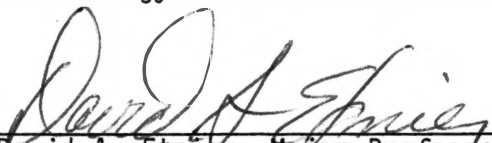


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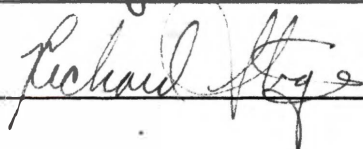
I am submitting herewith a thesis written by Peggy W. Shute entitled "Ecology of the Rare Yellowfin Madtom, Noturus flavipinnis Taylor, in Citico Creek, Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Zoology.



David A. Etnier, Major Professor

We have read this thesis and
recommend its acceptance:





Accepted for the Council:



The Graduate School

2

ECOLOGY OF THE RARE YELLOWFIN MADTOM, NOTURUS FLAVIPINNIS TAYLOR,
IN CITICO CREEK, TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Peggy W. Shute
June 1984

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Thomas Fields drew the map in Figure 2. Randy Shute delineated Figures 8, 9, 10, 11, 12, 18 and 19. Gerald Dinkins delineated Figures 13, 14, 15, 16, and 17, and lettered Figures 8 and 18. Dr. James Williams provided the photographs used in Figures 4, 5A, 6, and 20. Randy Shute provided photographs used in Figures 1, 5B, and 7. I also wish to thank Janice Nubold for her many editorial comments on the manuscript.

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ABSTRACT

The ecology and life history of one of three extant populations of the yellowfin madtom, Noturus flavipinnis Taylor, were studied, primarily by direct observations. Snorkeling at night with underwater flashlights was the most successful technique, as the species is nocturnal.

The yellowfin madtom was commonly found in shallow pools in Citico Creek. It inhabits a 3.6 km stretch of the creek from a small dam at creek km 13.8 to creek km 17.4. The size of this localized population was estimated by tag-recapture methods to be 549 individuals (312-1453, modified Schnabel). Recapture of six individually paint-tagged fish indicated that the population exists as separately isolated subpopulations, with little or no movement between pools.

Length-frequency histograms indicated that the yellowfin madtoms in Citico Creek may reach an age of three years, and that males attain a slightly larger average size than females. The largest specimen captured was 115 mm SL.

Initiation of nesting behavior is probably triggered by water temperatures of 20-23° C, and nests were found as early as 29 May and as late as 8 July. Newly fertilized eggs averaged 3.4 mm in diameter and were deposited beneath large, flat rocks. Males were observed guarding developing embryos and larvae. Clutch sizes averaged 89 embryos for two reproductive seasons, and the ovaries of

four female N. flavipinnis contained a mean of 177 ripe ova. Therefore, it is assumed that the species is polyandrous.

Ovarian eggs are separable into three distinct size classes. The mature ova from five females examined were 2.5-3.3 mm in diameter. Individual N. flavipinnis are not reproductively mature until their third summer of life (age two), and probably only spawn twice during their lifetime.

Freeswimming juveniles were observed in the Citico Creek population as early as August, and appeared to prefer smaller size substrate particles than adults. One recently hatched individual was 8.1 mm SL, and five young-of-the-year had reached an average standard length of 37.8 mm by November.

A total of 40 taxa representing sixteen families of organisms were identified from the guts of twelve N. flavipinnis. The diet is almost exclusively insect larvae, with dipterans, ephemeropterans, plecopterans, and trichopterans being the most important prey types consumed. The yellowfin madtom is probably mostly nocturnal and opportunistic in its feeding behavior.

Although the Citico Creek population of N. flavipinnis appears to be relatively healthy, it is dangerously small and extremely localized. This fact, coupled with the possible decline of the other two known populations, warrants continued protection (and possibly even upgraded from Threatened to Endangered) of the species.

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I. INTRODUCTION

The Mississippi River basin has apparently been the center of evolutionary radiation for the North American endemic catfish family, Ictaluridae, which includes the madtoms of the genus Noturus. The present area of Noturus species richness is in the eastern United States, and specifically in the uplands of the east central United States in a band from Arkansas and Missouri through North Carolina (Taylor 1969). Although the group is widespread and relatively diverse, their ecology and life history remained virtually unstudied until recently.

Madtoms were first discovered in the early nineteenth century (Taylor 1969), and some brief contributions were made on various aspects of life history of some of the known species (see Taylor 1969, for extensive bibliography); however, much of the literature dealt with systematics and confusing nomenclatorial problems. Indeed, Hubbs and Raney (1944), in a taxonomic work on the genus Schilbeodes (= Noturus), commented on the lack of available information on the habits of these madtom catfishes. Even by 1969, when Taylor synonymized the several described madtom genera into the genus Noturus, little was known of the thirteen previously described species. Taylor (1969) added ten new species and one new subspecies to the growing list of known madtoms, and since that time two additional species have been described (Douglas 1972, Etnier and Jenkins 1980). There are at present 25 described species and at

least one undescribed species (Jenkins 1976, Jenkins and Palmer 1978). Because of their small size, cryptic coloration, and secretive nature (mostly nocturnal) many of the species are infrequently collected, and this has surely contributed to the paucity of information on the genus.

In the southeastern United States, it is becoming increasingly more difficult to protect streams from direct or indirect damage of urban, industrial, or agricultural encroachment. As a result, there are only a few areas in which some species of Noturus have been able to survive. These species have present distributions that are fragmented remains of once more widespread populations (Taylor 1969). Many other madtom species have relatively restricted distributions, being endemic to one drainage, or shared exclusively between two drainages. Because of these localized distributions, many Noturus species have been listed as endangered, threatened, or of special concern by various states and societies. Nine species of concern were listed by the American Society of Ichthyologists and Herpetologists (ASIH) (Miller 1972), and ten species were listed by Williams (1981).

The sudden interest and concern for rapidly declining populations of Noturus has led to a recent flurry of ecological works on the group, including those of Clugston and Cooper (1960); Curd (1960); Thomerson (1966); Carlson (1966); Mahon (1977); Mayden et al. (1980); Burr and Dimick (1981); Mayden and Burr (1981); Burr and Mayden (1982 a, b); and Miller (1984). Several unpublished theses

and status survey reports have added knowledge concerning the habits of madtoms. These include Gilbert (1953); Andrews (1963); Case (1970); Madding (1971); Bowen (1980); Robison and Harp (1981 a, b); Moss (1981); and Dinkins (1982). In many cases, however, information required as sufficient to allow federal protection has not been easily obtainable, or if so, may be available only after it is too late to protect the species.

At present, two madtom species are officially listed by the federal government, N. flavipinnis Taylor as Threatened, and N. trautmani Taylor as Endangered (Rohde 1978). In addition, the recent discovery of the smoky madtom, N. baileyi Taylor, believed by most ichthyologists to have been extinct, has prompted the recommendation for protection under the federal Endangered Species Act (Dinkins 1982, Bauer et al. 1983). A study by Robison and Harp (1981a) has also recommended an Arkansas endemic, the Ouachita madtom, N. lachneri Taylor, for federal protection.

The contraction of the particular habitat type that most Noturus prefer is due to man's intervention and consequential degradation of water quality and this may explain increasing rarity of many madtom species. Catfish are known to be highly social animals, and bullheads (Ictalurus) have been reported to display sophisticated behaviors based on chemical input perceived by olfaction. They apparently recognize each other as individuals and are thus able to coexist successfully by forming dominance hierarchies (Atema et al. 1969, Todd et al. 1967, Todd 1973). As the majority

of madtoms are nocturnal, they presumably also rely heavily on chemoreception for survival (finding food, potential mates, and raising young). If this is the case, then the more sensitive members of the genus may be detrimentally affected by small changes in water quality. Etnier and Jenkins (1980) have speculated that "... recent extinction and extirpation . . . of several species of madtoms may, in addition to visible habitat degradation, be related to their being unable to cope with 'olfactory noise' being added to riverine ecosystems in the form of a wide variety of complex organic chemicals that may occur in only trace amounts."

This thesis presents ecological data obtained by monitoring reproductive success, demography, and food habits for one of three extant populations of the yellowfin madtom, Noturus flavipinnis. Although the population examined in this study is highly localized, it is hoped that the information obtained and methods for collecting data may be useful to insure the future protection of this species. This study may also enable investigators to monitor other populations of threatened madtoms.

Background

The yellowfin madtom, Noturus flavipinnis (Figure 1), was placed in the subgenus Rabida by Taylor (1969) and was considered to belong to a group of three similar allopatric species, the miurus species group, which also includes N. miurus Jordan and N. flavater Taylor. LeGrande (1981) agreed with Taylor's proposed relationship between N. flavipinnis and N. miurus on the basis of his karyotype



Figure 1. Male yellowfin madtom, *Noturus flavipinnis* Taylor 94 mm standard length.

studies. In his phylogeny, he considered N. flavipinnis to be the most primitive member of the subgenus, with N. flavater much more derived. Taylor (1969), on the other hand, considered his miurus group to be the most advanced within Rabida based mainly on specialization of pectoral spine serrae and relative increase in spine length.

Based on a few old collecting records and accounts by Jordan (1890), Evermann (1918) and Evermann and Hildebrand (1916), it appears that N. flavipinnis was probably once relatively common in most of the upper and middle Tennessee River drainage (Figure 2). Although a total of thirteen specimens were collected in 1884, 1888 and 1893, the species was not recognized as distinct until 1969 when Taylor revised the genus. Specimens Taylor examined included: one from the North Fork Holston River at Saltville, Virginia, collected by David Starr Jordan in 1888 (Jordan 1890); five specimens collected from Hines Creek, Clinton, Tennessee (type locality) by C. H. Gilbert and J. Swain in 1884 (Evermann 1918); one specimen from Chickamauga Creek at Lee and Gordon's Mill, Georgia, collected by B. W. Evermann in 1893 (Evermann and Hildebrand 1916); and six other specimens with no known locality data (Taylor 1969).

Burkhead and Jenkins (1982) questioned the validity of including the "Clinch River at Walker's Ford" and the "Tennessee River at the mouth of Lyon Creek" localities (Taylor 1969) as known collection sites for N. flavipinnis when specimens were not examined from these localities. They suggest that Evermann and Hildebrand may

Figure 2. Map of the upper Tennessee River drainage. Open circles indicate extirpated and solid circles indicate extant populations of Noturus flavipinnis.

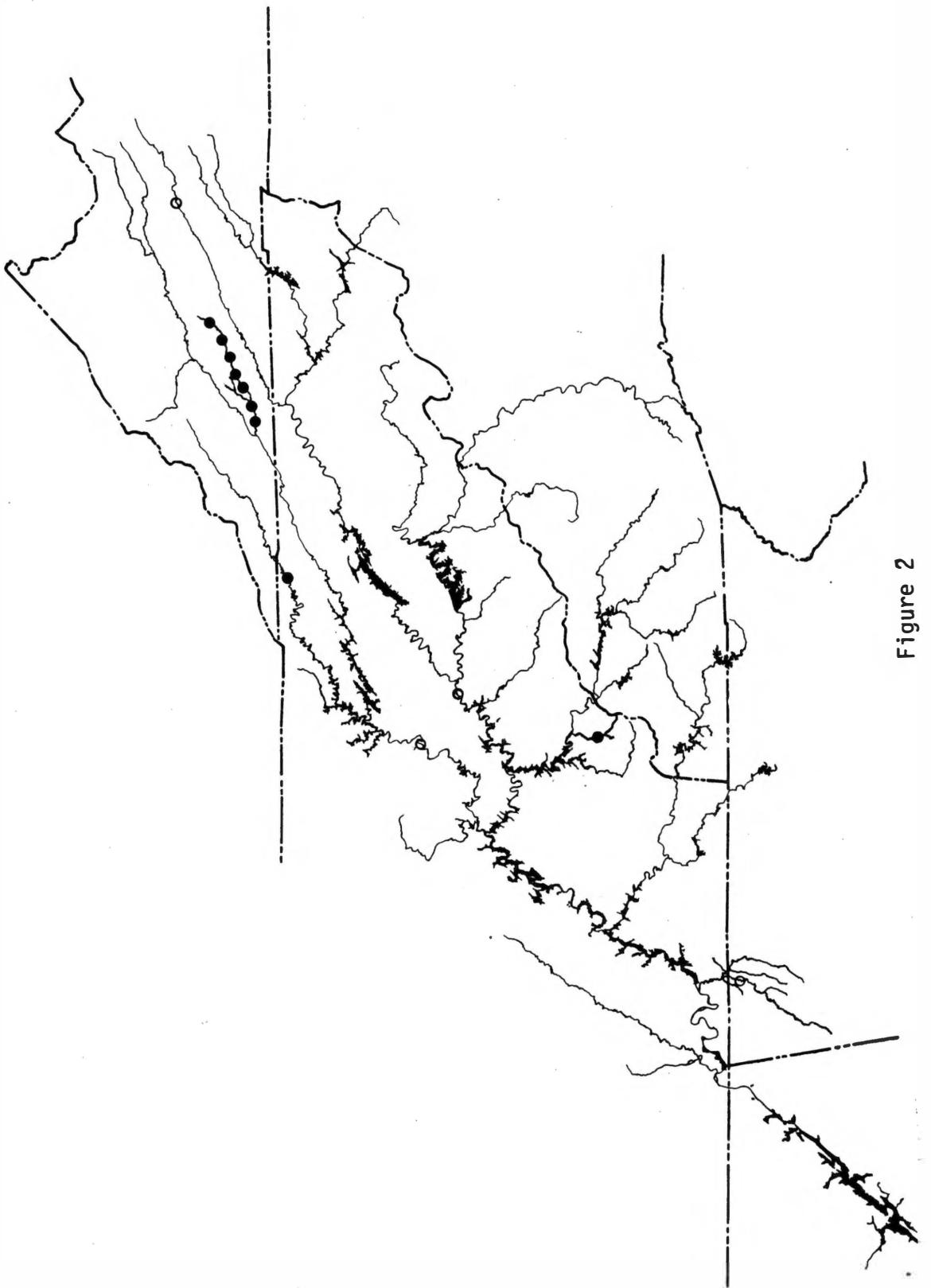


Figure 2

not have distinguished between N. flavipinnis and N. eleutherus Jordan. Taylor listed these specimens as N. flavipinnis but did not map the localities on his distribution map for N. flavipinnis.

However, based on the three collections that Taylor did examine, it is apparent that the former range of the yellowfin madtom included the Ridge and Valley Province in the upper Tennessee River drainage of Georgia, Tennessee, and Virginia. At the time of his revision Taylor presumed the species had become extinct since the capture of the last specimen in 1893. The Clinch River, Tennessee River, and Chickamauga Creek populations were believed to have been extirpated because of habitat alterations (due to impoundments) in most of the upper Tennessee River drainage, and pollution in Chickamauga Creek. Habitat quality in the North Fork Holston River was believed to be adequate to support the madtom, but attempts to collect any additional specimens of the yellowfin madtom in this locality have been futile. Taylor (1969) mentioned the possibility of extirpation in this area due to the inability of the species to compete with an apparently recently established member of the community, the margined madtom, N. insignis (Richardson) (possibly introduced by stream capture or bait bucket from Atlantic drainages).

Since Taylor's original description, three geographically isolated populations of the yellowfin madtom have been discovered. One specimen was taken in 1968 during nighttime sampling in the Powell River (an upper Tennessee River tributary) at McDowell Shoals (river km 171.8, Hancock County, Tennessee) by Tennessee Valley

Authority biologists (Taylor et al. 1971; Charles Saylor pers. comm.). In 1969, four samples from the mouth to the upper sections of Copper Creek (a Clinch River tributary in Scott and Russell counties, Virginia, yielded 28 specimens of N. flavipinnis. The species was redescribed by Taylor et al. (1971) based on these individuals.

Jenkins (1975) recommended threatened status for N. flavipinnis for several reasons: the vulnerability of Copper Creek and the Powell River to coal mining and agricultural activities and the potential for chemical spills to occur in Copper Creek because of major road crossings. On 9 September 1977, the yellowfin madtom was listed as a Threatened species. The Critical Habitats (i.e., the areas which are protected because they are presumed to be critical to the survival of the species) were listed as the main channel of the Powell River from Lee County, Virginia, downstream to the backwaters of Norris Lake; and Copper Creek from Dickensonville, Virginia, downstream to its confluence with the Clinch River (Anonymous 1977).

Jenkins (1975) and Taylor (1969) described the habitat of the yellowfin madtom as pools and backwaters of warm-water streams with moderate gradient. Jenkins further suggested that N. flavipinnis had probably not dispersed into the higher gradient streams of the Blue Ridge physiographic province since all known collections of the species were from the Ridge and Valley province and since its close relatives, N. miurus and N. flavater, are known to inhabit low gradient streams.

However, in June, 1981, five specimens of N. flavipinnis were discovered by a University of Tennessee graduate student, G. R. Dinkins, while snorkeling at night in Citico Creek, Monroe County, Tennessee (a Little Tennessee River tributary). This Citico Creek population represents an additional locality and is apparently confined upstream of a small concrete dam in higher elevations and cooler waters rather than in the lower portions of the creek, which is more typical (Burkhead and Jenkins 1982). The lack of intraspecific variation between these disjunct populations of N. flavipinnis indicates a relatively recent continuous population (Starnes and Etnier manuscript).

The discovery of the Citico Creek population is especially significant due to the fact that other known populations may be in danger. Burkhead and Jenkins (1982) indicated that the Copper Creek population of N. flavipinnis appears to be declining, and Jenkins (pers. comm.) noted that during four trips to Copper Creek in June 1983, with good collecting efforts for N. flavipinnis, no specimens of the yellowfin madtom were taken.

