Distribution, Status, and Life History of the Bluestripe Darter, *Percina cymatotaenia*

AQUATIC SERIES NO. 18

By
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ABSTRACT

This report of the distribution, abundance, and life history of the bluestripe darter, a fish endemic to the Osage and Gasconade stream systems, Missouri, is based on collections and observations obtained at 228 localities during the period 27 July, 1974 to 23 April, 1982.

The bluestripe darter is presently restricted to the Salem Plateau subdivision of the Ozark Uplands, where it occurs in at least 240 miles of stream channel. This species is found in the Niangua River (Osage System) and the Osage Fork, Gasconade River, Whetstone Creek, Roubidoux Creek, and Big Piney River (Gasconade System). These are clear streams of medium size, draining hilly topography underlain by chert-bearing limestones and dolomites. The habitat of the bluestripe darter is backwaters along the stream margin, where there are deposits of organic debris and dense growths of aquatic vegetation.

Bluestripe darters were collected at 17 stations, and 117 individuals were seined. The seining rate averaged 2.3 individuals per hour. Density estimates for the bluestripe darter at two stations ranged from 0.7 to 5.2 individuals per 100 linear feet of stream.

Some 78 species of fishes were identified at stations where bluestripe darters occurred. The longear sunfish and three species of minnows (bleeding shiner, largescale stoneroller, and bluntnose minnow) occurred at all bluestripe darter stations. The rainbow darter and orangethroat darter were the most abundant darters at these stations.

The food of the bluestripe darter consisted mostly of immature mayflies *(Ephemeroptera)* and true flies *(Diptera),* supplemented by microcrustacea, amphipods, and other aquatic invertebrates. Only minor variations in the diet of the species occurred with season or fish size.

Five age groups (0-IV) were found, with females predominate in most age groups. Growth rate and longevity were similar in males and females, and approximately 55% of the maximum adult size of about 82mm SL was achieved during the first year of life.

Slightly more than half (52%) of Age I bluestripe darters were sexually mature when captured in early spring. Males had a longer soft dorsal fin and soft anal fin than females, and the genital papilla was triangular-shaped rather than truncate and scalloped. Males possessed a prominent flange-like keel on the lower surface of the caudal peduncle. The color pattern of the sexes was similar except when spawning. Males underwent a dramatic color change when engaged in breeding behavior, in which the prominent longitudinal stripe was replaced by vertical bars.

Spawning occurred in early spring, with a peak in March and early April. The eggs were buried in gravel substrate, where they hatched in about 10 days at ambient temperatures. Eggs were about 2mm in diameter, and newly hatched fry were about 8.5mm TL.

The bluestripe darter has declined in distribution and abundance since the turn of the century, but populations appear to have been relatively stable in recent decades. Barring drastic changes in habitat, or man-induced disasters such as fish kills resulting from pipeline breaks or the widespread aerial application of pesticides, this species is probably secure from extinction. However, its population trends should be monitored by periodic sampling. Based on the findings of this study, I do not support a recommendation that the bluestripe darter be listed as a nationally endangered or threatened species at this time.

Figure 1. The bluestripe darter *(Percina cymatotaenia*

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INTRODUCTION

The bluestripe darter, *Percina cymatotaenia* (Gilbert and Meek) is endemic to the Osage and Gasconade stream systems of central Missouri. It has been proposed for inclusion in the U.S Department of the Interior's list, *Threatened Wildlife of the United States.* This study was undertaken to document the present distribution and abundance of the bluestripe darter, to identify existing and potential threats to its survival, to determine if it qualifies as a nationally endangered or threatened species, and to obtain information on its life history and requirements.

Percina cymatotaenia is a slender darter with a broad dusky stripe extending along the midside, ending in a small, triangular-shaped black spot at the base of the caudal fin (Fig. 1). The dorsum is pale' with brownish lengthwise streaks; the venter is pale with scattered dusky specks. The lateral stripe is overlain with an irridescent, greenish, tinge that is most evident in bright sunlight or intense artificial light such as an electronic strobe. The maximum length is about 4 inches.

The closest relative of the bluestripe darter is an undescribed species that occurs in Kentucky. These two species are the only members of the subgenus *Odontopholis* (Page 1974).

