Life Histories of *Noturus baileyi* and *N. flavipinnis* (Pisces: Ictaluridae), Two Rare Madtom Catfishes in Citico Creek, Monroe County, Tennessee

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ABSTRACT: Dinkins, Gerald R. and Peggy W. Shute. 1995. The Life Histories of *Noturus baileyi* and *N. flavipinnis* (Pisces: Ictaluridae), Two Rare Madtom Catfishes in Citico Creek, Monroe County, Tennessee. Bulletin Alabama Museum of Natural History, Number 18:43–69, 8 tables, 18 figures. The life histories of the federally endangered smoky madtom (*N. baileyi*) and the federally threatened yellowfin madtom (*N. flavipinnis*) were studied in Citico Creek, a tributary to the lower Little Tennessee River in eastern Tennessee. Most of the observations and measurements were made between May 1981 and June 1984. Live and preserved individuals were observed for information on distribution, macro- and microhabitat occurrences, age and growth, reproduction and nesting, larval development, feeding ecology, and parasitism.

Noturus baileyi lives in only a 10.8 km reach of Citico Creek, beginning at creek km 6.0. From late spring to late fall, *N. baileyi* occur underneath flat, palm-sized rocks (slabrocks) in riffles, especially riffle crests. During the colder months, pools are occupied and slabrocks similar in physical dimension to those used as shelter in the riffles are used. *Noturus baileyi* lives approximately two years, and sexual maturity is reached in the second summer of life (one year of age). *Noturus baileyi* nests under large, flat rocks where one or both parents excavate a cavity for the egg mass. Nesting takes place from May to July, and an average of 36.3 eggs were found in four nests. Larval development is described for hatchlings and subsequent stages.

Noturus flavipinnis is found in only three widely distributed locations in the upper Tennessee River system. In Citico Creek, *N. flavipinnis* occurs year-round in pools in a 3.6 km reach beginning above a small concrete dam at creek km 13.7. Movement between these pools is limited. The species lives three to four years, and sexual maturity is reached in the third summer of life (two years of age). *Noturus flavipinnis* nests under large, flat rocks that are slightly larger in physical dimensions than those used by *N. baileyi*. Nesting takes place from May to July, and an average of 55 eggs were found in ten nests. Evidence supporting polyandry is given for both species. Larval development is described for several larval stages of *N. flavipinnis*. Both species are almost exclusively insectivorous.

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Introduction

Although Federal environmental regulations have resulted in some relatively recent, localized improvements in water quality, many rivers and streams in the southeastern United States have been permanently altered because of urban, industrial, and agricultural encroachment. As a result, numerous fish species specialized for particular stream habitats have been able to survive only as fragmented remains of once more widespread populations. This is particularly true of many species of madtom catfish, *Noturus* (Taylor 1969). Several madtom species have relatively restricted distributions and may be naturally rare (sensu Sheldon 1987).

Because of these localized distributions, nine madtom species were listed in 1972 as species of concern by the American Fisheries Society (Miller 1972) and increased to eleven in 1989 (Williams et al. 1989). Currently five are listed by the Department of Interior under the Endangered Species Act: *N. baileyi*–endangered; *N. flavipinnis*–threatened; *N. placidus*–threatened; *N. stanauli*–endangered; and *N. trautmani*–endangered, probably extinct (U.S. Fish and Wildlife Service 1994a). The latest listing of taxa being considered for federal status includes six species and one subspecies (U.S. Fish and Wildlife Service 1994b). As a group, members of the genus *Noturus* are imperiled disproportionately to the percentage of the ichthyofauna which they comprise (Etnier and Starnes 1991, Warren and Burr 1994).

Before the last two decades, there were relatively few published discussions of madtom life histories. The earlier works on this group of fishes included: Clugston and Cooper (1960); Curd (1960); Carlson (1966); Thomerson (1966) and Mahon (1977). With the recent interest and concern for rapidly declining populations of *Noturus*, numerous ecological works on the group have appeared in the literature. These include: Mayden et al. (1980); Burr and Dimmick (1981); Mayden and Burr (1981); Burr and Mayden (1982a, b); Lindquist et al. (1982); Burr and Mayden (1984); Mayden and Walsh (1984); Miller (1984); Starnes and Starnes (1985); Walsh and Burr (1985); Whiteside and Burr (1986); Burr et al. (1989); Vives (1987); Luttrell et al. (1992); Simonson and Neves (1992); Baker and Heins (1994); Fuselier and Edds (1994); and Pfingsten and Edds (1994). One of the most comprehensive studies, which suggests application of life history data to management of threatened and endangered species is that of Mayden and Walsh (1984).

Several unpublished theses and status survey reports have also added knowledge about ecology of madtoms. These include Bowman (1932, 1936); Gilbert (1953); Andrews (1963); Case (1970); Madding (1971); Bowen (1980); Moss (1981); Robison and Harp (1981a, b); Dinkins (1982); Bauer and Clemmer (1983); Dinkins (1984); Shute (1984); Burr et al. (1993); and Shute et al. (1992). As a result, today there are only a few species of *Noturus* for which there is no available biological information. In many cases, however, specific information sufficient to allow protection, management, and possible recovery has not been easily obtainable, or may be available only when it is too late to protect the species. For example, *N. trautmani* is probably extinct (Rohde 1978).

Catfish are known to be highly social animals, and bullheads (*Ameiurus*) have been reported to display sophisticated behaviors based on chemoreception. 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). The more sensitive members of the genus may be detrimentally affected by small changes in water quality. Etnier and Jenkins (1980, p. 20) 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 paper presents ecological data obtained by monitoring reproductive success, demography, and food habits for the only known population of the federally endangered smoky madtom, *N. baileyi*, and one of the three extant populations of the federally threatened yellowfin madtom, *N. flavipinnis*. These data were collected and documented in more detail by Dinkins (1984) and Shute (1984) as partial fulfillment for their M.S. degrees. Our work has also been supplemented with data obtained 1986 to present while monitoring and performing a captive rearing and reintroduction project for both species (see Shute et al. 1992 for a detailed description of these projects). Populations of both species examined are highly localized and it is hoped that the information obtained and methods used to collect the data may be useful to ensure their future protection.

Background

NOTURUS BAILEYI—*Noturus baileyi* (Figure 1a) was described by Taylor (1969) from five specimens collected during a 1957 stream reclamation (poisoning) project conducted on Abrams Creek (Figure 2), a tributary to the Little Tennessee River in the Great Smoky Mountains National Park. This project, designed to eliminate "rough" fish and enhance conditions for trout stocking, was done in conjunction with the closure of the gates of Chilhowee Dam (Lennon and Parker 1959). The exact locality where *N. baileyi* was captured was unknown at the time of description, but Dinkins (1982) concluded that the type specimens were collected from the Abrams Creek campground area (approximate creek km 12.9) based on habitat,

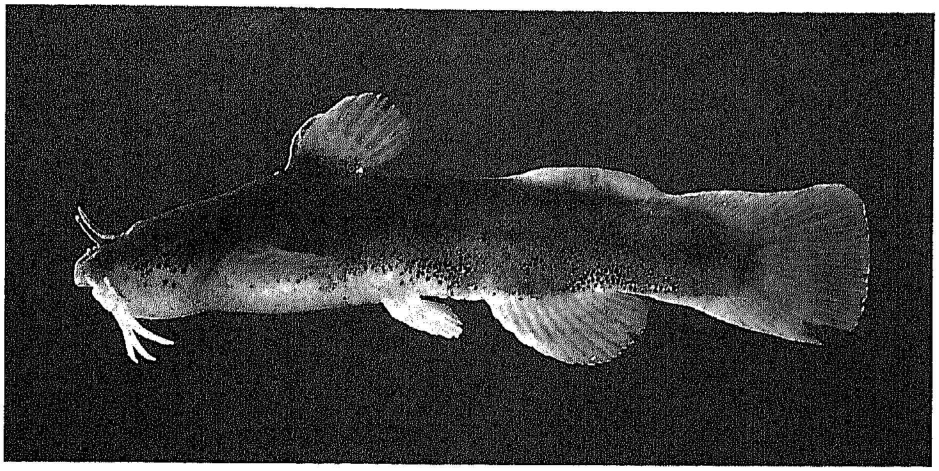

Figure 1a: ***Noturus baileyi*** **(Photograph by J. R. Shute).**

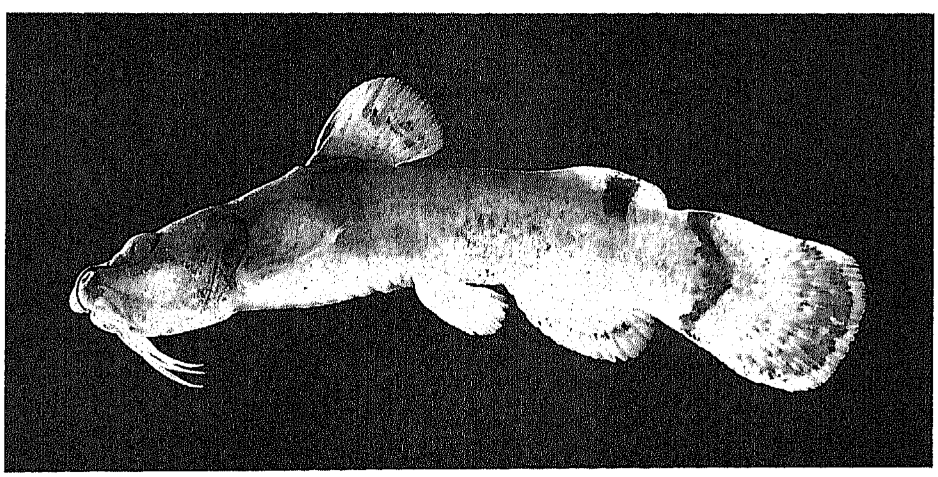

Figure 1b: ***Noturus flavipinnis*** **(Photograph by J. R. Shute).**

stream gradient, elevation, and discussions with personnel involved with the reclamation. Collections made in Abrams Creek and other Little Tennessee River tributaries subsequent to Taylor's monograph revealed no additional specimens of *N. baileyi*, and the species was believed to be extinct.

On 23 July 1980, while surveying Citico Creek for the spotfin chub (*Cyprinella* (=*Hybopsis*) *monacha*) a single specimen of *N. baileyi* was collected (Bauer et al. 1983). Citico Creek is a direct tributary to the Little Tennessee River; the mouth of Citico Creek is approximately 11 river km downstream from the mouth of Abrams Creek. With funding from the U.S. Fish and Wildlife Service (FWS) for a status survey of the species, Dinkins (1982) concluded that *N. baileyi* only existed in a 10.6 km stretch of Citico Creek, and recommended the species be given federal endangered status. On 26 October 1984 *N. baileyi* was listed as federally endangered and Citico Creek was designated as Critical Habitat (U. S. Fish and Wildlife Service 1984). Williams et al. (1989) also considered the species nationally endangered because of present or threatened destruction, modification or curtailment of its habitat or range. *Noturus baileyi* is also listed as endangered by the state of Tennessee (Tennessee Wildlife Resources Agency 1994).

Noturus flavipinnis—*Noturus flavipinnis* (Figure 1b) was described by Taylor (1969) from thirteen specimens collected between 1884 and 1893 at four locations in the upper Tennessee River system. Only three of the original localities are known with certainty: West Chickamauga Creek, Georgia; North Fork Holston River, Virginia; and Hines [Hinds] Creek, Tennessee (Figure 3). In his description of the species, Taylor speculated that the historical range of *N. flavipinnis* was the upper Tennessee River basin, but because of impounded or polluted conditions of historical localities, and the lack of specimens in pre-impoundment and other numerous surveys, the species had become extinct, presumably in the early 1900's.

Since Taylor's original description, three geographically isolated populations of *N. flavipinnis* have been discovered. One specimen was taken in 1968 during nighttime sampling in the Powell River at McDowell Shoals (river km 171.8, Hancock County, Tennessee) by Tennessee Valley Authority (TVA) biologists (Taylor et al. 1971). In 1969, four localities in Copper Creek (a Clinch River tributary in Scott and Russell counties, Virginia) yielded 28 specimens of *N. flavipinnis*. Because the original description was based on 13 faded specimens, *N. flavipinnis* was redescribed by Taylor et al. (1971) based on these individuals from Copper Creek and the Powell River. In June 1981, five specimens of *N. flavipinnis* were collected by the senior author while skin diving at night in search of *N. baileyi* in Citico Creek. Subsequent to this discovery, Shute (1984) was funded by FWS to perform a status survey and make management recommendations. She determined that the Citico Creek population is apparently confined upstream of a small concrete dam at creek km 13.7. Starnes and Etnier (1986) concluded that the lack of morphological intraspecific variation between the Citico Creek and Copper Creek populations indicated a relatively recent continuous population.

Noturus flavipinnis was listed as federally threatened on 9 September 1977 (U. S. Fish and Wildlife Service 1977) with the Powell River and Copper Creek designated as Critical Habitat. Williams et al. (1989) listed the species as nationally threatened for the same reasons given for *N. flavipinnis*. *Noturus flavipinnis* is listed as endangered by the state of Tennessee; endangered in Virginia (Burkhead and Jenkins 1991); and presumed extirpated in Georgia (B. J. Freeman pers. comm.)