Although the Powell River has been sampled intensively since 1968 (Joe Feeman and Charles Saylor pers. comm.), only two other specimens of the yellowfin madtom have been taken. Both of these specimens were collected at Buchanan Ford (river km 159.6, Claiborne County, Tennessee). One was captured in 1979 by TVA biologists while seining at night, and another individual was collected by the author and other University of Tennessee graduate students in September 1983.

Ahlstedt and Brown (1980) indicated that water quality problems present in the Powell River due to land disturbance and coal mining activities may have already eliminated several species from the benthic community and may severely impact those remaining.

The Copper Creek and Powell River populations of the yellowfin madtom appear to exist in very low numbers, and both are threatened with probable extirpation in the near future. It is hoped that the information presented herein will help to prevent the extinction of this rare fish by reporting elements essential to their survival.

Study Area

Citico Creek is a moderate size (10 to 25 m width) pristine fourth order stream located in eastern Tennessee (Figures 2 and 3). The headwaters of the stream originate in the Cherokee National Forest, along the Tennessee/North Carolina state line and the creek is a direct tributary to the Little Tennessee River (into Tellico Reservoir). The lower portion of the creek above the area inundated by Tellico Reservoir (creek km 0-48) is located in the Ridge and Valley physiographic province (creek km 4.8-approximately 17.4), and moderate elevational gradient, cool water, and alternating riffles and pools with gravel boulders and cobbles, slabrocks, and bedrock characterize this portion of the stream. A small concrete dam constructed in 1973 (creek km 13.8) (Figure 4) to enhance the trout fishery in the upper portion of the stream is located in an area of the creek which is transitional between the lower elevations of the Ridge and Valley and the higher elevation where the stream enters

Figure 3. Map of Citico Creek. Range of Noturus flavipinnis is indicated by stipling. The arrow to the left of the stipled area indicates Caney Creek. Modified from Bauer et al. (1983).

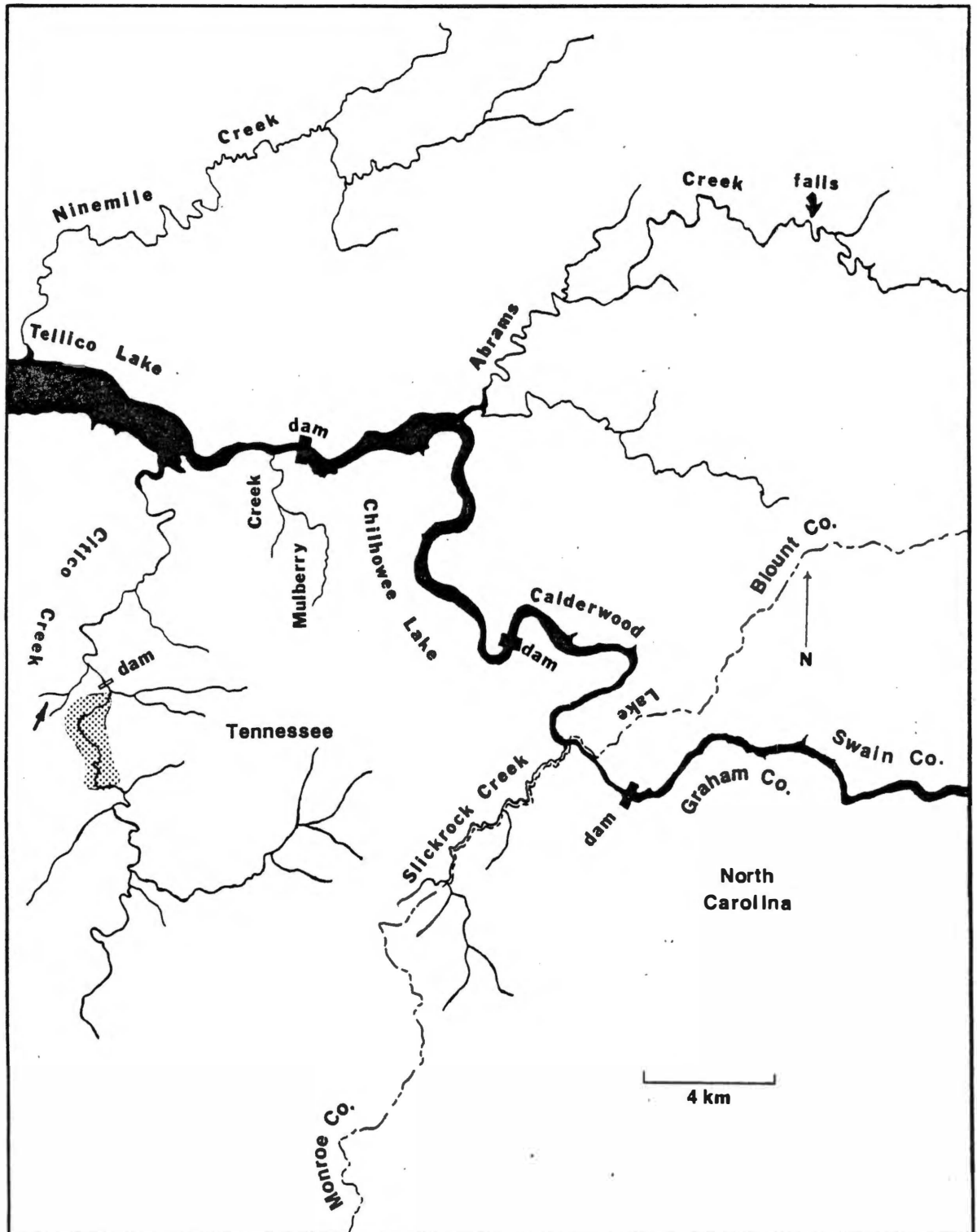


Figure 3



Figure 4. Dam located at Citico Creek km 13.8.

the Blue Ridge physiographic province. In this portion of the creek, gradients become more abrupt and large boulders and bedrock become more predominant. Pools are deeper and less frequent. Elevation in the creek ranges from 256 m at the U. S. Forest Service boundary at creek km 6.9 to 427 m at the confluence of Doublecamp Creek (creek km 26.7). Gradients in the creek range from 1.9 m per km in the lower portions of the creek to 3.8 m per km in the transition zone, to 7.6 m per km in the stretch of the creek between the transition zone and the confluence of Citico and Doublecamp creeks.

Most of the watershed is heavily forested and mountainous, and is within the Cherokee National Forest and the Tellico Wildlife Management Area. Although the watershed receives an average of 152 cm of precipitation annually (Anonymous 1972), the creek water is seldom turbid, and the bottom is relatively free of organic debris and silt.

In the lower stretches and transition zone the creek consists mainly of alternating riffles with palm-sized rocks and cobble substrates and long, shallow pools with medium-sized gravel, pebbles, slabrocks and bedrock substrates. With the gradient and elevation change, pools become deeper, shorter, and bedrock and large boulders make up a larger portion of the substrate.

Fish life in Citico Creek is fairly diverse. Fifty-one species are present or have been collected from the stream (Table 1), and in addition to N. flavipinnis, the fauna also includes two other rare fishes: Noturus baileyi, the smoky madtom, which has been proposed

Table 1. List of Fish Species Found in Citico Creek, Tennessee

<u>Ichthyomyzon castaneus</u>	chestnut lamprey
<u>Lampetra appendix</u>	American brook lamprey
<u>Lepisosteus oculatus</u>	spotted gar
<u>Salmo gairdneri</u>	rainbow trout
<u>Salmo trutta</u>	brown trout
<u>Salvelinus fontinalis</u>	brook trout
<u>Camptostoma anomalum</u>	stoneroller
<u>Cyprinus carpio</u>	carp
<u>Hybopsis amblops</u>	bigeye chub
<u>Hybopsis insignis</u>	blotched chub
<u>Hybopsis monacha*</u>	spotfin chub
<u>Nocomis micropogon</u>	river chub
<u>Notropis coccogenis</u>	warpaint shiner
<u>Notropis cornutus</u>	common shiner
<u>Notropis galacturus</u>	whitetail shiner
<u>Notropis leuciodus</u>	Tennessee shiner
<u>Notropis lirus</u>	mountain shiner
<u>Notropis spilopterus</u>	spotfin shiner
<u>Notropis telescopus</u>	telescope shiner
<u>Notropis sp.</u>	sawfin shiner
<u>Phoxinus phoxinus</u>	mountain redbelly dace
<u>Rhinichthys atratulus</u>	blacknose dace
<u>Hypentelium nigricans</u>	northern hogsucker
<u>Moxostoma (erythrurum or duquesnei)</u>	golden or black redbreast
<u>Ictalurus melas</u>	black bullhead
<u>Ictalurus natalis</u>	yellow bullhead
<u>Noturus baileyi</u>	smoky madtom
<u>Noturus flavipinnis</u>	yellowfin madtom
<u>Pylodictis olivaris</u>	flathead catfish
<u>Fundulus catenatus</u>	northern studfish
<u>Ambloplites rupestris</u>	rockbass
<u>Lepomis auritus</u>	redbreast sunfish
<u>Lepomis cyanellus</u>	green sunfish
<u>Lepomis gulosus</u>	warmouth
<u>Lepomis macrochirus</u>	bluegill
<u>Lepomis megalotis</u>	longear sunfish
<u>Micropterus dolomieu</u>	smallmouth bass
<u>Micropterus punctulatus</u>	spotted bass
<u>Micropterus salmoides</u>	largemouth bass
<u>Pomoxis annularis</u>	white crappie
<u>Etheostoma sp.</u>	duskytail darter
<u>Etheostoma blennioides</u>	greenside darter
<u>Etheostoma jessiae</u>	blueside darter
<u>Etheostoma rufilineatum</u>	redline darter
<u>Etheostoma simoterum</u>	Tennessee snubnose darter
<u>Etheostoma zonale</u>	banded darter
<u>Percina caprodes</u>	logperch
<u>Percina evides</u>	gilt darter
<u>Perca flavescens</u>	yellow perch
<u>Aplodinotus grunniens</u>	freshwater drum
<u>Cottus caroliniae</u>	banded sculpin

Compiled from personal observations, records from The University of Tennessee fish collection, and a U.S. Forest Service memo.

*Probably extirpated.

for federal Endangered status (Bauer et al. 1983, Dinkins 1982), and the undescribed duskytail darter, Etheostoma sp. which is considered threatened by the states of Tennessee (Starnes and Etnier 1980) and Virginia (Jenkins and Musick 1980), and is also listed federally as threatened by the American Fisheries Society (Deacon et al. 1979).

The shallow pool habitat required by the yellowfin madtom is common in the lower portion of Citico Creek, but thorough surveys indicate that N. flavipinnis populations in Citico Creek are confined to a 3.2 km stretch of the creek upstream of the small concrete dam located at creek km 13.8. Although this dam is an adequate barrier to fish migration within the creek, there seems to be no good explanation for the existence of N. flavipinnis populations above rather than below the dam. In fact, the opposite situation might be expected as the yellowfin madtom appears to inhabit more lowland areas in the Powell River and in Copper Creek.

The autecology of the yellowfin madtom in Citico Creek was studied primarily by observations of the populations inhabiting two adjacent pools. These pools, located at creek km 16.4, were representative of two different types of pool habitat that could be found in the stretch of the stream inhabited by N. flavipinnis. The downstream pool is long and shallow, 147 m long, and averages about one meter midstream depth. Substrate consists mainly of gravel and pebbles, with occasional slabrocks. Boulders and bedrock predominate at the head of the pool, and bedrock shelves line the northern shore

of the pool. Current velocity is moderate to slow in this pool (0.33 m/sec, Figure 5A). The upstream pool is 173 m long and deeper, with large portions of the pool deeper than 2.5 m. The substrate is mainly characterized by large boulders and bedrock. Current is somewhat swifter in this pool. The two pools described above are separated by a riffle area (45 m in length, Figure 5B) and a ford. Stream discharge at this point is 4.9 cubic meters per second.



A



B

Figure 5. (A) Lower study pool; (B) riffle separating study pools.

II. METHODS AND MATERIALS

Collection of Fishes

Conventional techniques are generally unsuccessful for collecting this species because of its highly secretive and nocturnal nature and its presumed ability to bury into the gravel (Stegman and Minckley 1959). In addition, the pools inhabited by the yellowfin madtom are often difficult to seine efficiently because of large boulders. The clarity of Citico Creek waters also enables fish to elude capture by seines moving slowly through the "obstacle course" of boulders.

The most successful technique for collecting individuals or observing the yellowfin madtom populations in Citico Creek is by direct observation with a face mask and snorkel or SCUBA diving gear. This direct observation technique has also been used in observing and collecting other rare species (Pflieger 1978, Hickman and Fitz 1978), and may be preferable in such cases as it does not disturb critical habitats or unduly stress the fish, and it is often more efficient than seining in certain habitats.

The direct observation technique was used most often to collect the yellowfin madtom during this survey, and with the exception of the breeding season, this method was successful only when conducted after sunset. To collect the fish a series of collectors (experienced "madtomologists" who had developed a proper search image for the madtoms) were spaced across the pool and each

collector swam the length of the pool. The collectors searched in the open, under rocks, and under debris, using underwater flashlights to spot the madtoms. When individuals were spotted, they were usually not difficult to capture because the bright lights seemed to temporarily hypnotize these fish. The majority were captured by using small dipnets, and on some occasions a slurp gun was used. Very few individuals evaded capture, and the ones that did were often seen again and caught during a second swim through the pool. Flow-through minnow buckets were used to contain the madtoms while snorkeling to insure that the fish were not unduly stressed by water quality changes while confined.

An alternative method of observation was used during the breeding season, for at this time the yellowfin madtom could be found during the day by searching beneath (and carefully lifting) large slabrocks used for nests (See Figure 6). After this initial discovery, however, surveys were not conducted in pools with known populations of N. flavipinnis during the breeding season for fear of dislodging the egg mass or disturbing the larvae. Dislodged eggs (or larvae) were easily lost and the ubiquitous minnows often found these before the observer was able to replace them. There was also the possibility that the guardian male would not return to care for his brood after fleeing.

Because of the rarity of the species, very few specimens were preserved; therefore most individuals captured in the manner described above were used for length and weight measurements and



A



B

Figure 6. (A) Method used for searching beneath slabrocks for nests of Noturus flavipinnis; (B) typical nesting slabrock.

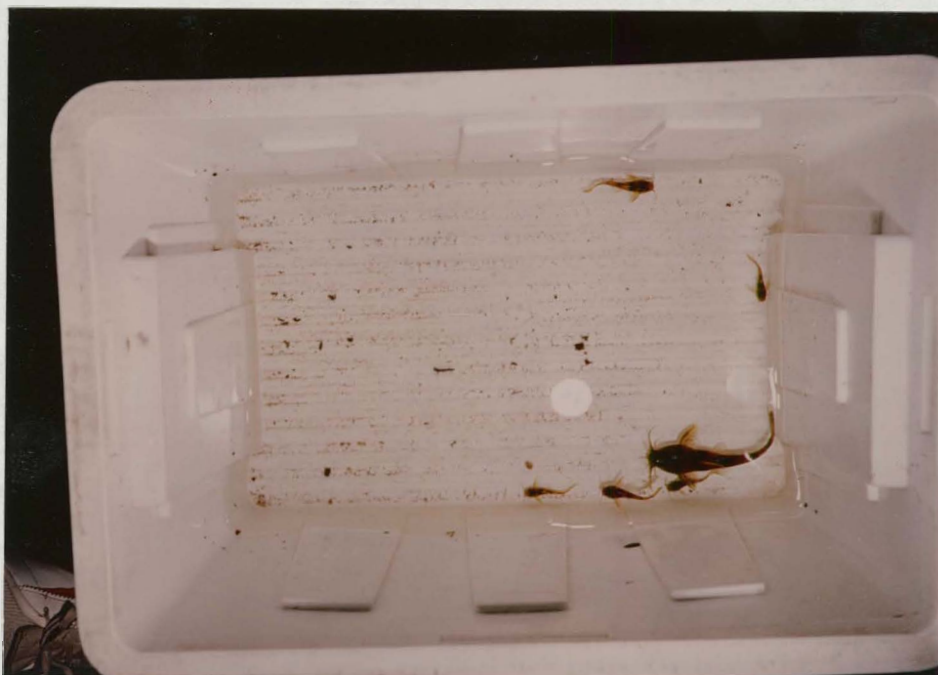
released into the same pool from which they were removed (Figure 7). To minimize temperature changes during this period, madtoms were held within an insulated container.

During the survey, a total of 12 yellowfin madtoms was preserved for laboratory study. These specimens were preserved in a 10% formalin solution and were later stored in 40% isopropanol.