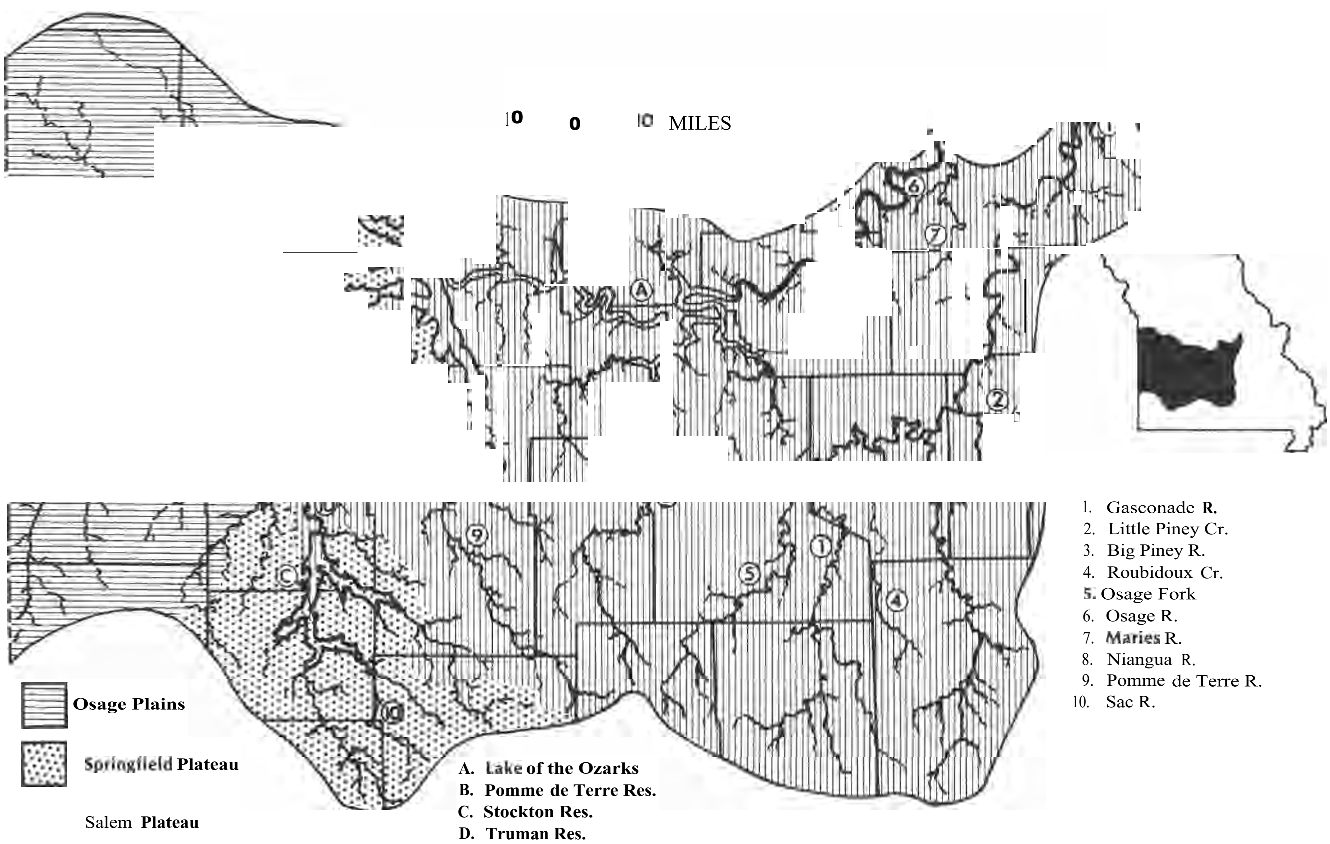
THE STUDY AREA

This study was conducted in the Osage and Gasconade stream systems (Fig. 2) because previous general surveys have demonstrated that the bluestripe darter is confined to these drainages (Pflieger 1971). The Gasconade River is a seventh order tributary of the Missouri River, joining the latter stream 104 miles above its mouth. Its drainage area comprises 3,600 square miles and lies entirely within the boundaries of Missouri. The Osage River is an eighth order stream, and joins the Missouri River 130 miles above its mouth. It drains an area of 15,300 square miles within Missouri.

Four major flood control and hydroelectric reservoirs are present within the study area, all in the Osage River drainage. Two of these (Lake of the Ozarks and Truman Reservoir) are on the Osage River mainstem, Stockton Lake is on the Sac River, and Pomme de Terre Reservoir is on the Pomme de Terre River.

