Aspects of the Life History of the Tadpole Madtom, *Noturus gyrinus* (Siluriformes: Ictaluridae), in Southern Illinois[1]

LISA A. WHITESIDE and BROOKS M. BURR, Department of Zoology, Southern Illinois University at Carbondale, Carbondale, IL 62901

ABSTRACT. Aspects of the life history of *Noturus gyrinus* were studied from collections and observations made at Dutchman Creek, Johnson County, Illinois, between 25 October 1982 and 21 April 1984, and from specimens collected from Silver and Sugar creeks, Clinton, Madison, and St. Clair counties, Illinois, in July and August, 1982. *N. gyrinus* grew in length at a decreasing rate and in weight at a nearly constant rate for at least three (females) or four years (males). The largest individuals observed were a 97.5-mm standard length (SL) male and a 78.1-mm SL female. Mean annual SL was not significantly different between sexes except that males were both longer and heavier than females at age 3+. There were 4.5 times as many males as females at age 3+, although the overall sex ratio was nearly 1:1 in the total sample. Only 29% survived past their first year; 90.5% did not live past their second year. Individuals (78%) usually matured in two years (sexes combined), although about 5% of males and 17% of females matured in one year. Mature males were 55-mm SL or longer, and mature females 48-mm or longer at one year. Mature females examined for the presence of eggs ranged from 52.6 to 78.9-mm SL, and contained 48 to 323 ($\bar{x}$ = 151.3) mature ova. Lengths and weights of mature females were both significant ($P < 0.05$) predictors of the numbers of mature ova. Dipteran larvae (chironomids) and small crustaceans (mainly isopods) constituted the major portion of the annual diet of all size classes. Gut contents of five species of piscivorous fish were examined; no evidence of predation on *N. gyrinus* was found.

OHIO J. SCI. 86 (4): 153-160, 1986

INTRODUCTION

The tadpole madtom, *Noturus gyrinus,* is a small catfish endemic to eastern North America. Knowledge of its biology is limited to brief observations or anecdotal accounts of reproductive habits (Hankinson 1908, Forbes and Richardson 1920, Bailey 1938, Clark 1978, Wang and Kernehan 1979), larval development (Wang and Kernehan 1979, Tin 1982), fecundity (Evermann and Clark 1920, Menzel and Raney 1973, Todd 1973, Mahon 1977, Clark 1978, Mayden and Walsh 1984), age and growth (Hooper 1949, Mahon 1977), and diet (Forbes 1888, Hankinson 1908, Pearse 1918, Evermann and Clark 1920, Ewers and Boesel 1935, Todd 1973). *N. gyrinus* typically inhabits low-gradient streams or lentic waters over soft substrates near some vegetation or debris.

Larimore (1981) recently emphasized the need for more basic ecological data on warmwater fishes. Mayden (1983) and Mayden and Walsh (1984) summarized available life history data on species of *Noturus* noting that additional data were needed before more meaningful comparisons of the ecologies of madtoms can be made. The present study provides information on the age, growth, reproductive biology, and diet of *N. gyrinus* from a 19-month study conducted in southern Illinois.

STUDY SITE

Dutchman Creek is a low-gradient stream in the Cache River drainage of the Coastal Plain of southern Illinois. The study site is located at the upstream side of the Rt. 146 bridge over Dutchman Creek, 5.6 km West of Vienna, Johnson County, Illinois. At the study site, two pools connected by channels were the main areas sampled. During low water, pools were 1.0 to 1.5 m deep and about 2.0 to 4.0 m wide. The easternmost channel was usually divided into a series of shallow riffles less than 0.5 m deep and 0.5 to 2.0 m wide. The bottoms of the pools and channels were composed of silt, clay, gravel, and organic debris. Piles of leaf litter and pieces of wood often accumulated after high water, but no permanent brush piles, logs, or large rocks were present. Filamentous algae, water willow (*Justicia* sp.), and grass were sparsely present only in the spring and summer. The water was generally turbid in all seasons. *N. gyrinus* was collected at water temperatures ranging from 6° C in January to 26° C in June.

METHODS AND MATERIALS

Methods of study followed Mayden and Burr (1981) and Burr and Mayden (1982 a,b) except as noted. Observations and minnow-seine collections were made at Dutchman Creek at approximately 1-month intervals from 25 October 1982 to 21 April 1984. Collections were not made in November 1982, December and February 1983, and January, February, and March 1984, because of inclement weather. All collections were made during daylight hours (1030-1800 h) with exceptions on 30 January and 2 March 1983, when they were made shortly after dusk (1800-2000 h). In addition to 161 specimens examined from Dutchman Creek, 430 specimens were studied from seven rotenone collections made in Silver and Sugar creeks in the Kaskaskia River drainage, Illinois, during July and August 1982. All specimens examined in this study are deposited in the Southern Illinois University at Carbondale ichthyological collection.

In the laboratory, all preserved specimens (N = 591) were measured to the nearest 0.1 mm standard length (SL) and were sexed by examination of gonads. Adjusted body weights (weight of specimens minus stomach, intestine, liver, and gonads) were measured to the nearest 1.0 mg. Gonads were blotted dry, and their weights were recorded to the nearest 1.0 mg and used to calculate the gonadosomatic index (GSI) by the formula GSI = weight of gonads (g)/adjusted body weight (g) × 1000. Samples from each monthly collection (N = 267 total) were dissected, and stomach contents were identified to at least the ordinal level. Drawings of genital papillae were made with the aid of a camera lucida.

Ages of 179 individuals were estimated by counting annual rings on cross sections of pectoral spines following the procedures of

---

[1]Manuscript received 1 November 1985 and in revised form 26 March 1986 (#85-53).

Clugston and Cooper (1960) and modified by Mayden and Burr (1981). Aging to month was done by using June, the first whole month of breeding activity, as month zero. Individuals not aged by counting annual rings on cross sections of pectoral spines were assigned ages on the basis of SL. The ranges of SL of age classes were estimated through examination of length-frequency histograms.

Statistical analyses were carried out with the Statistical Analysis System (SAS). F-tests were used to test for homogeneity of regression and group differences with respect to regression coefficients. Analysis of Variance (ANOVA) and Tukey's procedure were used to determine significant differences in sample means between age, size, sex, or site classes. Correlation coefficients (r) were all Pearson product moments. The level of significance for all analyses was set at $P < 0.05$.