Study Area

Citico Creek is a moderate sized (10 to 25 m width), relatively pristine, fourth order stream located in eastern Tennessee (Figure 2). The stream originates in the steep, mountainous Blue Ridge physiographic province along the Tennessee/North Carolina border and has its confluence with the Little Tennessee River at the eastern edge of the Valley and Ridge Province (Swingle et al. 1966). The lower 2.3 km of Citico Creek are inundated (since 1979) by Tellico Reservoir. Most of the heavily forested and mountainous watershed is within the Cherokee National Forest and the Tellico Wildlife Management

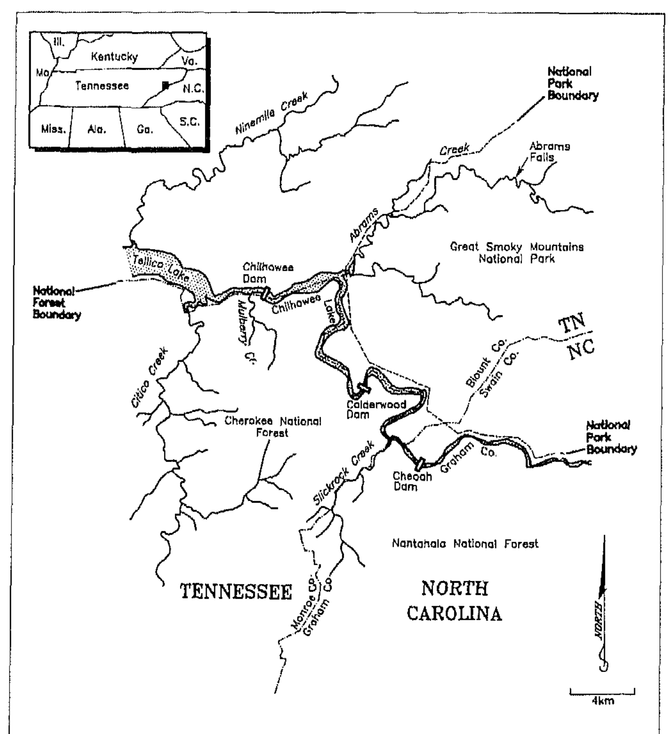

Figure 2: Map of the middle Little Tennessee River system.

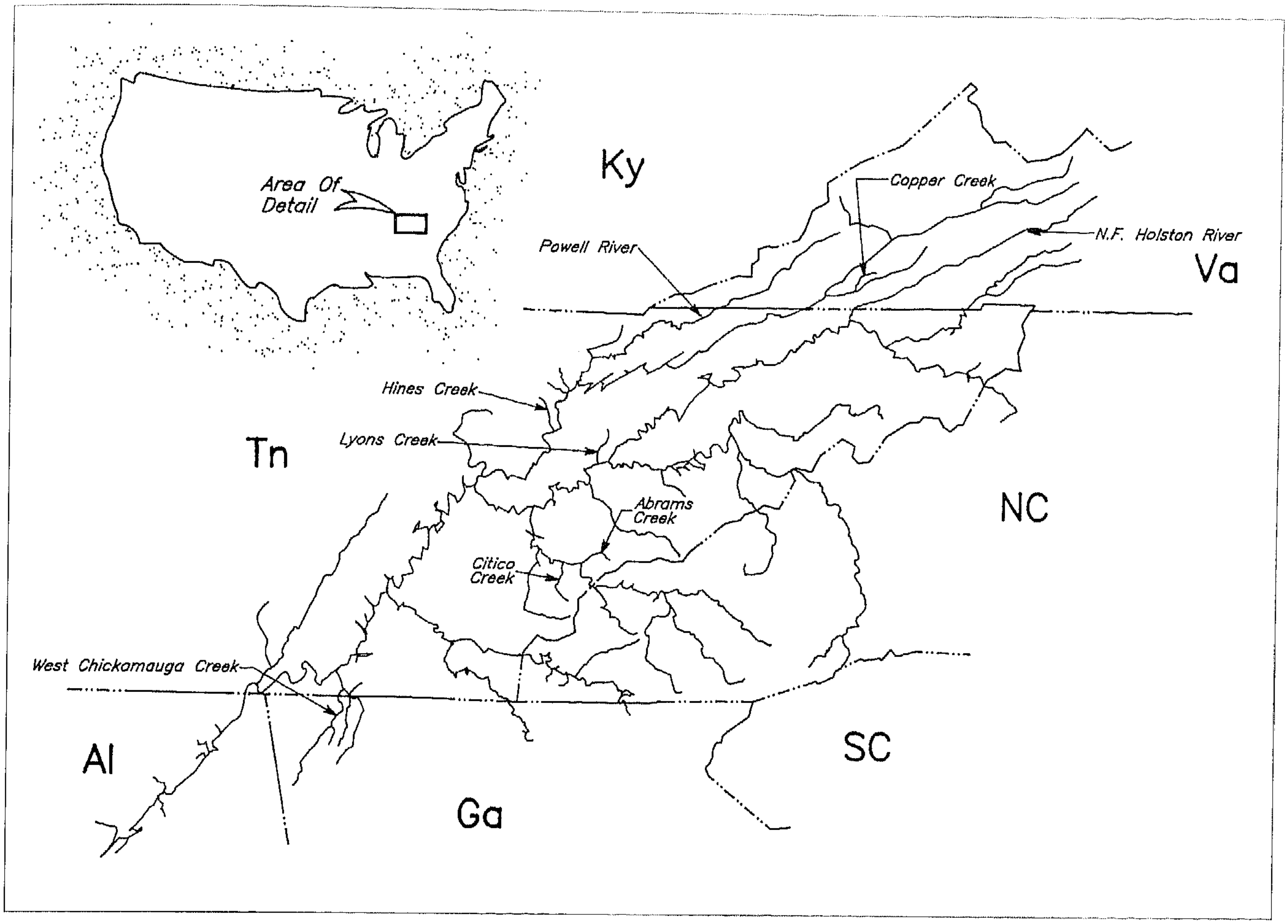

Figure 3: Map of the upper Tennessee River system.

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.

There are two, small concrete dams located at creek km 13.7 and 25.3 which were built in 1973 to impede the vernal migration of redhorses (*Moxostoma* spp.) into upstream reaches where hatchery-raised trout are released. These structures inundate two short stretches of creek (approximately 91 m and 18 m respectively, during normal water level).

Citico Creek proper has a gradient drop of 6.8 m per km with a noticeable gradient change at creek km 16.7. When Citico Creek is separated into two contiguous sections—the upper being creek km 26.5 to 16.7, and the lower being 16.7 to the mouth–the gradient is 14.4 m per km and 2.5 m per km, respectively.

In the lower section, the creek consists mainly of riffles with flat, palm-sized rocks (slabrocks) and cobble substrates alternating with long, shallow pools with medium-sized gravel, pebble, slabrock, and bedrock substrates. Where the stream enters the higher elevations of the Blue Ridge physiographic province, pools become deeper, shorter, and bedrock intrusions dominate the substrate.

Fishes are relatively diverse in Citico Creek. Fifty-six (56) species were documented during this study (Table 1). In addition to *N. flavipinnis* and *N. baileyi*, the fish fauna also includes the duskytail darter (*Etheostoma percnurum*) listed as federally endangered and considered endangered by the states of Tennessee (Tennessee Wildlife Resources Agency 1994) and Virginia (Burkhead and Jenkins 1991), and threatened by the American Fisheries Society (Williams et al. 1989).

Materials and Methods

COLLECTION OF FISHES—Several collections of fishes using standard techniques were made in Citico Creek prior to the discovery of *N. baileyi* (Etnier 1978; University of Michigan, unpublished collection records). The first specimen was collected with an electroshocker and seine net, but this collecting technique used on many subsequent trips to Citico Creek between September 1980 and

Table 1. Species List of Fishes in Citico Creek

Species	Common Name	Species	Common Name
Ichthyomyzon castaneus	chestnut lamprey	*Noturus baileyi*	smoky madtom
Lampetra appendix	American brook lamprey	*N. flavipinnis*	yellowfin madtom
Lepisosteus oculatus	spotted gar	*Pylodictis olivaris*	flathead catfish
Campostoma anomalum	central stoneroller	*Oncorhynchus mykiss*	rainbow trout
Clinostomus funduloides	rosyside dace	*Salmo trutta*	brown trout
Cyprinella galactura	whitetail shiner	*Salvelinus fontinalis*	brook trout
C. monacha[1]	spotfin chub	*Fundulus catenatus*	northern studfish
C. spiloptera	spotfin shiner	*Cottus carolinae*	banded sculpin
Cyprinus carpio	common carp	*Ambloplites rupestris*	rock bass
Erimystax insignis	blotched chub	*Lepomis auritus*	redbreast sunfish
Luxilus coccogenis	warpaint shiner	*L. cyanellus*	green sunfish
L. chrysocephalus	striped shiner	*L. gulosus*	warmouth
Lythrurus lirus	mountain shiner	*L. macrochirus*	bluegill
Nocomis micropogon	river chub	*L. megalotis*	longear sunfish
Notropis sp.	sawfin shiner	*Micropterus dolomieu*	smallmouth bass
N. amblops	bigeye chub	*M. punctulatus*	spotted bass
N. leuciodus	Tennessee shiner	*M. salmoides*	largemouth bass
N. photogenis	silver shiner	*Etheostoma blennioides*	greenside darter
N. telescopus	telescope shiner	*E. chlorobranchium*	greenfin darter
Phenacobius uranops	stargazing minnow	*E. jessiae*	blueside darter
Phoxinus tennesseensis	Tennessee dace	*E. percnurum*	duskytail darter
Rhinichthys atratulus	blacknose dace	*E. rufilineatum*	redline darter
R. cataractae	longnose dace	*E. simoterum*	Tennessee snubnose darter
Ictiobus sp.	buffalo	*E. zonale*	banded darter
Hypentelium nigricans	northern hog sucker	*Percina caprodes*	logperch
Moxostoma carinatum	river redhorse	*P. evides*	gilt darter
Ameiurus natalis	yellow bullhead	*Perca flavescens*	yellow perch
Ictalurus punctatus	channel catfish	*Aplodinotus grunniens*	freshwater drum

[1] *Cyprinella monacha* is represented by a single 1936 record and is probably extirpated from Citico Creek.

June 1981 yielded only 16 specimens (13 catalogued at the University of Tennessee Research Collection of Fishes and three others released). Direct underwater observations using skin and SCUBA diving gear ultimately proved to be the most efficient method for collecting life history data and capturing specimens in all habitats. This approach provided the additional benefits of minimizing the disturbance to the benthic habitats where both of these rare species occur, and made it possible for a single collector to capture several specimens in a short period of time. Daytime and nighttime searches were conducted from creek km 26.6 to the area inundated by Tellico reservoir (creek km 2.3).

Daytime riffle searches were conducted by lying head forward in the current, and moving slowly across the channel while all substrate within an arm's reach was examined. By moving approximately one arm's length upstream when the stream edge was reached and then returning across the channel, a riffle area from lower to upper end could be thoroughly examined. Daytime searches for *N. baileyi* in pools were accomplished by examining the substrate while floating downstream. Care was taken during the breeding season to avoid disturbance of potential nesting habitat.

Attempts to collect *N. flavipinnis* during the day were unsuccessful, except during the breeding season. After dark, however, individuals were often observed in the open. To collect them, snorkelers were spaced from bank to bank across a pool. Each observer swam the length of the pool and searched in the open, under rocks, and among debris. When *N. flavipinnis* were spotted, they were easily captured with small dip nets. Very few individuals evaded capture, and ones that did were often seen again and captured during a second swim through the pool. Flow-through minnow buckets were used to temporarily hold both madtom species. Individuals collected were measured and weighed (some were marked) and released in the same general area from which they were taken.

Both species use large, flat rocks as cover for nests. Searches for nests were made during the breeding season by carefully lifting appropriate rocks. After a few nests were observed in this manner, however, this type of survey was discontinued for fear of dislodging egg masses or disturbing larvae which might be lost to current or consumed by minnows. There was also the possibility that the guardian madtom would not return after being disturbed, although our observations indicated that it usually did not move far from the nest.

The Citico Creek *N. flavipinnis* population was studied primarily by observing individuals inhabiting two adjacent pools. These pools, located at creek km 16.4, were representative of two different pool habitats found in the stretch of stream inhabited by *N. flavipinnis*. Physical characteristics of these pools were measured in March 1994. The downstream pool was long (147 m) and shallow, and averaged about 1 m midstream depth. Substrate consisted mainly of gravel and pebbles with occasional slabrocks. Boulder and bedrock predominated at the head of the pool, and bedrock shelves lined the northern shores of the pool. Current velocity was slow (0.33 m/sec). The upstream pool was long (173 m) and deeper, with a large proportion of the pool exceeding 2.5 m. The substrate was large boulders and bedrock. Current was somewhat swifter in this pool. These two pools were separated by a 45 m riffle. Stream discharge in this area averaged 4.9 m^3/sec.

Most collections of preserved material and observations of live individuals were made between May 1981 and June 1984. Preserved specimens used for this paper included 13 *N. baileyi* and 12 *N. flavipinnis* from Citico Creek, and 30 *N. flavipinnis* from Copper Creek, Virginia.

