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Aspects of the Life History of the Smoky Madtom, *Noturus baileyi* Taylor, in Citico Creek

Gerald R. Dinkins
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To the Graduate Council:

I am submitting herewith a thesis written by Gerald R. Dinkins entitled "Aspects of the Life History of the Smoky Madtom, *Noturus baileyi* Taylor, in Citico Creek." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ecology and Evolutionary Biology.

David A. Etnier, Major Professor

We have read this thesis and recommend its acceptance:

J. Larry Wilson, Ralph W. Dimmick

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this thesis and recommend its acceptance:

Gary Watson

Ralph W. Dimmick

Accepted for the Council:

Carl Winkel

The Graduate School

ASPECTS OF THE LIFE HISTORY OF THE SMOKY MADTOM, *NOTURUS BAILEYI* TAYLOR, IN CITICO CREEK

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Gerald R. Dinkins

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ABSTRACT

A two-year study of certain aspects of the life history of the smoky madtom, Noturus baileyi Taylor, in Citico Creek was conducted from 1981 to 1983. This species was rheophilic in the summer and fall and a pool dweller during winter and spring. Smoky madtoms occupied the undersides of palm-sized slabrocks to the exclusion of other species in both habitats. N. baileyi lives at least 2+ and possibly 3+ years, with females attaining greater lengths than males. Individuals of both sexes generally matured at two years; however some one-year-old individuals showed adult chracteristics. Nests were located under large, flat rocks during June and July; clutch size in four nests averaged 36 eggs. As reported for other species of Noturus, the male guarded the nest. The distribution of N. baileyi in Citico Creek was directly related to stream gradient and a soil association. Consideration for Endangered Species status is discussed and suggestions for further study are given.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

To any student of southeastern freshwater fishes, members of the ictalurid catfish genus Noturus, commonly known as madtoms, are well known for their fragmented distribution, toxic spines, and enigmatic nature. Taylor (1969) revised the genus and summarized most of the literature prior to 1967. Since then, many excellent ecological studies have been published. Mahon (1977) studied age and fecundity of two populations of Noturus gyrinus; Clark (1978) studied ecology and life history of N. leptacanthus; Bowen (1980) presented information on the life history of N. miurus in two counties in Ohio; Mayden et al. (1980) presented information on aspects of the life history of N. albater in southeast Missouri; Mayden and Burr (1981) studied the life history of N. exilis in southern Illinois; Burr and Dimmick (1981) presented information on the nesting habits and early development of N. elegans from a stream in Kentucky; Burr and Mayden (1982) studied the life history of N. nocturnus in a stream in Illinois. Life history studies are currently being prepared for N. eleutherus (Starnes and Starnes in press), N. hildebrandi (Mayden and Walsh in press), and N. flavipinnis (Peggy Shute pers. comm.).

The smoky madtom was described by Taylor (1969) from five specimens collected during a 1957 stream reclamation project conducted on Abrams Creek, a tributary to the Little Tennessee River (now Chilhowee Reservoir) in the Great Smoky Mountains National Park. The

purpose of the project was to enhance trout fishing in conjunction with the closure of the gates of Chilhowee Dam (Lennon and Parker 1959). The exact locality of capture was unknown at the time of description; Dinkins (1982) concluded that the type specimens were collected at the Abrams Creek campground area (approximate creek mile 8) based on habitat, stream gradient, elevation, and discussions with U. S. Fish and Wildlife Service personnel involved with the reclamation. Subsequent collections made in Abrams Creek and other tributaries to the Little Tennessee River after Taylor's description revealed no additional specimens of N. baileyi and the species was feared extinct.

In 1978, personnel from the U. S. Fish and Wildlife Service in Gatlinburg, Tennessee, began a survey for Hybopsis monacha, the spotfin chub. On July 23, 1980, while surveying Citico Creek in Cherokee National Forest, Monroe County, Tennessee, a Young Adult Conservation Corps field crew collected a single specimen of N. baileyi (see Bauer et al. 1983). This serendipitous find represented the first known collection of N. baileyi since 1957. In 1981 a grant was issued by the U. S. Fish and Wildlife Service to determine the range and status of N. baileyi. Dinkins (1982) concluded that N. baileyi existed in only a 6.5 mile stretch of Citico Creek and warranted federal endangered species status. He presented some information on its ecology. It is the purpose of this paper to elucidate aspects of the life history of N. baileyi.

II. TAXONOMY

Taylor (1969) placed N. baileyi in the subgenus Rabida because of the shape of its pectoral spine and its color pattern. Within the subgenus, N. baileyi is included in the hildebrandi species group along with both subspecies of N. hildebrandi based on morphologic characters. Later, Etnier and Jenkins (1980) concurred with this arrangement and added N. stanauli to the species group.

Noturus albater, an endemic madtom of the Ozarks of southern Missouri and northern Arkansas, was described by Taylor (1969) as a distinctive species without close affinity to any other species of the subgenus Rabida, although the pectoral rays, pectoral serrae, and posterior process of the cleithrum "suggest a remote relationship with typical N. hildebrandi." He also suggested N. albater may be related to the elegans species group (N. elegans, N. trautmani) because of its elongate body form and small head. Legrande (1981) karyotyped most members of the genus Noturus and found chromosomal similarities between N. hildebrandi and N. elegans, giving strong evidence for relationships between the two. Legrande, however, was not able to resolve the exact relationship of N. albater to N. hildebrandi and N. elegans. The smoky madtom was not examined because Legrande's study preceded the discovery of the Citico Creek population.

III. METHODS

Collection of Specimens

Collections and observations were made in Citico Creek from May, 1981, to July, 1983. Except for a male nest-guarder collected and preserved in 10% formalin on 10 July 1982, all specimens were weighed, measured, and released. Skin/SCUBA diving with handnets was the sole method used in capturing specimens. The temperature regime of Citico Creek demanded wetsuits in the warmer months and drysuits in the colder months. Thirty-one trips were made to Citico; in excess of 150 man hours were spent skin/SCUBA diving.

Twelve specimens collected and preserved by personnel of the U.S. Fish and Wildlife Service between 23 July 1980 and 2 May 1981 were also used. These specimens were deposited at The University of Tennessee Research Collection of Fishes, Knoxville.

Metric lengths of live and preserved specimens were measured using a small, plastic ruler. Where used, SL and TL refer to standard length and total length, respectively. Weights of live specimens were taken using a handheld Pesola scale. Handheld scales, however, were found to be accurate only to the nearest 0.5 gm. Since juvenile *N. baileyi* nearly always weighed less than 0.5 gm, life history aspects such as growth rates in body weight, sex specific length-weight relationships, and gonadosomatic indices could not be accurately treated and thus were not examined.

Range and Occurrence

Daytime and nighttime searches were conducted from creek mile 16.5 to the area inundated by Tellico reservoir (creek mile 1.8) in order to determine the range of N. baileyi in Citico Creek. Daytime riffle searches were conducted by lying head forward in the current, and moving slowly across the channel while all substrate within an arm's reach was examined. By moving approximately one arm's length upstream when the stream edge was reached and then returning across the channel, a riffle area from lower to upper end could be thoroughly examined. Daytime searches for N. baileyi in pools were accomplished by examining the substrate while floating downstream head first. Nighttime searches in all habitats were aided by underwater lights (Dacor UL-800) and were conducted while floating downstream, stopping occasionally to examine the substrate.

Age and Maturity

Pectoral spine sectioning as outlined by Marzolf (1955) and Clugston and Cooper (1960) has become a popular and useful tool in the age determination of madtoms (Mayden and Burr 1981, Burr and Mayden 1982a, Burr and Mayden 1982b, Mayden and Walsh in press). The difficulty encountered in capturing specimens of N. baileyi coupled with the apparently small Citico Creek population precluded age and growth determination by techniques requiring immolation. Consequently, age classes were determined by length-frequency distributions.

From June to November 1982, subcutaneous injections of non-toxic acrylic paint were used to individually mark 46 smoky madtoms (see

Dinkins 1982). This same method was used with success on N. flavipinnis, the yellowfin madtom, in Citico Creek. Smoky madtoms, however, were much smaller than yellowfin madtoms and were very difficult to hold as they were injected. The results of the mark-recapture study on N. baileyi were largely inconclusive due to the lack of recaptures. Because of the uncertainty over the possibility of introduced mortality due to the acrylic marks, the project was abandoned in November 1982.

Diet

Stomachs and intestinal tracts from preserved specimens were excised and slit lengthwise and their contents placed in labelled vials filled with 40% isopropyl alcohol. Prey items were identified with assistance from Brigham et al. (1982), Edmunds et al. (1976), Hitchcock (1974), and Wiggins (1977). Difficulty was encountered in identifying some mayfly (Ephemeroptera) nymphs due to digestion of soft body parts. For this reason, N. baileyi capture localities were surveyed for mayflies. Results of the survey were used to devise a diagrammatic key for identifying mayfly fragments in the stomachs and intestines of madtoms. In this way, almost all prey items were identified to the generic level.

Percent of occurrence was determined by dividing the total number of madtoms in which the prey item was found by the total number of prey items. Percent frequency of occurrence was determined by dividing the total number of madtoms in which the prey item was found by the total number of stomachs.

Habitat

Riffle areas and shallow pools in Citico Creek between creek mile 3.7 and 10.4 abound in flat, smooth rocks, denoted here as "slabrocks." Smoky madtoms occurred underneath slabrocks to the exclusion of other species (N = 126); 122 (96.8%) occurred singly; excluding breeding pairs, 4 (3.2%) were found underneath a slabrock with another N. baileyi. To determine the relationship between fish length and slabrock size, slabrocks under which N. baileyi were found were retained in a nylon mesh bag as the fish were collected. After an area was searched, slabrock dimensions and the corresponding fish length (SL and TL) were recorded in the field notes. Using a small, plastic ruler, slabrock dimensions were obtained by taking one to four thickness measurements and two to seven rock-face measurements. The general shape of the slabrock was also recorded. Slabrock-face-area is defined here as the surface area of the slabrock as viewed from above and was determined by geometric calculations. Multiple regression analyses of the relationship between fish length and slabrock dimensions, by season, were executed on an IBM computer using the regression procedure provided by the Statistical Package for the Social Sciences (SPSS version 9.1).