The Osage and Gasconade stream systems drain three major physiographic subdivisions of Missouri: Salem Plateau, Springfield Plateau, and Osage Plains. The physical and biological features of these subdivisions and their streams within the Osage stream system were described in some detail by Pflieger (1978). The Gasconade stream system lies entirely within the Salem Plateau subdivision, and is similar in character to the Salem Plateau portion of the Osage stream system.

Figure 2. Map of the study area, showing physiographic regions, streams, and reservoirs mentioned in this report.



METHODS AND MATERIALS

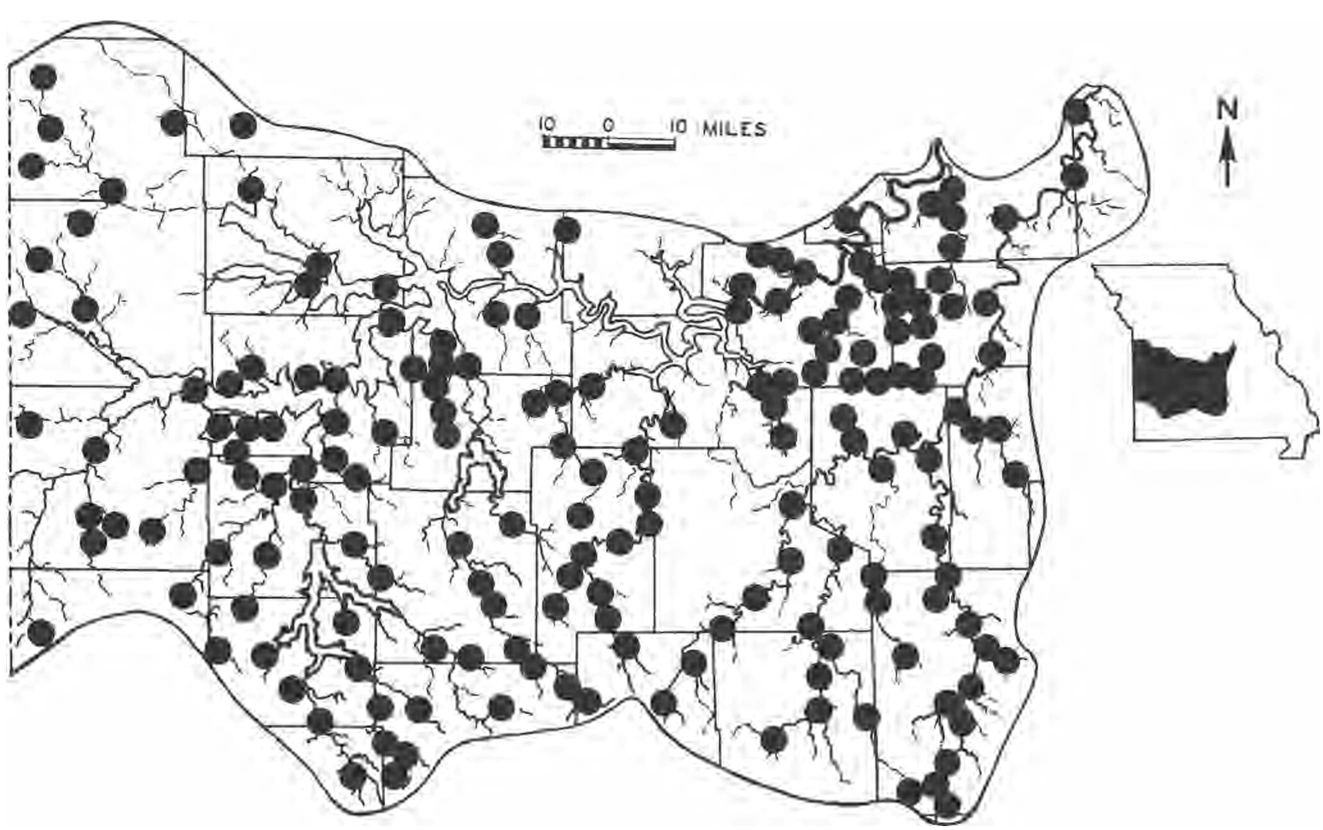
The sampling techniques used in this study were similar to those used in a recent study of the Niangua darter (Pflieger 1978), and collections from the latter study were also used in determining the status and distribution of the bluestripe darter. In all, collections obtained at 228 localities during the period July 27, 1974 to April 23, 1982 were studied (Fig. 3). These collections were compared with other collections made at 192 localities between 1940 and 1974 to determine changes in distribution and relative abundance in recent decades. A few collections made in 1884 and 1889 provided the earliest records of the occurrence of this species. More intensive analyses of habitat, abundance, and life history were made at 49 stations within the known range of the bluestripe darter (Appendix 1).