RESULTS AND DISCUSSION

AGE. Ages of *N. gyrinus* taken from Dutchman Creek ranged from 1 to 46 months. Individuals less than 12 months old were designated age 0, those 12-23 months, 1 or 1+, those 24-35 months, 2 or 2+, and those 36-37 months old, 3 or 3+. The 430 individuals from Silver and Sugar creeks ranged in age from 1 to 49 months. These collections contained two individuals in age class 4+ (49 months).

Hooper (1949) recognized only ages 0, 1+, and 2+ among 250 *N. gyrinus* from Demming Lake, Minnesota. These specimens, collected in August 1946, were aged by counting annuli on vertebral centra. His length-frequency analysis of 4,206 additional specimens also indicated these three ages. In a study of 474 *N. gyrinus* collected in May and August 1975 from Long Point, Lake Erie, ages 1+, 2+, and 3+ were found (Mahon 1977). Counts of annuli on vertebral centra were used to estimate ages of 182 of the specimens. The absence of age 0 individuals was attributed to sampling bias. The greater proportion of age 3+ individuals from Silver and Sugar creeks (16.7%), as compared to the Mahon (1977) estimate (3.4%), may be due to decreased mortality in Illinois, may reflect limitations in recognizing older individuals from the number of annuli on vertebral centra, or may simply be sampling bias.

GROWTH. *N. gyrinus* from Dutchman Creek grew in length at a decreasing rate. The relationship between SL and age in months (A) was similar for males and females. The curvilinear growth equation for both sexes combined was $SL = 7.97 + 12.95 \text{ Log } A$ ($r = 0.81$; Fig. 1). Both sexes attained about one-half of the first year's length in four weeks and one-half of the first year's weight in about four months. Weight increased linearly with increasing age. The relationship between adjusted body weight (W) and age did not differ significantly between the sexes. The equations were $W = -0.312 + 0.136A$ ($r = 0.75$) for males and $W = -0.180 + 0.125A$ ($r = 0.87$) for females (Fig. 2).

The relationship between SL and age was similar for specimens from Silver and Sugar creeks compared to those from Dutchman Creek. Males and females both grew at a decreasing rate; however, these rates were significantly ($P < 0.05$) different between the sexes. The regression equation for this relationship was $SL = 8.77 + 17.37 \text{ Log } A$ ($r = 0.88$) for males and $SL = 15.14 + 14.1 \text{ Log } A$ ($r = 0.88$) for females. Just as *N. gyrinus* from Dutchman Creek, individuals from Silver and Sugar creeks exhibited a linear increase in weight with increasing age. For males, this relationship was $W = 0.017 + 0.233A$ ($r = 0.64$); for females it was $W = 0.586 + 0.163A$ ($r = 0.72$).

The relationship between SL and adjusted body weight was linear among males and females from Dutchman, Silver, and Sugar creeks. The relationship was not significantly different between sexes or among the sites, and

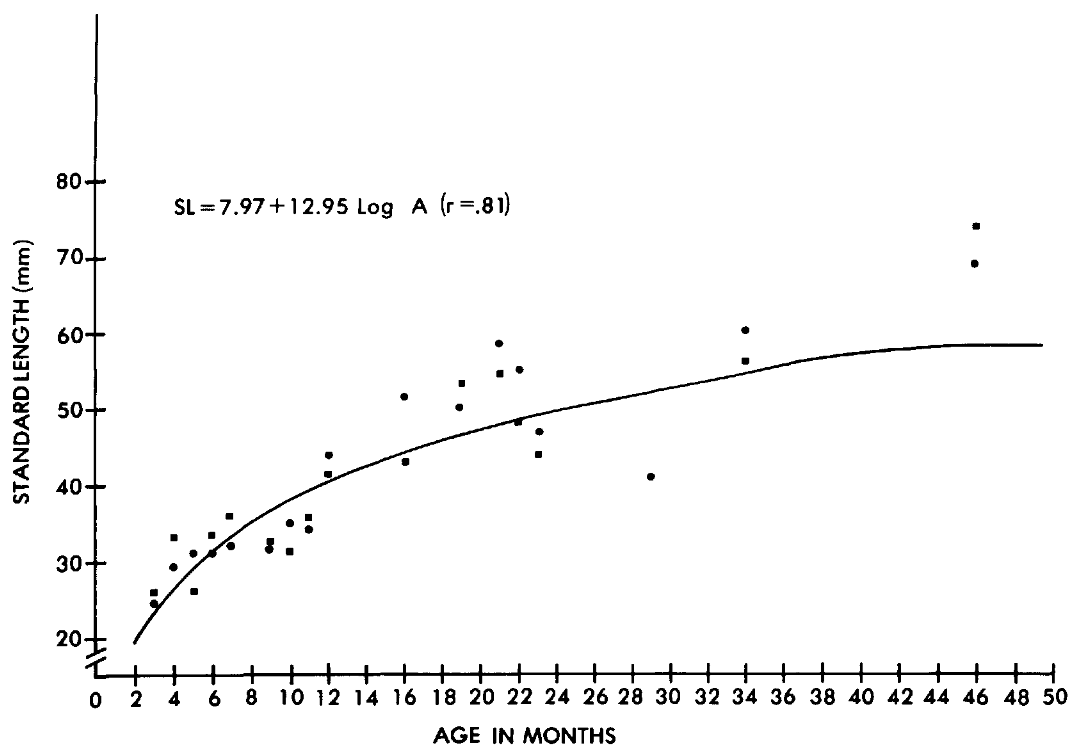

FIGURE 1. Size (SL) distribution by age (A) of *N. gyrinus* from Dutchman Creek, Illinois. Regression line is for total sample (N = 161). Dots represent sample means for females (N = 81); squares represent sample means for males (N = 80).