Direct observations indicated that N. baileyi occupied riffles, riffle bases, and riffle crests from late May to early November. During the colder months, pools and shallow pools were preferred habitats. One-way analyses of variance tests were used to determine if significant differences existed between the dimensions of riffle

slabrocks (summer/fall habitat) and pool slabrocks (winter/spring habitat) occupied by N. baileyi.

Problems arose as a result of the extremely wary and elusive nature of N. baileyi. It was not uncommon for a madtom to be uncovered only to elude capture (N = 40). Thus, there were slabrocks under which N. baileyi were found for which there were no corresponding fish lengths.

The velocity of current was measured by timing a floating object (lemon) through a premeasured distance. As noted by Bryant (1979), this is arbitrary in regard to fish which live between or under substrate and therefore are sheltered from the current.

Water temperatures were measured with an armored thermometer. Elevation and gradients were calculated from USGS 7.5 minute quadrangle maps.

Reproduction, Nesting, and Larval Development

Studies on reproductive aspects of N. baileyi were achieved by examination of preserved museum specimens and live specimens in the field. Ovaries were removed from museum specimens and the eggs counted with the aid of a 30X binocular dissecting microscope. Details of breeding coloration and nesting habitat were recorded at creek-side in field notes.

Development of N. baileyi was examined from one clutch of eggs taken from Citico Creek. These were hatched in a small, well aerated aquarium kept at room temperature. Periodically, larvae were removed and placed in 10% formalin. Drawings of embryos and larvae were prepared with the aid of a camera lucida and a dissecting microscope.

IV. STUDY AREA

Citico Creek is a tributary to the Little Tennessee River (Figure 1), now Tellico Reservoir since the closure of the gates of Tellico Dam in 1979. Roughly 16.5 miles in length, Citico Creek proper flows northward through the southeast corner of Monroe County, Tennessee, and is contained, except for the lower 4.4 creek miles, within Cherokee National Forest. Citico Creek proper is defined here as that stretch of water beginning at the confluence of Doublecamp Creek with Citico Creek and extending downstream to the mouth (Figure 2). Nearly the entire Citico Creek watershed is heavily forested; consequently, flooding rarely occurs and water clarity remains exceptional year-round. The North Fork Citico watershed has a mean annual precipitation of 179 cm (Tennessee Valley Authority unpublished report 1971); while no studies exist for annual precipitation in the Citico Creek proper area, similar elevations elsewhere in Monroe County report an average annual precipitation of 128 cm (Hall et al. 1981).

There are two concrete dam structures located at creek miles 8.5 and 15.7 on Citico Creek. Built in 1973, these structures inundate two short stretches of creek (approximately 91 m and 18 m, respectively, during normal water level) and serve to impede the upstream vernal migration of redhorses (Moxostoma spp.) into the stocked trout waters at Doublecamp Creek.

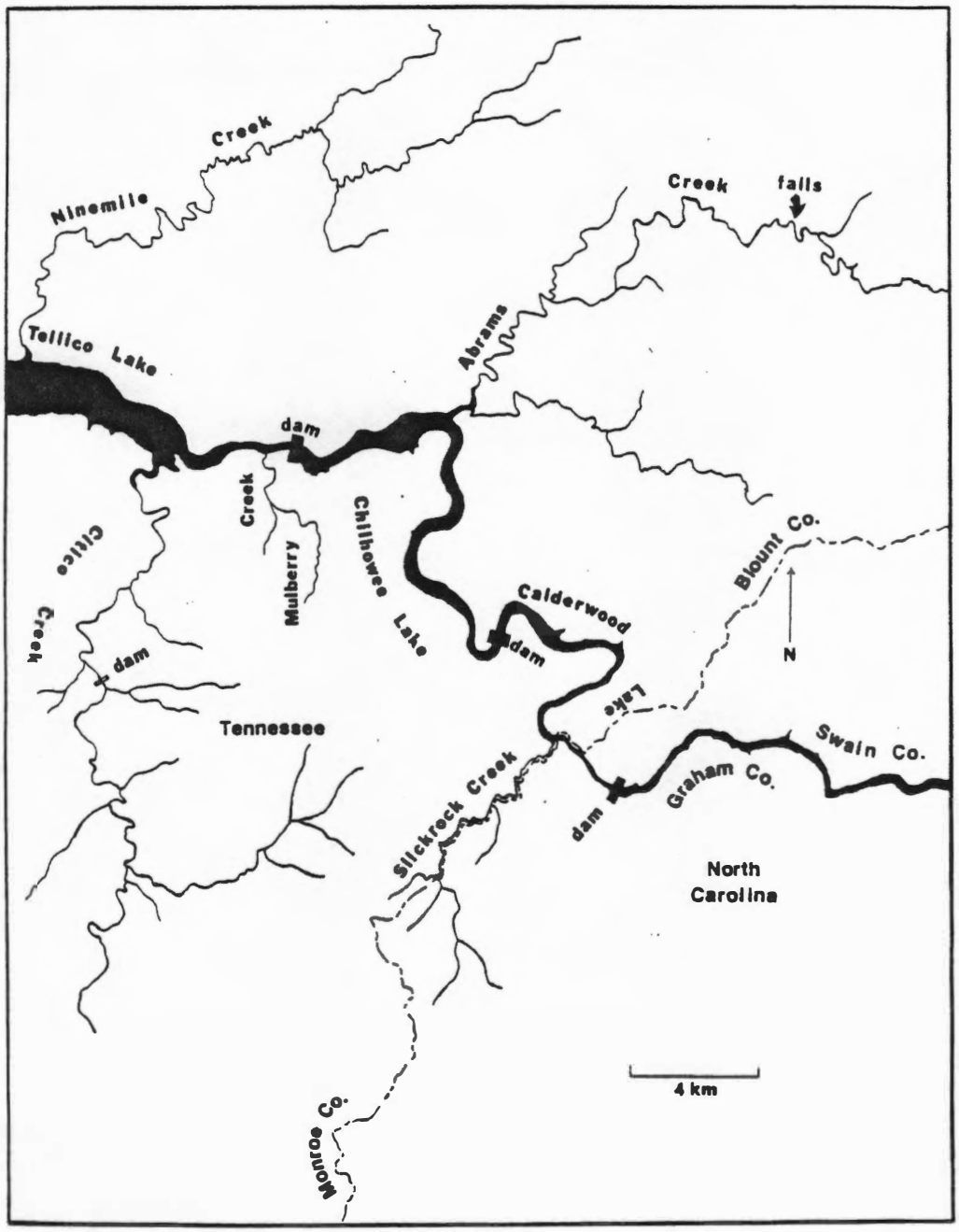

Figure 1. Map of the upper Little Tennessee River system (revised from Bauer et al. 1983).

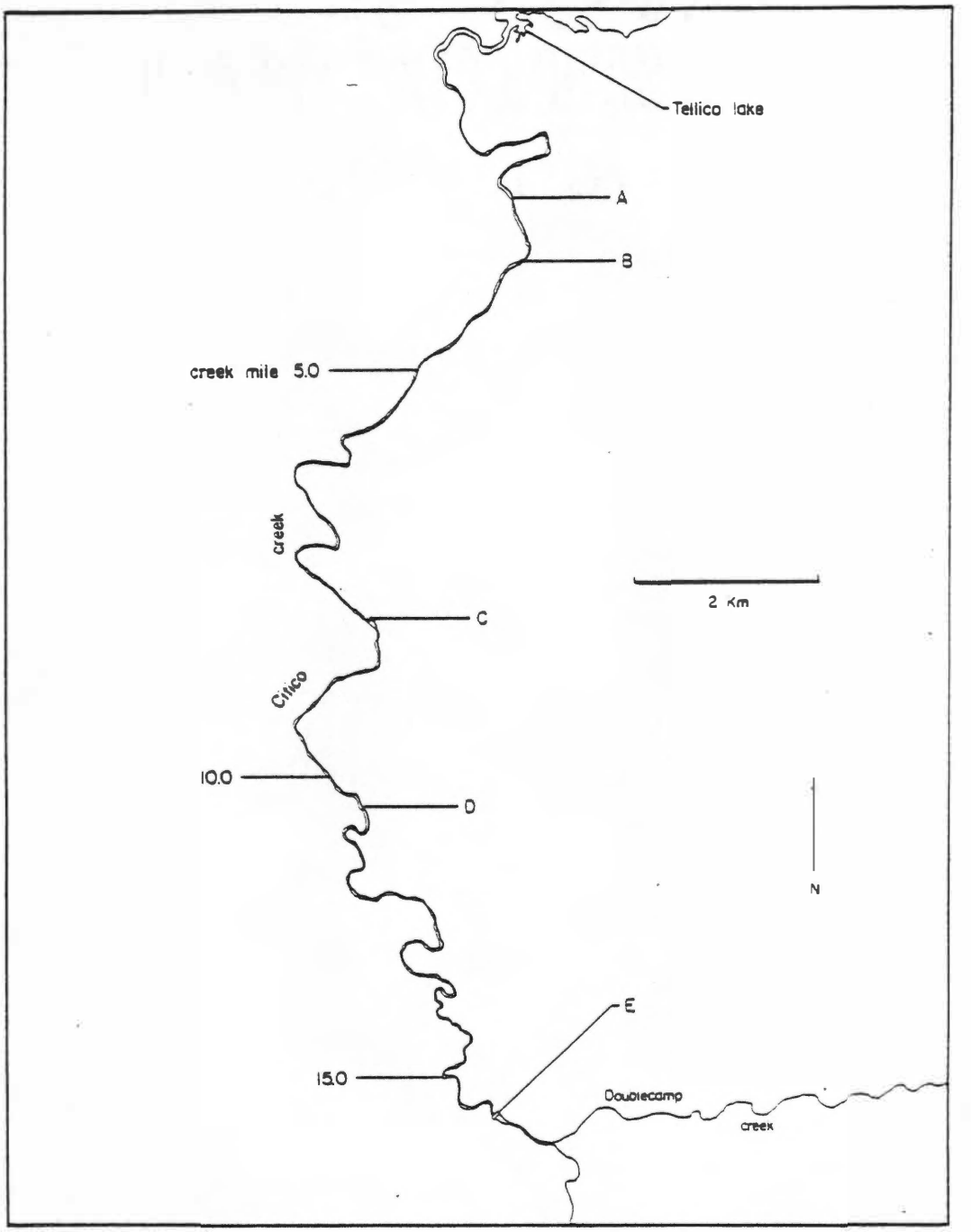

Figure 2. Map of Citico Creek proper, Monroe County, Tennessee. (A) Creek mile 3.7; downstream extent of N. baileyi, edge of Ranger-Citico-Fletcher soil association. (B) Creek mile 4.3; Cherokee National Forest boundary. (C) Creek mile 8.5; U.S. Forest Service dam. (D) Creek mile 10.4; upstream extent of N. baileyi, edge of Ranger-Citico-Fletcher soil association, gradient change. (E) Creek mile 15.7; U.S. Forest Service dam.

