above the eight km Whites Creek arm of Watts Bar Reservoir created on Tennessee River in 1942. (The record in Jenkins and Burkhead, 1980, on Tennessee River between the mouths of Whites Creek and Emory River is erroneous, and should be deleted).

Negative collecting results for *H. monacha* in Whites Creek follow. One rotenone collection each from three different sites in the later impounded section, made by the TVA in 1941 (Etnier, in litt.), yielded 19–35 species including expected species of darters and a sculpin, suggesting good effort; the fauna of lower sections of Tennessee River tributaries in that area is not particularly diverse. Lower Whites Creek was inspected above and below the record site

by diving in January 1975 by TVA biologists. Shiners and darters were plentiful, but *H. monacha* was not found, somewhat opposite of results from lower Emory River the previous month by the same crew (C.F. Saylor, in litt.). In 1981 E. Crittenden and USFWS crew unsuccessfully sought *H. monacha* at four sites in Whites Creek, two below the Escarpment.

The population may have been restricted to below the Escarpment and, based on absence in the 1941 collections, was generally sparse or localized. Immediately above, the system branches into a network of apparently small streams. During dry periods the stream in the Escarpment gorge recedes to pools (Anon., 1938), probably forcing the chub into marginal habitat and intensified interspecific competition. We are unaware of human-caused stresses in the system other than impoundment, which it survived for at least 17 years. However, impoundment probably constricted its range, and it may have died out during a time of drought.

Emory River System. — This largely Cumberland Plateau system, Tennessee, has been well surveyed, mostly recently (82 collections, 37 sites, Fig. 6). In 1941, seven collections from five sites were taken by the TVA. At least three of these sites were later impounded; the exact location of the Little Emory site is unknown. Three wide surveys were made: In 1968, 16 sites were ichthyocided by R.B. Fitz and TVA crew (Anon, 1970). In 1973–1975, Riddle (1975) sampled by various methods; probably only his 14 ichthyocide collections would have sampled *H. monacha* (extant series of *H. monacha* taken in 1974; year unspecified for general collections, regarded as 1974 in Fig. 6 herein; latter collections examined by Bauer or Etnier). In 1981, 26 collections specifically for *H. monacha*, mostly by ichthyocide, a few by electroshocker, were made by E. Crittenden and USFWS (collections identified by and all data obtained from Bauer; data also in USFWS Asheville office report). Etnier seined Emory River intermittently since 1968, mostly in the Obed River mouth-Nemo Bridge area (Rkm 44.2–46.0), and several others worked the latter. Beets and Smith (in litt.) made important observations in the latter section in 1979, as did Burkhead in 1981.

The known range of *H. monacha* is Emory River up to about the Obed River mouth (largest Emory tributary), Obed River to the Daddys Creek mouth, and the lower portions of Clear and Daddys creeks (largest Obed tributaries). Generally *H. monacha* was nearly consistently taken at record sites worked at least twice. Usually it was uncommon or rare; numbers greater than 20 generally were from collection and/or observations of ca. 0.8 km at a time. Effort in the unsurveyed ca. 10–30 km sections above the uppermost record localities may reveal greater upstream extension, notably in Clear Creek. The upper limit in this stream is suggested as the White Creek mouth, implying improved water quality by influx of White Creek. However, in 1981 lowermost White Creek had much silt, algae and

sewage odor; *H. monacha* was not found.

Uncertainties regarding collection data attend the range statement for Obed River, which is based on the following two records. Riddle (1975:table 12) listed 27 specimens from Rkm 0.6, but none was located by us. The record is accepted based partly on long establishment of *H. monacha* in Emory River in the Obed River mouth area, and on occurrence in lower Clear Creek. Riddle did not list *H. monacha* at Rkm 15.0 (Daddys Creek mouth), but two specimens with such data and taken by Riddle in 1974 are at AU. Although *H. monacha* was not found there in 1968 and 1981, it was found consistently (1974, 1981) in lowermost Daddys Creek; perhaps the AU specimens were caught by a method other than those yielding the data in Riddle's Table 12.

Problems are here considered for the 1968 TVA population density estimates (Anon., 1970: table 5). The spotfin chub was misidentified as suckermouth minnow, *Phenacobius mirabilis*. Two series of *H. monacha* (UT 44.563, 44.564, originally labeled *P. mirabilis*) from Emory River sites were found by Etnier at the Norris TVA laboratory. We assume, and R.B. Fitz (in litt., 1974) thought it probable, that the other *P. mirabilis* record, from lower Clear Creek (from which we have examined *H. monacha*), was also the latter. *Phenacobius mirabilis* is superficially similar to *H. monacha*, absent from the upper Tennessee, and not expected in habitat typical of the Emory. The numbers of specimens reported from the three sites, supposedly double the actual catch for each one-half mile section (expressed as density per mile, Anon., 1970:table 5), are also in error based on reexamination by Fitz of the original data: 24 specimens were reported at the lower Emory site, 4 are listed in original data, 4 are extant; 677 reported at middle Emory, 47 originally, 36 extant (the 11 missing may have been among those discarded at streamside, Anon., 1970); 176 reported from Clear Creek, 89 originally, none extant. Only the number reported from Clear Creek approaches doubling of the original, and Fitz (in litt., 1975) cautioned usage of even original numbers for population estimates. Relative abundance would also be clouded if data reported for other species are also defective.

The range of *H. monacha* in the system has been reduced. The lower 21.4 km of Emory River was impounded in 1942 by Watts Bar Dam. Upper Emory River, which did not yield a record, has been disturbed primarily by silt from coal mining, which also affects lower Emory River at least by high sulphate concentration (Anon, 1970; Riddle, 1975). Tackett (1963) noted Emory River is the only sizeable Tennessee drainage tributary that drains extensive sandstone areas and is consistently acidic. Although Anon. (1970) reported pH at widely located stations in August to be 7.1–7.8 at 11 stations (6.4–6.9 at 5 other stations), Riddle's 84 readings from throughout the system and year ranged 6.41–6.95. Low buffering capacity was also indicated by conductivities and alkalinities reported by Anon. and Riddle. Rock Creek, a small tributary entering Emory River at

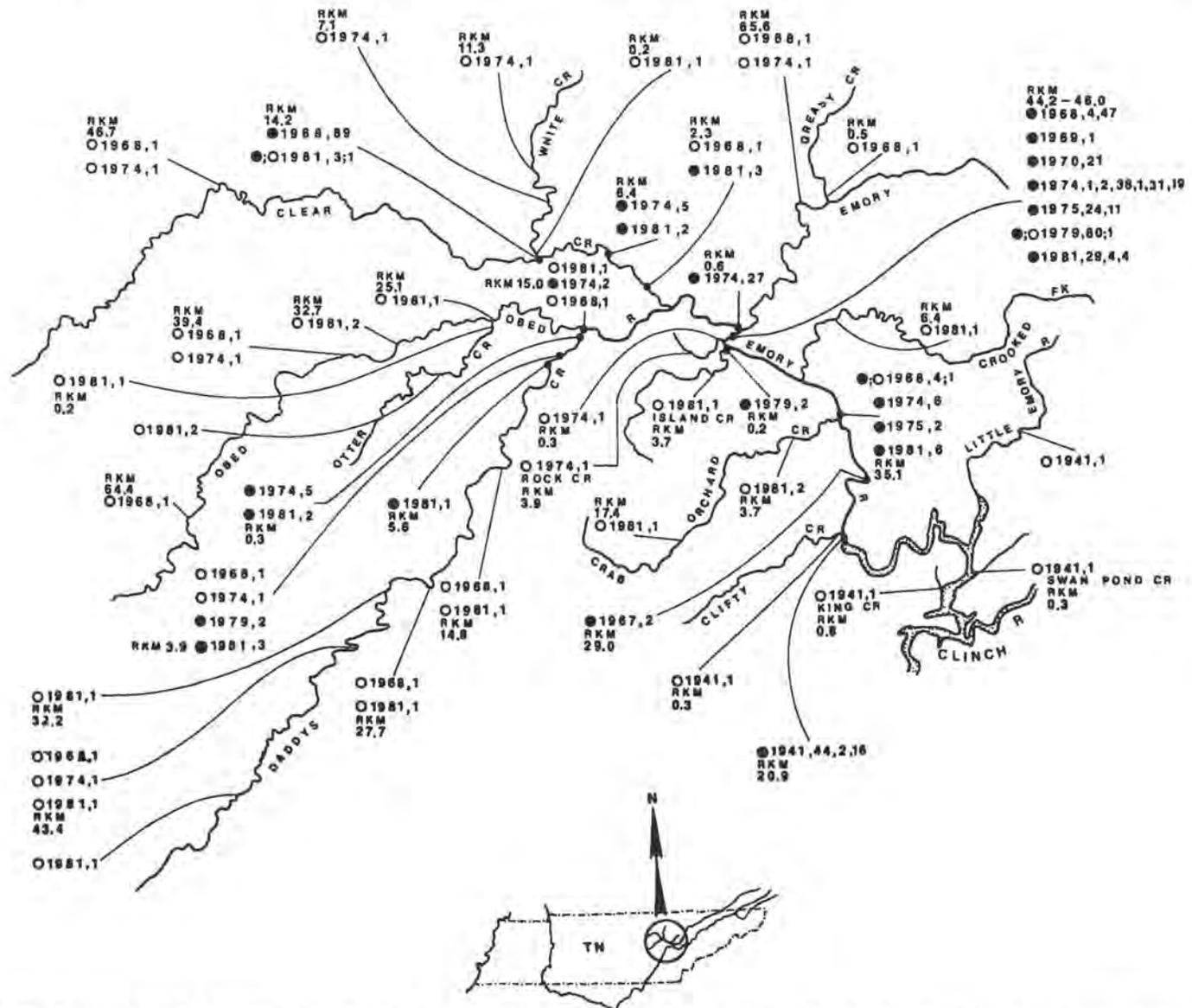


Fig. 6. Geochronology of *Hybopsis monacha* in the Emory River system, Tennessee. Map shows virtually all collections known from the system made by methods of sampling small fishes. Data format explained in Fig. 5.

Nemo Bridge, carries acid discharge from active coal strip mines (Smith, in litt., 1979). Smith collected the Emory at its mouth during a heavily turbid time and did not take *H. monacha*, but concurrently found two young in clear-running lowermost Island Creek, entering Emory River just below Rock Creek. (Smith's and Beets' observations of *H. monacha* made one week prior in Emory River were from just above Rock Creek.) Major parts of the system, additional to upper Emory, afflicted by silt and chemical discharge from mines and/or domestic and industrial pollution are Crooked Fork, Crab Orchard, White and Daddys creeks and upper Obed River.

It appears that dilution of wastes upgrades quality of lower Obed River, Clear and Daddys creeks, in turn enhancing recovery of lower Emory River. It is only these sections

where *H. monacha* remains, and to which native muskellunge are largely confined (Riddle, 1975; Crossman, 1978). Parts of these stream sections (except Clear Creek) form boundaries of the Catoosa Wildlife Management Area, which apparently benefits the watershed.

Clinch River System. — Only one specimen is known from Clinch River. Evermann and Hildebrand (1916) reported six *H. monacha* taken in 1893 from Walkers Ford, Tennessee, but five were reidentified (Hubbs and Crowe, 1956) as *H. cahni*. The Walkers Ford and other probable populations in the lower Clinch may have been waning in the late 1800s-early 1900s. Collecting effort is insufficient for judgement. Their demise was sealed by filling of Norris Reservoir in 1936, temperature depression and often very low discharge

of its tailwater, and Melton Hill Reservoir created in 1963 farther down the Clinch.

Hybopsis monacha probably was an early occupant of Clinch River above Norris Reservoir, but was undetected; extensive survey occurred after 1965 (Masnik, 1974; Jenkins et al., in prep.) and produced no specimens. This section of the river in Tennessee and Virginia has long been adversely affected by sedimentation of coal fines from coal washing operations in Virginia (Tackett, 1963; Wollitz, 1968). The ichthyofauna was virtually eliminated in 106 km of the Virginia section and some kill occurred in the upper ca. 50 km in Tennessee, from a major spillage of alkaline waste in 1967 (Jaco, 1967; Wollitz, 1970; Crossman et al., 1973). Perhaps surprisingly, the Clinch from Norris Reservoir to somewhat into Virginia still supports a highly diverse fish fauna (Masnik, 1974; Etnier and Jenkins, 1980). Apparently sensitive species that persist in this section in Tennessee include *H. cahni*, *Notropis ariommus*, *Noturus stanauli*, *Ammocrypta clara* and *E. tippecanoe*.

The single record from a Clinch system, Tennessee tributary also dates from 1893. It is from an unspecified site in Ball Creek, a small tributary of Big Sycamore Creek, which enters Clinch River ca. one km below the Ball Creek mouth. Evermann and Hildebrand (1916) did not give number of specimens, and the collection apparently is not extant. The site probably was in lower Ball Creek. Young of a nearly strictly riverine species, *Moxostoma carinatum* (misidentified by Evermann and Hildebrand as *M. aureolum*) were taken in the same collection. Lower Big Sycamore and Ball Creeks now are impounded by Norris Reservoir.

Powell River System. — As for the Clinch, the only Powell system record is from 1893. Three specimens (Evermann and Hildebrand, 1916), two located, were from Indian Creek, Tennessee, the locality descriptor being unspecific and habitat not described. We found lower Indian Creek to be 10-15 m width and of varied habitat, somewhat silted but not heavily in swift areas. This major unimpounded tributary has been moderately sampled. The Powell itself has been extensively sampled, including collections at the Indian Creek mouth by us and others, and still supports a diverse fauna, notably *H. cahni*, *Notropis ariommus*, *N. flavipinnis* and *A. clara* (Taylor et al., 1971; Masnik, 1974; Starnes et al., 1977; recent TVA collections reviewed by Jenkins et al., in prep). However, its lower portion is impounded by Norris Reservoir, and through much of Virginia and part of Tennessee it is plagued with coal and silt deposits.

North River Holston River System. — Results of 205 collections from 50 main river sites, three in Tennessee, 47 in Virginia, are in Fig. 7. Extensive sampling in tributaries (in part, Ross and Carico, 1963) did not reveal *H. monacha*.

The early seiners, Cope (1868), Jordan (1889) and Becker

(in 1928, UMMZ), provided a good qualitative concept of the fauna in the Saltville vicinity, upper river. Patrick (1961) listed fishes in a 1954 collection above Saltville. During 1954-1958, R.D. Ross (Ross and Carico, 1963) made 69 collections by shocker or seine at 36 localities (with lumping, 24 herein) throughout the river. Unfortunately the qualitative value of many of Ross' collections is suspect; although some sites were more adversely impacted by pollutants in the 1950s than currently, species numbers (some augmented by us from original data and specimens at VPI) from less perturbed sites often are well below those usually found by recent intensive sampling. However, we include all Ross' data as they agree with patterns found by others, and he collected some sites 3-13 times.

During 1970-1977, the TVA established 22 stations which were netblocked and poisoned 1-4 times a year for 1-6 years, totaling 67 collections. Burkhead aided with four of these. Hill et al. (1975) analyzed collections made during 1970-1973 at some of the stations, and Feeman (1980) discussed 1973 collections. Feeman transmitted to us original fish data from all of 1970s collections and four TVA collections taken in 1981 from one of the original stations (Click Island). Each 1981 collection was made by electroshocker and a novel seine-snorkel method, partially described and figured by Hickman and Fitz (1978) and Hickman (1981). The operation involved four snorkelers moving abreast, over transects of ca. 8 m at a time, toward a seine held by other workers. Fishes were herded toward the seine by the snorkelers with aid of poles held end to end, forming a line generally perpendicular to the current. Feeman (pers. comm.) regarded this method to be very effective for inventory of benthic fishes. A major part of the Click Island area was covered on each date.

In 1963 Jenkins electrofished two sites with Ross. None of the above efforts were particularly aimed for *H. monacha*, but they provided firm ground for conclusions on its distribution and abundance. The following efforts by Burkhead and/or Jenkins were made especially or entirely for *H. monacha*. In 1970-1975 nine sites were worked mostly by seine, yielding 19 collections; in 1976 one site was widely inspected by snorkeling; in 1981 10 localities were sampled once by shocker or seine; in 1982 six were shocked.

Although the populations of the lower and upper river probably were contiguous, for convenience they are discussed separately.

Lower North Fork Holston River: The reach currently populated is from the mouth in Tennessee, through Scott County, Virginia to the Mendota area, western Washington County, comprising 72 km. Populations are discontinuous partly due to avoidance of frequent long pools.

