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Aspects of the Life History of the Slender Madtom Noturus exilis in Northeastern Oklahoma (Pisces: Ictaluridae)

STEPHEN P. VIVES
Department *of* Zoology, *University* of Wisconsin, Madison 53706

ABSTRACT: The ictalurid, Noturus exilis, was studied from 13 February 1981 to 23 May 1982 in Flint and Cloud creeks in northeastern Oklahoma. Current speed, depth and substrate type in areas occupied by N. exilis were compared with frequency distributions of habitat availability. Noturus exilis were selective in their choice of current speed and substrate type; however, depths were used in the same proportion they were available. Slender madtoms in Flint Creek consumed ephemeropteran naiads and dipteran larvae most frequently by number (57.8% and 25.9%, respectively) and these organisms also occurred in proportionally more stomachs (66.1% and 57.6%, respectively). Compared with N. *exilis* in Green Creek, Illinois (studied by R.L. Mayden and B.M. Burr): (1) Flint Creek N. exilis were smaller at a given age; (2) Flint and Cloud creek N. exilis had a higher percentage of females that were mature in their 1st summer of life (age 0 +); (3) Flint and Cloud creek N. exilis had significantly fewer ova per gram adjusted body weight, and (4) Cloud Creek *N.* exilis had significantly larger ova and Flint Creek N. exilis nearly so.

INTRODUCTION

Several life history studies have been published recently on the ictalurid genus Noturus. These studies have increased our knowledge of N. albater (Mayden et al., 1980), *N.* elegans (Burr and Dimmick, 1981), *N.* exilis (Mayden and Burr, 1981), N. *flavater* (Burr and Mayden, 1984), *N. flavus* (Walsh and Burr, 1985), N. hildebrandi (Mayden and Walsh, 1984), N. miurus (Burr and Mayden, 1982a), *N.* munitus (Miller, 1984) and Nnocturnus (Burr and Mayden, 1982b). Literature reviews on the genus Noturus are available in Taylor (1969), Mayden and Burr (1981) and Mayden and Walsh (1984). Little is known, however, about a Noturus species in different areas of its range (see Walsh and Burr, 1985, for an exception). The present study reports on aspects of the life history of the slender madtom N exilis from the western portion of its range. These results are compared with a study done by Mayden and Burr (1981) on N exilis in Green and Hutchins creeks, Union Co., Illinois.

STUDY AREA

Samples for this study were taken from two streams, Flint and Cloud creeks, located in Delaware Co., Oklahoma. Both sites are located in the Ozark biotic district (Blair and Hubbell, 1938). Both creeks have gravel banks and forested edges, or are lined by limestone outcrops, and are inhabited by "typical" Ozarkian fish assemblages (Miller and Robison, 1973).

Flint Creek is a spring-fed tributary of the Illinois River. The study site has gravel, cobble and rubble substrates and a swift current. Width ranged from 5-30 m and depth to 2 m, but depths were typically less than 0.5 m. Water temperatures varied from 3 C in January 1982 to 28 C in July 1981.

Cloud Creek is a small tributary of Spavinaw Creek, which feeds into the Grand River. This study area is 280 river km and six dams removed from Flint Creek, yet the two sites are only separated by 8 km. Cloud Creek has substrates of gravel, cobble and rubble. Width ranged from 1.5-5 m, depths to 1.5 m.

METHODS

Specimens of Noturus exilis were collected monthly from Flint Creek from 13 February 1981 to 23 May 1982 with the exception that more collections were made in April and May during the 1982 season. One collection was made from Cloud Creek on 23 May 1982 to determine if any differences in reproductive characteristics existed among females in the same area but in different drainages.

Madtoms were collected during daylight by kicking the substrate, upstream of a set 2-m long, 9.5 mm Ace mesh seine. Specimens were fixed in 10% formalin for 3 days, washed in water for 3 days and stored in 40% isopropyl alcohol.