Citico Creek proper has a gradient drop of 36 feet per mile (U.S. Geologic Service quad map) with a noticeable gradient change at creek mile 10.4. When Citico Creek proper is separated into two contiguous sections—the upper being creek mile 16.5 to 10.4, and the lower being 10.4 to the mouth—the gradient is 76 feet per mile and 13 feet per mile, respectively. The gradient change at creek mile 10.4 marks the upstream extent of N. baileyi.

The headwaters of Citico Creek originate along the Tennessee/North Carolina border in the rugged Unicoi Mountains. This area lies in the Ditney-Brookshire-Jeffrey soil association which is characterized by steep and very steep soils, formed in material under slate, phyllite, graywacke, arkosic sandstone, and probably granite and conglomerate in some places (Hall et al. 1981). Further downstream (just upstream from the confluence of the North Fork and South Fork), Citico Creek passes through the Sylco-Citico-Brookshire soil association. This association consists of steep, well-drained and excessively drained soils, formed in slate, phyllite, and arkosic or graywacke sandstone (Hall et al. 1981). From approximately creek mile 10.4 to 3.7, Citico Creek passes through the Ranger-Citico-Fletcher soil association. The soils in this association formed in material weathered from phyllite or siltstone. Continuing downstream to the mouth, Citico passes through the Statler-Staser-Transylvania soil association. Here the soil association was formed in alluvium from mountain sediment (Hall et al. 1981).

The Ranger-Citico-Fletcher soil association section of Citico Creek roughly delineates that section of creek occupied by N. baileyi (Figure 2). This 6.7-mile stretch of creek is typified by shallow riffles composed of abundant slabrocks, long shallow pools composed of pea gravel and occasional slabrocks, and deep pools with large boulders and silty/sandy bottoms. Above creek mile 10.4, Citico Creek proper appears much more montane; the substrate consists largely of boulders with short cascades alternating with short, shallow pools. Below creek mile 3.7, the substrate is dominated by bedrock and sand. From July 1982 to June 1983, water temperatures in Citico Creek between creek miles 3.7 and 10.4 ranged from 5° C. (January) to a high of 23° C (July) (Figure 3).

Citico Creek contains the most diverse ichthyofauna in the Little Tennessee River system (Dinkins 1982) (Table 1). Included are N. flavipinnis, the yellowfin madtom, and Etheostoma sp., the duskytail darter. The federally threatened N. flavipinnis is known from only three other localities: Copper Creek, Scott County, Virginia; McDowell Ford of Powell River, Hancock County, Tennessee; Buchanan Ford of Powell River, Claiborne County, Tennessee. The duskytail darter, an undescribed member of the subgenus Catanotus, is also known from only three other localities: lower Little River, Blount County, Tennessee; Copper Creek, Scott County, Virginia; Big South Fork of the Cumberland River at Station Camp Creek, Scott County, Tennessee.

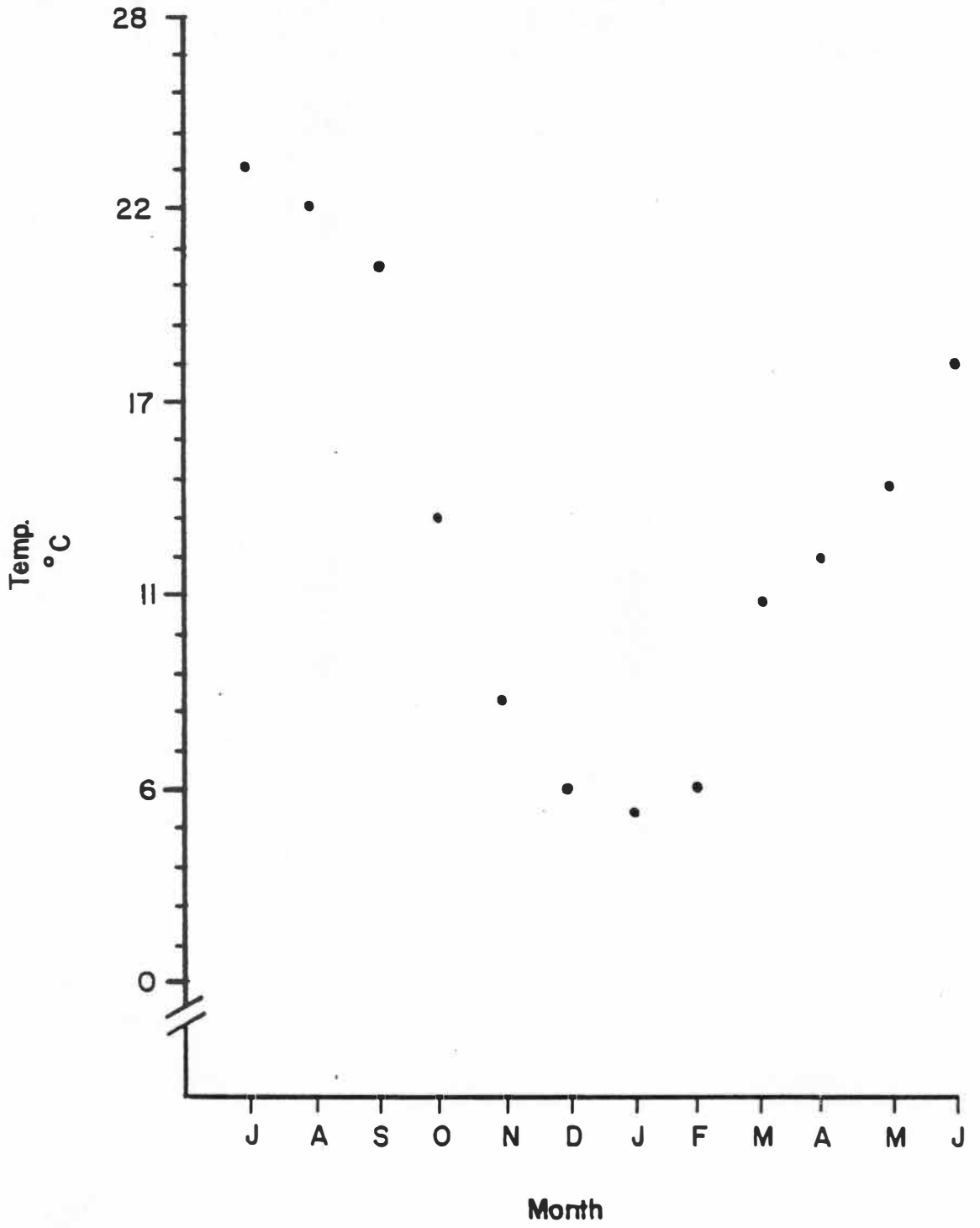

Figure 3. Temperature regime of Citico Creek proper showing monthly average temperature, July 1982 to June 1983.

TABLE 1

Species List of Fishes in Citico Creek, Monroe County, Tennessee[1]

Ichthyomyzon castaneus	chestnut lamprey
Lampetra appendix	American brook lamprey
Lepisosteus oculatus	spotted gar
Salmo gairdneri	rainbow trout
S. trutta	brown trout
Salvelinus fontinalis	brook trout
Campostoma anomalum	stoneroller
Clinostoma funduloides	rosyside dace
Cyprinus carpio	carp
Hybopsis amblops	bigeye chub
H. insignis	blotched chub
H. monacha[2]	spotfin chub
Nocomis micropogon	river chub
Notropis sp.	sawfin shiner
N. coccogenis	warpaint shiner
N. cornutus	common shiner
N. galacturus	whitetail shiner
N. leuciodus	Tennessee shiner
N. lirus	mountain shiner
N. photogenis	silver shiner
N. spilopterus	spotfin shiner
N. telescopus	telescope shiner
Phenacobius uranops	stargazing minnow
Phoxinus oreas	mountain redbelly dace
Rhinichthys atratulus	blacknose dace
R. cataractae	longnose dace
Hypentelium nigricans	northern hog sucker
Moxostoma carinatum	river redhorse
Ictalurus natalis	yellow bullhead
Noturus baileyi	smoky madtom
N. flavipinnis	yellowfin madtom
Pylodictus olivaris	flathead catfish
Fundulus catenatus	northern studfish
Amblopites rupestris	rock bass
Lepomis auritus	redbreast sunfish
L. cyanellus	green sunfish
L. gulosus	warmouth
L. macrochirus	bluegill
L. megalotis	longear sunfish
Micropterus dolomieu	smallmouth bass
M. punctulatus	spotted bass
M. salmoides	largemouth bass
Etheostoma sp.	duskytail darter
Etheostoma blennioides	greenside darter
E. jessiae	blueside darter
E. rufilineatum	redline darter
E. simoterum	Tennessee snubnose darter
E. zonale	banded darter
Percina caprodes	logperch
P. evides	gilt darter
Perca flavescens	yellow perch
Aplidinotus grunniens	freshwater drum
Cottus carolinae	banded sculpin

[1]Compiled from University of Tennessee museum records and direct observation.

[2]Hybopsis monacha is represented by a single 1936 record and is probably extirpated from Citico Creek.