Tagging and Population Estimation

Between June and November 1982, 46 adult *N. baileyi* were individually marked with a mixture of water and acrylic paint injected under the skin. However, the difficulty in handling individuals of this diminutive species, fear of causing mortality, and the lack of recaptures led us to abandon efforts to mark and recapture *N. baileyi*. However, adult *N. flavipinnis* are larger and the same technique was much easier to perform on this species. Data on individual growth rates, longevity, movement, and population density were gathered from this effort.

Forty-five *N. flavipinnis* were individually marked with acrylic paint using different combinations of colors and body locations. In addition to the acrylic marks, the left pelvic fin was clipped on 21 other *N. flavipinnis* from the upper pool, and the right pelvic fin was clipped on 32 madtoms from the lower pool. Yearling *N. flavipinnis* were neither marked nor fin-clipped for fear of potential injury.

In order to meet the multiple census restrictions of negligible recruitment or mortality, mark-recapture took place after the breeding season was over and before winter began (between August and October 1983). During each census subsequent to the initial tagging, the number of recaptured fish and location of marks were recorded, and any unmarked fish were tagged. From these data two different population estimates (Schumacker and modified Schnabel) were determined for each pool in the manner described by Ricker (1975).

Each pool within the 3.2 km of Citico Creek inhabited by *N. flavipinnis* was characterized and designated as being similar to the upstream or the downstream study pool. The total length of each pool type was then summed, stream width was fixed at 20.7 m, and a population estimate for the 3.2 km was extrapolated.

Reproduction and Early Life History

Annual fecundity was determined by examining ovaries from preserved 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. In the summer of 1983, one nest of each species was removed from the field, taken to the laboratory, and placed in a small aerated container of creek water. The container was maintained at 18 to 20 °C. Larvae were periodically removed, preserved in 5% buffered formalin and illustrated. Larval terminology follows that of Snyder (1976).

Between 1986 and present, 79 smoky and 16 *N. flavipinnis* nests containing eggs or larvae were removed from Citico Creek and reared in captivity as part of a recovery project designed to reestablish extirpated populations of both species (Shute et al. 1992; Shute et al. 1993; Shute and Rakes 1994; Rakes et al. 1990; Rakes et al. 1995). Some data from the recovery project are included in this paper.

Diet

Stomachs and intestinal tracts from preserved specimens were examined for gut contents. Prey items were identified to the lowest practical taxonomic unit. Difficulty was encountered in identifying some mayfly nymphs due to digestion of soft body parts. For this reason, madtom capture localities were surveyed for Ephemeroptera. Results of the survey were used to devise a diagrammatic key for identifying mayfly fragments in the stomachs and intestines of madtoms. In this way, almost all prey items were identified to the generic level.

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

Results and Discussion

Range Within Citico Creek

NOTURUS BAILEYI—The habitat change at creek km 16.8, as the creek descends from the higher elevations of the Blue Ridge physiographic province, marks the upstream extent of *N. baileyi* (Figure 4). Upstream, the substrate consists

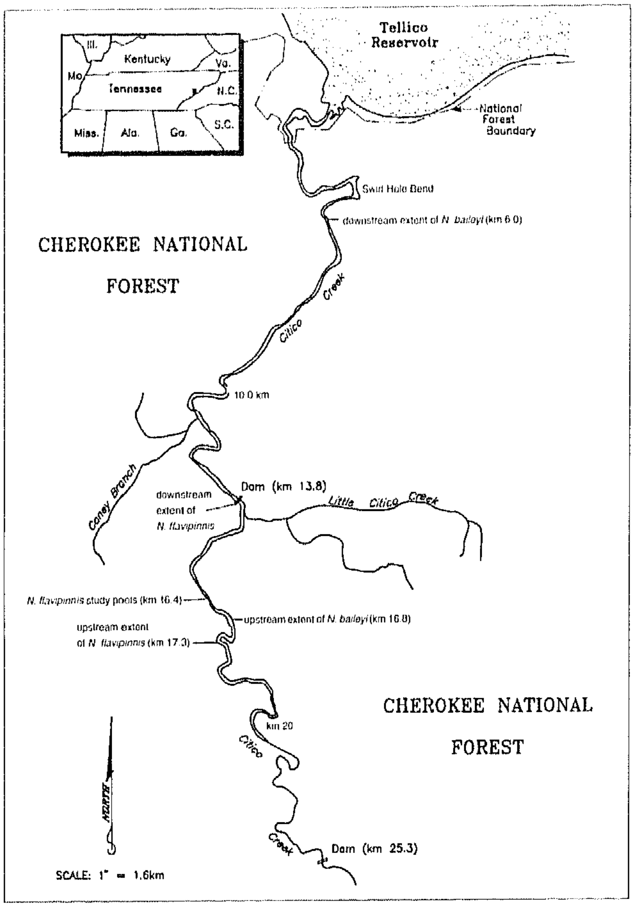

Figure 4: Map of lower Citico Creek.

largely of boulders and bedrock, and short cascades alternate with short pools. The 10.8 km stretch of creek occupied by *N. baileyi* between creek km 6.0 and 16.8 is typified by shallow riffles composed of abundant slabrocks, long shallow pools with pea-sized gravel and occasional slabrocks, and a few deeper pools with large boulders and silty/sandy bottoms. The Ranger-Citico-Fletcher soil association roughly delineates that section of the stream occupied by *N. baileyi* (Hall et al. 1981). Below creek km 6.0, the substrate is dominated by bedrock and sand. During this study, water temperatures in the reach occupied by *N. baileyi* ranged from a low of 5 °C (January) to a high of 23 °C (July).

Noturus flavipinnis—In Citico Creek, *N. flavipinnis* occurs in a 3.6 km reach upstream of a small concrete dam at creek km 13.7 (Figure 4). The absence of *N. flavipinnis* below the dam is puzzling, as pools in the lower reaches are plentiful and habitat is apparently similar to that above the dam. Absence of the species from the lower reaches of Citico Creek may be related to short-term degradation that occurred during dam construction or may be related to agricultural practices in the headwaters of Caney Branch, a second order stream that flows into Citico Creek at creek km 11.4. On several occasions following heavy rains, we have watched Caney Branch release heavy sediment loads into Citico Creek. Caney Branch's headwaters drain approximately 0.4 km^2 of a private property inholding within the National Forest.

The presence of *N. baileyi* in this lower stretch of Citico Creek adds further complexity to this question. Because of their preference for riffles during most of the year, *N. baileyi* may be more tolerant of siltation than the year-round pool-dwelling *N. flavipinnis.* Occasional periods of turbidity are common, however, at the other two localities where *N. flavipinnis* occurs (Powell River and Copper Creek). Finally, because of the popularity of Citico Creek with local campers and fishermen, it is possible that *N. flavipinnis* was introduced into Citico Creek and has been unable to expand its range downstream of the dam. This is an appealing theory because it would indicate that another, most likely local, population may exist.

Habitat

Noturus baileyi—From late May to early November nonnesting *N. baileyi* were found underneath slabrocks in swift to moderate currents in all parts of riffles, especially riffle crests. At three riffle crest localities where 48 specimens were captured, current ranged from 0.52 to 0.67 m/sec ($\overline{X}$ = 0.58), and depths ranged from 30 to 41 cm ($\overline{X}$ = 34.0). In these areas, the substrate was comprised largely of slabrocks lying in a pea-sized gravel matrix. Physical dimensions of riffle area slabrocks used as shelter by *N. baileyi* are presented in Table 2. Some of these slabrocks (18%) had slight depressions on the undersurface.

Between early November and late May, *N. baileyi* were found in shallow pools. The shift in habitat from the riffles they inhabit in warmer months occurred in less than one week and coincided with a drop in water temperature to 7–8 °C. Mayden and Walsh (1984) also suggested a late fall/early winter habitat shift for the least madtom, *N. hildebrandi,* based on a shift in gut contents.

Water depth at three localities where 41 *N. baileyi* were collected during late fall and winter ranged from 60 to 68 cm ($\overline{X}$ = 62.7); current ranged from 0.15 to 0.43 m/sec ($\overline{X}$ = 0.27). Substratum was comprised primarily of large boulders, with occasional slabrocks, and a sand/gravel matrix. Roughly half of the pool slabrocks used by *N. baileyi* were either entirely concave (side view) or had a depression on the undersurface. Analyses of variance tests on slabrock dimensions examined for the two habitat types produced low F-ratio values (Table 2), indicating that the slabrocks *N. baileyi* used for cover in the riffles were not significantly different from those used for cover in the pools. No statistical tests were conducted to determine if the slabrocks used for cover by *N. baileyi* differed significantly from other available slabrocks in the same area. Our observations indicate a wide range of rock sizes occur in the riffles and pools and rocks of the preferred size and shape are less abundant in the pools than in the

Table 2. Dimensions of Slabrocks Occupied by Non-Nesting *Noturus baileyi* with Standard Lengths, by Habitat, from Citico Creek, June 1982 to June 1983

	N	SL (mm) X̄ ± SE	SL (mm) Range	F-Ratio	Rock Surface Area (mm) X̄ ± SE	Range	F-Ratio	Rock Thickness (mm²) X̄ ± SE	Range	F-Ratio
					Untransformed Data					
Riffles	46	39.78 ± 1.35	22–57	0.001	8300.65 ± 638.67	2796–18265	0.130	19.89 ± 1.42	4–50	0.010
Pools	30	39.83 ± 3.16	27–58		8422.47 ± 1180.68	3117–33006		20.93 ± 1.70	8–50	
Both	76	39.80 ± 1.08	22–58		8348.74 ± 600.79	2796–33006		20.30 ± 1.09	4–50	
					Log_{10} Transformed Data					
Riffles	46	1.59 ± 0.02	1.34–1.76	0.003	3.86 ± 0.03	3.45–4.26	0.115	1.25 ± 0.03	0.60–1.70	0.042
Pools	30	1.59 ± 0.03	1.43–1.76		3.85 ± 0.05	3.49–4.52		1.28 ± 0.03	0.90–1.70	
Both	76	1.59 ± 0.01	1.34–1.76		3.85 ± 0.03	3.45–4.52		1.26 ± 0.02	0.60–1.70	

riffles. Thus, competition for slabrocks may have increased as *N. baileyi* left the riffle areas and entered the pools. While *N. baileyi* selected for a certain size of protective cover rock in both habitats, multiple regression results showed no relationship between fish length, rock thickness, and rock surface area. An analysis of variance test on the standard lengths (SL) of madtoms captured in the two habitats produced low F-ratio values, indicating an equally collected distribution of sizes. Thus, there was no selection for age class in the areas sampled.

Noturus flavipinnis—According to Jenkins (1978), *N. flavipinnis* is an inhabitant of pools and backwaters in Copper Creek. In Citico Creek, *N. flavipinnis* were usually found in shallow pools (less than one m deep); in deeper pools individuals were almost always observed at depths of less than two m. Thorough searching beneath movable cover in the main stream bed rarely revealed any individuals during daylight hours or at dusk. Presumably, they were diurnally associated with other cover types such as stream banks, bedrock ledges, or tree roots. During spring, summer, and fall, adult *N. flavipinnis* were nocturnally associated with open benthic areas and occasionally, cover. Adults were increasingly scarce in open benthic areas as the water temperature decreased in late fall, and we presume that very little activity occurred during winter months. Young *N. flavipinnis* may be more active at cooler temperatures than adults. This is based on a November observation when five young and only one adult were observed (water temperature was 6 °C). Substrate in pools occupied by *N. flavipinnis* consists mainly of gravel and pebbles, with occasional slabrocks, boulders, and bedrock.

Movement

Recapture data from marked fish indicate that adult *N. flavipinnis* do not ordinarily move between pools. Of 45 fish individually tagged with acrylic paint, seven were recaptured between seven and 32 months after tagging (Table 3). All of these recaptures were found in the same pool where originally tagged. The 13 recaptured fin-clipped individuals also had not moved from their pool of original capture.

That localization of small populations may be common in madtoms is further supported by other evidence. In a study of *N. gyrinus*, Case (1970) showed that movement of this species is very limited; of 693 adult fish marked, only 5 individuals were recaptured at sites other than where they were first captured and released. Fuselier and Edds (1994) reported that only one of twelve marked *N. placidus* had moved from the locality of original capture.

Limited movement patterns observed in this study apply to adult *N. flavipinnis* only, since small individuals were not marked. Proper censusing of the young by snorkeling requires a great deal more time than searching for adults, and a much different search image is needed to detect the cryptic juveniles. It is possible that juveniles are the dispersal agents for the species.

Jenkins (1975) reported that all life stages of *N. flavipinnis* in Copper Creek occupy the same habitat. The same appears to be true for *N. flavipinnis* in Citico Creek; none were found beneath rocks in riffles or runs while searching for *N. baileyi*. Free-swimming juveniles as small as 19 mm SL were observed over fine-grained substrates in pools as early as mid-August. Perhaps the reason two such closely related congeners can occur sympatrically in Citico Creek is that adult *N. flavipinnis*, unlike *N. baileyi*, have never been observed to switch habitats. Therefore, there is little interaction during warmer months when both species are most active.