Diurnal habitat use was quantified for 77 madtoms collected from 13 February 1981 to 5 January 1982. A numbered cork, attached to a weight, was placed at each spot where one or more madtoms were taken (Lehtinen, 1982). Habitat measurements were made later (within 6 hr) at each marked location. Depth and current velocity (at 0.6 depth) were determined with a Gurley Pygmy current meter. Substrate was characterized for 0.5 m around the marked location and categorized as silt/sand, gravel, predominantly gravel with at least one cobble or rubble rock present, cobble, predominantly cobble with rubble rock(s) present, or rubble. Silt/sand is defined as substrates up to 1 mm in size, gravel from 1-64 mm, cobble from 64-256 mm, and rubble greater than 256 mm (modified from Hynes, 1970). Habitat measurements were also taken along transects every 5 m (paced off) along the length of the study area (approximately 100 m). At each transect, habitat measurements (i.e., depth, velocity and substrate type) were recorded at approximate 2-m intervals across the stream (patterned after Gorman and Karr, 1978). Distributions from these data could then be compared with frequency distributions of the same measures taken where madtoms were captured. The cumulative distributions were compared using the Kolmogorov-Smirnov (K-S) test (Siegel, 1956). In addition, capture locations for 66 *Noturus exilis* were subjectively classified as "pool," "above riffle," "riffle," "riffle edge" and "below riffle!'

Standard length (SL) in mm and total weight (WT) in g are used throughout unless otherwise indicated (total length is related to standard length by the equation TL =4.4 + 1.09SL, N = 202, r = .98). Adjusted body weight (ADJWT =WT minus stomach, air bladder, kidney and gonads) was used for fish collected 14 May 1982 and 23 May 1982, to provide data comparable to Mayden and Burr (1981).

Stomachs from 76 fish taken 13 February 1981 to 5 January 1982 were excised at the esophagus and separated from the intestine at the pyloric valve. Prey items were identified to the lowest practical taxon.

The fourth or fifth vertebra was removed for age determination. Vertebrae were dried, cleaned and examined at 20-40 power against a dark background with a dissecting microscope. The number of annuli were counted and used in age determination (Gilbert, 1953; Mahon, 1977). Vertebral analysis revealed opaque rings representing fast growth and translucent narrow rings representing slow growth. Narrow rings appeared to be laid down in March-April, prior to spawning. Mayden and Burr (1981) produced similar results aging *Noturus exilis* with pectoral spines. Some fish were difficult to age because of the formation of accessory rings. Gilbert (1953) found that these accessory rings usually occurred before the first annulus and were not as deeply indented into the vertebra as true annuli. Because May and early June coincided with peak spawning activity June was designated month one. Individuals aged from 0-11 months are 0 +, from 12-23 months are 1 =, etc.

Gonads were removed, blotted dry and weighed. Ovary weight was divided by total weight minus stomach weight and gonad weight to determine the gonosomatic index (GSI). Mature ova were counted and an average diameter determined from 10 ova per fish. Ovum diameters were measured using an ocular micrometer.

Statistical methods follow Sokal and Rohlf (1969) unless otherwise stated.

RESULTS AND DISCUSSION

Habitat.—Taylor (1969) and Mayden and Burr (1981) reported *Noturus exilis* were more active at night. My observations support this. Thirty-six (55%) slender madtoms were captured in riffles followed by 14 (21%) above riffles, seven (11%) in pools, six (9%) below riffles and three (4%) along riffle edges. Mayden and Burr (1981) collected 45% of their N exilis in pools during their study. Only eight of 65 madtoms were captured in, or in the immediate vicinity of aquatic vegetation. Miller and Robison (1973) noted, however, that *N.* exilis can be abundant at times in aquatic vegetation.