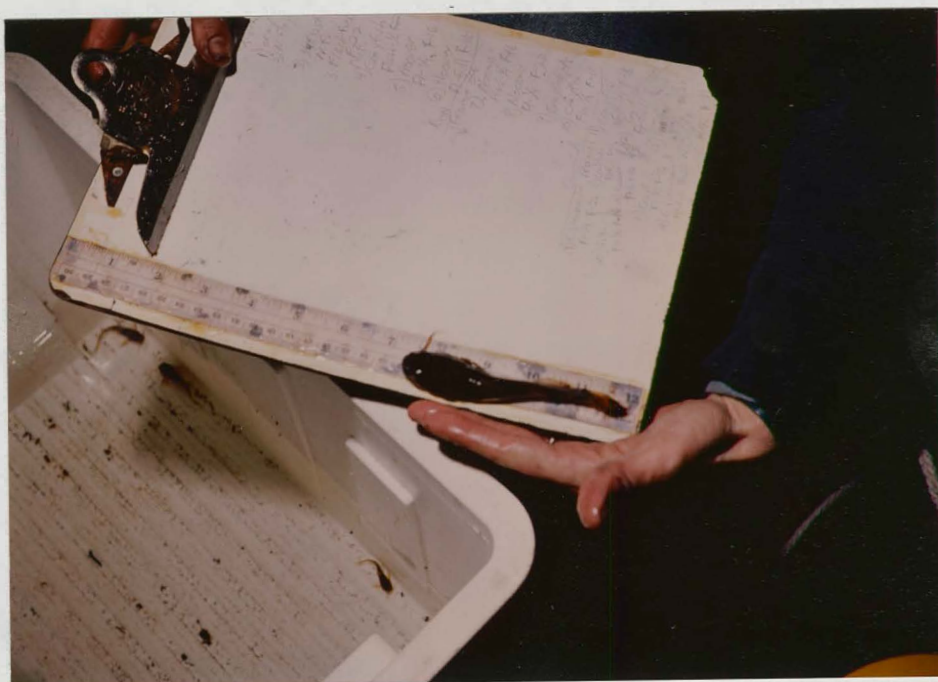
At the beginning of this survey, both standard and total lengths (SL and TL) were recorded (to the nearest mm) in the field, and these data were used to compute a linear regression of SL versus TL. Total and standard length of preserved specimens were also included in the regression analysis. Therefore, only total lengths were recorded in the field and were later converted to standard lengths. Preserved specimens were weighed on an analytical single pan balance to the nearest 0.01 gram.

Range Determination in Citico Creek

Pools with potential habitat for yellowfin madtoms were surveyed by searching beneath the characteristic nest-sized slabrocks during the breeding season. If at least one individual was discovered in a particular pool, it was assumed that there was a resident population, and the effort was then concentrated on the next adjacent pool. This was the manner in which the upstream limit of the species was determined. This same technique was used to locate any populations which may have existed downstream of the dam, and to corroborate the results from these breeding season surveys, most pools between



A



B

Figure 7. Specimens of Noturus flavipinnis contained (A) while recording lengths; (B) in the field.

the dam and the inundated area were surveyed by snorkeling at night in the previously described manner.

Tagging and Population Estimation

In order to observe individual growth rates, longevity, movement, and population density, fish were marked by injecting a small amount of a mixture of acrylic paint and water under the skin and released back into their respective pools (Thresher and Gronnel 1978). Fish were individually marked by using different combinations of colors and body locations.

To test the marking and handling procedure (percent mortality) and the longevity of the tags, five mountain madtoms, N. eleutherus, were marked and kept in a laboratory aquarium. Two additional mountain madtoms were kept in the same aquarium for controls. This experiment, which began on 28 October 1981, was terminated 8 May 1982, when disease killed the fish.

Fin clipping was used to estimate population sizes in each pool, and also to provide additional data on migration between pools. Young-of-the-year (YOY) fish were omitted from this phase of the study because it was feared that the procedure would prove much more detrimental to these small fish than to the adults. Including these YOY was also believed to provide a less realistic population estimate, as the young are very cryptic and could be very easily overlooked during the census periods.

Adult fish collected in the downstream pool were tagged by clipping the left pelvic fin with surgical scissors as close to the

body as possible, and the right pelvic fins were removed from specimens captured in the upstream pool.

This experiment was initiated after the breeding season was over and before winter (August 1983 to October 1983) in order to meet the conditions (no recruitment or mortality) of multiple census recapture studies (Ricker 1975). During each census subsequent to the initial tagging, the number of recaptured fish and location of marks were recorded, and any unmarked fish were also tagged. From these data two different population estimates (Schumacker and modified Schnabel) and confidence limits were determined for each pool in the manner described by Ricker (1975).

By measuring the length of each pool and characterizing the pool habitat as compared with the downstream or upstream study pools within this stretch of stream, the total pool length for each of the two types of pools was determined for the stretch of Citico Creek known to be inhabited by the yellowfin madtom. Individual pool population estimates were then extrapolated to include this entire 3.2 km stretch of the creek. Confidence limits for these total population estimates were also obtained by extrapolating individual confidence limits in the same manner.

Age Determination

An attempt was made to determine age on several available preserved specimens of N. flavipinnis by mounting pectoral spines in the method described by Clugston and Cooper (1960). As this method was unsuccessful, length frequency data (from preserved specimens

and individuals captured and released) and acrylic tagging data were the main methods used to determine age classes and longevity in the yellowfin madtom. These data from the Citico Creek population were also compared with length frequencies of specimens collected from Copper Creek and the Powell River.

Reproduction and Early Life History

To determine the extent of the breeding season, gonads of preserved specimens were examined. In addition to the preserved specimens, the gonads were removed and preserved in a 10% formalin solution from two specimens collected and immediately frozen on dry ice for an electrophoretic study by James Grady (Southern Illinois University).

A gonadosomatic index was computed for males by comparing the greatest width of the left testes to the square root of the standard length (Schenck and Whiteside 1977). The width of the left testis was measured to the nearest 0.025 mm using an ocular micrometer and a binocular dissecting microscope. Female gonadosomatic indices were computed by comparing the entire ovary weight with the adjusted body weight (body weight without abdominal contents) as described by Mayden and Burr (1981). Gonads were weighed to the nearest 0.01 g on a single pan analytical balance after thorough blotting on paper towels.

Fecundity was determined by examination of ovaries from preserved museum specimens with the aid of a dissecting microscope. Ova were excised from the ovary and sorted into various size classes,

the diameters measured with an ocular micrometer, and counted. Estimates of clutch sizes observed in the field were compared with the average number of mature (translucent) ova found in the ovaries of preserved mature females.

One clutch of eggs was removed from the field and taken to the laboratory where they were placed in a small container with creek water and maintained at 18 to 20° C. An airstone was placed in the container to provide adequate aeration and to prevent the buildup of silt on the egg mass. A few specimens of eggs and larvae were periodically removed and preserved in 5% buffered formalin. The early life history of N. flavipinnis was studied in this manner, although rearing the larvae to an advanced age was unsuccessful. Illustrations of egg and larval stages were made with the aid of a camera lucida and a dissecting microscope. Larval terminology used follows that of Snyder (1976).

Diet

Although few preserved specimens exist, an indication of food preferences was noted by examination of the gut contents of those museum specimens available from Citico Creek. In addition, the alimentary canals were removed from two specimens that had been collected and immediately frozen on dry ice for an electrophoretic study.

Prey items were examined with the aid of a dissecting microscope and identified to the lowest possible taxon. Food items were expressed as a percentage of the total number of items identified

(percent frequency of occurrence) and also as the percentage of composition of that prey item in the different guts examined.

III. RESULTS AND DISCUSSION

Habitat

According to Jenkins (1978), N. flavipinnis is an inhabitant of pools and backwaters. In Citico Creek, the yellowfin madtom was commonly found in shallow pools (less than one meter deep) and was almost always observed at depths of less than two meters in deeper pools. No yellowfin madtoms were found during nighttime benthic surveys (with the aid of SCUBA equipment) in the deeper part of the upstream study pool. With the exception of the breeding season, they were diurnally associated with cover, presumably near the stream bank beneath bedrock ledges or tree roots, as thorough searching beneath rocks in the main stream bed rarely revealed any individuals during daylight hours. During spring, summer, and fall, the adult madtoms were nocturnally associated with open benthic areas or under cover during their nighttime forages. Adults were increasingly scarce in open benthic areas as the water temperature decreased in late fall (Table 2), and it is presumed that very little adult activity occurs during the winter months. The young-of-year (YOY) yellowfins appeared to prefer benthic areas where substrate was primarily fine gravel or sand and gravel mixed, as opposed to the cobble, slabs and bedrock substrates that adults seemed to prefer. Young of the year madtoms also appeared to remain active longer in the late fall or winter than adults (Table 2). Possibly the young fish did not grow fast enough during their first summer to have enough stored energy

Table 2. Number of Adult and Young Noturus flavipinnis Taken from Citico Creek at Various Water Temperatures

Date	Water Temperature	No. Adults Collected	No. Young Collected
3-12-83	10° C	21	0
5- 8-83	14° C	6	0
6- 2-83	16° C	11	0
6-14-83	20° C	6	0
6-25-83	22° C	6	0
7- 8-83	18° C	2	0
7-15-83	18° C	4	0
8-16-83	21° C	11	6
8-25-83	25° C	10	4
9- 1-83	22° C	13	2
9-28-83	17° C	15	4
10-16-83	13° C	7	10
11-13-83	6° C	1	5

reserves to enable them to last through the winter without continuation of foraging.

Case (1970) carried out overwintering experiments on the tadpole madtom, N. gyrinus, by subjecting seven madtoms to winter water temperatures in a laboratory aquarium. He observed occasional activity by the madtoms, but the majority of the time was spent huddled together on the bottom. No feeding took place until the water temperature rose to 3.5° C. Bowman (1932) reported congregations of margined madtoms, N. insignis, during the winter, and Andrews (1963) also observed winter concentrations of stonecats, N. flavus, and brindled madtoms, N. miurus.

This may also be the case with the yellowfin madtom in Citico Creek. On 13 November 1983, when five YOY were captured, only one adult was taken (Table 2). This adult was noticed only because its yellow caudal fin was protruding from a large mat of newly fallen leaves that had been deposited in a large quantity in the head of the pool. The cryptic coloration of N. flavipinnis (see Figure 1, p. 5, yellow/brown mottling) made detection of individuals in such places very difficult by direct observation techniques used in this study.

Range Within Citico Creek

The yellowfin madtom is known to inhabit only a 3.6 km stretch of Citico Creek between creek km 13.8 and 17.4 and is confined upstream of a small concrete dam at creek km 13.8 (Figures 3 and 4, pp. 13 and 15). The factor limiting upstream distribution of the

species and also its congener, N. baileyi, found also in Citico Creek, appears to be habitat change associated with gradient change as the creek ascends into the higher elevations of the Blue Ridge physiographic province.

The absence of the yellowfin madtom downstream from the dam at creek km 13.8 is enigmatic. Their range within the creek would more likely be expected to include the pools in the lower stretch of the stream. Therefore, to corroborate the daytime (breeding season) surveys of pools below the dam, most pools between the dam and the inundated area were surveyed by snorkeling at night, but no populations were found below the dam.

It is obvious that the N. flavipinnis population present in Citico Creek is a relict one. The species must have once occupied the pools in the lower stretches of the creek, as pool habitat in this area is plentiful and appears comparable to that found above the dam. A degradation of water quality below the dam is the first possibility that may be suggested to explain extirpation. The majority of the watershed is located within the Cherokee National Forest and is heavily forested, and water quality throughout the entire creek appears to be excellent. On several occasions following heavy rains, however, it has been observed that the stretch of Citico Creek below the mouth of Caney Creek (creek km 11.2 (see Figure 3, p. 13)) receives a great deal of runoff, and the creek waters become extremely turbid. On these occasions, there has been a marked decrease in turbidity immediately above the mouth of this creek.

Although Caney Creek is a relatively small (approximately two meters wide at its mouth) third order stream, its headwaters arise on private property, and it drains a fairly large area. It is possible that agricultural practices in this area are causing the siltation problem.

The presence of the smoky madtom, N. baileyi, in the lower stretch of Citico Creek adds further complexity to this problem. It is possible that the smoky madtom is more tolerant of siltation than the yellowfin madtom. It is more likely, however, that the habitat and behavioral differences between the two species explain this apparent difference in environmental sensitivity. The smoky madtom inhabits mainly riffles (at least during the reproductive season) (G. R. Dinkins pers. comm. and pers. obs.), and the yellowfin madtom is found only in pools. The silt, which is detrimental to eggs and larvae (Starnes and Starnes manuscript) is more likely to settle in pools and to severely impact the benthic species in these pools than riffle-dwelling species.

There also appears to be a difference in activity patterns for the two madtoms found in Citico Creek. Although most Noturus species are nocturnal (Taylor 1969, and others), some exceptions have been noted (Clark 1978), and this may especially be true with sympatric congeners. The smoky madtom has been observed to be more active during the daylight hours (G. R. Dinkins pers. comm.) and the yellowfin madtom is strictly nocturnal. This is confirmed by collecting efforts and by gut content analysis of two individuals of

N. flavipinnis collected during the daytime which indicated no feeding for several hours prior to capture. It seems that nocturnal inhabitants of still waters (pool dwellers) would rely much more heavily on chemoreception for finding food, mates, etc., whereas diurnal riffle inhabitants may depend on vision for survival. Therefore, benthic pool dwellers, such as N. flavipinnis may be more sensitive to siltation (which would affect the ability of the madtom to use properly its olfaction) or to other pollution sources (pesticides, etc.) that may be present in runoff, even in trace amounts.

Although one individual was reported from creek km 6.9 (G. R. Dinkins pers. comm.), the sighting was made from above water, and the specimen was not captured. Several exhaustive attempts at finding other individuals in this pool immediately after this sighting, and at later dates (during the breeding season and at night) proved futile.

Movement

Based on tag-recapture data from both acrylic paint tags and fin clips, it is evident that adult N. flavipinnis do not ordinarily move from pool to pool. Of 45 fish individually tagged with acrylic paint, seven were recaptured (Table 3) between seven months and 19 months after tagging. Of these recaptures, five were found in the same pool as they were originally found to inhabit. The color of the mark on the sixth fish (possibly bearing a tag 20 months old) was not distinguishable and possible movement by this individual could not be determined.

Table 3. Recapture Data from Individually Tagged Noturus flavipinnis from Citico Creek, Tennessee

Locality of Tagging	Date of Tagging	Size When Tagged	Sex	Locality of Recapture	Date of Recapture	Size at Recapture	Growth
Upper pool	10- 1-81	110 mm SL	♂	Upper pool	5-29-82	114 mm SL	4 mm
Upper pool	10- 1-81	103 mm SL	♀	Upper pool	5- 8-83	108 mm SL	5 mm
Lower pool	10- 1-81	73 mm SL	?	Lower pool	7-15-83	106 mm SL	33 mm
Lower pool	10- 1-81	80 mm SL	?	Lower pool	6-27-83	93 mm SL	13 mm
Upper pool	10- 4-81	83 mm SL	♂	Upper pool	5-29-82	104 mm SL	21 mm
Lower pool	6-27-82	100 mm SL	?	Lower pool	8- 9-82	106 mm SL	6 mm

For the population estimates in the two adjacent study pools, over a two-month period a total of 21 fish were fin clipped (left side) from the upper pool and 32 fish were fin clipped from the lower pool (right side, Tables 4 and 5). Four fish were recaptured from the upper pool on one occasion, and on four different censuses there were two, four, three, and two recaptures from the lower pool. All recaptures indicated no movement of individuals between pools.

That localization of small populations may be common in madtoms is further supported by evidence presented by Case (1970). In a study of the tadpole madtom, N. gyrinus (Mitchell), Case (1970) showed that movement of this species is very limited. Of 693 adult fish marked, only five individuals were recaptured at sites other than where they were first collected and released.

Movement patterns discussed above are applicable to adult yellowfin madtoms only. In this study, small individuals were not marked by either paint tagging or fin clipping because of possible harmful effects caused by excessive handling. Also, proper censusing of the YOY by snorkeling techniques requires a great deal more time than searching for adults and a totally different search image is needed to detect the extremely cryptic juveniles. It is possible that the juveniles are the dispersal agents for the species, and act as colonizers or provide a renewed source of genetic material.

G. R. Dinkins (pers. comm.), during his survey of the smoky madtom in Citico Creek, did not observe any N. flavipinnis while systematically searching beneath rocks in the riffles between pools,

Table 4. Recapture and Population Estimation Data for Noturus flavipinnis from Fin-Clipped Tagging in the Upper Study Pool, Citico Creek, Tennessee

Date	C_t	R_t	M_t	$C_t M_t$	$M_t R_t$	$C_t M_t^2$	R_t^2 / C_t	Estimate	95% Confidence
8-25-83	6	0	0	0	0	0	0	--	--
9- 1-83	6	0	6	36	0	216	0	--	--
9-28-83	11	4	12	132	48	1584	1.4545	33 ^a 34 ^b 38 ^c	13-132 (Poisson)
10-16-83	2	0	19 21	38	0	722	0	53 ^c 41 ^b	20-206 (Poisson)

R_t = total recapture on day t.

C_t = total fish (adult) captured on day t.

M_t = effective number of tags at large on start of t^{th} day (number previously marked).

^aPetersen estimate.

^bModified Schnabel estimate.

^cSchumaker estimate.

Table 5. Recapture and Population Estimation Data for Noturus flavipinnis from Fin-Clipped Tagging in the Lower Study Pool, Citico Creek, Tennessee

Date	C_t	R_t	M_t	$C_t M_t$	$M_t R_t$	$C_t M_t^2$	R_t^2 / C_t	Estimate	95% Confidence
8-16-83	11	0	0	0	0	0	0	--	--
8-25-83	6	2	11	66	22	726	0.6667	33 ^a	9-330 (Poisson)
9- 1-83	11	4	15	165	60	2475	1.4545	33 ^b 39 ^c	18-105 30-56
9-28-83	11	3	21	231	63	4851	0.8181	46 ^b 56 ^c	27-116 35-160
10-16-83	5	2	29 32	145	58	4205	0.800	51 ^b 60 ^c	41-114 31-112

R_t = total recaptures on day t.

C_t = total fish captured on day t.

M_t = effective number of tags at large on start of t^{th} day (number previously marked).

^aPetersen estimate.

^bModified Schnabel estimate.