Population Estimate

Recaptures of fin-clipped individuals were used to esti-

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

Locality of Tagging (pool)	Date of Tagging	Size When Tagged (mm SL)	Sex	Locality of Recapture (pool)	Date of Recapture	Size at Recapture (mm SL)	Growth (mm)
Lower	10/1/81	39	?	Lower	6/30/84	108	69
Upper	10/1/81	110	♂	Upper	5/29/82	114	4
Upper	10/1/81	103	♀	Upper	5/8/83	108	5
Lower	10/1/81	73	?	Lower	7/15/83	106	33
Lower	10/1/81	80	?	Lower	6/27/83	93	13
Upper	10/4/81	83	♂	Upper	5/29/82	104	21
Lower	6/27/82	100	?	Lower	8/9/82	106	6

Table 4. Recapture and Population Estimation Data for *Noturus flavipinnis* Based on Mark-Recapture (Fin-clipping) in the Upper and Lower Study Pools

Date	C_t	R_t	M_t	C_tM_t	M_tR_t	$C_tM_t^2$	R_t^2/C_t	Estimate	Confidence 95%
				Upper Pool					
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]	13–132
								34[b]	(Poisson)
								38[c]	
10/16/83	2	0	19	38	0	722	0	53[c]	20–206
			21					41[b]	(Poisson)
				Lower Pool					
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]	18–105
								39[c]	30–56
9/28/83	11	3	21	231	63	4851	0.8181	46[b]	27–116
								56[c]	35–160
10/16/83	5	2	29	145	58	4205	0.800	51[b]	41–114
			32					60[c]	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).
[a]Petersen estimate.
[b]Modified Schnabel estimate.
[c]Schumaker estimate.

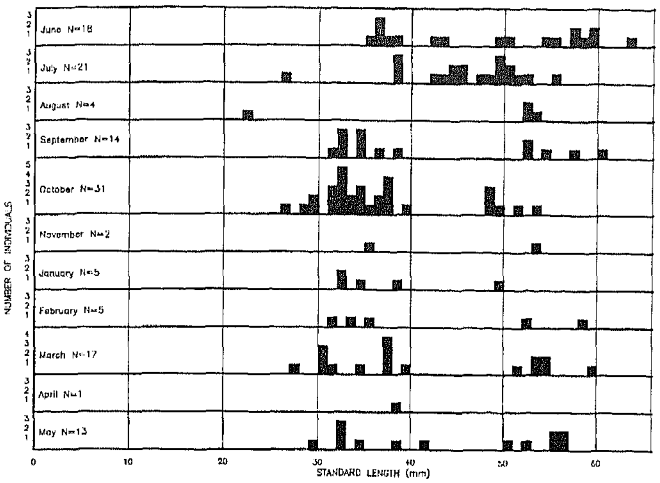

Figure 5: Length frequency histograms for specimens of *Noturus baileyi* from Citico Creek.

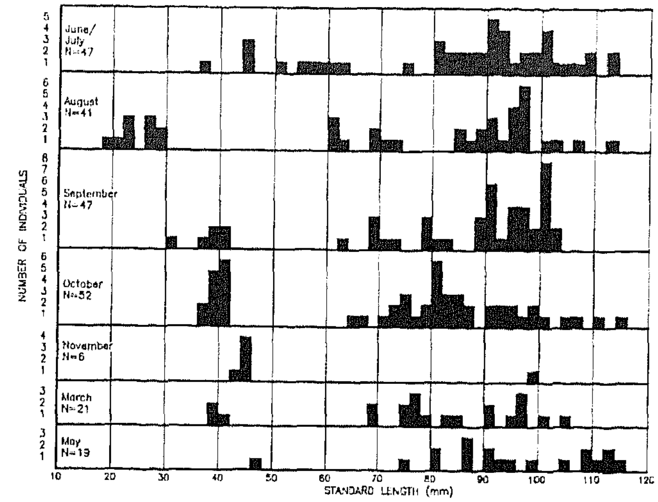

Figure 6: Length frequency histograms for specimens of *Noturus flavipinnis* from Citico Creek.

mate a population size of 41 and 53 adult *N. flavipinnis* for the upper pool (modified Schnabel and Schumaker methods, respectively; Table 4). Estimates obtained for the lower study pool were 51 and 60. By extrapolating these figures to the total length of each pool type within the range of *N. flavipinnis* in Citico Creek, estimates of 451 (modified Schnabel) and 549 (Schumaker) with confidence limits of 312–1453 were obtained. Using these figures, the density of adult *N. flavipinnis* in this stretch of creek is 1.4 and 1.8 madtoms per 10 m^2, respectively. The density of the rare, riffle-dwelling *N. placidus* was estimated at 3.3 madtoms per 100 m^2 (Fuselier and Edds 1994).

Age and Growth

Noturus baileyi—Length-frequency distribution of 131 *N. baileyi* suggests an average lifespan of two years (Figure 5). The proportion of small individuals in the population indicates healthy recruitment. Data from individuals raised in captivity under conditions simulating those in Citico Creek (Shute et al. 1992) support these field observations. Thirteen 9-month old, five 14-month old, 21 21-month old and 12 24-month old captive reared *N. baileyi* averaged 52.9, 61.4, 63.3 and 68.9 mm SL, respectively.

Juveniles may be free-swimming and released from paternal care as early as July. In Citico Creek, six juveniles captured on 30 August 1994 measured 12–29 mm SL ($\overline{X}$ = 18). Two captive reared individuals from the 1990 breeding season, when measured on 27 November 1990, were 30 and 32 mm SL.

A maximum lifespan of 18 months to nine years has been reported for various species of madtoms (Mayden and Walsh 1984; Mayden and Burr 1981). However, 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). Members of the *hildebrandi* species group as defined by Grady and LeGrande (1992), of which *N. baileyi*, *N. hildebrandi*, and *N. stanauli* are members, are the smallest and shortest-lived madtoms. Etnier and Jenkins (1980) noted two age classes in *N. stanauli*, indicating a lifespan of 1+ years. Mayden and Walsh (1984) and Baker and Heins (1994) reported a lifespan of 1+ years for *N. hildebrandi*.

Noturus flavipinnis—Length frequency histograms of 233 *N. flavipinnis* in Citico Creek indicated a three-year lifespan (Figure 6). Jenkins (1978) reported that *N. flavipinnis* lives three to four years in Copper Creek.

Juvenile *N. flavipinnis* may be free-swimming and released from paternal guardianship as early as August. W. C. Starnes (pers. comm.) reported a 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 (19–29 mm SL) and five individuals captured in November 1983 averaged 37.8 mm SL (34–45 mm SL). Three juveniles captured from Copper Creek in November averaged 23.7 mm SL (31 to 35 mm SL). Captive-reared young average 40 mm SL by November (P. L. Rakes pers. comm).

Data on individual growth rates were also obtained by recapturing madtoms that had been tagged with acrylic paint. These data indicate that *N. flavipinnis* may reach a certain maximum size limit after which growth ceases or occurs at a much slower rate. There may be a genetically predetermined maximum length of 110–115 mm SL, at least for the Citico Creek population (see Table 2 and Figure 6).

Data from captive-reared individuals which support the field observations include the following: one five-month old individual was 40 mm SL, four nine-month old individuals averaged 60.8, five 14-month old individuals aver-

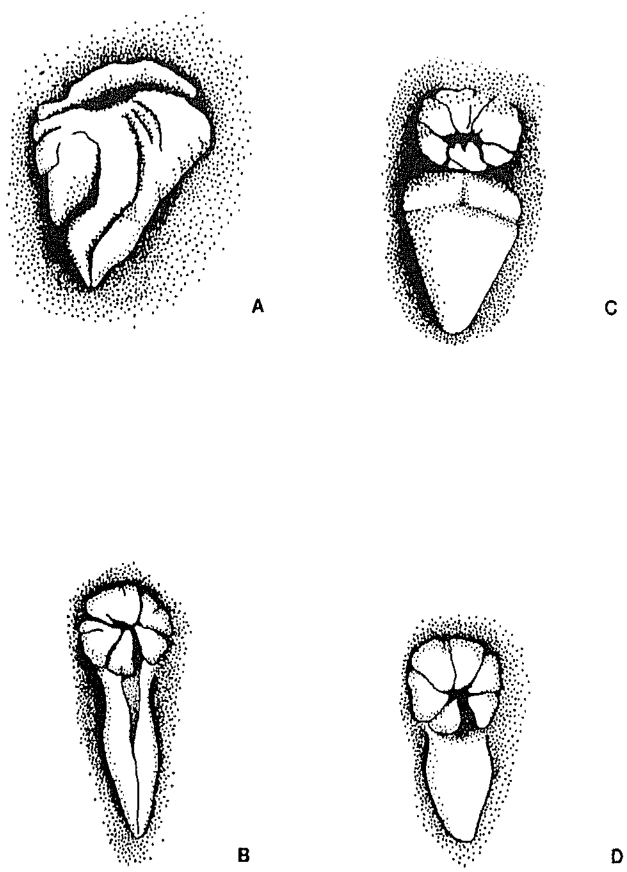

Figure 7: Genital papillae of *Noturus baileyi.* (A) Breeding female 52 mm SL. (B) Non-breeding female 37 mm SL. (C) Breeding male 52 mm SL. (D) Non-breeding male 34 mm SL.

aged 74.8 mm SL and one 26-month old individual was 96 mm SL.

Sexual Dimorphism

NOTURUS BAILEYI—Seven of eight *N. baileyi* 57 mm SL or larger collected during this study were females (the largest measured 63 mm SL). The largest male collected was 58 mm SL. Ten reproductively mature male and 14 female *N. baileyi* collected during breeding seasons in 1981 to 1983 averaged 49 mm SL (ranging from 43–58, SD = 4.8) and 52 mm SL (ranging from 38–63, SD = 7.4), respectively. Although these data indicate that female *N. baileyi* attain greater lengths than males, the difference was not statistically significant (χ^2 of 0.0675 < χ^2 0.05 (1) = 3.841).

Within the *hildebrandi* species group, sexual size dimorphism is equivocal. D. S. Wilkins (pers. comm.) indicated that there was no significant size difference between males and females of a Mississippi population of *N. hildebrandi.* Mayden and Walsh (1984) reported that male and female *N. hildebrandi* from a population in western Tennessee did not differ significantly with respect to growth in either weight or length, although the largest female collected during their study was 51.6 mm SL while the largest male was 48.6 mm SL; the female was 15 months old and the male was 18 months old. No such information exists for *N. stanauli.* Given that *N. stanauli* is probably an annual species (Etnier and Jenkins 1980), it would be difficult to discern sexual size dimorphism as a function of longevity.

Male *N. baileyi* in breeding condition show more body color (yellow) than immature males and gravid females. No similar pattern has been reported for *N. hildebrandi* (Mayden and Walsh 1984) or *N. stanauli* (Etnier and Jenkins 1980).

Secondary sexual characteristics and length frequency data from wild and captive-reared fish (Figure 5, in part), indicate that individuals of *N. baileyi* can become sexually mature in their second summer of life (at one year of age). Two females collected and released in July 1982

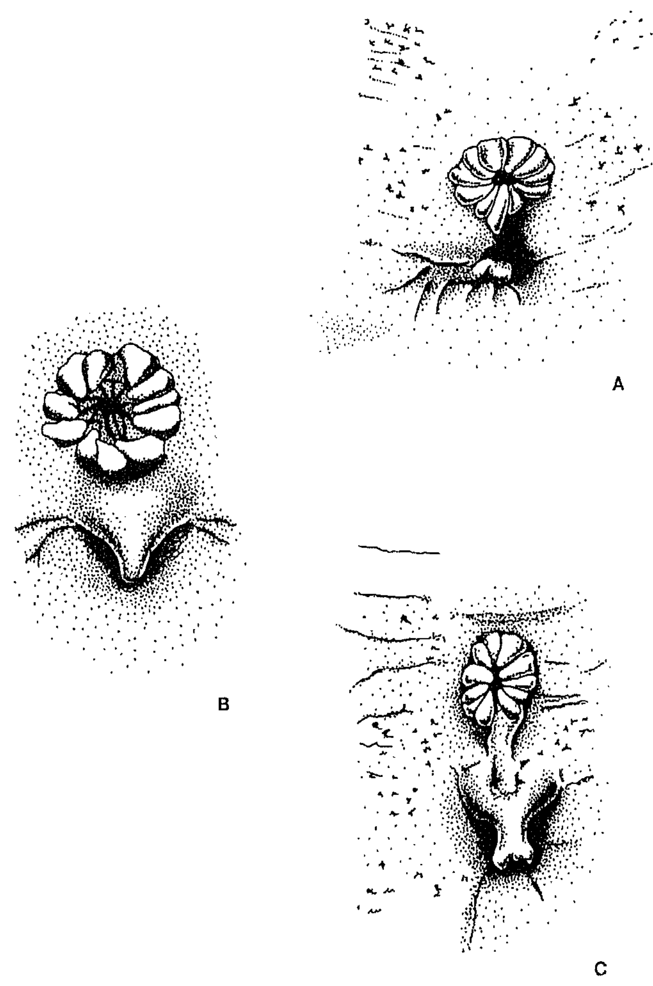

Figure 8: Genital papillae of *Noturus flavipinnis.* (A) Breeding female 79 mm SL. (B) Breeding male 90 SL. (C) Non-breeding male 47 SL.

were 38 mm SL each and appeared to be gravid. Two male *N. baileyi* in breeding condition collected in June 1982 measured 43 and 44 mm SL. That these madtoms were all likely one year old is supported by an average length of 51 mm SL from 17 captive reared individuals that were 16 months old.