Noturus exilis were collected from a wide range of current speeds, from 8-92 cm/sec ($\bar{x}$ =37.8, SD =20.97). The average of the monthly means of current speed in Flint Creek was 30.8 cm/sec (SE =0.26). The proportions of current speeds sampled from the habitat and those selected by the madtoms were significantly different (K-S; P< .005; Fig.1). The major differences were that in Flint Creek, N exilis were infrequently found in current speeds below 10 cm/sec and were frequently found at intermediate speeds. When the distribution for smaller madtoms (those less than the median of 61.2 mm SL) was compared to that of larger N. exilis no significant difference (K-S; P> > .05) in current speed distributions was found. Orth (1980) found 90% of *N.* noctumus captured in current speeds of 0-39 cm/sec (range 0-119 cm/sec).

Noturus exilis were captured at depths between 5-42 cm (= 18.2, SD =8.58). The average of monthly means for depth in the sampled habitat was 17.1 cm (SE = 2.47). Depths used by N exilis were not significantly different from the frequency distribution of depths available in the habitat (K-S; P> > .05; Fig. 1). Nearly 90% were collected at depths less than 30 cm. There was no significant difference in depths occupied by smaller madtoms vs. larger madtoms (K-S; P> > .05). Orth (1980) found the highest densities of N noctumus at depths of 10-19 cm.

Although some madtoms were found in or over gravel only, most (61 of 77, 79%) were captured in the presence of at least one rock capable of providing shelter. Shelter must be important to madtoms during the day as a smallmouth bass (Micropterus dolomeui, common in Flint Creek), a visual predator, readily consumed Noturus exilis in the laboratory (S.P. Vives, pers. oberv.). The distribution of substrate availability was significantly different (K-S; P < .001) from the distribution of substrate selected by N exilis (Fig. 1) showing that they prefer larger substrates. There was no significant difference between small and large slender madtoms in their use of substrate (K-S; P> .05).

Age and growth.—The oldest individual captured was a male, 48 months old (70.0 mm SL, 6.67 g total body weight). Most fish were of the 0 +, 1 +, and 2 + year classes (Fig. 2). Sampling error may have been responsible for the low number of 0 + fish taken. Mayden and Burr (1981) captured a 59-month-old male from Green Creek but most madtoms were in the 0 +, 1 +, and 2 + age classes. Most Noturus insignis captured by Clugston and Cooper (1960) were in age groups 1, 2 and 3, only a few age 0 and 4 fish were taken.

The curvilinear equation describing standard length (mm) and age (months) for both sexes was $SL = 31.1 + 1.45A - 0.011A^2$ (r = .86, N =202; Fig. 2). The equations for males and females were not significantly different. No difference between sexes was found in this relationship for Noturus exilis from Green Creek (Mayden and Burr, 1981). Green Creek madtoms, however, appear to attain a greater body length than Flint Creek madtoms at a given age (Fig. 2).

The first-order linear equation for the weight (g) vs. age (months) relationship for both sexes was $WT = 0.253 + 0.149A$ (r = .84, N = 202). Males and females did not differ significantly. Mayden and Burr (1981) found that the growth equations differed significantly between the sexes; however, they used adjusted body weights. Removal of the ovaries from females, especially in larger individuals, could produce the difference in the male and female equations. Adjusted body weights of 35 fish (males and females) collected 14 May 1982 yielded the equation $ADJWT = 0.042 + 0.13A$ (r = .90) indicating the Green Creek madtoms are heavier than Flint Creek madtoms at the same age.

The total weight (g) vs. standard length (mm) equations for males and females were not significantly different. The relationship for both sexes (with logarithmic transformation) is described by $\log_{10} WT = -1.52 + 2.70 \log_{10} SL$ (r = .93, N = 202). Mayden and