^cSchumaker estimate.

and nighttime observations revealed freeswimming juveniles (as small as 19 mm SL) over fine-grained substrates in pool habitat as early as mid-August. Jenkins (1975) reported that all life stages of the yellowfin madtom in Copper Creek occupy the same habitat. In the study of the tadpole madtom, Case (1970) observed no dispersal by YOY, as none of the 77 YOY madtoms tagged were recaptured at a site other than where they were marked and released.

Population Estimate

After the final census period in the upper study pool, estimates of 41 and 53 adult animals were obtained by the modified Schnabel and Schumaker methods (Ricker 1975), respectively (Table 4). Estimates obtained for the lower study pool were 51 by the modified Schnabel and 60 by the Schumaker methods (Table 5). By extrapolating these figures to the total lengths of each pool type within the range of the yellowfin madtom in Citico Creek, estimations of the size of the Citico Creek population of N. flavipinnis adults were calculated as 451 (modified Schnabel) and 549 with confidence limits of 312-1453 (Schumaker). Using these total population estimates and the area of pool habitat within the yellowfin madtom's known range (actual pool length measurements, and an estimated average width of 20.7 m), densities of 1.4 and 1.8 adult yellowfin madtoms per ten square meters (using modified Schnabel and Schumaker estimates, respectively) were calculated.

Age and Growth

Although the maximum lifespan of various species of madtoms is reported to be between eighteen months (Mayden and Walsh in press) and nine years (Mayden and Burr 1981), the average lifespan of most madtoms is two or three years (Case 1970, Mahon 1977, Thomerson 1966, Clark 1978, Burr and Mayden 1982b; and others).

Length frequency histograms of N. flavipinnis in Citico Creek indicate a three year lifespan (Figure 8). Jenkins (1978) reports a longevity of three to four years for N. flavipinnis, based on Copper Creek specimens. The length frequency histogram constructed for Copper Creek specimens (Figure 9), based on data provided by Jenkins (pers. comm.), can indeed be interpreted to show four or possibly five year classes.

For both the 1969 Copper Creek population and the 1982 Citico Creek population, YOY are first evident in September (Figures 8 and 9). In August 1983, however, a concerted effort was made for early detection of YOY in order to determine possible differences in habitat preferences. Therefore, as Figure 8 indicates, these juveniles may be freeswimming (and released from guardianship) as early as August. To corroborate this, W. C. Starnes (pers. comm.) reports a single 16.5 mm SL individual taken from Copper Creek on 9 August 1975.

In Citico Creek, ten juveniles captured in August 1983 averaged 24.9 mm SL (ranging from 19 to 29 mm SL) and five individuals captured in November 1983 averaged 37.8 mm SL (ranging from 34 to

Figure 8. Length frequency histograms for specimens of Noturus
flavipinnis from Citico Creek, Tennessee.

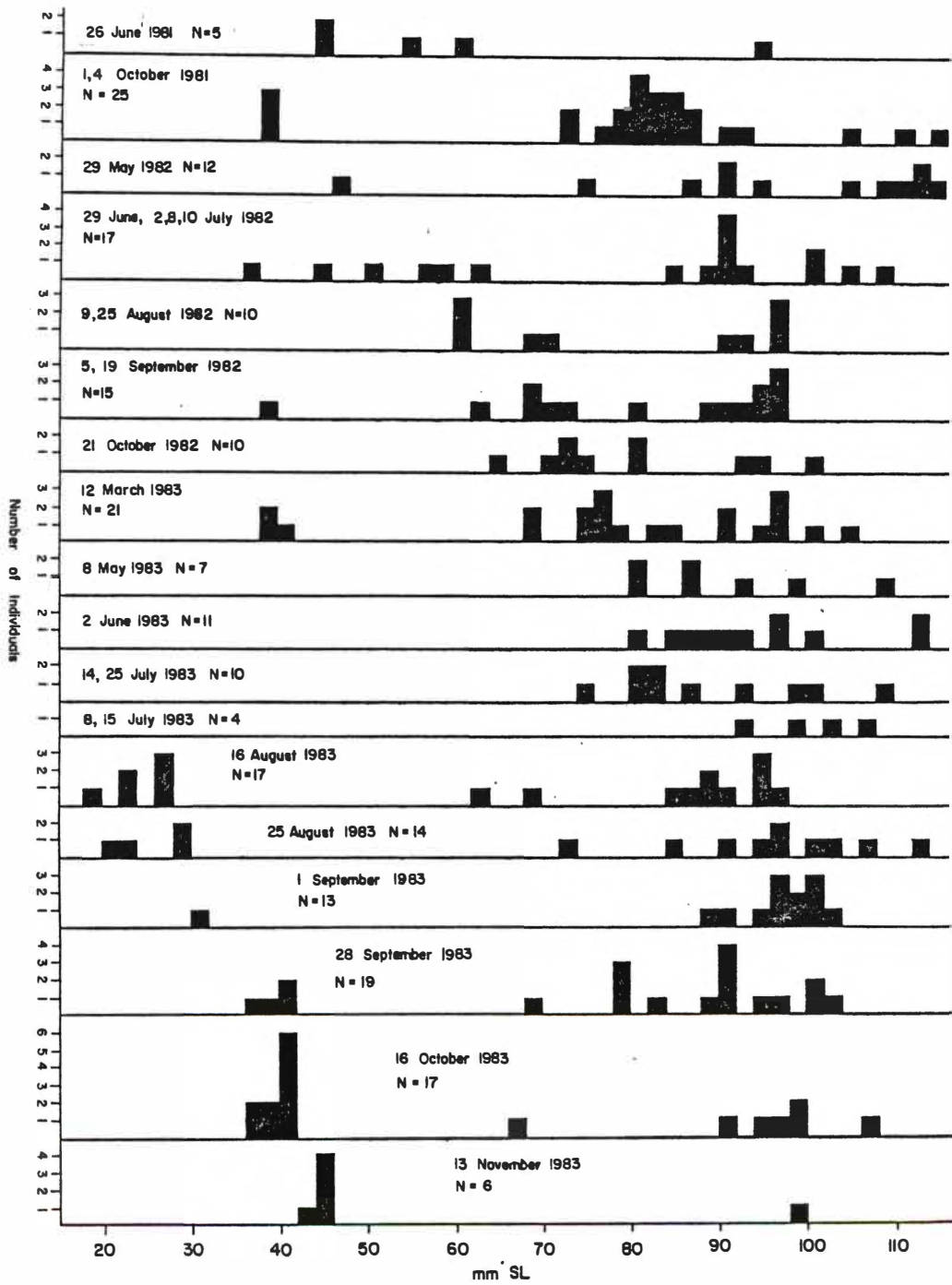


Figure 8

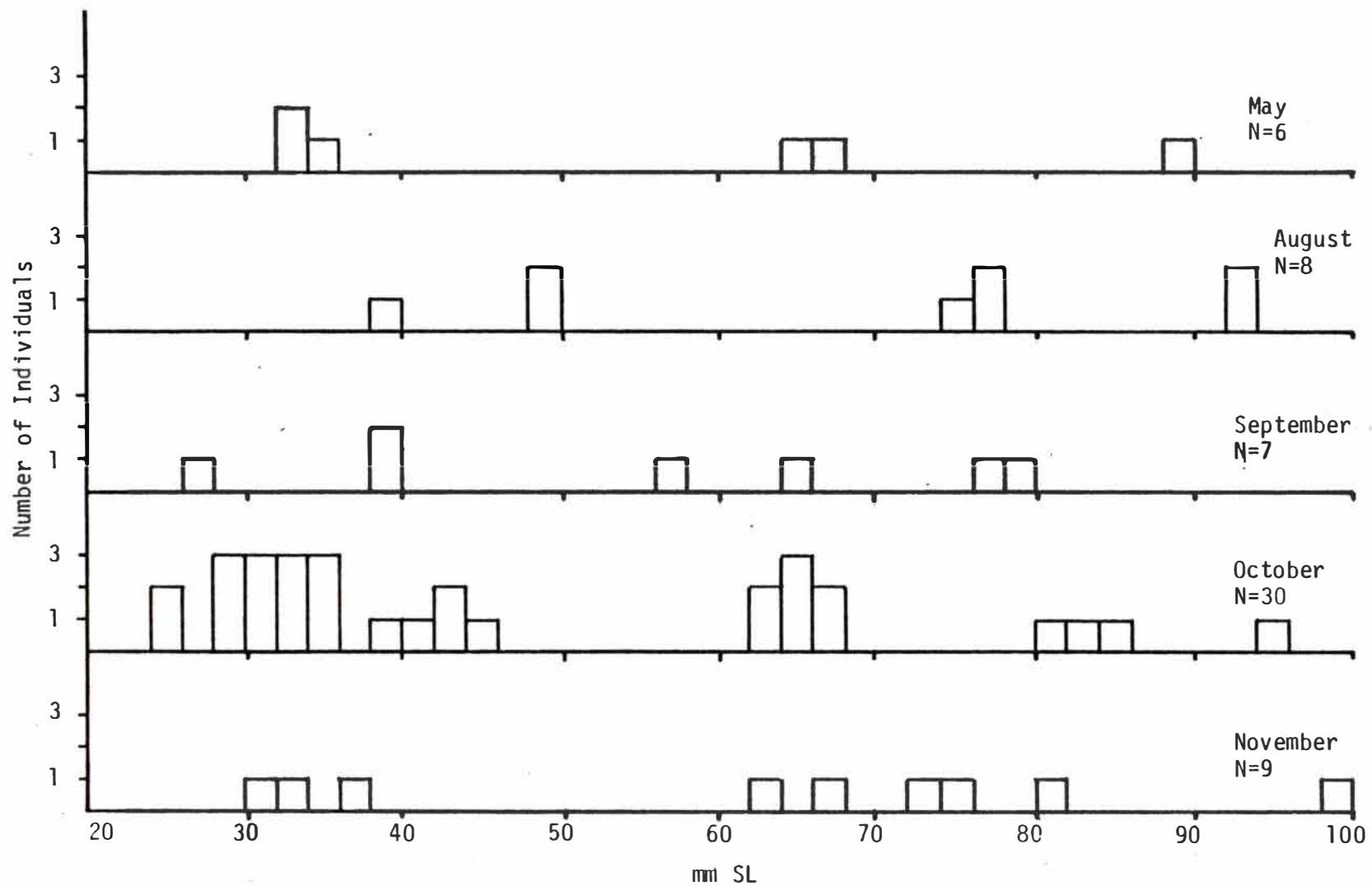


Figure 9. Length frequency histograms for specimens of Noturus flavipinnis from Copper Creek, Virginia.

45 mm SL). In comparison, of three YOY captured from Copper Creek in November average standard length was 23.7 mm (31 to 35 mm SL).

Accurate data on individual growth rates were obtained by recapturing acrylic paint tagged madtoms (Table 3, p. 37). From these data, it is evident that N. flavipinnis may reach a certain maximum size limit, and growth ceases or occurs at a fraction of its original rate. For example, an 83 mm SL individual marked on 4 October 1981, was recaptured 29 May 1982, and had grown 21 mm during this period, to attain a length of 104 mm SL, while a 110 mm SL individual marked and recaptured during approximately the same time period (10-1-81 to 5-29-82) had grown only four mm during the same length of time. Additionally, a 100 mm SL specimen grew six mm in a little over one month (between 27 June 1982, and 9 August 1982).

To complicate further interpretation of individual growth rate data, it appears that, as reported for other Noturus species (Burr and Mayden manuscript, and others), the majority of the larger fish are males (Figure 10). This may explain anomalies such as the observation of two specimens that were relatively the same size at marking (73 and 80 mm SL), but when they were recaptured after 21 months (from 1 October 1981, to 27 June 1983, and 1 October 1981, to 15 July 1983, respectively) one had increased thirteen mm in length while the other increased 33 mm.

Sexual dimorphism by size observed for Noturus and other species of fish where only one parent exhibits parental care of eggs

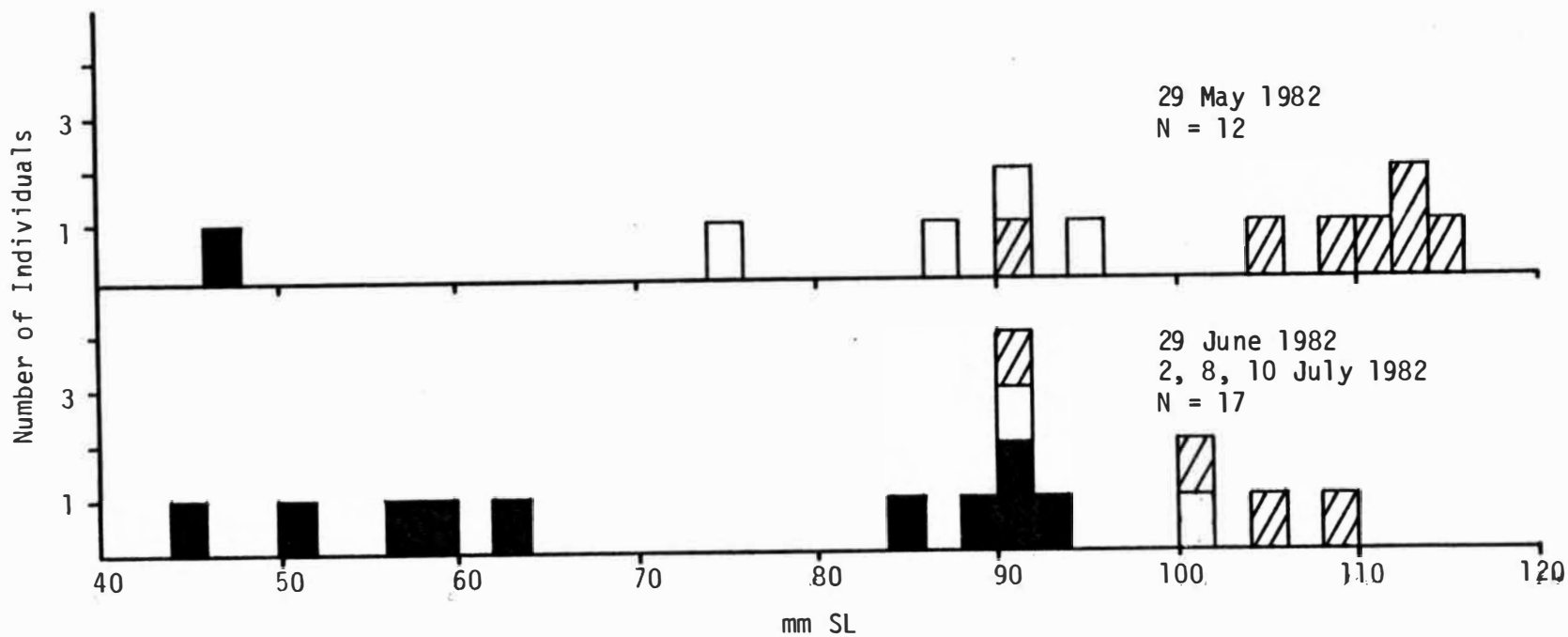


Figure 10. Length frequency histogram showing sizes of male and female *Noturus flavipinnis* from Citico Creek, Tennessee. Diagonal lines represent males, open bars indicate females, and solid bars indicate individuals whose sex was undetermined.

and/or larvae is possibly due to selective pressures which favor larger body size by the guardian parent, enabling better protection of the broods. Also, during the seasons in which more rapid growth occurs (spring and summer), much of the energy from food resources ingested by females is required for gonadal development.

An alternative to this explanation of size dimorphism apparent in Noturus is presented by Burr and Mayden (1982b) who suggest that in N. miurus, males attain a larger size than do females because the majority of females do not live as long as males. This theory was also proposed by N. eleutherus (Starnes and Starnes manuscript), and N. exilis Nelson (Mayden and Burr 1981). Additional support of differential longevity as an explanation for apparent sexual size dimorphism is the lack of such dimorphism in the only known annual species of Noturus, N. hildebrandi (Bailey and Taylor) (Mayden and Walsh in press). If males do indeed live longer than females, it would also be possible that natural selection favors nest-builders and guardians that are more experienced (i.e., older males).

Contradictory evidence is presented by Bowman (1932) who reported that although both males and females of the margined madtom, N. insignis, live for three years, the males attain a slightly larger size. He used length frequencies to demonstrate that the same three peaks were evident in both sexes. Bowen (1980) also presented similar evidence, which contradicts that of Burr and Mayden (1982b). He determined ages of the brindled madtom, N. miurus, by analyzing annuli formation on otoliths and vertebrae and found that although

males and females live three years, males of age three are significantly longer than females of the same age. Other age classes show no significant sexual dimorphism in size. This indicates that both males and females may have a specific maximum size limit. Burr and Mayden (in press) also report differential growth for male and female checkered madtoms, N. flavater. Although both live to three years of age, females average 6-25 mm smaller than males.

Mean standard length of 22 mature (reproductive) female N. flavipinnis averaged 93.8 mm (ranging from 80 to 112) and 20 mature males averaged 102.5 mm SL (ranging from 74 to 114). Although the ages of these individuals are not positively known, it is likely that most were two years of age at the time of capture since they mature at that age, and the third year class makes up a small proportion of adults (Figure 8). Therefore, the average 8.7 mm difference in standard lengths indicated by the above data of male and female yellowfin madtoms may be actual, although some exceptions are noted.

The linear regression analysis which was used to compute standard lengths from field-collected total lengths is represented by the equation $SL = 0.85TL - 2.13$ ($r = 0.99$) and is shown in Figure 11.

