REFERENCES

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LIFE HISTORY OF *ETHEOSTOMA PUNCTULATUM* (PISCES: PERCIDAE) IN NORTHEASTERN OKLAHOMA

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ABSTRACT—The stippled darter, *Etheostoma punctulatum*, was studied from February 1981 to May 1982 in Flint Creek, Delaware Co., Oklahoma. *Etheostoma punctulatum* was captured in riffles and pools, and 68% were caught in or near vegetation or detritus. *Etheostoma punctulatum* was captured in slower water more often than predicted from the habitat available, but depths and substrates were used in proportion to availability. The stippled darter lives to a maximum of 3 years in Flint Creek, and females are larger than males. Ephemeropteran naiads and chironomid larvae are eaten most frequently and found in proportionally more stomachs. *Etheostoma punctulatum* spawns from late winter to early spring, and females had an average of 78.3 (SD = 21.75) mature oocytes per g total weight.

Etheostoma punctulatum (Agassiz), the stippled darter, is the type species of the darter subgenus *Ozarka* (Williams and Robison, 1980) which also includes *Etheostoma boshungi, Etheostoma cragini, Etheostoma pallididorsum,* and *Etheostoma trisella. Etheostoma punctulatum* has been collected in the Ozark highlands of northwestern Arkansas, southern Missouri, southeastern Kansas, and northeastern Oklahoma (Cloutman, 1980). Except for *E. punctulatum*, all members of this subgenus are rare (Page, 1983) or threatened (Deacon et al., 1979); yet, little is known about the biology of this darter. This paper reports aspects of the life history of *E. punctulatum* in Flint Creek, a stream in the Ozark biotic district (Blair and Hubbell, 1938) of northeastern Oklahoma.

MATERIALS AND METHODS—Samples were taken from Flint Creek, a spring-fed tributary of the Illinois River in Delaware Co., Oklahoma. The substrate consisted mostly of gravel and cobbles derived from the limestone and flint bedrock. The main stream channel had a swift current, but pool and backwater areas were present. Width of the stream ranged from 5 to 30 m, and depth ranged from 0 to 2 m but was typically less than 0.5 m. Water temperatures varied from 3°C (in January 1982) to 28°C (in July 1981).

Other species of fish occurring with *E. punctulatum* in this portion of Flint Creek were: *Campostoma anomalum, Nocomis asper, Notropis nubilus, Notropis pilsbryi, Notropis rubellus, Phoxinus erythrogaster, Semotilus atromaculatus, Hypentelium nigricans, Ictalurus natalis, Noturus exilis, Fundulus catenatus, Fundulus olivaceus, Gambusia affinis, Labidesthes sicculus, Cottus carolinae, Amploplites rupestris, Lepomis cyanellus, Lepomis macrochirus, Lepomis megalotis, Lepomis microlophus, Micropterus dolomieui, Micropterus punctulatus, Micropterus salmoides, Etheostoma blennioides, Etheostoma spectabile, Etheostoma zonale,* and *Percina caprodes.*

Specimens of *E. punctulatum* were collected approximately monthly from 13 February 1981 to 23 May 1982 (n = 101) with more collections made during the spring of 1982. Methods used were the same as in Vives (1987). Fish were collected during daylight hours with a 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 then preserved in 40% isopropyl alcohol.

Habitat measurements (depth, current velocity, substrate type) for 37 *E. punctulatum* collected from 13 February 1981 to 5 January 1982 were made at each capture location (Lehtinen, 1982). Depth and current velocity (at 0.6 of depth) were determined with a Gurley Pygmy current meter. Substrate was characterized for a 1-m circle centered on the capture 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. Habitat measurements were also made along transects every 5 m (paced off) along the length of the study area (approximately 100 m). At each transect, habitat measurements were recorded at approximate 2-m intervals across the stream (patterned after Gorman and Karr, 1978). Distributions of habitat availability could then be compared with distributions of habitat use. The cumulative distributions were compared using the Kolmogorov-Smirnov (K-S) test (Siegel, 1956). Capture locations for 35 *E. punctulatum* were subjectively classified as "pool," "above riffle," "riffle," "riffle edge," and "below riffle." The presence of vegetation or detritus within 0.5 m of the capture location was also noted.

Standard length (SL) in mm and total weight (TW) in g were used unless otherwise indicated (total length = 0.897 + 1.172 SL, $n = 101$, $r = 0.996$). Length frequency and scale analysis were used to age the fish.