In Tennessee and Scott County, *H. monacha* was found at 7 of 15 sites. At least five record sites had a significant area(s) of small to medium gravel, and sites lacking a record generally lacked such areas. A striking exception was apparent absence of *H. monacha* in an extensive area of clean,

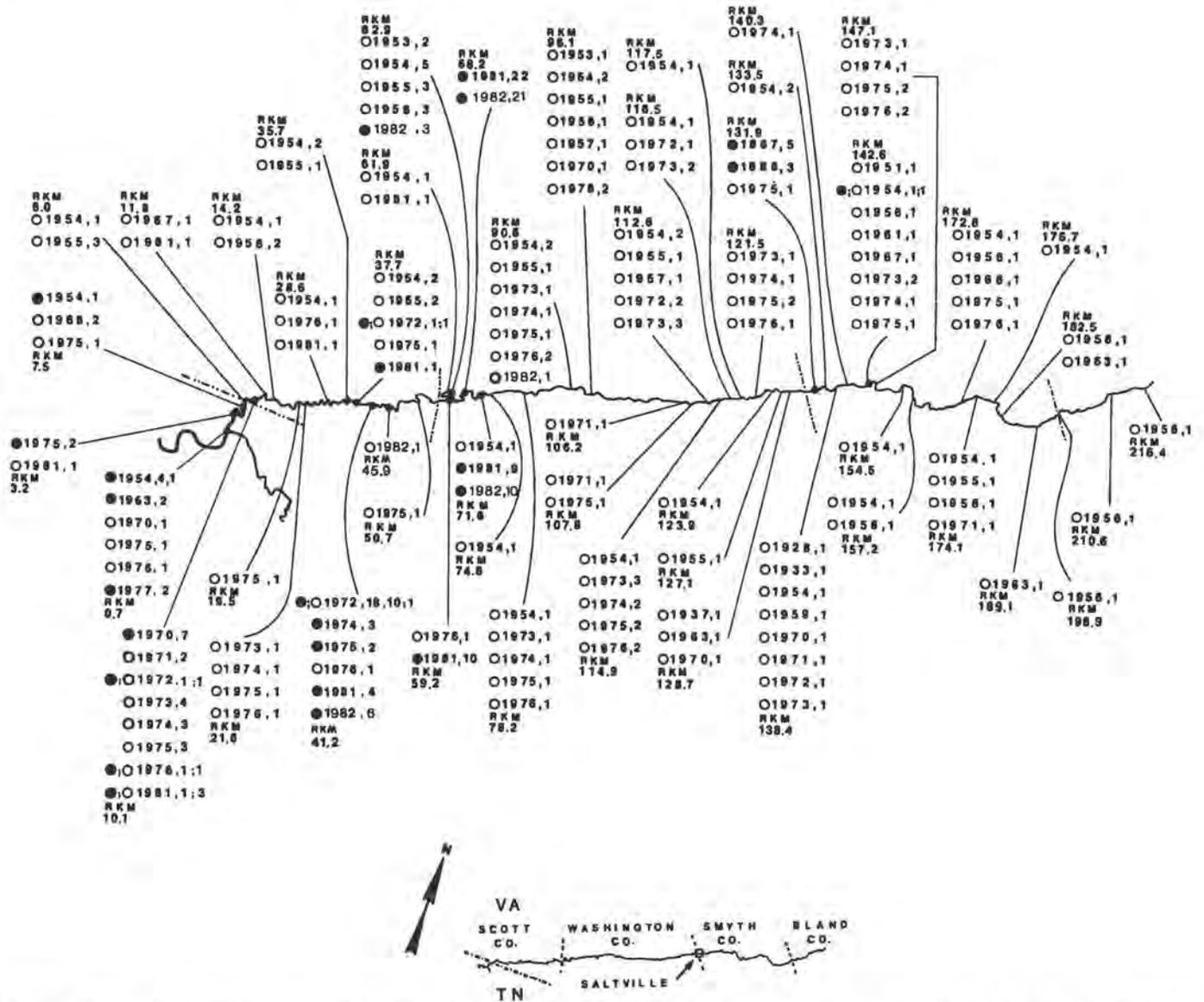


Fig. 7. Geochronology of *Hybopsis monacha* in North Fork Holston River, Tennessee and Virginia. Map shows virtually all known collections from the river. Data format explained in Fig. 5.

small-medium gravel (and large gravel-rubble) near Weber City (Rkm 11.8, where Rt. 614 reaches the river), seined in 1981. We give data in the Habitat section indicating *H. monacha* has an affinity for gravel in the North Fork Holston. However, even at record sites *H. monacha* generally was rare when found, and more frequently it was not taken at most record sites. At five sites its rarity apparently was natural. Reduction at the other two sites, in Scott County, probably relates partly to collecting; the sequence of collections and numbers taken is instructive concerning slow population recovery, here reviewed.

When the Click Island (Rkm 10.1) population was discovered in 1970 by Jenkins, seven specimens were quickly seined along the gravel bar at its tail. Further sampling yielded no more, nor did our effort at that spot and closeby the tail of the island in 1971, 1975 and 1981. The 13 Click Island

rotenone collections by the TVA in 1971–1976 took only two specimens; all collections were from the narrower channel along the main island, with larger substrate than at the tail. The data suggest the island population was initially small, largely concentrated at the tail, depleted by the 1970 seining, and that recruitment was insignificant (our seine collection in May 1971 predated the 1971 rotenoning). It is possible that incomplete neutralization of rotenone inhibited population increase at the tail during 1971–1976, but recovery during the subsequent five years hiatus in all collecting was insignificant based on capture of only one specimen in five collections in 1981. Throughout the seven years of collecting, fishes in general remained common.

The island at Rkm 41.2 is similar to Click Island in having a bar and then a flat bed of small-medium gravel extending well below the tail. The remainder of the island is sur-

rounded mostly with large gravel-rubble. When we first seined the island, widely on 16 May 1972, *H. monacha* was somewhat common; 18 were taken, only in the tail area. On 4 June 1972, 10 were seined; only the tail area was sampled. On 12 June 1972, the full periphery of the island and below were seined without finding *H. monacha*. Collecting conditions had improved through the period and other fishes remained common. We conclude that a good population for *H. monacha*, small compared to many species, first occupied the lower island area, and that seining effectively depleted, perhaps temporarily extirpated it. We seined three specimens at the tail in 1974, and two in a slow run to the right of the tail in 1975. The left channel of the island was rotenoned by the TVA in 1976, without capture of *H. monacha*. In 1981, we seined two in the tail and one on each side of the island. In 1982, we shocked completely around the island and below for 1.5 h, and snorkled near the end of the island; six specimens were taken or seen, all at the lower right side of the island. Obviously the population had not returned to near the initial 1972 level, suggesting that, as at Click Island, recruitment occurs slowly at best. The dam at Holston Mill, Rkm 37.7, would prevent distant dispersal upstream to the island. Possibly the initial island population level was atypically high for the site.

The western Washington County populations, in a 13 km section bracketing Mendota, were discovered by us in 1981. It was uncommon to common at three sites, probably most dense at Hobbs Ford (Rkm 68.2) where the most extensive area of clean, small-medium gravel we have seen in the river occurs. It was not found in 1954 and 1981 at Barker Mill Dam (Rkm 61.9), where substrate averaged larger. Ross' 13 collections in the 1950s at Mendota (Rkm 62.9) lacked *H. monacha*; perhaps only a slow, deep section was worked; we took three specimens there in 1982, over rubble.

North Fork Holston River has had a long history of industrial pollution emanating from Saltville (Kent, 1955; Higgins, 1978), just above the Washington-Smyth County line. Toxic waste spillage apparently was chronic, and the effects of breakage in 1924 of a lateral dam, impounding a large area of dissolved alkaline waste and sediment over the flood plain at Saltville, must have been catastrophic. Residents along the river in Scott County and Tennessee told us fish kills extended through that section since at least the 1940s. Although the polluting industrial operation closed in 1972, and the ichthyofauna recovered somewhat (Hill et al., 1975; Feeman, 1980), sediments throughout the river and assayed fish species are contaminated with mercury. Mercury and other toxic chemicals continue to enter the river from extensive, abandoned waste storage ponds (Bailey, 1974; Toole and Ruane, 1976; Milligan and Ruane, 1978; Turner, 1981). Although many fish species exhibit normal size, vigor and population density, at least in Scott and western Washington counties, fishing has been banned in the river since 1970 (Anon., 1981).

The question arises concerning past longevity of the

populations below Saltville, particularly those most proximate (ca. 60 km below, near Mendota). They may have been long extant but at low level, or intermittently extirpated with reestablishment via recruitment - from above Saltville (but population probably long tenuous there, and it would have had to traverse the heavily stressed zone); from the lesser impacted lower section (if milldams were passable); and/or from tributaries. Although a tributary population is unknown in the system, a few streams may have provided refuge from toxic slugs. Dispersal in recent years from lower South Fork Holston River was unlikely due to impoundment of that river and pollution from the Kingsport area (at junction of North and South Forks), which also degrades upper main Holston River (Anon., 1961; Higgins, 1978). The latter is identified by the Environmental Protection Agency as one of the 34 most polluted urban rivers in the United States (Anon., 1981). The range gap between Mendota and Saltville may be real. Although an undetermined number of the included 14 collection sites lack significant areas of small gravel, some do not (Feeman, pers. comm.), and sampling intensity probably is sufficient to have detected at least one population. The data imply *H. monacha* may have just recently achieved population level large enough to allow detection around Mendota, and may be extending farther up Washington County.

Upper North Fork Holston River: The spotfin chub was regarded as "rather rare" and "scarce" in the Saltville area during 1867 and 1888 by Cope (1868) and Jordan (1889) respectively. Both seined lengthy sections. Becker in 1928 and the TVA in 1933 did not find it. Patrick (1961) reported one specimen from seven km above Saltville in 1954. The early results suggest a low population, and the 44 other collections made in 1954-1976 indicate it vanished. *Lagochila* and *N. flavipinnis*, taken only by Jordan, also disappeared. Siltation possibly rendered the area unsuitable for *H. monacha*.

South Fork Holston River System. — Eight specimens came from the 21 km section of main channel in Tennessee whose upper end is the Virginia state line, and one specimen was from Jacob Creek, a small tributary of this section. All were taken in preimpoundment survey, including lower Watauga River, during 1947 by R.M. Bailey and the TVA; the 21 km section was also collected in 1949. Bailey noted (UMMZ file) for one collection of three *H. monacha* that it was rare, and that the Jacob Creek specimen was from a pool ca. 200 m above the mouth.

The population apparently was extirpated with filling of South Holston Reservoir in the early 1950s (dam just below lowermost *H. monacha* site), other mainstream reservoirs and cold tailwaters (Jenkins and Burkhead, 1975), and pollution of the extreme lower river (Anon., 1961; Higgins, 1978). The duskytail darter and *P. burtoni* also disappeared. The rare *Etheostoma acuticeps* was thought to have been eliminated, but was found in 1972 in South Fork Holston

River, Virginia within two km above the impoundment (Jenkins and Burkhead, 1975). The *E. acuticeps* population appeared tenuous then, and specimens were not found in 1976 and 1977. Although the freely flowing lower 15 km of South Fork Holston in Virginia is in fairly good condition, and was collected by Bailey once in 1947 and moderately well surveyed during 1959-1977, *H. monacha* is not known to have extended into it.

Discussion

Although the spotfin chub is endemic to one drainage, the 1050 km long Tennessee River is fed by numerous extensive tributary systems with upland or montane habitat, and the chub probably occupied all of these. In fact, the 12 tributary systems known to have been populated span the limits of the drainage except for extreme western lowlands. Many hypothetical populations, now extirpated, would have been undiscovered due to prior lack of collecting, or were undetected due to localization and general rarity during early survey. Its first recorded capture in 1867 postdates much of the general deforestation and consequent siltation of the basin. The evidence of extirpation of most known populations is good to strong, based on habitat modification(s) and, except for Little Bear Creek, negative results from collecting that has been extensive and often intensive over the past 20 years. The long persistence or recent recovery of numerous associated, apparently sensitive fishes is noted throughout the Distribution section. Although some of these are faring no better overall than *H. monacha*, the trend for the latter clearly has been decline.

Hybopsis monacha survives in about 166 total km of four isolated tributary systems: one site in Buffalo River of the lower drainage; and in the upper drainage, one section each of Little Tennessee and North Fork Holston rivers, and essentially four streams of the Emory system (Table 6). Although current ranges identified within three of these systems (Little Tennessee excepted) may actually be somewhat greater, many subpopulations probably are discontinuous and no population is generally flourishing. Given the history of demise of *H. monacha*, and stresses affecting at least three of the remaining populations (Buffalo possibly excepted), their survival is remarkable and tenacity is suggested.

Hybopsis monacha is a victim of numerous impacts, generally at least two on each population (Table 6). For the 24 formerly or currently inhabited stream sections (and inferred downstream extension through formerly suitable habitat in some), the following anthropogenic stresses are invoked to have adversely impacted or exterminated populations, followed by number of streams directly affected: silt or coal fine sedimentation 12; pollution 10; inundation by reservoir 10; temperature depression of dam tailwater 3; and channelization 1. Most of these factors also affect master streams of tributaries; some tributary populations may have been dependent upon immigration from the master streams.

Massive application of ichthyocide wiped out the entire Abrams Creek population. Localized seining in the North Fork Holston may have sharply depleted populations. Natural factors such as cool maximum temperature and small stream size probably limited some populations. The latter two conditions tend to coincide, and when so, populations may have been truly marginal.

The spotfin chub seems to be extinction prone. We could expect this of a large species when confined to a limited area, because of intrinsically low population density, and of predators at the top of food chains (Terborgh, 1974), but such clearly are unapplicable to *H. monacha*. Its competitive abilities, however, may be low. Except for one observation possibly more related to reproductive territoriality, its feeding activity seemed unaggressive and unopportunistic compared with several syntopic *Notropis* species, *Hybopsis dissimilis*, *Nocomis micropogon* and *Phenacobius uranops*. Spotfin chubs did not alter their benthic feeding to take drifting food stirred up from the substrate by observers; other fishes did. Specimens cupped in a net and held in a bucket remained quiet on the bottom, contrasting behaviorally with many shiners. However, such behaviors may be typical of many benthic insectivores such as *H. monacha*. Size and number of eggs are in the range of small cyprinids (Carlander, 1969), and the spawning period appears to be protracted. Fecundity may be much greater if it is a fractional spawner, and enhanced hatching success may attend crevice spawning, suggested in the Reproduction section. However, in North Fork Holston River self-recovery of and recruitment into depleted subpopulations were slight at best.

The surviving populations are in streams with low to moderately diverse fish faunas. Intensive inventory by ichthyocide of sections occupied by *H. monacha* found the usual range of species number to be 12-21 in the Emory system (Anon., 1970; Riddle, 1975:table 12), and 25-35 in North Fork Holston River (Feeman, in litt.; our data). In Little Tennessee River species numbers range 15-25 based on often repeated sampling at each site (det. from collection summary by Etnier, in litt., 1978; only seven species at two sites by Messer and Ratledge, 1963). In Buffalo River at the Grinders Creek mouth the number of species was 23; at two sites below, 31 and 34 (Anon., 1973). Species richness in spotfin chub streams is significantly less than in Clinch, Powell and Duck rivers, where in some sections 40-60 species are taken at a time (Etnier and Jenkins, 1980). Faunal recovery after environmental stress probably favored species more competitive than *H. monacha*, which seems to have persisted mainly only in moderately diverse fish communities.

Concerning *H. monacha* in the lower Tennessee, we postulate in the Distribution section that it may have been relatively unsuccessful due to natural factors. Based on most known populations being in the upper Tennessee (possibly an artifact), *H. monacha* may qualify as a "Cumberland-

dian" species. Stansbery (1964) and Isom (1969) found that Cumberlandian species of bivalve mollusks tend to be more susceptible to environmental changes in the Tennessee drainage, compared with Ohian or Mississippian components of that fauna.

In 1977 *H. monacha* was designated as a Threatened species nationally, with Critical Habitat being Little Tennessee River, Swane (sic, Swain) and Macon counties, North Carolina; Emory River and specified portions of (most of) Obed River and Clear and Daddys creeks, Morgan, Cumberland and Fentress counties, Tennessee; North Fork Holston River, Hawkins-Sullivan County line, Tennessee, and Scott and Washington counties, Virginia (Fed. Reg., 1977). Critical Habitat comprises all known extant populations except for the Buffalo in Tennessee. The latter, rediscovered in 1978, should not alter Threatened status, which Deacon et al. (1979), Williams (1981) and we deem appropriate for the species nationally.

The spotfin chub is considered Endangered in three states (Bailey, 1977; Jenkins and Musick, 1980; Starnes and Etnier, 1980). The more precarious category is applied as each state contains fewer than the four known tributary system populations (one in North Carolina and Virginia; three, one barely, in Tennessee). It is extirpated in Alabama (Ramsey, 1976) and Georgia.

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Addendum

Hybopsis monacha is a crevice spawner. Eggs were observed being deposited on the under surface of a flat, small rock that formed a crevice by lying nearly vertical against a larger rock, in Emory River on 8 July 1983. The findings are further evidence that *H. monacha* is closely related to *Notropis (Cyprinella)*. Details of behavior and habitat will be reported elsewhere by the observers, Burkhead, W.H. Haxo and S.P. McIninch.

Life History of the Banded Pygmy Sunfish, *Elassoma zonatum* Jordan (Pisces: Centrarchidae), in Western Kentucky

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ABSTRACT: Walsh, Stephen, J. and Brooks M. Burr. Life history of the banded pygmy sunfish, *elassoma zonatum* jordan (pisces: centrarchidae), in Western Kentucky. Bulletin Alabama Museum of Natural History, Number 8:31-52, 10 tables, 6 figs. The autecology of the banded pygmy sunfish, *Elassoma zonatum*, was studied at a swamp near Mayfield Creek, on the Graves-McCracken County line, Kentucky. On 16 dates between 9 March 1979 and 11 October 1980, 555 *E. zonatum* were collected and preserved for laboratory analyses of growth, reproductive biology, diet, and other aspects of life history. Sexually mature individuals were removed alive from the study site, and from Wolf Lake, Union County, Illinois, and transported to the laboratory for observations on spawning and larval development.

Elassoma zonatum from Mayfield Creek swamp attained a maximum length of 32.3 mm SL and a maximum lifespan of 25 months. However, most individuals did not survive beyond one year. Growth in length was at a decreasing rate, with one-half of the first year's mean growth attained in eight weeks. Growth in adjusted body weight was at a constantly increasing rate, with one-year-old specimens averaging 316.3 mg. No significant differences were found in growth rates between males and females.