Sex Ratios

The determination of sex in the field was possible only for reproductively mature individuals, and could be determined only during the breeding season. Therefore, data on sex ratios are available only for May (1982), June (1983) and July (1982). In May, males outnumbered females by a ratio of 1.75 to one (seven males and four

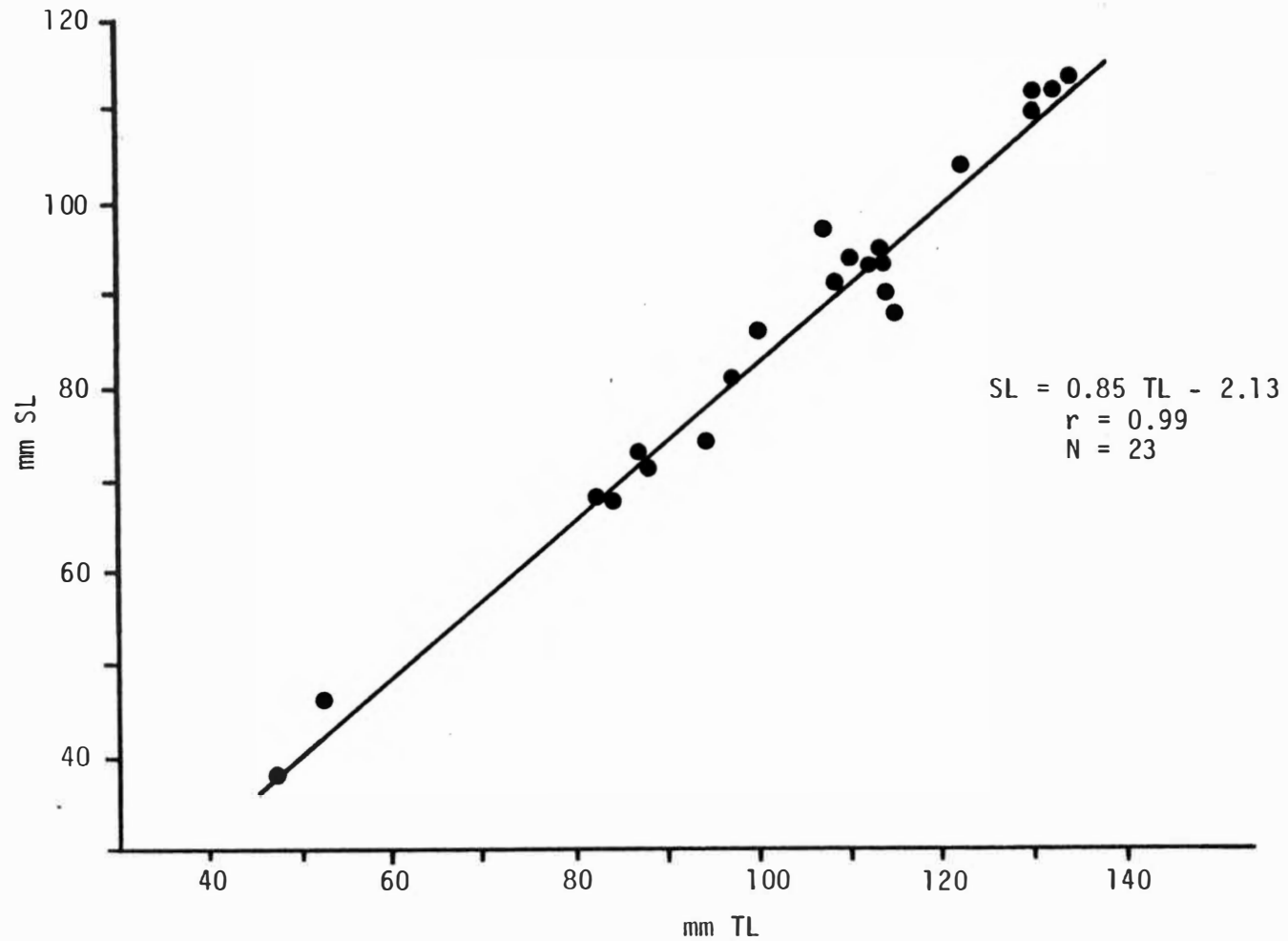


Figure 11. Standard length/total length regression analysis of Noturus flavipinnis from Citico Creek, Tennessee.

females). This slight deviation from the expected 1:1 sex ratio was reversed for the June sample, when the ratio was one male to 1.5 females (six males and nine females). In July the ratio was three males for every one female (six males and two females). Males may have greatly outnumbered females in this sample because of the hypothesized death of larger individuals after spawning. On this date (2 July 1982), many larger females had probably spawned their complement of ova, but males were still occupied in the guardianship of their broods.

Reproductive Period

Data on gonad development and field observation of nesting indicated the yellowfin madtom is an early summer spawner. The earliest nest was found on 29 May 1982, and nesting continued that year through June (Table 6). In 1983, field surveys for nests began in early May. Although gravid females were evident in May and June, and several pairs of fish were observed beneath nesting-sized slab-rocks (four pairs on 2 June 1983) no nests were found until 25 June (Table 6), and nesting appeared to be almost over by mid-July. This apparent difference in spawning seasons between two years may be due to a comparatively cold spring in 1983, which may have delayed spawning by sustaining lower water temperatures. If this is the case, then photoperiod may be important in preparing the gonads for reproduction, but water temperature appears to be more important in spawning initiation. The temperature which initiated spawning behavior was approximately 20°-23° C.

Table 6. List of Water Temperatures and Number of Nests of Noturus flavipinnis Found in Citico Creek, Tennessee

Date	Number of Nests Found	Water Temperature
5-29-82 ^a	1	20° C
6-27-82 ^a	0	21° C
7- 2-82 ^b	5	23° C
7- 8-82 ^b	1	23° C
7-10-82 ^b	0	24° C
8- 9-82 ^a	0	?
3-12-83 ^a	0	10° C
5- 8-83 ^a	0	14° C
6- 2-83 ^b	0	16° C
6-14-83 ^b	0	20° C
6-25-83 ^b	3	22° C
7- 8-83 ^b	0	18° C
7-15-83 ^b	0	18° C

^aNighttime survey with snorkel.

^bDaytime survey beneath slabrocks.

Starnes and Starnes (manuscript) reported a possible delayed reproductive period in 1983 for the mountain madtom, N. eleutherus, and Clark (1978) indicated a spawning period in the speckled madtom, N. leptacanthus Jordan, which coincided with peak water temperatures, although she suggested that this relationship may be coincidental. She also reported, however, a difference in reproductive period for N. leptacanthus between two successive years. In 1976, she did not note ripe individuals until the end of June, and in 1977 she suggested that spawning occurred in May, based on the collection of nearly ripe individuals in mid-April. Breder (1935) indicated that water temperature is the determining factor in initiation of reproductive behavior in the brown bullhead, Ictalurus nebulosus (Leseur).

Gonadosomatic indices (Tables 7 and 8) also indicate reproductive period in Citico Creek populations of N. flavipinnis for 1982 and for the 1969 Copper Creek populations by showing relative gonadal development. Although many gaps appear in the data, it is clear that the beginning of the reproductive period for the species may be as early as May.

Nesting Behavior

Madtoms are included in the reproductive guild of fishes where a nest is constructed, or a natural cavity is chosen for a nesting chamber, and the male guards the eggs. Fishes belonging to this guild are termed speleophils by Balon (1975). For the purpose of nesting, N. flavipinnis choose large rectangular flat rocks (slab-rocks, Figure 7, p. 25). Not only does an appropriate size appear to

Table 7. Gonadosomatic Indices (GSI) and Numbers of Ova for Female Noturus flavipinnis from Citico Creek, Tennessee, and Copper Creek, Virginia

		SL	GSI	Total No. Eggs	No. Ripe Eggs
Citico Creek	May	78	131.3	424	188
		79	106.1	386	190
		75	106.1	456	182
	June	92	77.9	390	174
	July	98	155.2	382	150
		93	21.7	250	spent
	$\bar{X}$ TOTAL OVA = 381		$\bar{X}$ RIPE OVA = 177		
Copper Creek	May	88	174.3	662	212
		65	36.6	678	(not mature) 227
					(not mature)
	September	78	10.9		
		56	7.3		
	November	80	14.7	614	278
					(not mature)
		74	13.3		
		99	25.9	424	160
					(not mature)
		68	19.2		
		63	17.7		

Table 8. Gonadosomatic Indices (GSI) for Male *Noturus flavipinnis* from Citico Creek, Tennessee, and Copper Creek, Virginia

		SL	GSI
Citico Creek	May	90	47.8
		88	60.4
Copper Creek	August	75	24.6
	September	78	30.1
		66	9.2
	October	81	16.7
		97	33.8
		42	12.9
	November	76	14.8

be important in the choice of nesting site, but the availability of a crevice or open space beneath the slab also is a major factor. Although it is assumed that one or both parents may enlarge this nesting cavity by fanning with body and fins, no nests have been found beneath rocks (that looked otherwise suitable) that were slightly buried beneath the substrate, even though the number of "appropriate" nesting rocks within the pool was limited. Other species of Noturus have been reported to use manmade artifacts (bottles and cans) for the purpose of nesting. One one occasion an immature yellowfin madtom was collected from a can, and it is assumed, that should they be provided with containers with openings large enough to permit entry by the comparatively large adult N. flavipinnis, they might choose to use these for nesting purposes. The openings on most cans and bottles which are likely to be found in a stream, however, are much too small for the adult madtoms to enter. Although some Noturus species have been reported to occupy a different habitat in the reproductive period than during the rest of the year (Starnes and Starnes, manuscript; Mayden and Walsh in press, G. R. Dinkins pers. comm.), nests of the yellowfin madtom were found only in typical pool habitats occupied by the madtoms during the rest of the year.

It would appear that of the Noturus species for which reproductive behavior is known, the majority prefer to place their nests in pools. If the species is typically found in pool habitat, no pre-spawning migration is necessary. If the typical habitat of

the species is riffles, a migration to the more still waters of pools may be expected, or a preference of most individuals for pool nesting habitat may be noted. For example, the slender madtom, N. exilis, is commonly found in both pools and riffles, and apparently exhibits no preference for either habitat type (Mayden and Burr 1981). Of sixteen nests found, however, Mayden and Burr (1981) report that most (twelve, or 75%) were located in pool habitat. In addition, the stonecat, N. flavus Rafinesque, which usually inhabits riffles, was found to place its nests in pools more than half of the time (four of seven nests found, Walsh and Burr, manuscript).

As reported by Clark (1978) for N. leptacanthus, it appears that guardian males do not feed, based on the only parent removed from a nest. Preserved on 29 May 1982, this individual was removed during the night (1:00-2:00 A.M.) from a very freshly laid clutch of eggs. The stomach was completely empty, and the hindgut contained only a few sand grains and some well digested chironomid and trichopteran larvae. In comparison with gut analysis of specimens collected at night that were apparently feeding (see Diet section), the diversity and amount of food organisms found in this male's gut was greatly reduced, and the larval insects present could have been ingested during the nest-building (or maintenance) process.

Fecundity

Madtoms in general exhibit low fecundity in comparison with other North American freshwater fishes (Breder and Rosen 1966). Members of the genus Noturus are k-selected in their life history

strategies, with respect to other North American freshwater fishes (Clark 1978). A combination of relatively large egg size and the high level of parental care given to fertilized eggs and larvae reduce early mortality and therefore the need to produce a large number of gametes. In comparison with other Noturus, however, N. flavipinnis is fairly fecund. The average number of ova contained within the ovaries of five females from Citico Creek was 408 (382-456). One spent female was omitted from this analysis. Although several life history studies on Noturus indicate only two size classes of ova (Clark 1978; Burr and Mayden in press, Walsh and Burr manuscript), eggs of N. flavipinnis are separable into three distinct size classes. Mature eggs, which are translucent yellow in color in comparison to white opaque nonripe ova, are 2.5 to 3.3 mm (unfertilized) in diameter. There are three size classes of ova present in the gonads of female N. flavipinnis, but since sexual maturity is not reached until age two, and lifespan is probably three years, most individuals probably only spawn a maximum of two times, during their lifespan.

The average number of ripe eggs per female for the five females mentioned above was 177 (150-190). The number of mature ova averaged 218 for four females from Copper Creek (160-278). Mean ovum numbers for the medium and smallest size classes for six females from Citico Creek were 114 and 116, respectively, and four females from Copper Creek averaged 165 and 212 ova for these same size classes. Although many authors (Hubbs et al. 1968, and others) have reported a

correlation between the size (length) of a female and the number of ova (total ova or ripe ova), no such correlation appears to exist for N. flavipinnis (Figure 12).

Age at Maturity

Females from Citico Creek appear to be sexually mature by the third summer of their life (two years of age), as indicated by the presence of ripe or nearly ripe ova in the gonads of three females taken in May 1982 that were 75, 78 and 79 mm SL. Gonadosomatic indices (GSI) for these fish were 106.1, 131.3, and 106.1, respectively (Table 7). For comparison, the GSI of a spent female taken 15 July 1983 (93 mm SL) was 21.7. These three individuals, based on the length frequencies shown in Figure 7 (p. 25) were probably entering their third summer. The ovaries of three females taken in June 1981 that were probably in their second summer of life (one year old, measuring 49, 57 and 58 mm SL) contained no mature ova. Gonadosomatic indices for these individuals were 7.3, 5.8, and 3.7, respectively.

Although the evidence is too scanty to be conclusive, in Copper Creek, females may not mature until their fourth summer of life. The GSI of a 65 mm SL female taken 1 May 1969, was 36.6, and the largest ova measured only 1.0-1.2 mm in diameter. On the other hand, an 88 mm SL female taken on May 20 during the same year had more well developed ovaries, with a GSI of 174.3. The largest ova were only slightly larger (1.4-1.5 mm diameter) in this individual, however, and this may be indicative of a delayed spawning season for that year.

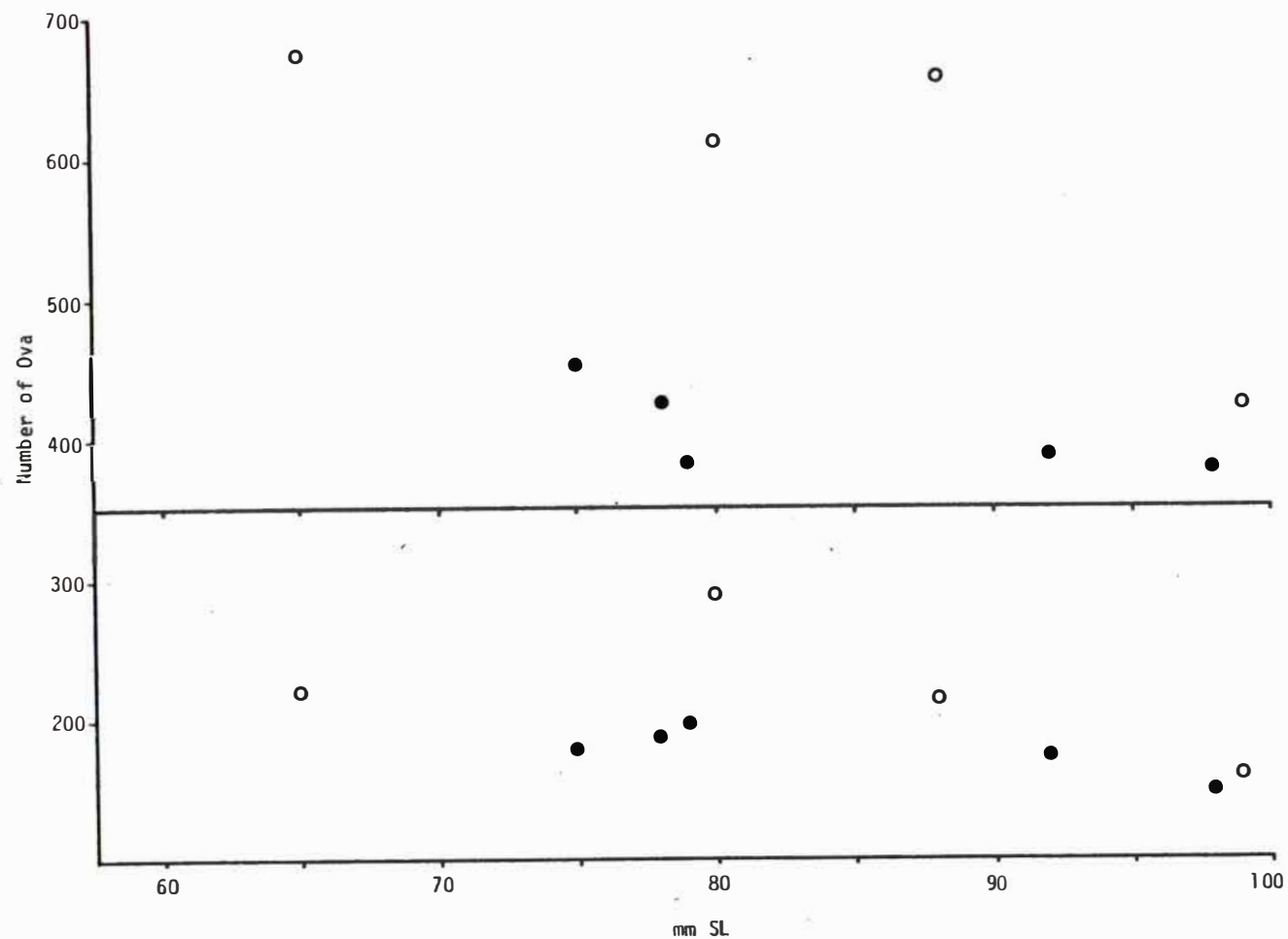


Figure 12. Correlation of female Noturus flavipinnis standard lengths with number of mature ova (below the horizontal line) and the total number of ova (above the horizontal line). Open circles represent individuals from Copper Creek, Virginia, and solid circles represent individuals from Citico Creek, Tennessee.

