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**Ecology and Life History of the Speckled Madtom, *Noturus leptacanthus* (Ictaluridae)**

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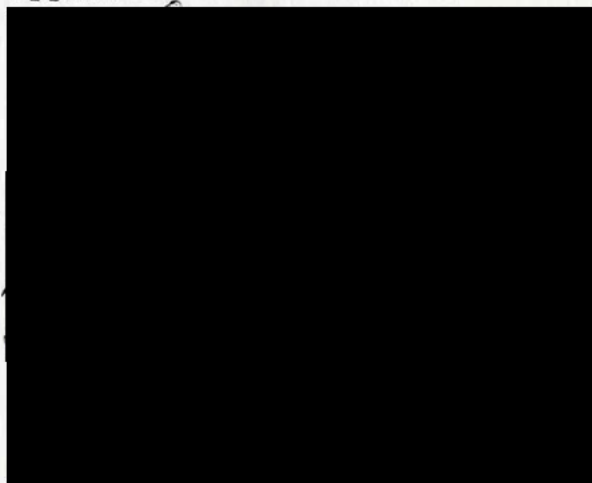
ECOLOGY AND LIFE HISTORY OF THE SPECKLED MADTOM,  
NOTURUS LEPTACANTHUS (ICTALURIDÆ)

by

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A Thesis  
Submitted to the Graduate School  
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## I. INTRODUCTION

Noturus leptacanthus Jordan, the speckled madtom (Fig. 1), is widely distributed along the Gulf Coastal Plain from Louisiana east to South Carolina and south to the St. Johns and Suwanee river drainages of Florida (Taylor 1969). It inhabits moderate to fast moving creeks and is particularly common in areas of dense aquatic vegetation. In Mississippi, N. leptacanthus is statewide in distribution (Taylor 1969), and in the Black Creek drainage of the south central coastal plain it appears to be the most common madtom species in lotic habitats.

Noturus leptacanthus was first described by Jordan (1877a) from Silver Creek, Dekalb County, Georgia. It was later included by several authors in the genus Schilbeodes Bleeker, along with other madtoms lacking prominent serrations on the pectoral spines. Taylor (1969), in his revision of the genus Noturus, placed N. leptacanthus in the subgenus Schilbeodes, containing those members of the genus lacking serrations on the anterior edge of the pectoral spines, being uniformly dark in coloration, and having the ossified pectoral radials fused. Because N. leptacanthus has eight (rather than nine) pelvic rays, smooth and slender pectoral spines, and a distinctive color pattern of large, discrete, brown chromatophores, Taylor (1969) did not

Fig. 1. Noturus leptacanthus, male, SL = 46.5 mm.





consider it closely related to other members of its subgenus. Noturus leptacanthus is the smallest member of the Schilbeodes group, and one of the smallest of its genus, reaching a maximum standard length of about 75 mm (Taylor 1969).

Most of the literature pertaining to Noturus species is taxonomic. Prior to Taylor's (1969) revision, the genus had been reviewed by Jordan (1877b), Swain and Kalb (1883), and Jordan and Evermann (1896). Hubbs and Raney (1944) discussed a number of species in the (then accepted) genus Schilbeodes. Although Noturus is the largest of the six ictalurid genera, with 24 described species (Taylor 1969; Douglas 1972) and two undescribed (Jenkins 1976), and although its members are widespread east of the Rocky Mountains and south of the St. Lawrence River, there is little published literature pertaining to the ecology, life history, or behavior of any of its members. This lack is undoubtedly a result of the small size, reclusive nature, and nocturnal habits of madtoms, as well as the restricted distributions of some of the species. An exhaustive bibliography (to 1967) for the genus is provided by Taylor (1969).

In 1944 when Hubbs and Raney revised the nomenclature of several Schilbeodes (= Noturus) species, they commented that madtoms were among the least completely known of eastern North American fishes. In 1977 much the same statement could be made. This research represents an effort to

understand the life history strategy and ecological relationships of Noturus leptacanthus. In particular I have tried to compare the combination of low fecundity, large egg size, parental care, and marked sexual dimorphism in N. leptacanthus with the patterns of these parameters in other ictalurid species.

## II. MATERIALS AND METHODS

### Collection and Preservation

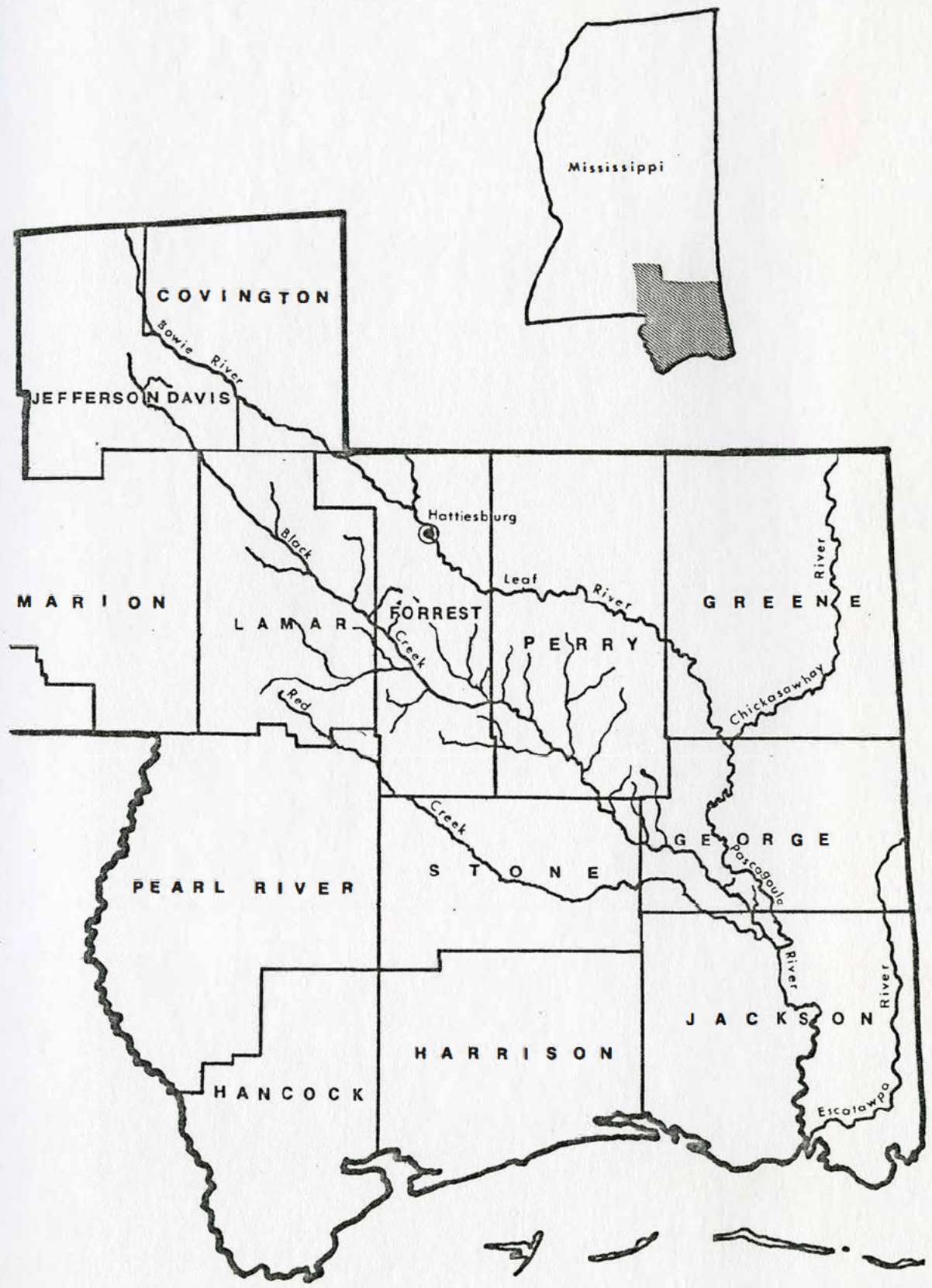
Most of the animals used in this study were collected in Black Creek and some of its tributaries in Lamar and Forrest Counties, Mississippi. A few specimens were obtained from the Bowie River in Covington County. Personnel of the Mississippi Game and Fish Commission provided one rotenone collection of N. leptacanthus from the Escatawpa River and rotenone collections of N. gyrinus from Fort Bayou, Paige Lake, Escatawpa River, Bogue Homa Lake, Catchemall Bayou, and Barnes Lake. All of the locations are part of the Pascagoula River drainage system of south central Mississippi (Fig. 2). Specimens examined are listed in the Appendix.

Most of the Noturus were captured with a 3.7 m, 3.2 mm mesh seine or with a 6.1 m, 3.2 mm mesh bag seine. The most effective method for catching N. leptacanthus was to set a net below a patch of aquatic vegetation or some other source of cover and to dislodge the fish in a small area above the net by tearing up plants and overturning logs.

Night trapping of Noturus was also successful, using unbaited traps of 3.2 mm mesh hardware cloth, 45.7 x 15.2 x 10.2 cm, with a 15 cm long funnel at one end. The funnel



Fig. 2. The Pascagoula River and its major tributaries, including the Black Creek system. The inset shows the location of the Pascagoula drainage within the state of Mississippi.



openings were about 1 to 3 cm in diameter. Whenever possible these traps were placed with the mouths opening downstream to prevent clogging with drifting leaf litter.

The fish were fixed in 10% formalin in the field, later rinsed in water, and stored in 40% isopropanol. Only very large specimens required injection with formalin.

Because speckled madtoms are nocturnal, their activities are difficult to observe. I used a mask and snorkel in shallow (50 cm or less) water to observe their daytime resting behavior and their faunal associates in patches of riffle vegetation. Noturus leptacanthus were observed in this manner on 14 occasions, totaling about 3-4 hours. More time was spent looking for madtoms and their nests than actually watching them.

#### Physical Parameters and Habitat Data

I kept extensive field notes with most collections and made an effort to sample and describe small, discrete microhabitats. Physical and chemical data were not obtained with each collection, but such information was recorded periodically throughout the study. Much of the physical and chemical data are from Ross, Baker, and Clark (S. T. Ross, J. A. Baker, and K. E. Clark. University of Southern Mississippi, Hattiesburg, Mississippi. Unpublished.).

Water temperatures were recorded to the nearest 0.5°C with a mercury bulb thermometer. Dissolved oxygen

was measured with a Yellow Springs Instruments oxygen probe (Model 54 ABP) and recorded to the nearest 0.5 ppm. Either a Corning Model 3 portable pH meter or a Hach water chemistry test kit (Model DR EL) was used to determine pH to the nearest 0.5 unit. Results from the two methods were comparable within the pH range encountered during the study. Water turbidity was measured in Jackson Turbidity Units (JTU) using the Hach kit. Conductivity was determined in micromhos/cm with a Lab-Line Instruments portable Lectro Mho-meter. Current velocities (cm/s) were found with a General Oceanics Model 2031 current meter, or by averaging the times of low floating objects over a measured course.

Four categories of habitat data were described: substrate type, amount of aquatic vegetation, amount of litter, and amount of submerged cover (including vegetation, logs, brush, roots, and rubble). These were characterized with coded numerical values (Table 1). The codes for substrates increased with increasing mean particle size. The other codes increased with the increasing density of each parameter.

I collected samples of all aquatic plant species encountered. Representative specimens are housed in the herbarium of the University of Southern Mississippi. The nomenclature of all plant species follows that of Godfrey and Wooten (in press) or Radford, Ahles, and Bell (1964).

Drainage areas and stream gradient were obtained from



TABLE 1. Coded Values of Four  
Habitat Parameters

Parameter	Code	Description
Substrate Type	1	Clay
	2	Mud
	3	Silt
	4	Sand
	5	Sand and gravel
	6	Gravel and sand
	7	Small gravel
	8	Small and large gravel
	9	Large gravel
	10	Rubble
Litter Amount	1	None
	2	Slight trace
	3	Moderate, substrate visible
	4	Heavy, substrate obscured
	5	Very heavy
Amount of Aquatic Vegetation	1	None
	2	Scattered small clumps
	3	Dense clump, seining possible
	4	Seining impossible, stomp only
	5	Very dense, traps only
Submerged Cover	1	None
	2	Occasional scattered cover
	3	Moderate, seining possible
	4	Seining impossible, stomp only
	5	Very heavy, traps only

the data of Ross et al. (unpublished). These values were calculated from topographic maps (scale 1:24,000). Mean annual discharge rates for several locations in the study area were calculated by Ross et al. (unpublished) using the method of Leopold, Wolman, and Miller (1964).

#### Counts and Measurements

Morphometric measurements were made with vernier calipers. All counts and measurements followed the methods of Hubbs and Lagler (1958) with the following exceptions and clarifications. Soft-ray counts included all rudimentary, unbranched rays. In the evaluation of sexual dimorphism, head widths were measured just behind the eyes (on a transect across the mandibular muscles). This was the point of greatest head width in mature, breeding males, but not in females or nonbreeding males. Head depths were measured at the same point as head widths. Again, this was the greatest dimension for breeding males, but not for other specimens. I used dividers to find interorbital widths, placing the points at the orbital rims without squeezing the the dividers together. Standard lengths were recorded to the nearest 0.5 mm. All other measurements were recorded to the nearest 0.1 mm.

Preserved fish (40% isopropanol) were weighed to 0.01 g on a Mettler H35 balance, after blotting away excess fluid. Ovaries were blotted and weighed to 0.001 g. The gonadosomatic index (GSI) was calculated as the ovary weight

divided by the total body weight (including the ovaries).

Ovaries were dissected from fish and carefully teased apart under a dissecting microscope. I counted the total number of ovarian eggs for a few representative specimens throughout the year, but most counts were restricted to ripe or ripening eggs which were always clearly distinguishable by their size and color. An ocular micrometer was used in determining egg diameters.

Stomach fullness was estimated visually without removing or opening the stomachs in order to preserve their contents for later use. Fullness was rated as 1 = empty, 2 = partially full, and 3 = full.

#### Analysis of Length Frequency Data

I analyzed polymodal length frequency curves using the graphical method of Harding (1949). This involves the plotting, on probability graph paper, of cumulative length frequencies on the abscissa versus standard length on the ordinate. The inflection points in these curves represent division points between one normally distributed length group and another, and I used them to delimit year classes of N. leptacanthus.

#### Rearing of Eggs and Larvae

Clutches of eggs and larvae were reared in 1-gallon (3.78 l) plastic containers filled with tap water which had been aerated for several days prior to use. The jars were

kept at room temperature (ca. 24°C) and were not kept on any regular light-dark cycle. The water was lightly aerated, but not to the extent that the eggs were tumbled about by turbulence.

Larvae were fed finely chopped earthworms and pulverized commercial sinking fish chow. Larvae were generally fed 3 times a day and their water changed every 2 to 3 days.

Larvae were removed periodically and preserved in 5% formalin and were transferred to alcohol after rinsing in water. Different schedules of removal were used for different clutches in order to obtain specimens throughout the first month of life. Some larval specimens were lightly stained with alizarin red S to aid in the counting of fin rays. Larvae were sketched under a dissecting microscope with a camera lucida.



### III. THE STUDY AREA

The study area in which I collected N. leptacanthus falls within the Southern Pine Hills Belt of the East Gulf Coastal Plain physiographic region (Fenneman 1938). In general, the region is one of rolling hills with occasional high ridges between drainages (Cross, Wales, and Traylor 1974). The underlying substrate is porous, sandy or gravelly Citronelle, resting on sandstone (Fenneman 1938), and in the lower lying areas is composed of Miocene sands and clays of the Hattiesburg and Pascagoula formations (Cross et al. 1974). The soils are well drained clayey and sandy loams of low fertility and generally low pH (Cross et al. 1974).

Braun (1972) categorized the vegetation of Mississippi's coastal plain as Southern Evergreen Forest. This is intermixed with areas of farm and pastureland. The forests are composed largely of pines, particularly longleaf (Pinus palustris), slash (P. elliottii), and loblolly (P. taeda), with varying admixtures of oak (Quercus) and Magnolia species. The understory consists chiefly of ericaceous shrubs and hollies (Ilex spp.). The evergreen forest is replaced in river bottomlands by several deciduous tree species, primarily Acer rubrum, Salix nigra, Nyssa aquatica, Taxodium distichum, Liquidambar styraciflua, and Cyrilla

racemiflora.

The climate of the Mississippi Gulf Coastal Plain is considered humid subtropical (Cross et al. 1974). Climatological data were obtained from Cross et al. (1974) and represent 84-year (temperature) and 70-year (precipitation) averages. The mean yearly temperature is 18.9°C (66°F). Summer temperatures average 26.7°C (80°F) and winter temperatures 11.1°C (52°F). The Hattiesburg area receives about 147-152 cm (58-60 in.) of precipitation per year, almost entirely in the form of rain, measurable snowfall being infrequent. The fall months are the driest period of the year, and the spring, the wettest. The mean yearly evaporation and runoff may exceed the yearly rainfall in southern Mississippi, therefore during periods of low flow streams may be fed entirely by ground water sources.

Black Creek is a major tributary to the Pascagoula River, flowing generally southeastward through Jefferson Davis, Lamar, Forrest, Perry, Stone, George, and Jackson Counties, and is about 150 km in length (Fig. 2). The creek has an average gradient of 1.1 m/km from its headwater region at an elevation of about 150 m to its junction with the Pascagoula River at 15 m elevation. The upper portion of Black Creek (in Lamar and Forrest Counties) ranges in width from about 10 m to 30 m and is mostly less than 1 m in depth, although there are occasional deeper pools between riffle and run areas (Fig. 3).

Fig. 3. A typical Noturus leptacanthus habitat on Black Creek, Lamar County, Mississippi, about 100 m upstream of the bridge on State Road 589.







The system is subject to occasional heavy flooding, particularly during the spring, at which times the maximum depth may exceed 4 m and the width may increase to perhaps 100 m at some localities (especially those disturbed by roadways). During such periods of high water, the creek is connected to adjacent backwater and swamp areas.

The mean annual discharge rates in upper Black Creek range from 6.88 to 17.34 m<sup>3</sup>/s over a stream distance of about 50 km. Current speeds range from essentially 0 cm/s in backwater eddy areas to about 100 cm/s in the fastest riffles. Overall, the current could be characterized as moderate but sufficient to prevent water stagnation.

Except following periods of heavy rainfall, Black Creek is relatively clear, the mean recorded turbidity being 15.4 JTU (3-45 JTU) during times of normal flow. However, it is brownish yellow in color due to the presence of dissolved humic substances. The pH of the system is consistently low, ranging from 5.5 to 6.8 ( $\bar{x}$  = 6.4), and reflects the low soil pH. During the study the conductivity ranged from 10 to 50 micromhos/cm ( $\bar{x}$  = 24.8). Dissolved oxygen remained at saturation levels throughout the study, since the water is constantly moving and is generally protected from direct solar radiation by overhanging vegetation. During 1976 recorded temperatures in the upper Black Creek system ranged from 7 to 24°C. The upper portion of the creek is relatively free from industrial and municipal

pollution.

The substrate in the Black Creek system is predominately fine sand (1 to 2Ø); interspersed are patches of small to medium gravel (-3 to -4Ø) and occasional areas of hard packed clay. Large rocks occur only infrequently at bridge and trestle crossings as a result of earlier construction activities. Throughout the study area, Black Creek and its tributaries are heavily littered with submerged logs and sticks which, together with patches of aquatic vegetation, trap considerable quantities of leaf litter and silt.

In those areas where sunlight penetrates the canopy, there is extensive growth of aquatic vegetation in the shallow portions of the creek and along the banks. By far the most prominent vascular component of the aquatic plant community in flowing water is Sparganium americanum, which grows in areas of moderate current as well as along the banks in places subject to periodic inundation. Clumps of Potamogeton diversifolius are common, although scattered, in running water, while patches of Eleocharis acicularis, Nuphar luteum, and Scirpus etuberculatus are less frequent. Along the banks and in areas of quiet water, Orontium aquaticum predominates. Attached filamentous algae (largely Batrachospermum sp.) is prominent only in some of the small tributaries. In some of these small feeder creeks aquatic vegetation is more extensive than in the main

channel itself, and these localities might be described as weed-choked, although the current remains moderate.