Seining was the principal technique used in sampling bluestripe darter populations. A 25-foot by 8-foot, 1/4-inch mesh drag seine was used in sampling pools and the deeper sections of riffles and runs. A 6-foot by 4-foot, 1/8-inch mesh kick seine was used to sample riffles and cover along the margins of pools. All fishes captured were identified and counted in the field, or were preserved for identification and counting in the laboratory. Bluestripe darters released alive were measured (total length) and sexed (if possible).

Direct observations with face mask and snorkel were made to obtain information on habitat and behavior. No attempt was made to census bluestripe darters in this manner, because their cryptic coloration and occurrence in or near cover made them difficult to observe. Underwater observations and seining notes were taken with a soft pencil on Polypaper™ plastic paper. Stream flows were estimated using the method proposed by Robins and Crawford (1954). Current velocities were measured by timing a float over a measured distance.

Studies of food habits and growth were made from specimens preserved during this study or obtained from previous collections. Scales were taken from above the lateral line near the junction of the spinous and soft dorsal fins, cleaned, mounted between microscope slides, and studied on a scale projector. Back calculations of growth were made with a nomograph. Sex was determined by dissection in the laboratory, and in the field by differences in the anal papilla and anal fin, and in the development of the caudal keel. Food habits were determined by examining stomach contents. Food items were sorted into categories and counted, but only the total volume of the stomach contents was determined. Proportions of the volume represented by each class of food items were estimated visually. Fecundity determinations were based on total counts of the eggs in ovaries of females collected during February and March.

Figure 3. Localities sampled, July 27, 1974 to April 23, 1982. Some symbols represent two or more nearby localities.



Variations in the occurrence and relative abundance of fish species in the collections were used to characterize fish populations at localities where bluestripe darters were found. Because the sampling methods were species-selective, the following ecological groups were established to promote greater within-group uniformity for analysis.

Benthic fishes—Includes small species such as darters and madtoms that are generally found in or on the stream bottom. Kick-seining is selective for these species.

Nektonic fishes—Includes small species such as minnows and topminnows that occur in midwater or at the surface, frequently in schools. Drag-seining is selective for these species.

Large fishes—Includes those species that generally achieve an adult length of 6 inches or more. These species are often inadequately represented in seine collections because they occur in deep water or heavy cover, or are fast swimmers. Examples are most sunfishes, suckers, and the larger catfishes.

The common names of fishes in this report follow Robins, *et al.* (1980).

Physical features of streams and their drainage areas (stream length, gradient, and order; elevation and local relief) were determined from U.S. Geologic Survey topographic maps. Stream order was determined by the system proposed by Horton (1945). In this system, ultimate headwater streams are designated as order one. Two order one streams join to form a stream of order two, and the order continues to increase each time two streams of the same order join. Thus, the stream order is an indication of stream size, with larger streams being of a higher order.

In 1981 and 1982, bluestripe darter adults captured in February and early March were held for observations of spawning in a rectangular, fiberglass tank having an operating capacity of 140 gallons. Water in the tank was continuously recirculated, aerated, and cooled with a pump and refrigeration unit. The tank was illuminated by a fluorescent bulb suspended 24 inches above the water surface, and a photoperiod of 12 hours was provided by a timing device. The temperature of the tank was monitored with a continuous recording thermometer, supplemented by spot readings with a pocket thermometer to confirm the accuracy of the recording thermometer. The darters were confined to a central compartment measuring 31 3/4 inches long, by 211/4 inches wide, by 15 inches deep. The partitions setting off this compartment were composed of fiberglass screen. A double-paned plexiglass window permitted observation of the compartment.

Substrate varying from sand through coarse gravel was placed in the compartment. Water-soaked tree leaves and submerged aquatic vegetation was also placed in the compartment for the 1981 observations. Darters were fed amphipods, mosquito larvae, and zooplankton.

RESULTS AND DISCUSSION

Distribution

The bluestripe darter was described by Gilbert and Meek (In Gilbert 1888) from specimens collected in 1884 from the Niangua River, Osage Fork, and Sac River (Fig. 4). At that time these workers reported that *P. cymatotaenia* was "abundant in the Niangua River and the Osage Fork of the Gasconade, near Marshfield, Missouri, and in the Sac River near Greenfield, Missouri." Another early collector (Meek 1891) obtained this species from Little Piney Creek near Newburg, and the Maries River near Dixon in 1889.