Population densities of *E. zonatum* at the study site ranged from 3.8 fish/m³ in October to 30.4 fish/m³ in June. The sex ratio of 514 specimens from the study site was one male to 0.98 females for individuals between 1-25 months of age.

Males were in breeding condition from late February to mid-June. Histological examination of testes revealed that males matured at about 10 to 12 months of age. Seasonal progression of spermatogenesis peaked from late March to June, as evidenced by an abundance of mature spermatozoa within the testes. Breeding coloration of males was variable but usually most intense during sidling threat displays or immediately prior to spawning.

Ovarian growth increased gradually from August to May and reached a peak in late March through April. Ovaries of gravid females averaged 14.1% of the adjusted body weight, and the number of potentially mature oocytes taken from 16 gravid females averaged 144.9. No significant correlation was found between body size and the number of potentially mature oocytes in breeding females.

Peak spawning activity at Mayfield Creek swamp occurred from late March throughout most of April. In aquaria, males defended territories and often mated several times with the same or a different female within their prescribed territories. No nest was constructed, and spawning always occurred near submerged vegetation. Courtship or mating of two males simultaneously with a single female was observed five times. Females released demersal, adhesive ova that averaged 37.9 in number per mating.

At 21 ± 1° C, developing embryos hatched in 97-116 hr. Newly hatched protolarvae ranged in length from 3.0-3.6 mm TL and had an average heartbeat of 124.4 beats per min. Major organogenesis and yolk resorption were complete in 5-7 days post-hatching.

The diet of *E. zonatum* from Mayfield Creek swamp consisted primarily of small crustaceans, mollusks, and larval insects. Fluctuations in the invertebrate fauna may have accounted for seasonal variations in the types of food items consumed. Most feeding occurred between 0800 to 2000 hr.

The only evidence of predation upon *E. zonatum* was by a *Lepomis gulosus*, in February. Internal parasites were found in 79.2% of the 265 specimens examined for parasites, and were mostly immature flukes and acanthocephalans (*Neoechinorhynchus* sp.). Immature nematodes (*Camallanus* sp.), mature trematodes (*Pisciamphistoma* sp.), and acanthocephalans (*Leptorhynchoides* sp.) were found in a few specimens.

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Introduction

The pygmy sunfish genus *Elassoma* currently includes three described species (Jordan 1877, 1884; Böhlke 1956) and at least three undescribed forms (Böhlke and Rohde 1980, Jenkins 1976, Swift et al. 1977). All species of *Elassoma* are diminutive (maximum length less than 50 mm), cryptic fishes endemic to southcentral and southeastern United States, and prefer well-vegetated, sluggish swamps and backwaters or springs.

Most of the literature dealing with the genus *Elassoma* concerns species other than *E. zonatum*. Due to its popularity among aquarists, information on *E. evergladei* is well documented. In his doctoral dissertation, Mettee (1974) provided a summary of the literature on *Elassoma*, most of which is faunal or taxonomic in scope or popular articles in hobbyists magazines.

Little ecological information on pygmy sunfishes has been published, although aspects of reproduction in captive specimens have been included in several treatises. Breder and Rosen (1966) and Mettee (1974) summarized articles related to reproduction in *Elassoma*. Barney and Anson (1920) published the most detailed study to date on the life history of an *Elassoma*, in an investigation of the effectiveness of *E. zonatum* as an agent for mosquito control in Louisiana. Rubenstein (1981a,b,c) studied resource patterning and mechanisms of competition of *E. evergladei* under laboratory and field conditions. Gunning and Lewis (1955) included a brief discussion of the habitat, diet, and predation on *E. zonatum* in southern Illinois. Mettee (1974) described the reproductive behavior, embryology, and larval development of the three described and one undescribed species from individuals maintained in captivity.

This study was undertaken to supplement the paucity of ecological information on pygmy sunfishes and is the result of a 13-month life history study conducted in western Kentucky. Because the study site is near the northern extreme of the range of *E. zonatum*, the results of this study should provide comparative data for analysis of geographic variation in life history strategies.

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dale in partial fulfillment of the requirements for the M.A. degree.

Distribution

Elassoma zonatum is the most widely distributed member of the genus, and is often abundant locally (Fig. 1). The species occurs throughout the coastal plain of the southern United States, with a range extending from the Atlantic coast in North Carolina south to central peninsular Florida, west to the Brazos River system of Texas and the Red River drainage in extreme southeastern Oklahoma and north to southern Illinois. *Elassoma zonatum* is seldom collected above the Fall Line except in the central Mississippi and lower Ohio Valleys, where relict populations exist in the Wabash River drainage of southeastern Illinois and in the Tradewater and Green River drainages of westcentral Kentucky (Warren 1980). Smith (1979) speculated that this species was probably extirpated in the Wabash River of southeastern Illinois, apparently because of extensive habitat destruction and pollution in that area. Gerking (1945) included *E. zonatum* in a list of fishes possibly occurring in Indiana, but the species has never been taken in the state. Further collecting in the Wabash River drainage is needed to determine the status of the species at the northernmost boundary of its range.

There has been a question concerning the salinity tolerance of pygmy sunfish in coastal areas. Hoese and Moore (1977) included *E. zonatum* in a list of fishes possibly occurring in marine water in the Gulf of Mexico. However, Bailey et al. (1954) concluded that this species was intolerant of saline water.

Study Site

The study site is an extensive cypress swamp in the floodplain of Mayfield Creek, a direct tributary of the Mississippi River in western Kentucky. Mayfield Creek is a slow-to-moderate flowing, silt-laden stream that has been extensively channelized. Although swamps and forests occur intermittently along the creek, all collections were made at the Graves-McCracken County line on Hwy. 1241, about 4 km ESE of Melber and 20 km S of Paducah (36° 56' 55" N, 88° 40' 46" W). The study site, unnamed on recent U.S. Geological Survey topographic maps (photorevised 1971), will hereafter be referred to as Mayfield Creek swamp.

The study area is on the north shore of Mayfield Creek and is relatively isolated from the creek except during periods of high water in the spring, when the two are connected by intermittent sloughs and ditches. Man-made disturbances at the study site are considerable; Hwy. 1241, formerly a truck route (US 45), and three local businesses are adjacent to an undated habitat. The swamp is a common dumping ground for debris from local businesses, and during the study construction of a large highway (US 45) north of the swamp was initiated. Runoff and a soft, muddy substrate contribute to a high level of water turbidity in the swamp throughout the year.

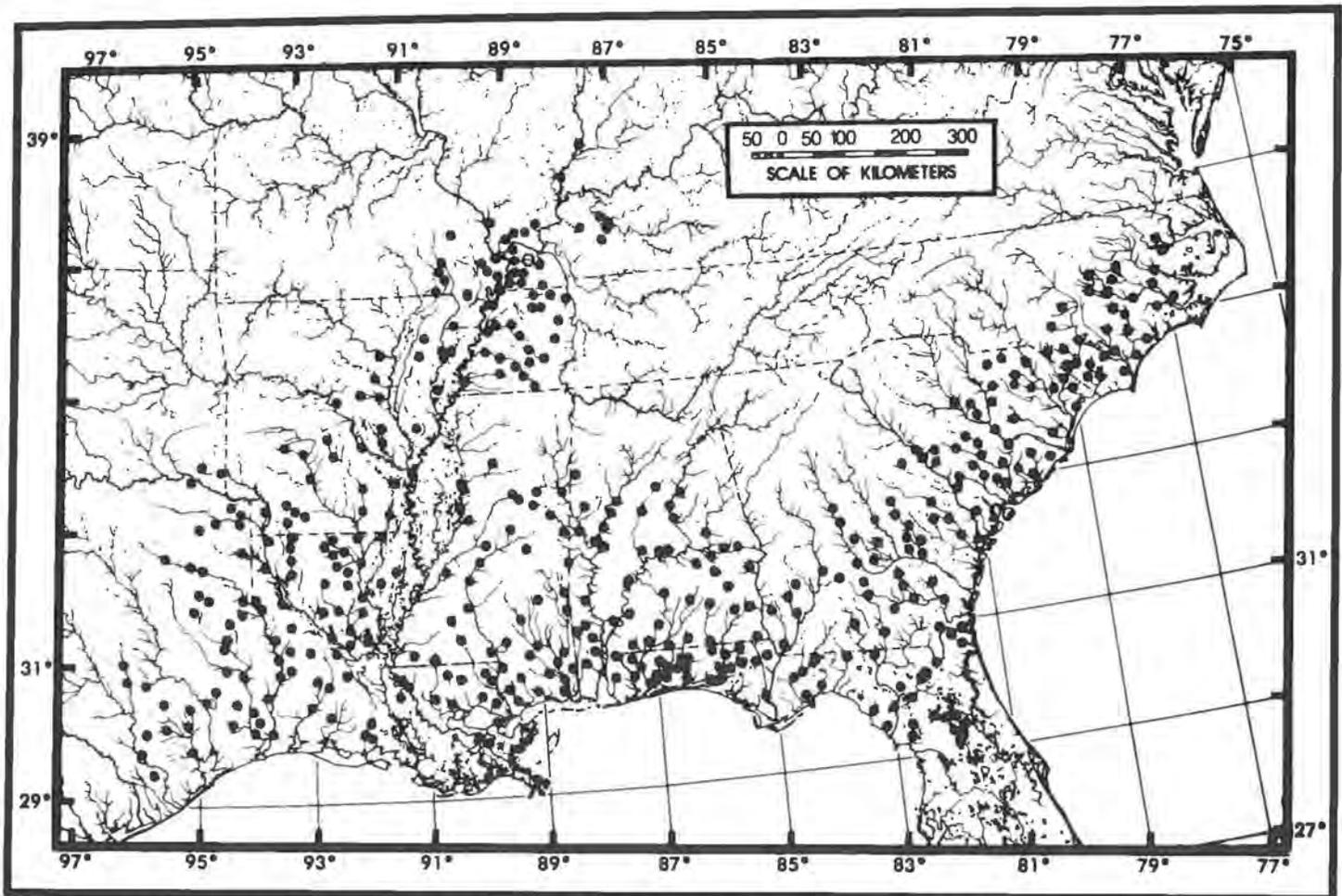


Fig. 1. Range of *Ellassoma zonatum*. Map modified from Bohlke and Rohde (1980). The life history study area is enclosed within the open hexagon.

Methods and Materials

Collections were made at approximately one-month intervals from 29 September 1979 to 11 October 1980, except during the breeding season when more frequent visits were necessary. Life-history data from 21 *E. zonatum* taken on 9 March 1979 are included in some analyses. About 30 specimens of *E. zonatum* and other syntopic species were collected each month with minnow seines and dip nets. An attempt to capture pygmy sunfish with conventional steel minnow traps on 25 April 1980 was unsuccessful. All specimens were killed and fixed in 10% formalin and later transferred to 70% ethanol. Routine field notes on water depth, temperature, turbidity, and vegetation were made during each collection. All preserved specimens are deposited in the ichthyology collection of the Department of Zoology at Southern Illinois University at Carbondale.

On 22 February, 4 June, and 11 October 1980, population density estimates were obtained from a prescribed area. The areas sampled were blocked off with small-mesh (3-6 mm) minnow seines, and intensively sampled with dip nets and seines until no additional specimens of *E. zonatum* were obtained. The enclosed areas were then measured and seined to capture any remaining specimens. It is likely that a

few pygmy sunfish within the enclosed areas eluded capture; the abundant aquatic vegetation and extensive organic detritus provided many hiding places and precluded thorough sampling.

In the laboratory, the standard lengths (SL) of all specimens were measured to the nearest 0.1 mm with dial calipers. Measurements of larvae and some juveniles were made under a stereomicroscope with an ocular micrometer.

Scoring specimens to year class was done by counting annuli of scales removed from the dorso-lateral trunk below the dorsal fin origin and scales from above the anal fin origin. Scoring to month was calculated by using April, the month of greatest spawning activity, as month 0.

Adjusted body weights of approximately ten males and ten females from each monthly sample were measured. Adjusted body weight was the wet weight of the specimen after removal of the stomach, liver, intestine, and gonads. Specimens were removed from preservative and hydrated in tap water for 3-6 hrs before being weighed to the nearest 0.1 mg on a Sartorius analytical balance.

The sexes of all specimens over 10 mm SL were identified by examining the gonads under a stereomicroscope at a magnification of 6-25 X. Because there is no significant

qualitative sexual dimorphism in *E. zonatum* except during the breeding season, the sex of only mature pre-spawning or spawning individuals could be reliably determined from external appearance. Detailed descriptions of ovaries and testes are included in the respective sections on reproductive cycles.

Ovary weights of several females from each monthly sample were measured to the nearest 0.1 mg using the same method as that for weighing entire specimens. The gonadosomatic index (GSI), equal to the weight of the ovaries X 1000 divided by the adjusted body weight, was recorded for females.

The testes of one male each from ten separate collections were removed for histological analysis of spermatogenesis. Specimens were used from all months between September and June except for October and December. Testes were embedded in paraffin and sectioned at 5–10 μm using standard histological techniques. Both longitudinal and transverse sections were obtained. Stains used were 1) Kernechtrot-Fast Green FCF, 2) Mallory's Phloxine-Methylene Blue, 3) Heidenhain's iron hematoxylin, 4) Bromophenol Blue and, 5) Toluidine Blue. Microscopic examinations of stained testicular tissues were made at magnifications of 30–1000 X.

Because of the high water turbidity at the study site, reproductive behavior and spawning could not be observed under natural conditions. Mature, live specimens from the study site collected on 4 April 1980 and 28 March 1981, and from Wolf Lake, Union County, Illinois (20 March 1981), were transported to the laboratory for observations of reproduction. They were maintained in 40–110 liter aquaria at temperatures of 20–25 °C. The aquaria were planted with aquatic vegetation taken from Mayfield Creek swamp.

Spawned eggs and developing embryos were removed from the aquaria and placed in 300-ml culture dishes aerated with air stones, and incubated at 21 ± 1 °C in a water bath. All aquaria and culture dishes containing live specimens were treated with Nitrofuracin, Malachite Green, or a commercial fungicide to control pathogenic bacteria and fungi.

Stomachs were removed from several specimens from each monthly collection for dietary analysis and examination for endoparasites. Stomach contents were removed and identified, and the numbers of food items of each prey taxon were recorded. Immature copepods and cladocerans were counted as individual food items. Filamentous algae, regardless of the number of strands present per stomach, were counted as one item in stomachs containing them. Variation in dietary composition was examined for differences among size classes, sexes, and monthly samples.

Diel feeding activity of *E. zonatum* was monitored on 18–19 August 1980. Beginning at 1400 hr on 18 August, collections of 5 to 9 specimens were made every two hrs for a 24 hr period. These specimens were preserved immediately. In the laboratory, each specimen was sexed and measured and the stomach contents of five randomly selected from

each sample were recorded. For each specimen, the degree of stomach fullness and relative digestion of food contents were evaluated subjectively. Degree of fullness by volume was visually ranked according to the following scale: 1 = 0–25%, 2 = 26–50%, 3 = 51–75%, 4 = 76–100%. A digestion index, based on a scale of 1 to 5 following the method of Mayden and Burr (1981), was as follows: 1 = empty, 2 = excessive digestion, 3 = moderate digestion, 4 = partial digestion, 5 = no digestion or fresh material. The relative degree of digestion of food material was evaluated from the number of appendages, shells, cuticles, etc. that were fragmented, decomposed, or missing. A third index, termed the index of feeding activity, was determined by multiplying the digestion index for each specimen by the degree of stomach fullness.

Most statistical analyses were performed by computer using the Statistical Analysis System (SAS). Regression coefficients were obtained through the method of least squares. Analysis of covariance was used to test for group differences in regression coefficients and homogeneity of regression. Correlation coefficients (r) are all Pearson product moment correlation coefficients and, unless noted, tests were performed using a level of significance of $\alpha = 0.05$. Standard deviations are abbreviated SD.

Habitat

The habitat at Mayfield Creek swamp is typical of Coastal Plain cypress swamps and bayous. The study site is heavily wooded with bald cypress (*Taxodium distichum*), tupelo (*Nyssa*), oaks (*Quercus*), willows (*Salix*) and other deciduous trees, with open surface land and underbrush composed of shrubs and grasses. During the warmer months, most inundated areas of the swamp are heavily choked with aquatic plants including coontail (*Ceratophyllum*), milfoil (*Myriophyllum*), pondweed (*Zannichellia*), duckweed (*Lemna*), watermeal (*Wolffia*), smartweed (*Polygonum*), and filamentous algae. Dominant emergent macrophytes occurring along pool margins and in shallow channels include cattails (*Typha*), false loosestrife (*Ludwigia*), lizard-tail (*Saururus cernuus*), rushes (*Juncus acuminatus*), water willow (*Justicia americana*), and arum (*Peltandra virginica*).

Inundated portions of the swamp consist primarily of shallow marshy areas, channels, and deeper pools around cypress knees. The presence of beaver (*Castor canadensis*) has resulted in many submerged logs and stumps, undercut banks, and subsurface canals. The substrate consists of decaying vegetation, silt, and soft mud. Maximum water depth varies from 0.2 m to 1.0 m in most areas. In a large open pool approximately 15 m wide, maximum water depth is at least 1.8 m. During the spring and early summer months, heavy rainfall usually results in some areas being temporarily inundated with water about 15–30 cm deep. Water temperatures range from 5–7 °C in December and January to 32 °C in August.

Mayfield Creek swamp maintains a moderate diversity of

at least 25 species of fishes (Table 1). Predominate members of the ichthyofauna are sunfishes and pirate perch. *Elassoma zonatum* was usually taken alone or with species frequenting shoreline areas, such as sunfishes, topminnows, and mosquitofish. Additional fish species expected to occur in the swamp, but never collected, include *Amia calva* and *Umbra limi*.