Based on extensive seine collections, 50 species comprise the fish fauna of upper Black Creek and its tributaries, but the community is dominated by large numbers of only a few species (Table 2), largely cyprinids and percids (Ross and Howell 1977). Ictalurids, including Noturus leptacanthus, are not a major component of the fauna, but it is likely that seining, particularly in the daytime, underestimates their true abundance. Both the species richness and species diversity vary locally within Black Creek, depending in part upon the habitat diversity (Ross and Howell 1977). They were generally highest at disturbed areas (e.g., road crossings).

TABLE 2. Percentage Occurrence and Percentage Abundance of the Dominant Fish Species in the Upper Black Creek System (From Ross and Howell 1977)

Family	Species	Percentage Occurrence	Percentage Abundance
Cyprinidae	<u>Notropis roseipinnis</u>	9.82	26.18
	<u>Notropis texanus</u>	8.80	16.60
	<u>Notropis venustus</u>	8.65	7.84
Percidae	<u>Percina nigrofasciata</u>	12.30	5.56
	<u>Etheostoma swaini</u>	4.55	2.19
	<u>Ammocrypta beani</u>	3.96	1.14
	<u>Etheostoma stigmaeum</u>	3.37	0.83
Cyprinodontidae	<u>Fundulus olivaceus</u>	8.50	7.62
Ictaluridae	<u>Noturus leptacanthus</u>	4.11	1.41
Atherinidae	<u>Labidesthes sicculus</u>	2.64	1.79
Centrarchidae	<u>Lepomis macrochirus</u>	2.49	1.14



#### IV. RESULTS

I examined 539 N. leptacanthus collected between September 1975 and May 1977, as well as 183 N. gyrinus, 47 N. nocturnus, and 49 N. funebris collected during the same period. I seldom collected speckled madtoms in large numbers at any site. However, in both seine and trap samples they were more abundant in the Black Creek system than N. gyrinus, N. nocturnus, or N. funebris. The adults of the latter three species were very rarely taken in seine collections, although each formed a significant part of trap collections during flood conditions in the spring of 1976 and the spring of 1977. Juveniles of these three species appeared more frequently in seine collections than adults, but in no case approached the abundance of N. leptacanthus.

##### Field Observations

In the upper Black Creek drainage N. leptacanthus inhabited vegetated riffles and runs (Fig. 4). Sparganium, Potamogeton, Scirpus, Eleocharis, and Nuphar patches were all utilized, as well as typically still water plant species where they grew adjacent to flowing water. By day, N. leptacanthus sought shelter in the area of reduced current flow afforded by aquatic vegetation. Isolated clumps of plants in otherwise unvegetated areas almost invariably harbored

Fig. 4. Sparganium americanum in Black Creek, Lamar County, Mississippi. A typical microhabitat of Noturus leptacanthus.





several speckled madtoms. The accumulated silt and leaf litter in such patches provided a substrate against which N. leptacanthus were well camouflaged by their possession of brown chromatophores on a yellowish background.

In direct observations with a mask and snorkel, I found that N. leptacanthus generally rested facing upstream, immediately behind and below the bases of trailing Sparganium culms. They were very reluctant to abandon such positions and responded to disturbance by moving in closer to the plant or by swimming to another plant within the patch. I never observed a fish leave a patch entirely to seek shelter elsewhere.

Juvenile N. leptacanthus up to about 20 mm in length commonly rested during the daytime in water only a few centimeters deep, especially in regions of slight current (ca. 10-20 cm/s) and characteristically in emergent hummocks of Potamogeton. I frequently found 5 to 10 juvenile speckled madtoms in hummocks about 250 cm<sup>2</sup> in area. They shared these sites with juveniles of other madtom species and also with juvenile bullheads (Ictalurus).

Several other fish species were often associated with aquatic vegetation. The rockbass, Ambloplites rupestris, the pygmy sunfish, Elassoma zonatum, and the tadpole madtom, N. gyrinus, were most typical of vegetation along banks and in quiet water and were not often found in mid-stream, vegetated riffles, although I did occasionally



collect them with N. leptacanthus. Juveniles of N. funebris and N. nocturnus, and occasionally adults as well, were collected from clumps of vegetation with speckled madtoms. Percina nigrofasciata and particularly Etheostoma swaini were frequent associates of N. leptacanthus in vegetation, although neither was restricted to such habitats.

Where vegetation was absent, I collected speckled madtoms from beneath other sources of cover, including logs, rubble around bridge pilings, and even from bare gravel riffles, where presumably they rested in the area of reduced current velocity just above the substrate. They also hid in discarded cans and bottles, particularly during the breeding season. No fish other than members of the genus Noturus used such containers; crawfish and snails were not infrequent inhabitants, but never shared cans with madtoms.

Based on multiple regression analysis, two parameters, amounts of aquatic vegetation and litter, explained 66% of the variation in N. leptacanthus density. The analysis was based on eight microhabitat parameters (including also amount of cover, drainage area, surface current speed, substrate type, mean depth, and mean annual discharge rate) and 22 collections. Estimates of relative fish density were obtained by dividing the number of individuals collected by the area seined (as recorded in the field). These data (Table 3) are part of a larger study of stream fish distribution (Ross et al. unpublished).

TABLE 3. Multiple Regression Statistics for Noturus leptacanthus Density versus Eight Habitat Parameters

Parameter	Simple <u>R</u>	Multiple <u>R</u>	<u>R</u> <sup>2</sup>	$\frac{F}{p} < 0.05$ (2, 19 df; $\frac{F}{p} < 0.05$ )
Amount of Aquatic Vegetation	.762	.762	.581	25.10
Amount of Litter	.451	.810	.657	4.20
Amount of Cover	.622	.827	.684	n.s.
Drainage Area	.056	.837	.700	n.s.
Surface Current Velocity	-.276	.844	.713	n.s.
Substrate Type	-.093	.853	.727	n.s.
Mean Depth	-.069	.854	.730	n.s.
Annual Mean Discharge	-.004	.856	.732	n.s.

### Diel Activity Pattern

Noturus leptacanthus is nocturnal. I observed individuals swimming away from cover on only three occasions during daylight hours, and these could be attributed to habitat disturbance. At night, with a flashlight, I observed small madtoms foraging in very shallow water (ca. 5-10 cm), but saw no large individuals.

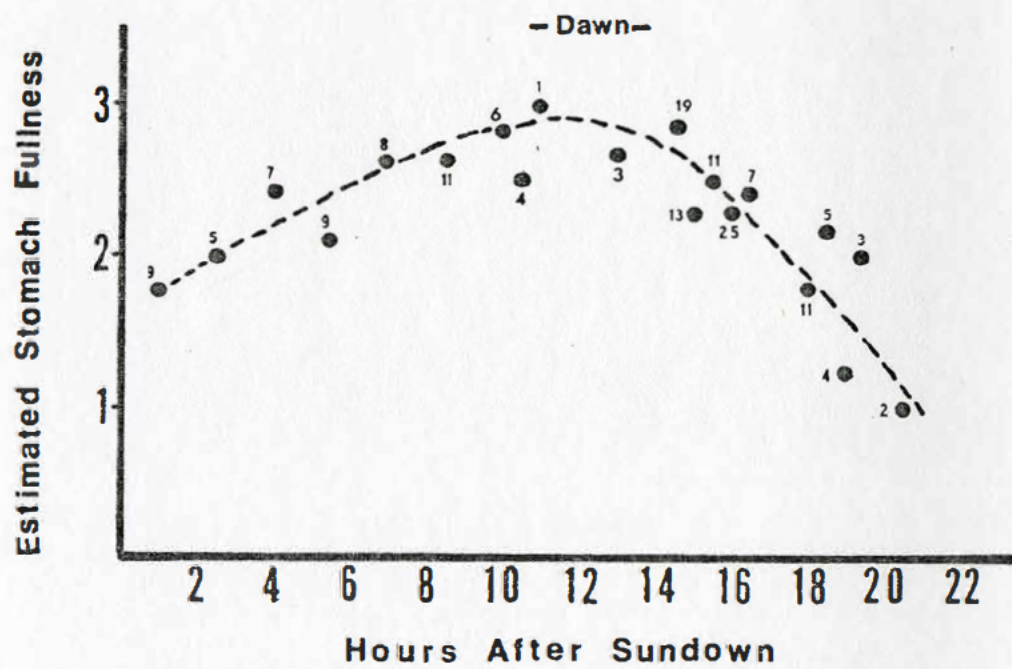
The nocturnal habits of N. leptacanthus are indicated by the results of trapping runs. A total of 2,748 daytime trap hours produced four speckled madtoms, while 5,830 nighttime trap hours produced 89 specimens, as well as substantial numbers of N. gyrinus, N. nocturnus, and N. funebris. These data represent 26 different trapping runs, and a chi-square test shows the daytime catch rate to differ significantly from the nighttime rate ( $\chi^2 = 34.33$ ; 1 df; p < 0.05).

I estimated stomach fullness for 163 N. leptacanthus collected between August 11 and October 10, 1976. These collections taken together span a 24-hour period. Feeding commenced shortly after sundown, and peak stomach fullness was reached about 12 hours later, approximately at dawn (Fig. 5). The time of day for each collection is expressed as the number of hours following sundown in order to correct for the 2-month range of sampling dates. Stomach fullness declined slowly throughout the daylight period, reaching a low about 20 hours following sunset, that is, about 4 hours

Fig. 5. Daily feeding activity of Noturus leptacanthus  
in terms of stomach fullness over a 24-hour period.

1 = empty, 2 = partially full, 3 = full. Sample sizes are  
indicated beside each data point. Curve fitted by eye.





before the initiation of a new feeding cycle. I found very few fish with entirely empty guts (both stomach and intestines), so digestion either proceeded slowly or fish fed at reduced rates throughout the day.

I did not systematically examine the stomach contents of speckled madtoms. The few stomachs examined contained aquatic insect larvae, chiefly tendipedids. These are the dominant insect larvae in upper Black Creek (Hartfield 1978). The stomachs of three N. nocturnus captured in April 1977 contained the remains of N. leptacanthus, including one individual about 40 mm long. Speckled madtoms were also readily eaten by large N. funebris in aquaria.

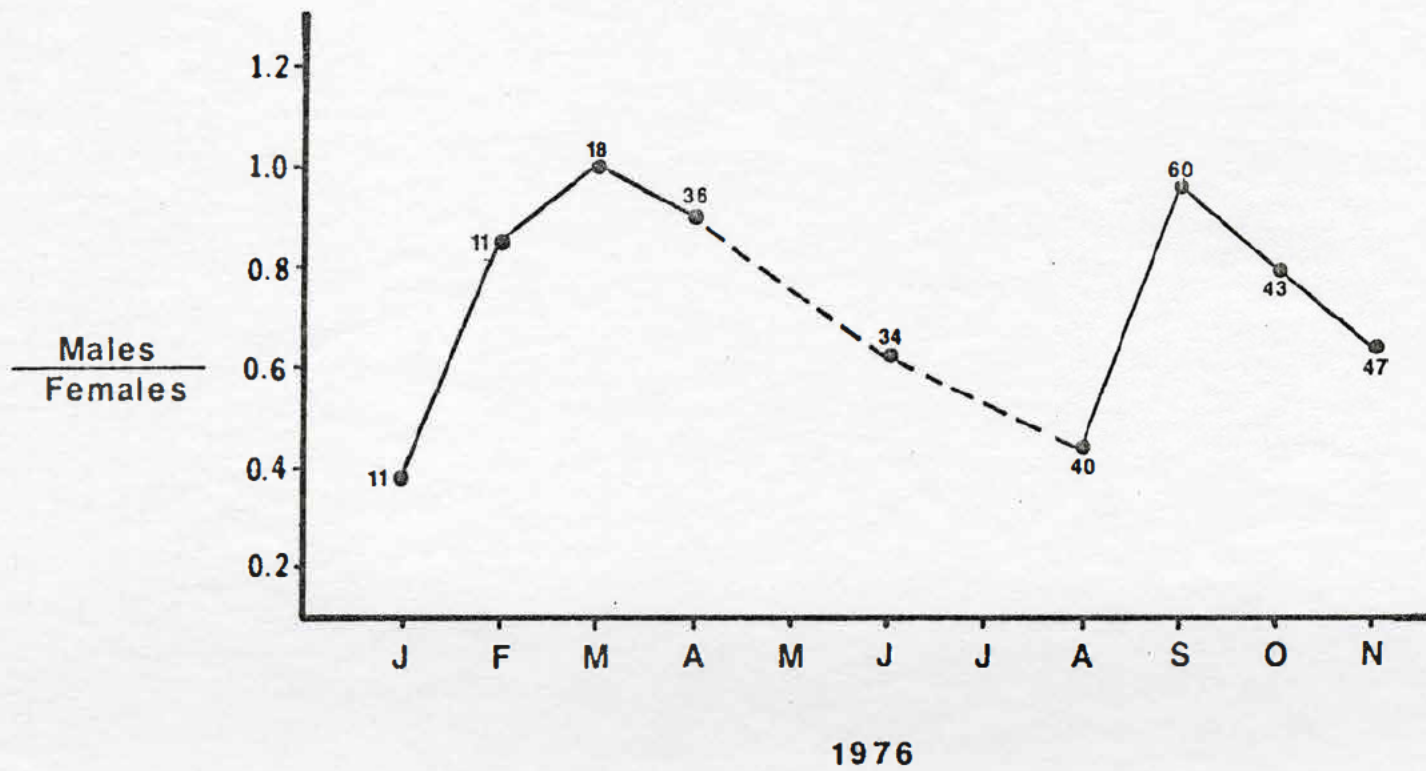
#### Sex Ratio

Monthly sex ratios (excluding May, July, and December) showed wide variation, although females were always more numerous (Fig. 6). These ratios were based on seine and trap collections only. Overall, the ratio of males to females was 0.83, a significant deviation from the expected one-to-one ( $\chi^2 = 8.33$ ; 1 df;  $p < 0.05$ ). Taken by month, only the August ratio deviated significantly from the expected ( $\chi^2 = 6.40$ ; 1 df;  $p < 0.05$ ). Males formed the smallest portion of the collections during the breeding season (June and August).

#### Age and Growth

Noturus leptacanthus apparently survive 2+ years,

Fig. 6. Monthly sex ratios (males:females) of Noturus leptacanthus during 1976 (excluding May, July, and December). Sample sizes are indicated beside each data point.





based on length frequency distributions (3 mm intervals) over 12 months (Fig. 7). The data represent animals captured from September 1975 to May 1977. Sexual size dimorphism appeared in only the March-April sample (Fig. 8), in which 2-year-old males were longer than females. This trend was not evident in the other bimonthly length frequency plots and may represent sampling error.

The standard length to weight ratios of 138 male and 172 female Noturus leptacanthus did not differ significantly ( $p < 0.05$ ), therefore the sexes were combined in calculating the length to weight relationship (Fig. 9). I also calculated length to weight relationships for 93 N. gyrinus, 29 N. funebris, and 26 N. nocturnus (Table 4). Noturus leptacanthus is significantly more slender in body form than these three species ( $F = 437.07$ ; 4, 452 df;  $p < 0.05$ ).

Using the length to weight relationship and the estimated mean lengths of year classes at bimonthly intervals derived from the Harding plots of length frequencies, I plotted the growth of N. leptacanthus over its presumed 2+ year life span (Fig. 10). From this it appears that growth was limited to the warm months of the year and ceased during the winter. Growth of adults was also interrupted during the spawning period, from June to August. Speckled madtoms averaged 39 mm and 0.92 g at the end of 1 year's growth. At the end of 2 years, the average length was 50 mm and the average weight, 1.96 g.

Fig. 7. Bimonthly length frequencies (percentage of total catch) of Noturus leptacanthus. Suggested division between year classes is indicated by the dashed lines. Sample sizes for each bimonthly group are indicated at the right.

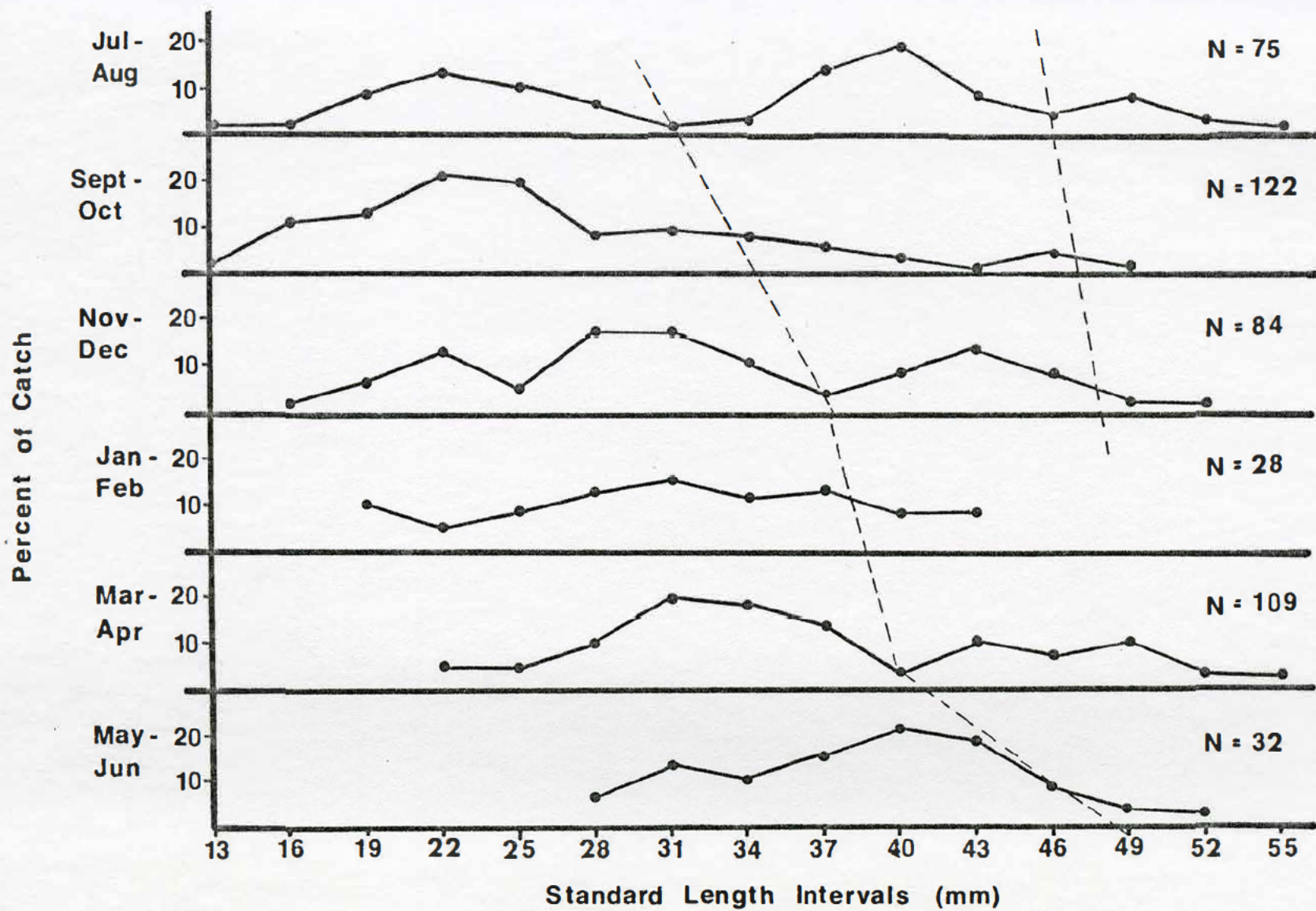


Fig. 8. Length frequencies of male (solid line) and female (dashed line) Noturus leptacanthus in the March-April sample, showing size dimorphism in the 2-year-old group.