V. AGE AND MATURITY

Month by month, the number of specimens collected before and during this study from Citico Creek were as follows: January (5); February (5); March (17); April (1); May (13); June (17); July (21); August (4); September (14); October (31); November (2); December (0).

Within the subgenus Rabida, members of the hildebrandi species group are our smallest and shortest lived madtoms. Etnier and Jenkins (1980) noted two age classes in N. stanauli, indicating a life span of 1+ years. Mayden and Walsh (in press) found that N. hildebrandi had a life span of 1+ years. While the relative paucity of smoky madtom specimens led to a certain amount of ambiguity in the delineation of age classes, three peaks are evident in Figure 4. Therefore, based on the length-frequency distribution of 45 madtoms collected during September and October 1982, N. baileyi lived 2+ years.

Maximum age of certain other recently studied species of Noturus are as follows: N. leptacanthus—2+ (Clark 1978); N. miurus—3+ (Burr and Mayden 1982a); N. albater—2+ (Mayden et al. 1980); N. eleutherus—3+ (Starnes and Starnes in press); N. flavipinnis—3+ (Peggy Shute pers. comm.); N. nocturnus—4+ (Burr and Mayden 1982b); N. exilis—4+ (Mayden and Burr 1981).

Based on secondary sexual characters, some individuals of both sexes of N. baileyi attained sexual maturity in their second summer of life. Larger (older) smoky madtoms became sexually active

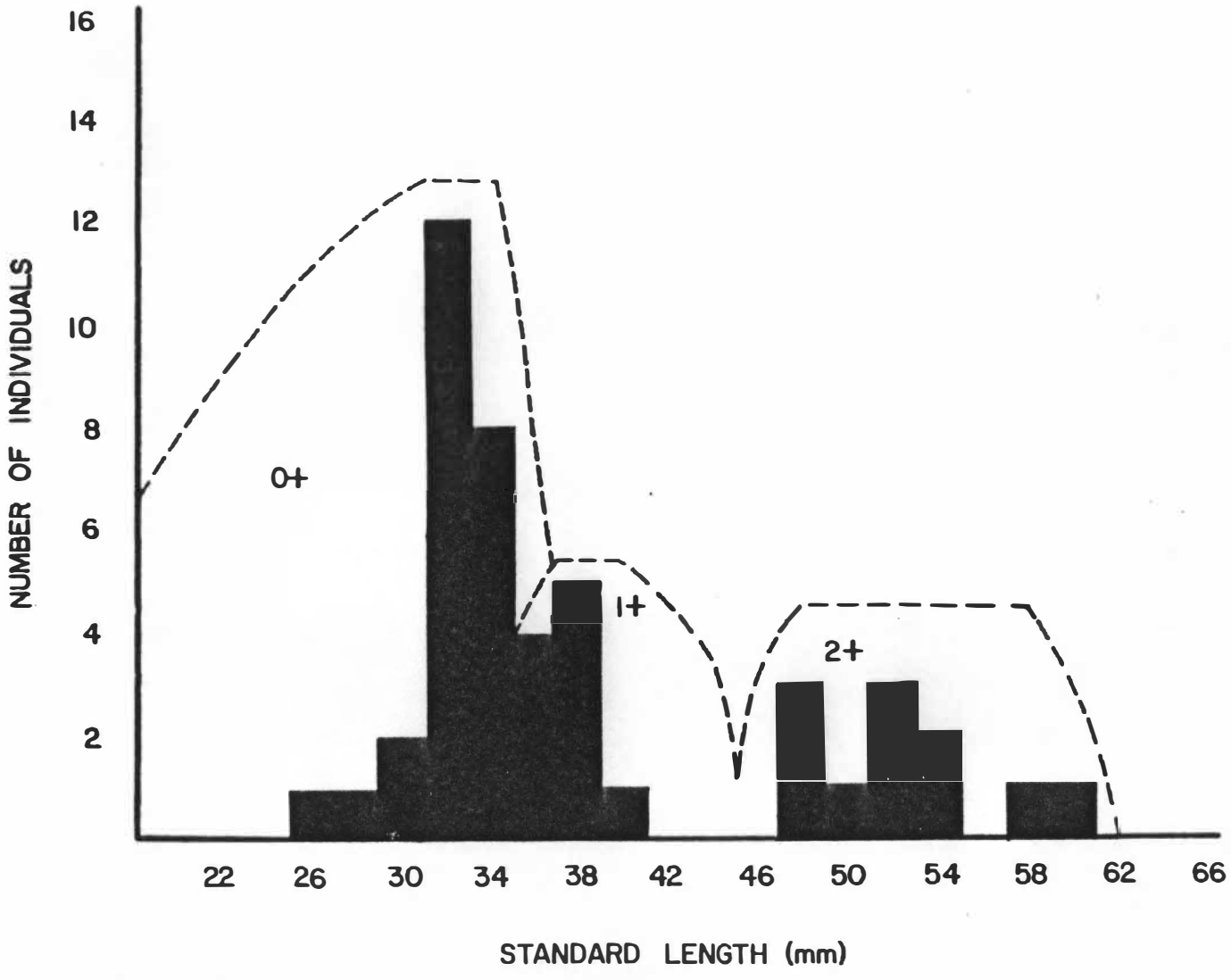

Figure 4. Length frequency of 45 smoky madtoms collected during September and October 1982.

earlier in the breeding season and smaller (younger) individuals spawned later (see Reproduction).

Female smoky madtoms attained greater lengths than males; of the 8 madtoms over 57 mm SL collected during this study, 7 were females. The largest male measured 58 mm SL, 71 mm TL. The largest female measured 63 mm SL, 73 mm TL.

VI. DIET

The stomach contents of 13 N. baileyi collected from Citico Creek before and during the study were examined (Tables 2 and 3). All specimens were deposited at The University of Tennessee (UT) Research Collection of Fishes. Except for possibly a few specimens taken by private collectors, these 13 represent the only known preserved specimens from Citico Creek. The five 1957 specimens from Abrams Creek were not examined because of their status as type specimens.

Aquatic insect larvae accounted for the majority of food items (89.3%); ephemeropteran nymphs were the most common aquatic insect (70.7%); dipterans, trichopterans, and plecopterans accounted for 23.9%, 4.4%, and 1.0% of the aquatic insects, respectively. Gravel was found in five of the stomachs and was probably ingested accidentally. No trends were detected for feeding periodicity, perhaps due to the small sample size.

TABLE 2

Stomach Contents of 13 *Noturus baileyi* from Citico Creek

Taxon	Percent of Occurrence	Percent Frequency of Occurrence
Ephemeroptera		
Baetidae		
Pseudocloen sp.	6.8	23.1
Unidentified	1.9	15.4
Heptageniidae		
Stenonema sp.	1.0	7.7
Rithrogena sp.	1.0	7.7
Unidentified	2.9	23.1
Oligoneuridae		
Isonychia sp.	2.9	23.1
Siphlonuridae		
Ameletus sp.	6.8	23.1
Ephemerellidae		
Drunella sp.	1.9	7.7
Ephemerella sp.	34.0	23.1
Ephemeroptera (unidentified)	3.9	23.1
Plecoptera		
Perlidae	1.0	7.7
Trichoptera		
Hydropsychidae		
Hydropsyche sp.	1.0	7.7
Philopotamidae		
Chimarra sp.	2.9	15.4
Diptera		
Tipulidae	3.9	7.7
Chironomidae	17.4	46.2
Gravel	10.7	38.5

TABLE 3

Feeding Periodicity of 13 Noturus baileyi from Citico Creek

UT Museum No.	SL (mm)	TL (mm)	Wt. (gr)	Sex	Creek Mile	Time of Collection	Collection Date	No. of Organisms	No. of Taxa	No. of Gravel	Diameter of Gravel (mm)
48.391/1	34	40	0.5	M	5.2	2130	9/15/80	2	2	0	--
48.391/2	32	39	0.5	F	5.2	2130	9/15/80	3	2	0	--
48.391/3	34	41	0.6	F	5.2	2130	9/15/80	26	6	0	--
48.391/4	34	41	0.6	M	5.2	2130	9/15/80	1	1	0	--
48.391/5	36	43	0.6	F	5.2	2130	9/15/80	0	0	0	--
48.391/6	38	44	0.8	F	5.2	2130	9/15/80	6	3	1	0.3
48.389	46	55	1.2	M	5.2	1500	7/23/80	6	4	0	--
48.390	32	39	0.5	M	5.2	1300	9/08/80	9	4	2	0.3,0.3
48.391/1	57	69	2.0	F	5.4	1130	9/16/80	1	1	3	0.3,1.0,2.0
48.391/2	60	72	2.6	F	5.4	1130	9/16/80	0	0	0	--
48.433	52	62	2.5	M	5.2	1205	5/02/81	22	3	3	0.5,0.5,0.5
48.430	52	63	2.6	F	8.2	1500	6/19/81	16	7	2	0.5,0.5
48.485	43	51	1.4	M[1]	10.0	1900	7/10/82	1	1	0	--

[1]Nest guarder.

VII. HABITAT

From late May to early November 1982, smoky madtoms were found in all parts of riffles, especially riffle crests. Water current at three riffle crest localities where 48 specimens were captured ranged from 0.52 to 0.67 m/sec ($\bar{X}$ = 0.58); depths ranged from 30 to 41 cm ($\bar{X}$ = 34.0). Substratum at these localities was comprised largely of flat slabrocks and small cobbles with a pea-sized gravel matrix. Riffle-area slabrocks occupied by N. baileyi ranged from 4 to 50 mm thick ($\bar{X}$ = 19.9), and from 3117 to 33006 mm^2 in face-area ($\bar{X}$ = 8422.5) (N = 46) (Table 4). A portion of these slabrocks (18%) were either concave in side-view or had depressions on the undersurface.

In early November 1982, water temperatures dropped to 7-8° C and N. baileyi disappeared abruptly from the riffle areas. Shallow pools were found to be preferred habitat until late May 1983. Water depth at three localities where 41 smoky madtoms were collected ranged from 60 to 68 cm ($\bar{X}$ = 62.7); current ranged from 0.15 to 0.43 m/sec ($\bar{X}$ = 0.27). Substratum at these localities was comprised of large boulders, occasional flat slabrocks, and sand/gravel matrix. Pool slabrocks occupied by N. baileyi ranged from 8 to 50 mm thick ($\bar{X}$ = 20.9), and from 2796 to 18265 mm^2 in face-area ($\bar{X}$ = 8300.7) (N = 30) (Table 4). Roughly half (52%) of these slabrocks were either concave in side-view or had depressions on the undersurface.