Table 1. Fish species occurring with *Elassoma zonatum* at Mayfield Creek swamp, arranged in order of decreasing abundance. Figures represent percentages of total number of fishes taken, excluding *E. zonatum*, in 16 collections between 9 March 1979 and 11 October 1980.

Species	Percent
<i>Lepomis symmetricus</i>	25.3
<i>Lepomis macrochirus</i>	19.1
<i>Lepomis gulosus</i>	18.0
<i>Aphredoderus sayanus</i>	11.0
<i>Gambusia affinis</i>	4.2
<i>Esox americanus</i>	3.4
<i>Etheostoma gracile</i>	3.4
<i>Centrarchus macropterus</i>	2.3
<i>Notemigonus chrysoleucas</i>	2.1
<i>Micropterus salmoides</i>	2.1
<i>Lepomis cyanellus</i>	1.5
<i>Ictalurus natalis</i>	1.5
<i>Fundulus olivaceus</i>	1.0
<i>Fundulus notatus</i>	1.0
<i>Notropis fumeus</i>	0.8
<i>Pomoxis annularis</i>	0.5
<i>Notropis emiliae</i>	0.5
<i>Noturus gyrinus</i>	0.4
<i>Hybognathus hayi</i>	0.4
<i>Poxomis nigromaculatus</i>	0.3
<i>Lepisosteus oculatus</i>	0.3
<i>Ictalurus melas</i>	0.3
<i>Erimyzon oblongus</i>	0.3
<i>Minytrema melanops</i>	0.3

In Louisiana (Barney and Anson 1920) and in southern Illinois (Gunning and Lewis 1955), *E. zonatum* were collected in plant communities that harbored few or no other fishes. Extensive sampling at Mayfield Creek swamp yielded specimens of *E. zonatum* in all areas except for open, deep-water habitats lacking vegetation or other cover. Shallow (15–30 cm), well-vegetated, clear-water areas sampled during spring and early summer were the only habitats in which *E. zonatum* was found to the exclusion of other fish species, although *Gambusia affinis* was sometimes observed or collected in these areas also. Throughout its range, *E. zonatum* frequents lentic waters such as cypress swamps, lake margins, sloughs, sluggish streams, and lowland backwater areas, and the species prefers shallower, well-vegetated water with protective cover such as logs, stumps, cypress knees, and overhanging banks over soft substrates (e.g., Barney and Anson 1920, Branson 1974, Coker 1917, Gunning and Lewis 1955, Warren 1980).

Age and Growth

Young-of-the-year *E. zonatum* from Mayfield Creek swamp, first collected on 26 May, ranged in size from

6.6–11.5 mm SL (\bar{x} = 9.34 mm; N = 26); adjusted body weights ranged from less than 20 mg to 40.1 mg (\bar{x} = 28.6 mg; N = 7). The extensive range in size was due to the prolonged breeding period, with some individuals having hatched as much as two to three weeks earlier than others. Juveniles collected 4 June ranged in length from 6.4–13.8 mm SL (\bar{x} = 9.70 mm; N = 39), indicating that some specimens hatched in late April or early May. Although the breeding period spanned most of April, young specimens collected in late May were designated as one-month-old.

Growth in length proceeded at a decreasing rate (Fig. 2), with rapid growth in the first five to six months corresponding to increased metabolism resulting from the warm water temperatures of the summer months. Curvilinear equations expressing growth in standard length of specimens between 1–25 months of age did not differ significantly between the sexes. The transformed relationship between standard length and age in months (A) for males was $SL = 7.82 + 14.50 \text{ Log } A$ ($r = 0.898$; N = 260) and for females was $SL = 7.90 + 14.38 \text{ Log } A$ ($r = 0.916$; N = 254). The regression equation for both sexes, including juveniles not sexed, was $SL = 7.36 + 14.94 \text{ Log } A$ ($r = 0.921$; N = 555). Mean standard lengths for each sex were similar within monthly samples. One-half of the first year's mean growth in length was attained in about eight weeks (Table 2). At one-year-of-age, specimens averaged 22.9 mm SL (range, 19.2–25.9 mm; N = 44) and had a mean adjusted body weight of 316.3 mg (range, 193.1–420.7 mg; N = 27). Specimens surviving beyond a year grew at a much slower rate, with an increase in mean length of only about 5.5 mm for the twelve-month period over one year of age. At 23–25 months, males averaged 30.2 mm SL and females averaged 29.6 mm SL ($t = 0.571$; $df = 9$).

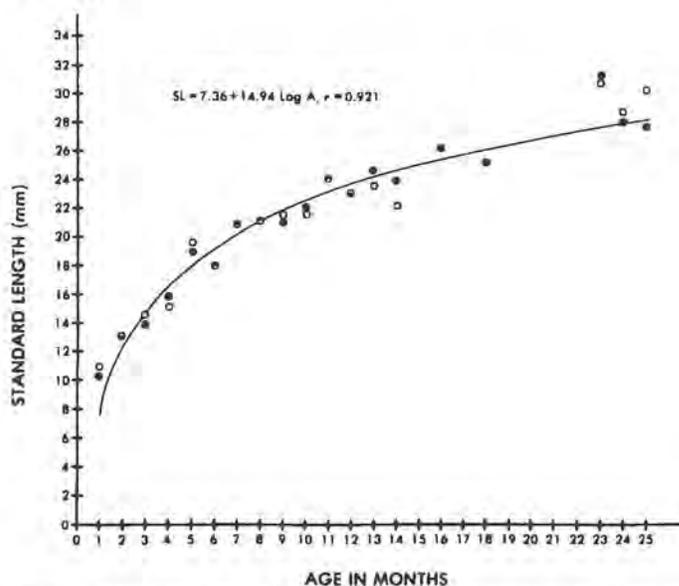


Fig. 2. Growth in standard length of *Elassoma zonatum* from Mayfield Creek swamp. Solid circles represent sample means for females, open circles represent sample means for males. The regression line is for both sexes combined.

Table 2. Standard lengths and adjusted body weights of *Elassoma zonatum* from Mayfield Creek swamp by age in months, from 9 March 1979 to 11 October 1980.

Age	Standard length (mm)				Body weight (mg)			
	N	Mean	Range	SD	N	Mean	Range	SD
1	26	9.3	6.6-11.5	1.32	7	28.6	20.0-40.1	6.3
2	75	11.5	6.4-15.6	2.57	35	65.4	28.3-110.5	25.9
3	50	14.3	10.3-17.5	1.61	20	105.0	37.4-159.2	24.4
4	99	15.5	12.8-18.8	1.28	17	122.3	70.4-172.5	29.1
5	30	19.5	16.9-21.6	1.08	20	177.4	120.8-251.5	32.7
6	28	18.1	15.9-20.5	1.10	19	132.2	82.4-201.5	27.7
7	30	20.8	17.7-24.4	1.92	20	207.9	139.4-313.4	46.9
8	30	21.1	18.0-25.3	1.72	20	220.5	153.0-405.2	52.2
9	30	21.4	17.8-25.9	1.76	18	250.0	148.1-433.9	77.6
10	38	21.8	19.0-26.2	1.64	20	279.4	187.2-458.6	65.3
11	47	23.9	19.5-29.3	2.69	20	329.8	206.9-60.0	97.4
12	44	22.9	19.2-5.9	1.55	27	316.3	193.1-20.7	62.7
13	13	24.2	20.6-6.0	1.48	12	346.0	247.8-54.8	52.3
14	2	23.1	22.2-3.9	1.20	2	384.8	370.1-99.5	20.8
16	1	26.2	—	—	1	345.4	—	—
18	1	25.0	—	—	1	290.5	—	—
23	6	31.1	28.6-2.3	1.28	5	750.2	617.4-01.6	75.8
24	3	28.3	27.8-8.7	0.47	3	589.2	547.6-47.6	52.1
25	2	28.7	27.5-9.8	1.63	2	567.8	507.9-627.6	84.6

Growth in body weight was linear for specimens between 1-25 months of age (Fig. 3). Although males generally maintained slightly higher mean monthly body weights at age classes greater than nine months, there was no significant sexual difference in regression equations. At 23-25 months, males had a mean adjusted body weight of 663.9 mg and females had a mean of 666.4 mg ($t = 0.033$; $df = 8$). The relationship between adjusted body weight in milligrams (W) and age in months (A) for males was $W = 10.52 + 27.43A$ ($r = 0.897$; $N = 129$) and for females was $W = 18.63 + 25.39A$ ($r = 0.915$; $N = 140$). For the sexes combined, the relationship was $W = 15.61 + 26.22A$ ($r = 0.905$; $N = 269$). One-half of the first year's mean growth in body weight was attained in about 5.5 months (Fig. 3).

Lengths and weights of specimens were highly correlated. The relationship between adjusted body weight in milligrams (W) and standard length was $\text{Log } W = -1.44 + 2.87 \text{ Log } \text{SL}$ ($r = 0.987$; $N = 269$). Although females maintained slightly higher mean body weights per millimeter of standard length, no significant sexual difference was found for the length-weight relationship.

The largest individuals of each sex collected during 1980 were a 25-month-old male (29.8 mm SL; 627.6 mg) and a 24-month-old female (28.5 mm SL; 572.5 mg). Five 23-month-old specimens collected 9 March 1979 were the largest individuals taken from the study site, averaging 31.6 mm SL (range, 31.3-32.3 mm) and 783.5 mg in weight (range, 763.3-801.6 mg). All specimens greater than 12 months of age averaged 26.4 mm SL (range, 20.6-32.3 mm; $N = 28$) and 469.9 mg in weight (range, 290.5-801.6 mg; $N = 26$).

The maximum length of *E. zonatum* is commonly given

as 32-38 mm, but most authors have failed to specify standard or total length (TL). Böhlke and Rohde (1980) gave a range of 25-45 mm TL for adults. In a collection from eastern Louisiana (University of Louisville 11531; St. Tammany Parrish, pineland pool at Slide II, 12 March 1950), four specimens were greater than 40 mm TL and one individual approximately 36 months old measured 46.6 mm TL (38.5 mm SL). That specimens at more southern latitudes attain a greater adult size is due to earlier spawning periods and longer available growing seasons when compared to populations from more northern, variably cool climates typified by western Kentucky. The oldest *Elassoma* reported was a three-year-old specimen of *E. zonatum* 34 mm in length (Barney and Anson 1920).

Reproduction

Coloration.—Exclusive of the breeding season, males and females were colored alike. Individuals were olivaceous to bronze or light brown, with fine melanophores profusely scattered over the body and head. The intensity of the basal olivaceous pigmentation was variable and probably influenced by water clarity. Most specimens became lighter in aquaria containing treated water. There were 8-11 dark olive-to-black, parallel vertical bands on each side between the operculum and caudal peduncle. The bands extended from the dorsum to the venter and were usually slightly wider than the intervening lighter areas. The bands generally became narrower caudally with the last one often broken into two-to-three elliptical spots. A dark black spot slightly larger than the eye was usually present on either side below the origin of the dorsal fin and slightly above and behind the pectoral fins. A narrow, dark band usually extended from the posterior edge of the eye caudad to just below the dorsal edge of the opercular opening. The unpaired fins were moderately pigmented with melanophores concentrated

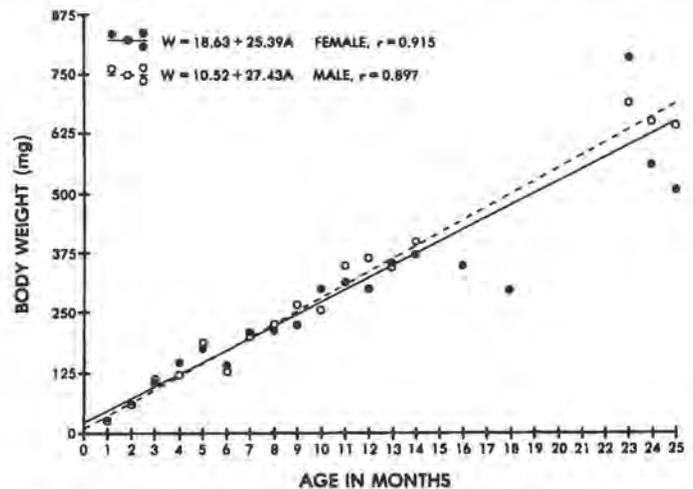


Fig. 3. Growth in body weight of *Elassoma zonatum* from Mayfield Creek swamp. Solid circles represent sample means for females, open circles represent sample means for males. Regression lines represent total samples for each sex.

along the edges of the spines and rays, and in the dorsal and anal fins two or three lateral rows of spots were present sub-basally, medially, and sub-marginally. Several faint vertical rows of spots were often present in the caudal fin. The pectoral fins were only lightly pigmented along the ray margins, and pigmentation in the pelvic fins was variably light to moderate, usually being slightly more extensive in males than in females.

From late February to early March, males (Fig. 4) began to assume the dark coloration characteristic of the breeding season. The head and body became dark blue to black, with the 8-11 vertical bars becoming more pronounced. Background coloration on the body, isthmus, and opercula became pale white to light blue. The opercula, isthmus, and belly had large, irregular blue-black spots on the light background. Irridescent blue and green speckles were scattered about the head and in the interspaces between the anterior bands of the sides; there was a large crescent-shaped, iridescent gold-green bar immediately ventral to the eye. All of the fins except the pectorals became heavily pigmented with blue or black. The dark lateral bar behind the eye and the large scapular spot present in non-breeding individuals often disappeared at the height of breeding coloration. The iris became light brown to orange prior to spawning. The intensity of coloration, particularly that of the fins, may undergo rapid changes (Poyser 1919), especially during sidling threat displays or courtship behavior (see spawning).

As noted by previous authors (e.g., Mettee 1974, Poyser 1919), females (Fig. 4) did not undergo noticeable color changes during the breeding season. The slight darkening prior to spawning observed by Taber (1964) is highly variable and not directly related to spawning activity.

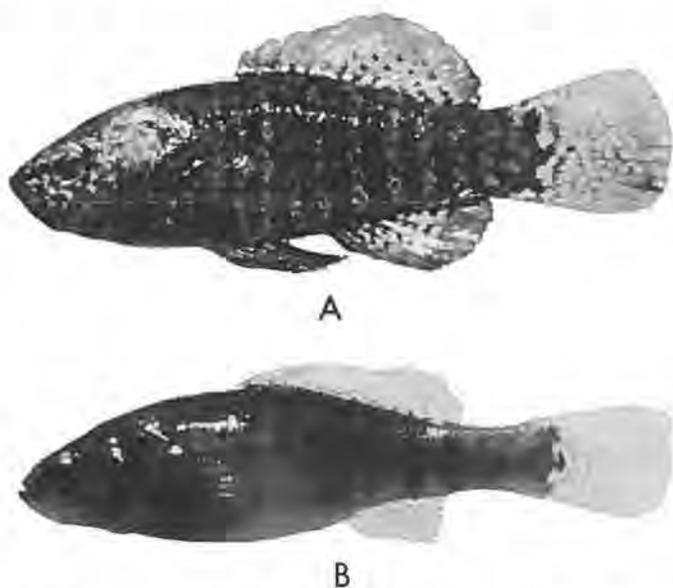


Fig. 4. *Elasmoma zonatum* from Mayfield Creek swamp. Above, 28.4 mm SL male in breeding condition. Below, 34.2 mm SL gravid female. Both collected 15 March 1983.

Male Reproductive Cycle.—The testes were elongate, flattened, and fused posteriorly, with the left testis about one-third to one-half the length of the right. A single duct led from the postero-medial edge of the testes to the genital papilla. Thin mesenteric strands attached the testes anteriorly to the connective tissue suspending the stomach and intestine. From June to January the testes were opaque white and underwent gradual enlargement as the breeding season approached. From February through May, they were opaque white and swollen, with the left testis more lobulate-shaped and concave anteriorly.

The genital papilla underwent little change prior to spawning. Marked increase in pigmentation around the anus and papilla, and slight swelling of the latter, were the only significant morphological changes in the papilla from the non-breeding condition.

Spermatogenic cycle.—Histologically, the testes resembled those of bluegill (Bright 1939, James 1946) and crappies (Cooper 1952). The testicular wall consisted of a thickened layer of connective tissue that branched inward forming numerous anastomosing tubules. Each tubule consisted of a lumen or interseptal space surrounded by an epithelium of several cell layers. A decrease in the thickness of the septa and enlargement of the tubule lumina paralleled successive stages of maturation and spermatogenesis. Irregular, spindle-shaped interstitial cells were found sparsely scattered throughout the testicular epithelium.

Spermatogonial cells were found within the connective tissue along the tubule margins and were observed in specimens from all months examined, although they were more numerous in males collected from September to November. The lightly stained primary spermatogonia were large cells, averaging 11.0 μm in diameter, and contained a darker, spherical nucleus with a prominent nucleolus. Mitotic divisions of primary spermatogonia resulted in secondary spermatogonia enclosed within discrete cysts. As in other teleosts, synchronized cellular divisions occurred independently within each cyst (Grier 1981).

Proliferation of spermatogonia was followed by further mitoses that resulted in the formation of slightly smaller primary spermatocytes enclosed within cysts. Primary spermatocytes (Figs. 5 and 6) were characterized by an indistinct cell membrane and a darkly stained nucleus that averaged 4.0 μm in diameter. Testes of specimens collected from November to February had a greater number of cysts containing primary spermatocytes in proportion to cysts in other stages of spermatogenesis. The tubular lumina remained small in those testes with a high concentration of primary spermatocytes.