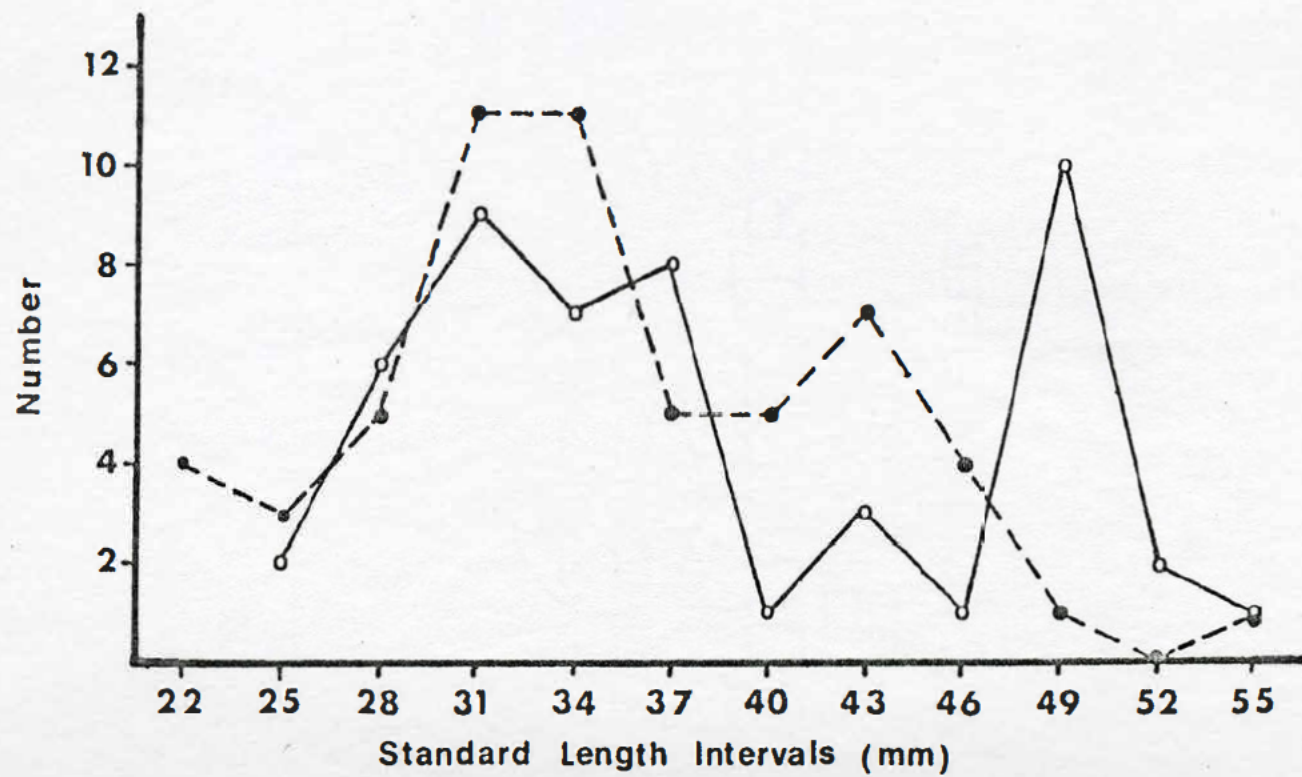


Fig. 9. Length to weight relationship of 310 Noturus  
leptacanthus.

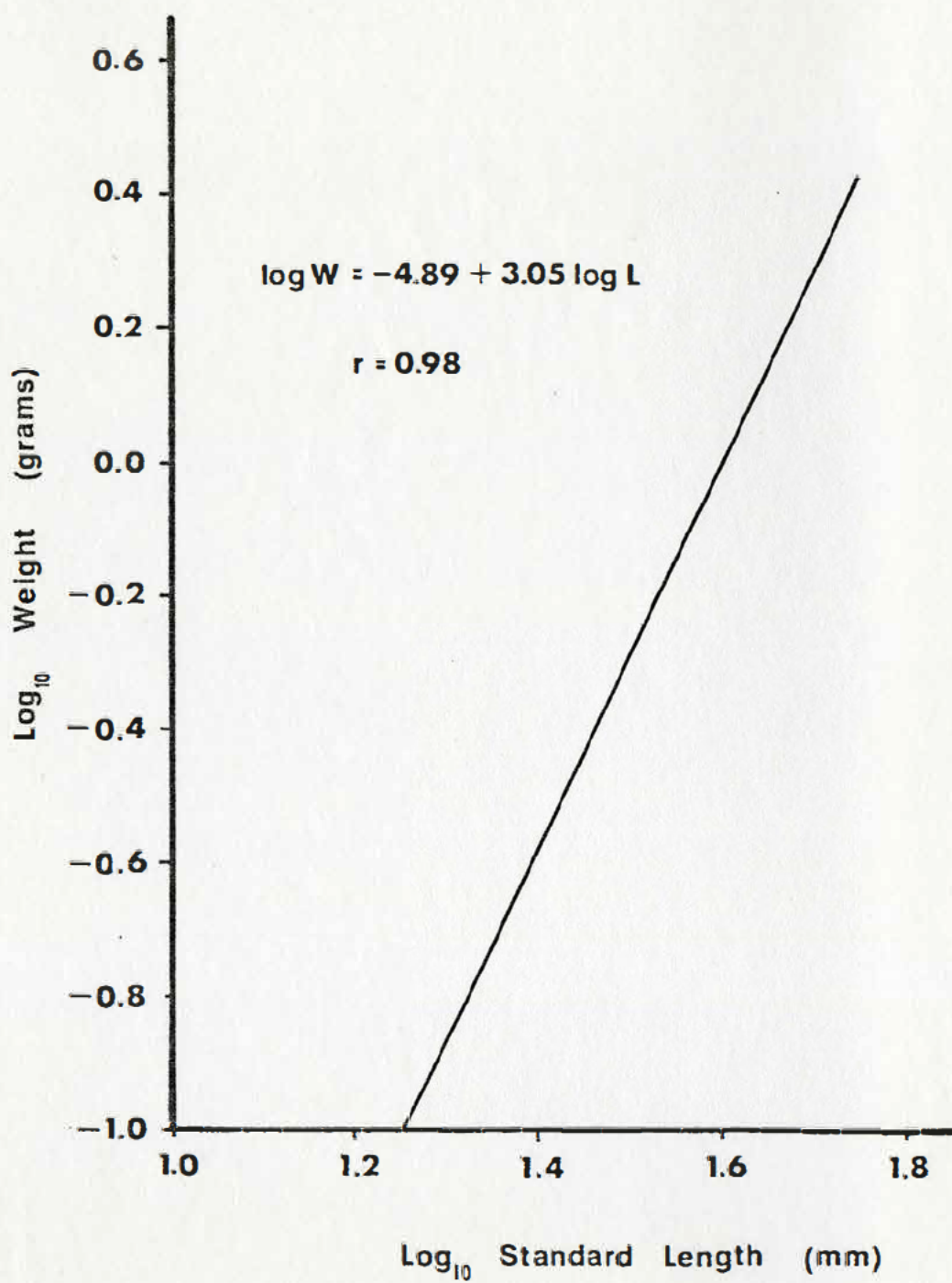
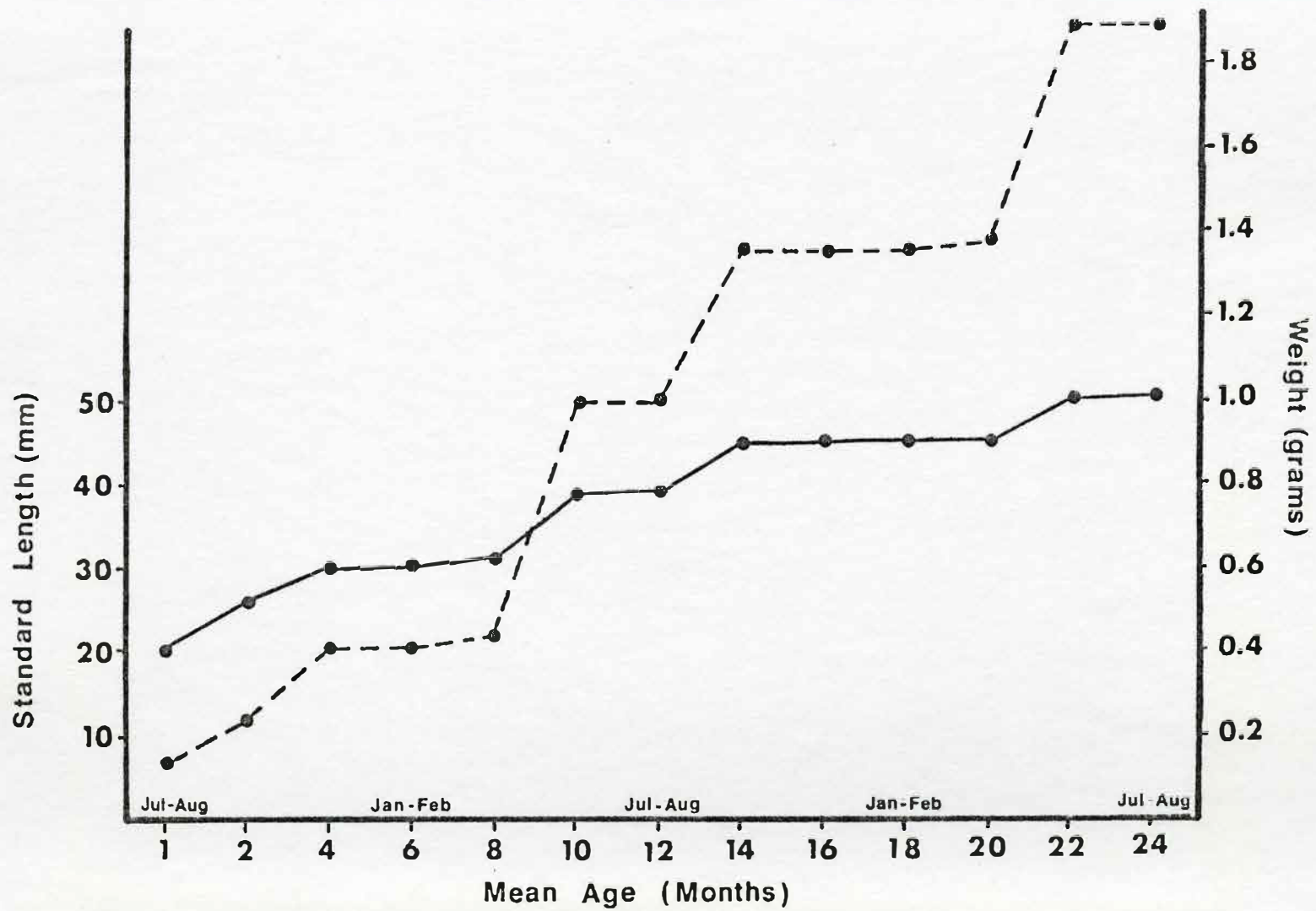


TABLE 4. Length to Weight Relationships of Noturus gyrinus, N. funebris, and N. nocturnus

Species	<u>N</u>	Length-to-weight Relationship	<u>r</u>
<u>N. gyrinus</u>	93	$\log W = -4.60 + 2.93 \log L$	0.99
<u>N. funebris</u>	29	$\log W = -4.72 + 3.02 \log L$	0.99
<u>N. nocturnus</u>	26	$\log W = -4.44 + 2.84 \log L$	0.99



Fig. 10. Growth in length (solid line) and weight (dashed line) of Noturus leptacanthus over 2 years.



### Sexual Dimorphism

The sexes were externally indistinguishable during most of the year, but were readily separated by examination of the gonads (Fig. 11), which were well differentiated in animals only about 2 months old and 20 mm long. Nucleated eggs were present in the ovaries of all females in which gonads could be found. The testes of N. leptacanthus possessed the fingerlike projections characteristic of ictalurid fishes (Sneed and Clemens 1963).

The sexes were externally very different during the spawning season. Mature females were greatly distended with eggs, while males assumed a duller coloration and developed enlarged head muscles (Figs. 12 and 13). Dissection of the heads and the anterior portion of the trunks of four breeding and four nonbreeding males showed that the mandibular muscles, and to a lesser extent the anterior epaxial musculature, were greatly enlarged in breeding males. Also, deposits of fat on the snout and across the back of the head and opercles were reduced in spawning males, although I did not measure relative fat quantities.

Breeding males could be distinguished readily from females or nonbreeding males by their characteristic head shape and size. I computed four morphometric ratios for groups of mature ( $SL \geq 34$  mm) male and female N. leptacanthus collected before (February to April), during (June to August), and after (September to November) the 1976

Fig. 11. Ovaries (left) and testes (right) of adult Noturus  
leptacanthus collected during April 1976.





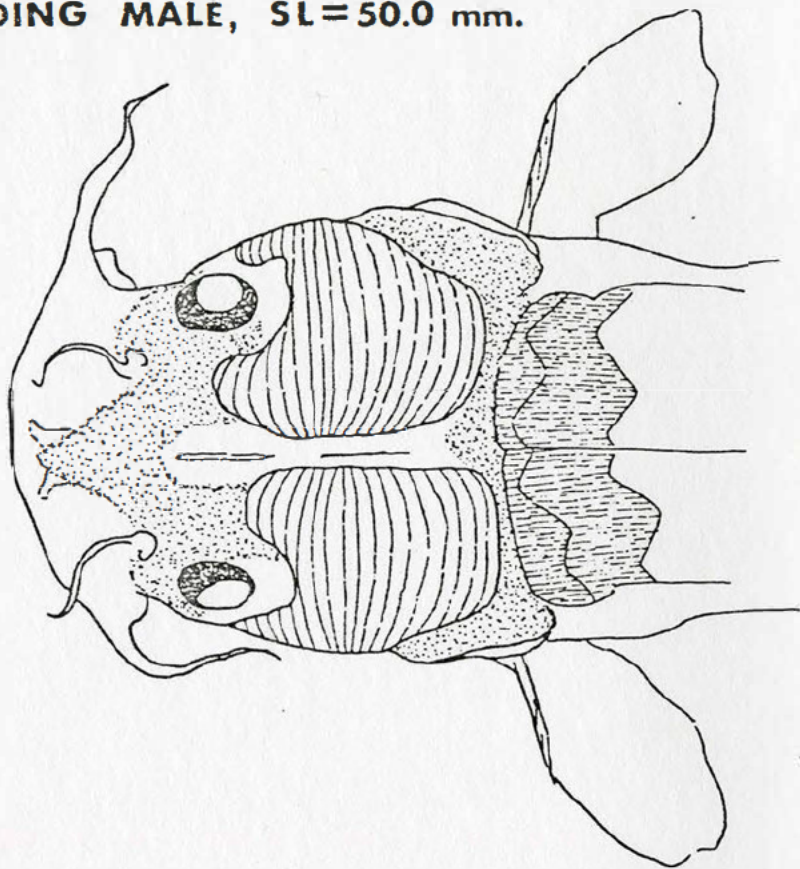
Fig. 12. Breeding male (above) and nonbreeding male (below) Noturus leptacanthus, collected in July and November 1976, respectively. SL breeding male = 54.0 mm and SL nonbreeding male = 46.5 mm.



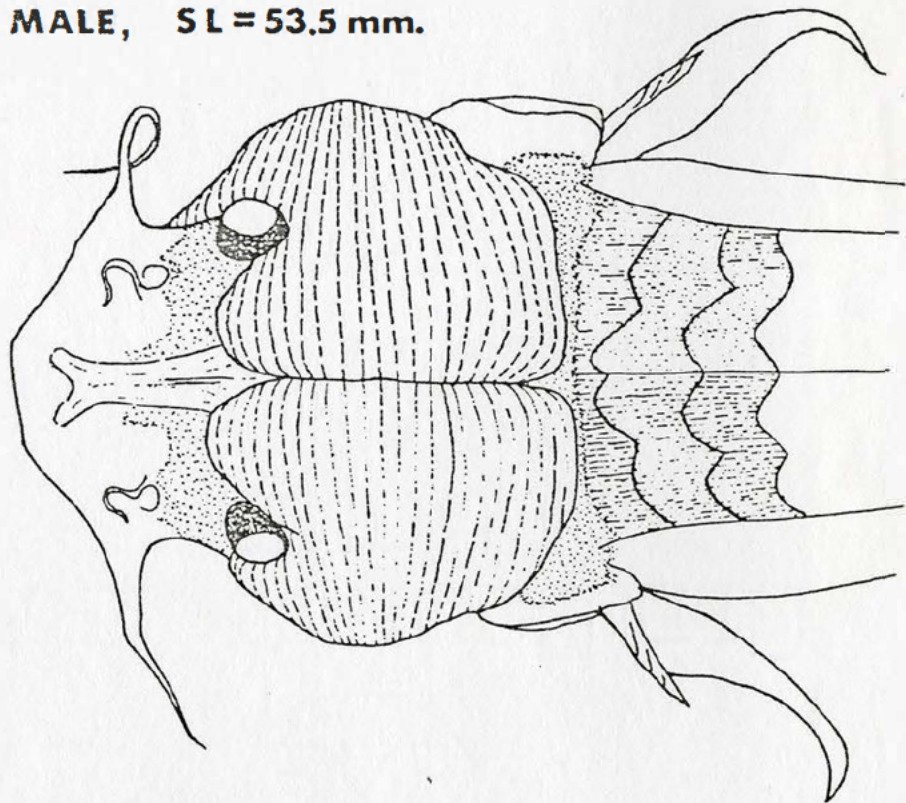
Fig. 13. Drawing of the dissected heads of breeding and nonbreeding male Noturus leptacanthus showing the development of the mandibular muscles (striped) and the locations of fat deposits (stippled).



**NONBREEDING MALE, SL = 50.0 mm.**



**BREEDING MALE, SL = 53.5 mm.**



spawning season (Table 5).

Ratios of head length to standard length varied 2% or less between groups (Fig. 14), and corresponded well with the proportions described by Taylor (1969).

The width of the head relative to its length was most useful in separating males and females during the spawning season (Fig. 15). The heads of breeding males were almost as broad as long and differed significantly in shape from the heads of either sex at any season ( $F = 43.99$ ; 5, 99 df;  $p < 0.05$ ). The difference between the sexes during the spawning period was increased by the females having significantly narrower heads at this time ( $F = 5.84$ ; 2, 50 df;  $p < 0.05$ ). The increase in head width relative to head length in breeding males involved a change in shape as well as size. The widest part of the head in all females examined and in all nonbreeding males was on a line just anterior to the opercular openings, while in breeding males the greatest width was just behind the eyes (Fig. 13).

There was no significant difference in the ratios of head depth to head length among the groups of females ( $p < 0.05$ ). The heads of spawning males were significantly deeper ( $F = 14.27$ ; 2, 68 df;  $p < 0.05$ ) than those of spawning females or other males (Fig. 16). Again, the change in head proportions involved a change in size and shape. In all groups the point of greatest depth coincided with the point of greatest width, just behind the eyes in breeding

TABLE 5. Morphometric Ratios of Groups of Male and Female Noturus leptacanthus Collected Before, During, and After the 1976 Spawning Season

	N	Mean and (Standard Deviation)			
		HL:SL	HW:HL	HD:HL	IOW:HL
Spawning Males	23	0.259 (0.009)	0.912 (0.029)	0.558 (0.047)	0.444 (0.027)
Postspawning Males	14	0.245 (0.012)	0.800 (0.038)	0.513 (0.026)	0.395 (0.030)
Prespawning Males	15	0.265 (0.010)	0.782 (0.062)	0.496 (0.030)	0.404 (0.044)
Spawning Females	19	0.244 (0.009)	0.758 (0.029)	0.509 (0.041)	0.406 (0.042)
Postspawning Females	20	0.247 (0.007)	0.789 (0.038)	0.507 (0.025)	0.394 (0.034)
Prespawning Females	14	0.257 (0.012)	0.791 (0.027)	0.491 (0.026)	0.402 (0.022)

Fig. 14. Head length to standard length ratios for groups of male and female Noturus leptacanthus collected before (spring), during (summer), and after (fall) the 1976 spawning season. Vertical lines are means, horizontal lines are ranges, and rectangles one standard deviation to either side of the means.