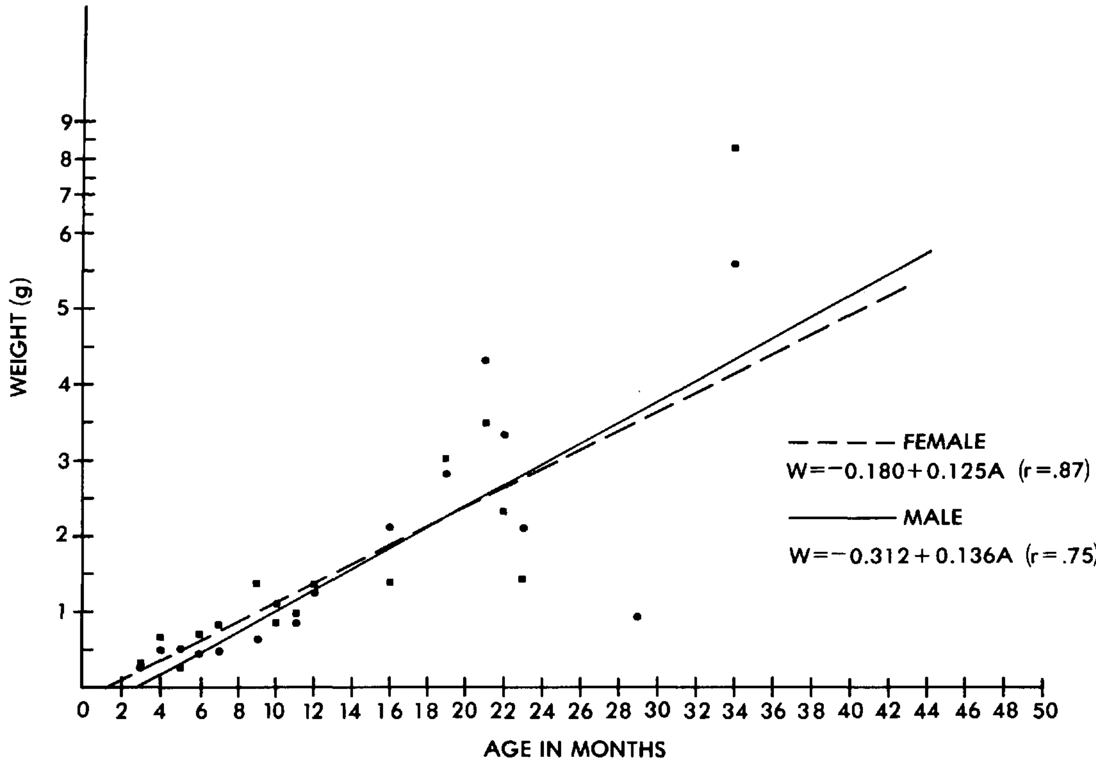

FIGURE 2. Weight (W) distribution by age (A) of *N. gyrinus* from Dutchman Creek, Illinois. Dots represent sample means for females (N = 64); squares represent sample means for males (N = 59).

was best described as Log W = −11.59 + 3.18 Log SL (r = 0.97). Clark (1978) reported a similar regression between weight and length in *N. gyrinus* from southern Mississippi.

The largest specimens from Dutchman Creek were a 75.1-mm SL male and a 69.3-mm female, both collected on 21 April 1984. The largest male and female examined were 97.5 mm and 78.1 mm, respectively, from Sugar Creek, near Highland, Illinois. Taylor (1969) reported a 105-mm male from Goose Creek, near Louisville, Kentucky.

AGE AND SIZE COMPOSITION. Of the 161 specimens collected from Dutchman Creek, 72.1% were less than one year (age 0), 21.1% between one and two years (age 1+), 4.9% between two and three years (age 2+), and 1.8% over three years (age 3+) (Table 1). The mean SL of age 0 individuals was 31.2 mm; of age 1+, 47.9 mm; of age 2+, 55.6 mm; and of age 3+, 72.3 mm. The mean SLs for ages 0, 1+, 2+, and 3+ from Silver and Sugar creeks were 24.3, 49.3, 62.5, and 75.7 mm, respectively (Table 2). These means did not differ significantly from those for the same age classes in Dutchman Creek except for age 0 fish. The value for age 0 fish in Silver and Sugar creeks is probably biased, since all specimens of this age that were taken were only one or two months old.

Mean SL and weights differed between the sexes only in age 3+ individuals from Silver and Sugar creeks, possibly because of the skewed sample size or sex ratios. Males averaged 77.1 mm SL and 8.65 g and females 69.5 mm SL and 5.84 g; males also outnumbered females 4.5 to 1 (Table 2).

SEX RATIO. The ratio of males to females (1.02:1) from Dutchman Creek did not differ significantly from 1:1 in any month, age group, nor in the total sample. Samples from Silver and Sugar creeks showed no significant deviation in sex ratio except in age 3+ (see paragraph above). Males represented 52% of the overall sample from Silver and Sugar creeks.

Mahon (1977) and Thomerson (1966) found significantly more males than females of *Noturus gyrinus* and *N. funebris* at ages 2+ and 3+, respectively. Females of *N. insignis*, *N. leptacanthus*, *N. albater*, *N. exilis*, and *N. hildebrandi* slightly outnumbered males (Clugston and Cooper 1960, Clark 1978, Mayden et al. 1980, Mayden and Burr 1981, Mayden and Walsh 1984), although males of *N. hildebrandi* significantly outnumbered females during the first month of life (Mayden and Walsh 1984). Unequal sex ratios in older age classes may result from differential mortality between the sexes or from

TABLE 1

Age classes of Noturus gyrinus *from Dutchman Creek, Illinois, with corresponding means and ranges in standard length (SL) by sex.*

Age class	Sample	N	% total sample	Mean SL (mm)	Range SL (mm)
0	Males	57	35.4	31.1	21.1-41.3
0	Females	59	36.7	31.3	19.9-48.3
0	Total	116	72.1	31.2	19.9-48.3
1+	Males	19	11.8	46.2	30.7-61.4
1+	Females	15	9.3	50.0	43.8-58.9
1+	Total	34	21.1	47.9	30.7-61.4
2+	Males	2	1.2	55.3	52.3-58.2
2+	Females	6	3.7	55.7	41.0-64.7
2+	Total	8	4.9	55.6	41.0-64.7
3+	Males	2	1.2	73.9	72.6-75.1
3+	Females	1	0.6	69.3	
3+	Total	3	1.8	72.3	69.3-75.1

