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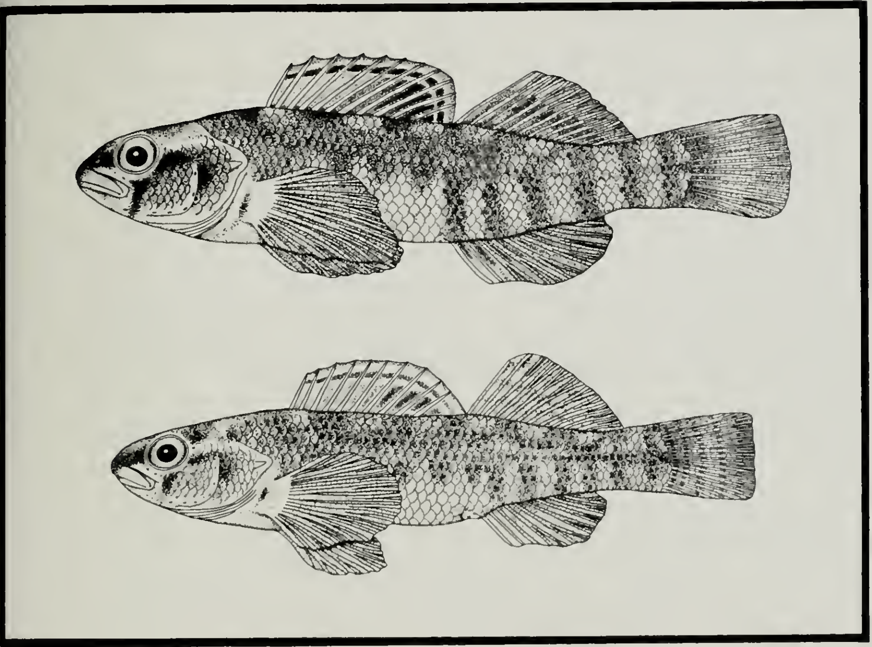
ILLINOIS NATURAL
HISTORY SURVEY

THE LIFE HISTORY OF THE MUD DARTER, *Etheostoma asprigene*, IN LAKE CREEK, ILLINOIS

KEVIN S. CUMMINGS, JAMES M. GRADY, and BROOKS M. BURR



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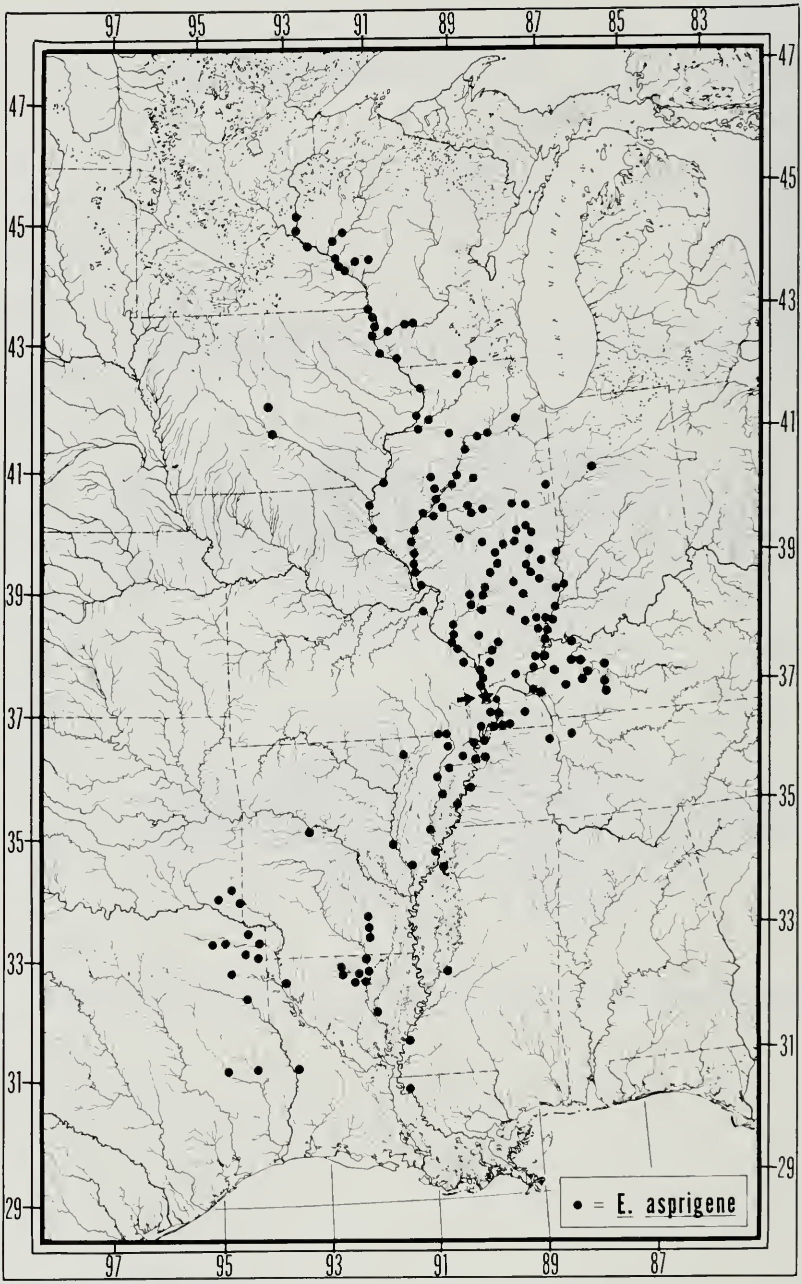

Fig. 1.—Range of *Etheostoma asprigene*. The study area is denoted by the star. Map modified from Page (1983:251).

THE LIFE HISTORY OF THE MUD DARTER, *ETHEOSTOMA ASPRIGENE*, IN LAKE CREEK, ILLINOIS

Kevin S. Cummings, James M. Grady, and Brooks M. Burr

The mud darter, *Etheostoma (Oligocephalus) asprigene*, was described by Stephen A. Forbes *in* Jordan (1878:41) as *Poecilichthys asprigenis* from 14 specimens collected in a small creek near Pekin, Illinois. Natural history studies of *E. asprigene* have been limited to food habits (Forbes 1880:25; Forbes & Richardson 1920:309), age and growth (based on eight specimens, Lutterbie 1979:5–6), spawning behavior (Page et al. 1982:140), and parasites (Whitaker & Schlueter 1975:446). Kritsky & Leiby's (1971) reference to parasites of *E. asprigene* is certainly based on a misidentification of *E. exile*, as North Dakota is approximately 900 river miles (1,440 river km) beyond the known range of the mud darter.

This investigation of the life history of *E. asprigene* in southern Illinois was undertaken to supplement scant ecological information on the species and on the subgenus *Oligocephalus* as a whole. Species of *Oligocephalus* generally are poorly known ecologically; there is little or no published information regarding any aspect of the life history of 11 of the 15 species (Page 1983).