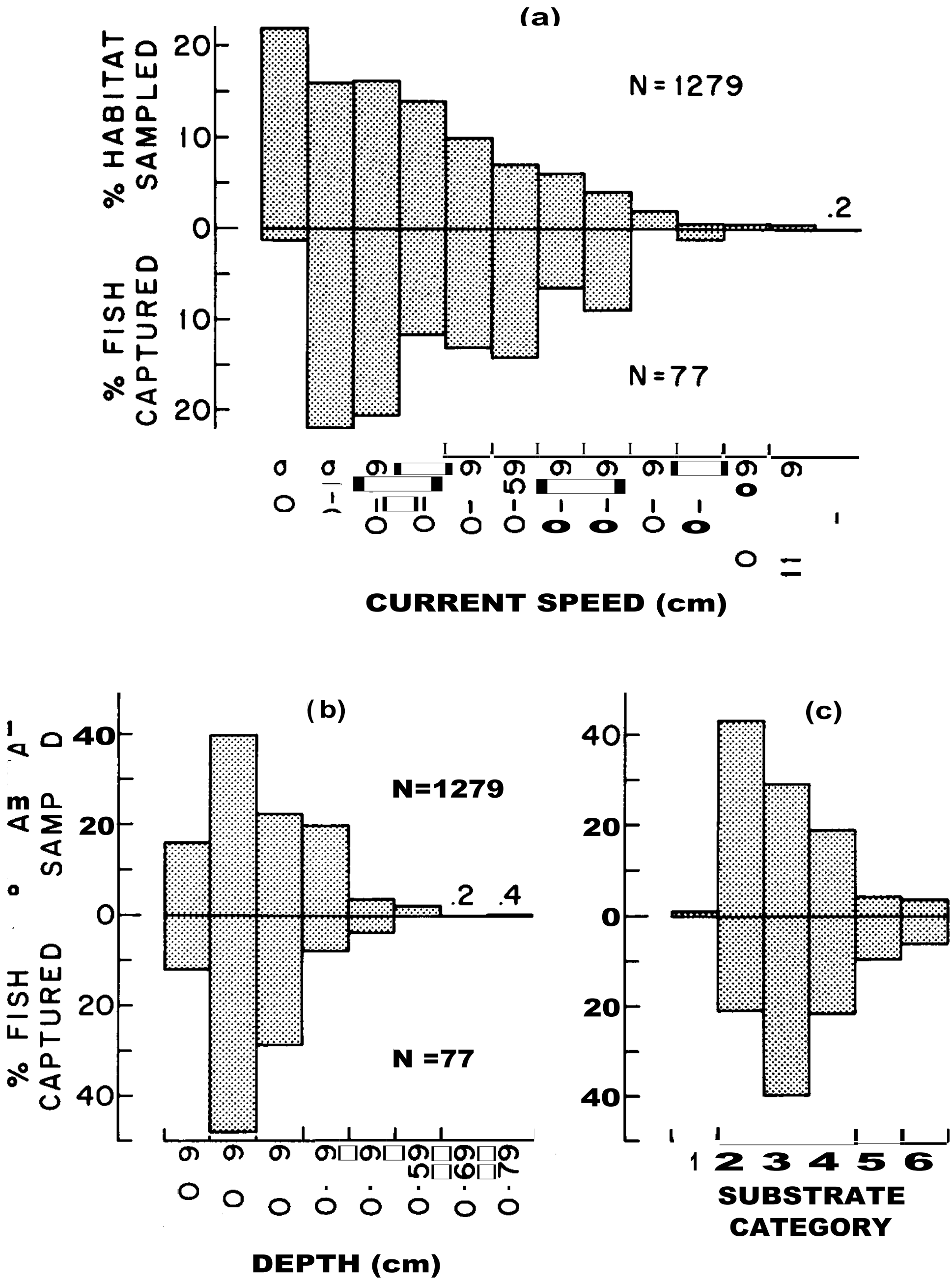

Fig. 1. —The frequency of current speeds (a), depths (b) and substrates (c; silt/sand = 1, gravel =2, predominantly gravel with one or more larger rocks present =3, cobble =4, predominantly cobble with rubble rock(s) present = 5, and rubble =6) compared to the same measures at locations occupied by individual Noturus *exilis* (below)