During the spawning season, male *N. baileyi* possess secondary sexual characters as described by Taylor (1969) for other species of *Noturus*, i.e., enlarged genital papilla, cephalic epaxial muscles and lips. In fact, the swollen lips of the type specimens of *N. baileyi* collected from Abrams Creek led Taylor (1969) to describe *N. baileyi* as having a lower jaw being only slightly included in the upper jaw (Bauer et al. 1983).

The genital papilla of preserved male *N. baileyi* in non-breeding condition is distinguishable from that of preserved non-gravid females (Figure 7) but could not be used as a reliable field character for sex determination of live, non-breeding madtoms. In preserved specimens, sex is easily discerned by inspecting the gonadal tissue. Testes of male *N. baileyi* consist of long, whitish, finger-like projections as described for catfish and other madtoms (Sneed and Clemens 1963; Mayden and Burr 1981; Burr and Mayden 1982a,b; Clark 1978).

Female *N. baileyi* in breeding condition were identified by their distended abdomens and swollen genital papillae (Figure 7). The enlarged cephalic muscles and swollen lips, apparent in nuptial males, are not present in gravid females.

Noturus flavipinnis—Female *N. flavipinnis* appear to be sexually mature by their third summer of life (at 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 – 79 mm SL. Three females 49 – 58 mm SL taken in June 1981 were probably in their second summer of life (one year of age) and contained no mature ova. However, most captive-reared individuals became gravid at one year of age. This may be related to "winter" water temperatures in the laboratory which were approximately 6 °C warmer than Citico Creek. Perhaps a more regular feeding schedule also contributed to this apparent early maturity of captive-reared individuals.

Some male *N. flavipinnis* may also become reproductively mature at one year of age as indicated by a 74 mm SL male found guarding a nest on June 1982. This male was the smallest male observed exhibiting nesting behavior.

Breeding male *N. flavipinnis* are not colored differently than immature males or gravid females. The coloration of breeding *N. nocturnus* males also remains unchanged (Burr and Mayden 1982b). Males of the closely related *N. miurus* were described as more drab than gravid females (Burr and Mayden 1982a). The general coloration of *N. exilis* males in breeding condition differs from non-breeding males in that there is more yellow on the venter, around the eyes and small areas anterior and posterior to the dorsal fin, and in the adipose and caudal fins (Mayden and Burr 1981).

Male and female *N. flavipinnis* in breeding condition exhibited secondary sexual characteristics similar to breeding *N. baileyi*. Non-breeding male and female *N. flavipinnis* could not be distinguished in the field using genital papillae as a guide (Figure 8).

Twenty mature male *N. flavipinnis* collected during the 1982 and 1983 reproductive seasons averaged 4 mm longer than 21 mature females collected during the same time period. This size differential was not statistically significant (χ^2 of 0.083 < χ^2 0.05(1) = 3.841). The mean standard length of the males was 98.8 mm SL (85–114, SD = 9.9), and the mean for the females was 94.8 mm (80–112, SD = 9.1). Most of these individuals were probably two years old at the time of capture.

The sexual size dimorphism reported for most madtom species (Burr and Mayden 1984; and others) may explain the observation of two specimens that were about the same size at marking (73 and 80 mm SL), but markedly different lengths when recaptured 21 months later (from 1 October 1981 to 15 July 1983, and 1 October 1981 to 27 June 1983, respectively). One had increased 33 millimeters and the other 13 mm in approximately the same length of time (Table 3).

Differential growth rates have also been reported for the checkered madtom, *N. flavater* (Burr and Mayden 1984). Bowen (1980) analyzed annuli formation on otoliths and vertebrae of *N. miurus* and found that no significant difference existed between the lengths of first and second summer males and their female counterparts. Third summer males were significantly longer than similar age females. Bowman (1932) reported that although both males and females of the margined madtom, *N. insignis*, live for three years, males are slightly larger. He used length frequencies to demonstrate that the same three peaks were evident in both sexes.

Although some species of *Noturus* apparently do not exhibit sexual size dimorphism (e.g., *N. furiosus*, Burr et al. 1989), males of many species attain a larger size than females. This sexual size-dimorphism is possibly due to selective pressures favoring a larger body size for the nest-guarding parent thereby affording better protection of the brood. Also, during the seasons in which more rapid growth (length) occurs (spring and summer), the female may require proportionately more energy from food resources for gonadal development.

An alternative explanation of *Noturus* size dimorphism was presented by Burr and Mayden (1982b) who suggested that *N. miurus* males attain a larger size than females because the majority of females do not live as long as males. This hypothesis was also proposed for *N. eleutherus* (Starnes and Starnes 1985) and *N. exilis* (Mayden and Burr 1981).

Table 5. Nesting Variables for *Noturus baileyi* and *N. flavipinnis* in Citico Creek

Nest No.	Date	Water Temp. (C)	Habitat/Creek Km	Length, Width[1], and Thickness of Nest Rock (cm)	Water Depth (cm)	Current (cm/sec)	Clutch Size	Sex and Total Length (mm) of the Guardian or Breeding Pairs
				N. baileyi				
1	7/2/82	23°	Shallow pool/9.0	26:21:4	50	40	33	♂:U
2	7/2/82	23°	Shallow pool/14.8	23:17:5	40	37	PS[2]	♂:55,♀:45
3	7/10/82	23°	Shallow pool/16.3	30:25:3	23	25	40	U[3]
4	7/10/82	23°	Shallow pool/16.1	30:30:3	55	34	42	♂:52
5	6/2/83	18°	Shallow pool/16.6	22:26:3	45	15	PS[2]	♂:63,♀:73
6	6/25/83	22°	Riffle crest/15.1	41:36:5	25	55	PS[2]	♂:71,♀:70
7	7/8/83	23°	Riffle crest/14.8	10:25:3	37	52	30	U[3]
				N. flavipinnis				
1	5/29/82	20°	Head of pool/16.4	52:50:10	100	33	89	♂:108
2	7/2/82	23°	Pool/16.4	51:25:—	—	33	45[4]	♂:132
3	7/2/82	23°	Pool/16.4	51:25:—	100	33	60[4]	♂:120
4	7/2/82	23°	Pool/16.4	51:25:5	41	33	50[4]	♂:125
5	7/2/82	23°	Pool/16.4	25:25:—	100	33	25[4]	♂:110
6	7/2/82	23°	Pool/16.4	51:51:—	—	33	45[4]	♂:130
7	7/8/82	23°	Pool/16.4	61:46:—	56	33	78[4]	♂:102
8	6/25/83	22°	Pool/16.4	61:36:12	46	33	100[4]	♂:90
9	6/25/83	22°	Pool/16.4	36:30:5	61	33	30[4]	U[3]
10	6/25/83	22°	Pool/16.4	56:23:5	61	33	25[4]	♂:104

[1]Length and width of nest rock was based on widest and narrowest measurements across rock face.
[2]Pre-spawning.
[3]Unknown (madtom escaped capture).
[4]Estimate, based on visual observation of nest cavity.

Nesting Behavior

NOTURUS BAILEYI—Madtoms are included in the reproductive guild of fishes termed speleophils by Balon (1975). Species in this guild construct a nest or choose a natural cavity for a nesting chamber and, generally, the male guards the eggs. *Noturus baileyi* choose large, flat rectangular rocks for nesting cover. Nest rocks were much larger in overall dimensions than those used for shelter during the remainder of the year. Presumably, one or both parents enlarge the nesting cavity by fanning with body and fins since the area beneath each nest rock was devoid of silt. No nests were found beneath rocks that were lying flush on the substrate with no apparent cavity underneath, even in areas where the number of large, flat rocks was limited.

Male *N. baileyi* were reproductively mature from the end of May through July. Gravid female *N. baileyi* were also found from early May to late July. *Noturus baileyi* in breeding condition were found underneath large, flat rocks in shallow pools and riffle crests from early June to mid-July (Table 5). Baker and Heins (1994) reported ripe females in a southern population of *N. hildebrandi* as late as mid-September. All females with ripe or ripening ova were one-year olds. They suggested that, because ovary maturity was correlated with female size, larger females spawn earlier than smaller ones.

Water depth at seven nest sites averaged 39 cm and current averaged 37.5 cm/sec. Nest rocks averaged 3.6 cm in thickness and 25.8 cm in length and in width. Aquatic insects and crayfish were noticeably absent from the underside of all nest rocks. Four nests collected in 1982 and 1983 were each attended by a single male. The stomach of one of these guardian madtoms was nearly empty. Exposing the nest cavity resulted in differing responses by the guardian madtom. In one instance (Nest no. 1, Table 5) the madtom was reluctant to leave the nest cavity even after the clutch was removed. In another (Nest no. 3), the madtom fled immediately after the nest was exposed. Several hours later this nest was re-examined and the guardian madtom had not returned. Other fish or crayfish had evidently moved in and consumed most of the eggs.

Noturus baileyi males were observed guarding larvae estimated to be five days old (post-hatching). Individuals hatched in an aquarium actively fed at about the age of five days, depending upon water temperature. Based on the length of time required for a freshly fertilized batch of

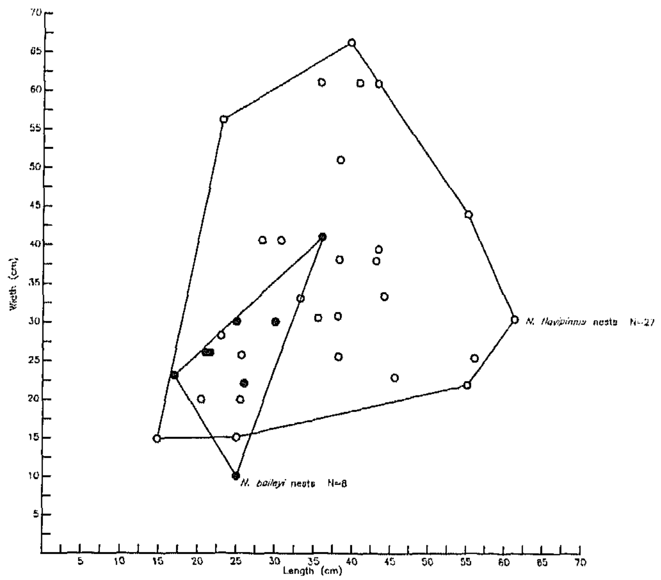

Figure 9: Graphic presentation of nest rock utilization (overlap) by *Noturus baileyi* and *N. flavipinnis* in Citico Creek.

eggs to hatch (16 days at 20–21 °C), a guardian male may attend his brood for at least three weeks.

Noturus flavipinnis—Male *N. flavipinnis* in breeding condition were found in Citico Creek from late May to mid-July. Water depth at eight nest sites found in late May to mid-July 1982 and June 1983 ranged from 41 to 100 cm. Nest rocks averaged 50 cm long and 34 cm wide (N = 10). Current measured 33 cm/sec. Substrate beneath the nest rocks consisted of gravel, cobbles and sand. Ten nests with eggs in varying stages of development averaged 55 eggs (Table 5). Three of these (Nests 1, 7 and 8) contained newly laid eggs with an average of 89 eggs per clutch. Each clutch was attended by a single male. The earliest *N. flavipinnis* nest was found on 29 May 1982, and nesting continued that year through June (Table 5).

In 1983, field surveys for nests began in early May. Although gravid females were evident in May and June, and four pairs of fish were observed beneath potential nest rocks on 2 June 1983, no nests were found until 25 June and nesting appeared to be almost over by mid-July. The difference in spawning seasons between these two years may have been due to a comparatively cold spring in 1983 which delayed spawning by sustaining lower water temperatures. Therefore, photoperiod may be important in preparing the gonads for reproduction and water temperature (20–23 °C) may be the environmental trigger which initiates spawning.

Starnes and Starnes (1985) reported a possible delayed reproductive period for *N. eleutherus*, and Clark (1978) indicated a spawning period for *N. leptacanthus* that coincided with peak water temperatures for two successive years, although she suggested that this correlation may have been coincidental. Breder (1935) indicated that water temperature is the determining factor in initiating reproductive behavior in the brown bullhead, *Ameiurus nebulosus*.

The spawning and nesting season for *N. baileyi* and *N. flavipinnis* in Citico Creek are essentially the same. Male and female *N. flavipinnis* have been found in breeding condition from late May to mid-July. While they normally are not syntopic with *N. baileyi* during the non-breeding season, juvenile *N. flavipinnis* have been found under large, flat rocks in shallow pools in close proximity to *N. baileyi* nests. Further, nests of both species have been found in proximity to each other in shallow pools.

Figure 9 illustrates the size of nest rocks used by each madtom species. Although there is overlap in the size of these rocks, in general *N. flavipinnis* uses larger rocks. Adult *N. flavipinnis* are larger than adult *N. baileyi*, and would therefore be expected to require and be able to defend a larger nesting space.