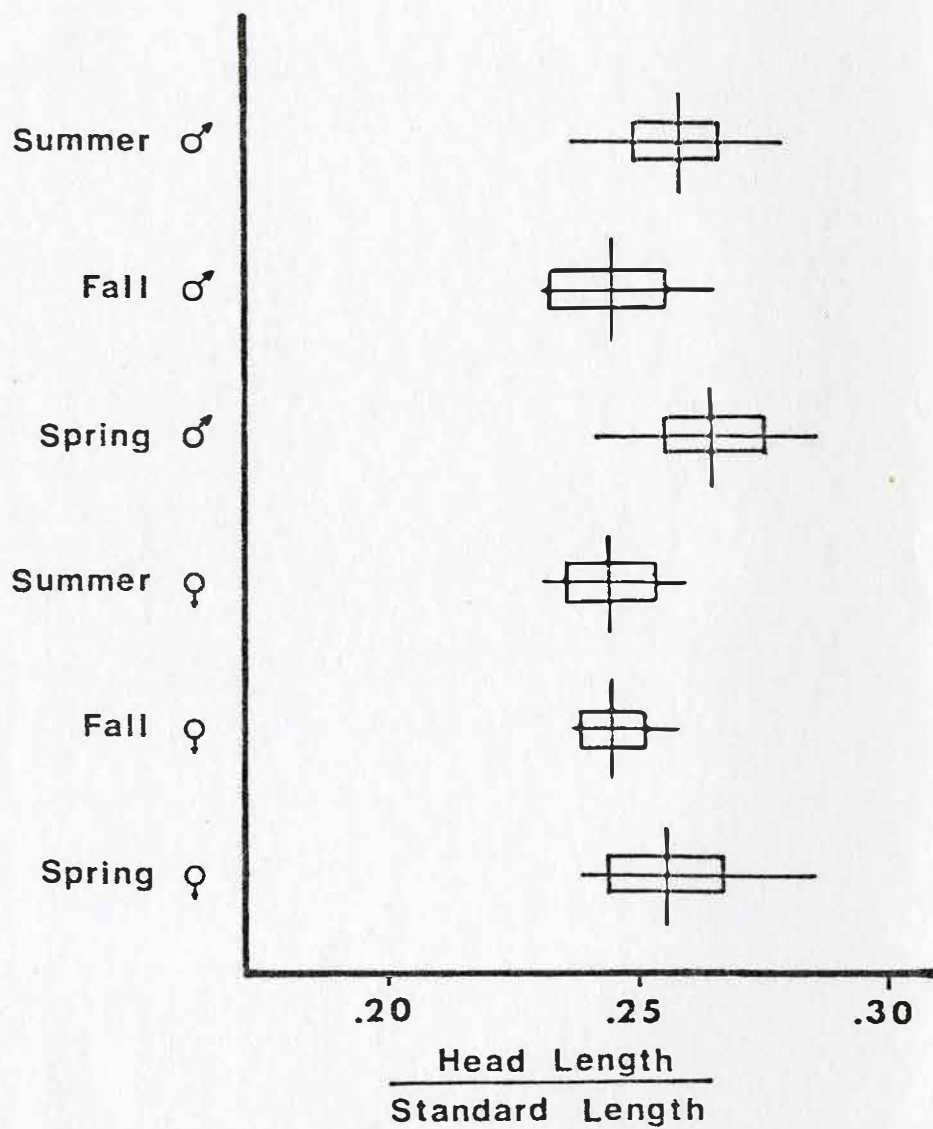


Fig. 15. Ratios of head width (across the cheeks) to head length for groups of male and female Noturus leptacanthus collected before (spring), during (summer), and after (fall) the 1976 spawning season. Vertical lines are means, horizontal lines are ranges, and rectangles one standard deviation to either side of the means.

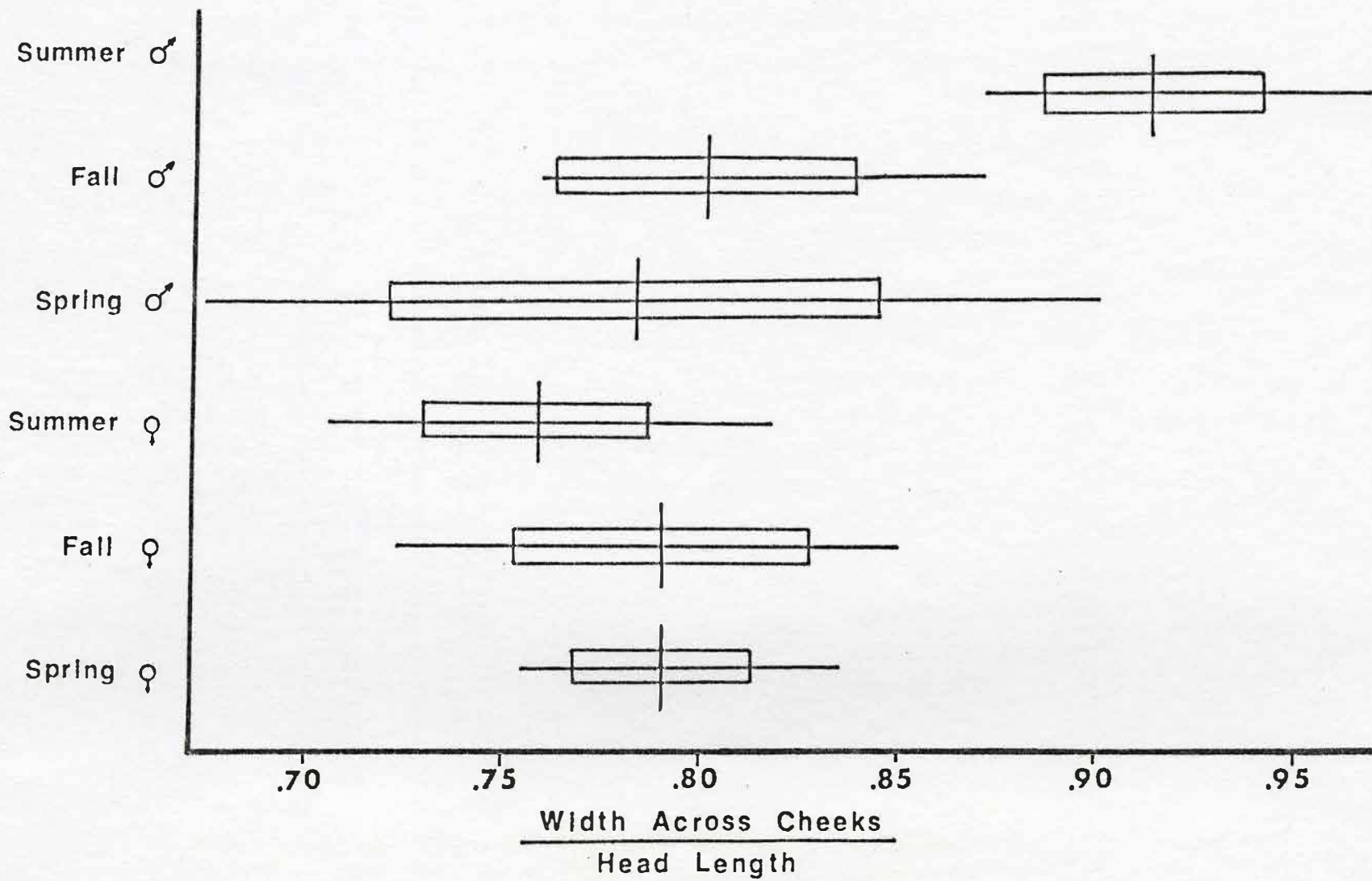
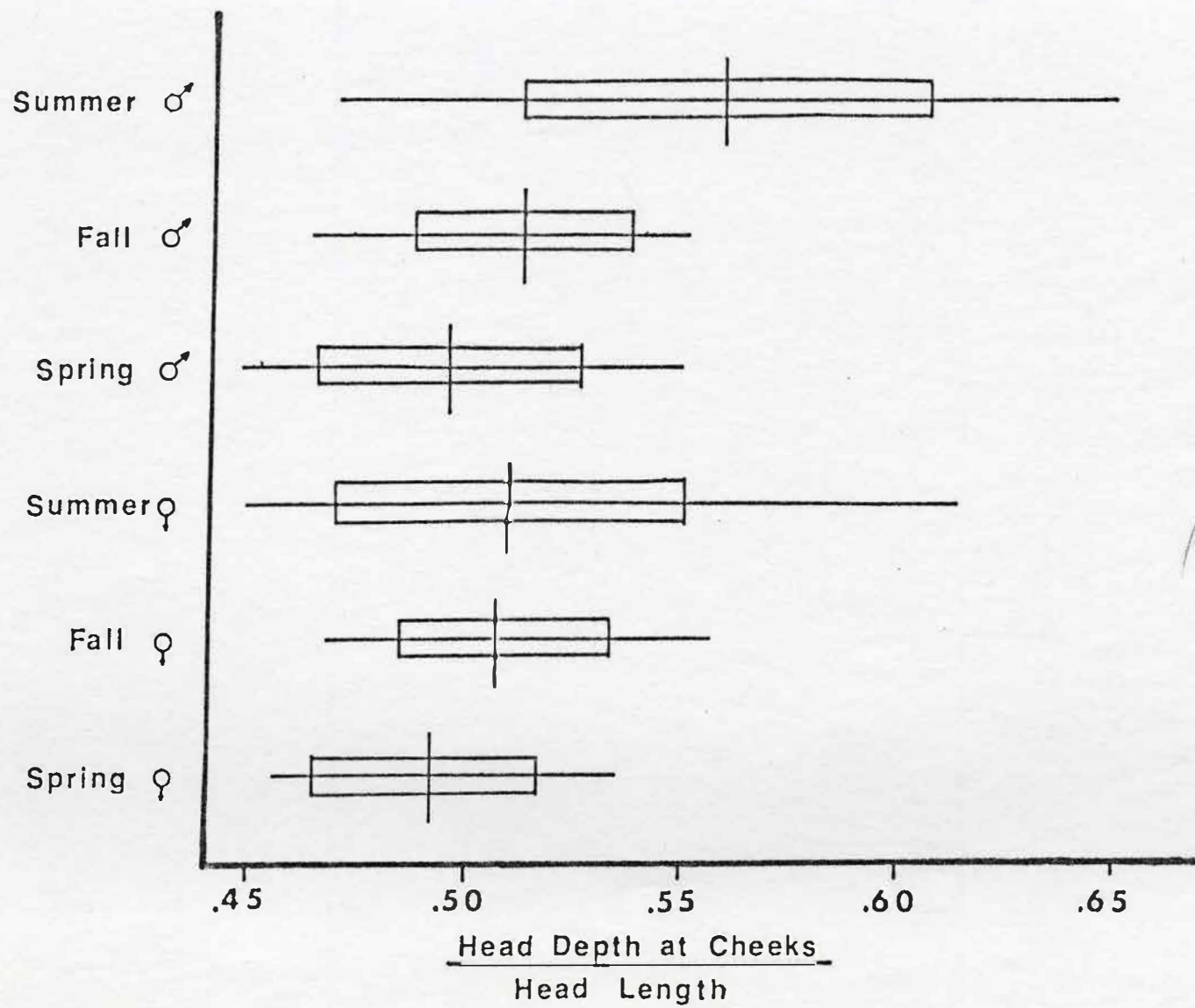


Fig. 16. Ratios of head depth (at the cheek) to head length for groups of male and female Noturus leptacanthus collected before (spring), during (summer), and after (fall) the 1976 spawning season. Vertical lines are means, horizontal lines are ranges, and rectangles are one standard deviation to either side of the means.





males and at the opercles in the other groups.

Spawning males differed significantly ( $F = 10.81$ ; 2, 68 df;  $p < 0.05$ ) from all other groups in the ratio of inter-orbital width to head length (Fig. 17). No other significant differences between groups for this ratio were found.

#### Reproduction and Larval Development

Noturus leptacanthus produced a small number of large eggs. During the fall and winter months of 1976, females contained the greatest number of eggs, the peak occurring in November ( $\bar{x} = 338$ ). Throughout the late winter and spring, the number of eggs declined steadily and reached a low in June ( $\bar{x} = 57$ ) just prior to the beginning of the spawning period (Fig. 18).

While the number of eggs decreased as spawning approached, the mean gonadosomatic index (GSI) increased, averaging less than 0.01 through the fall and winter and reaching a peak (0.10) in June (Fig. 18). The mean GSI for 11 females judged to be ripe or very nearly so was 0.13. The maximum GSI was 0.22 for a small female (SL = 33.0 mm) carrying a relatively large number of ripe eggs (21).

The GSI increased despite the great reduction in total egg number due to the greatly increasing size of individual eggs (Fig. 19). During the fall and winter, when the GSI was low, the ovaries contained nucleated eggs averaging about 0.7 mm in diameter. By March of 1976, females contained some yolked eggs. As these matured, there were

Fig. 17. Interorbital width to head length ratios for groups of male and female Noturus leptacanthus collected before (spring), during (summer), and after (fall) the 1976 spawning season. Vertical lines are means, horizontal lines are ranges, and rectangles are one standard deviation to either side of the means.

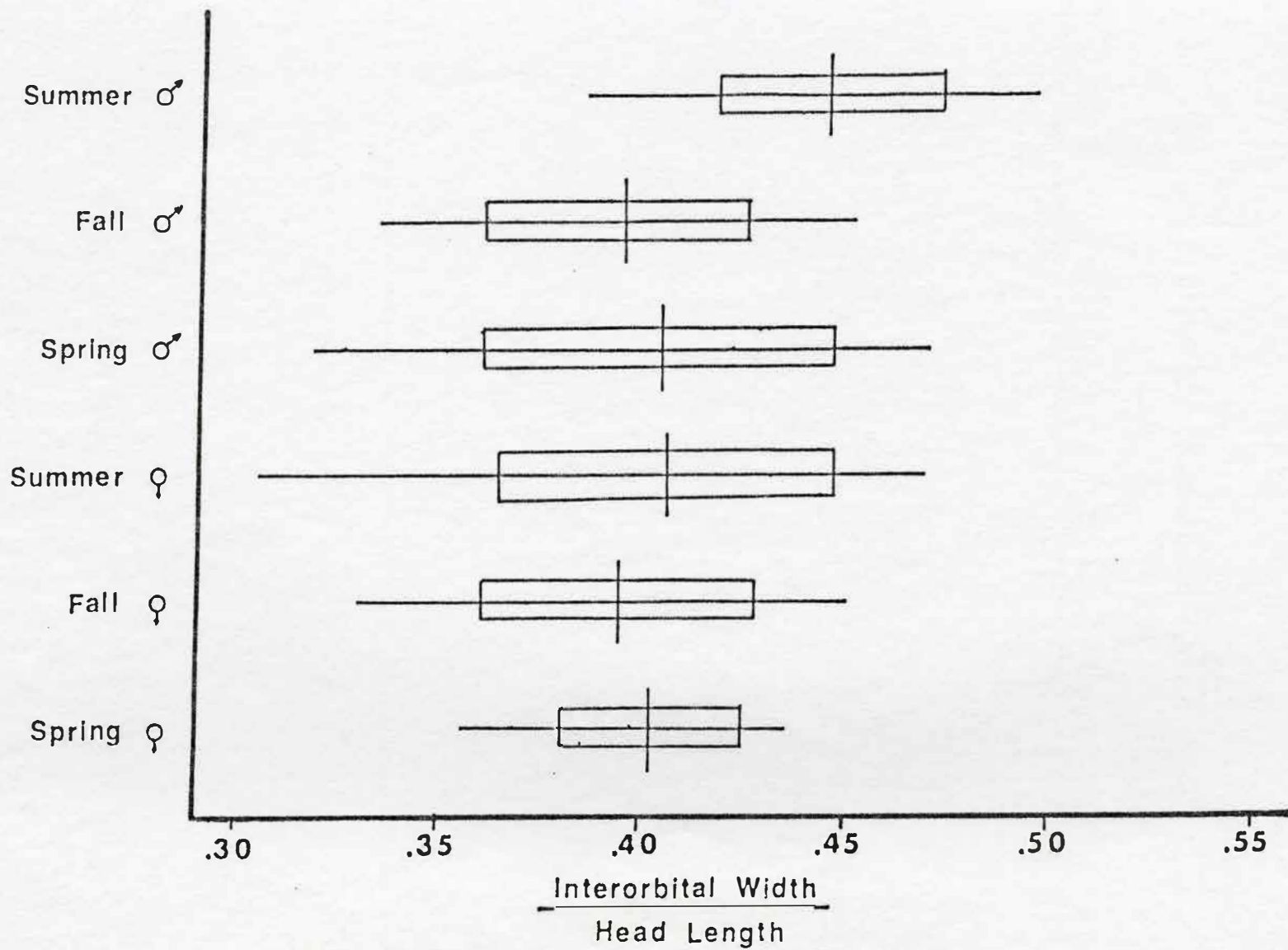




Fig. 18. Mean monthly gonadosomatic index (GSI) (dotted line), maximum monthly GSI (solid line), and mean monthly egg number (dashed line) of female Noturus leptacanthus during 1976.

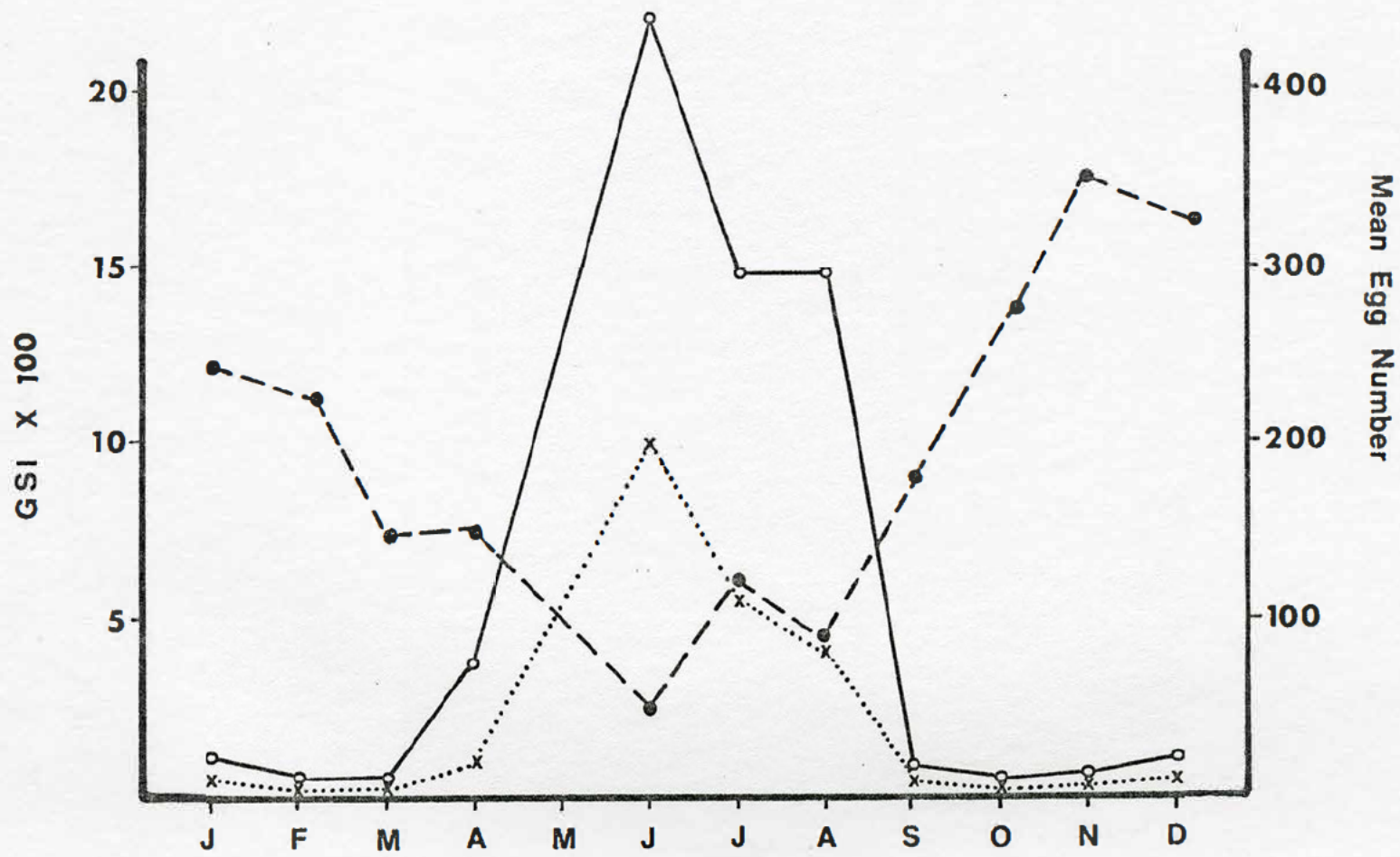
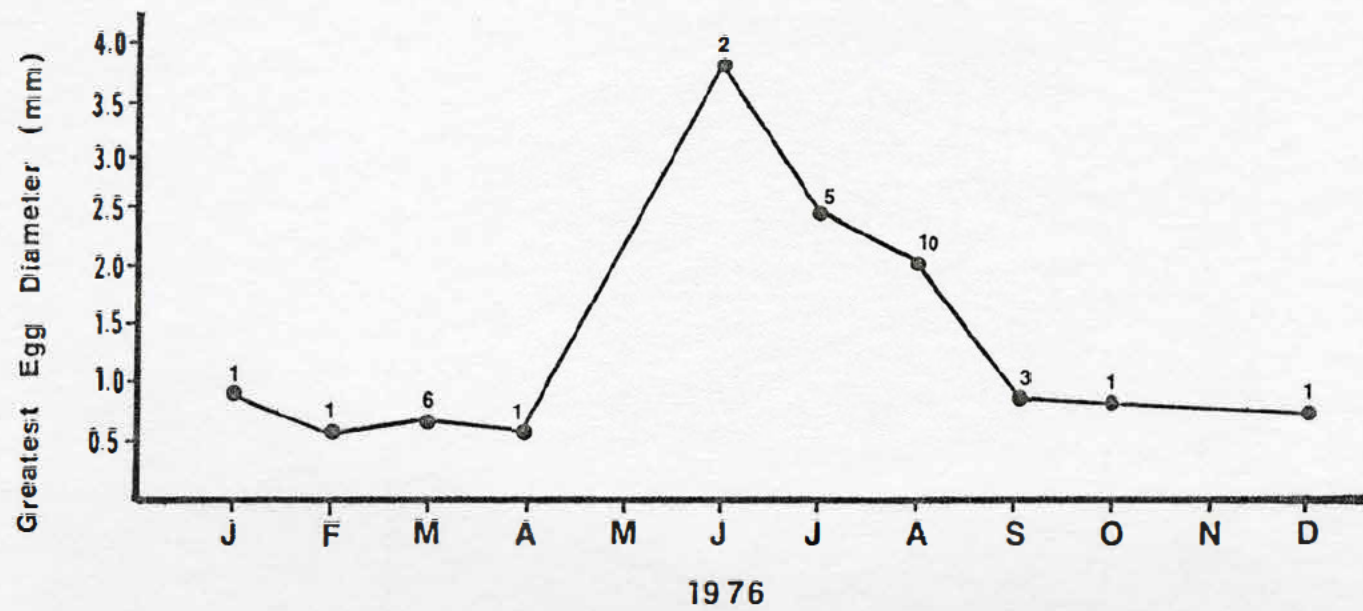