Burr (1981), using adjusted body weights, found males to be significantly heavier per unit standard length than females in Green Creek. Adjusted body weights taken from the 35 fish collected 14 May 1982 produced the equation $\log_{10}$ ADJWT = -4.88 +3.06 $\log_{10}$ SL (r = .97). Using Mayden and Burr's (1981) combined equation for males and females ($\log_{10}$ ADJWT =-4.77 +2.94 $\log_{10}$ SL), a madtom 65.0 mm SL would be predicted to weigh 4.65 g ADJWT in Flint Creek and 3.63 g ADJWT in Green Creek. Thus, Green Creek madtoms are predicted to be larger (heavier and longer) than Flint Creek madtoms at the same age. However, at the same standard length, Flint Creek madtoms are heavier, i. e., plumper.

Diet. —Ephemer oter an naiads and chironomid larvae constituted 83.7% of the total number of identifiable food items (57.8% and 25.9%, respectively; Table 1). Ephemeropterans and chironomids also occurred in 84.7% of the stomachs that were not empty (66.1% and 57.6%, respectively). Curd (1959) working on Noturus exilis in the Illinois River, Oklahoma (of which Flint Creek is a tributary) found ephemeropterans in 86.9% of the stomachs and chironomid larvae in 80.3% of the stomachs. These data differ from those of Mayden and Burr (1981); in Green Creek, chironomids made up 62.2% of the total diet and ephemeropterans, 10.2%. Chironomids occurred in 72.3% and ephemeropterans in 42.4% of the stomachs examined.

Fish below the median standard length (61.2 mm) were compared to those above the median standard length (Table 1). Larger and smaller fish were equally likely to contain ephemeropterans (73.5% and 56.0%, respectively; z =1.40, P = .16, Sokal and

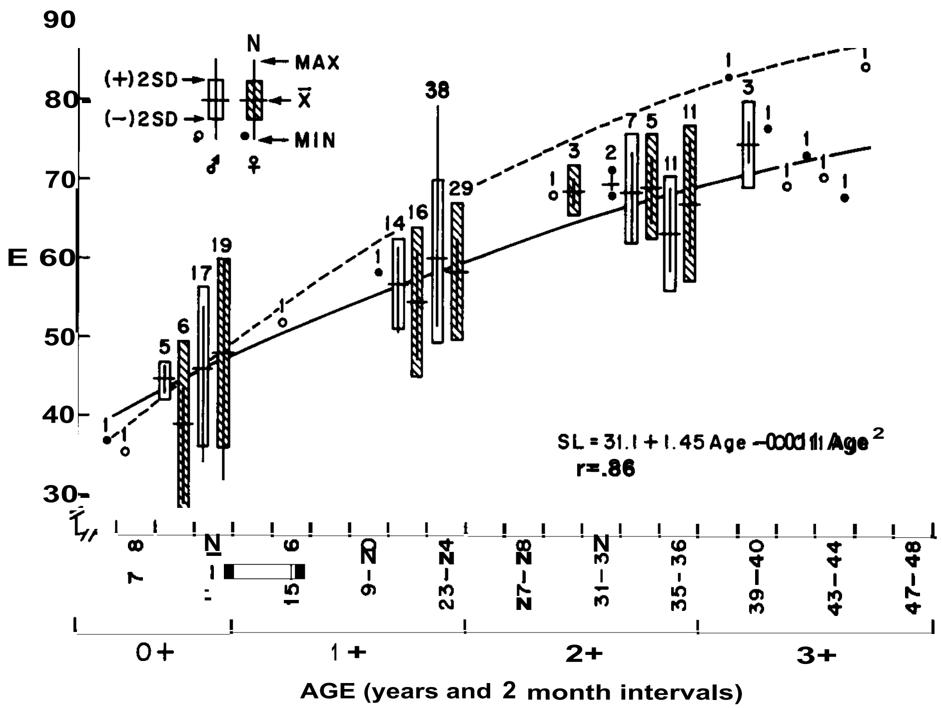

Fig. 2. -The standard length (mm) vs. age (months) relationship for a sample of 202 *Noturus* exilis captured in Flint Creek from 13 February 1981 to 14 May 1982. The solid line is the least squares line for Flint Creek madtoms. The dashed line is the line fit by Mayden and Burr (1981)