Several other species of *Noturus* coexist. *Noturus elegans*, *N. eleutherus*, *N. miurus*, *N. nocturnus*, and *N. stanauli* are known to occur at a single locality in the Duck River, Humphreys County, Tennessee (D. A. Nieland, unpubl. data), and *Noturus eleutherus*, *N. flavus*, *N. gyrinus*, *N. nocturnus*, and *N. miurus* are known to occur in the same reach of the Wabash River (R. Bogardus, pers. comm.). Where *N. albater*, *N. flavater*, and *N. exilis* are syntopic, *N. albater* nests under smaller rocks in shallower water in pools and riffle crests (Burr and Mayden 1984). In Lake Waccamaw, North Carolina, the undescribed broadtail madtom (subgenus *Schilbeodes*) coexists with *N. gyrinus*, and even spawns at the same time of year and under the same nesting cover (Lindquist et al. 1982); these two species are temporally separated by diel activity differences (Reynolds et al. 1982).

Nests of *N. flavipinnis* were only found in the pool habitats normally occupied by the species. Flat rocks of the size typically used by *N. flavipinnis* for nesting cover are uncommon in some pools, and although there is minimal competition with *N. baileyi* for this resource, there may be competition with other organisms. On several occasions, single egg-guarding mudpuppies (*Necturus maculosus*) were found beneath large, flat rocks in pools occupied by nesting *N. flavipinnis*. Burr et al. (1989) also suggested that syntopic *Necturus* compete with *N. furiosus* for nest rocks.

Guardian *N. flavipinnis* males apparently do not feed, based on the single parent removed from a nest of freshly laid eggs during the night of 29 May 1982 (1:00–2:00 A.M.). His stomach was completely empty, and the hindgut contained only a few sand grains and some well digested chironomid and trichopteran larvae. In comparison with other individuals collected at night, 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 nest construction or maintenance.

Whiteside and Burr (1986) reported two *N. gyrinus* guarding a single clutch of eggs. However, most recent life history studies have shown that males alone assume parental responsibility of the clutch and do not feed while in that capacity (Clark 1978; Mayden et al. 1980; Burr and Mayden 1984; Mayden and Burr 1981; Burr and Dimmick 1981; Mayden and Walsh 1984; Starnes and Starnes 1985). Brown bullheads (*A. nebulosus*) exhibit biparental care, but the males are the principal care-giver and fast while guarding eggs and larvae (Blumer 1985).

Fecundity

Noturus baileyi—Immature female *N. baileyi* taken from Citico Creek during the breeding season contained ova that were undifferentiated in size. The ovaries of a nearly gravid female (52 mm SL) collected in early May contained 287 oocytes of three sizes. The largest oocytes were orangish in color, spherical, and ranged in diameter from 0.9 to 1.0 mm ($\overline{X}$ = 1.0, N = 55). Intermediate-sized oocytes were either clear or whitish in color, spherical, and ranged in diameter from 0.3 to 0.5 mm ($\overline{X}$ = 0.4, N = 122). The smallest oocytes were translucent, somewhat flattened, and ranged in diameter from 0.1 to 0.3 mm ($\overline{X}$ = 0.2, N = 110). Because this female was collected one to two months before spawning, the largest oocytes may not have been fully developed.

A total of 653 eggs was found in a fully gravid female (63 mm SL) that had been reared from the egg stage in an aquarium. The abdomen of this apparently healthy female was severely distended, more so than in typically gravid females found in the wild. Her largest oocytes averaged 2.8 mm in diameter (N = 87), the intermediate-sized oocytes averaged 0.9 mm (N = 91 mm), and the smallest oocytes averaged 0.2 mm (N = 475). The wide difference in the number of immature ova between these two madtoms may have been the result of the environment in which each had been raised.

The clutch size of four nests found in 1982 and 1983 ranged from 30 to 42 eggs ($\overline{X}$ = 36.3, Table 5). Subsequent data collected during captive rearing efforts indicates a much wider range in clutch size; between 1986 and 1994 a range of 20 – 65 eggs ($\overline{X}$ = 30) was found in 79 *N. baileyi* nests of varying development stages (P. L. Rakes, pers. comm.).

Madtoms in general exhibit low fecundity in comparison with other North American freshwater fishes (Breder and Rosen 1966). A combination of relatively large egg size and the high level of parental care given to the fertilized eggs and larvae reduce early mortality and therefore the need to produce a large number of gametes.

Mayden and Walsh (1984) reported a mean of 29.9 mature oocytes for one of *N. baileyi*'s closest relatives, *N. hildebrandi*. Baker and Heins (1994) reported a range of 16-68 ova, correlated with female size, in a southern population of *N. hildebrandi*; further these authors emphasized that the lifetime reproduction potential of the short-lived *N. hildebrandi* (one year plus) is limited to one breeding season. In comparison with other madtoms, *N. baileyi* is among the least fecund.

Noturus flavipinnis—The total number of ova contained in five gravid *N. flavipinnis* ranged from 382 to 456 ($\overline{X}$ = 408). Oocytes of these females were separable into three size classes. The mature oocytes were translucent yellow and

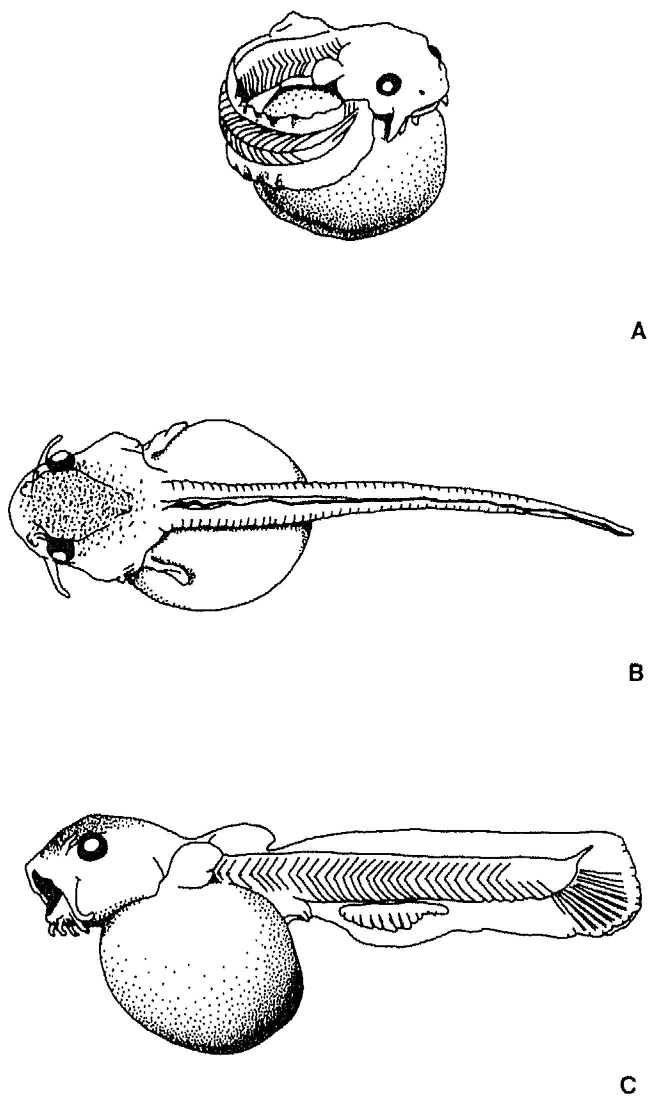

Figure 10: Embryo and larvae of *Noturus baileyi*. (A) Prehatchling, chorion removed. (B) Top and (C) Side view of one-day old larvae, 3.4 mm TL.

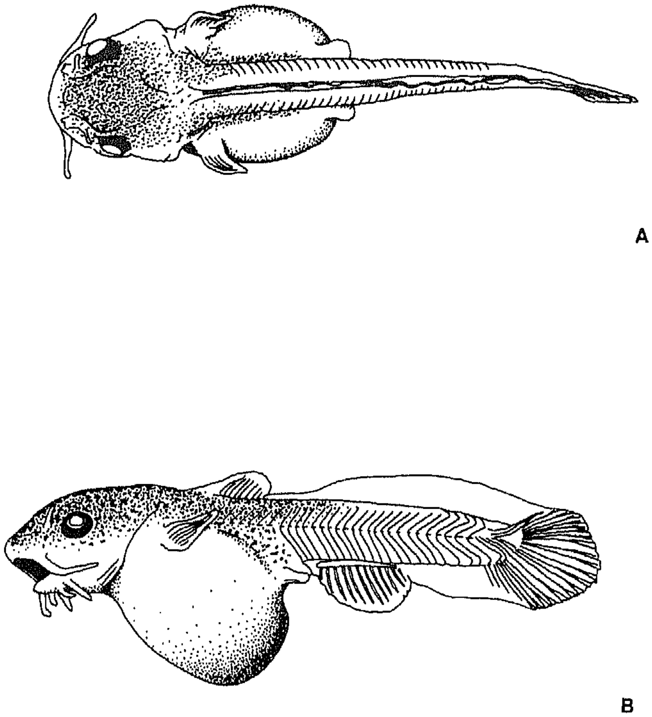

Figure 11: Larvae of *Noturus baileyi*. (A) Top and (B) Side view of three-day old larvae, 3.5 mm TL.

ranged in diameter from 2.5 to 3.3 mm; the average number of ripe eggs per female was 177 (150–190). Intermediate-sized oocytes averaged 114 and ranged in diameter from 0.8 to 1.0 mm; the smallest-sized oocytes averaged 116 and ranged in diameter from 0.3 to 0.8 mm. The ovaries of immature female *N. flavipinnis* collected during the breeding season contained ova that were undifferentiated in size. Since sexual maturity apparently is not reached until age two and maximum lifespan is probably three years, most individuals probably spawn only once or twice.

Menzel and Raney (1973), Clark (1978), Mayden and Burr (1981), Mayden and Walsh (1984), and Walsh and Burr (1985) have presented evidence suggesting that at least some species of *Noturus* may be polyandrous. However, the evidence is inconclusive because of the correlation between ova production and female body length. Also, some data presented in the above accounts often included larval broods and not freshly fertilized eggs.

No adult female *N. baileyi* or *N. flavipinnis* were found in nests with eggs, either with a male, or singly, but other observations indicate that both species may occasionally exhibit polyandry. On 2 July 1982, a partially spent gravid female *N. baileyi* was collected in a shallow pool, approximately one meter from a nest containing 33 eggs guarded by a single madtom. Several eggs were protruding from her urogenital opening. In late July 1989 while searching for *N. baileyi* nests as part of a project to reintroduce the species to the type locality, a single male *N. baileyi* was found guarding a nest comprised of two distinct age classes (Rakes et al. 1990). An average of approximately 89 newly laid eggs were found in three *N. flavipinnis* nests observed in 1982 and 1983, and an average of 99 eggs or larvae were found in 13 nests observed between 1986 and 1990 (Shute et al. 1992). Because the latter group included larval broods, the mean number of eggs originally deposited in each nest may have actually been higher. These average clutch sizes represent only about one-half of the average mature oocyte count determined by exam

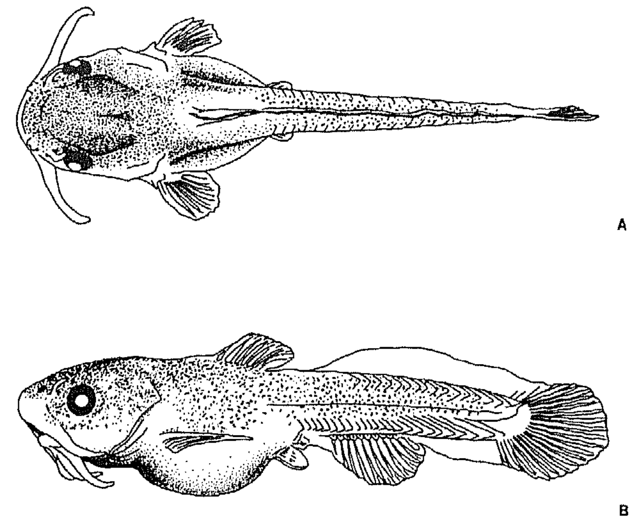

Figure 12: Larvae of *Noturus baileyi*. (A) Top and (B) Side view of six-day old larvae, 4.3 mm TL.

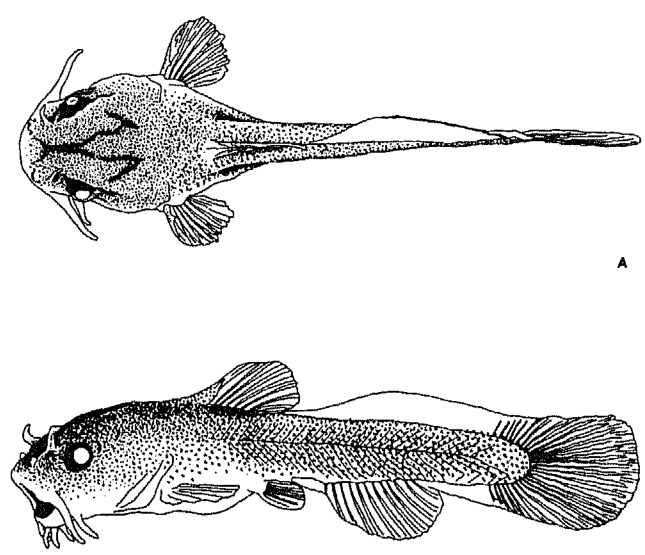

Figure 13: Larvae of *Noturus baileyi*. (A) Top and (B) Side view of 12-day old larvae, 10.5 mm TL.