TABLE 2

Age classes of Noturus gyrinus *from Silver and Sugar creeks, Illinois, with corresponding means and ranges in standard length (SL) by sex.*

Age class	Sample	N	% total sample	Mean SL (mm)	Range SL (mm)
0	Males	24	5.6	23.6	15.9-39.5
0	Females	29	6.7	24.9	17.0-38.5
0	Total	53	12.3	24.3	15.9-39.5
1+	Males	67	15.6	48.7	18.6-67.2
1+	Females	88	20.5	49.7	37.5-70.5
1+	Total	155	36.1	49.3	18.6-70.5
2+	Males	73	17.0	63.4	40.9-91.6
2+	Females	77	17.9	61.7	42.4-78.9
2+	Total	150	34.9	62.5	40.9-91.6
3+	Males	59	13.7	77.1	67.1-97.5
3+	Females	13	3.0	69.6	66.7-75.5
3+	Total	72	16.7	75.7	66.7-97.5

sampling bias because of difficulties in collecting nesting males (Clugston and Cooper 1960, Mayden and Burr 1981).

RELATIVE SURVIVAL AND LONGEVITY. Relative survivorship values of males and females in the total sample from Dutchman Creek showed that only 29% of the fish survived to the second year of life and 9.5% to the third year (Table 3). Relative survival values assumed that individuals of all year classes were collected in proportion to their relative abundance, approximately the same number of young hatched each year, and year classes were subject to similar mortality rates at corresponding ages (Ricker 1975). Relative survival values for Silver and Sugar Creek madtoms in some cases exceeded 100%, indicating a violation of at least one of these assumptions. It is likely that there may have been unequal numbers of young hatched each year or different mortality rates at corresponding ages.

As judged from the number of annuli on pectoral spine cross sections, length-frequency histograms, and survival values, the maximum lifespan of *N. gyrinus* at the study sites was four years. Only 9.5% of the fish lived longer than two years (Table 3). Longevity of other species of *Noturus* ranges from 18 months in *N. hildebrandi* (Mayden and Walsh 1984) to nine years in *N. flavus* (Gilbert 1953). Most species of *Noturus,* for which the lifespan is known, live between two and four years.

TABLE 3

Relative survival of year classes of Noturus gyrinus *from Dutchman Creek, Illinois, expressed as a proportion of the 1984 year class ($1x^1$) and the 1983 year class ($1x^2$).*

Sample	Year class	N	Survival $1x^1$	$1x^2$
Males	1984	57	1.000	.....
	1983	19	0.333	1.000
	1982	4	0.070	0.211
Females	1984	59	1.000	.....
	1983	15	0.250	1.000
	1982	7	0.119	0.467
Total	1984	116	1.000	.....
	1983	34	0.293	1.000
	1982	11	0.095	0.324

REPRODUCTIVE CONDITION A. MALES. Males as young as one month and as small as 16 mm SL could be identified by examination of gonads. The testes of immature males were single-stranded, translucent-white, and had many small fingerlike projections. Testes of mature males were lobed, opaque milky-white, and had numerous projections. The GSI of all males ranged from 0.31 to 11.11 with a mean of 3.36; however, the GSI of males 2+ and older ranged from 0.99 to 11.11 with a mean of 6.88, indicating increased development of the testes in these age classes.

Mature males in breeding condition were identified externally by their swollen lips and enlarged cephalic epaxial muscles that give the head a broad, flat appearance, and by their distinctive genital papillae (Fig. 3). The genital papilla of a breeding male was large, single, bulb-like, and pigmented with a few scattered melanophores. The genital opening was not swollen nor raised, in contrast to that of females in breeding condition. Testes and secondary sexual characteristics have been similarly described for other madtoms (e.g., Mayden and Burr 1981).

About 5% of age 1+ males were mature at the beginning of the second summer; males of age 2+ years and over 55 mm SL consistently exhibited well developed secondary sexual characteristics.

REPRODUCTIVE CONDITION B. FEMALES. Females as young as one month and as small as 18 mm SL were readily identified by examination of the gonads. Mature pre-breeding females were easily identified by the presence of a distended abdomen and distinctive genital papilla, which bore a deep median groove ending in a small bump. The female genital papilla was only slightly pigmented with a few melanophores at its edges (Fig. 3). The genital opening was often swollen or raised.

The ovaries of immature females contained only spherical, translucent-white ova less than 0.5 mm in diameter (N = 16 ova). Maturing ovaries contained both immature ova and larger milky-white ova up to 1.0 mm in diameter (N = 16 ova). Mature ova were translucent, yellow-orange with an average diameter of

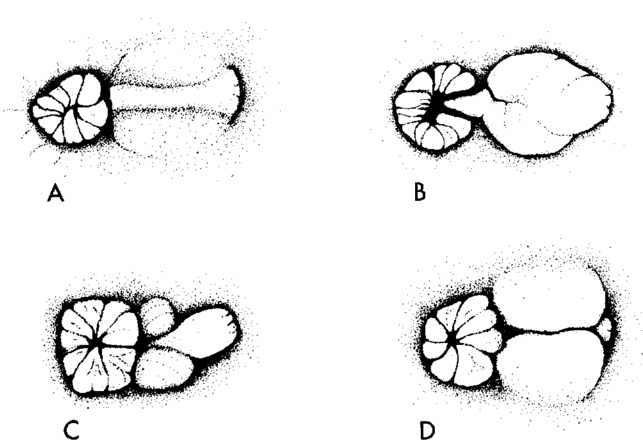

FIGURE 3. Genital papillae of *N. gyrinus*. A) Immature male (48.4 mm SL) collected on 14 July 1982. B) Mature male (85.6 mm SL) collected on 16 June 1984. C) Immature female (42.1 mm SL) collected on 14 July 1982. D) Mature female (52.9 mm SL) collected on 7 July 1982.

1.95 mm (N = 210 ova, range 1.10 – 2.41). Mature ova were surrounded by a single membrane, with the entire complement of ova suspended in a second sheet of connective tissue. Ovaries with mature ova always contained immature and maturing ova as well. Ovaries of spent females contained immature ova, degenerating yellow or brownish ova of intermediate sizes, and small bits of yolk. In each of two spent females, a single mature ovum remained in one ovary. The mean GSI for all females ranged from 0.4 to 225.9 ($\bar{x}$ = 25.6). The GSI of 33 gravid females ranged from 34.4 to 225.9 ($\bar{x}$ = 149.2).