The mud darter is a lowland species widely distributed in the Mississippi drainage and the Sabine and Neches River drainages of Texas. It occurs in 13 states: from Minnesota, Wisconsin, and Iowa south to Louisiana and Mississippi and west into Texas (Fig. 1). It is known from numerous localities in Illinois and western Kentucky where it may be common locally (Smith 1979:276; Burr & Mayden 1979:63). *E. asprigene* is considered rare in Wisconsin (Johnson & Becker 1970:289), threatened in Iowa (Roosa 1977), of peripheral status in Texas (Hubbs 1976:7), and rare and endangered in Kentucky (Miller 1972:247–251). However, recent collections from Kentucky have shown *E. asprigene* to be more common than previously thought; it was not placed on a recent listing of endangered, threatened, and rare animals and plants of Kentucky (Branson et al. 1981).

Etymology: *Etheostoma*, from the Greek *etheo*, "to strain," and *stoma*, "mouth"; *asprigene* from the Latin *asper*, "rough," and *gena* "the cheek;" in reference to the fully scaled cheek and opercle.

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STUDY AREA

The area selected for the study was a small, unnamed tributary to Lake Creek, Alexander County, Illinois (T16S, R2W, Section 12), which supports a large population of *E. asprigene*. The study area is located at the Illinois Route 3 bridge, 1.0 km west of Illinois Route 127 (Fig. 2). The creek, hereafter referred to as Lake Creek, is a short (about 8 km long) tributary to the Cache River, which meanders through cultivated fields upstream and patches of forested land downstream.

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Cover Illustration. — Male (top) and female (bottom) *Etheostoma asprigene* collected in Lake Creek, Alexander County, Illinois. From a drawing by Kevin S. Cummings.

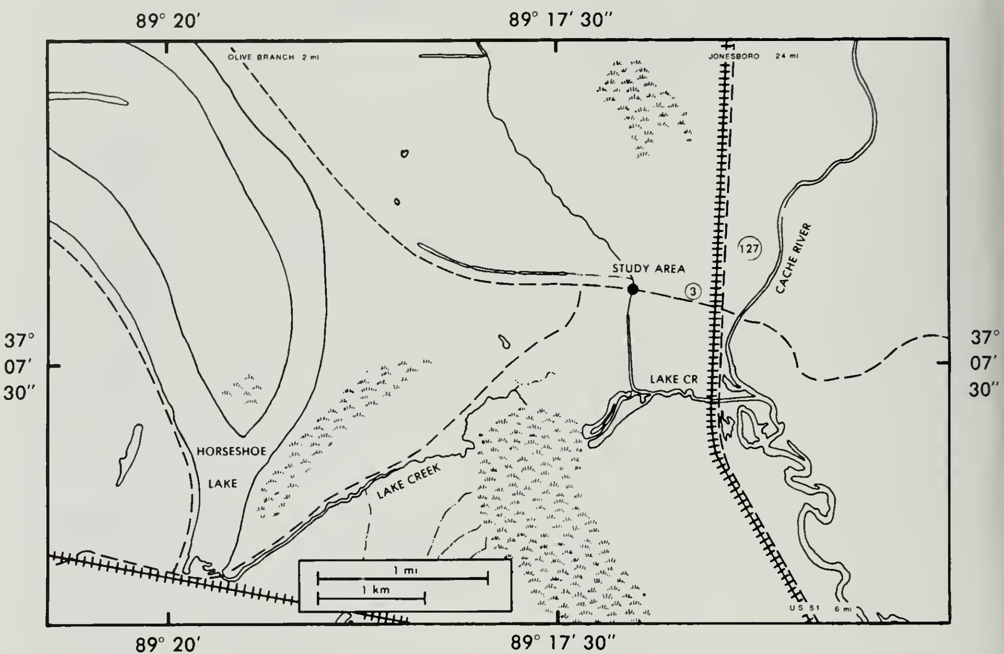

Fig. 2.—The *Etheostoma asprigene* life history study area, Lake Creek at Illinois Route 3 bridge, 1.0 km west Illinois Route 127, Alexander County, Illinois.

The study area was adjacent to a soybean field but was bounded by trees. During periods of low water, a few gravel riffles, mud-bottomed pools, and scattered areas of protruding cypress stumps were present (Fig. 3A). At low water, the creek was 3.0–6.1 m wide with riffles approximately 15 cm deep and pools about 1.0 m deep. Substrate in the riffles was a mixture of clay, gravel, mud, and detritus. In spring and summer, rooted vegetation grew along the banks, and filamentous algae covered the rocks. A short (5 m) gravel raceway was located about 50 m downstream from the Route 3 bridge. During spring floods, the creek overflowed its banks and inundated the adjacent soybean field, and the main channel was 4.5 to 6.0 m deep (Fig. 3B). Water temperatures varied from 0°C in December to 27°C in August.

A total of 36 species of fishes was collected at the study site (Table 1). The fishes most often associated with *E. asprigene* in descending order of abundance were *Notropis lutrensis*, *Noturus gyrinus*, and *Gambusia affinis*. Two other species of darters, *Etheostoma chlorosomum* and *E. gracile*, occur at the study site. Both are typically pool-inhabiting species (Page 1983:93,155) and were occasionally associated with *E. asprigene*.

METHODS

Methods of study were the same as those employed by Page in the study of *E. squamiceps* (1974:4–5), except as noted below. Observations and minnow-seine collections were made at approximately 1-month intervals between 19 October 1979 and 22 September 1982, except during periods of high water when specimens could not be collected, and during the spawning period when biweekly observations were made. Approximately 30 specimens of *E. asprigene* and associated fishes were collected each month; a total of 758 *E. asprigene* was examined. All specimens collected for laboratory examination were preserved in 10-percent formalin, stored in 70-percent ethanol, and deposited in the ichthyology collection of the Department of Zoology, Southern Illinois University at Carbondale.

In the laboratory, adults were sexed by examination of genital papillae; juveniles were sexed by examination of gonads. Standard lengths (SL) of all specimens were measured to the nearest 0.1 mm with dial calipers. Measurements of larvae, expressed as total length (TL) to the nearest 0.01 mm, were made with an ocular micrometer. Representatives of all age and size classes from each

Fig. 3.—Lake Creek at Illinois Route 3 bridge. A, Low water stage, 3 March 1983; B, high water stage, 10 June 1982.

monthly collection were examined for ecto- and endoparasites and subsequently dissected to determine stomach contents and condition of the gonads. Stomach contents were removed, identified, counted, and analyzed for differences among size classes and month of collection. Stomach contents of potential predators collected with *E. asprigene* were also examined.

Age estimates were made by use of length-frequency histograms and reading of scale annuli. Scales examined were taken from the dorsum above the lateral line at the junction of the first and second dorsal fins and below the lateral line at the tip of the depressed pectoral fin. Approximately eight scales were removed from each area, dry mounted between glass microscope slides, and read with the aid of a projecting microscope. In ageing to month, month zero was March, the month of the greatest breeding activity (Page 1974:5).

Gonad weights and adjusted body weights (weight of specimens minus the gonads, stomach, intestines, and liver) of approximately 10 darters (five males, five females) from

TABLE 1.—Fishes collected with *Etheostoma asprigene* in Lake Creek, arranged in descending order of relative abundance. Percentages are of total number of fishes collected, excluding *E. asprigene*.