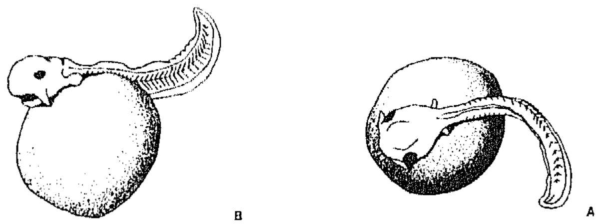

Figure 14: Embryo of *Noturus flavipinnis.* (A) Top and (B) Side view of prehatchling, six-days post-fertilization.

ining the ovaries of gravid females. In the laboratory, the number of *N. baileyi* and *N. flavipinnis* hatchlings is often only half that of freshly laid eggs (P. L. Rakes pers. comm.).

Larval Development

Noturus baileyi—On 2 July 1982, a nest containing 33 *N. baileyi* eggs was removed from Citico Creek and taken to the lab for observation. The eggs were well developed, sulphur-yellow in color, and had cohesive properties so that they remained together in a clump but would not stick to other objects. Embryos could be seen rotating inside their chorion. Egg diameters ranged from 2.6 to 3.0 mm ($\overline{X}$ = 2.9), yolk diameters ranged from 0.08 to 0.10

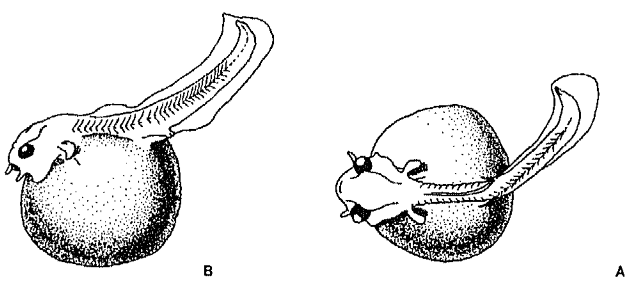

Figure 15: Embryo of *Noturus flavipinnis.* (A) Top and (B) Side view of prehatchling, nine-days post fertilization.

mm ($\overline{X}$ = 0.09, N = 4). The eggs were placed in a shallow petri dish containing well aerated stream water and kept at room temperature (ca. 20° C). At the time the nest was discovered, four eggs were preserved in buffered formalin for measurement, and one of these was in the process of hatching. Pre-hatchlings had rudimentary barbels, pectoral fins, and dorsal fin. The eyes were darkly pigmented (Figure 10). The remainder of the clutch hatched within the next 12 hours. Hatching success of the 33 eggs in this nest was 94%. *N. baileyi* hatchlings break through the chorion tail first as noted by Mayden and Burr (1981) in *N. exilis*,

Hatchlings had heavily pigmented eyes and scattered melanophores on top of the head (Figure 10). All fins were formed but only the caudal and anal fins showed any ray differentiation. At this stage, ray primordia were evident in the dorsal fin. Four pairs of rudimentary barbels

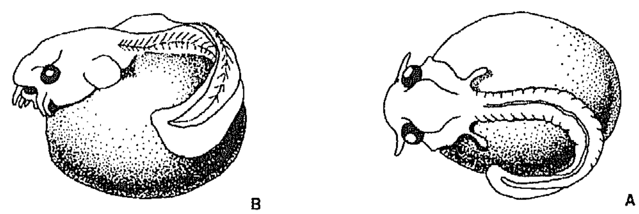

Figure 16: Embryo of *Noturus flavipinnis.* (A) Top and (B) Side view of prehatchling, 12 days post-fertilization.

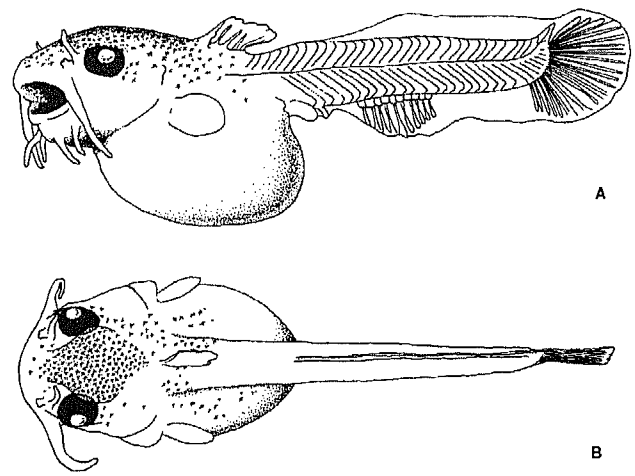

Figure 17: Larvae of *Noturus flavipinnis.* (A) Top and (B) Side view of eight-day old larvae 12.0 mm TL.

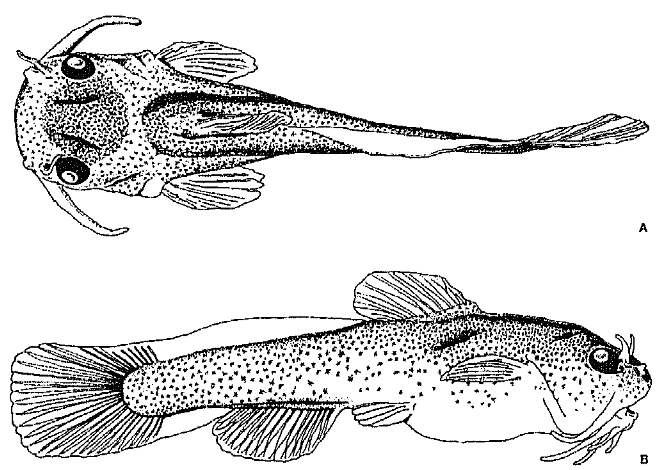

Figure 18: Larvae of *Noturus flavipinnis.* (A) Top and (B) Side view of 24-day old larvae 17.0 mm TL.

were present and the nares were discernible. The urogenital duct and anus were also evident. Hatchlings exhibited tight schooling behavior and oriented themselves toward the airstone.

There was increased pigmentation on the dorsal sur-

Table 6. Stomach Contents of 13 Smoky Madtoms from Citico Creek

Prey Item	1	2	3	4	5	6	7	8	9	10	11	12	13	Percent of Occurrence		Percent Frequency of Occurrence
Gravel						1	2	3		2		3		10.7		38.5
Ephemeroptera																
Baetidae																
Pseudocloen sp.			4				2			1				6.8		23.1
Unid. Baetidae							1	1						1.9		15.4
Heptageniidae																
Stenonema sp.			1											1.0		7.7
Rithrogena sp.	1													1.0		7.7
Unid. Heptageniidae							1	1		1				2.9		23.1
Oligoneuridae															63.1	
Isonychia sp.		1					1				1			2.9		23.1
Siphlonuridae																
Ameletus sp.			6			1								6.8		15.4
Ephemerellidae																
Drunella sp.							2							1.9		7.7
Ephemerella sp.			8				7	20						34.0		23.1
Unid. Ephemeroptera				1			2		1					3.9		23.1
Plecoptera																
Perlidae									1					1.0		7.7
Trichoptera																
Hydropsychidae																
Hydropsyche sp.	1													1.0		7.7
Philopotamidae															3.9	
Chimarra sp.						1			2					2.9		15.4
Diptera																
Tipulidae										4				3.9		7.7
Chironomidae		2	7			3			2	3		1		17.5	21.4	46.2
Total Number of Prey Items[1]	2	3	26	1	0	6	18	22	6	9	1	1	0			

[1]Excluding gravel.

face of the three-day-old larvae and melanophores extended down to the anal region and dorsolaterally behind the dorsal fin (Figure 11). Melanophores extended onto the yolk sac adjacent to the embryo. At this stage, the dorsal fin had its adult complement of rays while the pelvic fins did not yet show any ray differentiation.

The six-day-old larvae had developing rays in all fins, including the pelvics (Figure 12). By this stage, spines were developing on the pectoral and dorsal fins. Pigmentation was more dense on the dorsum with melanophores extending posteriad almost to the origin of the caudal fin. The yolk sac was nearly absorbed.

The twelve-day-old larvae essentially resembled adults except they lacked the dark blotches or saddles on the dorsum, typical of adult *N. baileyi*, and all other members of the subgenus *Rabida* (Taylor 1969), and they lacked the full complement of caudal fin rays. Twelve-day-old larvae were uniformly pigmented on the dorsal region (Figure 13). Young-of-the-year less than 30 mm SL collected in Citico Creek during the months of June and July also lacked this saddled pigmentation. Caudal fin-ray counts did not appreciably change in larval *N. baileyi* in the stages from day 12 to 26 (33 – 38, N = 12). Adults have 42 to 49 total caudal rays (Bauer et al. 1983); presumably adult pigmentation and full caudal development do not appear until well after the young leave the nest.

Twelve-day-old *N. baileyi* larvae began feeding on thawed brine shrimp. Over the next 13 days periodic mortalities occurred in the clutch of developing young. *Aeromonas hydrophila* was cultured from the broth but not directly from the tissue of a moribund larva frozen and sent to Dr. John New of the College of Veterinary Medicine at the University of Tennessee. *Pseudomonas putida*, *Corynebacterium sp.* and *Lactobacillus sp.* were cultured from the tissue. These four bacteria were considered either insignificant or contaminants at the level present, and Dr. New was unable to identify the exact cause of death.

Noturus flavipinnis—On 29 May 1982, a newly fertilized clutch containing 89 *N. flavipinnis* was collected for examination. The eggs averaged 3.4 mm in diameter and had opaque or orange yolks and cohesive properties similar to *N. baileyi*. One of the more immature of the embryos was preserved six days later. This embryo had rudimentary maxillary barbels and pectoral fins, dorsal and anal fin folds were present, and the eyes were lightly pigmented. At least 27 myomeres were apparent (Figure 14).

At nine days post-fertilization, the embryos showed more pronounced eye pigmentation and maxillary and mandibullary barbel development; on most individuals 29 myomeres were observable (Figure 15). At 12 days, mouth development and rudimentary pectoral fins were evident (Figure 16). The maxillary barbel had increased in length and the urogenital duct and anus were also evident. There was no pigmentation and all fins lacked ray primordia.

On 2 July 1982 four nests were found containing 20–60 *N. flavipinnis* larvae of various ages. A single larva measuring 8.1 mm SL (12.0 mm TL) was captured and preserved from one of these nests (Figure 17). Five rudimentary rays were evident in the dorsal fin, ten in the anal fin, and 20 in the caudal fin; and 32 myomeres were discernible. The eyes were darkly pigmented and melanophores were scattered over the top of the head and dorsolaterally onto the dorsal surface of the yolk sac. There was no evidence of rudimentary pelvic or pectoral rays. The age of this individual was estimated to be at least eight days post-hatching.

One individual metalarva (Figure 18) measuring 12.3 mm SL (17.0 mm TL) was collected from one of the other nests. The age of this individual was estimated to be at least 24 days. All fin rays and spines were completely developed; eight dorsal, eight pelvic, 15 anal and 34 caudal rays were evident. Although not yet possessing the distinctive color pattern of adult *N. flavipinnis*, this individual was more completely pigmented than the younger individual collected on the same day; melanophores were concentrated predorsally and lightly scattered over the remainder of the dorsum and sides.

Burr and Mayden (1982b) described 24-day-old *N. miurus* larvae with melanophores distributed in a pattern over the body in a pattern similar to that of an adult. Burr and Dimmick (1981) described *N. elegans* larvae (14.7 mm TL, age unknown) as having body form, fin ray, and spine shape similar to adults. Although pigmentation was well advanced, the barred pigment pattern typical of the adult apparently develops later.

Diet

Noturus baileyi—Like other madtoms, *N. baileyi* is primarily insectivorous. A total of 15 taxa of invertebrates were found in the stomachs of 13 specimens (Table 6); aquatic insect larvae accounted for the majority of food items (89.3%). Ephemeropteran nymphs were the most common aquatic insect (70.7%), followed by dipterans, trichopterans, and plecopterans, which accounted for 23.9%, 4.4%, and 1.0%, respectively. Gravel was found in five of the stomachs and was probably ingested accidentally while feeding on benthic insect larvae.

A significant amount of daytime feeding appears to occur in *N. baileyi* as the stomachs of six of the seven individuals collected during the daytime contained freshly eaten organisms. The stomach of the seventh individual, a nest-guarding male, contained only the remains of a single mayfly nymph (*Isonychia*). Slabrocks used as protective cover by *N. baileyi* may also serve as a daytime feeding site; aquatic insects were devoid from the undersurface of 98% (N = 123) of the slabrocks under which *N. baileyi* were found.

Mayden and Walsh (1984) found that the closely related *N. hildebrandi* is also insectivorous, with chironomid, trichopteran, plecopteran and ephemeropteran larvae as the predominant food organisms. They noted a proportional decrease in plecopteran nymphs and an increase in ephemeropteran nymphs in the stomach contents during autumn and early winter, suggesting a possible shift in habitat during the colder months. D. S. Wilkins (pers. comm.) reported that *N. hildebrandi* fed nocturnally.