Fig. 19. Greatest egg diameters of Noturus leptacanthus by month during 1976. The sample size is indicated next to each point. Where more than one fish is indicated, the points are means.



two distinct size classes which persisted until spawning time. The two classes appeared to constitute two separate clutches of eggs. Ripe individuals contained 14-45 ( $\bar{x}$  24.1) large (2.9-4.3 mm), translucent, pale yellow eggs and a like number of smaller (0.7-1.5 mm), opaque, white eggs. The data in Figure 20 were compiled from four ripe females in which all eggs were measured. Three of these animals contained two size classes of eggs while the fourth contained, in addition, a third class of very small eggs (those three OMU's or less in diameter).

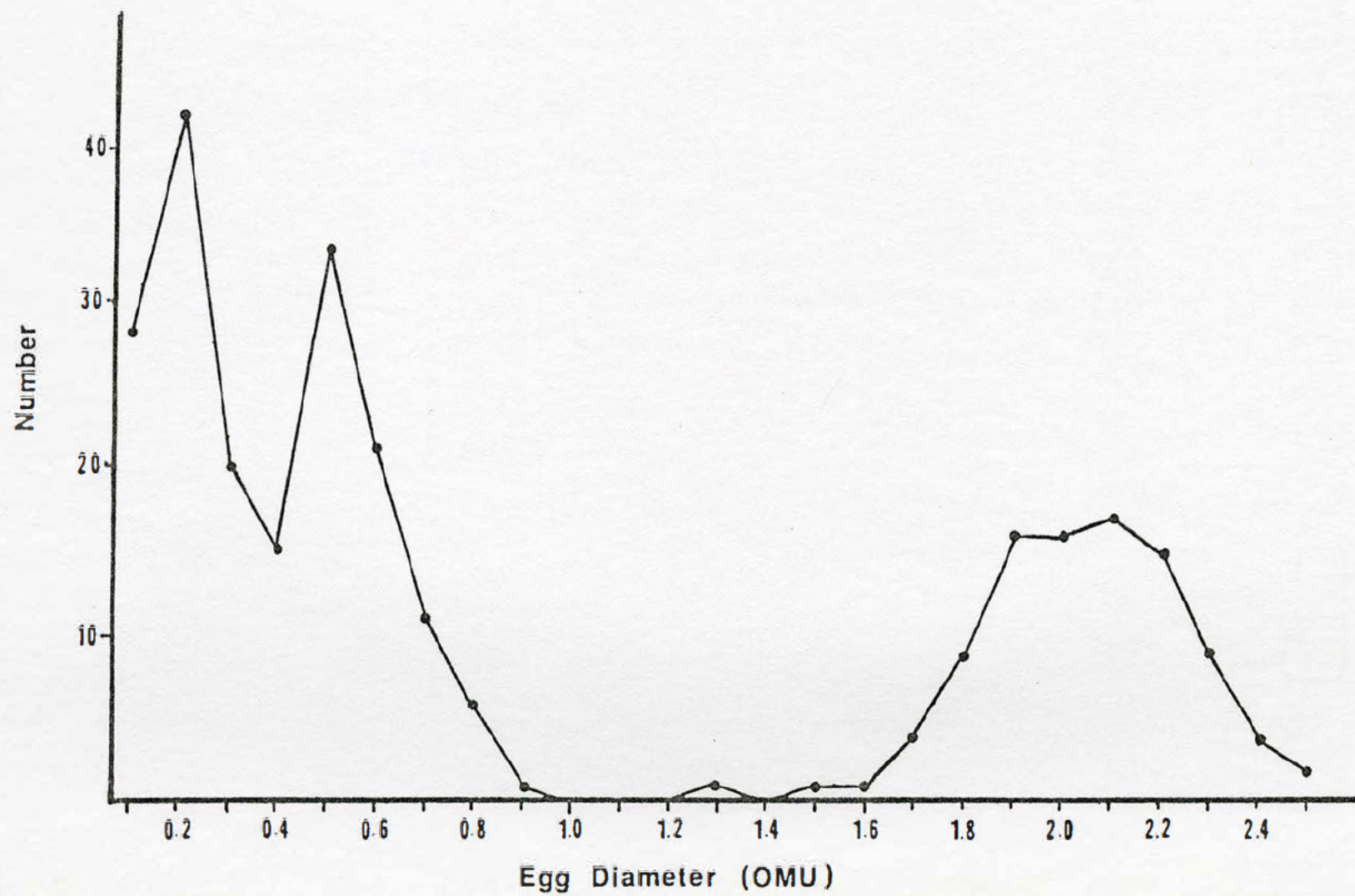
Although prespawning fish contained what appeared to be two clutches of eggs, I found no evidence of two spawnings in 1976. Spent individuals collected from July to September still contained the group of white, yolky eggs. These were evidently resorbed during the late summer and fall, as in no instance did I collect fish during this period with a single clutch of ripe eggs. Production of new eggs began shortly after (or perhaps even prior to) spawning, such that animals collected in the late summer contained nucleated eggs as well as the remains of the second (abortive?) clutch.

In 1976, *N. leptacanthus* did not ripen until the end of June, but in 1977 I collected nearly ripe animals in mid-April, suggesting spawning during May. Only the largest fish (those probably 2 years old) were ripe. These animals also contained a second clutch of small but yolky eggs. It



Fig. 20. Distribution of egg sizes (in ocular micrometer units) compiled from four ripe Noturus leptacanthus.

1 OMU = 1.7 mm.



is possible that spawning was for some reason delayed in 1976, allowing time for the production of only a single clutch, and that the time of spawning indicated by the early 1977 collections is more typical of N. leptacanthus.

There was a positive correlation between standard length and clutch size (Fig. 21). The data are plotted as the reciprocal of clutch size versus standard length as suggested by Sokal and Rohlf (1969). It was sometimes possible to determine the size of a clutch produced by a spent female by counting the number of empty ovarian follicles present. These data were not used in establishing the relationship between length and egg number except in one case in which the number of ruptured follicles corresponded with the number of eggs in the spawned clutch.

For comparison, I also counted the ripe ovarian eggs in 17 specimens of N. gyrinus and 3 N. funebris. The clutch size data for these species and for N. leptacanthus are summarized in Table 6, which also includes data from one unripe N. funebris in which a developing clutch was distinguishable and in which one quarter of the total egg mass was counted. I never collected N. nocturnus with ripe eggs, but judged by the appearance of immature ovaries its fecundity was similar to that of N. gyrinus which averaged 60.5 eggs per ripe clutch. N. funebris contained a mean of 111.3 eggs per clutch. Ripe egg sizes in N. leptacanthus were similar to those of N. gyrinus and N. funebris (Table 6).

Fig. 21. Regression of the reciprocal of clutch size versus standard length for 31 ripe or nearly ripe Noturus leptacanthus. Numbers beside points indicate two coincident data items.

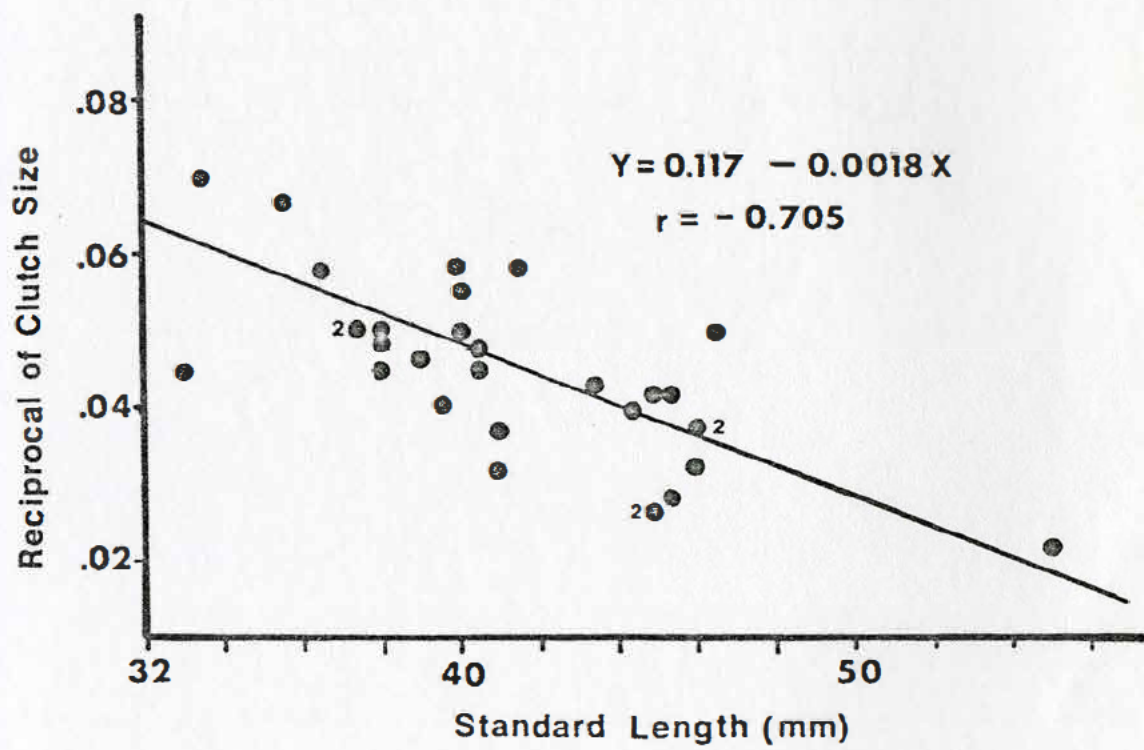




TABLE 6. Clutch Size and Mature Egg Size of Noturus leptacanthus, N. gyrinus, and N. funebris

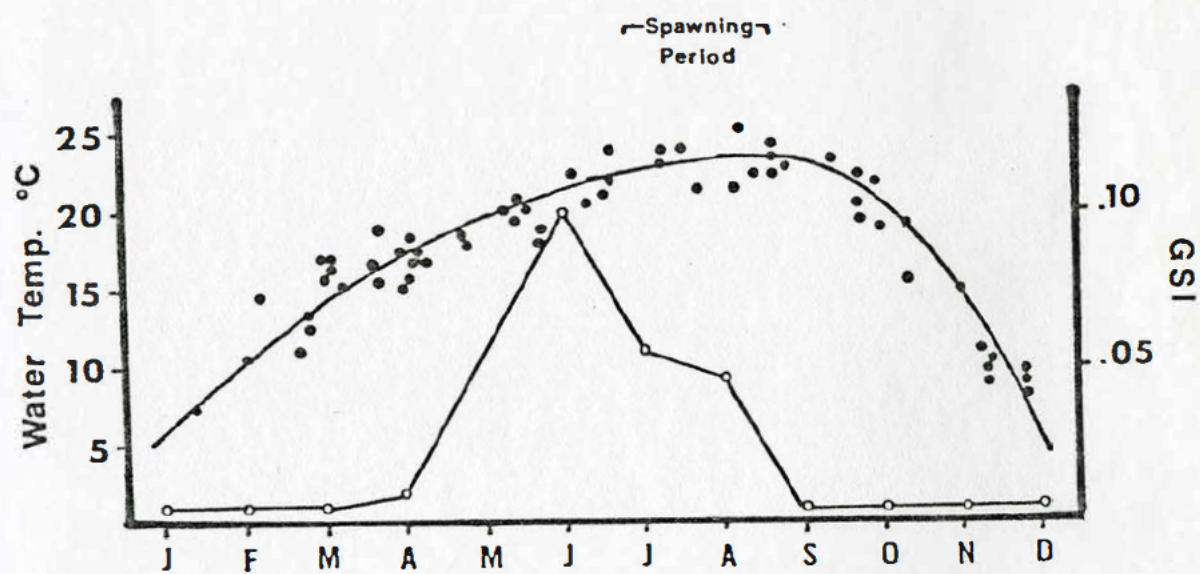
Species	<u>N</u>	Mean and (Range)		<u>N</u> Eggs ( <u>N</u> Fish)	Mean and (Range) Mature Egg Size (mm)
		SL (mm)	Clutch Size		
<u>N. leptacanthus</u>	31	41.5 (33.0 - 55.0)	24.1 (14 - 45)	93 (4)	3.6 (2.9 - 4.3)
<u>N. gyrinus</u>	17	65.0 (50.5 - 76.0)	60.5 (28 - 107)	30 (2)	3.7 (3.1 - 3.9)
<u>N. funebris</u>	4	85.4 (73.5 - 97.5)	111.3 (67 - 170)	30 (2)	3.4 (3.1 - 4.1)

In 1976 N. leptacanthus spawned during July and August. This period coincided with peak water temperatures (ca. 24°C) in the Black Creek system (Fig. 22). As mentioned above, some speckled madtoms appeared nearly ripe during April 1977 when the recorded water temperatures were 17-20°C, corresponding closely to those of April 1976. Thus, the relationship between breeding activity and water temperature in 1976 may be coincidental.

I was unable to observe courtship, spawning or nesting activities, as all the pairs of N. leptacanthus that I installed in aquaria failed to breed. Observations on reproductive habits are therefore based on seven collections of ripe males which had apparently established nest sites, four collections of mated pairs found in the same nest container prior to spawning, and ten collections of guardian males with offspring (eggs or larvae).

The nests I found were in old, submerged cans or bottles, generally in areas of slight to moderate current (0-35 cm/s,  $\bar{x}$  = 19 cm/s), with the mouths usually facing downstream or perpendicular to the current (10 out of 12). Such containers were used by N. leptacanthus as hiding places throughout the year, but occupancy rates seemed higher during the breeding season, although no data were kept on percentage habitation. Cans and bottles were used by small N. gyrinus, N. funebris, and N. nocturnus, but the adults of these species were generally too large to utilize

Fig. 22. Water temperatures in the Black Creek system (closed circles) and mean monthly gonadosomatic index (open circles) during 1976. The known spawning period coincided with peak water temperature.



ordinary beer and soft drink containers which were most abundant in the Black Creek system. One N. funebris nest was found in a quart oil can. Two N. gyrinus nests were found in cans and one in a wide-mouth quart jar. I found no N. nocturnus nests. Using a mask and snorkel, I was unsuccessful in finding nests in more "natural" situations (under logs, in vegetation).

Nest containers were invariably empty of sand, gravel, and litter. Inhabited containers during the non-spawning portion of the year were frequently packed with such materials, so that nest site preparation likely involves the removal of debris by one or both parents. Two facts suggest that it is the male which cleans the nest. First, the low proportion of males caught in seine collections during June 1976, the month prior to the initiation of spawning, suggests that males were engaged in some activity which reduced their susceptibility to seine capture. A similar phenomenon was noted in April 1977 trap collections in which ripe female N. gyrinus outnumbered ripe males by a ratio of 17 to 6. Secondly, on seven occasions I encountered apparently ripe male Noturus leptacanthus with well-developed head musculature alone in empty, cleared nest containers. These were presumably fish which had prepared nests but had not yet secured mates.

The two members of a pair inhabit the same container for at least a short while before spawning. I collected



four such cohabiting pairs and installed them in aquaria, however they failed to breed. Outside of the spawning season, I never found two fish inhabiting the same container.

The number of offspring ranged from 13 to 25 ( $\bar{x} = 17.6$ ,  $N = 8$ ) in field collected clutches, thus falling somewhat short of the mean clutch size observed in ripening females, perhaps as a result of egg and larval mortality. The other two clutches I collected consisted of males with only two well-developed larvae each; these were not included in the above average as presumably some of the larvae had already left the nest.

Six eggs (from three different clutches) averaged 5.5 mm in diameter and their yolks, 3.8 mm in diameter. The eggs adhered to each other in an irregular mass, and this was stuck, at one or two points, to the inside of the container. The egg masses were apparently attached to the bottom of the container.

Clutches of eggs and larvae were guarded by the male parent; on only one occasion were both parents found in attendance of a clutch spawned the preceding night. Apparently, if females assumed nest guarding duties it was only for a short while.