Species	Percentage
Notropis lutrensis	33.39
Noturus gyrinus	18.17
Gambusia affinis	8.39
Dorosoma cepedianum	6.37
Etheostoma chlorosomum	5.43
Lepomis megalotis	4.19
Etheostoma gracile	3.57
Lepomis macrochirus	3.26
Notropis fumeus	3.10
Fundulus olivaceus	1.54
Notropis atherinoides	1.54
Pimephales notatus	1.54
Campostoma anomalum	1.09
Elassoma zonatum	1.09
Lepomis gulosus	0.93
Notropis umbratilis	0.78
Erimyzon oblongus	0.62
Lepisosteus osseus	0.62
Labidesthes sicculus	0.47
Notropis chrysocephalus	0.31
Phenacobius mirabilis	0.31
Ictalurus natalis	0.31
Ictalurus punctatus	0.31
Aphredoderus sayanus	0.31
Lepomis cyanellus	0.31
Micropterus salmoides	0.31
Pomoxis annularis	0.31
Pomoxis nigromaculatus	0.31
Umbra limi	0.16
Carpoides carpio	0.16
Cyprinus carpio	0.16
Hybognathus nuchalis	0.16
Centrarchus macropterus	0.16
Lepomis humilis	0.16
Lepomis punctatus	0.16

each monthly sample were recorded. The gonadosomatic index (GSI), equal to the weight of the gonads × 1,000/ adjusted body weight, was recorded for both sexes. Mature ova from 12 females were counted and their diameters measured with an ocular micrometer to the nearest 0.01 mm.

Densities and seasonal habitat preferences were determined by repeatedly seining a 4-m² section of pool and riffle until no more darters were collected on 17 November 1979, 18 December 1981, 27 January 1983, 24 February 1983, 6 August 1982, and 22 September 1982.

Reproductive behavior and spawning were observed in the laboratory from darters collected at the study site on 6 March 1982, 24 February 1983, and 3 March 1983. Specimens were placed in 40- and 115-l aquaria at 22°C. Potential spawning sites (sand, gravel, rocks, rooted vegetation, and detritus) were placed in the aquaria and those used were recorded.

Fertilized ova were removed from the aquaria and placed in 300-ml culture dishes with air stones and incubated at 22 ± 2° C. Water in the culture dishes was treated with malachite green to control fungal growth. At 12-hour intervals, one to three embryos or larvae were preserved and stored in 5-percent formalin. Drawings of embryos, larvae, and genital papillae were made with the aid of a camera lucida. Terminology of larval stages follows Snyder (1976:52–53).

HABITAT

Bottomland lakes, sloughs, backwaters, and mouths of large rivers and creeks have been reported as the principal habitats of *E. asprigene* (Greene 1935:184; Harlan & Speaker 1956:151–152; Pflieger 1975:316; Smith 1979:276). In Lake Creek, adults typically occurred in shallow clay, gravel, detritus, and cypress-stump riffles. They were occasionally in shallow-to-deep pools directly upstream or downstream from the riffles. Juveniles occurred more frequently in pools or quiet water areas than in riffles.

REPRODUCTION

Reproductive Cycle of the Male

Males were olive-brown on the body with 6–10 dark brown saddles on the dorsum. During early March–early May they acquired bright nuptial coloration characteristic of members of the subgenus *Oligocephalus* (Page 1983:121). On the sides were 6–8 blue-green vertical bars with reddish-orange interspaces, and the belly was bright orange. The first dorsal fin had a longitudinal dark blue band distally, followed proximally by a thin clear band, a red submarginal band, a thin clear band, and a wide, dark blue basal band best developed posteriorly. The second dorsal and caudal fins had suffusions of red-orange medially, and melanophores developed in rows on their interradial membranes. The anal fin was blue-green and had red-orange spots in a few individuals. Pelvic fins were deep blue-black, and the pectoral fins were clear except for a few scattered melanophores. Orbital bars were black and prominent and the breast was darkly pigmented with melanophores.

Males in aquaria developed an extreme breeding coloration similar to that described by Page (1974:6, 1980:6) for males in the subgenus *Catonotus*. In this color phase, the sides of the body paled, the head and vertical bars became deep blue-black, and a prominent dark scapular bar appeared. The anal and pelvic fins and the bands in the first dorsal fin also darkened.

Other changes associated with the onset of the breeding season included enlargement of the testes and a slight increase in size of the genital papilla. The genital papilla of the breeding male was a broad-based, flattened, flaplike structure pigmented with melanophores (Fig. 4 A,B). As was noted by Collette (1965:601), breeding tubercles do not develop in this species.

For the males examined, the relationship between the GSI (Y) and month (X), with May = 1 and March = 11, was Y = −4.47 + 2.79 X, with r = 0.815. All males

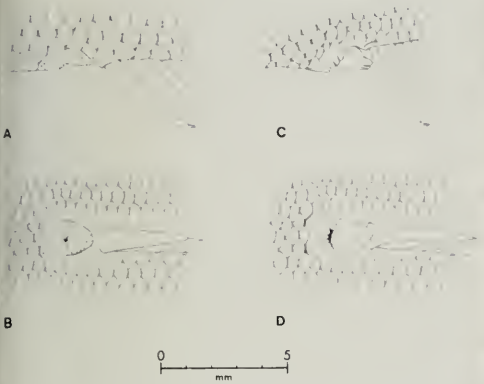

Fig. 4.—Genital papillae of *Etheostoma asprigene* from Lake Creek. A, breeding male 49 mm SL collected 24 February 1983, lateral view; B, ventral view of A; C, breeding female 45 mm SL collected 24 February 1983, lateral view; D, ventral view of C.

collected in March had enlarged testes and were assumed to be potential spawners. However, observations of males in aquaria indicated that large males (>46 mm) were more successful than smaller ones (<41 mm) in competing for available females.

Reproductive Cycle of the Female

The females' coloration remained essentially unchanged throughout the year. A submarginal red band in the first dorsal fin was the only bright color. With the onset of the breeding season (early March), the genital papilla enlarged and the girth increased as ova matured. Females retained these features until early May.

In breeding females, the genital papilla was an unpigmented, enlarged, broad-based, flaplike structure that tapered distally (Fig. 4C, D) and was similar in shape to that of *E. nuchale* (Page 1983:182), a closely allied species (Ramsey & Suttkus 1965:74).

Small white ova ($\bar{x}$ = 0.33 mm in diameter; range = 0.16–0.56, N = 20, SD = 0.08) were present in females collected in October. Larger yellow ova ($\bar{x}$ = 0.73 mm in diameter; range = 0.64–0.80, N = 20, SD = 0.06) appeared in females in December, and large, mature, orange-to-translucent ova ($\bar{x}$ = 1.06 mm in diameter; range = 0.96–1.20, N = 20, SD = 0.06) were present from late February to early May. Most of the May specimens had already spawned and only one contained mature ova. Just prior to spawning, the mature ova of *E. asprigene* were spherical with a pitlike indentation (Fig. 5). Similar and as yet unexplained indentations have been described in a number of darter species, including *E. proeliare, E. fonticola, E. microperca, E. olivaceum, E. striatulum,* and *E. caeruleum* (Page 1980:7; Burr & Page 1978:6, 1979:5; Burr & Ellinger 1980:556; Grady & Bart 1984:75).