Noturus flavipinnis—A total of 32 taxa, representing sixteen families of organisms were identified from the guts of 12 *N. flavipinnis* (Table 7). The diet of *N. flavipinnis*, like *N. baileyi*, is almost exclusively insect larvae. One individual contained the remains of a crayfish. Dipterans were found in all 12 stomachs, and in five of these, the order was represented by the family Chironomidae. Ephemeroptera (mainly Ephemerellidae), Coleoptera, and Trichoptera represented 33.8, 6.0 and 5.5% of the prey items, respectively.

The biomass of dipteran larvae was small in comparison with most of the other prey items, but they may be a preferred item given their numerical dominance and presence in all of the guts examined. Dipterans were numerically the most dominant prey item in *N. flavipinnis* from Copper Creek, although they were found in only 48% of the guts examined. Mayflies were found in 57% of the Copper Creek specimens (R. E. Jenkins, pers. comm.).

In *N. flavipinnis* from Copper Creek, water pennies (*Psephenus*) comprised 21% of the total number of organisms consumed, and were found in 23% of the guts examined. Two individuals had consumed a total of 33 water pennies, possibly indicating a preference for this prey

Table 7. Stomach Contents of 12 Yellowfin Madtoms from Citico Creek

Prey Item	1	2	3	4	5	6	7	8	9	10	11	12	13	Percent of Occurrence		Percent of Frequency Occurrence
Sand		P				P	P	P						0.8		33.3
Coleoptera																
Psephenus sp.					1				1	1	3			1.3	6.0	33.3
Unid. Coleoptera				12							7	3		4.7		25.0
Hemiptera					1									0.2		8.3
Ephemeroptera																
Baetidae																
Centroptilium sp.		1		2							1			0.8		25.0
Baetis sp.						7		11	11	8				7.9		33.3
Unid. Baetidae		1			7				1		2			2.3		33.3
Caenidae																
Caenis sp.									3	1		1		1.1		25.0
Ephemerellidae																
Drunella sp.						2					3			1.1		16.7
Seratella sp.						3								0.6		8.3
Eurylophella sp.						9								1.9	33.8	8.3
Attenella sp.						4								0.8		8.3
Dannella sp.						3								0.6		8.3
Unid. Ephemerellidae	1			16	2									4.0		25.0
Heptageniidae																
Stenonema sp.			2	1							16	1		4.2		33.3
Unid. Heptageniidae					1				1	1				0.6		25.0
Tricorythidae												2		0.4		8.3
Unid. Ephemeroptera	3			2	1	6			6	13	3	1		7.5		66.7
Plecoptera																
Perlidae																
Perlesta sp.				1		2					5			1.7		25.0
Chloroperlidae																
Alloperla sp.					1									0.2	4.0	8.3
Unid. Plecoptera			1								8	1		2.1		25.0
Odonata																
Corduliidae																
Neurocordulia sp.					3									0.6	1.2	8.3
Unid. Odonata								1	2					0.6		16.7
Trichoptera																
Hydropsychidae																
Hydropsyche sp.			1	2	2									1.1		25.0
Leptoceridae				1	1									0.4		16.7
Polycentropodidae																
Polycentropus sp.				1	1									0.4	5.5	16.7
Rhyacophilidae																
Ryacophila sp.	1													0.2		8.3
Unid. Trichoptera	1	7	3		1		1		1	1	1			3.4		66.7
Diptera																
Ceratopogonidae	13	2				1				2				3.8		33.3
Chironomidae				54	47	9	2	15	36	6	92			38.2		75.0
Dytiscidae				1										0.2	51.1	8.3
Unid. Diptera			1	6	33	2								8.9		33.3
Crayfish								1						0.2		8.3
Total Number of Prey Items[1]	19	11	8	99	102	48	3	17	62	33	58	11				

[1]Excluding sand.

Table 8. Comparison of the Ecology of *Noturus baileyi* and *N. flavipinnis* in Citico Creek

Characteristic	*N. baileyi*	*N. flavipinnis*
Principal nonbreeding habitat	Riffle crests/pools	Pools
Age at sexual maturity (years)	1	2
Size at sexual maturity (mm SL)	38 (♀) 43 (♂)	75 (♀) 74 (♂)
Spawning period	June–July	June–July
Spawning habitat	Pools, riffle crests	Pools
Egg deposition site	Under flat rocks	Under flat rocks
Nest cover size (cm^2)	$\bar{X}$ = 691	$\bar{X}$ = 1324
Number of eggs in nest	Approx. 35	Approx. 90
Number of mature ova	Approx. 55	Approx. 180
Parental care	Male	Male
Longevity (years)	2+?	3+?
Maximum size (mm SL)	63 (72*)	115
Migration	Riffle to pools	None noted
Territoriality	Male nest brooder	Male nest brooder
Principle diet	Aquatic insect larvae	Aquatic insect larvae, nymphs, crustacea
Activity pattern	Diurnal?	Nocturnal
Extent of range in Citico Creek (km)	10.8	3.6

*Individual reared in laboratory.

type. In Citico Creek, our observations indicate that water pennies are more common in riffles than pools. The smooth, flattened exoskeleton of these coleopteran larvae allows them to slide over rough rocks, even in swift currents, without breaking contact between the rock and the edge of the carapace. This would appear to be an effective predator avoidance mechanism and Murvosh (1971) reported little evidence of fish predation.

Bowman (1932) also found *N. insignis* feeding on water pennies and suggested that they were preferred over other abundant and easier to capture prey types. These data suggest selective feeding, although several authors (Starnes and Starnes 1985; Miller 1984; Walsh and Burr 1985; Mayden and Walsh 1984; Gutowski and Stauffer 1990) have suggested that madtoms take prey items depending upon their availability.

In this study, 10 of the 12 specimens examined for gut contents were collected at night. One of these was a male guardian removed from his nest. With the exception of this male guardian, the stomachs of all individuals taken at night contained easily identifiable and presumably, freshly eaten organisms. Two individuals captured during the daytime had completely empty guts. There was material in the hindguts of both, although it was well digested and mostly unidentifiable. Starnes and Starnes (1985) reported that complete digestion and voidance time for ingested prey of *N. eleutherus* is approximately 24 hours. Assuming a similar digestion cycle, the two individuals described above had probably been feeding during the middle of the night.

Taylor (1969) suggested that madtoms are nocturnal in their feeding activities. Based on the body of literature for the genus, activity patterns vary between species. *Noturus exilis*, *N. gyrinus*, and the undescribed broadtailed madtom are known to be crepuscularly active species (Reynolds et al. 1982; Lindquist et al. 1982; Mayden and Burr 1981). *Noturus eleutherus* apparently consumes most of its food within four hours of sunset (Starnes and Starnes 1985). 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. Peak feeding for this species was estimated to have taken place between 11:00 p.m. to 3:00 a.m. A similar feeding pattern was observed in *Noturus insignis* (Bowman 1932). Curd (1960) found that although 75% of stomachs from *N. exilis* collected during the daytime (midday) contained food, most of the contents were unidentifiable, and the majority of the feeding had probably occurred at night. Clark (1978) reported diurnal feeding activity for *N. leptacanthus*. In contrast to our findings in Citico Creek, Jenkins (1975) reported *N. flavipinnis* in Copper Creek commonly feed during the daytime as food organisms drift beneath their cover.

Nocturnal drift of many insect larvae is a phenomenon commonly observed in lotic ecosystems (Hynes 1970), and it has been suggested that these vulnerable prey are important food sources for madtoms (Starnes and Starnes 1985). However, Hynes (1970) also indicated that pools do not produce as much drift as riffle areas. Therefore, pool-dwelling species such as *N. flavipinnis* may be less dependent on this phenomenon for prey items. It is apparent that *N. flavipinnis* takes some of its prey from the substrate as indicated by the presence of crayfish, dragonfly nymphs and sand grains in some of the Citico Creek specimens. In four of the 21 *N. flavipinnis* specimens from Copper Creek, sand grains were found among the gut contents.

Parasitism

There are numerous reports of parasitism in ictalurids and specifically for madtoms (Hoffman 1967; Burr and Mayden 1982a,b; Mayden and Burr 1981; Mayden et al. 1980; Bowman 1932; Bowen 1980). During this study, no internal parasites of *N. baileyi* or *N. flavipinnis* were observed. On 1 September 1982, three adult *N. flavipinnis* were captured, each with eroded dorsal fin rays. This fin erosion was later determined to have been caused by *Epistylis*, a stalked ciliate. Hoffman (1967) reported that in a personal communication, Tom Wellborn had noted an infestation of catfish eggs by this genus of protozoan. However, Hoffman did not list *Epistylis* as a parasite for any particular ictalurids. *Epistylis* has a free swimming stage and a colonial stage which uses host fish as attachment sites. As such, Rogers (1971) did not consider it as an obligate parasite on fishes, and he suggested that an outbreak of fish parasitism by this protozoan may be due to organic enrichment. In Citico Creek, reduced flow during the extremely dry summer of 1983 may have produced such conditions in some of the more stagnant pools.

Summary and Conclusions

Because of the legal and ethical limitations of working with federally protected species, much of the important life history information presented herein for both species was obtained by direct observations. Understandably, every effort was made to limit the number of individuals sacrificed in the interest of scientific knowledge. We believe that one of the best ichthyological applications of this approach lies with the census or collection of rare benthic, non-schooling species; for observations of microhabitat use and certain behavioral aspects, few other techniques can compare.

Northcote and Wilkie (1963) and Goldstein (1978) reported comparable results between direct underwater observation and seining, and they found numerous advantages associated with the former. To name a few: amount of time and level of effort is often reduced, numbers of species observed is often greater, estimates of relative abundances are probably more representative of the actual community, and a greater variety of habitats can be more easily surveyed. Pflieger (1978) reported that direct observations via skin-diving was more efficient than seining for the federally threatened Nianguae darter (fish observed/effort), and collectors using only a seine net were twice as likely to miss this species at a locality. How many populations of *N. flavipinnis* or even *N. baileyi* may have been overlooked by collectors relying solely on standard methodologies? It is entirely likely that *N. flavipinnis* would never have been discovered in Citico Creek had nocturnal underwater observations not been employed.

Obviously, direct observations will not be successful in streams that are not normally clear. Moreover, the diver must be competent in identifying live specimens, which often look very different from preserved specimens, and be able to visually compensate for magnification caused by refraction. The latter is especially important if size is a characteristic used in species identification. Accurate estimation of population size for schooling species, or for benthic species which bury beneath the substrate, may also be difficult.

Table 8 summarizes the known life history information for both madtom species in Citico Creek. Some of these characteristics, such as low fecundity, short lifespan, specialized reproductive behavior, specific breeding and non-breeding habitat requirements, have almost certainly added to the vulnerability of both species, and possibly to extirpation of historical populations.

In comparison to most other cool to warmwater streams in the southeastern United States, the Citico Creek watershed is relatively pristine. Fortunately, the watershed is closely monitored by the U.S. Forest Service; unfortunately, the Citico Creek populations of both madtom species are small and localized. The fact that *N. baileyi* was extirpated from Abrams Creek, while many other fish species recolonized following the 1957 reclamation project documents this species' susceptibility to a single catastrophic event. Likewise, the relatively rapid decline of the once more wide-ranging and relatively common *N. flavipinnis* is indicative of its vulnerability. *Noturus flavipinnis* once occupied 78 stream km in Copper Creek and in the late 1960's and early 1970's individuals could be easily seined. However, in recent years, standard fish surveys (seining and electroshocking) in Copper Creek have produced no specimens. In the summer/fall of 1993, an intensive snorkeling effort involving 52.3 hours of underwater observations at several locations throughout the 78 km reach where *N. flavipinnis* was historically known revealed just two specimens in a single pool. Thus, while the species is still present in Copper Creek, the population is apparently much smaller and more localized than it was. The only other extant population of *N. flavipinnis* occurs in the Powell River. Since 1968, only three specimens have been taken, at two localities, despite frequent and intensive sampling efforts.

No museum specimens of *N. flavipinnis* exist from the 1957 poisoning of Abrams Creek although the brindled madtom, *Schilbeodes* (=*Noturus*) *miurus*, the name given by earlier collectors to *N. flavipinnis*, was reported as being collected during the reclamation of lower Abrams Creek (Lennon and Parker 1959). We speculate that *N. flavipinnis* probably occurred in the middle and lower reaches of Abrams Creek given the similarities between Abrams Creek and Citico Creek in a host of habitat variables (e.g., stream size, topographical position, gradient, and substrate composition).

Since 1986, Conservation Fisheries, Inc, a non-profit organization located in Knoxville, with assistance and funding from several federal and state agencies, has propagated, reared, and released into Abrams Creek a total of 821 *N. baileyi* and 404 *N. flavipinnis* (Shute et al. 1992; Shute et al. 1993; Shute et al. 1994; and Rakes et al. 1995). In June 1990 and June 1991, two *N. baileyi* were observed guarding potential nest rocks at the transplant site in Abrams Creek; at this same location in 1994, four *N. baileyi* and one *N. flavipinnis* were found.

Fortunately for both species, the attitudes of southeastern resource managers have changed greatly since 1957, when Lennon and Parker (1959, p. 1) reported on the results of the Abrams Creek reclamation project, and wrote... "the many successes which have been achieved in warm water and cold water lakes have prompted fishery biologists to consider the reclamation of streams with toxicants."

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