Although some females longer than 48 mm SL may have matured at 13 months, it was more likely that at least 25 months were required for most to mature. All gravid females examined were 48 mm SL or longer. About 17% of females at age 1+ were mature.

FECUNDITY. Estimates of fecundity and other aspects of reproduction for the 33 female *Noturus gyrinus* examined in this study are summarized in Table 4. The number of mature ova in these females ranged from 48 to 323 ($\bar{x}$ = 151.3). Longer and heavier females produced more ova. The relationship between number of mature ova (M) and weight (W) was M = 14.22 + 26.04W (r = 0.82); between number of mature ova and standard length (SL) it was M = −228.74 + 5.90SL (r = 0.75).

The mean number of mature ova present in females from southern Illinois was higher than mean ova counts from previous studies of *N. gyrinus.* Previously reported mean fecundities range from 60.5 in 17 females from southern Mississippi (Clark 1978) to 121.5 in four females from Cayuga Lake, New York (Menzel and Raney 1973). The lengths and weights of females used for fecundity estimates from southern Illinois and southern Mississippi were similar (Illinois, $\bar{x}$ SL = 64.3 mm, $\bar{x}$ wt. = 5.3 g, N = 33; Mississippi, $\bar{x}$ SL = 65.0 mm, $\bar{x}$ wt. = 4.3 g, N = 17). Interestingly, Illinois females contained over twice ($\bar{x}$ = 151.3) the number of mature ova when compared to Mississippi females ($\bar{x}$ = 60.5), but mean ova diameter (1.95 mm) in Illinois females was about half the mean size (3.70 mm) of mature ova in Mississippi females. We know of no other species of *Noturus* with such extreme geographic differences in fecundity and mature ova diameter. The use of partially spent females for ovarian egg counts by Clark (1978) might account in part for the difference in fecundity estimates between Illinois and Mississippi populations. However, it would not explain the differences in mature ova diameter. We are unable to offer a satisfactory explanation for these differences, but suggest that additional studies of fecundity (with explicit methodology stated) and parental care from other populations of the species might provide information on the nature of the differences. For example, is the variation in fecundity clinal or regional? Do small clutches with large embryos receive more efficient care than large clutches with small embryos? Are the reported differences in fecundity due to genetic differences among populations of the species? Before these questions can be answered, more research is needed on the nesting and care-giving behavior of parents as well as on geographic variation in other life history characteristics. Comparative allozyme analyses of populations of *N. gyrinus* might provide evidence for racial or subspecific differences among populations. It is difficult to make meaningful comparisons of fecundity estimates with other populations (viz., Evermann and Clark 1920, Menzel and Raney 1973, Todd 1973, Mayden and Walsh 1984) because comparable data for all of them are not available, and sample sizes in some cases are small.

Mayden and Walsh (1984) recently reviewed available data on fecundity and clutch size in 18 of 25 species of *Noturus.* They concluded that *N. gyrinus, N. hildebrandi,* and *N. leptacanthus* had the extreme relative fecundities in the genus, producing 30 or more oocytes per gram body weight. The relative fecundity value (29.1) of *N. gyrinus* derived from our study agrees closely with that reported by Mayden and Walsh (1984). Most *Noturus* have relative fecundities ranging from 15-20 oocytes per gram body weight (Mayden and Walsh 1984). Clark's (1978) data were based on predicted body weights derived from a summed length-weight regression of all ictalurids; this may account for her low value (16.9) of relative fecundity for *N. gyrinus.* Mayden and Walsh (1984) further concluded that high relative fecundity was a derived strategy in *Noturus,* and that it had evolved once in the subgenus *Noturus* (e.g., *leptacanthus, gyrinus*), and once in the subgenus *Rabida* (e.g., *miurus, hildebrandi*).

TABLE 4

Characteristics of females of Noturus gyrinus *in breeding condition from southern Illinois. Only potential spawning individuals are included. For columns 4-10, the range is given for each collection date or interval. Below each range is the mean, followed by the standard deviation.*

Collection date/interval	N	Age in months	SL	Adjusted body weight (g)	Gonad weight (g)	GSI	Relative fecundity	Number of mature ova	Mean diameter of mature ova (mm)
7-15 Jul	6	11-13	52.7-70.5 63.00 ±6.19	2.56-6.50 5.11 ±1.40	0.20-1.19 0.78 ±0.33	77.75-195.62 146.05 ±39.99	18.77-34.77 29.51 ±6.05	48-211 157.17 ±61.93	1.85-2.06 1.95 ±0.08
15 Jul	25	23-25	68.9-75.6 72.30 ±4.74	6.56-7.53 7.05 ±0.69	0.94-1.70 1.32 ±0.54	142.91-225.83 184.39 ±58.65	18.15-28.67 23.41 ±7.44	119-216 167.50 ±68.59	2.11-2.39 2.25 ±0.20
7 May-15 Jun	2	35-37	52.6-78.9 63.90 ±7.25	2.19-9.62 5.16 ±1.87	0.12-1.97 0.77 ±0.43	34.37-225.86 147.70 ±59.84	15.11-41.78 29.41 ±6.77	48-323 148.60 ±56.55	1.10-2.41 1.93 ±0.34

SPAWNING AND NESTING. Reports in the literature indicate that spawning in *N. gyrinus* occurs from May into September (Lindquist et al. 1982). Spent females have been found in early June (Forbes and Richardson 1920). Small juveniles in July collections from Sugar Creek and in September collections from Dutchman Creek indicated that the breeding season in Illinois may extend from early to late summer as well. Although collections were made at least weekly from mid-June through July 1983, no spawning was observed and no nests were found. Since it has been reported that *N. gyrinus,* like some other members of the genus, spawn in cans (Hankinson 1908, Bailey 1938, Clark 1978), empty 355-ml beer and soda cans were placed in channels at Dutchman Creek as potential spawning sites. Only crayfish and juvenile bullheads used these cans. However, the presence of young-of-the-year *N. gyrinus* in September indicated that successful spawning had taken place.