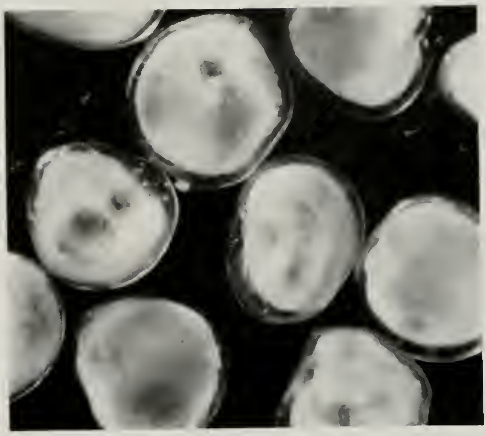

Fig. 5.—Mature ova removed from an *Etheostoma asprigene* collected in March.

All females examined were mature at 1 year of age and probably would have spawned. The number of mature ova from 12 females collected in March ranged from 72 to 346, $\bar{x}$ = 167.9 (Table 2). The largest females produced the greatest number of mature ova. Within *Oligocephalus, E. asprigene* produced more mature ova than has been reported for individuals of comparable size in other species (Scalet 1973a:160; Hubbs 1958:103; Ramsey & Suttkus 1965:76; Hubbs et al. 1968:313; Grady & Bart 1984:75). However, the size of mature ova is comparable to that of other egg-attaching species of darters (Page 1983:169). The relationship between number of mature ova (M) and adjusted body weight (W) was M = 54.74 + 145.41 W, with r = 0.771; between number of mature ova and standard length (L) was M = −290.71 + 10.96 L, with r = 0.799.

Table 2.—Size, age, ovary weight, and number of mature ova of female *Etheostoma asprigene* collected in March.

Standard Length in mm	Adjusted Body Weight in Grams	Age in Years	Ovary Weight in Grams	Number of Mature (Orange or Translucent) Ova
33	0.38	1	0.11	72
37	0.58	1	0.11	154
39	0.54	1	0.17	185
39	0.59	1	0.13	94
39	0.61	1	0.17	151
40	0.47	1	0.18	140
40	0.57	1	0.13	95
41	0.46	1	0.18	183
46	0.96	2	0.26	180
47	1 27	2	0.24	267
48	1 30	2	0 22	148
53	1.61	3	0.33	346

Ovaries increased markedly in size in relation to the adjusted body weight of females (Fig. 6). For the females examined, the relationship between GSI (Y) and month (X), with May = 1 and March = 11, was $Y = 72.58 - 40.05 X + 5.19 X^2$, with $r = 0.927$. The largest ovaries proportionally (equaling 38.64 percent of adjusted body weight) were found in a 1-year-old, 40-mm female collected 20 March 1981.

Spawning

Forbes & Richardson (1920:309) reported collecting ripe females from mid-March to mid-May. At Lake Creek, *E. asprigene* in breeding condition were found from early March to early May.

Gravid females and males in nuptial coloration were collected in shallow (20 cm deep) riffles or in pools upstream from the riffles that contained an abundance of leaves, sticks, and cypress tree stumps. Turbid and high water conditions at the study site prevented field observations of spawning behavior. Individuals collected at Lake Creek on 6 March 1982 ($N = 5$), 24 February 1983 ($N = 7$), and 3 March 1983 ($N = 15$) and transferred to aquaria, spawned in the laboratory on 8 March 1982, 1 March 1983, and 11 March 1983, respectively. Stream temperatures at the times of capture ranged from 11° to 15°C; aquarium temperature ranged from 20° to 24°C.

Darters placed in aquaria spawned throughout the day, and spawning behavior was observed between 0900 and 1500 hours on all three dates. A summary of these observations follows. Males actively pursued and courted females. Males did not establish or actively defend territories but were openly aggressive toward other males when a female was within 10 cm. Courtship displays by males involved repeatedly swimming around the female and displaying erect dorsal fins. The male occasionally stopped perpendicular to the female with his head resting upon her nape. No "chin rubbing" was observed as in *E. proeliare* (Burr & Page 1978:8) and *E. gracile* (Braasch & Smith 1967:7). The female occasionally returned the fin display of the male by erecting her dorsal fins. Males and females also swam head to tail in a circular pattern, with occasional mutual "head bobbing."

The female selected the egg deposition site while the male followed close behind. Females deposited eggs on vertical or elevated surfaces (sticks, leaves, aquarium filter), or released eggs over vegetation. The female, closely pursued by the male, entered the vegetation at the base and swam vertically into the plant. The male then assumed a position over the female and curved his body into an S shape with his caudal peduncle adjacent to hers. In this position they vibrated rapidly for a few seconds while swimming vertically into the vegetation. Typically 5 to 10 eggs were released over the vegetation and floated down onto the plant. Some eggs fell to the substrate while the remainder adhered to vegetation. Females also deposited from 1 to 3 eggs directly upon vegetation. During the spawning act the female had her mouth open. This "mouth open" behavior was also reported in *E. proeliare* by Burr & Page (1978:8). A few minutes to a half hour elapsed between spawnings. Males mounted females while in a horizontal position on the substrate, but no eggs were released during these attempted spawnings.

DEVELOPMENT AND GROWTH

The fertilized egg of *E. asprigene* was spherical, translucent, demersal, and adhesive. Fertilized ova averaged 1.38 mm in diameter (range 1.36–1.44 mm, $N = 20$, SD =

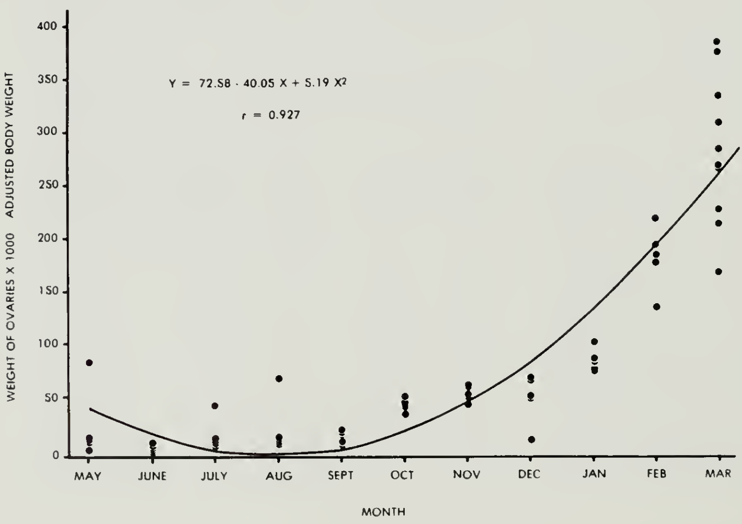

Fig. 6.—Monthly change in ovarian weight relative to adjusted body weight of *Etheostoma asprigene*.

0.05). A prominent, yellow, acentric oil droplet was present. Eggs incubated at 22° ± 2°C hatched in 122–146 hours (5.1–6.1 days). Hatchlings averaged 4.42 mm TL (range 4.22–4.48 mm TL, N = 6, SD = 0.10). All embryos emerged tail first.

Embryos usually developed synchronously. The development of 30 embryos from 0.5 hour post-fertilization to 48 hours post-hatching is outlined below. Fertilization time was taken at the moment both parents vibrated during spawning.