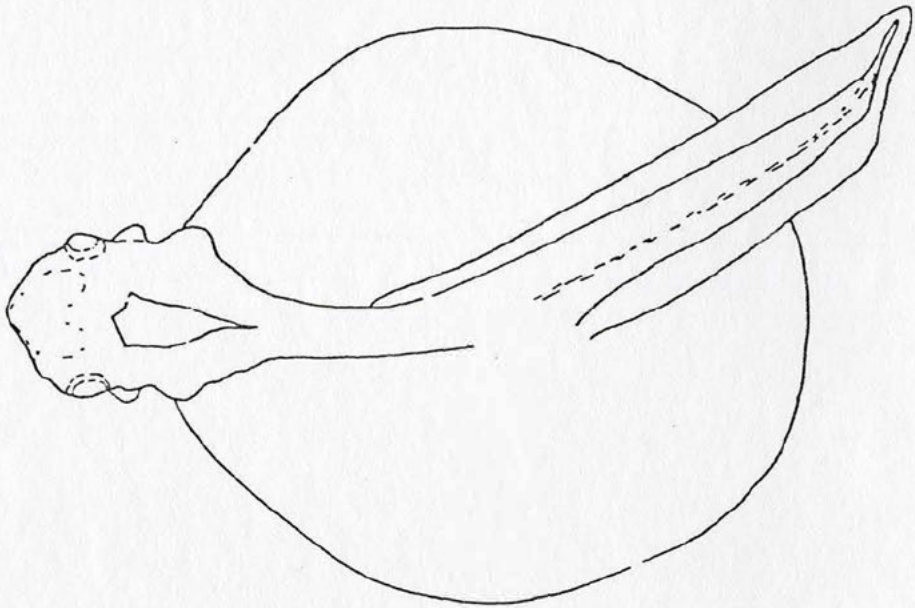
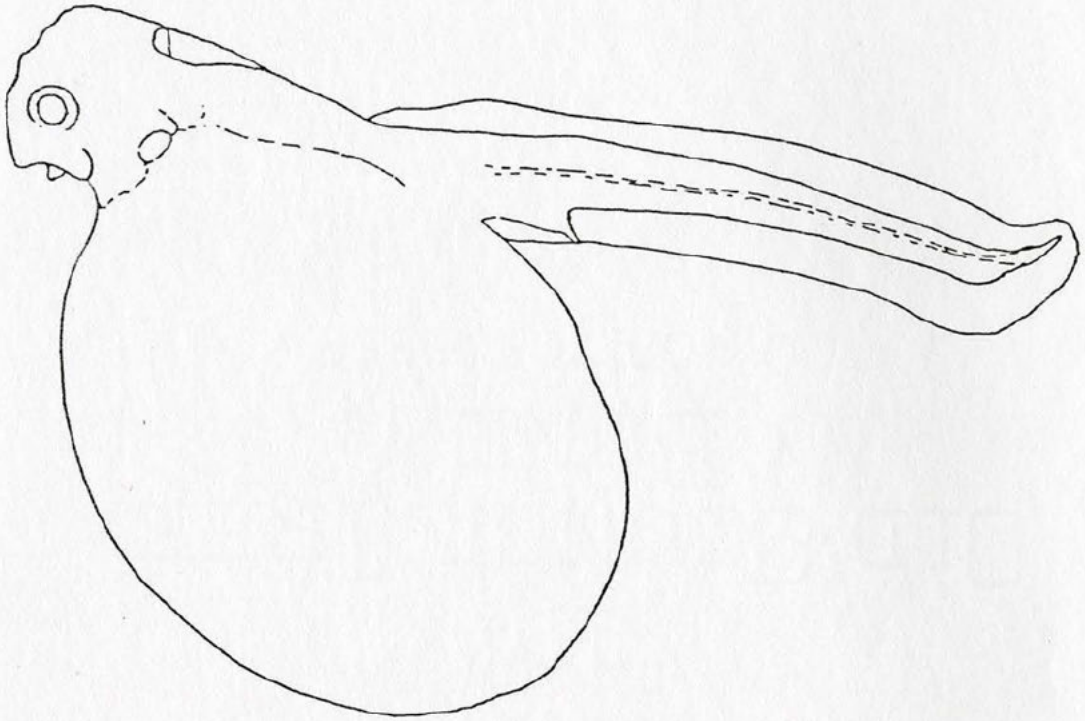
Guardian males were always reluctant to abandon their nests. Nonbrooding madtoms hastily left containers as the water was dumped out, but brooding males were

dislodged only with difficulty. This behavior was so characteristic that I could generally tell immediately whether eggs or larvae were present before actually seeing them.

The entire guts of nesting males were always empty. Since madtoms generally contained food remains in the digestive tract, apparently nesting males did not feed. The food intake of females was also seemingly limited during the spawning period. In trap collections made during two floods in April 1977, many madtoms were found with stomachs greatly distended with food. However, ripe females of N. leptacanthus, N. gyrinus, and N. funebris contained only small volumes of food. The volume of eggs they contained perhaps precluded the consumption of larger meals.

I brought three guardian males and their brood to the lab, but in each case the male consumed the eggs. However, four collections of N. leptacanthus eggs and larvae were successfully reared without a parent. Since the actual age of egg clutches at the time of collection was unknown, the time between spawning and hatching could only be estimated. All members of one clutch, apparently spawned the night preceding collection, succumbed to fungal infection. Some of these eggs survived 4 days, however, and their appearance was used to estimate the ages of other clutches. At about 24°C, the developmental period was estimated to be 7 days. Figure 23 shows an embryo 4 days before hatching and believed to be 3 to 4 days old. In

Fig. 23. Noturus leptacanthus embryo 4 days prior to hatching (chorion removed from egg).



4 mm



all cases the eggs hatched during the night or early morning.

Data on larval development are summarized in Table 7, and were taken from individuals of three clutches. Representative larvae are pictured in Figures 24 to 30.

The hatchlings were unpigmented and about 7.5 mm in total length (Fig. 24). They were well developed and in many respects resembled the adult fish. For the first few days they remained inactive and clustered together, their tails constantly beating, presumably to circulate the water. The pectoral fins were held vertically, closely appressed to the sides of the body, and did not assume the horizontal adult position until about the eighth day after hatching. The pectoral and dorsal fin spines were evident by the fourth day (Fig. 26), but did not harden until the larvae were 10 days old or more (Figs. 29 and 30).

At hatching, the median fins were well developed as compared to the paired fins. Rudimentary soft-rays were present in the dorsal fins of 1-day-old fish, and their development was completed by the fourth day. The anal fin reached its full complement of rays by the sixth to seventh day (Fig. 27). Eighteen to twenty simple caudal rays were present at hatching. At the end of 2 weeks, this number had doubled, but only one individual possessed any branched rays (and it only one). Mature N. leptacanthus have 46-58 total caudal rays, with an average of 16.7 branched rays (Taylor



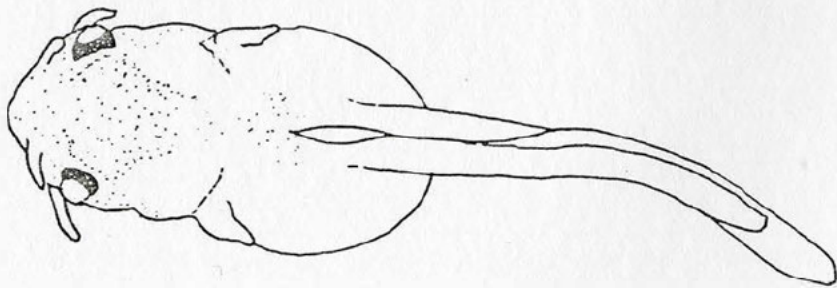
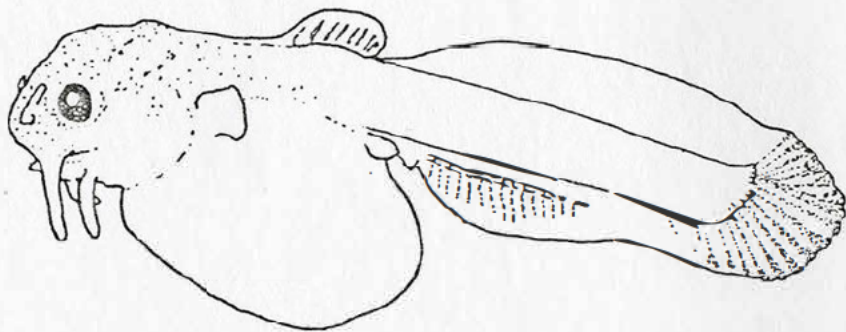
TABLE 7. Larval Development of Noturus leptacanthus

Age in Days	<u>N</u>	Pectoral Rays	Pelvic Rays	Dorsal Rays	Anal Rays	Caudal Rays	Total Length (mm)
1	3	0,4,0	0,0,0	7,0,6	14,13,10	18,21,20	7.1,7.7,7.0
2	2	6, -	0,0	7,6	16,12	25,22	7.8,7.8
3	3	3,5,7	0,0,0	6,7,6	14,14,14	21,24,25	8.0,9.4,8.7
4	2	6,7	0,0	7,7	16,14	25,25	9.2,9.2
5	3	6,7,8	4,6,0	7,7,7	15,16,17	25,30,31	9.2,10.2,10.5
6	2	7,8	7,7	6,7	17,17	28,32	10.5,10.9
7	3	7,8,8	7,8,8	6,7,7	17,17,17	31,33,35	10.5,11.6,11.4
8	1	7	7	7	17	31	10.5
9	3	8,8,8	8,8,8	7,7,7	17,17,16	35,36,39	11.2,11.9,11.9
10	1	8	8	7	17	36	11.9
11	3	8,8,8	8,8,8	7,7,7	17,17,17	35,37,40	11.9,12.6,13.6
12	1	8,9	8	7	18	39	12.2
13	3	8,8,8	8,8,8	7,7,7	17,17,16	39,37,40	12.8,12.8,13.6

TABLE 7--Continued

Age in Days	<u>N</u>	Pectoral Rays	Pelvic Rays	Dorsal Rays	Anal Rays	Caudal Rays	Total Length (mm)
14	1	8	8	7	17	39	12.2
15	3	8,8,8	8,8,8	7,7,7	17,17,17	36,40,40	11.9,12.8,13.9
17	2	8,8	7,8	7,7	17,16	42,42	13.6,13.8

Fig. 24. One-day-old Noturus leptacanthus larva (within 12 hours of hatching).

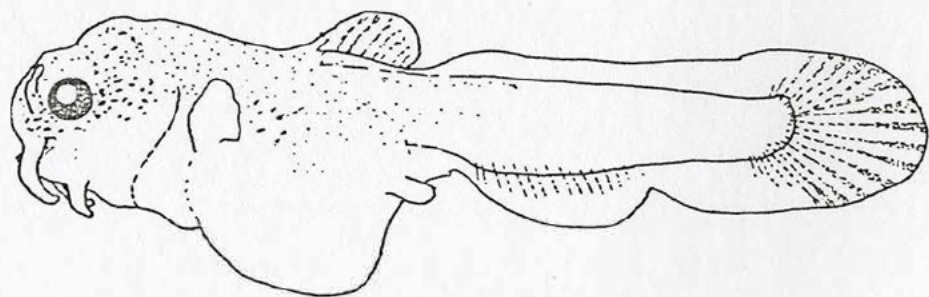
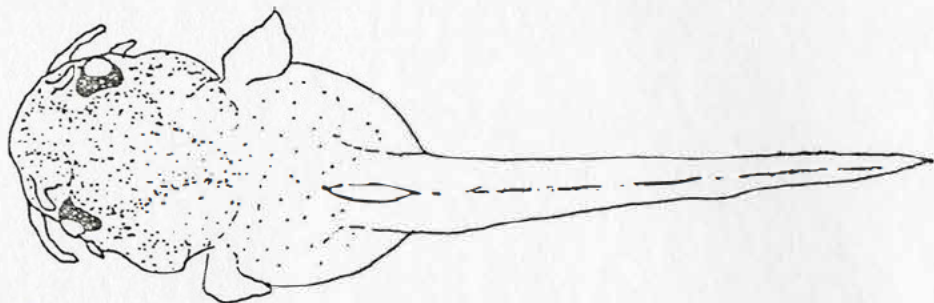


5mm



Fig. 25. Three-day-old Noturus leptacanthus larva.

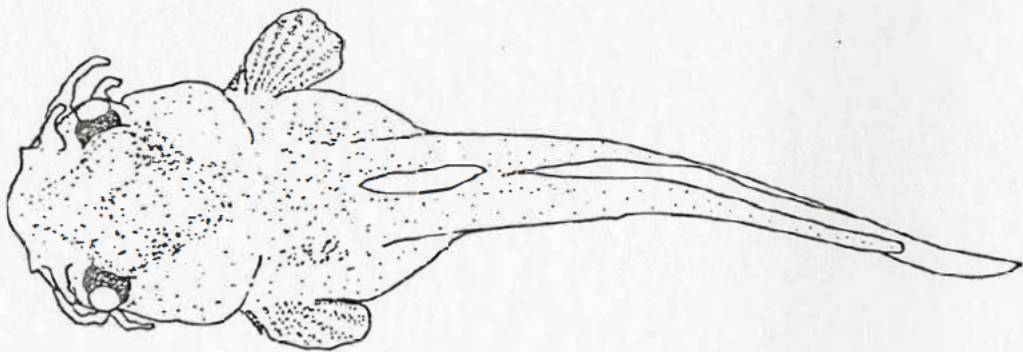
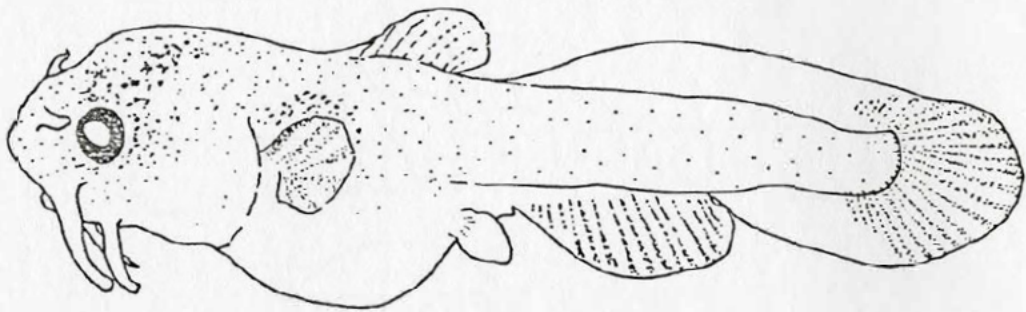




5 mm

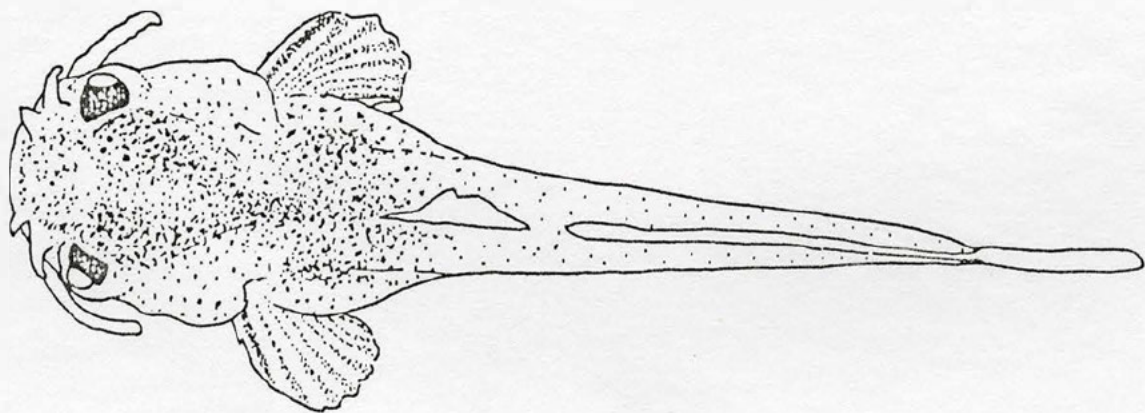
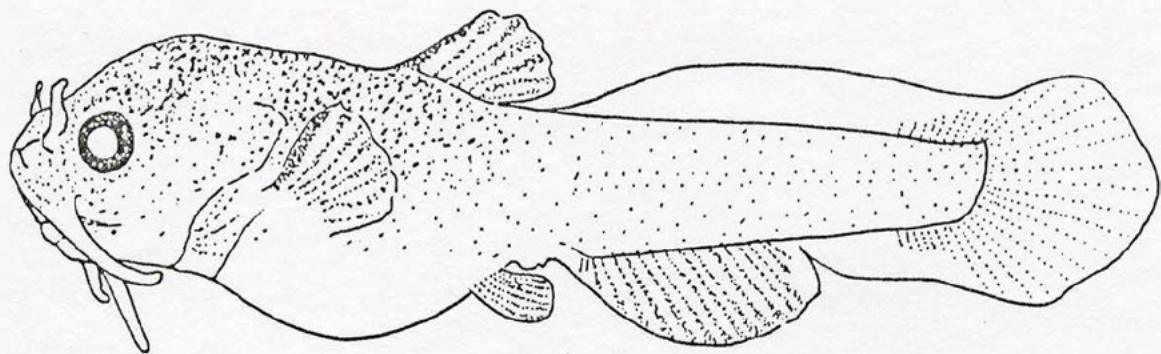


Fig. 26. Four-day-old Noturus leptacanthus larva.



5 mm

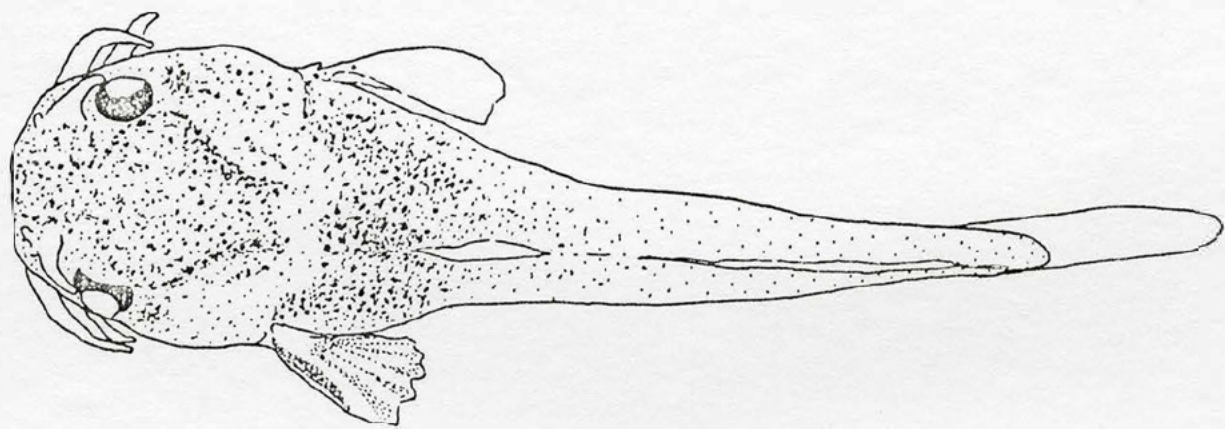
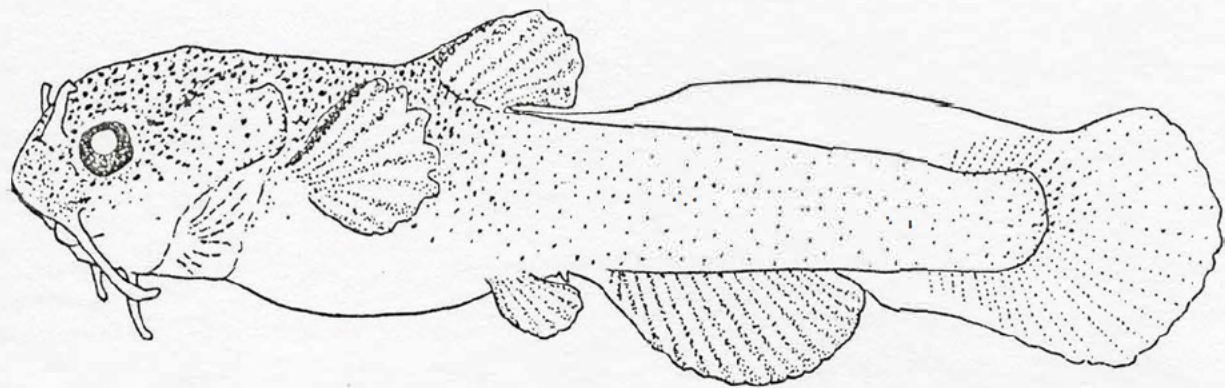
Fig. 27. Seven-day-old Noturus leptacanthus larva.