Few descriptions of egg clusters, clutch size, depth of nest, and date found have been reported. A clutch of 47 eggs from a single female *N. gyrinus* from Lake Waccamaw, North Carolina, is deposited in the SIUC Ichthyology collection. The clutch was found under a terracotta roofing tile on a sand bottom at a depth of 2 m on 9 May 1984. A pair of mature *N. gyrinus* guarded the nest. The eggs were spherical, light yellow-orange, and had a mean yolk diameter of 2.96 mm (range = 2.85 − 3.05, N = 5). Eggs have been described in the literature as spherical, demersal, adhesive, and light yellow, with a range in diameter of 2.8 − 3.5 mm, and surrounded by a gelatinous matrix (Bailey 1938, Wang and Kernehan 1979). Bailey (1938) found a clutch of 117 eggs with a guardian male in a beer can at a depth of 1 m on 14 June in the Merrimack River, New Hampshire. Similarly, Hankinson (1908) reported a nest in a can (containing about 50 eggs *fide* Mayden and Walsh 1984) at a depth of 1 m with a single parent (of unreported sex) on 26 June from Walnut Lake, Michigan. Two nests in aquaria (Wang and Kernehan 1979) contained 125 and 150 eggs and were guarded by both parents. Published reports of clutch sizes from nests exceed some accounts of fecundity estimated from preserved females, but fall within the range found in this study.

DIET. Hankinson (1908) described the stomach contents of one *N. gyrinus* as "a mass of insect fragments." Other reports of the diet of *N. gyrinus* list the predominant food organisms as crustaceans and dipteran larvae (Pearse 1918, Evermann and Clark 1920, Ewers and Boesel 1935, Todd 1973). Forbes (1888) reported the stomach contents of 13 *N. gyrinus* from Illinois as amphipods, isopods, microcrustaceans, insect larvae, one small fish, and one planarian. Amphipods did not constitute a large proportion of the diet of *N. gyrinus* in southern Illinois.

Of the 267 *N. gyrinus* stomachs that were examined in the present study, 60.7% contained food. Crustaceans and dipteran larvae (primarily chironomids) composed over 90% by number of the total diet of all sizes of *N. gyrinus* from Dutchman Creek; dipteran larvae comprised 46.5%, isopods 23.0% and other crustaceans made up 20.5% of the diet. The diet of *N. gyrinus* from Silver and Sugar creeks, like that in Dutchman Creek, was composed primarily of dipteran larvae (34.6%) and isopods (26.5%). Additionally, trichopteran larvae (17.7%) and ephemeropteran naiads (12.3%) consitituted an appreciable portion of the diet. Food organisms ingested less frequently at both sites included plecopteran larvae, odonate nymphs, annelids, fish, and fish eggs. Differences in diet may reflect differences in invertebrate composition between Silver and Sugar creeks as compared to Dutchman Creek. Additionally, the larger mean SL, and therefore larger mouth size, of *N. gyrinus* from Silver and Sugar creeks may have allowed the fish to ingest different food organisms. Seasonal changes in prey diversity and abundance may also partially explain the difference in diets of *N. gyrinus* from Dutchman Creek and Silver and Sugar creeks. All specimens from Silver and Sugar creeks were collected in July and August 1982; at Dutchman Creek, only one specimen with food in its stomach was collected in July and none in August.

Dipteran larvae, isopods, and amphipods were eaten by madtoms of all size classes. Only specimens less than 35 mm SL consumed copepods, cladocerans, and ostracods in Dutchman Creek (Fig. 4). These microcrustaceans made up 32.3% of the diet and together with isopods and dipteran larvae, constituted 92% of the total diet numerically. In Silver and Sugar creeks, copepods were the only microcrustacean consumed. They composed only 6.5% of the diet of specimens less than 35 mm SL and were not eaten by larger individuals. Dipteran larvae and isopods constituted over 55% of the diet of all size classes. Annelids, decapods (*Palaemonetes kadiakensis*), and fish were consumed only by individuals over 45 mm SL (Figs. 4, 5).

Isopods and dipteran larvae formed a major portion of the diet in all seasons (Fig.6). Nine taxa of prey, the most

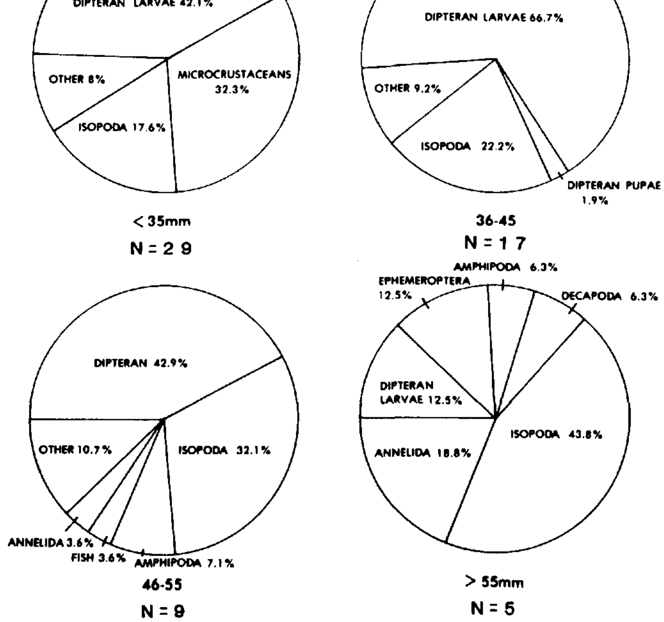

FIGURE 4. Composition of diet of *N. gyrinus* from Dutchman Creek, Illinois, expressed as percentage of total number of food organisms consumed by fish <35 (N = 29), 36-45 (N = 17), 46-55 (N = 9), and >55 (N = 5) mm SL.