Secondary spermatocytes (Fig. 6) differed from primary spermatocytes in being slightly smaller and in having darker nuclei that averaged 3.6 μm in diameter. Cysts containing secondary spermatocytes were uncommon in all months, probably because of rapid second meiotic divisions. In

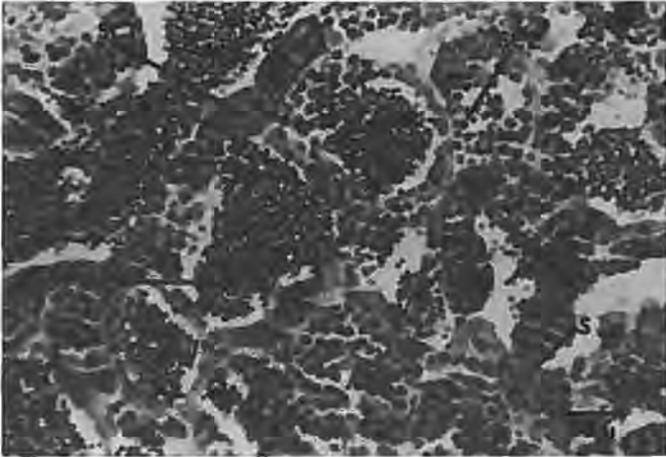


Fig. 5. Transverse section of testis of male *Ellassoma zonatum* collected 17 November 1979, stained with Kernechtrot Fast-Green FCF. 450 X. Abbreviations used: S = septum, IL = interlumen, SC1 = primary spermatocyte, SC2 = secondary spermatocyte, SP1 = spermatid, SP2 = spermatozoa.

Pomoxis, cysts burst at this stage and released secondary spermatocytes into the interseptal spaces (= intratubular lumina) where subsequent divisions into spermatids occurred (Cooper 1952). The stage at which cysts were broken in *E. zonatum* could not be determined. However, spermatids were generally liberated from cysts and concentrated near the periphery of the intratubular lumina. Cytological detail of spermatids (Figs. 5 and 6) was minimal with all of the stains used; the cytoplasm was not distinct, and the nearly spherical nucleus, approximately 1.8 μm in diameter, stained darkly.

Maturation of spermatids into spermatozoa occurred within the intra- and intertubular lumina. Spermatozoa (Fig. 7) were most easily discernible in sections stained with Heidenhain's iron hematoxylin and Bromophenol Blue, and were distinguished by the small, spherical nucleus approximately 1.6 μm in diameter, a short middle piece, and a long flagellum. No acrosome was formed (Grier 1981). Mature spermatozoa were usually clumped into compact masses within the tubular lumina similar to those of other sunfishes (Cooper 1952, James 1946). Testes of specimens collected from November through June contained mature spermatozoa; however, only those of males taken between March and June contained large numbers. Functional maturity (Stage V of Grier 1981), defined as tubules filled with sperm and very little spermatogenesis occurring, was attained at 10–12 months in *E. zonatum*.

Although testes of males from most months had cysts in varying stages of spermatogenesis, seasonal progression of spermatogenesis was observed. Testes of males collected in September had reduced tubular lumina and greatly expanded septa consisting mostly of spermatogonia, spermatocytes, and a few spermatids. By November, the enlarged lumina contained moderate numbers of spermatids and spermatozoa, while most of the spermatogonia had matured to

spermatocytes. From late autumn until April, the testes contained progressively more cells in advanced stages of spermatogenesis. At the onset of the breeding season testes were greatly distended, with spermatozoa-packed tubular lumina and reduced septa containing relatively few cysts in the early stages of development (Fig. 8). All stages of spermatogenesis were present in the testes of specimens taken throughout the breeding season. No marked reduction in the number of spermatozoa within the tubular lumina was observed following the breeding period, and one post-spawning male collected 4 June 1980 had a high concentration of mature spermatozoa.

Territoriality.—Species of *Ellassoma* are non-gregarious (e.g., Miller 1964, Rubenstein 1981a). Male territoriality has most commonly been associated with breeding behavior of captive specimens (Branson 1974, Mettee 1974, Miller 1964, Rubenstein 1981a, Taber 1964). In addition, Rubenstein (1981a,b,c) examined the mechanism of competition and resource partitioning in *E. evergladei* and found that significant changes in male social behavior were influenced by prey dispersion and population densities, which ultimately might influence reproductive success.

In aquaria, males established territories around submergent vegetation and assumed the characteristic breeding coloration. Territories maintained were slightly smaller than the 20–25 cm territories reported by Taber (1964), probably because of overcrowded conditions in the holding tanks (ca. 0.04–0.07 males per liter per aquarium). In agreement with the observations of Rubenstein (1981a), males often overlapped in their use of space. Males defending territories warded off intruding males and non-receptive females using sidling threat displays, as first defined by Miller (1964) and later elaborated by Rubenstein (1981b) for *E. evergladei*. The behavioral mechanics of territoriality in *E. zonatum* were nearly identical to those described for *E.*

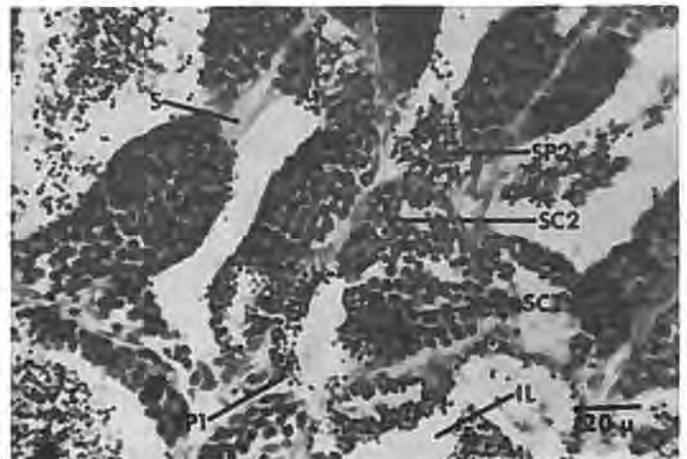


Fig. 6. Transverse section of testis of male *Ellassoma zonatum* collected 4 April 1980, stained with Kernechtrot-Fast Green FCF. 450 X. Abbreviations as in Fig. 5.

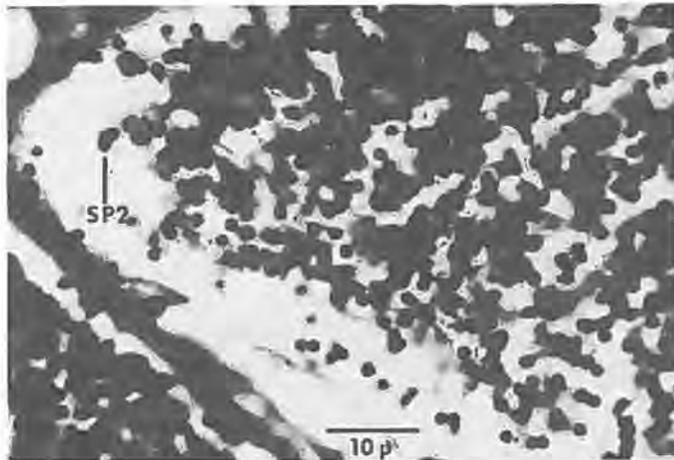


Fig. 7. Enlargement of mature spermatozoa (SP2) from testis of male *Elasmoma zonatum* collected 25 April 1980, stained with Heidenhain's iron hematoxylin. 1000 X.

evergladei. Contrary to the observations of Taber (1964), males fed actively within the confines of their territories (see also Rubenstein 1981a,b).

Female Reproductive Cycle.—Judged by gross appearance of ovaries, gradual enlargement of the abdomen, and increase in the GSI, females began to prepare for spawning from late February to March. All females examined were sexually mature by early spring and probably would have spawned at about one year of age. In 1980, heavily gravid females were collected from 20 March to 25 April. Spawning in 1979, as judged from specimens collected on 9 March, probably occurred one-to-two weeks earlier than in 1980.

The genital papilla of breeding females was only slightly swollen when compared to the papilla in non-breeding specimens.

Seasonal variation in ovarian development.—The ovaries were elongate and fused posteriorly, with the left ovary being wider, shorter, and more lobulate-shaped than the right. Ovaries of specimens taken from August to December appeared whitish and contained many small oocytes of varying sizes. Gradual enlargement of the ovaries occurred throughout the autumn and winter months until February and March when they became swollen and opaque, resulting in marked distention of the abdomen. Ovarian growth was slowest from September to December (Fig. 9). By mid-to-late March, light yellow ovaries were visible externally as they pressed against the peritoneum. For 96 females examined, the relationship between GSI (Y) and the month of collection (X), with August = 1 and April = 9, was $\text{Log } Y = 0.557 + 0.184 X$, with $r = 0.967$. The proportionally largest ovaries (equalling 19.6% of the adjusted body weight) were found in a 12-month-old female 24.6 mm SL. A 23-month-old female (31.0 mm SL) had ovaries equalling 17.2% of the adjusted body weight. The ovary weight as

a percentage of adjusted body weight of ripe females between 19.2–31.5 mm SL taken during March and April ranged from 10.2–19.6% and averaged 14.1% (N = 28).

For females from combined monthly samples, significant positive correlations were found between ovarian weight and SL and between ovarian weight and adjusted body weight. The relationship between ovarian weight in milligrams (Z) and adjusted body weight in milligrams (W) for 105 females was $Z = -25.657 + 0.178 W$, with $r = 0.894$. The relationship between ovarian weight in milligrams and standard length for the same females was curvilinear, and was best depicted by the equation $Z = 135.313 - 16.429 \text{ SL} + 0.502 \text{ SL}^2$, with $r = 0.836$ (Fig. 10). Hence, ovarian weight increased proportionally with larger adult size, although the ratio of ovarian weight to body weight varied seasonally and was greatest in March and April.

Ovaries of mature females taken throughout the breeding season usually had three distinct classes of oocytes. Small, whitish oocytes in varying stages of maturation and vitellogenesis were the most numerous and ranged in diameter from less than 0.10 mm to 0.74 mm. Oocytes less than 0.40 mm were not counted, but those between 0.40–0.74 mm averaged 0.50 mm (N = 190). Intermediate-sized oocytes in the middle stages of vitellogenesis appeared opaque white with light-yellow yolk globules concentrated near the center, and ranged in diameter from 0.48–0.86 mm ($\bar{x} = 0.64$ mm; N = 186). Large, mature, yolk-laden oocytes were reticulated in appearance, were usually loosely attached to the interstitial tissue and were dark yellow or amber in color. Mature oocytes were present only in specimens taken in late March and early-to-mid April, and ranged in diameter from 0.60–1.05 mm ($\bar{x} = 0.79$ mm; N = 150). Yolk diameters of mature oocytes ranged from 0.34–0.64 mm ($\bar{x} = 0.51$ mm; N = 75). Females taken as early as 20 March 1980 had swollen, amber ovaries but lacked oocytes in the late stages of vitellogenesis, while the ovaries of females col-

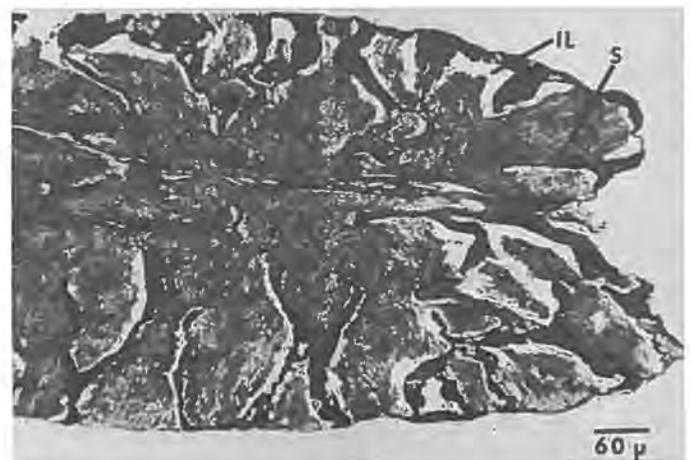


Fig. 8. Longitudinal section of testes of male *Elasmoma zonatum* collected 25 April 1980, stained with Bromophenol Blue. 100 X. Abbreviations as in Fig. 5.

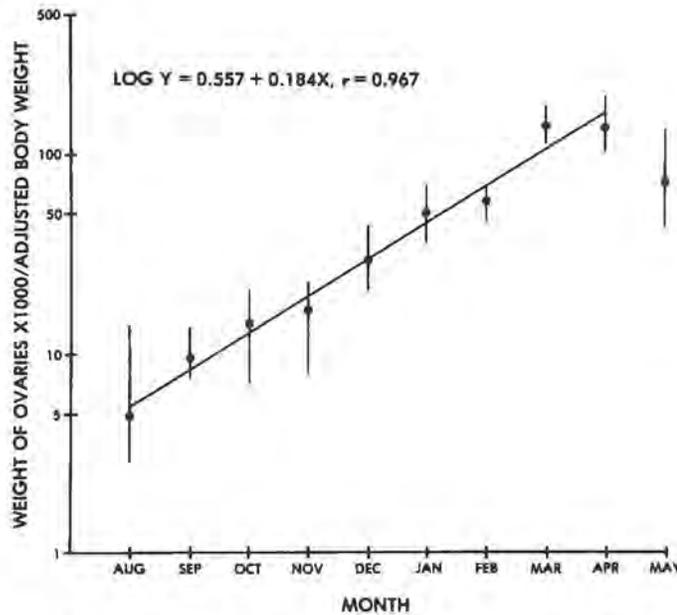


Fig. 9. Monthly variations in ovarian weight in relation to adjusted body weight for 105 *Elasmoma zonatum* females between 4 and 25 months of age. Solid circles represent sample means; vertical lines represent ranges of monthly samples. Regression line does not include 9 specimens collected in May. The ordinate is a logarithmic scale.

lected 20 May 1980 were devoid of mature oocytes and contained atretic, intermediate-sized oocytes.

Fecundity.—Published fecundity estimates, apparently expressed as single clutch sizes, have ranged from 2–68 (Barney and Anson 1920, Mettee 1974, Poyser 1919, Taber 1964). On the basis of an examination of preserved specimens, Barney and Anson (1920) gave a fecundity range of 96–970 ova, but apparently included immature oocytes that, at least at more northern latitudes, probably would not be spawned in a single breeding season. Pflieger (1975) gave an average fecundity estimate of about 300 eggs per female, a conclusion that was apparently based on the mean number of eggs from 12 females reported by Barney and Anson (1920). In captive specimens taken from Mayfield Creek swamp, clutch sizes per female markedly decreased with successive spawnings; Taber (1964) observed a similar phenomenon.

Small oocytes (less than 0.40 mm) were assumed not to contribute to fecundity in a single breeding season and were not included in counts. Counts of oocytes from breeding females (Table 3) undoubtedly included some counts from partially spent females. Variations in the total number of oocytes and in the number of mature and intermediate oocytes per gram of body weight are due, in part, to individual variation in fecundity, size differences of the females examined, and to some specimens having been partially spent when collected. Because the most mature oocytes could be spawned in a relatively short time, followed by the maturation of smaller oocytes, the most conservative

estimate of fecundity was considered to include the intermediate-sized oocytes (i.e., those in the middle stages of vitellogenesis and averaging 0.64 mm in diameter). The combined number of mature and intermediate oocytes per female collected between 20 March–20 May 1980 ranged from 43–255 and averaged 144.9 ($N = 16$; Table 3). For the same specimens, the total number of oocytes greater than 0.40 mm ranged from 350–797 and averaged 537.1 per female. An average-sized one-year-old female (22.7 mm SL) would probably spawn 100–200 eggs over a period of less than one month at the latitude of western Kentucky.

No significant ($\alpha = 0.10$) correlation was found between the number of oocytes potentially available for spawning (i.e., the combined number of mature and intermediate oocytes) and standard length, nor between the number of oocytes and adjusted body weight. Burr and Page (1978, 1979) also found no correlation in the small darters of the subgenus *Microperca* and attributed it to the facts that individuals of about the same size spawn only once (at one year of age), and that some specimens were partially spent when collected (see also Page 1980). In *E. zonatum* most females were also about the same size at spawning, and spawning of multiple clutches occurred over an extended period.

Significant ($\alpha = 0.05$) positive correlations were found between the total number of oocytes (> 0.40 mm) and standard length, and between the total number of oocytes and adjusted body weight. The least squares regression of total number of oocytes (Q) on standard length was $Q = -220.78 + 31.71 SL$, with $r = 0.654$. The relationship between number of oocytes and adjusted body weight in milligrams (W) was $Q = 263.97 + 0.78 W$, with $r = 0.683$. The relatively low correlation coefficients were due to small sample sizes that included partially spent females and specimens of about the same size.

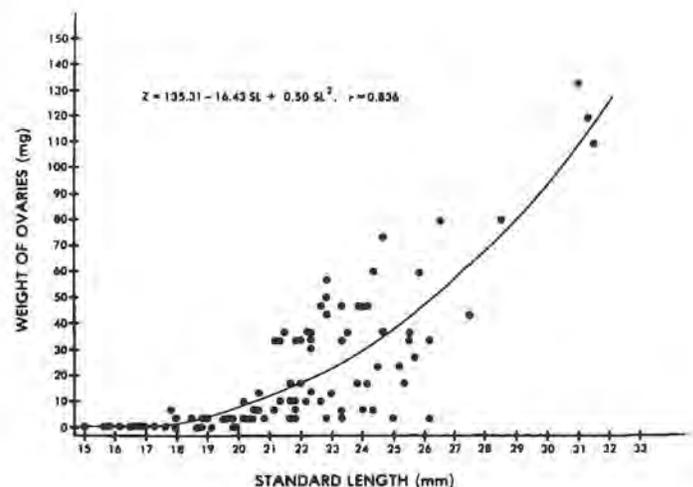


Fig. 10. Relationship between weight of ovaries and standard length in 105 *Elasmoma zonatum* females between 4 and 25 months of age.