5 mm

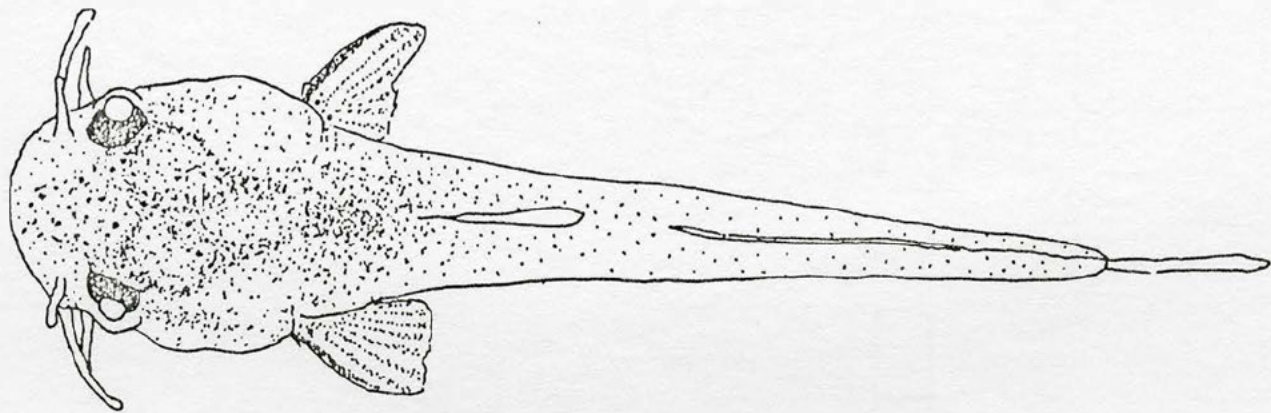
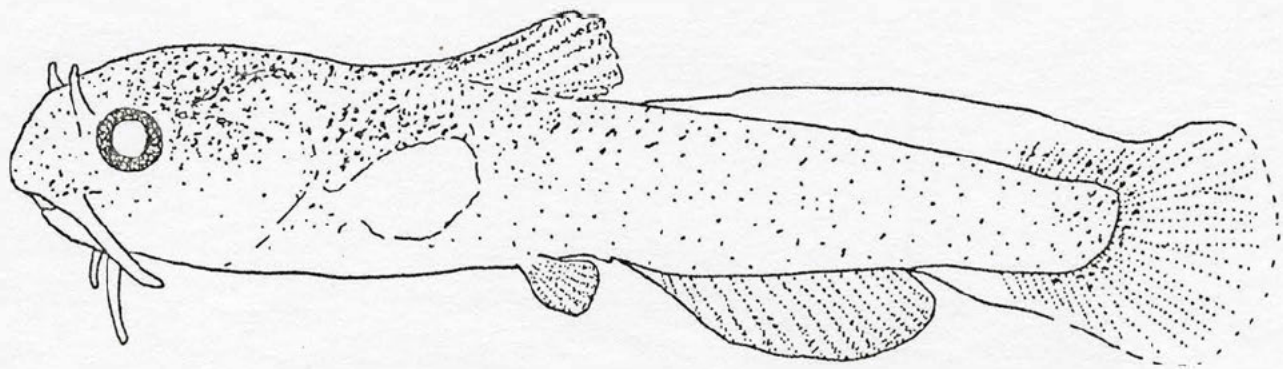


Fig. 28. Nine-day-old Noturus leptacanthus larva.



5 mm

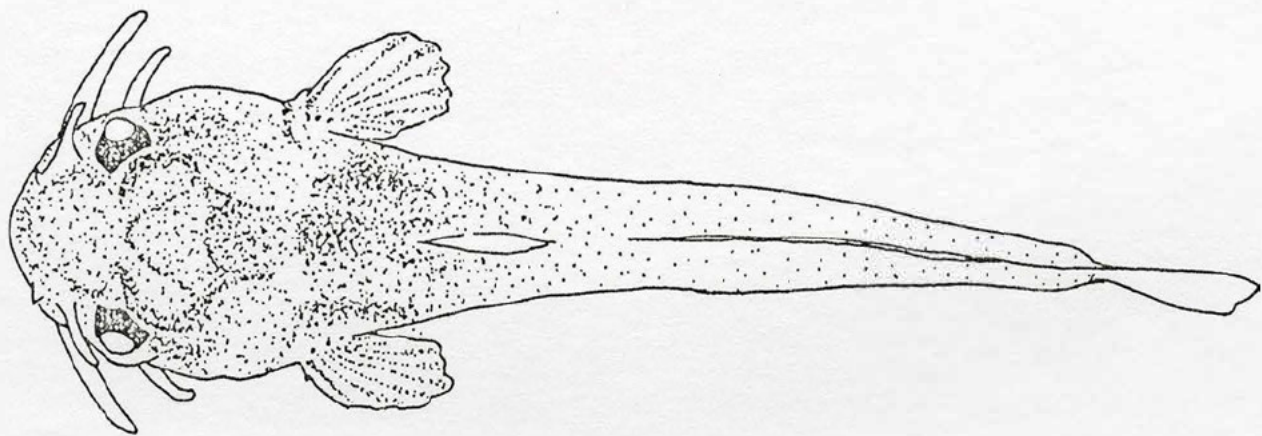
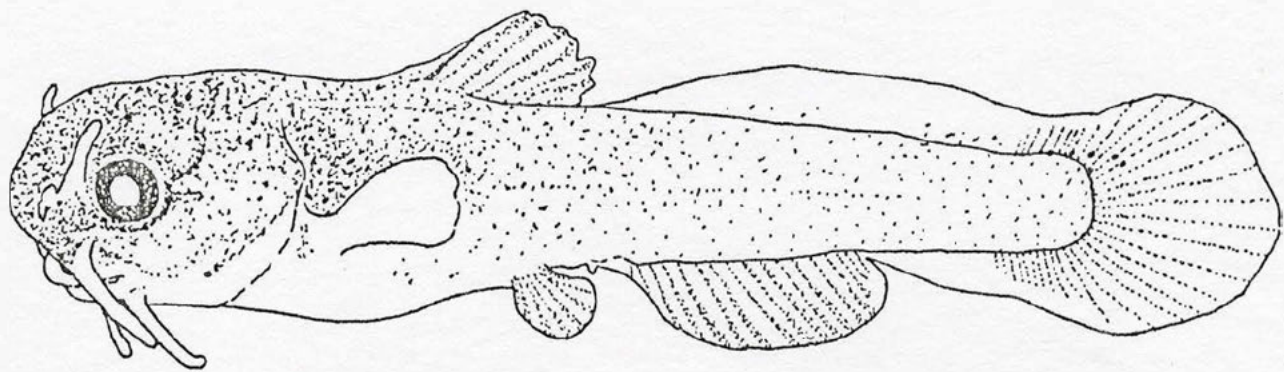
Fig. 29. Ten-day-old Noturus leptacanthus larva.



5 mm

Fig. 30. Eleven-day-old Noturus leptacanthus larva.





5 mm

1969), thus full caudal development is evidently not achieved until considerably after the young leave the nest. Ray primordia were distinguishable at hatching in the pectoral fins, and all soft-rays were developed by 8 days (Fig. 27). The pelvic fins developed more slowly, no rays were countable until the fifth day after hatching, and by 9 days the complement of pelvic rays was complete (Fig. 28).

I began introducing food when the larvae were 7 days old, but there was no evidence of actual feeding until they were 10 days old. At this time the larvae were about 12 mm in total length and the yolk sacs completely absorbed. Apparently, they left the nest at that time. The smallest seine collected larvae were 13 mm in standard length. Juveniles of this age closely resembled the adults in body proportions and pigmentation and were distinguishable from the juveniles of N. gyrinus, N. funebris, and N. nocturnus.

The spawning times of the four Noturus species in Black Creek apparently overlapped considerably during 1976, but there was some evidence that N. leptacanthus began spawning later than two of the other species. My first seine collection of young of the year speckled madtoms was on July 26, while juvenile N. gyrinus and N. funebris were first collected on June 4 and June 16, respectively. I found young N. nocturnus only once, on July 30.

## V. DISCUSSION

### Ecology

Noturus leptacanthus is common in small to moderate sized streams and is typically a creek species (Taylor 1969). Cook (1959) reported the species from sand, gravel, and clay bottomed streams in Mississippi, and my own collections corroborate this. The presence of adequate cover, particularly during the breeding season, is probably important in limiting populations of speckled madtoms. Aquatic vegetation is the most frequently used cover type, at least where it is available. Using discriminant analysis, Ross, Baker, and Clark (unpublished) found N. leptacanthus to load heavily on a factor involving fast current and shallow depth and also on a factor involving low drainage area. This combination of habitat characters is apparently conducive to the growth of certain aquatic plants (e.g., Sparganium americanum and Potamogeton diversifolius). The reduction of aquatic vegetation in the deeper, slower, and more turbid larger streams may curtail the distribution of N. leptacanthus.

Speckled madtoms often inhabit very shallow riffles. They are perhaps more tolerant of high light intensities than are some other ictalurids. Breder (1939) suggested



that the proclivity of brown bullheads for hiding and nesting in cavities or beneath sheltering objects was a negative reaction to light rather than to predation pressure. He was unable to hatch Ictalurus nebulosus eggs except in the dark. In this study, Noturus leptacanthus eggs hatched readily in a well-lit room. The distinctive brown coloration of N. leptacanthus may represent an adaptation to its relatively well-lit environment.

Speckled madtoms are clearly nocturnal feeders. They presumably detect food with their sensory barbels as do other ictalurids (Alexander 1965), and vision almost certainly plays little part in their foraging behavior. Baur (1970) reported that the stomachs of laboratory reared black bullheads (Ictalurus melas) were empty of food 12 hours after a meal, but that digestion was slower in fish occurring naturally in a lake. I observed a similar interval between maximum and minimum stomach fullness in N. leptacanthus. Curd (1960) discussed the food habits of N. exilis in Oklahoma. He found the ration to consist principally of aquatic insect larvae and crustaceans, with no items of terrestrial origin.

Madtoms, as other ictalurids, are protected to some degree by the possession of venomous pectoral and dorsal spines. The effectiveness of the spines as a defense is increased by the ability of the fish to lock them in an erect position, thereby increasing the animal's diameter and

the difficulty with which it might be swallowed or removed from shelter. Forbes and Richardson (1920) noted that catfishes are seldom found in the guts of predatory fishes. Madtoms must not be entirely unpalatable, however, as both Taylor (1969) and Rubec and Coad (1974) mentioned their use as bait by fishermen.

Members of the genera Ictalurus and Noturus possess axillary glands which produce an irritant poison (Reed 1907). However, Birkhead (1967, 1972) suggested that the integumentary tissues surrounding the spines are the most important source of venom. In bioassay studies using Gambusia affinis, Birkhead (1967, 1972) tested the venom of several ictalurids and found the species highly variable in toxicity. He considered N. leptacanthus nontoxic (to Gambusia). Birkhead (1972) suggested that the most venomous ictalurids might be those inhabiting lentic environments where they are subject to predation by large piscivorous fishes.

The predators of Noturus species have not been recorded except for a note (Viosca 1936) of the presence of one small speckled madtom in the gut of a rock bass, Ambloplites ariommus (= A. rupestris ariommus). My preliminary data indicate that larger Noturus species may be important predators of speckled madtoms. Nocturnally active fishes, including A. rupestris (Pflieger 1975) and Noturus species, are the most likely predators of N. leptacanthus. The association of rock bass with aquatic vegetation



increases the likelihood of encounters with speckled madtoms.

Noturus leptacanthus in Black Creek likely encounter their severest competition from other members of the same genus. Bullheads (Ictalurus), including juveniles presumably susceptible to the fishing methods employed in this study, were very seldom captured in the upper Black Creek system. Based on night trap collections, Noturus species were the predominate nocturnal, benthic feeders in the study area. The nocturnally feeding (Hoyt 1970; Wallace 1976) cyprinid, Ericymba buccata, was commonly collected only in the lower portion of the Black Creek system (Baker 1978). Mud puppies, Necturus beyeri, were common in night trap collections. Their food habits (Viosca 1937) may overlap those of the speckled madtom.

Potential competition for nesting space is confined to the genus Noturus, as no fishes other than madtoms seem to utilize cans and bottles in Black Creek. Noturus leptacanthus is favored in securing nest sites, since its size permits the use of containers with openings too small for the larger species. The pollution of Black Creek with beer and soft drink containers has thus perhaps favored the speckled madtom population relative to the populations of the other three species. There was slight evidence in 1976 that the spawning peak of N. leptacanthus followed those of the larger N. gyrinus and N. funebris, thereby possibly

lessening competition for nest sites and reducing competitive interactions among the juveniles of the three species.

Hybridization among madtom species is uncommon, or at least infrequently reported. Various hybrid combinations have been reported by Trautman (1948), Cross and Moore (1952), Hubbs and Lagler (1958), Taylor (1969), and Menzel and Raney (1973). Taylor reviewed most of the hybrid material in 1969. He noted that although many Noturus species are sympatric over at least parts of their ranges, hybrid records are few, and concluded that a breakdown of behavioral barriers is responsible for hybridization among madtoms, occurring where one or both parent species are uncommon and unable to find more suitable mates. Trautman (1948) considered hybrids to be a result of the breakdown of ecological barriers between species. Menzel and Raney (1973) supported this view in reporting that N. gyrinus X miurus hybrids were found in an area intermediate between the types favored for spawning by the two parent species.

The reported Noturus hybrids are all crosses between members of the subgenera Schilbeodes and Rabida. Possibly crosses within subgenera are not easily recognizable as hybrids. The four madtom species in the Black Creek drainage are all in the subgenus Schilbeodes. These four species live in close association in the system, and all four were occasionally captured together in the same trap. I found little obvious microhabitat segregation among the

species, although N. leptacanthus predominated in the shallow, well-lit riffles and runs, and N. gyrinus appeared to favor quiet backwaters. The reproductive barriers which separate the four species are unknown. Body size and spawning time may be involved in the reproductive isolation of N. leptacanthus. Speckled madtom nests were found within 1 m of the nests of N. gyrinus and N. funebris.

#### Life History

Life history tactics are complex combinations of traits, derived through natural selection, which adapt populations of organisms to prevailing environmental conditions. These traits include clutch size, size of young at birth, degree of parental care, age at first reproduction, distribution of reproductive effort over the various age classes, life span, and differential mortality (Ricklefs 1973; Stearns 1976). Theoretical considerations of the evolution of life history patterns in plants and animals have resulted in a number of (occasionally contradictory) predictions concerning the tactics likely to occur under various ecological conditions. Stearns (1976) summarized the history of ideas on this subject.

Two basic models have been advanced to explain life history strategies: the "r and K selection" approach which assumes stable levels of fecundity and mortality, and the "bet hedging" approach which attempts to deal with fluctuations of these parameters (Stearns 1976). Proponents of the



r and K selection model predict large clutch size, small young, semelparity, early reproductive age, short generation time, and no parental care under conditions of r-selection (fluctuating environment, density independent limiting factors). Where density dependent selection occurs (stable environment, K-selection), small clutches of large offspring, iteroparity, late maturation, long generation time, and parental care are predicted. The predictions of the bet hedging model depend upon the pattern of population mortality. In those situations in which environmental fluctuations most affect juvenile mortality rates, small clutches and long life span would be favored, while large clutches of short-lived organisms would prevail where fluctuations primarily affect adult mortality (Schaffer 1974).

R and K selectionists suggest that a population's level of fecundity is a consequence of selective pressures and represents an optimum value subject to temporal and individual variation. Cody (1966) concluded that organisms allocate energy to reproductive and other life functions in such a way that their fitness (in terms of genetic contribution to succeeding generations) is maximized. Lack (1954) pointed out that optimal clutch size in birds is not necessarily determined by physiological limits, but depends instead upon the capacity of the parents to provide food for the young. Since overly large broods may suffer increased mortality due to inadequate feeding, such broods may

actually produce fewer successful fledglings than smaller clutches. Lack concluded that clutch size in birds is a response to long-term prevailing food supplies. Svardson (1949) suggested that the evolution of greater fecundity in fishes is offset by the advantage of producing fewer, larger eggs and hence more robust and successful offspring. As a secondary limit to fecundity he suggested the increasing likelihood of parental mortality with increasing egg volume. Cody (1966) presented a more general theory of clutch size, suggesting that reduced fecundity is a response to stable environmental conditions and represents an evolutionary tactic tending to increase the carrying capacity ( $K$ ) of the environment by diverting energy from reproductive functions to predator avoidance and greater success in competitive interactions.

Mountford (1973) presented the alternative hypothesis that optimum clutch size is that which is least likely to result in extinction, rather than that which tends to maximize the growth of a population. Stearns (1976) termed this strategy "bet hedging" since its "goal" is to produce, under unpredictable environmental conditions, that number of offspring least likely on the average to result in complete brood failure. Mountford (1968) demonstrated that this number is less than the single most productive clutch size.

Generally, it has been held axiomatic that reduced



fecundity results from increased parental care. As Williams (1959) pointed out, however, at least among fishes, the relationship of low fecundity and parental care is often confounded with the effect of the generally small body size of egg-guarding species. In terms of relative ovary weight, he found two egg-scattering darters of the genus Etheostoma to be less fecund than two egg-guarding members of the same genus.

Comparison of the life histories of diverse organisms, or even closely related ones, is difficult. Parallels between unrelated groups must be cautiously drawn, and within taxa the effects of geography and time may obscure meaningful comparisons. For instance, a relationship between clutch or litter size and latitude appears to exist for birds and mammals (Lack 1954; Lord 1960), and variations in fecundity in birds between "good" and "bad" years have been reported several times (data summarized in Cody 1966).

Usable data on life history parameters of North American freshwater fishes are limited. Fecundities are often reported as isolated egg counts which represent standing crops of eggs (or ripe eggs) at some particular point in time. Such data are not useful for species which reproduce continuously or which mature and spawn several lots of eggs during one season. Egg size data may be unreliable if ovarian eggs were measured, since the degree of ripeness may be unclear. Quantifying parental care in terms of energy

expenditure has not been attempted, and descriptions of nest building and guarding activities are inadequate to estimate the relative amounts of time and energy devoted to the rearing of young. Breder and Rosen (1966) summarized the literature on the reproductive biology of fishes. Data on fecundity, egg sizes, and behavior in the following section were drawn from this work unless otherwise noted.

A survey of the material in Breder and Rosen (1966) indicates that members of the genus Noturus are among the least fecund of North American, freshwater, oviparous fishes for which data are available. My data indicate that N. leptacanthus, in particular, is at the lowest extreme, even presuming that individuals normally spawn two clutches of eggs per year (ca. 50 eggs total). Members of the families Cyprinidae and Percidae, which generally correspond with the size range of Noturus species, produce from several hundred to several thousand eggs per year. Cyprinodontids and the viviparous poeciliids apparently produce several hundred offspring per season over the course of several spawnings. The larger freshwater fishes (e.g., salmonids, centrarchids, and esocids) produce several thousand to many thousand eggs.