Stomachs were excised at the esophagus and separated from the intestine at the pyloric valve. Prey items were identified to the lowest practical taxon. Diets of stippled darters smaller than the median SL (45.5 mm) were compared to those larger than the median SL using a test-of-equality of two percentages (Sokal and Rohlf, 1969).

Gonads were removed, blotted dry, and weighed. Gonad weight was divided by TW minus stomach, intestine, and gonad weight to determine the gonosomatic index (GSI). Mature oocytes were translucent orange and, when fully mature, were ovoid with a visible micropyle. Oocytes greater than 0.6 mm in diameter were counted and plotted against TW. Oocyte diameters were measured using an ocular micrometer, and an average diameter was determined from 10 oocytes per fish.

RESULTS AND DISCUSSION—*Habitat*—The preferred habitat of *E. punctulatum* has been described as small chert-bottomed streams with pools, backwaters, organic debris, and vegetation present (e.g., Blair 1959; Branson, 1967; Miller and Robison, 1973). Of 35 *E. punctulatum* for which stream aspect was recorded, 5.7% were above riffles, 40% in riffles, 22.8% at riffle edges, and 31.4% in pools. None were caught in raceways immediately below riffles, where the current is often fastest and the substrate scoured. Sixty-eight percent ($n = 37$) were captured in (or within 0.5 m of) vegetation, algae, sticks, or leaves.

Although sample sizes were small, *E. punctulatum* occupied both fast water and slow water areas in Flint Creek. *Etheostoma punctulatum* was collected in currents of 0 to 66 cm/s ($X = 20.9$, $SD = 16.29$), depths of 4 to 47 cm ($X = 15.6$, $SD = 8.32$), and substrate sizes of gravel to rubble (Fig. 1). The average of the monthly means of current speed in Flint Creek was 30.8 cm/s ($SE = 0.26$), and the average depth was 17.1 cm ($SE = 2.47$). Of current speed, depth, and substrate size, only current speed distributions (available versus used) were significantly different (K-S test, $P < 0.05$; Fig. 1). It appears that *E. punctulatum* is found in slower water more often than predicted from the habitat available but that depths and substrates are used in proportion to availability.

Age and Size—The length frequency (Fig. 2) and scale analysis data indicated most *E. punctulatum* belonged to age classes 0+ (0 to 11 months), 1+ (12 to 23 months), and 2+ (24 to 35 months). Two females (69.5 and 74.5 mm) collected on 5 December 1981 and one female (64.0 mm) collected on 20 February 1982 were 2+ and 3 years old. No fish 3+ (36 to 47 months) years old were collected. These results are similar to those of Ryon (1986) who found one *E. trisella* to be 3+ , but most were of the 0+, 1+, and 2+ age classes. *Etheostoma cragini* lives to a maximum of 3 years (Taber et al.,