No additional reports are available until the first general survey of Missouri fishes in the early 1940s, when 12 specimens were recorded from 11 localities. Sampling between 1945 and 1974 resulted in 38 specimens from 14 localities. Some 25 of these specimens were collected from a 45-mile stretch of the Big Piney River that was seined annually during the 10-year period 1963-1972. Collections made between 1940 and 1974 revealed that *P. cymatotaenia* occurred in low population densities in the Niangua River (Osage drainage) and the Osage Fork, Gasconade River, Roubidoux Creek, and Big Piney River (Gasconade drainage).

Figure 4. Localities where bluestripe darters have been recorded.

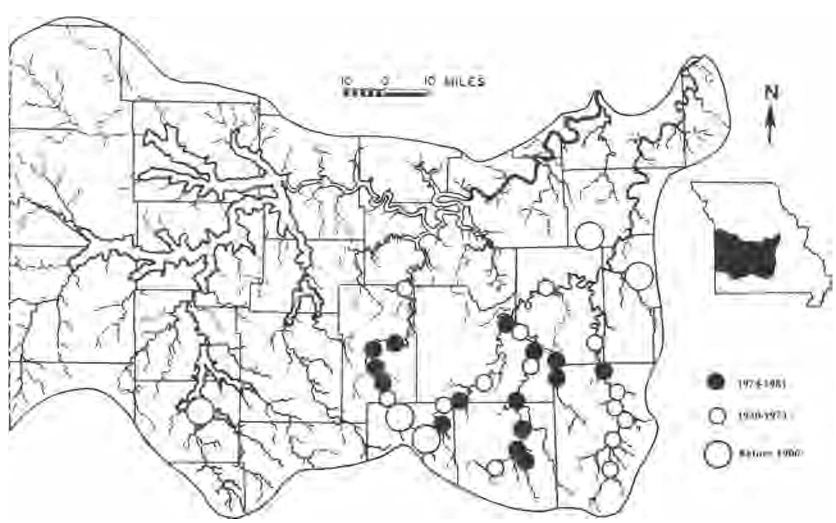


Table 1. Stream reaches presently inhabited by the bluestripe darter.

Stream name	Stream reach known to be inhabited (miles above stream mouth)	Total miles of stream known to be inhabited
Big Piney River	34-80*	50
Gasconade River	18-98	78
Roubidoux Creek	35-41	7
Osage Fork	38-66	29
Whetstone Creek	1*	1
Niangua River	39-113	75
Total miles		240

*Upper limits of distribution not precisely known.

Table 2. Occurrence of the bluestripe darter in relation to physical features of Ozark streams within the study area.

Physical feature	Number of localities sampled	Occurrences of the bluestripe darter	
		Number	Percent frequency
Physiographic Region			
Salem Plateau	205	28	13.7
Springfield Plateau	42	0	0.0
Osage Plains	1	0	0.0
Stream Order			
I-II	28	0	0.0
III	44	0	0.0
IV	56	2	3.6
V	72	14	19.4
VI	28	12	42.9
VII-VIII	20	0	0.0
Miles-to-Headwater			
1- 10	76	0	0.0
11- 30	80	7	8.8
31- 50	32	11	34.4
51- 70	17	4	23.5
71- 90	8	4	50.0
91-110	8	2	25.0
111-438	27	0	0.0
Stream Gradient (Ft./mile)			
1- 3	50	5	10.0
4- 6	50	16	32.0
7- 9	42	7	16.7
10- 12	25	3	12.0
13-121	81	0	0.0
Elevation (Ft.)			
490- 700	60	0	0.0
701- 820	59	2	3.4
821- 940	50	8	16.0
941-1060	45	11	24.4
1061-1180	20	7	35.0
1181-1470	14	0	0.0
Local Relief (Ft.)			
33- 80	14	0	0.0
81-160	47	1	2.1
161-240	129	15	11.6
241-320	61	11	18.0
321-400	7	1	14.3

In collections made since 1974 I collected 117 specimens from 17 localities. This survey revealed that the bluestripe darter had about the same distribution as during the 1940-1974 period. I did not record this species from as many localities in Big Piney River as in the 1940-1974 period, but my sampling effort was substantially less, and this probably was a factor.