Rohlf test of equality of two percentages) and chironomids (52.9% and 64.0%, respectively; $z = 0.86$, $P = .39$). Smaller fish ate significantly more chironomids (38.2%) than larger fish (20.7%; $z = 3.61$, $P < .001$). The variety of other organisms eaten indicate that Noturus exilis is opportunistic, consuming many different food items.

Mayden and Burr (1981) found Noturus exilis had feeding peaks just after dusk and just before dawn. Even though 17 of 76 N exilis stomachs were empty, many stomachs contained undigested items indicating some food is eaten during the day.

Spawning season. -Spawning season was determined by plotting the mean gonosomatic index and mean ovum diameter for each collection against time (Fig. 3). High reproductive condition in Flint Creek madtoms occurred from late April to early June. Similar results were found for Noturus exilis in Green Creek by Mayden and Burr (1981). Extended or multiple spawning may occur because one N. exilis (Okla. State Univ. Museum, Catalog No. 2538) taken on 21 August 1946 from the Illinois River, contained 52 mature ova.

TABLE 1. —Diet of Noturus *exilis* in Flint Creek, Oklahoma

Food item	Percent of stomachs containing item		Percent of total food items	
	<61.2 mm SL	>61.2 mm SL	<61.2 mm SL	>61.2 mm SL
Pelecypoda	• •	2.9	• •	0.3
Oligochaeta	4.0	• •	0.8	• •
Hirudinea	• •	5.9	• •	0.7
Ostracoda	• •	2.9	• •	0.7
Decapoda	• •	2.9	• •	0.7
Isopoda	4.0	8.8	0.8	1.4
Amphipoda	• •	2.9	• •	0.3
Ephemeroptera	56.0	73.5	52.0	60.2
Ephemeridae	4.0	8.8	0.8	1.0
Heptageniidae	12.0	23.5	2.4	5.1
Baetidae	56.0	70.6	48.8	54.1
Odonata	• •	11.8	• •	1.4
Plecoptera	4.0	17.6	0.8	2.4
Nemouridae	• •	2.9	• •	0.7
Perlidae	• •	14.7	• •	1.7
Perlodidae	4.0	• •	0.8	• •
Trichoptera				
Hydropsychidae	12.0	23.5	2.4	6.5
Lepidoptera				
Pyralidae	8.0	8.8	2.4	2.7
Diptera	64.0	52.9	39.0	22.1
Simuliidae	4.0	2.9	0.8	1.4
Chironomidae	64.0	52.9	38.2	20.7
Larvae	64.0	52.9	35.8	19.0
Pupae	12.0	11.7	2.4	1.7
Terrestrial Insecta	8.0	2.9	1.6	0.3
Amphibia				
Plethodontidae	• •	2.9	• •	0.3
Plant material	4.0	2.9	• •	• •
Pebbles	20.0	32.4	• •	• •
Unidentified material	64.0	61.8	• •	• •
Stomachs examined	38	38	• •	• •
Stomachs empty	13	4	• •	• •
Total food items	• •	• •	123	294

Female reproductive maturity.—Thirteen 12-month-old females from Flint and Cloud creeks were examined for reproductive maturity. Females (N = 7) with mature or maturing ova had an average ADJWT of 1.77 g (range 1.29-2.39) and an average length of 47.4 mm (range 43.5-52.0). Females (N = 6) that could not have spawned (no ova enlarging) during the 1982 season had an average ADJWT of 1.23 g (range 0.65-1.78) and length of 42.3 mm (range 33.6-46.5). The lengths of potential spawners were significantly greater than the lengths of nonspawners (Wilcoxon Rank Sum test, P = .013). This suggests that females can spawn in their 1st summer if a critical size is reached. Mayden and Burr (1981) found 35 of 169(21%) 1st summer (0 +) females to be potential spawners. Although my sample size for 0 + females is small, more females may spawn in their 1st summer in northeastern Oklahoma populations than in Green Creek (x^2 = 5.72, P = .025, test of independence with continuity correction).