Age 0.5–1.3 hours. Two-cell stage. As in other teleosts, cleavage was meroblastic, resulting in two equal-sized blastomeres, each approximately the size of an oil droplet (0.50 mm in diameter).

Age 1.5–2.0 hours. Four-cell stage. Axis of second cleavage at right angle to first cleavage, resulting in four equal-sized blastomeres.

Age 4.5 hours (Fig. 7A). 32-cell stage. Cells approximately equal in size. Difficult to determine if cleavage was synchronous at this point.

Age 12.5 hours. High blastula stage. Blastodisc appeared granular (consisted of many cells) and dome-shaped, and occupied a slightly elevated position on top of yolk sac.

Age 24 hours (Fig. 7B). Late gastrula stage. Migration of germ ring over surface of yolk. Embryonic shield visible and axis of embryo well developed.

Age 36 hours (Fig. 7C). Head, trunk, and tail regions discernible. Entire embryo attached along its ventral surface to yolk mass. Length of embryo extended over half circumference of yolk mass. Optic vesicles clearly visible.

Age 48 hours (Fig. 7D). Melanophores appeared stellate upon yolk mass and punctulate on ventral portion of tail. Tail free from yolk mass for about one-half its length. Head and trunk still attached ventrally. Eye lens formed. Brain regions present but poorly defined Length of embryo extended approximately three-fourths circumference of yolk sac.

Age 60 hours (Fig. 7E). Retina of eye began to show pigmentation. Melanophores more numerous on yolk sac and ventral portion of tail. Tail free along entire length. Head still attached ventrally. Prosencephalon, mesencephalon, and rhombencephalon distinct. Otic capsule clearly visible. Somites distinct. Embryo moved regularly inside capsule.

Age 72 hours (Fig. 7F). Melanophores still concentrated on yolk sac and ventral surface of tail. Rudimentary pectoral fin buds present but with no fin rays. Head free from yolk sac. Length of embryo reached completely around yolk with tip of tail overlapping head. Median finfold surrounded tail. Eye more heavily pigmented. Heart pumping but no red blood visible.

Age 84 hours. Similar to 72-hour stage. Two otoliths in otic capsule. Pectoral fin buds distinct. Melanophores still confined to ventral portion of tail and yolk sac only. Red blood visible. Heartbeat 140/min.

Age 96 hours (Fig. 8A). Embryo 3.60 mm TL. Eyes began to take on metallic appearance. Notochord well defined. Median finfold constricted at region where caudal

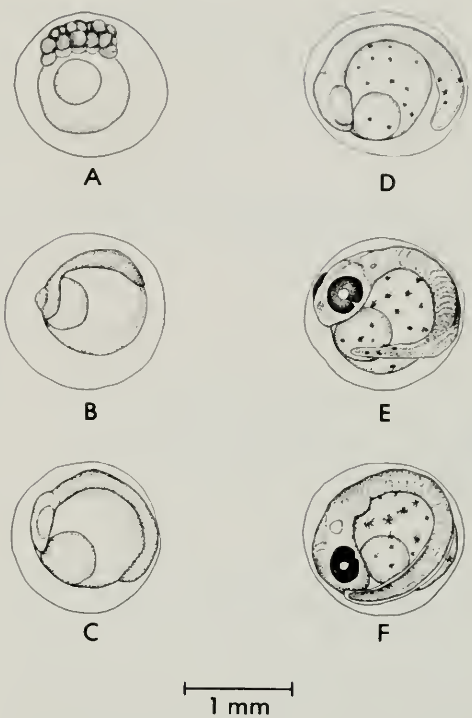

Fig. 7.—Developmental stages of *Etheostoma asprigene* between 4.5 and 72 hours. A, 32-cell stage, 4.5 hours; B, late gastrula stage, age 24 hours; C, embryonic axis, age 36 hours; D, tail-free, age 48 hours; E, embryo with eye pigmentation, age 60 hours; F, fin buds present, age 72 hours.

fin will develop. Gut present at junction of ventral finfold and yolk sac but not open to exterior.

Age 124 hours (Fig. 8B). Protolarval stage, 2 hours post-hatching. Protolarva 4.22 mm TL. Snout rounded and well-developed mouth present. Total myomeres 39 (16 pre-anal, 23 post-anal). Yolk sac with anterior oil droplet. Pectoral fins distinct with few fin rays. Eyes well developed and pigmented. Melanophores on dorsal surface of tail posteriorly, a few on dorsal portion of head above pectoral fin, and one at base of pectoral fin. Origin of median dorsal finfold at 7th pre-anal myomere. Caudal fin without rays. Heartbeat 142/min.

Age 170 hours (Fig. 8C). Protolarval stage, 48 hours post-hatching. No rays developed in median fins. Pectoral fins not completely developed. Length 4.86 mm with 39 myomeres. Mouth well developed with teeth present on lower jaw. Pigmentation similar to 124-hour stage. Heartbeat 140/min.

Forty-eight hours after hatching, the yolk sac was almost completely absorbed. At this point, protolarvae were

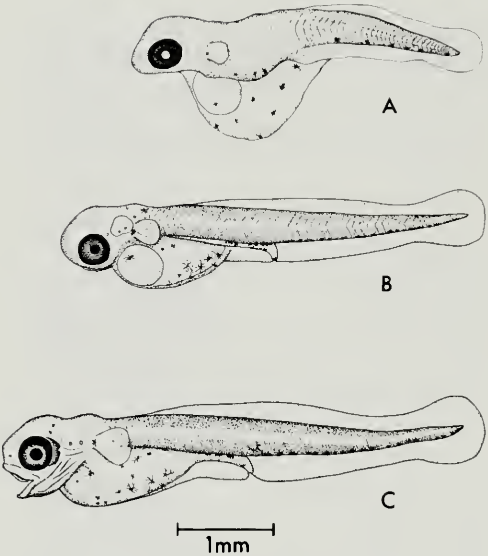

Fig. 8.—Embryonic and protolarval stages of *Etheostoma asprigene* between 96 and 170 hours. A, late embryo prior to hatching, 3.60 mm TL, age 96 hours (chorion removed); B, protolarva 2 hours post-hatching, 4.22 mm TL, age 124 hours; C, protolarva 48 hours post-hatching, 4.86 mm TL, age 170 hours.

offered newly hatched, brine shrimp nauplii but would not feed. Observations and descriptions of larvae were discontinued at this point because it was felt they would not be representative of normal development.

Overall, embryonic and larval development in *E. asprigene* were similar to those described for the rainbow darter, *E. (Oligocephalus) caeruleum* (Cooper 1979:46–56). Young of both species hatched as protolarvae with melanophores on the yolk sac and ventral portion of the tail. The two species differed in that melanophores found on the vent prior to yolk absorption in *E. asprigene* were absent in *E. caeruleum*. Myomere counts were similar in the two species with 16 pre-anal and 23 post-anal myomeres in *E. asprigene* and 17 pre-anal and 19 post-anal myomeres in *E. caeruleum*.