TABLE 4

Dimensions of Slabrocks Occupied by *Noturus baileyi* with Standard Lengths, by Season (Habitat), from Citico Creek, June 1982 to June 1983[a]

		SL		Slabrock Face Area		Slabrock Thickness	
	N	$\bar{X}$ ± SE	Range	$\bar{X}$ ± SE	Range	$\bar{X}$ ± SE	Range
				Untransformed Data			
Winter/Spring (Riffles)	30	39.83 ± 3.16	27-58	8422.47 ± 1180.68	3117-33006	20.93 ± 1.70	8-50
Summer/Fall (Pools)	46	39.78 ± 1.35	22-57	8300.65 ± 638.67	2796-18265	19.89 ± 1.42	4-50
Both	76	39.80 ± 1.08	22-58	8348.74 ± 600.79	2796-33006	20.30 ± 1.09	4-50
				Log_{10} Transformed Data			
Winter/Spring (Riffles)	30	1.59 ± 0.03	1.43-1.76	3.85 ± 0.05	3.49-4.52	1.28 ± 0.03	0.90-1.70
Summer/Fall (Pools)	46	1.59 ± 0.02	1.34-1.76	3.86 ± 0.03	3.45-4.26	1.25 ± 0.03	0.60-1.70
Both	76	1.59 ± 0.01	1.34-1.76	3.85 ± 0.03	3.45-4.52	1.26 ± 0.02	0.60-1.70

[a]Standard length and slabrock thickness are in mm; slabrock area is in mm^2.

Analyses of variance tests on slabrock dimensions examined for the two habitat types produced very low F-ratio values (Table 5). These results suggested that no significant difference existed between the slabrocks smoky madtoms used for cover in the riffles and those used for cover in the pools. Although no statistical tests were conducted to determine if the slabrocks used for cover by smoky madtoms significantly differed from other slabrocks in the same areas, personal observations revealed a wide range of slabrock sizes occurred in the riffles and pools. In fact, smoky madtoms used the larger slabrocks in both habitat types for nesting cover (see Nesting). While smoky madtoms selected for a certain size of cover slabrock in both habitats, multiple regression results showed no relationship between fish length, slabrock thickness, and slabrock-face-area (Table 6).

Slabrocks were relatively abundant in all areas of riffles (especially riffle crests). Slabrocks in pools, however, occurred sporadically and usually in small, concentrated groupings. Thus, competition for slabrocks may have increased as the smoky madtoms left the riffle areas and entered the pools.

Analyses of variance test on the standard lengths (SL) of madtoms captured in the two habitat types produced a very low F-ratio value (Table 5). The result suggested an equally collected distribution of sizes. Thus, there was no preference for age class in the areas sampled.

TABLE 5

Analysis of Variance Summary for Slabrocks Occupied by Noturus baileyi

	Untransformed	Log_{10} Transformed
Diameter (mm)	$F = 0.010^{ns}$	$F = 0.042^{ns}$
Face-area (mm^2)	$F = 0.130^{ns}$	$F = 0.115^{ns}$
SL (mm)	$F = 0.001^{ns}$	$F = 0.003^{ns}$

^{ns}Not significant.

TABLE 6

Multiple Regression Results for Slabrock Dimensions as Selected for by *Noturus baileyi*, by Season (Habitat), from Citico Creek, June 1982 to June 1983[a]

	N	Equation	R^2
		Untransformed Data	
Winter/Spring (Riffles)	30	$\hat{Y}_{SL} = 0.0553(X_{thick}) - 0.0001(X_{area}) + 39.863$	0.00404 (0.4%)
Summer/Fall (Pools)	46	$\hat{Y}_{SL} = 0.0228(X_{thick}) + 0.0003(X_{area}) + 38.0388$	0.01361 (1.3%)
Both	76	$\hat{Y}_{SL} = 0.0075(X_{thick}) + 0.0001(X_{area}) - 0.0513X_{season*} + 39.5440$	0.0086 (0.01%)
		Transformed Data	
Winter/Spring (Riffles)	30	$YLog_{10}SL = 0.0052(Log_{10}X_{thick}) - 0.0343(Log_{10}X_{area})$	0.00750 (0.75%)
Summer/Fall (Pools)	46	$YLog_{10}SL = -0.0342(Log_{10}X_{thick}) + 0.0616(Log_{10}X_{area}) + 1.3928$	0.01760 (1.7%)
Both	76	$YLog_{10}SL = -0.0311(Log_{10}X_{thick}) + 0.0257(Log_{10}X_{area}) - 0011X_{season*} + 1.5298$	0.00416 (0.4%)

[a]Computations for standard length(SL) and rock thickness(thick) were made using mm. Computations for rock face area(area) were made using mm^2.

*Winter/spring was assigned a value of 1; summer/fall was assigned a value of 2.

In all habitats, N. baileyi occurred under slabrocks which were flush with but not embedded in the sand or gravel substrate. Slabrocks may serve not only as protective cover but also as feeding sites as suggested by the fact that 98% (N = 123) of the slabrocks used for cover by smoky madtoms were devoid of aquatic insects on their undersurface.

Redline darters (Etheostoma rufilineatum), "duskytail darters" (Etheostoma sp.), and crayfish (Cambarus sp., Orconectes sp.) occurred syntopically with smoky madtoms in the shallow pools. While many fish species occurred in the riffle areas, only greenside darters (Etheostoma blennioides), redline darters, and banded sculpins (Cottus carolinae) occurred underneath slabrocks.

VIII. REPRODUCTION

Mature male smoky madtoms were found in Citico Creek during the months of May, June, and July (Table 7). They exhibited secondary sexual characters typical of all members of the genus Noturus as described by Taylor (1969); the genital papilla enlarged (Figure 5), cephalic epaxial muscles increased noticeably in size, and the lips swelled. The swollen lips of the type specimens of N. baileyi collected from Abrams Creek led Taylor (1969) to describe the smoky madtom as having a lower jaw being only slightly included in the upper jaw (Bauer et al. 1983).

The genital papilla of males in non-breeding condition was barely distinguishable from that of non-gravid females (Figure 5) and could not be used as a reliable character for sexing live madtoms in the field. In preserved specimens, sex is easily discerned by inspection of the gonadal tissue. Testes of male N. baileyi consist of long, whitish, finger-like projections as described for catfish (Sneed and Clemens 1963) and other madtoms (Mayden and Burr 1981, Burr and Mayden 1982a, Burr and Mayden 1982b, Clark 1978).

Male smoky madtoms in breeding condition showed more body color (yellow) than did gravid females. Noturus miurus males were found to be more drab than gravid females (Burr and Mayden 1982a), while the coloration of N. nocturnus males did not change with the breeding season (Burr and Mayden 1982b).

TABLE 7

Characteristics of Breeding Male and Female *Noturus baileyi* in Citico Creek for 1981 to 1983

Date	SL (mm)	TL (mm)	Sex	Estimated Age
5-2-81	52	62	♂	2
5-13-81	56	66	♀	2
6-2-83	59	69	♀	2
6-2-83	59	69	♀	2
6-2-83	63	73	♀	2
6-2-83	55	63	♀	2
6-2-83	57	67	♀	2
6-19-81	54	62	♀	2
6-25-83	58	71	♂	2
6-25-83	57	70	♀	2
6-26-82	50	55	♀	2
6-27-82	49	57	♀	2
7-2-82	55	64	♂	2
7-2-82	50	56	♀	2
7-2-82	50	56	♂	2
7-2-82	49	56	♀	2
7-2-82	47	55	♂	2
7-2-82	38	45	♀	1
7-7-82	47	55	♂	2
7-7-82	38	45	♀	1
7-7-82	49	56	♂	2
7-10-82	53	61	♂	2
7-10-82	44	52	♂	1-2
7-10-82	43	51	♂	1-2

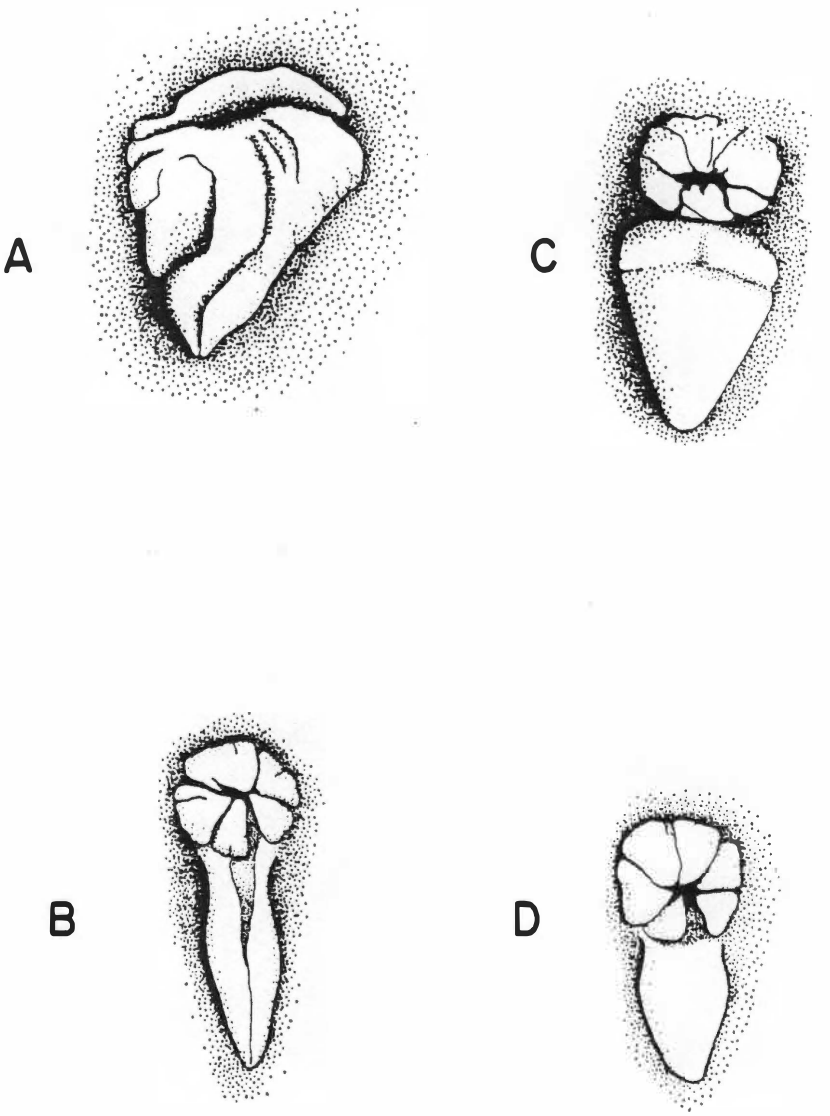

Figure 5. Genital papillae of Noturus baileyi from Citico Creek. (A) Breeding female 52 mm SL collected May 2, 1981. (B) Non-breeding female 37 mm SL collected September 15, 1980. (C) Breeding male 52 mm SL collected June 19, 1981. (D) Non-breeding male collected September 15, 1981.