Courtship and Spawning.—Most previous accounts of the spawning behavior of *E. zonatum* in aquaria were summarized by Mettee (1974), who also presented original supporting evidence that members of the genus are not nest builders. Not included in his summary was Taber's (1964) description of spawning, which also documented that the species does not construct a nest. Spawning behavior of captive specimens taken from Mayfield Creek swamp on 4 April 1980, 28 March 1981, and from southern Illinois (Union Co., Wolf Lake, 20 March 1981), was similar to previous accounts (e.g., Branson 1974, Mettee 1974, Poyser 1919, Taber 1964). Spawning always occurred in or above submerged vegetation, and there was no attempt to construct a nest.

When a receptive female entered a male's territory, he initiated the distinctive courtship behavior (Branson 1974, Mettee 1974, Miller 1964, Poyser 1919, Taber 1964). The courtship movements of the male, termed the "wiggle waggle" display by Miller (1964), consisted of fin erection, pelvic fins alternately erected in the sagittal plane, bobbing, and lateral fin and body undulations, accompanied by rapid darkening of the head, body, and fins. Some aspects of the courtship display, particularly semaphoric fin movements, occur in other social behaviors of males (Miller 1964, Rubenstein 1981a,b). The characteristic bobbing behavior of males toward females is restricted to reproductive behavior (Rubenstein 1981a). The courtship display was initially performed with the male stationary in the water column. When a female was attracted to a displaying male, the male coaxed the female by moving toward the vegetation, often turning back toward the female while continually exhibiting the courtship display. When the pair reached the

spawning site selected by the male, the female repeatedly moved about in the vegetation until a stationary position was maintained. The male then began to vibrate his entire body and fins rapidly and positioned himself parallel to the female while nudging the female near the vent and vibrating his head against her belly. Ova were expelled in short, rapid bursts as the male, remaining in an upright position, apposed his genital papilla near that of the female and released milt. The demersal, adhesive ova attached to the vegetation. Clutch sizes of spawned eggs by captive females between 24 March–12 April 1981 ranged from 6–76 and averaged 37.9 ($N = 11$). Immediately following spawning, the female swam away or was chased from the territory by the male, who then remained near the vegetation and defended the developing embryos for up to 48 hrs if they were not removed. Both parents have been reported to guard eggs in *E. evergladei* (Axelrod and Shaw 1967, Robison 1971), but not in *E. zonatum*. Females are involved in fewer aggressive encounters than males (Rubenstein 1981a), and biparental guarding of fertilized eggs is considered an uncommon event.

Spawning activity in laboratory-maintained specimens was usually highest between 0600–1000 hrs but was observed as late as 1900 hr. Branson (1974) and Taber (1964) also found that spawning was most intense in early morning, gradually decreased in the afternoon, and ceased during the night.

Partially spent females spawned repeatedly with the same or different males at intervals of several hours to several days, with clutch sizes diminishing with successive spawns. Three successive clutches of one female, spawned over a four day period, numbered 63, 15, and 6. Barney and Anson (1920) reported that clutches were spawned at intervals of about one week. However, our observations resembled those

Table 3. Characteristics of breeding females of *Elassoma zonatum* from Mayfield Creek swamp taken during 1980.

Date of collection	Age in Months	SL (mm)	Adjusted body weight (mg)	Weight of ovaries (mg)	GSI*	Total number of mature and intermediate oocytes	Total number of oocytes (> 0.40 mm)	Number of mature and intermediate oocytes per g body weight
20 March	11	22.0	279.6	34.3	122.7	110	556	393.4
20 March	11	23.4	286.7	33.3	116.1	43	524	150.0
20 March	11	24.1	360.7	46.5	128.9	120	553	332.7
4 April	12	21.4	254.3	—	—	140	489	550.5
4 April	12	21.4	238.2	33.7	141.5	119	407	499.6
4 April	12	22.8	336.5	55.1	163.7	156	502	463.6
4 April	12	23.3	319.8	46.7	146.0	146	475	456.5
4 April	12	23.9	334.7	47.1	140.7	162	618	484.0
4 April	12	24.6	380.5	74.6	196.1	255	797	670.1
4 April	12	25.9	406.0	59.6	146.8	176	529	433.5
4 April	24	28.5	572.5	78.4	136.9	139	742	242.8
25 April	12	19.2	193.1	—	—	118	350	611.1
25 April	12	21.1	235.9	33.8	143.3	136	379	576.5
25 April	12	25.5	340.9	37.2	109.1	152	484	445.8
25 April	24	27.8	547.6	—	—	177	725	323.2
20 May	25	27.5	507.9	44.0	86.6	169	463	332.7

*GSI equals weight of ovaries (mg) X 1000 divided by adjusted body weight (mg).

of Shortt (1956) for *E. okefenokee* and Nachstedt and Tuschke (1954) for *E. evergladei*, in that individual females spawned at more frequent intervals.

Water temperatures at which *E. zonatum* have bred in captivity range from 21.6–23.3° C (Poyser 1919, Taber 1964). Estimates of water temperatures at which spawning occurred in nature are limited to those published by Barney and Anson (1920), although they apparently never observed spawning; they collected gravid specimens from water that was 16.7–20° C, but did not find ripe specimens in an area having a surface mat of vegetation and a water temperature of 13.9° C.

At Mayfield Creek swamp, gravid specimens were taken in early-to-mid April 1980 from water 12.0–16.0° C. On 28 March 1981, several gravid specimens were removed from swamp water 14.5° C and transported to the laboratory where spawning took place at 23° C. Gravid specimens collected in water 11° C (Illinois: Union Co., Wolf Lake, 20 March 1981) spawned 1–4 days later at aquaria temperatures ranging from 21–24° C. The onset of spawning seems to be less limited by lower temperatures than the cessation of breeding is accelerated by higher temperatures. By 26 May 1980, when most females were spent, water temperature in the swamp was 27° C. Shortt (1956) found that spawning in *E. okefenokee* occurred at temperatures as low as 15.6° C. In *E. zonatum* from Mayfield Creek swamp, the cessation of breeding in mid-to-late May 1980 corresponded to a marked increase in water temperature.

Polyandry.—Only one incidence of polyandry, the mating of more than one male with a female in a single spawning, has been reported for *Elassoma* (Poyser 1919). We observed two males spawning or attempting to spawn with the same female on five occasions. The high occurrence of polyandry observed was probably related to a high density of subordinate males not defending territories.

The courtship behavior of a dominant male toward a female attracted a nearby male to the spawning site. When the female did not retreat from the vegetation, both males displayed courtship movements and showed little agonistic behavior toward each other. Spawning usually occurred while the female was flanked on both sides by a male. Immediately after spawning, the female and the subordinate male fled or were chased from the territory by the defending male. Poyser (1919) observed two males guarding the same clutch for several hours after polyandrous spawning.

Sexual Dimorphism.—In addition to sexual dimorphism in reproductive behavior and coloration discussed elsewhere, 10 meristic and 18 morphometric characteristics were tested (t-test; $\alpha = 0.05$) in 100 specimens from Mayfield Creek swamp. Three of these 28 characteristics were found to be sexually dimorphic: males had proportionally longer pelvic and anal fins and females had a significantly greater vent to pelvic fin base length. Expressed as a percentage of stan-

dard length, the mean pelvic fin length of males was 22.2 (range, 17.5–29.3) and the mean anal fin length was 19.2 (range, 15.0–22.6). For females, pelvic fin length averaged 20.2 (range, 17.1–23.3) and anal fin length averaged 17.8 (range, 15.2–20.7). The vent to pelvic fin base length as a percentage of SL averaged 18.8 (range, 16.1–21.4) in females and 17.5 (range, 15.8–20.3) in males. Although not measured in this study, the dorsal fin is also slightly higher in males than in females (Axelrod and Schultz 1971). Because of the degree of overlap in these values, external identification to sex is not reliable except on the basis of pigmentation, which is reliable only during the breeding season.

Development

Development was observed in embryos collected from nine spawnings of captive adults taken from Mayfield Creek swamp, and from two spawnings of specimens collected at Wolf Lake, Illinois. Development was similar to that reported by Conner (1979) and Mettee (1974), except for slight variations in developmental rates due to fluctuations in ambient water temperature. Because of temperature-dependent developmental rates, stages were based on morphological features rather than on developmental time. Terminology of larval phases follow those of Conner (1979) and Snyder (1976). Immediately after a clutch of spawned eggs was removed for culture, embryos were observed under a stereomicroscope several times a day for the first 4–5 days. Following hatching, larvae were examined once or twice a day. A high mortality of developing larvae precluded observation of most individuals beyond three weeks of age.

Age 0 hr. Unfertilized oocytes. Mature oocytes removed from preserved, gravid females were reticulated in appearance, irregularly shaped, and averaged 0.79 mm in diameter. The large yolk (0.51 mm) consisted of many small lipid globules.

Age 0–0.25 hr. Fertilized egg. Immediately following spawning, chorions of fertilized eggs began to expand due to water absorption. Spawned eggs were adhesive, demersal, and non-spherical initially. The diameters of 11 freshly-spawned eggs, including chorions, averaged 1.68 mm (range, 1.4–1.8 mm). The difference between egg diameters reported here and those of 2.6–2.7 mm given by Mettee (1974) are attributed to rapid enlargement of chorion diameters from water absorption, size differences of adult females spawning eggs, or, possibly, to geographic variation in ovum diameter. One large and often several smaller oil droplets eccentrically enclosed in yolk. Expansion of chorion resulted in subchorionic space about 0.26 mm wide enveloping egg. Within 30 mins post-spawning, cytoplasmic condensation appeared at animal pole. Egg became spherical incident to water absorption and cytoplasmic rearrangement. Micropyle not observed.

Age 0.5–0.8 hr. One-cell stage. Increased cytoplasmic condensation resulted in hemispheric cytoplasmic cap at animal

pole. Yolk discernible as small, translucent-to-opaque lipid droplets scattered throughout vegetal hemisphere. Adhesiveness of chorion reduced to one or a few small areas (Mettee 1974), a condition associated with water hardening of egg membranes (Laale 1980).

Age 1.3–1.5 hr. Two-cell stage. Like other teleosts, cleavage in *E. zonatum* was discoidal and meroblastic. Two equally-sized blastomeres resulted from first vertical cleavage.

Age 2.0–2.3 hr. Four-cell stage. The second cleavage was vertical and perpendicular to first, resulting in four smaller, flattened blastomeres of similar size.

Age 2.8–3.1 hr. Eight-cell stage. The third vertical cleavages were oriented parallel to plane formed by first cleavage and perpendicular to plane formed by second cleavages. Lobulate portion of yolk reduced to small area ventral to developing cytoplasmic cap.

Age 4.2–4.6 hr. Sixteen-cell stage. A rounded morula having unevenly distributed blastomeres of similar size was formed as a result of fourth cleavage planes, which were oriented parallel to plane two and at right angles to planes one and three. Cleavages began to occur out of synchrony. Lobulate portion of yolk very reduced to missing.

Age 5.8–7.3 hr. Thirty-two to sixty-four cell stage. Un-synchronized vertical and tangential cleavages subsequent to previous stage resulted in many smaller blastomeres of equal size distributed as several cell layers. Counts of number of cells present were not made, but Mettee (1974) reported 38–56 cells in several embryos.

Age 7.8–9.3 hr. Early high blastula stage. Additional cell divisions resulted in dome-shaped blastodisc consisting of many minute cells. Diameter of chorion membrane about 2.2 mm.

Age 12.5–13.0 hr. Early gastrula stage. Flattening and expansion of blastoderm over yolk. Epiboly characterized by thickened germ ring at margin of blastodisc evenly enveloping about one-half of yolk. Rudimentary embryonic shield present.

Age 13.5–17 hr. Late gastrula stage. Continued expansion of blastoderm over yolk resulted in large blastopore encircling yolk plug. Axial involution completed and embryonic keel formed from convergence of neural ectoderm at midline.

Age 19–22 hr. Neurula stage. Blastopore closure completed. Embryonic shield visible in frontal view as thickened cord of cells. Neural groove faintly visible (50 X).

Age 24–30 hr. Tail bud stage. Optic placodes developed on sides of head. Development of mesencephalon apparent as bulge above and slightly behind optic placodes. Rhombencephalon evident as slight swelling immediately posterior to mesencephalon. Notochord and 2–6 somites visible dorsally. Oil droplet located immediately beneath tail bud at posterior edge of yolk sac.

Age 30–32 hr. Little change from previous stage. 8–10 somites present. Notochord, mesencephalon, and optic

placodes more pronounced. Continuous caudal fin fold began to develop on dorsal, ventral, and posterior edge of tail bud.

Age 36–40 hr. 12–16 somites present. Translucent lens developed in each eye. Otic vesicles formed posterior to eyes. Ventricle of mesencephalon distinct. Absorption of yolk into oblong sac about 1/3 to 1/2 original size, with rudimentary pericardial cavity formed as slight depression in yolk sac ventral and posterior to eyes. Posterior somites began to form myomeres. Tail with distinct fin fold began to detach from yolk posteriorly. Large melanophores randomly scattered on yolk sac and tail bud.

Age 42–49 hr. 18–22 somites present. Notochord very pronounced, extending from just anterior to otic vesicles to tip of tail bud. Choroid fissure in posteroventral area of eye. Greater number of melanophores scattered randomly about on head and tail bud, with heavier concentration on yolk sac.

Age 52–70 hr. 24–27 somites present, divided medially by lateral groove. Caudal fin fold detached ventrally from surface of yolk sac formed sub-caudal fold. Antero-lateral flexion of trunk and tail resulted in tip of caudal fin fold in close proximity to head, while embryo maintained dorsal position on top of yolk. Occasional to frequent contractions of embryo. Weak pulsations of bulbus arteriosus ranged from 54–120 beats per min (\bar{x} = 87.2; N = 8). Clear blood (light pink in later stages) traced through vitelline blood vessels, head vessels, through dorsal and ventral lateral trunk vessels, and in vessels between trunk myomeres. Increased pigmentation along developing vertebral column and surface of head. Longitudinal diameter of yolk sac about 1.3 mm.

Age 70–96 hr. Maximum development of embryo prior to hatching. Prosencephalon, mesencephalon, and rhombencephalon distinct. Lateral ventricles, third ventricle, and fourth ventricle of brain differentiated. Heartbeat increased to mean of 109.6 beats per min (range, 86–134; N = 11). Contractions of sinus venosus followed by ventricular contractions. Circulation of light red blood traced through major vessels of head, trunk, and yolk sac. Dorsal aorta, subintestinal veins, and cardinal veins discernible. Gut differentiated posteriorly as narrow tube opening into vent. Continuous fin fold extended dorsally from behind head around tail to vent. Pectoral fin buds present ventro-lateral to and slightly behind otic vesicles. Increased pigmentation along trunk and dorsal surface of head.

Age 97–116 hr (Fig. 11). Hatching stage. Frequent flexion and torsion of embryo resulted in eventual rupture of chorion by tail. Continued spasmodic movements freed embryo of chorion. Lengths of newly hatched protolarvae ranged from 3.0–3.6 mm TL (\bar{x} = 3.23 mm; N = 26). Mettee (1974) reported a mean length of 3.22 mm TL for 15 hatchlings of *E. zonatum*. At hatching, the heartbeats of protolarvae ranged from 114–143 beats per min (\bar{x} = 124.4; N = 10). Mettee (1974) reported a heartbeat of 134–136 beats per min for recently hatched protolarvae. Discrepancies between these results and those of Mettee (1974) are at-

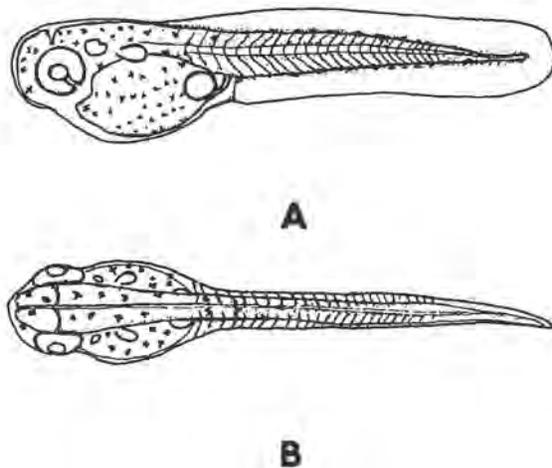


Fig. 11. Recently hatched (100 hr) protolarva of *Elassoma zonatum*, 3.4 mm TL. A) Lateral view. B) Dorsal view.

tributed to individual variation and to possible differences in water temperatures at which larvae were maintained.

Age 1 day. Protolarvae inactive unless disturbed. Most hatchlings rested on sides on bottom of culture dish. Occasional, erratic, rapid movement through water column by undulating entire body. Lengths of protolarvae averaged 3.48 mm TL (range, 3.0–3.8 mm; $N = 23$). Yolk diminished in size to about 1 mm in length. Oil droplet located at posterior edge of yolk sac. Pectoral fin buds postero-lateral to head lacking ray primordia. About 27 myomeres counted in most specimens to a maximum of 31 in one individual. Eyes translucent to lightly pigmented and with distinct choroid fissure. Mouth undeveloped. Posterior gastrointestinal duct and anus differentiated.