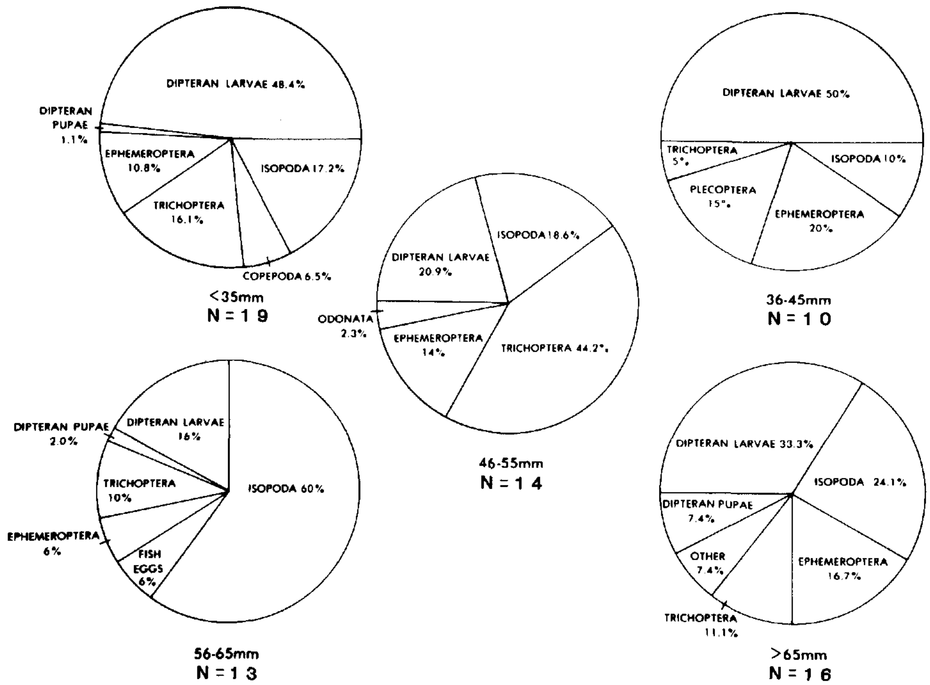

FIGURE 5. Composition of diet of *N. gyrinus* from Silver and Sugar creeks by size class, expressed as percentage of total number of food organisms consumed by fish <35 (N = 19), 36-45 (N = 10), 46-55 (N = 14), 56-65 (N = 13), and >65 (N = 16) mm SL.

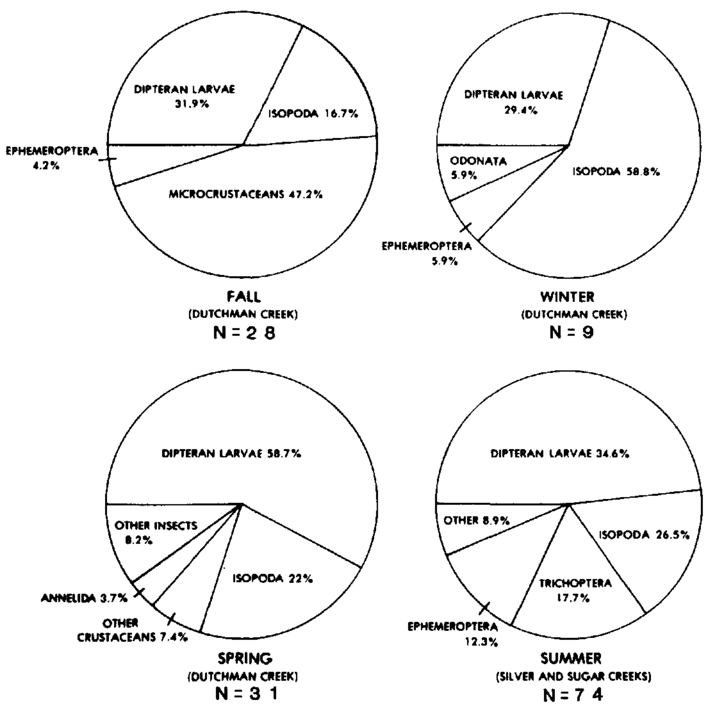

FIGURE 6. Seasonal composition of diet of *N. gyrinus* from Dutchman (N = 68), Silver, and Sugar (N = 74) creeks, Illinois, expressed as percentage of total number of food organisms consumed.

present in the diet in any month, were represented in stomach contents of specimens collected in April 1982 from Dutchman Creek. With the exception of May, the greatest variety of food organisms was consumed from March through October. Oligochaetes were the only non-aquatic food item in the diet. These forms were probably washed into Dutchman Creek by the heavy spring rains. Fish and fish eggs were found in the stomachs of two specimens collected in July. Microcrustaceans, isopods, and dipteran larvae formed over 95.8% of the fall diet. The composition of the diet in the fall reflected the fact that over 86% of the fish collected at that time were young-of-the-year (<35 mm SL), whose diet always consisted of microcrustaceans, isopods, and dipteran larvae. The relative abundance of small *N. gyrinus* at that time may have obscured any seasonal trend in diet.

PREDATION. The stomachs of seven individuals of five species of piscivorous fishes (*Esox americanus, Ictalurus natalis, Micropterus salmoides, Lepomis gulosus,* and *L. megalotis*) that were large enough to have preyed upon *N. gyrinus* in Dutchman Creek were examined; none contained remains of *N. gyrinus* eggs, juveniles, or adults. Although *N. gyrinus* is used as bass bait in some areas, there have been few reports in the literature of predation on this species (Adams and Hankinson 1928). The rock bass, *Ambloplites rupestris,* and the eastern garter snake, *Thamnophis sirtalis sirtalis,* are the only reported natural predators (Evermann and Clark 1920, Lagler and Sayler 1945). Case (1970) tested predation by northern pike, *Esox lucius,* on *N. gyrinus* in aquaria. One individual was eaten after all but one pike had been cannibalized.

The morphology of *N. gyrinus* may preclude, or at least reduce, its acceptability as prey. As Birkhead (1972) noted, madtoms may hold their spines erect, presenting a physical barrier to being swallowed; in addition, they have a toxic sting.

ACKNOWLEDGMENTS. We are grateful to Kevin S. Cummings, Douglas A. Carney, Andrew F. Finkbeiner, James M. Grady, Bernard R. Kuhajda, Richard L. Mayden, John Mellen, Michael A. Morris, and Stephen J. Walsh for assistance in field work. Butch Atwood, Division of Fisheries, Illinois Department of Conservation, donated numerous large samples of *N. gyrinus* in breeding condition from southern Illinois. Without his valuable collections, this study would not have been possible. Karen Schmitt of the SIUC Scientific Photography and Illustration Facility assisted in preparation of the figures. James M. Grady prepared the illustrations of genital papillae. Ronald A. Brandon, Roy C. Heidinger, Richard L. Mayden, and Stephen J. Walsh offered critical suggestions and comments on an earlier draft of the manuscript.