Fecundity and size *of* ova.—The number of ova increased with increasing ADJWT in Flint and Cloud creeks (Fig. 4). Green Creek madtoms apparently have more ova per unit body weight (Mayden and Burr, 1981). An analysis of variance was used to compare ova/g ADJWT among fish from the three sites. The analysis showed fish from Flint and Cloud creeks have significantly lower means (= 16.21 and 14.76 ova/g, respectively) than those from Green Creek ($\bar{x}$ = 19.64 ova/g) but are not significantly different from each other (AOV F-test, F = 11.53, P<.005; Tukey multiple comparison test alpha = .05). Many of the females that Mayden and Burr (1981) examined for number of mature ova were heavier, having more ova than the females captured from Flint and Cloud creeks. This is due to Green Creek madtoms being larger than those from Flint and Cloud creeks at the same age.

Fish from Cloud Creek have larger mature ova ($\bar{x}$ = 2.94 mm) than fish from Green Creek (=2.48 mm; AOV F-test, F =3.73, P< .05; Tukey multiple comparison

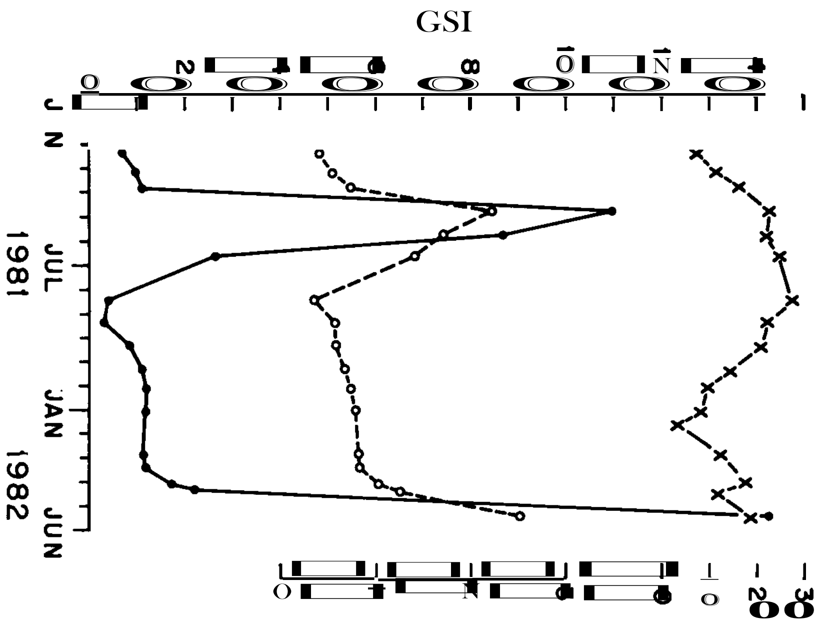

Fig. 3. —Gonosomatic Index (ovary weight divided by body weight (g) minus the stomach weight and ovary weight and multiplied by 1000), average water temperature on a collecting day, and mean ovum diameter plotted against collecting dates

test). Ova diameters of fish from Flint and Cloud creeks were not significantly different and the average diameter of ova from Flint Creek madtoms (= 2.83) was very close to being significantly different from ova from Green Creek madtoms (using Tukey's multiple comparison test).

Nesting. —One egg cluster of *Noturus exilis* was dislodged during seining on 23 May 1982 at Cloud Creek (water temperature was 22 C). The cluster contained 44 eggs with an average diam of 4.47 mm (range 3.8-4.9 mm, SD = .259). Mayden and Burr (1981) found eggs in a cluster averaged 4.11 mm in diam. Interestingly, many madtoms collected during the spawning season were aggregated, with large numbers occurring in a small area. Perhaps an olfactory signal is employed in mate attraction as in some other ictalurids (Todd, 1971).