A pigmentation pattern similar to that described above has also been reported in other larval percids, such as *Perca flavescens* (Fish 1932:362), *Stizostedion vitreum* (Nelson 1968:168), *Percina caprodes* (Cooper 1978:261), *Percina sciera* (Page & Smith 1970:9), *Percina tanasi* (Starnes 1977:83), *Etheostoma blennioides* (Fahy 1954:187), and *Etheostoma variatum* (May 1969:89).

Other larval percids exhibit scattered melanophores on the head and lateral surfaces of the body in addition to those on the yolk sac and ventral margin of the tail. These percids include *E. olivaceum, E. squamiceps, E. flabellare, E. kennicotti, E. smithi* (subgenus *Catonotus*) (Cooper 1979:49; Lake 1936:827; Page 1974:11, 1975:9, 1980:9; Page & Burr 1976:8), *E. proeliare, E. microperca* (subgenus *Boleichthys*) (Burr & Page 1978:10, 1979:9), and *E. perlongum* (subgenus *Boleosoma*) (Shute et al. 1982:565).

Young-of-the-year from Lake Creek, collected 29 May 1980, ranged from 15.02 to 17.87 mm ($\bar{x}$ = 16.59, N = 5, SD = 1.16). These juveniles resembled adults in overall morphology but lacked scales on the nape and cheeks. Unlike the dark-banded adults, juveniles were light in color without distinct bands on the caudal peduncle. Juveniles collected 15 June 1980 ranged in size from 18.75 to 26.27 mm ($\bar{x}$ = 22.56, N = 16, SD = 2.51).

Males and females grew at almost the same decreasing rate (Fig. 9). For males, the relationship between mean standard length (Y) and age in months (X) was $Y = 9.81 + 26.19 \log X$, with $r = 0.951$ ($N = 374$); for females $Y = 11.37 + 24.56 \log X$, $r = 0.955$ ($N = 384$). No significant differences in size were found between males and females of any age group. The largest specimens at the study site were a 55-mm female collected 25 October 1980 and a 55-mm male collected 27 March 1981.

A 59-mm male, larger than the maximum size (55 mm) reported for the species (Page 1983:132), was collected approximately 6.4 km upstream from the study site on 10 April 1982.

At 12 months of age, males averaged 38.9 mm (range = 36.6–41.4, N = 10, SD = 1.6) and females averaged 37.8 mm (range = 33.4–42.9, N = 21, SD = 2.3). They reached one-half of their first year's mean growth in approximately 10 weeks. Males averaged 47.2 mm (range = 44.9–49.7, N = 4, SD = 2.4) and 54.9 mm (range = 54.8–55.0, N = 2, SD = 0.3) at 24 and 36 months of age, respectively. Females averaged 46.3 mm (range = 42.5–50.9, N = 7, SD = 2.7) and 50.6 mm (range = 48.3–53.2, N = 3, SD = 2.5) at 24 and 36 months of age, respectively. Lutterbie (1979:5) reported similar growth rates for *E. asprigene* in Wisconsin.

DEMOGRAPHY

Density

Quantitative samples taken by habitat (e.g., pools and riffles) on six dates indicated greater density of *E. asprigene* in riffles than in pools during all months except February (Table 3). Density in riffles ranged from 0.25 darters/m^2 in February to 8.25 darters/m^2 in November. A strong seasonal variation in density of *E. asprigene* was observed with ranges of 4.50–8.25/m^2 from August to November and 0.25–1.00/m^2 from December to February (Table 3). A similar situation was found in *E. microperca* from the Iroquois River, Illinois (Burr & Page 1979:10). The higher density estimates in the summer and fall probably reflect an influx of young-of-the-year into the population. Low densities reported for winter and spring months may be due to natural mortality during harsh winter months or a seasonal migration to another area.

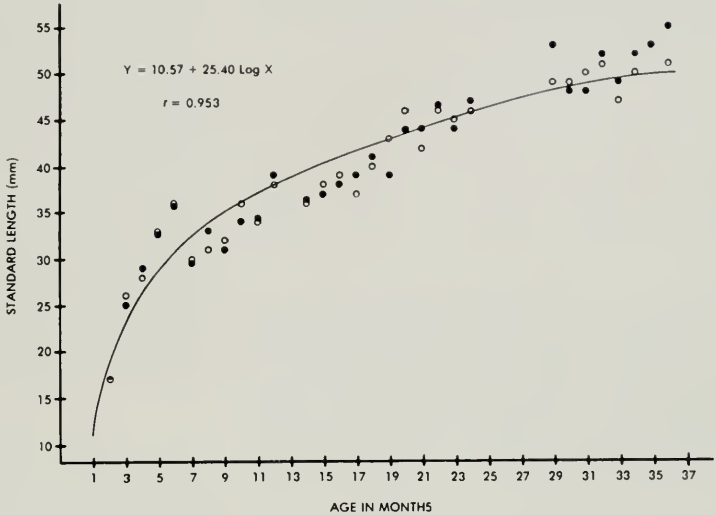

Fig. 9.—Size distribution by age of *Etheostoma asprigene* from Lake Creek. Black dots represent sample means for males (N = 374); open circles represent sample means for females (N = 384). Regression line is for both sexes.

TABLE 3.—Number of *Etheostoma asprigene* collected per square meter of habitat in Lake Creek.

Collection Date	Number Collected		Number of *E. asprigene* per Square Meter in Riffles	Pools
6 August 1982	26		6.00	0.50
22 September 1982	20		4.50	0.50
11 November 1979	33		8.25	. . .
18 December 1981	4		1.00	0
27 January 1983	2		0.50	0
24 February 1983	7		0.25	1.50
		Mean	*3.42*	*0.50*
		SD	*3.33*	*0.61*

Stream Movements

Several darters whose migration has been studied appear to have an annual cycle of movement. Darters move downstream into pools during winter months and migrate upstream to riffles coincidental with the onset of spawning (Trautman 1957:584–586). Some migrations involved distances of up to 4.8 km (May 1969:86). Other studies have found that some darters do not migrate or migrate only short distances (May 1969:87; Reed 1968:174; Scalet 1973b:383–384).

E. asprigene was common in Lake Creek during all months of the study except December through February. It is not known whether darters remained in the main channel during spring floods or moved to the periphery of the flood waters. Limited collecting in the flooded area yielded few fishes and no mud darters. Larimore et al. (1973:115) collected mud darters moving out of the Kaskaskia River and into floodplain pools in late April.

On 6 August 1982, 11 *E. asprigene* collected from a riffle directly below the bridge on Illinois Route 3 were marked with injections of Napthol Red Light (value 4.0) Liquitex Acrylic ®, released, and the release sites marked and recorded. Four of the 11 were recaptured 22 September within 5–8 m of the release point. Collections made 0.5 km upstream and downstream yielded no other marked fishes. An additional four were marked and released on 22 September. Collections throughout the day and night of 16-17 October 1982 yielded one individual marked on 6 August (in a pool approximately 3 m from the release point at 0030 hours) and another specimen (in the same pool) marked on 22 September at 0530 hours. During this 24-hour period, *E. asprigene* were observed moving into riffles during the day and into pools at night.