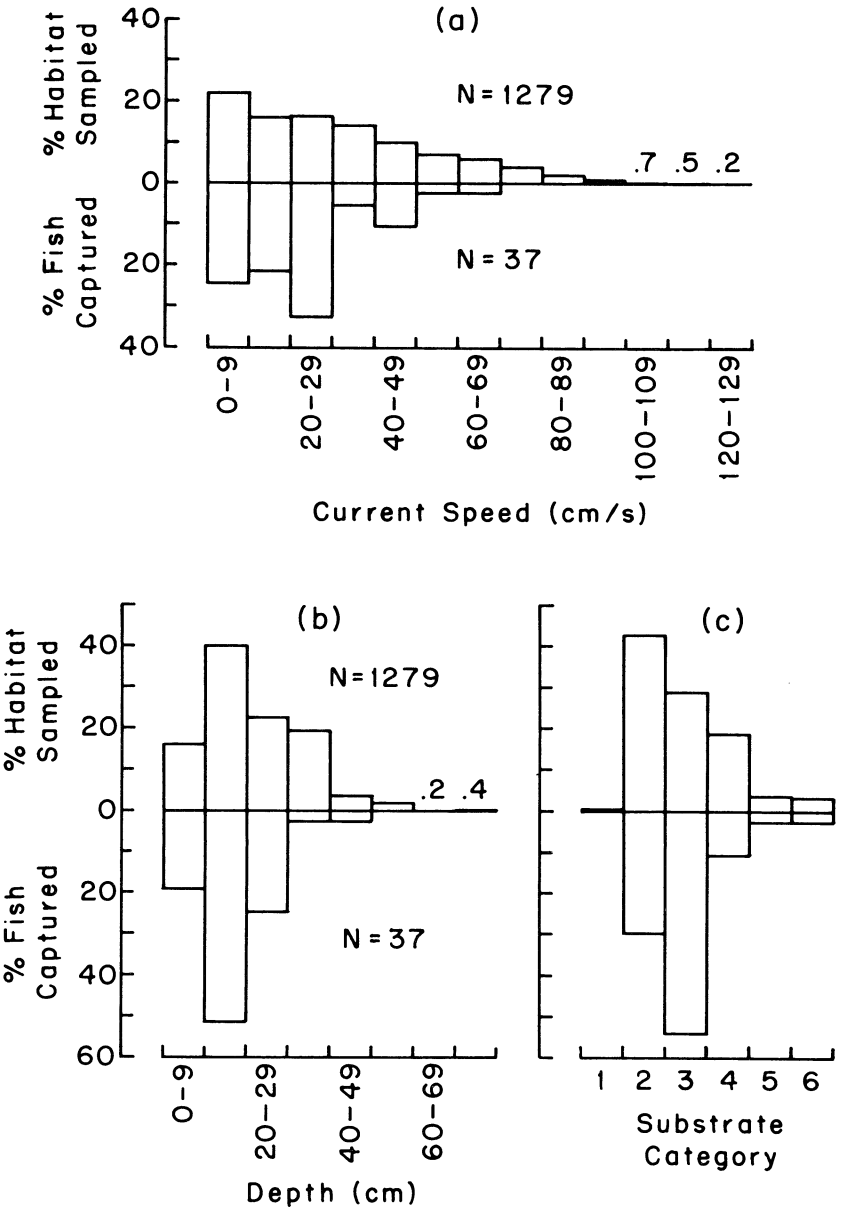

FIG. 1—The frequency of current speeds (a), depths (b), and substrates (c; silt/sand = 1, gravel = 2, predominantly gravel with one or more larger rocks present = 3, cobble = 4, predominantly cobble with rubble rock(s) present = 5, and rubble = 6) compared to the same measures at locations occupied by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