Comparison of reproductive strategies. — Madtoms from Flint and Cloud creek populations in northeastern Oklahoma were more similar to each other with respect to number of ova/g ADJWT and ova diameter than either population was to the Green Creek madtoms. This result is expected if regional environmental (biotic and/or abiotic) influences shape life history characteristics. Individuals in northeastern Oklahoma populations do not get as large as Green Creek individuals. One result of this size difference between Illinois and Oklahoma *Noturus exilis* is that more eggs are released over a female's lifetime in Green Creek. Flint and Cloud creek *N. exilis* might be predicted, therefore, to allocate more energy for reproduction (Williams, 1966, Chap. 6). To test whether similar amounts of ovarian mass per unit body weight are invested in, gonosomatic indices were compared among fish from the three sites. No significant differences existed among the three populations (AOV F-test, F = 1.16, $P > .25$) indicating a similar investment in gonadal weight. (It should be remembered that tests among populations for differences in ova diameter and gonosomatic indices are only completely accurate if populations are compared at the same point in maturation, and this could not be controlled.) Fish in the two areas appear to be packaging ova differently, Flint and Cloud creek madtoms containing fewer, larger ova than Green Creek madtoms.

Although Flint and Cloud creek madtoms produce fewer eggs over their lifetime, more energy is invested in each offspring. Hatching at a larger size should better enable the madtom fry to escape death (Williams 1966, Chap. 6). Possible factors affecting survivorship include predation, intraspecific competition and interspecific competition.

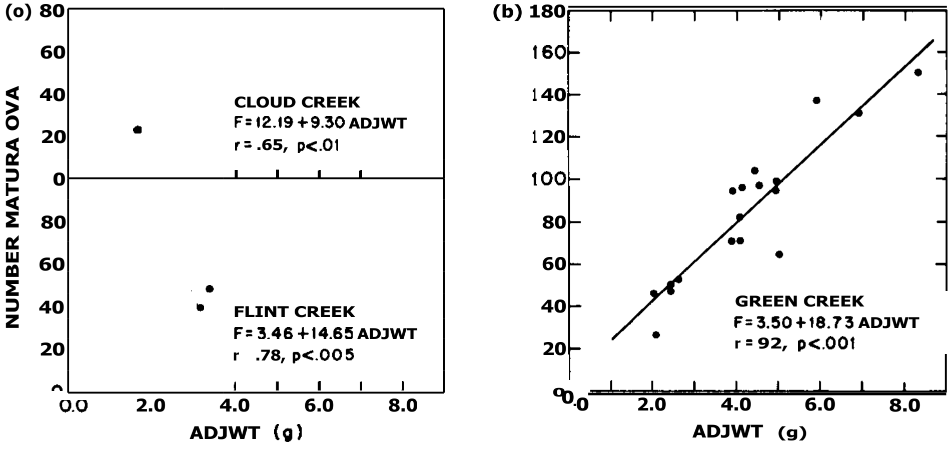

Fig. 4. —The number of mature ova plotted against adjusted body weight (g) for (a) Flint Creek, Cloud Creek and (b) Green Creek *Noturus exilis*. Data on Green Creek fish are taken from Mayden and Burr (1981)

Periods of high discharge and temperature fluctuations are the most important abiotic factors affecting survivorship.

Geographical variation in life history traits has been observed in other fish species (Hubbs, 1958; Hubbs and Johnson, 1961; Carscadden and Leggett, 1975; Schaffer and Elson, 1975; Constantz, 1979; Stearns, 1983). Mechanisms underlying such variation, however, are seldom clear (see Reznick and Endler, 1982, for an exception) and can only be elucidated by experimentation or long-term studies of natural populations.

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