Composition and Survival

Of the 758 *E. asprigene* collected in Lake Creek between 27 October 1979 and 22 September 1982, 52.5 percent were 1 year old or less, 40.5 percent were between 1 and 2 years old, and 7.0 percent were over 2 years old (Table 4). A chi-square analysis revealed no significant deviation from a 1:1 sex ratio. The oldest *E. asprigene* examined were five 36-month-old individuals collected 27 March 1981. This age probably represents the maximum life span in this population; it is doubtful that any individuals live past their third spawning season.

TABLE 4.—Distribution of sexes and age groups in samples of *Etheostoma asprigene* collected in Lake Creek between 27 October 1979 and 22 September 1982. The age group − 1 = 1–11 months, 1 + = 12–23 months, and 2 + = 24–36 months.

Sex	Number by Age Group			Total
	− 1	1 +	2 +	
Males	200	145	29	374
Females	198	162	24	384
Total	*398*	*307*	*53*	*758*

Relative survival values for males, females, and the total sample (Table 5) showed that in Lake Creek 72.5 percent of the first-year males and 81.8 percent of the first-year females survived into their second year. Only 14.5 percent of second-year males and 12.1 percent of second-year females survived into their third year of life. For the total sample, 77.1 percent of first-year individuals survived into their second year and 13.3 percent into the third year.

TABLE 5.—Relative survival of age groups of *Etheostoma asprigene* expressed as a proportion of the − 1 age group (1 x¹) and the 1 + age group (1 x²).

Sample	Age Group	Number of Specimens	Survival	
			1 x¹	1 x²
Males	− 1	200	1.000	. . .
	1 +	145	0.725	1.000
	2 +	29	0.145	0.200
Females	− 1	198	1.000	. . .
	1 +	162	0.818	1.000
	2 +	24	0.121	0.148
Total sample	*− 1*	*398*	*1.000*	. . .
	1 +	*307*	*0.771*	*1.000*
	2 +	*53*	*0.133*	*0.173*

DIET

Of the 48 species of darters for which food habits have been studied, 37 have been found to have a crustacean-insect diet. They feed mainly on microcrustaceans as juveniles and on immature aquatic insects as adults (Page 1983:171). The diet of *E. asprigene* basically fits this pattern, as do those of its close relatives *E. caeruleum, E. spectabile,* and *E. radiosum* (Turner 1921:52–53; Cross 1967:318; Scalet 1972:515; Grady & Bart 1984:77–79). Forbes (1880:25) and Forbes & Richardson (1920:309) noted that the food of *E. asprigene* in Illinois consisted of mayfly naiads and dipteran and trichopteran larvae, but they made no mention of the age or locality of the fishes studied.

Stomachs of 150 *E. asprigene* collected at Lake Creek contained prey of 17 taxa (Tables 6 & 7). The diet consisted of aquatic insects, arachnids, small crustaceans, and teleost eggs. The predominant food items were dipteran larvae (chironomids and simuliids), isopods, mayfly naiads, and caddisfly larvae. Less predominant food items included amphipods and other small crustaceans, water mites, stoneflies, beetle larvae, aquatic hemipterans, and fish eggs.

As in most darters studied, dipteran larvae comprised the bulk of the diet in all size classes (Fig. 10). The smallest darters examined (< 25 mm) fed mainly on chironomids, simuliids, and microcrustaceans (Table 6, Fig. 10). Darters in the 26- to 35-mm range consumed the largest number of taxa (14). Those larger than 35 mm fed predominantly on chironomids, simuliids, isopods, caddisfly larvae, and mayfly naiads. No cladocerans, ostracods, nor eubranchiopods were found in darters larger than 35 mm. Darters

TABLE 6.—Stomach contents of *Etheostoma asprigene* by size class of darter. Mean number of food organisms per stomach is followed parenthetically by percentage of stomachs in which food organism occurred.

Food Organism	< 26 mm N = 15	26–35 mm N = 75	36–45 mm N = 38	> 45 mm N = 22
Arachnida				
Acarina	. . .	1.0 (4)	1.0 (5)	. . .
Crustacea				
Cladocera	1.0 (7)	. . .	. . .	. . .
Ostracoda	1.0 (7)	1.0 (1)	. . .	. . .
Copepoda	5.0 (13)	3.0 (1)	. . .	. . .
Eubranchiopoda	. . .	1.0 (1)	. . .	. . .
Isopoda	4.0 (7)	2.8 (32)	3.3 (37)	2.7 (45)
Amphipoda	1.3 (20)	1.0 (4)	. . .	2.0 (5)
Insecta				
Plecoptera	. . .	1.0 (3)	. . .	. . .
Ephemeroptera	1.3 (20)	1.8 (24)	2.6 (24)	2.0 (5)
Hemiptera	2.0 (7)	1.0 (1)	. . .	. . .
Trichoptera	1.0 (7)	1.9 (28)	2.4 (45)	1.4 (36)
Lepidoptera	. . .	. . .	. . .	1.0 (5)
Coleoptera	1.0 (7)	. . .	. . .	. . .
Diptera				
Simuliidae	4.8 (27)	7.4 (29)	3.8 (37)	5.4 (36)
Chironomidae	6.8 (73)	9.5 (47)	11.0 (55)	4.5 (36)
Tabanidae	. . .	1.0 (3)	. . .	. . .
Others	. . .	1.0 (3)	. . .	2.0 (5)
Teleostomi eggs	. . .	. . .	. . .	1.0 (9)
Empty	. . .	(7)	(11)	(9)

TABLE 7.—Stomach contents of *Etheostoma asprigene* by month of collection. Mean number of food organisms per stomach is followed parenthetically by percentage of stomachs in which food organism occurred.

Food Organism	Jan. N = 11	Feb. N = 14	Mar. N = 11	May N = 11	June N = 14	July N = 11	Aug. N = 11	Sept. N = 11	Oct. N = 12	Nov. N = 27	Dec. N = 17
Arachnida											
Acarina	...	...	...	...	...	...	1.0 (27)	...	1.0 (27)	...	...
Crustacea											
Cladocera	...	...	...	...	1.0 (7)	...	...	...	...	...	...
Ostracoda	1.0 (9)	...	...	...	...	...	...	...	...	...	1.0 (6)
Copepoda	...	...	...	1.0 (9)	...	...	...	...	9.0 (4)	...	3.0 (6)
Eubranchiopoda	...	...	...	...	...	...	...	...	1.0 (4)	...	...
Isopoda	4.2 (91)	2.1 (50)	2.0 (64)	3.2 (45)	...	...	...	1.0 (9)	1.0 (4)	1.7 (25)	3.3 (82)
Amphipoda	1.3 (27)	...	...	2.0 (9)	...	...	...	...	...	...	2.0 (12)
Insecta											
Plecoptera	...	...	...	...	...	...	...	...	1.0 (4)	1.0 (8)	...
Ephemeroptera	...	...	...	...	1.3 (21)	1.7 (55)	1.3 (27)	3.2 (91)	1.3 (26)	...	1.0 (6)
Hemiptera	...	...	...	...	2.0 (7)	...	...	...	1.0 (4)	...	...
Trichoptera	1.0 (9)	1.0 (7)	1.2 (55)	1.3 (27)	...	1.3 (27)	2.7 (82)	3.0 (100)	1.5 (41)	...	1.0 (18)
Lepidoptera	...	...	...	...	...	...	...	...	...	1.0 (8)	...
Coleoptera	...	...	...	...	1.0 (7)	...	...	...	...	...	...
Diptera											
Simuliidae	4.3 (36)	12.0 (100)	2.0 (27)	2.0 (45)	5.5 (79)	1.0 (9)	...	...	3.3 (44)	4.8 (92)	1.0 (6)
Chironomidae	2.3 (36)	...	9.5 (91)	26.8 (91)	5.3 (86)	4.4 (45)	2.7 (27)	3.8 (36)	2.2 (48)	...	...
Tabanidae	...	...	...	...	1.0 (7)	1.0 (9)	...	...	...	...	...
Others	...	...	...	1.0 (9)	...	...	...	2.0 (9)	...	1.0 (8)	...
Teleostomi eggs	...	...	1.0 (18)	...	...	...	...	...	...	...	...
Empty	...	...	(9)	(9)	...	(27)	(9)	...	...	(8)	...

larger than 25 mm consumed more isopods and caddisflies than did smaller individuals (Fig. 10).