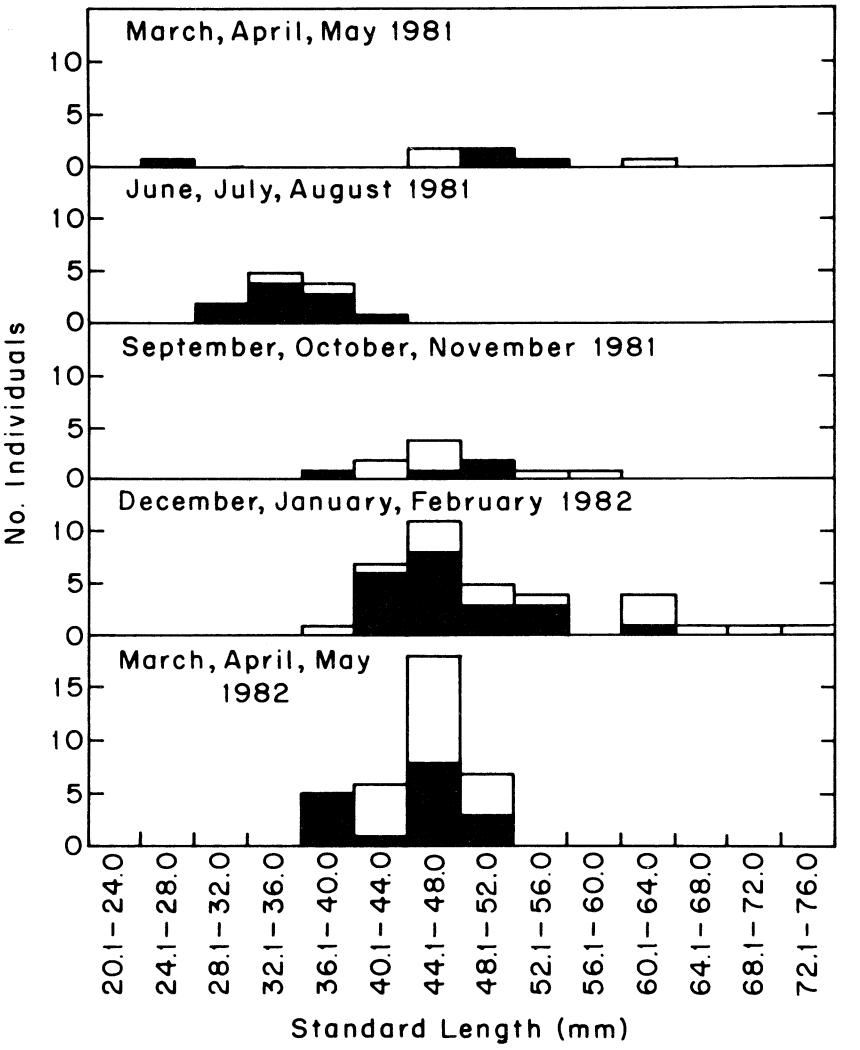

FIG. 2—Length-frequency histograms for *Etheostoma punctulatum* collected from 13 February 1981 to 23 May 1982 in Flint Creek, Oklahoma (open bars = females, closed bars = males).

1986), and Hambrick and Robison (1979) found that *E. pallididorsum* lives to a maximum of 2 years.

The largest individual collected in Flint Creek was a female 74.5 mm SL and 8.09 g TW. Kuehne and Barbour (1983) reported the maximum size for *E. punctulatum* as 88 mm SL. Females in Flint Creek attain a greater size than males. The largest 7 of 101 darters collected were females, and females also attained a significantly greater weight at the same SL. The relationship for females was $\log_e TW = -12.15 + 3.33 \log_e SL$ and for males $\log_e TW = -11.19 + 3.08 \log_e SL$ ($F = 5.046$, $P = 0.03$). In Missouri, female *E.*

TABLE 1—Diet of *Etheostoma punctulatum* in Flint Creek, Oklahoma. Fish were examined as two size classes: (A) less than 45.5 mm standard length ($n = 50$); (B) greater than 45.5 mm standard length ($n = 49$).

	Percent of stomachs containing item[2]		Percent of total food items	
Food item[1]	A	B	A	B
Cladocera	0.0	3.4	0.0	0.7
Isopoda	11.4	27.6	3.1	9.1
Amphipoda	13.6	6.9	8.6	4.9
Ephemeroptera				
Heptageniidae	22.7	10.3	6.2	3.5
Baetidae	77.3	51.7	50.0	29.4
Plecoptera				
Nemouridae	0.0	10.3	0.0	2.1
Perlodidae	2.3	0.0	0.6	0.0
Trichoptera				
Hydropsychidae	6.8	10.3	2.5	2.1
Lepidoptera				
Pyralidae	0.0	3.4	0.0	0.7
Coleoptera				
Psephenidae	2.3	3.4	0.6	0.7
Diptera				
Chironomidae	6.8	48.3	27.8	46.2
Culicidae	0.0	3.4	0.0	0.7
Terrestrial Insecta	2.3	0.0	0.6	0.0
Pebbles	2.3	3.4	0.0	0.0
Unidentifiable Material	18.2	31.0	0.0	0.0

[1]Total number of food items was 162 (A) and 143 (B).
[2]Number of empty stomachs was 6 (A) and 20 (B).

punctulatum were also found to be larger than males (Taber et al., 1986). Female *E. pallididorsum* and *E. cragini* are larger than males as well (Hambrick and Robison, 1979; Taber et al., 1986). Page (1983) concluded that only in the darter subgenera *Ozarka* and *Boleichthys* were the females larger than the males. He attributed this phenomena to the lack of territoriality in the species of these subgenera.

Diet—The diet of *E. punctulatum* consisted of small crustaceans and aquatic insects. Baetid mayfly naiads and chironomid larvae were eaten most frequently and also were in proportionally more stomachs (Table 1). Larger darters (greater than 45.5 mm SL) were more likely to contain chironomid larvae ($z = 3.65$, $P < 0.001$, test-of-equality of two percentages) and less likely to contain baetid naiads ($z = 2.84$, $P = 0.005$). In addition, larger darters ate more chironomid larvae ($z = 1.98$, $P = 0.05$) and fewer baetid naiads ($z = 2.24$, $P = 0.025$). These results are surprising in that chironomid larvae are smaller than most baetid naiads. Ryon (1986) reported that *E. trisella* contained chironomid larvae most frequently (70.0%) followed by ephemeropteran naiads (19.0%). Taber et al. (1986) found that *E. cragini* contained primarily isopods (58% by volume), ephemeropterans (12% by volume), and chironomids (8% by volume). *Etheostoma pallididorsum* contained cladocerans, ephemeropteran larvae, and dipteran larvae most often, and ephemeropteran larvae were the largest component volumetrically (Hambrick and Robison, 1979).