Gravid female smoky madtoms were found in Citico Creek from early May to late July (Table 7) and were identified by their distended abdomens and swollen genital papillae (Figure 5). The enlarged cephalic epaxial muscles and swollen lips, apparent in nuptial males, were not developed in gravid females. A gravid female collected and preserved 2 May 1981 had ovaries containing three sizes of oocytes. The mature oocytes were orangish in color, spherical, and ranged in diameter from 0.88 to 1.00 mm ($\bar{X}$ = .95, N = 55). Intermediate-sized oocytes were either clear or whitish in color, spherical, and ranged in diameter from .30 to .50 mm ($\bar{X}$ = .38, N = 122). The smallest sized oocytes were translucent, somewhat flattened, and ranged in diameter from .13 to .28 ($\bar{X}$ = .23, N = 110). Immature female smoky madtoms captured and preserved during the breeding season contained ova undifferentiated in size.

Recent evidence provided by Mayden and Walsh (in press) lends strong support for polyandry in the closely related N. hildebrandi. On 2 July 1982, a partially spent gravid female N. baileyi was collected in a shallow pool, approximately 1 m from a nest containing 33 eggs guarded by a single madtom. Several eggs were protruding from her urogenital opening. After considerable time and effort, two more N. baileyi were collected from the shallow pool, both of which were males in breeding condition. The occurrence of polyandry in N. baileyi is not clearly documented. If proposed production of this species in hatcheries by the U.S. Fish and Wildlife Service and Tennessee Wildlife Resources Agency proceeds, more data should become available.

IX. NESTING

Male and female smoky madtoms in breeding condition were found together from early June to mid-July (Table 8). Water temperatures during this period ranged from 18° to 23° C. Rocks under which either breeding pairs or nests were found averaged 3.6 cm in thickness and 25.8 cm in length and width (N = 7). A nesting site consisted of a large, flat rock under which a small pit had been dug into the substrate. Nests were lined with small gravel and rock, were devoid of silt, and were presumably prepared by one or both parents. Aquatic insects were noticeably absent from the underside of all nest rocks. Smoky madtoms were found to nest in riffle crests and shallow pools. Water depth at seven nest sites ranged from 23 to 55 cm, $\overline{X}$ = 39.3; current ranged from 0.5 to 1.8 ft/sec, $\overline{X}$ = 1.2. Clutch size averaged 36 eggs (N = 4); each clutch was attended by a single madtom.

A clutch of 33 eggs (nest number 1) was taken from Citico Creek and brought to The University of Tennessee. The eggs were maintained in an aquarium and hatched (see Larval Development). The madtom guarding the clutch was very reluctant to leave the nest cavity even after the eggs had been removed, yet he still eluded capture. Personal observations of the guardian madtom before its departure revealed it to be a male, judged by its swollen head muscles and lips.

TABLE 8

Nesting Variables for *Noturus baileyi* in Citico Creek

Nest No.	Date	Water Temperature (C)	Habitat and Creek Mile	Length, Width[1] and Thickness of Nest Rock (cm)	Water Depth (cm)	Current (ft/sec)	Clutch Size	Sex and Length[2] (mm) of the Guardian or Breeding Pairs
1	7-2-82	23°	shallow pool 5.6	26.0:21.0:4.0	50	1.3	33	♂:U
2	7-2-82	23°	shallow pool 9.2	23.0:16.5:5.0	40	1.2	*	♂:55,♀:45
3	7-10-82	23°	shallow pool 10.1	30.0:25.0:3.0	23	0.8	40	U
4	7-10-82	23°	shallow pool 10.0	30.0:30.0:2.5	55	1.1	42	♂:52
5	6-2-83	18°	shallow pool 10.3	22.0:26.0:3.0	45	0.5	*	♂:63,♀:73
6	6-25-83	22°	riffle crest 9.4	40.5:35.5:5.0	25	1.8	*	♂:71,♀:70
7	7-8-83	23°	riffle crest 9.2	10.0:25.0:2.5	37	1.7	30	U

[1]Length and width of nest rock was based on widest and narrowest measurements across rock face.

[2]Length is expressed as total length (TL).

*Pre-spawning. U = Unknown (madtom escaped capture).

Upon exposure of nest number 3, the guardian madtom immediately fled; its sex could not be ascertained. The clutch size was estimated and placed back into the pit and the nest rock was repositioned over the nest cavity. Several hours later the nest was re-examined but the guardian madtom had not returned. Other fish or crayfish had evidently moved in and consumed most of the clutch as only a few eggs were left intact or whole.

Nest number 4 contained a newly spawned clutch which was removed to the lab for rearing but failed to hatch. The guardian madtom was reluctant to leave the nest cavity and was captured and preserved. Examination of its gonadal tissue revealed it to be a male. As in the guardian of nest number 1, he exhibited swollen head muscles and lips. Except for a single mayfly nymph (Isonychia sp.) his stomach was empty. Recent life history studies on species of Noturus have shown that males ultimately assume parental responsibility of the clutch post-spawning and do not feed while in that capacity (Clark 1978, Mayden et al. 1979, Burr and Mayden 1980, Mayden and Burr 1981, Burr and Dimmick 1981, Starnes and Starnes in press). A male N. flavipinnis guarding a nest at Citico Creek mile 9.0 was found to have an empty stomach and the remains of 11 chironomids in his hindgut, however the clutch was newly spawned and the hindgut contents may have been remnants from feeding before nest guarding began (Peggy Shute pers. comm.).

The spawning and nesting season for N. baileyi and N. flavipinnis overlap considerably in Citico Creek; male and female

yellowfin madtoms have been found in breeding condition from late to mid-July. Normally not syntopic with N. baileyi during the non-breeding season, juvenile yellowfin madtoms have been found under large, flat rocks in shallow pools in close proximity (less than 3 m) to N. baileyi nests and there may be some competition for these rocks.

Mayden et al. (1980) suggested that the enlarged head musculature of breeding male N. albater is associated with nest construction; the clearing and burrowing by males under large rocks during the spawning season necessitating the development of a sturdy cephalic musculature. Mayden (1981) concluded that nest construction by N. exilis apparently involves only adult males. On 2 June 1983, two gravid female smoky madtoms, 60 mm and 69 mm TL, were found under large, flat rocks approximately 2 m apart above a riffle at Citico Creek mile 10.3. The rocks measured 18 x 17 x 10 cm and 18 x 18 x 11 cm (length x width x thickness); water depth at the rocks was 51 cm. The area under each rock had presumably been prepared as a nesting site, as a cavity had been excavated. Both females were reluctant to leave their respective cavities. An intensive search of the riffle crest and adjacent shallow pool area revealed no other madtoms. It is unknown whether spawning eventually took place under these rocks as they were not checked at a later date.

The rocks under which N. baileyi constructed nests were much larger in overall dimensions than those used for cover during the remainder of the year. The area of the face of 7 nest rocks ranged from 25,000 to 143,775 mm^2 ($\bar{X}$ = 69075); thickness ranged from 25 to 50 mm ($\bar{X}$ = 36).

X. LARVAL DEVELOPMENT

On 2 July 1982, a clutch of 33 eggs was removed from a *N. baileyi* nest in Citico Creek and taken to the lab for study. The eggs were well developed, sulphur-yellow in color, and had cohesive properties so that they remained together in a clump but would not stick to other objects. Larvae could be seen rotating inside the chorion. Egg diameters ranged from 2.63 to 3.00 mm ($\bar{X}$ = 2.85, N = 4), yolk diameters ranged from 0.08 to 0.10 mm ($\bar{X}$ = 0.09, N = 4). The eggs were placed in a shallow petri dish containing well aerated stream water and kept at room temperature. At the time the nest was discovered, four eggs were preserved in formalin for measurement, one of which was in the process of hatching. As noted by Mayden (1981) in *N. exilis* eggs, *N. baileyi* hatchlings break through the chorion tail first. The remainder of the clutch hatched within the next 12 hours. Based on the clutch of 33 eggs, hatching success was 94%.

Hatchlings had heavily pigmented eyes and scattered melanophores on top of the head (Figure 6). All fins were formed but only the caudal and anal fins showed ray differentiation (Table 9). Ray primordia were evident in the dorsal fin. Four pairs of rudimentary barbels were present and the nares were discernible. The urogenital duct and anus were also evident. Hatchlings exhibited a tight schooling behavior and oriented themselves toward the air stone.