Age 2–4 days. Protolarvae slightly more active. Hatchlings occasionally maintained dorsal position over yolk for short periods by rapidly vibrating pectoral fin buds. Gradual development of mouth, opercula, eye pigmentation, and pectoral fins. Four gill arches visible dorsally. Increased contractions of opercula and mouth. Gradual pigmentation of eye proceeded with spectacle and iris first, followed by darkening of lens. Taber (1964) presented morphological description of eye development in *E. zonatum*. By day 4, mean lengths of protolarvae 3.65 mm TL (range, 3.1–4.0 mm; $N = 34$). Mean heartbeat increased to 135.4 beats per min (range, 115–150; $N = 10$).

Age 5–7 days. (Fig. 12). Yolk in most protolarvae nearly or completely resorbed by 6 or 7 days. Prominent pyramid-shaped oil droplet present immediately anterior to anus. Concurrent with yolk resorption, protolarvae begins active feeding on *Artemia* nauplii. Most protolarvae remained upright by rapidly vibrating transparent pectoral fins, although movement through water column was infrequent. Regions of brain well differentiated; cerebrum, optic lobes, cerebellum, and medulla oblongata prominent. Eye pigmentation dark black and iridescent blue; choroid fissure not discernible. Lateral eye movements well coordinated. Jaw structure well formed. Branchiostegals and external nares

visible. Liver apparent as light yellow-green structure posterior to heart and dorsal to gut. Pigmentation in postero-dorsal regions of coelomic cavity marked paired opisthonephric kidneys. Large melanophores concentrated over head and venter. Lighter concentrations of pigment along trunk and dorsal and ventral proximal areas of continuous fin fold. Twelve 6-day-old protolarvae averaged 3.66 mm TL (range, 3.2–3.9 mm).

Age 8–12 days. At 10 days post-hatching, individuals averaged 4.40 mm TL (range, 3.7–4.8 mm; $N = 10$). Most protolarvae did not develop beyond this time due to an abnormally high mortality rate, attributed to starvation and saline toxicity incident to feeding with *Artemia*. Mettee (1974) reported a larval mortality rate in *E. zonatum* of 40–45% for specimens in the first week after hatching. Few morphological changes from previous stage. No fin ray primordia present.

Age 14–16 days. Transition of protolarva to mesolarva. Few morphological changes from prior stage. Three 14-day-old individuals averaged 4.80 mm TL (range, 4.6–5.1 mm). Five 16-day-old individuals increased in mean length to 4.96 mm TL (range, 4.6–5.6 mm). At about day 16, the tip of the caudal fin fold and posterior end of the notochord and vertebral column flexed upward forming a temporary heterocercal tail, followed by the sequential appearance of rudimentary caudal fin rays from the ventral to dorsal margins.

After 16 days (Figs. 13 and 14), larvae underwent few major morphological changes except for fin development, increase in pigmentation, changes in body proportions, and development of scales. Pelvic fin buds were first observed in specimens about 23 days old. Although pelvic fin ray development was not observed, Mettee (1974) found that development of the pelvic rays preceded the appearance of the single pelvic spine. Dorsal and anal fin ray primordia were first observed in two specimens about 27 days old (Fig. 13). Dorsal and anal fin elements developed from posterior

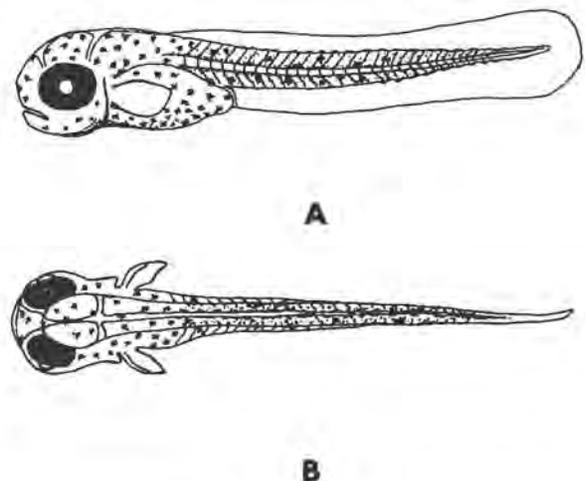


Fig. 12. Late protolarva of *Elassoma zonatum* 6 days posthatching, 3.8 mm TL. A) Lateral view. B) Dorsal view.

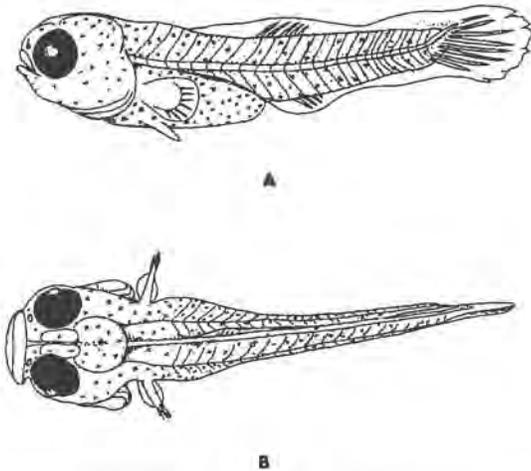


Fig. 13. Early mesolarva of *Elassoma zonatum* 31 days posthatching, 5.8 mm TL. A) Lateral view. B) Dorsal view.

to anterior. By about 40 days post-hatching, the continuous fin fold remnant between the caudal fin and the dorsal and anal fins had disappeared. Pigmentation of larvae gradually increased with age. However, observations ended before any individuals developed the adult squamation or pigmentation pattern.

Diet

Elassoma zonatum is an opportunistic, carnivorous feeder, consuming small invertebrates from all levels of the water column. The diet consisted primarily of small entomostracan crustaceans and aquatic insects, particularly dipteran larvae, as first noted by Barney and Anson (1920). Individuals eat only moving prey, as evidenced by their refusal to eat prepared or dried foods in captivity. Catching of prey occurs with a lateral movement of the head (Poyser 1919, Rubenstein 1981a).

Small crustaceans, mollusks, and aquatic insects made up over 99% of the combined diets of 362 specimens examined (Tables 4-6). Cyclopoid copepods (36.2%) and cladocerans (39.4%) were the most frequently consumed prey. Ostracods (10.2%), amphipods (3.0%), and isopods of the genus *Asellus* (3.1%) were eaten less frequently. Chironomid and ceratopogonid larvae (3.9%) and mayfly naiids (0.7%) were the most frequently consumed aquatic insects. Small snails and clams made up 1.1% of the diet. Rarely eaten organisms included nematodes, oligochaetes, turbellarians, and collembolans. The presence of adult mosquitos and springtails in the diet indicates that *E. zonatum*

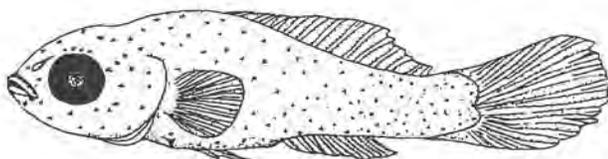


Fig. 14. Late metalarva of *Elassoma zonatum*, 9.0 mm TL, collected from Mayfield Creek swamp 26 May 1980.

may occasionally feed at the water's surface. Algal strands, detritus, and other plant matter found in 5.5% of the stomachs examined were surely accidentally ingested.

There was no significant difference in the types of foods consumed by males and females. Juveniles fed on the same types of organisms as adults, but preferred smaller items such as copepod nauplii, rotifers, and small ostracods.

Seasonal variation in diet (Tables 4-6) was probably due to seasonal fluctuations in the invertebrate fauna. Cladocerans, amphipods, and chironomids were consumed in greatest quantities during the spring, summer and autumn months (Tables 4-6). Ostracods were eaten in largest numbers from November to March. Copepods were consumed in large quantities throughout the year except during the hot summer months (Tables 4-6). Immature mayflies were eaten most frequently from June to October.

The diet of *E. zonatum* in southern Illinois (Gunning and Lewis 1955), in Louisiana (Barney and Anson 1920) and in Reelfoot Lake, Tennessee (Rice 1942) was similar to that of the western Kentucky population. Food taxa reported by Barney and Anson (1920), but not found during this study, were aquatic beetles and soldier fly larvae.

Feeding Periodicity.—Diel feeding activity, as estimated from the mean number of food items per stomach and the index of feeding activity, occurred from dawn to dusk. Immediately prior to sunrise, feeding began until it reached a peak at 0800 hr, after which time it dropped precipitously and then rose to another peak at 1200 hr (Table 7; Fig. 15). Feeding remained high throughout the afternoon and early evening, with only a gradual decline from 1200 hr to dusk, followed by a sharp fall from about 1800 hr until dawn.

Feeding activity, as measured by the percent of stomachs containing food items, corresponded to an increase in water

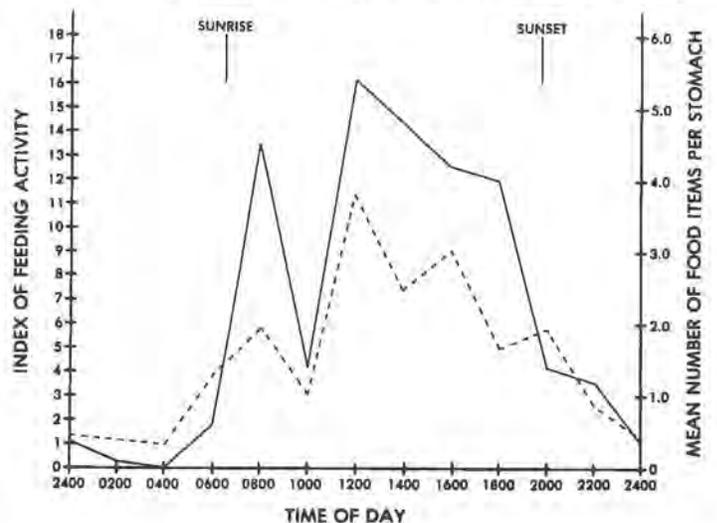


Fig. 15. Feeding periodicity in *Elassoma zonatum* expressed as index of feeding activity and as mean number of food items per stomach. Solid line indicates index of feeding activity; hatched line indicates mean number of food items per stomach. Lines determined from means for each sampling period.

Table 4. Stomach contents of *Elassoma zonatum* from Mayfield Creek swamp, by month of collection. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Monthly Diet that Each Food Organism Comprised											
	Jan (30)	Feb (30)	Mar (32)	Apr (47)	May (14)	Jun (30)	Jul (30)	Aug (30)	Sep (30)	Oct (29)	Nov (30)	Dec (30)
Platyhelminthes												
Turbellaria												
<i>Dugesia</i>	—	—	—	—	—	—	—	—	0.7	—	—	—
Nematoda	—	0.5	0.4	—	—	—	—	—	3.4	—	—	—
Annelida												
Oligochaeta	0.4	1.0	0.4	0.1	—	—	—	—	—	—	0.4	—
Crustacea												
Cladocera	12.2	6.8	22.8	49.4	27.6	69.8	57.6	46.9	13.6	49.1	13.2	22.3
Ostracoda	28.2	18.8	12.4	5.8	4.5	3.6	3.0	9.0	8.1	8.0	17.4	14.4
Copepoda	50.0	60.4	46.8	35.4	37.2	13.0	15.2	6.3	49.6	28.8	54.5	49.5
Isopoda	3.0	—	2.4	4.3	9.0	0.7	3.0	—	2.7	0.4	2.1	2.1
Amphipoda	3.0	9.7	8.9	1.7	7.0	5.8	3.0	5.4	0.7	0.9	2.1	2.1
Unidentified	—	—	—	—	—	—	—	—	0.7	—	—	0.5
Mollusca												
Pelecypoda	—	—	0.4	0.2	—	—	—	—	0.7	0.9	—	0.5
Gastropoda												
Physidae	—	0.5	—	0.3	—	—	1.0	—	—	1.3	0.9	—
Lymnaeidae	—	—	—	—	2.6	—	—	—	—	—	—	—
Planorbidae	0.8	0.9	—	0.3	1.3	—	1.0	—	0.7	—	0.4	—
Ancyliidae	0.4	—	0.2	—	—	—	—	—	—	—	—	—
Insecta												
Collembola	0.4	—	0.2	—	—	—	—	0.9	2.0	—	—	2.1
Plecoptera	—	—	—	0.1	—	—	—	—	—	0.4	—	1.6
Ephemeroptera	0.4	—	—	0.3	—	1.4	4.0	3.6	1.4	3.0	0.4	1.1
Odonata												
Anisoptera	—	—	—	0.1	—	—	—	1.8	—	—	—	0.5
Zygoptera	—	—	—	—	—	0.7	—	0.9	0.7	—	—	—
Trichoptera	—	—	0.4	—	—	—	—	—	0.7	—	—	—
Megaloptera	—	—	—	—	0.6	—	—	—	—	—	—	—
Diptera												
Chironomidae	0.4	1.4	3.9	1.0	9.0	2.9	6.1	18.9	10.9	4.7	3.0	2.1
Ceratopogonidae	0.4	—	0.4	0.2	0.6	1.4	5.1	0.9	0.7	2.1	0.9	—
Culicidae	—	—	—	0.1	—	—	—	2.7	—	—	—	—
Anthomyiidae	—	—	—	—	—	—	1.0	—	—	—	—	—
Unidentified	0.4	—	—	0.1	0.6	—	—	1.8	0.7	—	0.4	—
Algae	—	—	0.4	0.6	—	0.7	—	0.9	2.0	0.4	4.3	1.2

temperature throughout the daylight hours (Fig. 16). That 80–100% of the stomachs examined between 0800–2000 hr contained food confirms that the species is a diurnal feeder. The presence of food in 40–80% of the stomachs examined from dusk to 2400 hr was probably due to a slow rate of digestion and occasional ingestion of prey after sunset. Because *E. zonatum* feeds principally by visual stimuli, nocturnal feeding would not be expected except during moonlit nights.

The diversity of food organisms consumed during the diel feeding study in August was considerably less than the diversity consumed throughout the year, and consisted primarily of cladocerans, chironomids, and copepods (Table 7). The reduced diversity is attributed to the small sample size of

specimens examined. Generalizations concerning daily fluctuations in the types of food organisms consumed are treated with caution because of the small sample size. Cladocerans were eaten throughout the daylight and early evening hours, but were taken at the highest frequency from 1200–1600 hr. Consumption of ostracods and amphipods was greatest in the morning and evening (0600–1000 hr, and 1800–2000 hr, respectively). Copepods were not eaten during the morning and made up a higher proportion of the diet from 2000–2200 hr than during the rest of the day. Chironomids were taken in the greatest quantity from 0800–1000 hr and from 1600–1800 hr. Isopods and collembolans were ingested only during the night. Prey of the remaining taxa were consumed so sporadically that no trend was evident.

Table 5. Stomach contents of *Elassoma zonatum* from Mayfield Creek swamp, by month of collection. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs Containing Food Organism											
	Jan (30)	Feb (30)	Mar (32)	Apr (47)	May (14)	Jun (30)	Jul (30)	Aug (30)	Sep (30)	Oct (29)	Nov (30)	Dec (30)
Platyhelminthes												
Turbellaria												
<i>Dugesia</i>	—	—	—	—	—	—	—	—	3.3	—	—	—
Nematoda	—	3.3	6.2	—	—	—	—	—	6.7	—	—	—
Annelida												
Oligochaeta	3.3	3.3	3.1	2.1	—	—	—	—	—	—	3.3	—
Crustacea												
Cladocera	50.0	33.3	81.3	95.7	64.3	83.3	70.0	56.7	50.0	82.8	60.0	60.0
Ostracoda	66.7	60.0	62.5	57.4	21.4	13.3	6.7	23.3	30.0	55.2	56.7	73.3
Copepoda	93.3	83.3	100.0	95.7	71.4	43.3	36.7	23.3	56.7	89.7	80.0	73.3
Isopoda	20.0	—	21.9	55.3	57.1	3.3	3.3	—	10.0	3.5	16.7	13.3
Amphipoda	20.0	43.3	71.9	40.4	42.9	23.3	10.0	20.0	3.3	6.9	16.7	10.0
Unidentified	—	—	—	—	—	—	—	—	3.3	—	—	3.3
Mollusca												
Pelecypoda	—	—	6.3	4.3	—	—	—	—	3.3	6.9	—	3.3
Gastropoda												
Physidae	—	3.3	—	2.1	—	—	3.3	—	—	10.3	6.7	—
Lymnaeidae	—	—	—	—	14.3	—	—	—	—	—	—	—
Planorbidae	6.7	6.7	—	6.4	7.1	—	3.3	—	3.3	—	3.3	—
Ancylidae	3.3	—	3.1	—	—	—	—	—	—	—	—	—
Insecta												
Collembola	3.3	—	3.1	—	—	—	—	3.3	6.7	—	—	13.3
Plecoptera	—	—	—	2.1	—	—	—	—	—	3.4	—	10.0
Ephemeroptera	3.3	—	—	8.5	—	6.7	13.3	13.3	6.7	24.1	3.3	6.7
Odonata												
Anisoptera	—	—	—	2.1	—	—	—	6.7	—	—	—	3.3
Zygoptera	—	—	—	—	—	3.3	—	3.3	3.3	—	—	—
Trichoptera	—	—	6.3	—	—	—	—	—	3.3	—	—	—
Megaloptera	—	—	—	—	7.1	—	—	—	—	—	—	—
Diptera												
Chironomidae	3.3	10.0	40.6	21.3	35.7	13.3	16.7	3.3	33.3	34.5	16.7	13.3
Ceratopogonidae	3.3	—	6.3	6.4	7.1	6.7	13.3	3.3	3.3	6.9	6.7	—
Culicidae	—	—	—	2.1	—	—	—	6.7	—	—	—	—
Anthomyiidae	—	—	—	—	—	—	3.3	—	—	—	—	—
Unidentified	3.3	—	—	2.1	7.1	—	—	6.7	3.3	—	3.3	—
Algae	—	—	6.3	17.0	—	3.3	—	3.3	10.0	3.4	10.0	6.7

Demography

Density.—Estimates of densities of *E. zonatum* made on three separate occasions at Mayfield Creek swamp ranged from a low of 3.8 fish/m³ in October to a high of 30.4 fish/m³ in June, and an intermediate density of 11.5 fish/m³ in February. The area sampled on 4 June 1980 appeared to be a nursery, with young-of-the-year composing 96.7% of the total number of *E. zonatum* collected. The nursery area was about 60 cm deep with thick growths of submergent vegetation, particularly *Polygonum*, and had undercut banks and a muddy bottom. Other species collected in the nursery area were *Lepomis symmetricus* (0.8 fish/m³), *L. macrochirus* (0.4 fish/m³), *L. gulosus* (0.6

fish/m³), *Ictalurus natalis* (0.2 fish/m³), *Aphredoderus sayanus* (0.8 fish/m³, and *Esox americanus* (0.2 fish/m³). The low density of *E. zonatum* on 11 October 1980 was perhaps due to mortality of older fish during the summer months, water level fluctuations, wide dispersal of individuals, and possible sampling inconsistency.