Reproduction—Females with mature oocytes were collected on 9 March 1981 (n = 1, average water temperature (AWT) = 11.1°C), 28 March 1981 (n = 1, AWT = 16°C), 5 January 1982 (n = 2, AWT = 8.0°C), 17 January 1982 (n = 2, AWT = 3.0°C), 20 February 1982 (n = 1, AWT = 12.5°C), 27 February 1982 (n = 3, AWT = 7°C), and 3 April 1982 (n = 1, AWT = 17.5°C). By 5 December 1981 (AWT = 9.5°C), males and, to a lesser extent, females showed dark orange and black spawning coloration. *Etheostoma punctulatum* in Flint Creek appears to be a late winter, early spring spawner. The gonosomatic index plotted against collection date (Fig. 3) suggests a spawning season from January to April. The stippled darter has been observed spawning in other northeastern Oklahoma streams in late winter (S. F. Lehtinen, pers. comm.) and has been reported to breed from mid-February through mid-May near Fayetteville, Arkansas (Hubbs, 1985) and from early February to May near Verona, Missouri (Taber et al., 1986). Moore and Paden (1950) also suggested that *E. punctulatum* was an early spring or winter breeder. This pattern of spawning early in the year is shared by other members of this subgenus. Ryon (1986) found that *E. trisella* spawns from January to March. *Etheostoma boschungi* is an early spawner (Page, 1983); egg and sperm were easily stripped from *E. cragini* on the 25 March 1918 (Ellis and Jaffa, 1918), and Taber et al. (1986) report the spawning season of *E. cragini* to be from mid-February to mid-July. In Arkansas, *E. pallididorsum* reached maximum spawning activity in February and March (Hambrick and Robison, 1979).

The average diameters of maturing oocytes ranged from 0.69 mm to 1.39 mm (X = 1.08, SE = 0.668, n = 11 individuals). Water hardened eggs stripped from *E. punctulatum* captured near Fayetteville, Arkansas, averaged 1.50 mm (Hubbs, 1967). Oocytes measured from preserved *E. pallididorsum* ranged in diameter from 0.70 to 0.90 mm (Hambrick and Robison, 1979). Diameter of oocytes ranged from 0.95 mm to 1.09 mm in *E. trisella* (Ryon, 1986) and from 0.95 mm to 1.1 mm in *E. cragini* (Taber et al., 1986).

The number of mature oocytes (F) from *E. punctulatum* collected in Flint Creek was positively correlated (r = 0.91, $P < 0.01$) with TW (Fig. 4). This relationship is described by the regression equation F = 25.25 + 68.86 TW (F = −489.39 + 13.95 SL). Hubbs (pers. comm.) counted translucent eggs from *E. punctulatum* captured in Arkansas, and the regression equation computed from his data is F = −178.43 + 6.89 SL (r = 0.62, n = 37). The Arkansas and Oklahoma data on fecundity versus SL need to be investigated further to determine if a real geographic difference exists, or if the difference is due to sample size effects and differing counting techniques. *Etheostoma punctulatum* from Flint Creek had from 63 to 447 mature oocytes per female (X = 78.3 per g TW, SD = 21.75). The range in number of oocytes per female is higher than ranges reported from other members in the subgenus *Ozarka*. *Etheostoma trisella* had 56 to 154 mature oocytes per female (Ryon, 1986), and *E. pallididorsum* 21 to 134 mature oocytes per female (89.74 per g TW; Hambrick and Robison, 1979). Even though sample size was small, two distinct groups appeared, representing those females spawning at age 1+ and those spawning at age 2+ (Fig. 4).