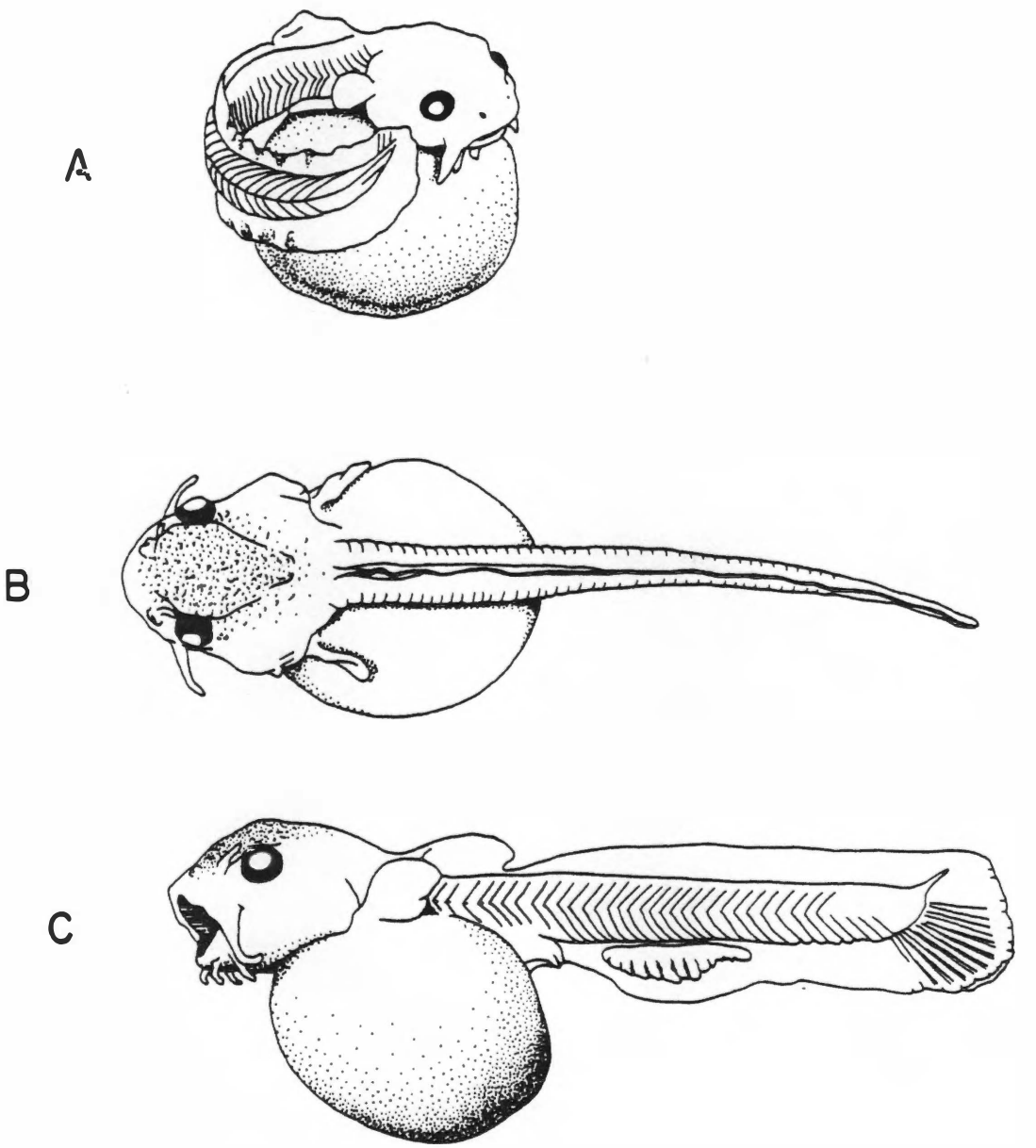

Figure 6. Larvae of Noturus baileyi. (A) Prehatching with chorion removed: (B) top and (C) side view of hatchling, 3.4 mm TL.

TABLE 9

Development of Larval Noturus baileyi Taken from Nest in Citico Creek on 2 July 1982
(The range is followed by the mean in parentheses)

Age (days)	N	Pectoral Rays	Dorsal Rays	Anal Rays	Caudal Rays	Pelvic Rays	Total Length (mm)
-1[a]	3	0	0	0		0	--
1[b]	2	0	0	9(9)	16-17(16.5)	0	3.7-3.9(3.8)
3	2	6(6)	6(6)	11-12(11.5)	19-20(19.5)	0	3.9-4.1(4.0)
6	2	6(6)	6(6)	11-12(11.5)	23(23)	5-6(5.5)	4.8(4.8)
12	2	8(8)	6(6)	12(12)	37-38(37.5)	8-9(8.5)	11.6(11.6)
18	2	8(8)	6(6)	12(12)	38(38)	8-9(8.5)	13.3-13.7(13.5)
20	3	8(8)	6(6)	12-13(12.7)	34-37(35.3)	8-9(8.3)	13.0-13.9(13.4)
26	5	7-8(7.8)	6(6)	12-13(12.8)	33-38(36.0)	8-9(8.2)	13.4-14.6(14.1)
Adult[c]	10	8(8)	6(6)	12-14(13.1)	42-49(46.2)	8-9(8.3)	--

[a]Prehatching (preserved less than 24 hours before hatching).

[b]Hatchling (less than 24 hours old).

[c]Data from Bauer et al. (1983); presented for comparison.

Three-day-old larvae had increased pigmentation on the dorsal surface as well as melanophores extending down to the anal region and dorsolaterally behind the dorsal fin (Figure 7). Melanophores could also be seen extending onto the yolk sac adjacent to the embryo. The dorsal fin had its adult complement of rays while the pelvic fins had yet to show any ray differentiation.

Six-day-old larvae had developing rays in all fins, including the pelvics (Figure 8). The pectoral and dorsal fins had developing spines. Pigmentation was more dense on the dorsum with melanophores extending posteriad almost to the origin of the caudal fin. The yolk sac was nearly absorbed.

Twelve-day-old larvae essentially resembled adults except for two characters: pigmentation and caudal ray number. Adult N. baileyi exhibited dark blotches or saddles on the dorsum, typical of all members of the subgenus Rabida (Taylor 1969). Twelve-day-old larvae were uniformly pigmented on the dorsal region (Figure 9). Young-of-the-year less than 30 mm SL collected in Citico Creek during the months of June and July did not exhibit saddled pigmentation. Fin ray counts did not appreciably change in the larval smoky madtoms from day 12 to 26. Adults were found to have 42 to 49 total caudal rays (Bauer et al. 1983); presumably full caudal development as well as adult pigmentation do not appear until well after the young leave the nest. Mayden and Burr (1982a) found that 24-day-old N. miurus larvae had melanophores distributed in a pattern over the body similar to that of an adult. Burr and Dimmick (1981) examined N. elegans larvae that had

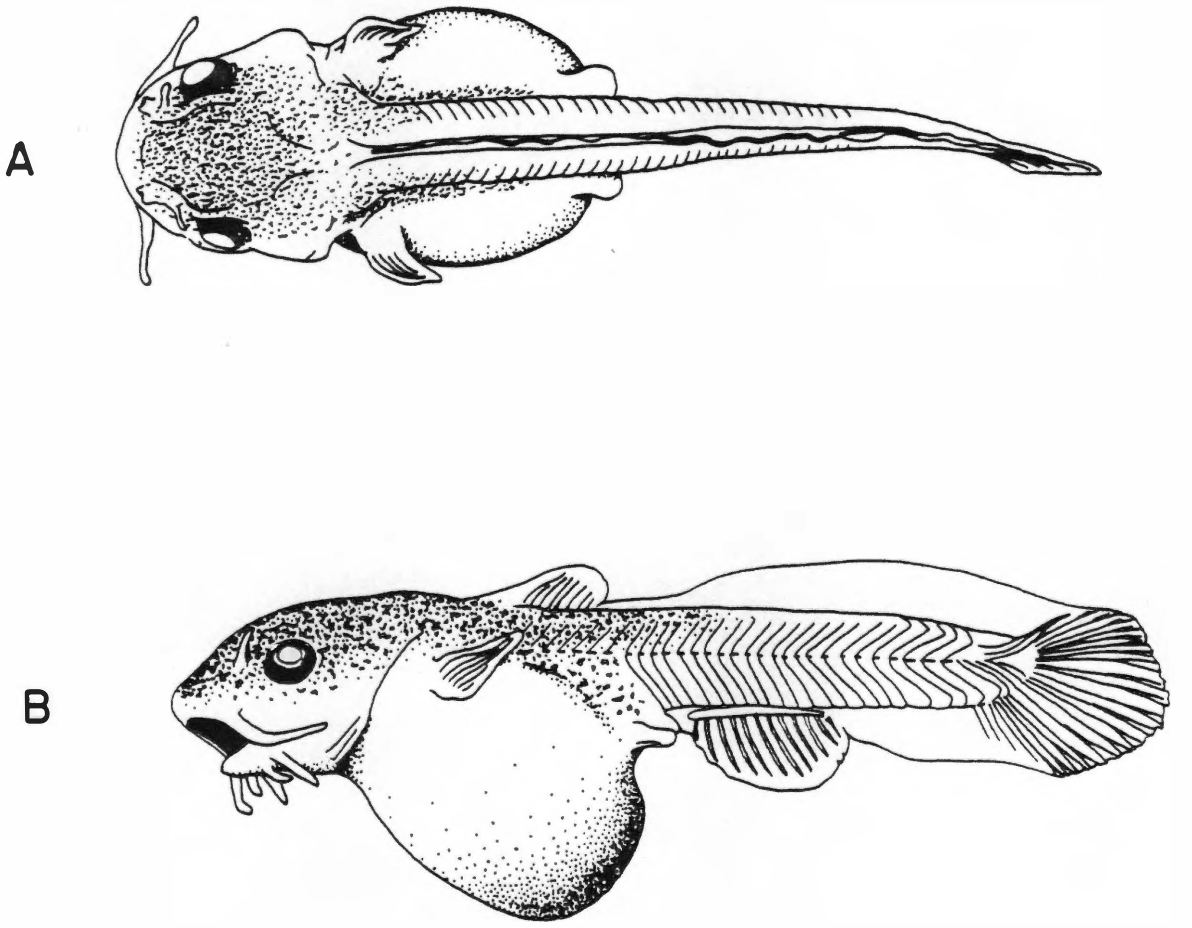

Figure 7. Top (A) and side (B) view of three-day-old larva, 3.5 mm TL.