Within the Ictaluridae egg numbers tend to increase logarithmically with increasing body size (Table 8 and Fig. 31). These data were compiled from numerous sources and in several cases represent crude estimates. Pylodictis olivaris, the largest species, reportedly produces up to

TABLE 8. Mature Length and Clutch Size of Thirteen Ictalurid Species

Species	Adult Length (mm) (source)	Clutch Size (source)
<u>N. leptacanthus</u>	33.0-55.0 (personal observation)	14-45 (personal observation)
<u>N. miurus</u>	51-71 (Taylor 1969)	28-46 (Taylor 1969)
	52.5-74.2 (Menzel and Raney 1973)	31-143 (Menzel and Raney 1973)
<u>N. gyrinus</u>	52.0-60.6 (Menzel and Raney 1973)	82-179 (Menzel and Raney 1973)
	50.5-76.0 (personal observation)	28-107 (personal observation)
<u>N. stigmosus</u>	67-90 (Taylor 1969)	61-141 (Taylor 1969)
<u>N. funebris</u>	103-119 (Thomerson 1966)	114-192 (Thomerson 1966)
	73.5-97.5 (personal observation)	67-170 (personal observation)
<u>N. insignis</u>	122 (Clugston and Cooper 1960)	107 (Clugston and Cooper 1960)
	ca. 100+ (Taylor 1969)	ca. 200 (Fowler 1917)
<u>N. flavus</u>	ca. 175-240 (Taylor 1969)	ca. 200-500 (Greely 1929)
<u>I. melas</u>	ca. 150-350 (Carlander 1969)	ca. 200 (Breder and Rosen 1966)
	ca. 250-300 (Trautman 1957)	

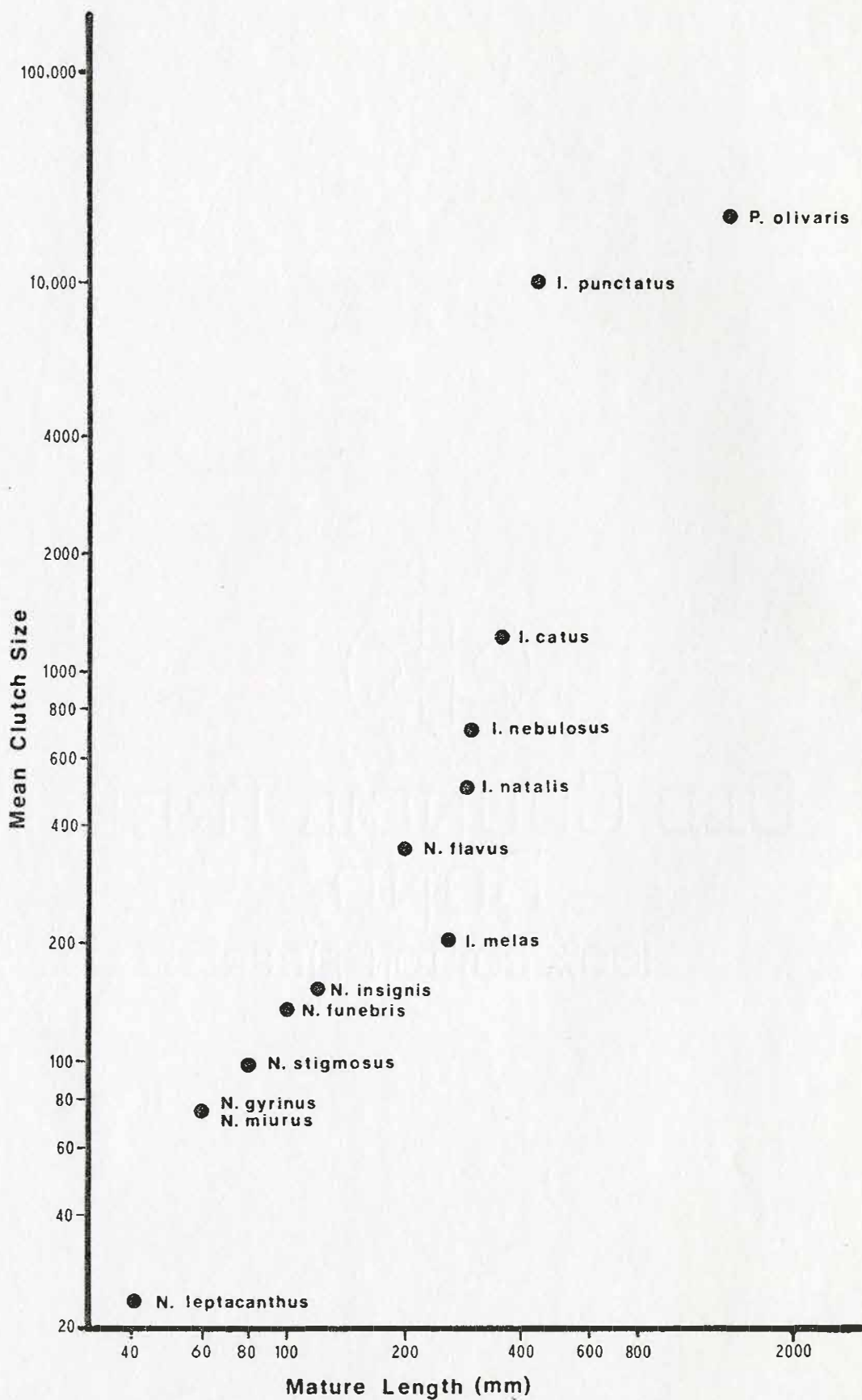
TABLE 8--Continued

Species	Adult Length (mm) (source)	Clutch Size (source)
<u>I. natalis</u>	ca. 150-400 (Carlander 1969)	ca. 500 (Breder and Rosen 1966)
	ca. 250-380 (Trautman 1957)	
<u>I. nebulosus</u>	ca. 150-450 (Carlander 1969)	ca. 700 (Breder and Rosen 1966)
	ca. 250-380 (Trautman 1957)	
<u>I. catus</u>	ca. 200-550 (Carlander 1969)	ca. 1,400-1,500 (Breder and Rosen 1966)
	ca. 250-450 (Trautman 1957)	ca. 2,500-4,000 (Carlander 1969)
<u>I. punctatus</u>	ca. 250-650 (Miller 1966)	ca. 4,000-16,000 (Miller 1966)
<u>P. olivaris</u>	ca. 1200 (Breder and Rosen 1966)	ca. 100,000 (Breder and Rosen 1966)
	458-917 (Turner and Summer- felt 1971)	4,076-31,579 (Turner and Summer- felt 1971)



Fig. 31. Mean reported clutch size versus estimated mature length of thirteen ictalurid species. Both axes logarithmically scaled.





100,000 eggs, and various Ictalurus species from 200 to 16,000 eggs. Clutch sizes in the genus Noturus are mostly less than 200 and in many cases, less than 100. Because of the rough nature of these data it is difficult to ascertain whether the egg production of N. leptacanthus is low or high relative to its body size. To provide an approximation, I estimated the mature weight of the various species and computed their egg production per gram of body weight, based on reported mature lengths and clutch sizes (Table 9). Adult lengths were converted to weights using the formula:  $\log W = -4.7 + 3 \log L$ , derived from the length to weight relationships I found for N. leptacanthus, N. nocturnus, N. gyrinus, and N. funebris, that reported by Clugston and Cooper (1960) for N. insignis, and those of N. flavus, I. melas, and I. catus (Carlander (1969)). From these figures, based on compounded estimates, it appears that among ictalurids N. leptacanthus produces a large number of eggs relative to its weight.

Noturus eggs are large, both in absolute terms and relative to their body size. Few North American freshwater fishes lay eggs over 3 millimeters in diameter, and in most cases the diameters range from 1 to 2 millimeters. Only the ictalurids and salmonids reportedly lay eggs in excess of 4 millimeters. Among members of the Ictaluridae, egg sizes have been reported for I. nebulosus (ca. 3 mm), N. insignis (3 mm), and N. flavus (3.5-4 mm). Thus,

TABLE 9. Estimated Mature Weight\* and Egg Production Per Gram Body Weight of Thirteen Ictalurid Species

Species	Est. Weight (g)	No. Clutches	Clutch Size	Egg Production Per Gram
<u>N. leptacanthus</u>	1.3	31	14-45 ( $\bar{x}$ = 24)	18.5
<u>N. miurus</u>	4.3	16	28-143 ( $\bar{x}$ = 74)	17.2
<u>N. gyrinus</u>	4.3	21	28-179 ( $\bar{x}$ = 73)	16.9
<u>N. stigmosus</u>	10.2	3	61-141 ( $\bar{x}$ = 97)	9.5
<u>N. funebris</u>	20.0	7	67-192 ( $\bar{x}$ = 134)	6.7
<u>N. insignis</u>	34.5	11	107 - ca. 200 ( $\bar{x}$ = ca. 150)	4.3
<u>N. flavus</u>	160	?	ca. 200-500 ( $\bar{x}$ = ca. 350)	2.2
<u>I. melas</u>	350	?	ca. 200	0.6
<u>I. natalis</u>	480	?	ca. 500	1.0
<u>I. nebulosus</u>	540	?	ca. 700	1.3
<u>I. catus</u>	930	?	ca. 1,400-4,000 ( $\bar{x}$ = ca. 2,700)	2.9
<u>I. punctatus</u>	1,800	?	ca. 4,000-16,000 ( $\bar{x}$ = ca. 10,000)	5.6
<u>P. olivaris</u>	6,800	55	ca. 4,000-100,000 ( $\bar{x}$ = ca. 20,000)	2.9

\*  $\log W = -4.7 + 3 \log L$

N. leptacanthus, one of the smallest ictalurids, with eggs 5.5 mm in diameter, reaches an extreme in the ratio of egg size to body size, both within its family and probably among North American freshwater fishes in general.

In N. leptacanthus, the small clutch size is apparently compensated by the unusually large egg size. The gonadosomatic index of ripe females falls within the range of GSI's reported by Williams (1959). These values range from 5 to 36% and among egg-guarding species, from 10 to 33%. Thus, the relative ovary weights of ripe N. leptacanthus are neither unusually large nor small.

As could be predicted from the size of their eggs, N. leptacanthus larvae are large at hatching. They are also well developed, perhaps as a consequence of their relatively long embryonic period. Although ictalurids are warm water fishes, and thus reproduce under conditions favorable for rapid development, a lengthy developmental period is apparently typical of the group. Breder (1939) reported developmental times of 6 to 10 days for I. nebulosus, and Armstrong (1962), 8 days for the same species. Larval N. leptacanthus do not feed until approximately 10 days after hatching, thus their developmental period in this sense exceeds 2 weeks. Brown bullhead larvae remain in the nest for a similar period of time (Breder 1939; Armstrong 1962). Larval size increments and the chronology of fin ray development in N. leptacanthus parallel those of N. miurus (Taylor 1969) and



I. nebulosus (Armstrong 1962).

The larvae are guarded by the male parent until they leave the nest to forage on their own. Whether the young form aggregations after leaving the nest, as do juvenile bullheads, is unknown. N. leptacanthus spend about 2-1/2 weeks guarding the nest, not including that period of time spent in construction. This is comparable to the amount of time spent by bullhead parents. However, unlike bullheads and N. flavus (Carlander 1969), female N. leptacanthus apparently contribute little in the way of care to the offspring and very possibly are not involved in nest construction either. An interesting possibility is that N. leptacanthus (and perhaps most other Noturus species as well) pursue a strategy of allocating female energy to egg production rather than dividing it between egg production and nesting activities as do the large ictalurids. This could explain the combination of relatively large egg number and egg size in Noturus leptacanthus.

Sexual dimorphism, in the form of enlarged head muscles, is common among ictalurids (Taylor 1969), but is evidently less prominent in the larger species, as Breder (1939) commented that the sexes of nesting brown bullheads were difficult to distinguish. The function of these muscles is unknown, but they are presumably involved in either nest construction or guarding behavior. It is unlikely that they play a part in sex recognition since this



is almost certainly an olfactory and gustatory process (Breder and Rosen 1966). Breder (1939) described nest construction in I. nebulosus as involving "rooting" behavior and fanning motions of the pelvic fins. Breder and Rosen (1966) mentioned reports of bullheads removing gravel from nest sites in their mouths. This kind of construction activity may necessitate extra muscle development, particularly in small species and in those in which only the male participates in nest construction. Another possibility is that the muscles are used in ventilating the nest. Brown bullheads fan their eggs with the pelvic fins, as well as churn them about in the mouth (Breder 1935, 1939). They also periodically "yawn" deeply. Breder (1935) suggested that this behavior may serve to replenish the supply of oxygenated water in the nest. A third possible explanation is that the enlarged head musculature is used in the defense of the nest. Breder (1939) reported that brown bullheads butted objects introduced into their nests. Increased head size may serve to heighten the threatening appearance of guardian males and be of particular value when nests are attended by a single parent.

Age and growth studies of Noturus species have been based on patterns discernable in pectoral spines (Clugston and Cooper 1960), vertebrae (Hooper 1949; Carlson 1966), and on length frequencies (Thomerson 1966). Generally, madtoms are small and probably short-lived fishes. Carlson (1966)

reported a maximum age of 7 years for the largest species, N. flavus. Moderately large species were believed by Taylor (1969) to live 3 to 4 years, and this estimate was supported by Clugston and Cooper (1960) for N. insignis and Thomerson (1966) for N. funebris. Hooper (1949) found the oldest N. gyrinus in a large sample to be in their third summer.

My data indicate a maximum life span of slightly more than 2 years for N. leptacanthus; however, Taylor (1969) reported an individual 78.7 mm in standard length, and this is perhaps a 3-year-old animal. In general, the sizes of 1 and 2-year-old N. leptacanthus fall short of the sizes reported for these age groups among larger Noturus species (Hooper 1949; Clugston and Cooper 1960; Carlson 1966; Thomerson 1966).

The pattern of growth I observed in N. leptacanthus resembles that found by Clugston and Cooper (1960) for N. insignis. In both species growth occurs chiefly during the warm months of the year, and in mature individuals is interrupted during the summer spawning period. Reduced feeding by females and fasting by males during the breeding season, along with the increased energy expenditures occasioned by spawning activities, may account for the cessation of growth I observed in July and August.

Noturus leptacanthus first spawn during their second summer, thus maturing at an earlier age than that reported for N. insignis (24 months, Clugston and Cooper 1960) or

N. funebris (36 months, Thomerson 1966). From the available data it is impossible to reliably evaluate the reproductive contribution of the two mature year classes of speckled madtoms. Animals in their second year constituted about 40% of the March-April sample, but only about 18% of the mature individuals in July and August. The bulk of the reproductive output is probably attributable to 1 year olds; however, larger (and therefore older) animals tend to produce larger clutches.

Viewed from the perspective of r and K-selection, the life history of Noturus leptacanthus suggests strong K selection in comparison with most North American, freshwater fishes. It combines small clutch size, large egg size, a high level of parental care, and a slight degree of iteroparity within its short life span. Relative to other ictalurids, however, its life history pattern is not as clear-cut. The combination of relatively large clutch size, very large egg size, and early maturation in N. leptacanthus may represent a response to a level of predation greater than that experienced by larger ictalurid species. Even adult speckled madtoms are not large enough to avoid predation by large piscivores and, if Birkhead's (1972) analysis is accepted, they are less well armed than some other ictalurid species. A strategy of early reproduction would be of value where the likelihood of future survival is low. The allocation of female reproductive energy to the production of a

large number of large eggs may preclude her participation in nest guarding. Such a trade-off between parental care and fecundity may be advantageous in species such as N. leptacanthus whose size permits the utilization of nest sites inaccessible to many egg predators and in which the small volume of eggs produced reduces the problems of providing sufficient aeration.



APPENDIX

LIST OF COLLECTIONS EXAMINED



APPENDIX. List of Collections Examined

Locations 1-23 are in the Pascagoula River drainage, 1-15 are in the Black Creek system, and 1-7 are in Black Creek itself. Location 24 is in the Pearl River drainage. The specimens from locations 17-23 were collected by personnel of the Mississippi Game and Fish Commission; specific locality data are lacking for some of these.

Location	Collection Number	Date	<u>N.</u> <u>lepta-</u> <u>canthus</u>	<u>N.</u> <u>gyrinus</u>	<u>N.</u> <u>funēbris</u>	<u>N.</u> <u>nocturnus</u>
1.						
Black Creek, Lamar Co.	C76-20	2-26-76	3	3		
Bridge on Miss.Hwy 589.	R76-21	4-1-76	4	7		2
T3N, R15W, Sec. 1	R76-22	4-2-76	3			
	R76-23	4-3-76	10	4	1	10
	R76-24	4-5-76	1			
	R76-25	4-6-76	11	2		1
	C76-47	4-8-76	7	2		
	C76-80	7-26-76	2			
	C76-82	7-28-76	2			
	B76-97	9-29-76	44	4	3	
	B76-109	11-10-76	3			
	R77-7	4-1-77	10	4		6
	R77-10	4-2-77	5	2		4

Location	Collection Number	Date	<u>N.</u> <u>lepta-</u> <u>canthus</u>	<u>N.</u> <u>gyrinus</u>	<u>N.</u> <u>funēbris</u>	<u>N.</u> <u>nocturnus</u>
1. continued	R77-12	4-21-77	3	2		
	R77-13	4-21-77	14	19	8	2
	R77-15	4-25-77	20	12	3	9
2.						
Black Creek, Lamar Co. ca. 200 m downstream from Bridge on Oak Grove-Purvis Road. T3N, R14W, Sec. 21	C76-21	2-27-76	5			
	C76-91	8-19-76	1	9		
	C76-94	8-22-76	87	2		
	B76-108	11-9-76	7			
3.						
Black Creek, Lamar Co. at Southern Railroad trestle. T3N, R14W, Sec. 27.	C76-26	3-2-76	1			
	B76-107	11-9-76	15			
4.						
Black Creek, Lamar Co. ca. 500 m upstream from Bridge on U.S.Hwy. 11. At outfall of Amerada- Hess Refinery. T3N, R14W, Sec. 26.	R75-38	9-18-75	7			
	C76-25	3-2-76	3			
	C76-63	6-14-76	11			
	C76-64	6-15-76	1			
	B76-74	7-26-76	1			
C76-88	8-11-76	43		4	3	

Location	Collection Number	Date	<u>N.</u> <u>lepta-</u> <u>canthus</u>	<u>N.</u> <u>gyrinus</u>	<u>N.</u> <u>funebri</u> <u>bris</u>	<u>N.</u> <u>nocturnus</u>
4. continued	B76-106	11-9-76	1			
5. Black Creek, Forrest Co. Bridge on blacktop road SE of P.B.Johnson State Park. T2N, R13W, Sec.22	C75-47	10-30-75				1
	B76-103	11-5-76	12		3	
6. Black Creek, Perry Co. Moody's Landing. Brooklyn-McCain Road. T1N, R11W, Sec. 17	B76-100	10-10-76	4			
7. Black Creek, Lamar Co. Bridge at Interstate Hwy. 59. T2N, R14W, Sec. 1.	B76-102	11-5-76	36			
8. Sandy Run, Lamar Co. At Southern Railroad trestle. T3N, R14W, Sec. 22.	C75-52	12-5-75	2			
	C76-36	3-19-76	6			

Location	Collection Number	Date	<u>N.</u> <u>lepta-</u> <u>canthus</u>	<u>N.</u> <u>gyrinus</u>	<u>N.</u> <u>funnebris</u>	<u>N.</u> <u>nocturnus</u>
9.						
Perkins Creek, Lamar Co.	C76-8	1-23-76	11	2		
ca. 200m upstream from junction with Black Creek	C76-73	7-14-76			2	
near Miss. Hwy. 589.	C76-78	7-24-76	15	14		
T3N, R15W, Sec. 1.						
10.						
Walls Creek, Forrest Co.	C76-35	3-18-76	9	1	1	3
0.4 km S of Lake Shelby, at Bridge. T2N, R12W,	B76-98	10-1-76	7			
Sec. 18.						
11.						
Little Black Creek, Lamar Co. Bridge on paved road, ca. 1 km	C76-65	6-16-76	9	1	4	
NW of junction with Miss. Hwy. 589.	C76-79	7-26-76	4	2	9	
T3N, R15W, Sec. 2						
12.						
Boggy Hollow, Lamar Co.	R76-38	6-18-76	2			
W of Purvis on Baxter- ville Road. T2N, R15W,	C76-70	6-23-76	2		4	
Sec. 11.	B76-95	9-22-76	27		3	

Location	Collection Number	Date	<u>N.</u> <u>lepta-</u> <u>canthus</u>	<u>N.</u> <u>gyrinus</u>	<u>N.</u> <u>funnebris</u>	<u>N.</u> <u>nocturnus</u>
13. Clear Creek, Forrest Co., at Bridge, near U.S. Hwy. 11. T2N, R13W, Sec. 5.	C76-75	7-21-76	8		2	1
	C76-84	8-4-76	2	1		
14. Unnamed Creek, Lamar Co. Bridge on Oak Grove- Purvis Road, ca. 2.5 km W of Oak Grove. T4N, R14W, Sec. 19.	B76-86	8-17-76	5		1	
15. Black Tom Creek, Forrest Co. Bridge on Interstate Hwy. 59. T3N, R13W, Sec. 17.	B77-1	1/13/77	6			
16. Bowie River, Covington Co. Bridge at Miss. Hwy. 589.	C76-38	3-23-76	2			
	C76-83	7-30-76	1		1	3
	R76-50	10-5-76	33			2
17. Fort Bayou, Jackson Co. T6S, R7W, Sec. 31.	C76-71	6-22-76		9		



Location	Collection Number	Date	<u>N.</u> <u>lepta-</u> <u>canthus</u>	<u>N.</u> <u>gyrinus</u>	<u>N.</u> <u>funnebris</u>	<u>N.</u> <u>nocturnus</u>
18. Escatawpa River, Jackson Co. T6S, R5W, Sec. 24	C76-72	6-24-76	11	8		
19. Bogue Homa Lake, Jones Co. Miss. Hwy. 84 between Laurel and Waynesboro.	C76-74	7-16-76		24		
20. Catchemall Bayou, Jackson Co.	C76-76	7-21-76		27		
21. Barnes Lake, Jackson Co.	C76-77	7-21-76		8		
22. Paige Lake, Jackson Co.	C76-81	7-27-76		1		
23. Okatibbee Reservoir	C76-86	8-2-76		12		
24. White Sands Creek, Jef- erson Davis Co. 0.5 km SE jct. Miss.Hwys.13 & 42	C76-59	6-4-76		1		

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