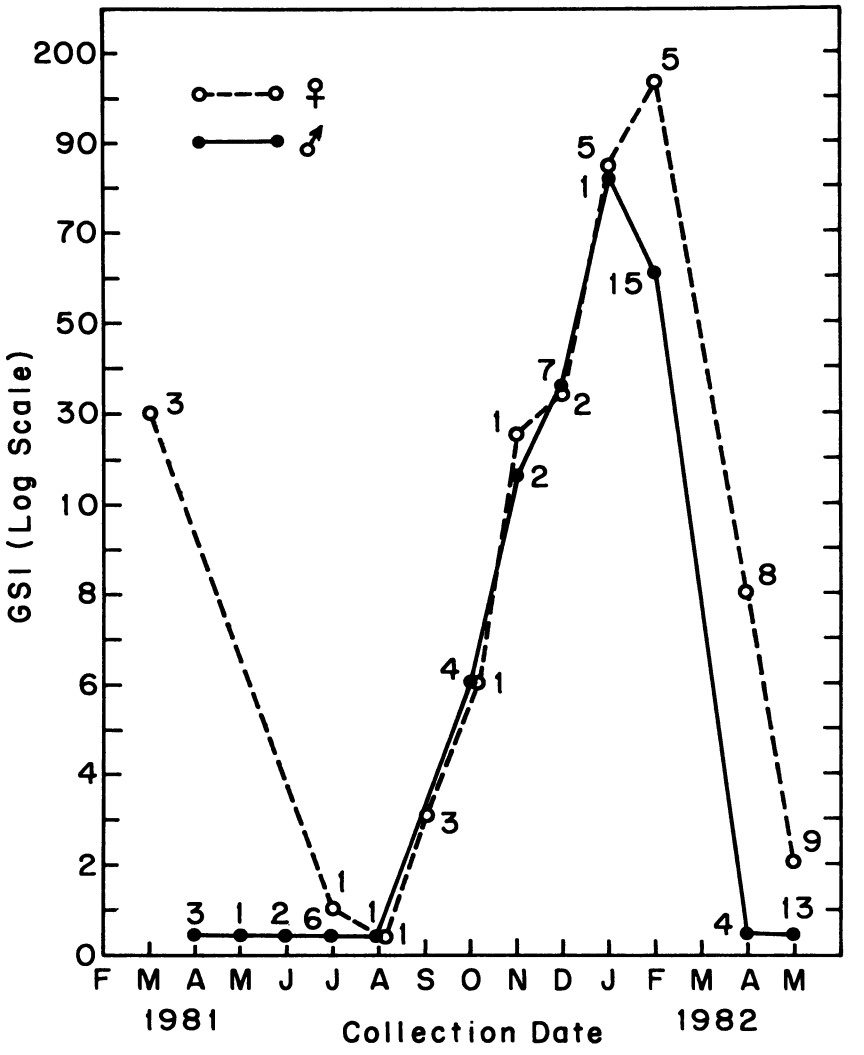

FIG. 3—Gonosomatic index (ovary weight divided by body weight minus the stomach weight and ovary weight and multiplied by 1,000; weights in g) plotted against time. Sample size for each point is given.

Status—Although *E. punctulatum* is not the dominant darter species in any stream of which I am aware, it is locally common in the Ozark highlands. Pflieger (1975) noted, however, that *E. punctulatum* may be less common in the southeastern Ozarks than it was before 1900. Three members of the subgenus are listed as threatened by Deacon et al. (1979). Habitat destruction is listed as the reason for reductions in the population sizes of these species. The numbers of *E. punctulatum* should, therefore, be carefully monitored as changes in Ozarkian watersheds occur. Many of the

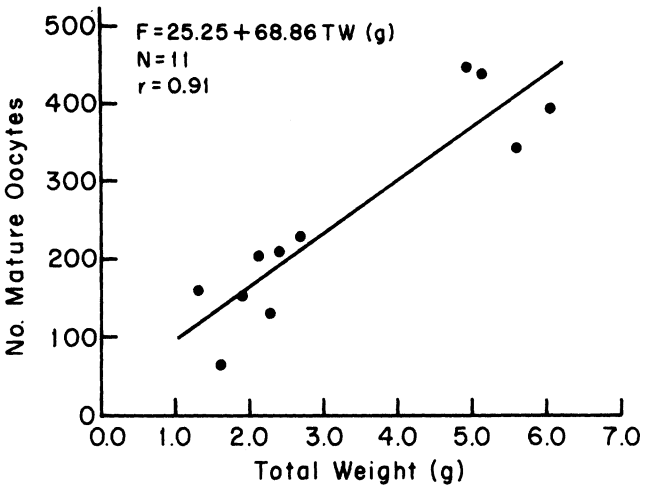

FIG. 4—The number of mature oocytes plotted against total body weight (g) for *Etheostoma punctulatum*.

streams that are currently suitable for *E. punctulatum* are being modified by impoundment, tourism, siltation, and pollution from treatment facilities.

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