Considerable variation in egg diameters has been observed between populations of several darters in the genus Etheostoma (Hubbs et al. 1968), and it is presumed that the same phenomenon may also occur in Noturus. Burr and Mayden (in press) also report a variation in clutch sizes for N. flavus populations from Missouri and Illinois, although they indicate the possibility of racial differences. Further discussion by Hubbs et al. (1968) suggests that environmental factors may affect egg sizes. Fish living in highly oxygenated streams (such as Citico Creek) may be successful at producing fewer, larger eggs. Oxygen is not limited, and the larger size of the hatchling enables early maturation. In comparison, smaller eggs have a greater surface area to volume ratio, and are therefore more efficient at oxygen absorption, yet hatchlings may be more vulnerable to predation for a longer period of time. Therefore, an alternative explanation to apparent ovum size and fecundity differences between the Citico and Copper Creek populations may be explained by environmental (or possibly genetic) differences.

The difference in egg number and size is also evident when comparing egg production per gram of body weight, a method of indicating relative fecundities suggested by Clark (1978). For five Citico Creek females, egg production averaged 14.1 mature ova per gram of body weight (ranging from 9.5 to 17.9), and the three Copper Creek females averaged 20.9 mature ova per gram of body weight (10.5 to 36.2). Although these Copper Creek fecundities are relatively high in comparison with other ictalurids, they are based

on actual body weight measurements, and not estimates of weight, as are Clark's (1978) data. Walsh and Burr (manuscript) also reported much higher ratios for N. flavus than those estimated by Clark.

Although most guardian males were not removed from their nests for length measurements, the presence of a 74 mm SL individual that was removed from his clutch of eggs on June 25, 1983, indicates that males from Citico Creek probably mature at the same age as do females. Based on Bowen's (1980) report that the sexual size dimorphism observed in populations of N. miurus does not become evident until the third year of life (or the fourth summer) and length frequencies presented in Figure 7 (p. 25), this 74 mm SL male was probably entering his third summer. This individual was the smallest male observed to exhibit nesting behavior.

Mature breeding Noturus males typically have swollen epaxial muscles, which enlarges their head width and depth (Clark 1978). The development of head musculature apparently aids the guardian in protection of his offspring, and possibly in nest preparation. This characteristic, in combination with distended abdomens evident on ripe females allowed observers to easily distinguish between the sexes in the field during the reproductive period. Many fish smaller than the sizes mentioned above for mature individuals were captured and measured during the nesting season, but the sex of these animals was undetermined, based on external characteristics, indicating that they were not reproductively mature during that season. Shape and

size of genital papillae was also a possible method to distinguish between the sexes, but this method was not useful in the field.

Courtship and Spawning

Breder and Rosen (1966) summarized the published literature on the well-known reproductive behavior of Ictalurus, primitive relatives of Noturus. From these accounts, it appears that female Ictalurus may select a nest site and initiate any necessary excavation and males may sometimes join them in these activities.

Except for observations of N. miurus spawning in laboratory aquaria reported by Bowen (1980), very little is known about the actual sequences involved in courtship and mating of madtoms. Because only males have been observed singly in nest sites (with no eggs present), it has generally been assumed by most authors that male Noturus select nest sites and perform any excavation necessary to produce a cavity for the eggs (e.g., Mayden and Burr 1981, Clark 1978). Burr and Mayden (in press), however, report finding single large females of the checkered madtom, N. flavater, beneath potential nest rocks during the early part of their reproductive period. Mayden and Walsh (in press) also report the observation of gravid females and reproductive males of the least madtom, N. hildebrandi, singly or in pairs beneath potential nest rocks in late June.

On 27 June 1982, during a nighttime survey of the lower study pool, only five N. flavipinnis were captured during a 1.5 hour survey by two snorkelers. Of these, only one individual, a 91 mm SL gravid female, was of reproductive age. On 2 June 1983, three pairs, two

single males, and two single females were found under potential nesting slabrocks. One single male and three single females were observed beneath potential nest rocks on 14 June 1983, and on 8 July 1983, a pair was noticed beneath a slabrock. Because of the inconsistencies of these data, and reports by the authors mentioned above, it is not possible to determine whether the female may play an active role in the selection of nesting sites.

According to laboratory observations reported by Bowen (1980), male N. miurus select nest sites and begin excavation. He also noted that once a female was paired with a particular male in the laboratory experiments, she aided in any further preparation of the nest site, and remained with the male for one to ten days until eggs were produced.

The courtship and spawning behavior of one pair of N. miurus was actually observed by Bowen (1980), and is similar to that summarized by Breder and Rosen (1966) for Ictalurus species. According to these observations, courtship consists mainly of a period of time when the pair swims in circles beneath the nesting cover. Often during this time, the male makes repeated dashes to the entrance of the nesting site. They then enter a spawning embrace, with the caudal fin of the male wrapped around the head of the female, and presumably (although Bowen does not mention), egg deposition occurs.

Unlike Ictalurus, in which both parents assume guardianship of developing eggs, larvae, and juveniles (Breder and Rosen 1966), it has generally been assumed that female madtoms leave the nest

site subsequent to the production of an egg mass, and guardianship is solely the responsibility of the male parent. This was observed for most of the laboratory spawnings of N. miurus, and although females always left the nest site and males only rarely left their brood, Bowen suggested that female N. miurus may provide some form of parental care, as they occasionally swam outside the nesting cover in the laboratory experiments, and on one occasion a spent female remained within the nest for two days. Mayden and Burr (1981) noted that three of sixteen nests of the slender madtom, N. exilis, were attended by both male and female parents.

On eighteen occasions, from 8 July through 18 September 1981, groups of males and females of the undescribed broadtail madtom, Noturus (Noturus) sp. were observed beneath artificial nest covers placed in Lake Waccamaw with eggs or fry (Lindquist et al. 1982 and pers. obs.). Since the sexes were found together on so many occasions with broods in varying degrees of development, it is assumed that females of this species either contribute some parental care, or that the males of the species are more passive in chasing the female out of the nest site. Carlander (1969) reports that females of the stonecat, N. flavus, exhibit parental care, although Walsh and Burr (manuscript) found only adult males guarding nests.

Menzel and Raney (1973), Mayden and Burr (1981), Mayden and Walsh (in press), and Walsh and Burr (in press) have presented evidence which suggests that at least some species of Noturus may be polyandrous. Data presented by these authors, although suggesting

this occurrence, is inconclusive due to the correlations reported for these species between ova production and female body length. Also, data presented in these accounts often includes brood counts of larvae, and not freshly fertilized eggs. From personal observations in the laboratory and in the field, a great deal of mortality occurs subsequent to fertilization of Noturus eggs. Often, brood counts of hatchlings were observed to be half that of freshly (very little development evident) laid and fertilized eggs.

For species exhibiting polyandry, it seems unlikely that females which may mate with more than one male during their reproductive period would form strong pair bonds, and would contribute significantly in providing care for eggs and larvae. Because of evidence presented below that the yellowfin madtom is polyandrous, it is assumed that males of the species assume sole responsibility for raising their offspring.

The ovaries of four female N. flavipinnis contained a mean of 177 ripe ova (150-190, Table 7). The mean clutch size of three N. flavipinnis nests from 29 May 1982 (actual count of ova), 2 July 1982 (estimate) and 25 June 1983 (estimate) containing fresh eggs (not larvae) was 89 (Table 9), which is exactly half of the entire complement of mature ova found in the N. flavipinnis ovaries. Therefore, it is assumed that yellowfin madtoms are among those species which exhibit polyandry, and probably little parental care by the female parent. During this survey, no adult females were found in nests with a clutch of eggs, either with a male, or singly.

Table 9. Clutch Sizes for Nests of Noturus flavipinnis Found in Citico Creek, Tennessee

Date	Number of Eggs in Clutch	Number of Larvae in Brood
5-29-82	89* fresh	
7- 2-82		40-50 60 50 20-30
7- 8-82	75-80 fresh	
6-25-83	100 fresh 25 tail-free stage	

*Direct count; all others are estimates.

Larval Development

Newly fertilized eggs average 3.4 mm in diameter, with an opaque yellow or orange yolk. Figures 13 and 14 illustrate the development of N. flavipinnis raised in laboratory aquaria after the removal of a nest on 29 May 1982. The earliest embryo, preserved six days later, shows evidence of paired fin buds (Figure 13). Presumably, this embryo was not sufficiently developed for hatching to occur (as is indicated in the illustration), and the chorionic membrane was probably prematurely ruptured. Dorsal and anal fin folds were present at this stage, and the eyes were lightly pigmented. At least 27 myomeres were apparent on this specimen, and it had reached the tail-free stage of development by the time of preservation.

Three days later two specimens were found freshly dead and were preserved (Figure 14 C and D). These individuals showed more pronounced eye pigmentation and maxillary and mandibullary barbel development. Also, at this stage, 29 myomeres were noted. After three more days another individual was preserved, and on this specimen mouth development, and rudimentary pectoral fins were evident (Figure 14 A and B).

On 2 July 1982, a recently hatched mesolarvae (12 mm TL and 8.1 mm SL) was captured from a nest and preserved (Figure 15). At this stage, although there was no evidence of rudimentary pelvic or pectoral fin rays, dorsal, anal and caudal fin rays had begun to develop. This particular specimen exhibited five dorsal, eleven

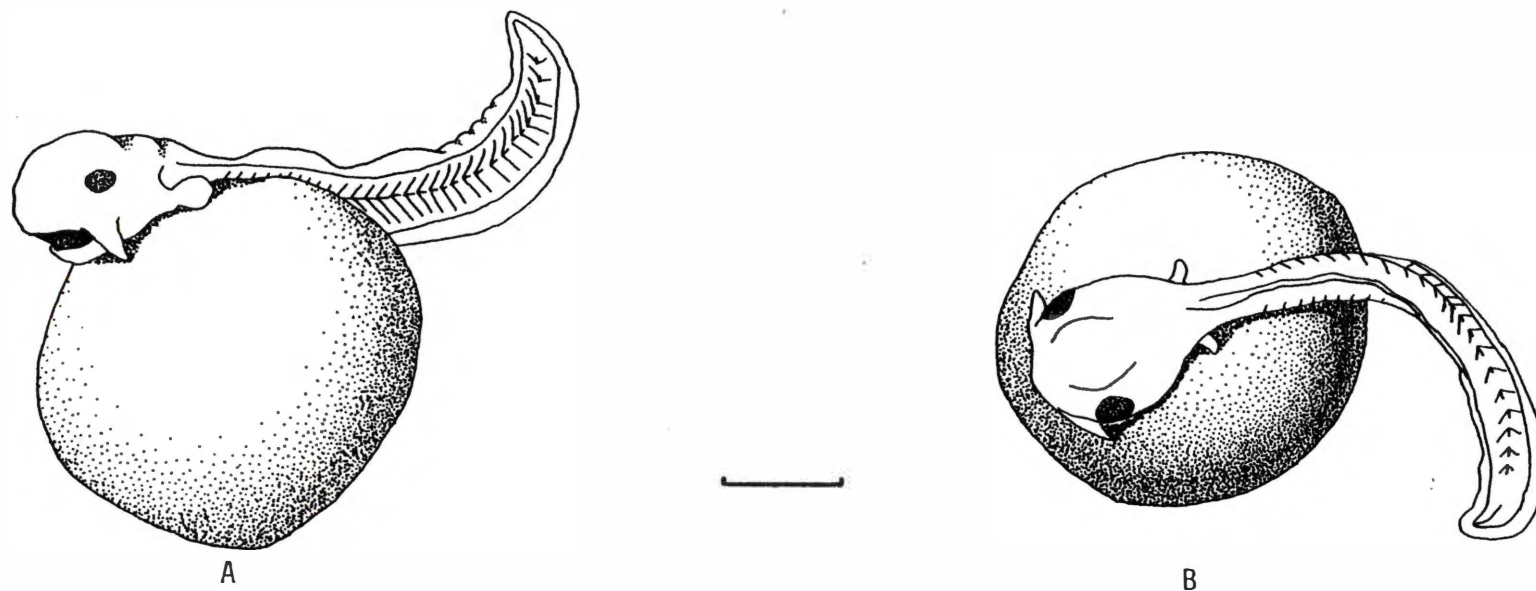
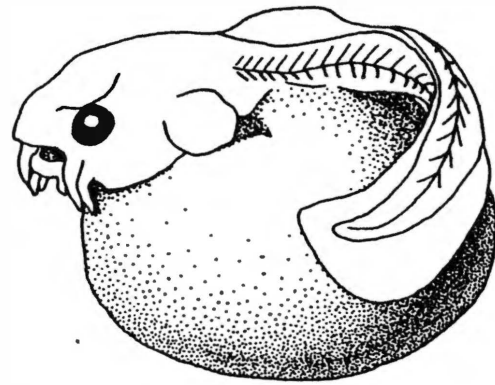
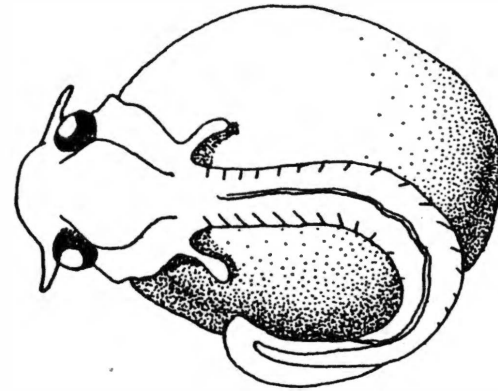


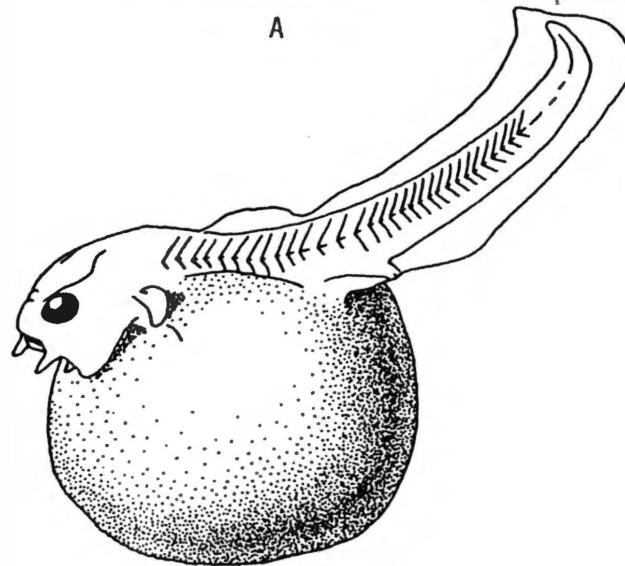
Figure 13. Six-day-old Noturus flavipinnis embryo (removed from chorionic membrane).
 (A) Lateral view; (B) dorsal view. Scale mark equals 1 mm.



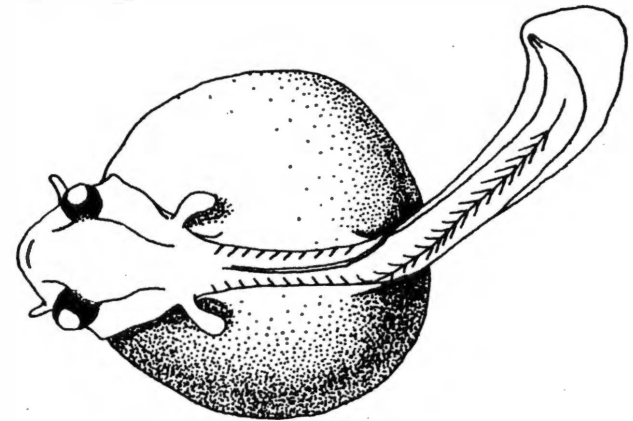
A



B



C



D



Figure 14. Nine-day-old (C and D) and twelve-day-old (A and B) embryos of Noturus flavipinnis. Scale mark equals 1 mm.