Dipteran larvae were the predominant food items through all seasons, with consumption highest in the spring and lowest in the fall (Fig. 11). Isopods were the major food items in December and January and were found in 82 and 91 percent of the stomachs, respectively (Table 7).

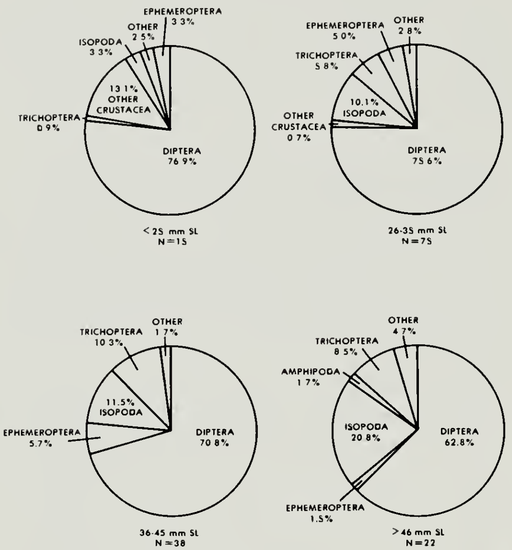

Fig. 10.—Composition of the diets of four size classes of *Etheostoma asprigene* from Lake Creek, Illinois, expressed as a percentage of the total number of individual prey items consumed.

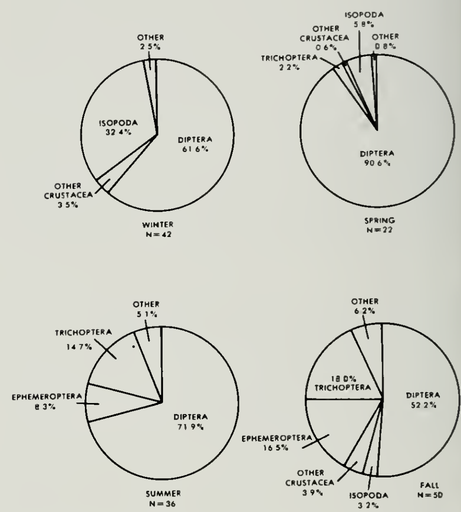

Fig. 11.—Composition of the diet of *Etheostoma asprigene* by season from Lake Creek, Illinois, expressed as a percentage of the total number of individual prey items consumed. Winter = Dec., Jan., and Feb. Spring = Mar. and May. Summer = June, July, and Aug. Fall = Sept., Oct., and Nov.

Caddisflies and mayfly naiads were common food items during summer months (Fig. 11). Trichopterans were found in 100 percent of the stomachs examined in September (Table 7). Diversity of prey items consumed was lowest in February and August, months of temperature extremes and probably of reduced activity of darters.

PREDATION AND PARASITISM

The following potential predators of *E. asprigene* were preserved and their stomach contents examined: 2 *Ictalurus punctatus* (116 and 117 mm SL), 1 *Centrarchus macropterus* (57 mm SL), 2 *Lepomis gulosus* (67 and 95 mm SL), 1 *Lepomis humilis* (57 mm SL), 1 *Lepomis macrochirus* (122 mm SL), 11 *Lepomis megalotis* (51-121 mm SL), 2 *Micropterus salmoides* (101 and 130 mm SL), 2 *Pomoxis annularis* (114 and 126 mm SL), and 2 *Pomoxis nigromaculatus* (120 and 125 mm SL). The remains of a partially digested *E. asprigene* found in a 113-mm *Lepomis megalotis* collected in June was the only evidence of predation on *E. asprigene* in Lake Creek.

Of the 150 *E. asprigene* examined, 16 collected from December to March contained 47 spiny-headed worms (*Acanthocephalus* sp.). Infestation ranged from 1 to 10 worms/fish ($\bar{x}$ = 2.94). Darters greater than 40 mm were more heavily parasitized (4.75 worms/darter) than smaller ones (1.67 worms/darter). Although no other endo- or ectoparasites were discovered during this study, Whitaker & Schlueter (1975:446) reported *Lernaea cyprinacea* on one specimen of *E. asprigene* from the White River, Indiana.

SUMMARY

Major aspects of the life history of *E. asprigene* from Lake Creek are summarized in Table 8.

TABLE 8.—Summary of life history information on Lake Creek *Etheostoma asprigene*

Characteristics	Life History Data
Principal habitat of adults	Clay, gravel, detritus, and cypress stump riffles
Age at sexual maturity	1 year
Age at first spawning	1 year
Size at sexual maturity	Females about 33 mm; males about 37 mm
Sexual dimorphism	Adult males with pigmented breast, orange belly, blue-green bars with reddish-orange interspaces on sides, red second dorsal and caudal fins, blue-green anal fin, and red and blue-black bands in first dorsal fin; females without bright body colors, but with a single submarginal red band in first dorsal fin
Breeding tubercles	Absent
Description of genital papillae	Females have a broad-based, flaplike papilla that tapers distally and is not pigmented; males have a broad-based, flattened papilla that is pigmented
Number of mature ova in preserved females	77–346
Description of mature ova	1.1 mm across, rounded, and with a pitlike indentation
Description of fertilized ova	1.4 mm across, spherical, translucent, demersal, and adhesive
Spawning period	From early March to early May
Spawning habitat	Unknown in nature
Egg deposition sites in aquaria	Egg attached on elevated surfaces, usually plants, leaves, or sticks
Number of eggs laid per spawning act	1–10
Spawning position	Both male and female in vertical position, male mounted on back of female
Egg guarding	None observed; probably no parental care
Incubation period	122–146 hours at 22° ± 2°C
Size at hatching	4.2–4.5 mm TL
Description of hatchling	Hatch as protolarvae with punctulate melanophores concentrated along ventral margin of tail and stellate melanophores on yolk sac
Influence of sex on growth rate	Both sexes grew at approximately the same rate
Density	Up to 8.25 darters/m^2 in riffles
Sex ratio	1 male : 1 female
Longevity	Up to 36 months
Maximum size	55 mm SL
Migrations	Daily, occupying riffles during day and pools at night; no long distance migrations observed
Territoriality	None observed
Principal diet	Aquatic insect immatures and small crustaceans

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