Composition.—Of the 555 specimens collected between 9 March 1979 and 11 October 1980, 94.9% were up to one year of age, 4.7% were over one and up to two-years old, and 0.4% were greater than two years old.

Males predominated slightly in the young-of-the-year (-1) age class with a ratio of 1 male to 0.94 females; in the 1 +

Table 6. Stomach contents of *Elassoma zonatum* from Mayfield Creek swamp, by month of collection. Figures in parentheses are numbers of stomachs examined.

Food Organism	Mean Number of Food Organisms Per Stomach											
	Jan (30)	Feb (30)	Mar (32)	Apr (47)	May (14)	Jun (30)	Jul (30)	Aug (30)	Sep (30)	Oct (29)	Nov (30)	Dec (30)
Platyhelminthes												
Turbellaria												
<i>Dugesia</i>	—	—	—	—	—	—	—	—	1.00	—	—	—
Nematoda	—	1.00	1.00	—	—	—	—	—	2.50	—	—	—
Annelida												
Oligochaeta	1.00	2.00	2.00	1.00	—	—	—	—	—	—	1.00	—
Crustacea												
Cladocera	1.93	1.40	4.12	15.76	4.78	3.88	2.71	3.65	1.33	4.83	1.61	2.33
Ostracoda	3.35	2.17	2.90	2.96	2.33	1.25	1.50	1.43	1.33	1.19	2.41	1.73
Copepoda	4.25	5.00	6.88	11.27	5.80	1.38	1.36	1.00	4.29	2.62	5.33	4.23
Isopoda	1.67	—	1.57	2.38	1.75	1.00	3.00	—	1.33	1.00	1.00	1.00
Amphipoda	1.67	1.54	1.83	1.32	1.86	1.14	1.00	1.00	1.00	1.00	1.00	1.33
Unidentified	—	—	—	—	—	—	—	—	1.00	—	—	1.00
Mollusca												
Pelecypoda	—	—	1.00	2.00	—	—	—	—	1.00	1.00	—	1.00
Gastropoda												
Physidae	—	1.00	—	4.00	—	—	1.00	—	—	1.00	1.00	—
Lymnaeidae	—	—	—	—	2.00	—	—	—	—	—	—	—
Planorbidae	1.00	1.00	—	1.33	2.00	—	1.00	—	1.00	—	1.00	—
Ancylidae	1.00	—	1.00	—	—	—	—	—	—	—	—	—
Insecta												
Collembola	1.00	—	1.00	—	—	—	—	—	1.50	—	—	1.00
Plecoptera	—	—	—	1.00	—	—	—	—	—	1.00	—	1.00
Ephemeroptera	1.00	—	—	1.00	—	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Odonata												
Anisoptera	—	—	—	1.00	—	—	—	1.00	—	—	—	1.00
Zygoptera	—	—	—	—	—	1.00	—	1.00	1.00	—	—	—
Trichoptera	—	—	1.00	—	—	—	—	—	1.00	—	—	—
Megaloptera	—	—	—	—	1.00	—	—	—	—	—	—	—
Diptera												
Chironomidae	1.00	1.00	1.38	1.50	2.80	1.00	1.20	2.10	1.60	1.10	1.40	1.00
Ceratomyxidae	1.00	—	1.00	1.00	1.00	1.00	1.25	1.00	1.00	2.50	1.00	—
Culicidae	—	—	—	2.00	—	—	—	1.25	—	—	—	—
Anthomyiidae	—	—	—	—	—	—	1.50	—	—	—	—	—
Unidentified	1.00	—	—	1.00	1.00	—	—	1.00	1.00	—	1.00	—
Algae	—	—	1.00	1.00	—	1.00	—	1.00	1.00	1.00	1.00	1.00

year class, females outnumbered males by a ratio of 1 female per 0.53 males. However, the slightly skewed ratios for the first two age classes were non-significant and considered the result of sampling error. Of a total of 514 individuals sexed from Mayfield Creek swamp, 50.6% were males and 49.4% were females. The observed male to female sex ratio of 1: 0.98 did not differ significantly ($\chi^2 = 0.07$; $P < 0.900$) from the expected ratio of 1:1. The monthly sex ratios of males to females ranged from a minimum of 1: 2.36 ($\chi^2 = 8.54$; $P < 0.005$) in April to a maximum of 1: 0.42 ($\chi^2 = 7.68$; $P < 0.010$) in January. The significantly skewed sex ratios observed in several months were probably the result of small sample sizes, sampling bias, or non-random disper-

sal of the sexes during certain seasons. Barney and Anson (1920) recorded a male to female sex ratio of approximately 1:2 for *E. zonatum* during March, the height of the breeding season in Louisiana. On the basis of the results of this study and those of Barney and Anson (1920), the apparent preponderance of females during early spring months is probably due to wider dispersal of males resulting from increased social aggressiveness and territory establishment.

Survival.—Relative survival values for each year class of males, females, and the total sample of specimens from Mayfield Creek swamp are presented in Table 8. Calculations were based on the assumptions that each age class was

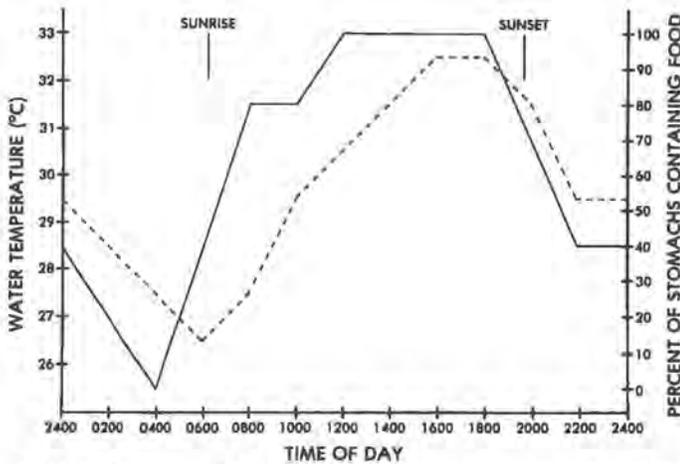


Fig. 16. Feeding periodicity in *Ellassoma zonatum* expressed as percent of stomachs containing food, and daily temperature fluctuations at Mayfield Creek swamp between 18-19 August 1980. Hatched line indicates water temperature; solid line indicates percent of stomachs with food, determined from means for each sampling period.

collected in proportion to its relative number in the population, that the number of fry entering the population was constant from year-to-year, and that the population was neither increasing nor decreasing. The shapes of survival curves for each sex and for the total sample were nearly identical (Fig. 17). Only two specimens over two years of age were collected.

Barney and Anson (1920) speculated that, following the spawning season, adults sought out deeper and inaccessible areas, accounting for the paucity of specimens over one-year-old in collections. Extensive sampling in all areas of Mayfield Creek swamp after the spawning season yielded few specimens over one-year-old. At least at more northern latitudes, it seems plausible that most adults die following their first spawning season, when slightly over one-year-old. Woodhead (1979) suggested that extensive energy depletion for reproduction in older fish is an important factor in mortality, and Miller (1979) summarized mortality patterns in small teleosts, noting that several factors including ecotype preference, predation, population densities, and reproductive expenditure resulted in few survivors beyond a single breeding season in several groups of small fishes. Wide population density fluctuations of *E. zonatum* seems to indicate that high mortality rates of mature fish are countered by high reproductive success in producing relatively large numbers of offspring.

Interactions With Other Organisms

Predation.—As potential predators, the following were preserved and later examined for evidence that they had eaten *E. zonatum*: nine *Esox americanus* (92.0–117.0 mm SL), one *Lepisosteus oculatus* (168.0 mm SL), one *Ictalurus natalis* (70.4 mm SL), one *I. melas* (71.0 mm SL), two *Aphredoderus sayanus* (47.6–50.3 mm SL), two *Centrarchus*

Table 7. Stomach contents of *Ellassoma zonatum* from Mayfield Creek swamp during diel feeding study. Figures in parentheses are numbers of stomachs examined.

Food Organism	Hourly Collections												Percent of diet that each food organism comprised	Percent of stomachs in which food organism occurred
	Percent of hourly diet that each food organism comprised													
	2400	0200	0400	0600	0800	1000	1200	1400	1600	1800	2000	2200		
	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)		
Crustacea														
Cladocera	—	—	—	33.4	22.2	14.3	77.8	75.0	47.6	45.0	28.6	16.7	48.9	38.3
Ostracoda	—	—	—	33.3	—	14.3	3.7	12.5	4.8	15.0	—	—	7.3	11.7
Copepoda	33.4	—	—	—	—	—	3.7	8.3	4.8	5.0	14.3	16.7	5.8	13.3
Isopoda	—	100.0	—	—	—	—	—	—	—	—	—	—	0.7	1.7
Amphipoda	—	—	—	33.3	11.1	—	—	—	—	—	28.6	16.7	4.4	10.0
Insecta														
Collembola	—	—	—	—	—	—	—	—	—	—	—	16.7	0.7	1.7
Ephemeroptera	—	—	—	—	5.6	14.3	3.7	—	—	—	14.3	—	2.9	6.7
Odonata														
Anisoptera	—	—	—	—	—	—	3.7	—	—	—	14.3	—	1.5	3.3
Zygoptera	—	—	—	—	—	—	—	—	4.8	—	—	—	0.7	1.7
Diptera														
Chironomidae	33.3	—	—	—	50.0	42.8	7.4	4.2	28.5	15.0	—	—	17.5	20.0
Ceratopogonidae	—	—	—	—	—	—	—	—	4.8	—	—	—	0.7	1.7
Culicidae	—	—	—	—	—	—	—	—	—	15.0	—	—	2.2	3.3
Miscellaneous	33.3	—	—	—	11.1	14.3	—	—	4.7	5.0	—	33.2	6.7	15.0

macropterus (89.5–97.5 mm SL), nine *Lepomis macrochirus* (50.0–132.0 mm SL), one *L. cyanellus* (75.9 mm SL), two *L. symmetricus* (41.2–41.6 mm SL), thirteen *L. gulosus* (36.6–134.5 mm SL), three *Pomoxis annularis* (56.3–81.0 mm SL), and two *Micropterus salmoides* (48.3–104.1 mm SL). Potential predators were examined from all months of the year except from October. The only evidence of predation upon *E. zonatum* was the presence of a female (21.8 mm SL) in the stomach of a male *L. gulosus* (86.8 mm SL) collected on 22 February 1980. Gunning and Lewis (1955) found predation upon *E. zonatum* by *L. gulosus* and by *Esox vermiculatus* (= *americanus*) in southern Illinois. Barney and Anson (1920) observed belostomatid beetles and odonate nymphs preying upon *E. zonatum*, and speculated that the well-vegetated habitat and preference for areas not occupied by many other species may preclude a higher incidence of predation upon *E. zonatum* by other fishes. In addition, the cryptic coloration and the sluggish habits of this species probably reduce predation from larger piscivorous species that feed by visual stimuli.

Table 8. Relative survival by year class of *Elassoma zonatum* from Mayfield Creek swamp expressed as proportions of the -1 year class (1 X¹) and the 1+ year class (1 X²).

Sample	Year Class	Number of Specimens	Survival	
			1 X ¹	1 X ²
Males	-1	250	1.000	—
	1+	9	0.036	1.000
	2+	1	0.004	0.111
Females	-1	236	1.000	—
	1+	17	0.072	1.000
	2+	1	0.004	0.059
Total* sample	-1	527	1.000	—
	1+	26	0.049	1.000
	2+	2	0.004	0.007

*Includes 41 juvenile specimens not sexed in the -1 year class.

Parasitism

Specimens of *E. zonatum* from Mayfield Creek swamp were heavily infested with endoparasites. Of 265 specimens examined for endoparasites, 79.2% contained mature or immature parasites. No ectoparasites were found on any specimens examined.

Encysted larvae of an unidentified trematode were the most common parasite, occurring in 64.9% of the specimens examined. Cysts ranged in number from 1–22 per fish (\bar{x} = 2.45) and were commonly found in the liver, peritoneum, mesenteries, attached to the kidney and gonads, or free within the coelom.

Small acanthocephalans (*Neoechinorhynchus* sp.) were found in the intestine, mesenteries, or protruding from the anus in 18.9% of the specimens, and numbered one to two per fish (\bar{x} = 1.1). One fish contained a large *Leptorhyn-*

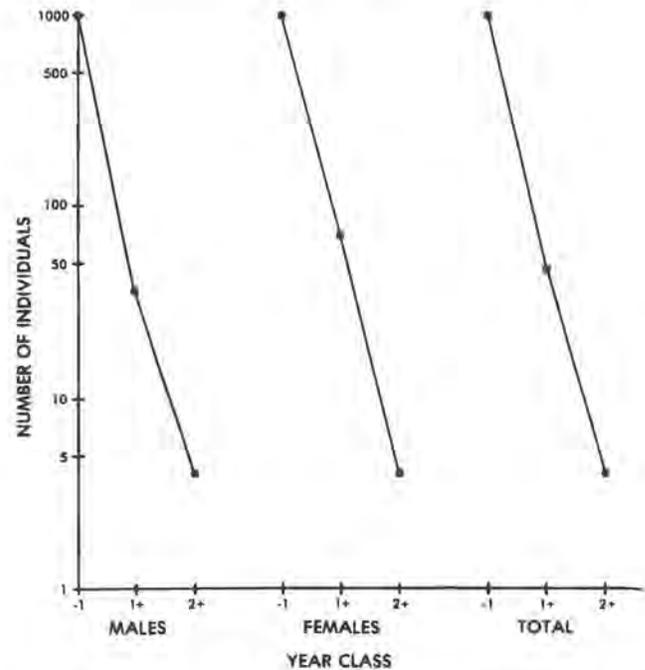


Fig. 17. Survival curves by year class of *Elassoma zonatum* from Mayfield Creek swamp. Points on curve were obtained by multiplying values in 1 X¹ column of Table 8 by 1000. The ordinate is a logarithmic scale.

choides sp. in the posterior intestine.

Immature nematodes of the genus *Camallanus* parasitized 13.9% of the fish examined. Nematodes were found in the intestine, coelom, or imbedded in the mesenteries of the gut and gonads and ranged in number from 1–3 (\bar{x} = 1.3) per fish.

Mature trematodes of the genus *Pisciamphistoma* were found in the intestines of 9.8% of the specimens, and ranged in number from 1–5 per fish.

Other parasites reported from *E. zonatum* were the fluke *Gyrodactylus heterodactylus*, and larvae of the nematode *Contracaecum spiculegerum* (Hoffman 1967). The relatively high incidence of parasitism in *E. zonatum* noted here was probably related to the large percentage of the diet made up of crustaceans and mollusks, which may have served as intermediate hosts or vectors for the parasites.

Summary

Major aspects of the life-history of *E. zonatum* from Mayfield Creek swamp collected from 9 March 1979 to 11 October 1980 are summarized in Table 9.

Table 9. Summary of life-history information on *Elassoma zonatum* from Mayfield Creek swamp.

Principal habitat	Well-vegetated, detritus-laden, sluggish water bodies
Density	Up to 30.4 fish per m ³ in June
Influence of sex on growth rate	Both sexes grew at approximately the same rate
Longevity	25 months (up to 3 years at southern latitudes)
Maximum length	32.3 mm SL (up to 38.5 mm SL at southern latitudes)
Sex ratio in total sample	1 male: 1 female
Sexual dimorphism	Males had proportionally longer pelvic and anal fins and females had greater vent to pelvic fin base length. During breeding season, males were territorial and in nuptial color.
Principal diet	Microcrustaceans, chironomid larvae, and mollusks
Principal times of feeding	From about 0600-1800 hr.
Territoriality	Males were territorial during the breeding season
Age at reaching sexual maturity	10-12 months
Age at first spawning	1 year
Size at reaching sexual maturity	All spring-collected individuals regardless of size were potential spawners
Spawning period	From mid-March through April
Spawning habitat	Shallow, sluggish water with accumulations of detritus and thick growths of vegetation
Number of potentially mature ova in preserved females	43-255
Number of eggs laid per spawning act	6-76
Description of egg	About 0.8 mm across, reticulated on the surface, amber, adhesive
Egg deposition sites	Fine-leaved submergent vegetation
Spawning position	Both male and female side by side
Egg guarding	Parental care of eggs by male only
Polyandry	Two males occasionally mated with the same female in a single spawning act
Incubation period	97-116 hr at 21° ± 1° C
Size at hatching	Hatchlings averaged 3.28 mm TL (range, 3.0-3.6 mm)

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