LITERATURE CITED

Adams, C. C. and T. L. Hankinson 1928 The ecology and economics of Oneida Lake Fish. Bull. N. Y. St. Coll. Forestry, Roosevelt Wildl. Annals 1: 235-548.

Bailey, R. M. 1938 The fishes of the Merrimack watershed. *In*: Biological survey of the Merrimack watershed. New Hampshire Fish and Game Surv. Rep. 3: 149-185.

Birkhead, W. S. 1972 Toxicity of stings of ariid and ictalurid catfishes. Copeia 1972: 790-807.

Burr, B. M. and R. L. Mayden 1982a Life history of the brindled madtom, *Noturus miurus,* in Mill Creek, Illinois (Pisces: Ictaluridae). Am. Midl. Nat. 107: 25-41.

——— and ——— 1982b Life history of the freckled madtom, *Noturus nocturnus,* in Mill Creek, Illinois (Pisces: Ictaluridae). Occ. Pap. Mus. Nat. Hist. Univ. Kan. 98: 1-15.

Case, B. E. 1970 An ecological study of the tadpole madtom *Noturus gyrinus* (Mitchill) with special reference to movements and population fluctuations. Unpubl. M. Sc. Thesis, Univ. Manitoba, Winnipeg.

Clark, K. E. 1978 Ecology and life history of the speckled madtom, *Noturus leptacanthus* (Ictaluridae). Unpubl. M. Sc. Thesis, Univ. So. Miss., Hattiesburg.

Clugston, J. P. and E. L. Cooper 1960 Growth of the common eastern madtom, *Noturus insignis* in central Pennsylvania. Copeia 1960: 9-16.

Evermann, B. W. and H. W. Clark 1920 Lake Maxinkuckee, a physical and biological survey. Ind. Dep. Conserv. Publ. 1: 1-660.

Ewers, L. A. and M. W. Boesel 1935 The food of some Buckeye Lake fishes. Trans. Am. Fish. Soc. 65: 57-70.

Forbes, S. A. 1888 Studies of the food of freshwater fishes. Bull. Ill. State Lab. Nat. Hist. 2: 433-473.

——— and R. E. Richardson 1920 The fishes of Illinois. Ill. Nat. Hist. Surv. 357 p.

Gilbert, C. R. 1953 Age and growth of the yellow stone catfish, *Noturus flavus* (Rafinesque). Unpubl. M. Sc. Thesis, Ohio State Univ., Columbus.

Hankinson, T. L. 1908 A biological survey of Walnut Lake, Michigan. Mich. State Bd. Geol. Surv. Rep. 1907: 153-288.

Hooper. F. F. 1949 Age analysis of a population of ameiruid fish, *Schilbeodes mollis.* Copeia 1949: 642-644.

Lagler, K. F. and J. C. Sayler 1945 Influences of availability on the feeding habits of the common garter snake. Copeia 1945: 159-162.

Larimore, R. W. 1981 Progress and challenges of the fishery biologist in warmwater stream investigations, pp. 120-126. *In*: L. A. Krumholz (ed.), The warmwater streams symposium. Proc. Symp. Univ. Tennessee, Knoxville, Southern Div. Am. Fish. Soc.

Lindquist, D. G., P. W. Shute, and J. R. Shute 1982 Spawning and nest site selection by the broadtail and tadpole madtoms: utilization of experimental spawning cover in Lake Waccamaw, N. C. ASIH Program and Abstracts, 62nd Annual Meeting, Northern Ill. Univ., DeKalb.

Mahon, R. 1977 Age and fecundity of the tadpole madtom, *Noturus gyrinus,* on Long Point, Lake Erie. Can. Field-Nat. 91: 292-294.

Mayden, R. L. 1983 Madtoms, America's miniature catfishes. Trop. Fish Hobbyist 31: 66-73.

——— and B. M. Burr 1981 Life history of the slender madtom, *Noturus exilis,* in southern Illinois (Pisces: Ictaluridae). Occ. Pap. Mus. Nat. Hist. Univ. Kan. 93: 1-64.

———, B. M. Burr, and S. L. Dewey 1980 Aspects of the life history of the Ozark madtom, *Noturus albater,* in southeastern Missouri (Pisces: Ictaluridae). Am. Midl. Nat. 104: 335-340.

——— and S. J. Walsh 1984 Life history of the least madtom *Noturus hildebrandi* (Siluriformes: Ictaluridae) with comparisons to related species. Am. Midl. Nat. 112: 349-368.

Menzel, B. W. and E. C. Raney 1973 Hybrid madtom catfish, *Noturus gyrinus* × *Noturus miurus,* from Cayuga Lake, New York. Am. Midl. Nat. 90: 165-176.

Pearse, A. S. 1918 The food of the shore fishes of certain Wisconsin lakes. Bull. U.S. Bur. Fish. 35: 245-292.

Ricker, W. E. 1975 Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can. 191. 382 p.

Taylor, W. R. 1969 A revision of the catfish genus *Noturus* Rafinesque, with an analysis of higher groups in the Ictaluridae. Bull. U.S. Natl. Mus. 282: 1-315.

Thomerson, J. E. 1966 A collection of madtom catfish, *Noturus funebris,* from western Florida. Trans. Ill. State Acad. Sci. 59: 397-398.

Tin, H. T. 1982 Family Ictaluridae, catfishes. pp. 437-457. *In*: N. A. Auer (ed.), Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. Great Lakes Fish. Comm. Spec. Publ. 82-3. 744 p.

Todd, R. D. 1973 Some aspects of the natural history of the tadpole madtom, *Noturus gyrinus.* Proc. Nebr. Acad. Sci. Affil. Soc. 83: 19.

Wang, J. C. S. and R. J. Kernehan 1979 Fishes of the Delaware estuaries: a guide to the early life histories. EA Communications, a division of Ecological Analysts, Inc., Towson, Maryland. 410 p.