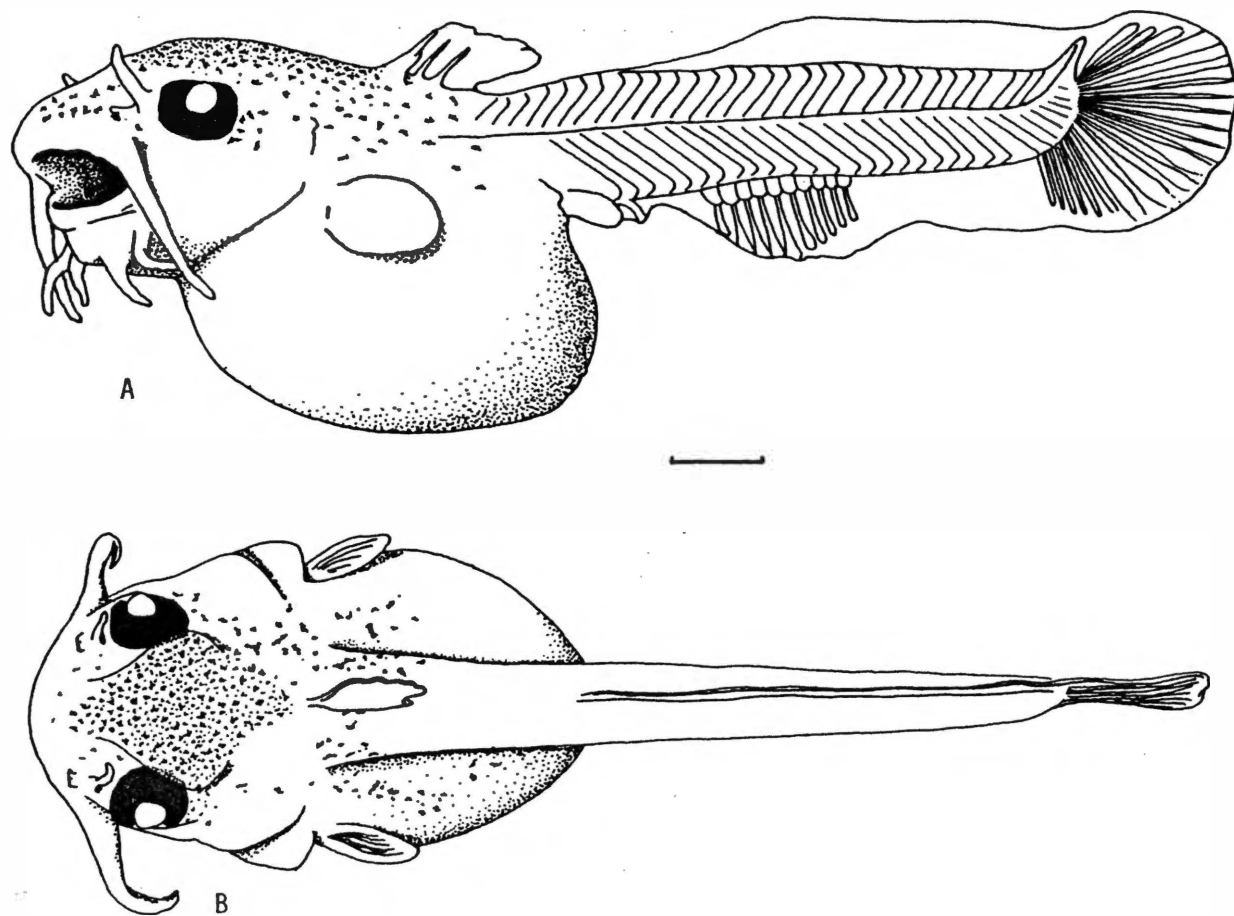


Figure 15. Recently hatched mesolarvae of Noturus flavipinnis. (A) Lateral view; (B) dorsal view. Scale mark equals 1 mm.

anal, and twenty caudal rays, and thirty-two myomeres were also apparent. Eye pigmentation had begun, with melanophores scattered over the nape and on the yolk sac. This presumed 8 mm SL hatching size compares well with that reported for other species of Noturus. If, as Mayden et al. (1980) indicate, development times for species of Noturus are similar, the age of the specimen illustrated in Figure 15 may be approximately eight days post-fertilization (based on hatching time for N. exilis, Mayden and Burr 1981).

Figures 16 and 17 illustrate a 12.3 mm SL, 17 mm TL metalarva also taken from the field and preserved on 2 July 1982. At this stage of development, all fin rays and spines appear to be completely developed. Eight dorsal, eight pelvic, fifteen anal and 34 caudal rays were evident in the specimen illustrated. Although not yet possessing the distinctive color pattern of N. flavipinnis, this specimen showed more complete pigmentation, with melanophores lightly scattered over the body, but concentrated predorsally.

Diet

A total of 40 taxa, representing sixteen families of organisms were identified from the guts of twelve N. flavipinnis examined (Table 10 and Figure 18). The diet of the yellowfin madtom appears to be almost exclusively insect larvae, however one individual contained the remains of a crayfish. In the Citico Creek specimens, dipterans were found in 100% of the guts examined, and in 92% of these guts, the order was represented by the family Chironomidae.

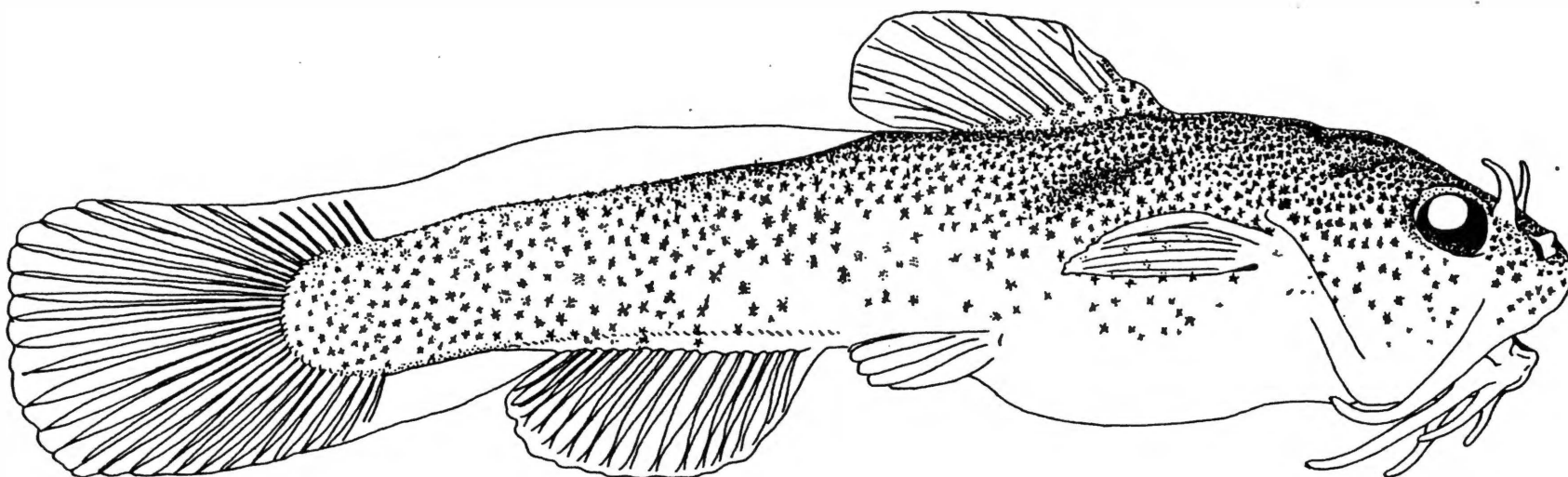


Figure 16. Lateral view of a 12.3 mm SL metalarva of Noturus flavipinnis. Scale mark equals 1 mm.

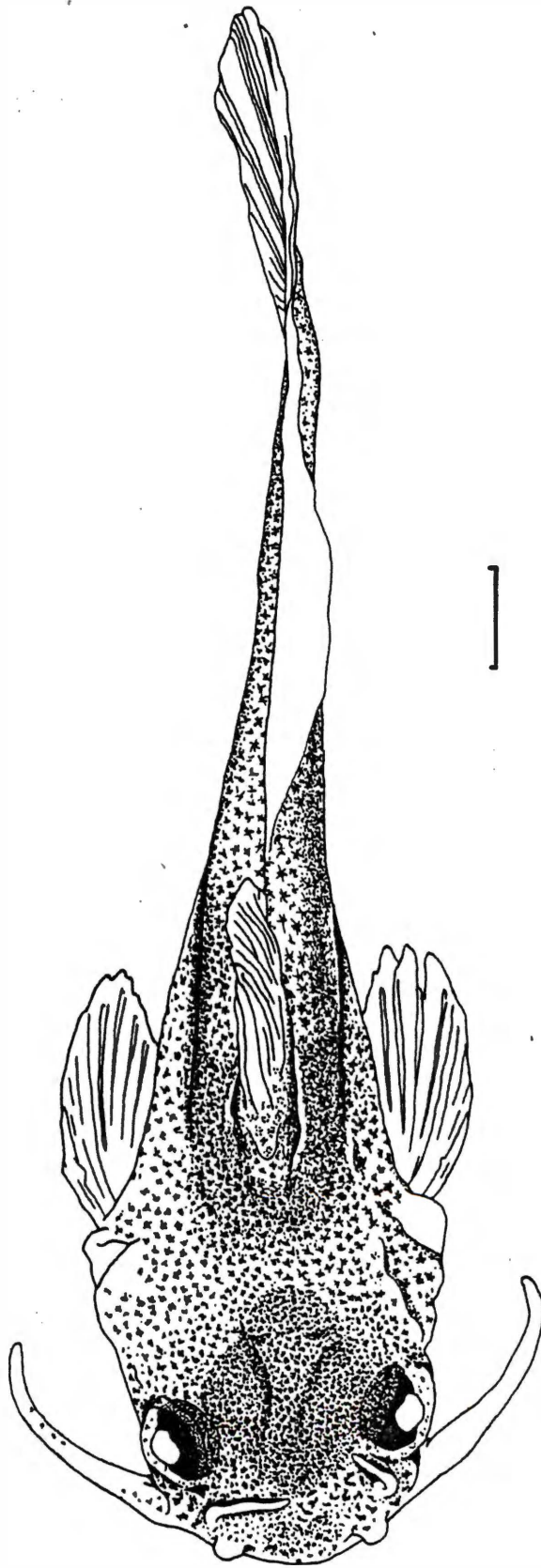


Figure 17. Dorsal view of a 12.3 mm SL metalarva of Noturus flavipinnis. Scale mark equals 1 mm.

Table 10. Dietary Contents of the Guts of Twelve Noturus flavipinnis from Citico Creek, Tennessee

Sand		X				X	X	X				
Coleoptera				12							7	3
<u>Psephenus</u>					1				1	1	3	
Hemiptera					1							
Diptera			1	6	33	2						
Ceratopogonidae	13	2				1				2		
Chironomidae				54	47	9	2	15	36	6	9	2
Dytiscidae				1								
Trichoptera	1	7	3		1		1		1	1	1	
Hydropsychidae												
<u>Hydropsyche</u>			1	2	2							
Leptoceridae				1	1							
Polycentropodidae												
<u>Polycentropus</u>				1	1							
Rhyacophilidae												
<u>Rhyacophila</u>	1											
Ephemeroptera	3			2	1	6			6	13	3	1
Baetidae		1			7				1		2	
<u>Centroptilum</u>		1		2							1	
<u>Baetis</u>						7			11	8		
Ephemerellidae	1			16	2							
<u>Drunella</u>						2					3	
<u>Serratella</u>						3						
<u>Eurylophella</u>						9						
<u>Attenella</u>						4						
<u>Dannella</u>						3						
Heptageniidae					1				1	1		
<u>Stenonema</u>			2	1							16	1
Trichorythidae												2
Plecoptera			1								8	1
<u>Perlesta</u>				1		2					5	
Chloroperlidae												
<u>Alloperla</u>					1							
Caenidae												
<u>Caenis</u>									3	1		1
Odonata									1	2		
Corduliidae												
<u>Necrocordulia</u>					3							
Crayfish									1			

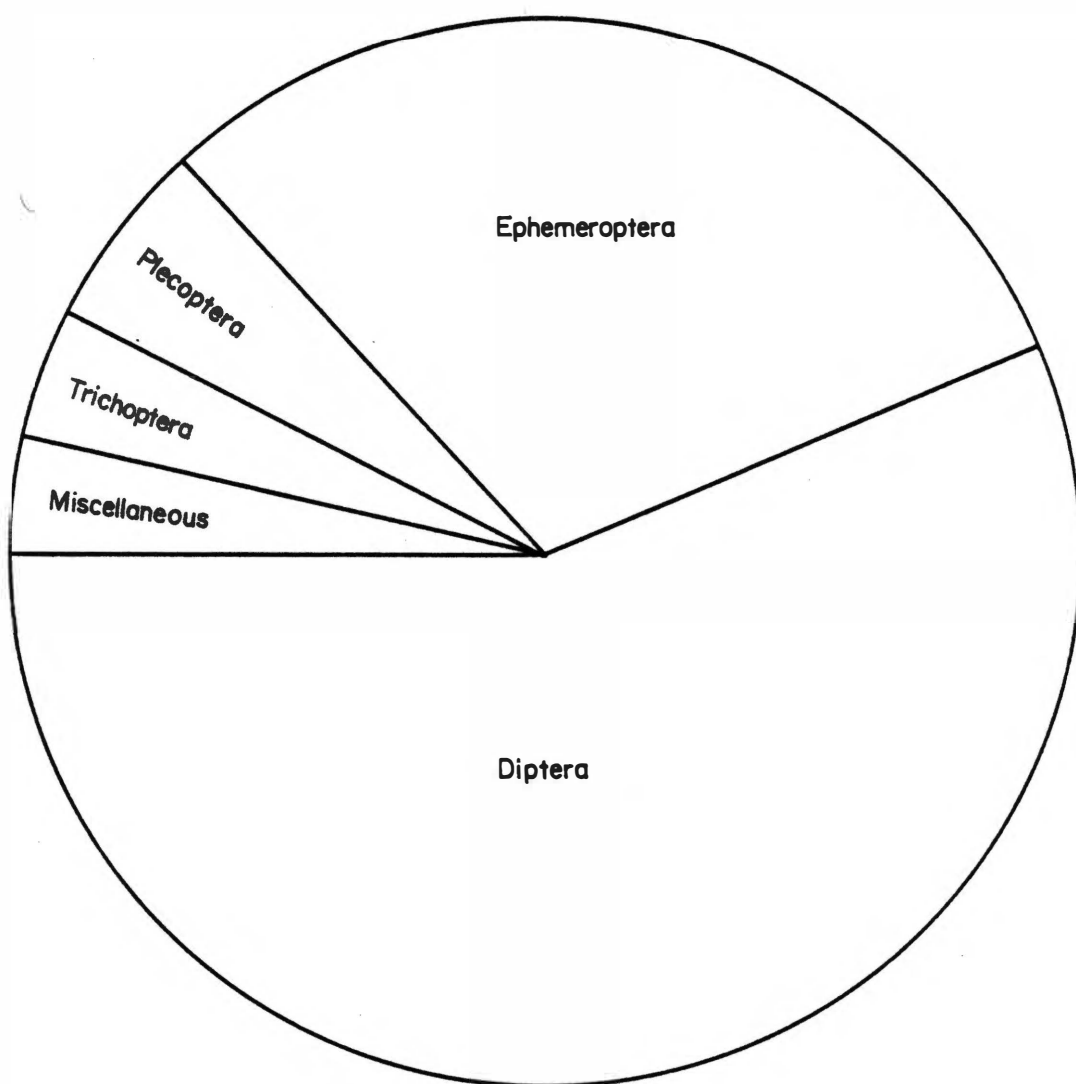


Figure 18. Pie diagram showing major components of the diet of twelve *Noturus flavipinnis* from Citico Creek, Tennessee. N = 474 food items.

Ephemeroptera (mainly Ephemerellidae), Plecoptera, and Trichoptera were all found in the guts of 75% of the individuals examined.

Dipterans were numerically the most important food item, making up 56.6% of the 474 items found in all of the guts. Ephemeroptera, Plecoptera, and Trichoptera made up 30.4%, 5.5% and 4%, respectively, of the food items identified.

Although the biomass of dipteran larvae (mainly chironomids) is very small in comparison with most of the other prey items found in N. flavipinnis guts, they may be a preferred item as they were found in all guts examined and were numerically the predominant prey item found in the Citico Creek population. And, although dipterans were found in only 48% of the guts examined from Copper Creek specimens (Jenkins pers. comm.), they were also numerically the most dominant prey item taken there.

Ephemeropterans were also important items as they were found in the guts of 75% of the Citico Creek specimens and in 57% (Jenkins pers. comm.) of Copper Creek specimens. Numerically they formed the second most important prey item for both Copper Creek and Citico Creek specimens (21%, Jenkins pers. comm., and 30%, respectively).

In Copper Creek Psephenus (water pennies) were found in 23% of the guts examined by Jenkins, and made up 21% of the total number of organisms consumed. The smooth, flattened exoskeleton of these Coleoptera larvae, which allows them to cling to the surface of the stones in the streams that they inhabit (Merritt and Cummins 1978) would appear to be an effective predator avoidance mechanism. Two

individuals, however, consumed large numbers (14 and 19) of these larvae, possibly indicating a preference for this prey type. Bowman (1932) also found N. insignis feeding on water pennies and suggested that they were preferred to other prey types which were abundant in the stream and probably easier to capture.

Several authors (Starnes and Starnes manuscript, Miller 1984, Walsh and Burr manuscript, Mayden and Walsh in press) have suggested that madtoms take prey items depending upon their availability. Because of the differences in food habits between the Citico and Copper Creek populations of N. flavipinnis it appears that these madtoms, although they may exhibit some preferences, are also opportunistic feeders. They consume the prey items which are commonly available in the largest quantities, but will not hesitate to capture other types of food as they are encountered. This may be more true of larger individuals, as they are more able to consume a greater diversity of organisms with regard to size, may be more experienced at capturing different types of prey, and may also be able to forage in more diversified habitats within their pools. The young appear to be confined to areas with smaller substrates where their cryptic coloration presumably affords them more protection from potential predators which limits their ability to encounter a variety of prey types. Bowman (1932) also found that larger individuals of N. insignis consumed a wider variety of prey organisms. Other authors have also reported increasing trophic diversity in madtoms with increasing body size (Bowen 1980, Miller 1984, Mayden and Walsh in press, Mayden and Burr 1981, Burr and Mayden 1982b).

Taylor (1969) suggested that madtoms are probably nocturnal in their feeding activities. Although this is probably true, activity patterns vary between species. Some are reported to be active crepuscularly (Reynolds et al. 1982, Mayden and Burr 1981). Noturus eleutherus apparently consumes most of its food within four hours of sunset (Starnes and Starnes manuscript). Andrews (1963) reported that although some N. miurus collected during the daytime contained food in their guts, the amount was small and usually well digested. He estimated peak feeding to occur between 11:00 p.m. and 3:00 a.m. Bowman (1932) reported that specimens of N. insignis collected during the afternoon either had completely empty stomachs or contained organisms in advanced stages of digestion. In contrast, he noted that individuals collected between 11:00 p.m. and 3:00 a.m. contained freshly eaten organisms. Curd (1959) found that although 75% of stomachs from N. exilis collected during the daytime (midday) contained food, most was unidentifiable, and he concluded that most feeding had been done at night.