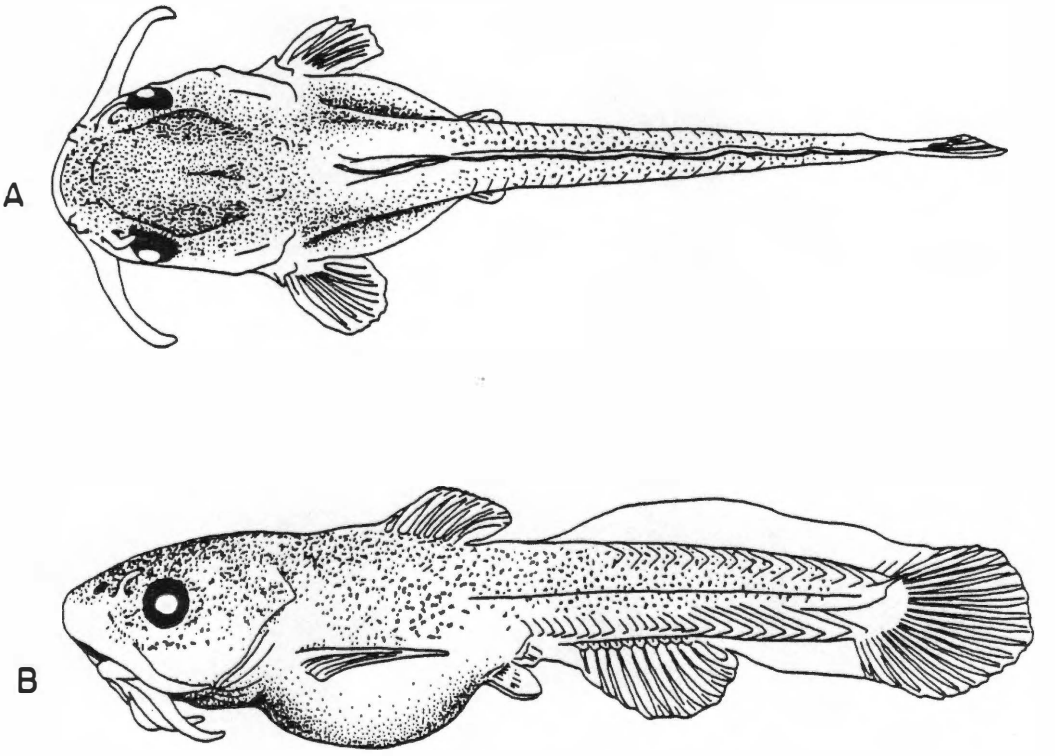

Figure 8. Top (A) and side (B) view of six-day-old larva, 4.3 mm TL.

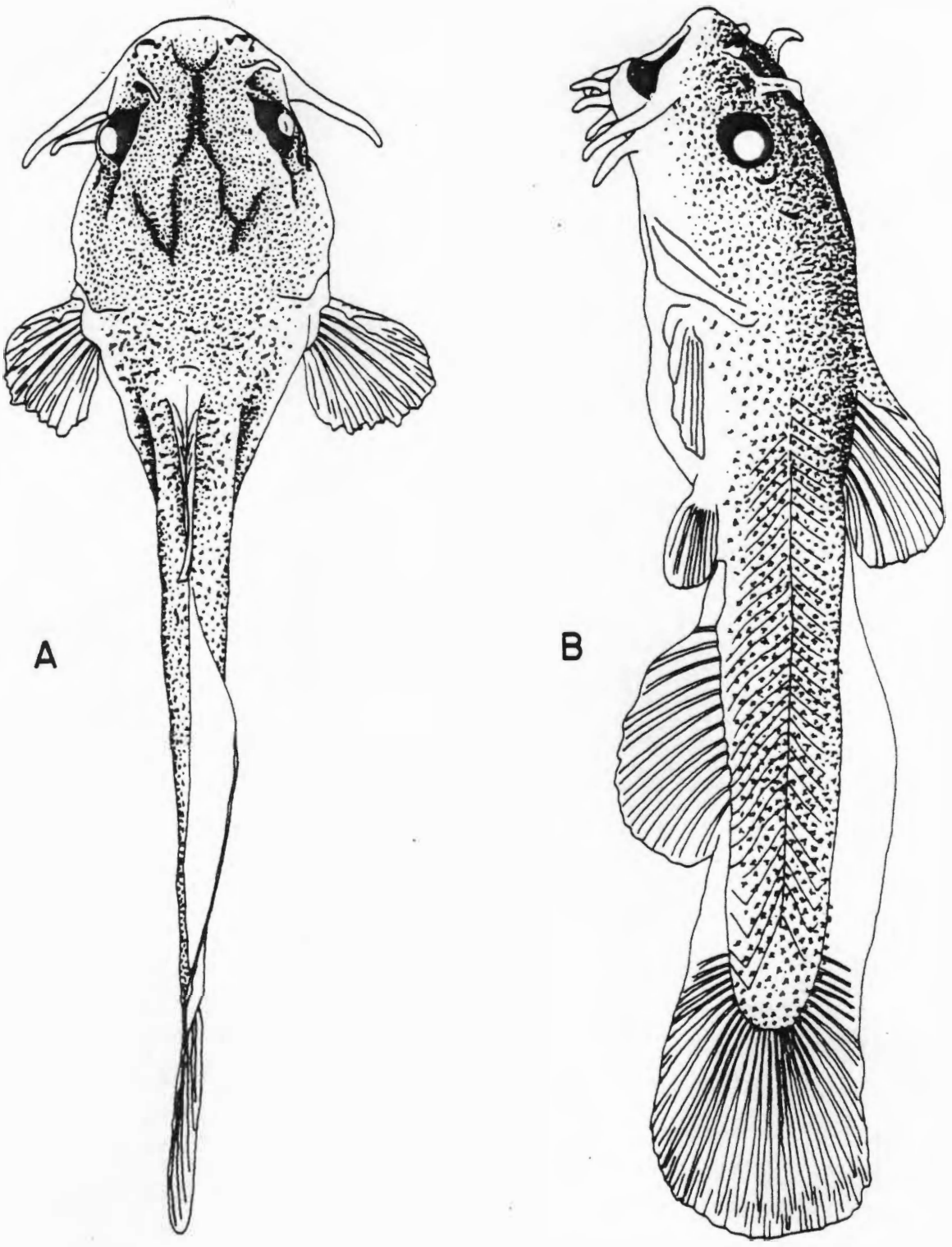

Figure 9. Top (A) and side (B) view of 12-day-old larva, 10.5 mm TL.

body form, fin ray, and spine complement like that of an adult and found that although the pigmentation was well advanced, the barred pigment pattern typical of the adult apparently develops later.

Twelve-day-old N. baileyi larvae were introduced to and began feeding on frozen brine shrimp. Over the next 13 days periodic mortalities occurred in the clutch of developing young. A moribund larvae was frozen and sent to Dr. John New of the College of Veterinary Medicine at The University of Tennessee for examination. Because of the larvae's size, the entire fish was macerated and cultured. No bacteria were seen on a direct smear of the tissue. Aeromonas hydrophila was cultured from the broth but not directly from the tissue. Pseudomonas putida was cultured from the tissue (two colonies). In addition, single colonies of Corynebacterium sp. and Lactobacillus sp. were also cultured. While these four bacteria were considered either insignificant or contaminants at the level present, the exact cause of death was unknown (Dr. New pers. comm.). Anaerobic cultures were negative.

XI. FEDERAL STATUS AND SUGGESTIONS FOR FURTHER STUDY

Currently N. baileyi is being considered for Endangered Species status survey findings and dialogue from the U.S. Fish and Wildlife Service indicate that federal status is forthright. The present range of this species magnifies the danger of even minor perturbations in the Citico Creek watershed. The fact that N. baileyi was extirpated from Abrams Creek while many other fish species survived the 1957 reclamation project documents its susceptibility to a single catastrophic event.

A joint effort by personnel from the U.S. Fish and Wildlife Service, National Park Service, Tennessee Wildlife Resource Agency, U.S. Forest Service, and The University of Tennessee is presently underway to reclaim the lost Abrams Creek population. If the viability of the Citico population is to be maintained, of importance is the establishment of a statistically sound population estimate of N. baileyi in Citico Creek. Development of a hatchery rearing scheme is also under consideration and appears promising due to the relative wealth of information on the commercial raising of larger members of the Ictaluridae.

XII. SUMMARY

1. Life history observations were made on N. baileyi utilizing in situ observations in their natural habitat, larvae reared in aquaria, and museum specimens. Distribution of N. baileyi in Citico Creek was discussed in relation to elevational gradient and soil associations.

2. Smoky madtoms occupied the undersides of palm-sized slabrocks to the exclusion of other fish species. Riffles, especially riffle crests, were the preferred habitats from late May to early November, when water temperatures ranged from 7° to 23° C. During the winter and spring months N. baileyi occurred in both deep and shallow pools; water temperature during this time ranged from 4° to 14° C. There was no relation between size of fish (SL) and thickness of surface area of the slabrocks under which smoky madtoms were found. Further, no significant difference was found between the riffle slabrocks and pool slabrocks used by smoky madtoms, in terms of rock thickness and rock-face area.

3. N. baileyi lived 2+ years. Females generally attained greater lengths than males.

4. Mayflies (Ephemeroptera) constituted the bulk of the stomach contents of 13 preserved N. baileyi.

5. Smoky madtoms exhibited secondary sexual characteristics typical of all members of the genus Noturus. Both sexes were in

breeding condition from May to July. Determining sex was possible only when individuals were in breeding condition.

6. Smoky madtoms nested under large, flat rocks in riffle crests, run/pools, and shallow pools from early June to late July. Clutch size in four nests averaged 36 eggs. As reported for other Noturus species, males guard the clutch. The postulation by other researchers that male madtoms prepare the nest cavity was questioned.

Slabrocks used for shelter were smaller than those used for nesting cover: mean surface area 8348.7 mm^2 vs. 69075 mm^2, mean thickness 20.3 mm vs. 36.0 mm.

7. Larval development was discussed and diagrammed. Adult pigmentation developed after the young left the nest.

8. Federal status and suggestions for further study of the Citico Creek population were discussed.

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