Other authors, however, have reported that some diurnal feeding activity takes place for some madtom species (Clark, 1978), including N. flavipinnis. Jenkins (1975) reported that a significant amount of daytime feeding may occur as food organisms drift beneath the madtom's cover. He found (pers. comm.) that eleven of 21 guts examined from fishes collected during the daytime contained food.

In this study, ten of the twelve specimens examined for gut contents were taken during the night. The stomachs of all individuals

taken at night, with the exception of the male guardian removed from his nest, contained easily identifiable and presumably freshly eaten organisms. Two individuals were captured during the daytime, and their stomachs were completely empty. There was material in the hindguts of each, although it was well digested and mostly unidentifiable. Starnes and Starnes (manuscript and pers. comm.) indicate that complete digestion and voidance time for ingested prey of N. eleutherus is approximately 24 hours. Therefore, based on similar voidance times, feeding by the two individuals described above had probably occurred during the middle of the night.

Nocturnal drift of many insect larvae (e.g., chironomids, ephemeropterans, plectopterans, Hynes 1970) is a phenomenon commonly observed in lotic ecosystems, and some authors have suggested that these vulnerable prey are important food sources for madtoms (Starnes and Starnes manuscript). But, Hynes (1970) also indicated that pools do not produce as much drift as do riffle areas. Therefore, pool-dwelling species may be less dependent on this drift phenomenon for prey items. Furthermore, it is assumed that for N. flavipinnis at least, some benthic feeding occurs. This is indicated by the presence of sand grains in four of the twelve Citico Creek and four of the 21 Copper Creek (R. E. Jenkins pers. comm.) specimens examined. Also, crayfish remains and odonata nymphs (Table 10) are indicative of benthic feeding.

Although no winter specimens were examined for gut contents, it is assumed that yellowfin madtoms exhibit little feeding activity

during the winter months, as has been reported for N. miurus and N. eleutherus (Bowen 1980 and Starnes and Starnes manuscript).

Parasitism

There are numerous reports of parasitism in ictalurids (Hoffman 1967), and specifically for madtoms (Hoffman 1967, Burr and Mayden 1982a and b, Mayden and Burr 1981, Mayden et al. 1980, Bowman 1932, Bowen 1980). During this survey, no internal parasites of N. flavipinnis were observed.

However, on one occasion (1 September 1982) three adult madtoms with an undetermined infection on their dorsal fins were collected from the downstream study pool. One individual, which was emaciated and appeared to be in worse condition than the other two was transported to the laboratory to determine the cause of the infection.

It was determined that a stalked protozoan ciliate, Epistylis, produced the erosion of the dorsal fin rays. Although Hoffman (1967) mentioned a personal communication from Tom Wellborn which reports an infestation of catfish eggs by this genus of protozoan, he did not list it as a parasite for any particular ictalurids. Epistylis is an organism which has a free swimming stage and a colonial stage, which merely uses host fish as attachment sites. Therefore, it is not an obligate parasite (Rogers 1971). Rogers (1971) suggested that an outbreak of Epistylis may be due to organic enrichment. In Citico Creek, the very reduced volume of flow during the summer months of 1983 may have produced such conditions in pools.

Ribelin and Migaki (1975), however, reported that because of the large numbers of parasites normally found on the gill arches and filaments of infested animals, death may be caused by suffocation subsequent to interference with respiration. In addition to gill arches and filaments, scales and fins are often a site of parasite attachment. Enzymes secreted by the colony in these areas often erodes spines, scales and even a portion of epithelium, and may also be the cause of inflamed lesions. Although mortalities are rarely caused by this external type of infection, secondary bacterial infections in these lesions may result in death (Rogers 1971).

Predators

Possible predators on N. flavipinnis in Citico Creek include: rainbow trout, Salmo gairdneri Richardson; rock bass, Ambloplites rupestris (Rafinesque); largemouth, smallmouth and spotted basses, Micropterus salmoides (Lacepede), M. dolomieu Lacepede, and M. punctulatus (Rafinesque), and flathead catfish, Pylodictis olivaris (Rafinesque). All of these species, with the exception of the flat-head catfish, have been observed to exhibit little or no nocturnal activity during the nighttime surveys, and are therefore considered to present little threat to yellowfin madtoms. An exception to this may be during the breeding season when the madtoms are diurnally active, and these predators may play a more important role.

Other potential predators include large snapping turtles, Chelydra serpentina, several of which have been seen during the nighttime surveys, "cruising" in pools. Water snakes (Nerodea spp.)

are another predator which are numerous and observed to be nocturnally active. That water snakes prey on madtoms is confirmed by Jordan's (1977, not seen, but cited in Taylor 1969) description of the capture of the holotype of N. eleutherus from the mouth of a water snake. Also, Starnes and Starnes (manuscript) suggested that the nocturnal habits, large mouth and "lie-in-wait" feeding strategy which sculpins (Cottus) exhibit may enable them to prey upon young madtoms. However, an examination of Cottus guts by these authors, in conjunction with a life history study of N. eleutherus, did not confirm this.

Competitors

Proper nesting cover is often a limited resource in Citico Creek, and therefore a possible source of competition between yellow-fin madtoms and other organisms which may also use these slabrocks. Other organisms which have been observed to utilize the large slabrocks preferred by N. flavipinnis for nesting include the mudpuppy, Necturus maculosus, and the smoky madtom, N. baileyi.

Guardians and nests of N. baileyi were often found to be syntopic with N. flavipinnis during the nesting season. This was especially true in the long, shallower pools, although smoky madtoms also place their nests in riffle crests (Dinkins, pers. comm. and pers. obs.). By comparing the surface area of slabrocks that were "occupied" by N. baileyi and N. flavipinnis, the amount of niche overlap for this resource was calculated between the two species of madtoms, using the equation:

$$\alpha_{jk} = \alpha_{kj} = \frac{\sum P_{ij} \cdot \sum P_{ik}}{\sqrt{\sum P_{ij}^2 \cdot \sum P_{ik}^2}}$$

α_{jk} = niche overlap between species "j" and species "k" and P_{ik} = the proportion of the data for species "j" falling within each subclass for that parameter and P_{jk} = the proportion of the data for species "k" falling within each subclass for that parameter (Pianka 1974). The degree of niche overlap with regard to utilization of slabrocks by the congeners is approximately 1.6% (Figure 19).

Not enough data were collected to perform this analysis between Necturus and N. flavipinnis. Based on field observations, however, slabrocks used by mudpuppies appear to be more similar to those preferred by yellowfin madtoms than the slabrocks used by N. baileyi. On several occasions during the reproductive period of N. flavipinnis, single Necturus guarding broods of eggs were found beneath large slabrocks. Therefore, of the two potential competitors for utilization of slabrocks, the mudpuppy is probably worthy of more consideration than N. baileyi and should be studied at more length.

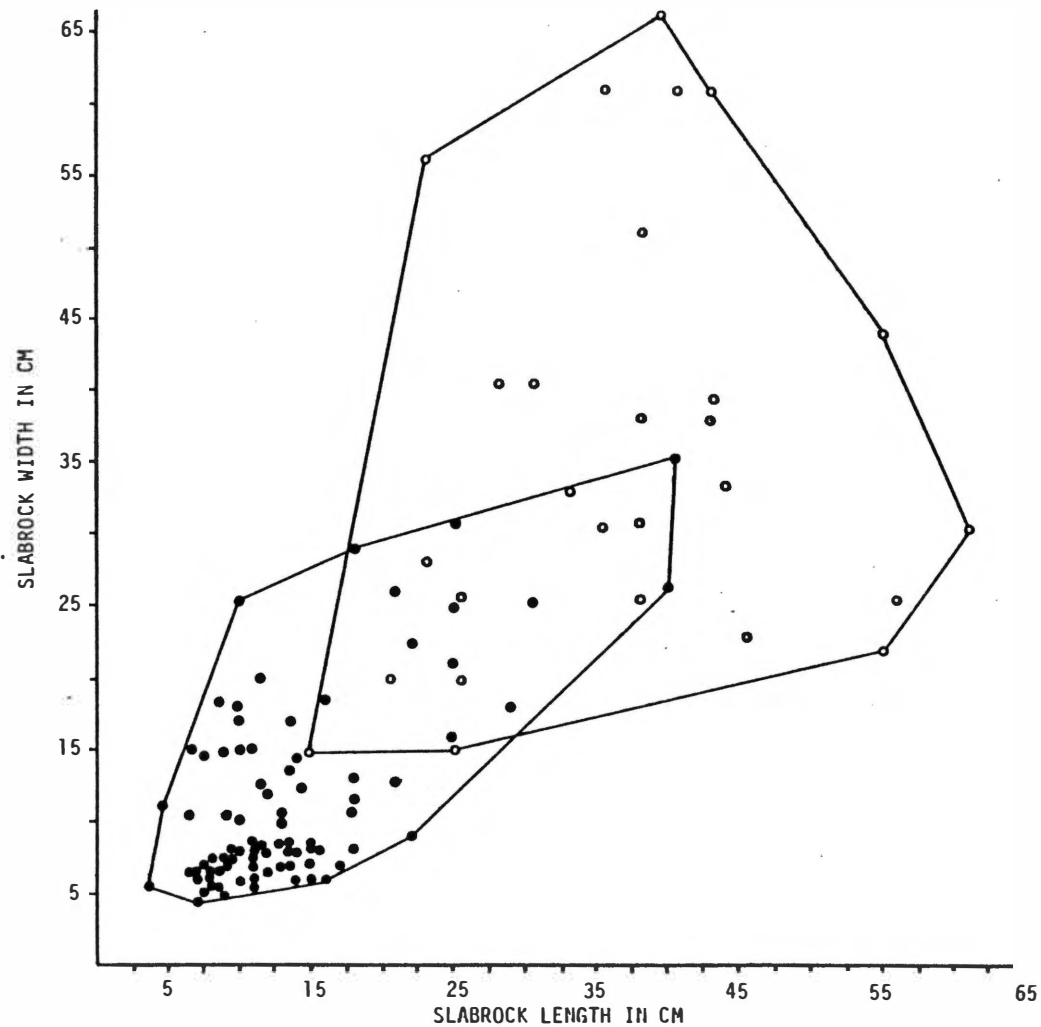


Figure 19. Niche overlap with respect to slabrock utilization between the syntopic *Noturus flavipinnis* and *Noturus baileyi*. Open circles represent *N. flavipinnis* (N = 26) and closed circles represent *N. baileyi* (N = 91).

IV. SUMMARY AND CONCLUSIONS

Many species of Noturus are presently threatened with extinction, because of habitat degradation or pollution associated with man's activities. Although many of these threatened madtom species may be relict populations, they have not been known to recently occupy a range which was much more extensive than that which they now occupy. Noturus stanauli Etnier and Jenkins (Etnier and Jenkins 1980), N. munitus Suttkus and Taylor (Taylor 1969), and N. flavipinnis, however, were probably much more widespread than their present distributions indicate.

If Taylor's (1969) miurus species group shows true evolutionary affinities, their present distributions may be explained by a widespread ancestral form, which differentiated in the uplands of the Tennessee River drainage (N. flavipinnis) and in the Ozard uplands (N. flavater), and the more wide ranging, larger river form (N. miurus), which was able to tolerate a wider variety of ecological situations. Old collecting reports (Jordan 1980, Evermann 1918, Evermann and Hildebrand 1916) indicated that the yellowfin madtom may have been fairly common in most of the upper Tennessee River drainage (Taylor 1969, Starnes and Etnier manuscript). The rapid decline in the abundance of this species illustrates its relative sensitivity and inability to tolerate habitat alterations in the Tennessee River drainage because of pollution, siltation, and impoundments. For comparison, other members of the genus (e.g., N. flavus, N. gyrinus, and

N. miurus) have apparently been able to adapt to habitat modifications and are fairly successful, with widespread distributions.

Although three extant populations of the yellowfin madtom are known today, the Copper Creek population appears to be declining (Burkhead and Jenkins 1982) and the Powell River population must exist in very low numbers, based on the collection of only three specimens over a fifteen year time period (despite intensive sampling, Burkhead and Jenkins 1982, Charles Saylor pers. comm.). In addition, populations in these areas are constantly threatened by water degradation resulting from coal mining activities in the Powell River, and agricultural runoff or threat of accidental chemical spills because of several bridge crossings on Copper Creek.

Tagging data results presented in this thesis show limited movement and that, although the species is fairly fecund in comparison with congeners, their ability to find potential mates may be greatly reduced unless population densities are fairly high. For this reason, although both Powell River and Copper Creek populations of N. flavipinnis are protected by federal Threatened status and Critical Habitat, their future in these areas may be extremely tenuous.

The possibility that Powell River specimens are "strays" from other extant populations in nearby tributaries does exist. All three specimens taken from there were collected singly. Indeed, Burkhead and Jenkins (1982) suggest that the absence of N. flavipinnis from unimpounded areas in the Clinch River is indicative of its preference for smaller streams.

In Citico Creek, there appears to be no imminent threat to the quality of the water, at least above the influence of Caney Creek, and the Citico Creek watershed must have a fairly good buffering capacity. This is extremely fortunate, for the effects of acid drainage produced in the headwaters of Citico Creek by the weathering of Anakeesta rock formations exposed during the construction of a highway between Robbinsville, North Carolina, and Tellico Plains, Tennessee (Arway et al. 1979), provide an example of only one project which could have produced disastrous effects. Long-term effects of any planned future construction or logging practices should be thoroughly studied in order to prevent any possible catastrophies. Potential threats to the upper part of the Citico Creek watershed due to construction or logging will be eliminated if this area is included as part of the national forest Wilderness Area, as has been proposed.

The mere existence of a road running beside the creek for much of its length poses a threat. Although much of the traffic is due to recreational use of the area, the road is also used for logging purposes by heavy trucks. Accidents, which are not infrequent on this road, always present the potential for oil, gasoline, or other hazardous chemical spills. Although this may seem an unlikely threat, only one catastrophe of this type, strategically placed, could possibly extirpate the entire yellowfin madtom population in Citico Creek.

Another more pressing concern to the yellowfin madtom population in Citico Creek is frequent construction of dams by campers at Citico

Creek (Figure 20). Although this behavior may actually improve pool habitats, the major problem is caused by the removal of many nesting-sized slabrocks from the pools in order to construct these dams. Unsuspecting "engineers" may even remove the cover from the nest of an already brooding male madtom. A possible solution to this problem, although it may be difficult to enforce, is to restrict camping from the portion of Citico Creek known to be inhabited by N. flavipinnis. Indeed, some of these areas (at the upstream study pool, for example) are often choice camping localities, and may be occupied by a single group of campers for long periods of time. In this particular site, by damming the pool above, a ford is created which enables vehicles to cross the creek to the desired camping spot. (In addition to creating problems for the yellowfin madtom, dam building also threatens the habitat for the smoky madtom, N. baileyi, by drastically reducing the flow of water in riffle areas inhabited by this species.)

This study indicates that the yellowfin madtom population that inhabits Citico Creek is relatively healthy, but it is dangerously small (less than 500 animals) and extremely localized. This fact, coupled with the uncertain future of the other two known populations, illustrates the species' need for continued protection.

Unless a recovery of the Copper Creek population is indicated, and other extant populations are found, the Threatened status which they currently "enjoy" is not sufficient to insure the protection of the species. Protection should be upgraded to federal Endangered



Figure 20. An example of dam construction in Citico Creek, Tennessee.

species status, with Citico Creek added to the list of areas considered to be Critical Habitat.

If the water of Caney Creek is proven to contain any pollutants which may be linked to downstream extirpation of the yellowfin madtoms in Citico Creek, steps should be taken to correct the problem. Furthermore, as suggested in the U.S. Fish and Wildlife Service's "Yellowfin Madtom Recovery Plan" (Anonymous 1983), an attempt should be made to extend the range of the species in Citico Creek where habitat appears suitable.

Additionally, the population sizes of individual pools may be increased by providing adequate nesting cover where this resource is limited. This intervention may lessen the impact of competition between congeners by allowing the yellowfin madtoms to choose the larger nest covers that they prefer, and leave the smaller ones for the smoky madtom. Also, if competition for the same resource does exist between mudpuppies and yellowfin madtoms, as is indicated, this should be lessened with the addition of "extra" nesting covers.

Until these measures can be undertaken, Critical Habitat designation, in conjunction with the probable listing of the smoky madtom as Endangered as has been proposed by Bauer et al. (1983), will also provide additional protection of the yellowfin madtom. The range of N. flavipinnis within Citico Creek is entirely within the range of N. baileyi.

At the same time, using the techniques described in this thesis and the data presented for comparison, the reproductive success and

fluctuations in population size of the Citico Creek population should be monitored. Small, but detrimental changes in water quality may be indicated which could affect the ability of the species to use chemoreception to find food, potential mates, or to raise young.

Man should feel a sense of moral responsibility for any species which is declining because of the direct or indirect effects of his activities. Therefore, every effort should be made to conserve any species that may reasonably be within our ability to do so. It is within our power to conserve the Citico Creek population of yellowfin madtom, which at present, represents the only stronghold of a species in danger of a "second extinction."

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VITA

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She spent one year working as a laboratory and field research assistant for Dr. John M. Miller at North Carolina State University in Raleigh. She then returned to the University of North Carolina at Wilmington for a three-year contract as a Research Technician for Dr. David G. Lindquist studying the endemic fishes in Lake Waccamaw, North Carolina.

Peggy was married to John R. Shute in August 1976, and has been involved with her husband in many aquatic research projects.

The author is a member of the American Society of Ichthyologists and Herpetologists, the Association of Southeastern Biologists, and the Southeastern Fishes Council.