I estimate that the bluestripe darter presently inhabits 240 miles of channel in six streams (Table 1). This estimate is based on the assumption that this species still has the same distribution in Big Piney River that was indicated by previous surveys.

Two records of doubtful validity are not plotted in Fig. 4, and are not considered in the above estimate. Each of these records are of a single specimen recorded by personnel of the Department of Conservation from stations in the lower Sac and lower Gasconade rivers that were sampled repeatedly over a period of 10 years from 1947-1957. No specimens are available to support these records. I doubt that the bluestripe darter presently occurs at the Sac River locality, even if this record is valid, since the station is now in the tailwater of Stockton Dam, and the habitat is considerably modified from its condition during the 1947-1957 period. The Gasconade River locality is 46 river miles from the nearest confirmed locality for the bluestripe darter, and this species has not occurred in numerous other collections from the same river reach.

Table 3. Numbers of bluestripe darters seined and number seined per hour in riffles and pools of stream reaches known to be inhabited by the bluestripe darter. See Appendix 2 for rates obtained at each station.

	Bluestripe Darter			
	Number collected		Number per hour	
Stream	Riffle	Pool	Riffle	Pool
Big Piney River	0	18	0.0	1.6
Roubidoux Creek	0	15	0.0	1.0
Gasconade River	0	34	0.0	3.5
Whetstone Creek	0	11	0.0	4.1
Osage Fork	0	10	0.0	1.8
Niangua River	0	29	0.0	3.9
All streams	0	117	0.0	2.3

Habitat

In the Osage and Gasconade stream systems, the bluestripe darter was confined to the Salem Plateau physiographic section of the Ozark Uplands (Table 2). It was largely restricted to streams of order V and VI, having gradients of 1-12 ft./mile. It was not collected closer to the ultimate head-water divide than 18 miles, nor farther from the headwater divide than 98 miles. Most localities where the bluestripe darter occurred were in areas where the local relief was 150-400 feet, at elevations of 800-1180 feet above sea level.

Streams in which the bluestripe darter occurred may be characterized as clear, large creeks and small rivers, having moderate gradients, and draining hilly topography underlain by bedrocks consisting principally of chert-bearing limestones and dolomites (Fig. 5). *P. cymatotaenia* avoided high-gradient creeks and spring branches, and the larger Ozark rivers.

Bluestripe darters occupied the same habitat throughout the year, and no obvious differences in habitat were noted between juveniles and adults. This species was almost invariably found along the quiet margins of pools, associated with deposits of sticks, leaves, and other organic debris, or thick growths of submergent or emergent aquatic plants. Water depths in areas where bluestripe darters were found ranged from about 10 to 54 inches, averaging 27 inches. Current velocities were often too slight to measure, with a maximum of about 0.8 ft./sec., and an average of 0.3 ft./sec. The bluestripe darter exhibited a definite affinity for aquatic vegetation, including stands of the emergent aquatic plant *Justicia,* and beds of the submergent aquatic plants *Ranunculus, Myriophyllum, Potamogeton* and *Heteranthera.* In winter and early spring when aquatic plants were dormant, the bluestripe darter was associated with mats formed by the dead stems, runners, and roots of *Justicia,* or deposits of organic debris, comprised mostly of water-soaked tree leaves and sticks.

Substrates beneath and around the plant growths and detritus beds where *P. cymatotaenia* occurred were variable, including everything from bedrock and rubble to sand. Silt was often present as a thin layer over the substrate, but was rarely the predominant bottom type.

Table 4. Numbers of bluestripe darters seined and number per 100 linear feet of habitat during repeat censuses at two stations.

				Number of bluestripe darters seined	
Locality	Stream	Date	Linear feet of habitat seined	Total	No./100 linear feet
16	Roubidoux Creek	24 March 1980	200	5 (5 adult)	2.5*
16	Roubidoux Creek	18 April 1980	200	8 (6 adult)	4.0*
16	Roubidoux Creek	15 March 1981	1,230	27 (4 adult)	2.2**
16	Roubidoux Creek	11 March 1982	910	6 (6 adult)	0.7**
30	Whetstone Creek	25 March 1980	115	6(6 adult)	5.2*
30	Whetstone Creek	20 May 1980	115	6 (6 adult)	5.2*
30	Whetstone Creek	28 Feb. 1981	115	4 (2 adult)	3.5*

*Only habitat known to be occupied by bluestripe darters was seined.
**All habitats in the stream reach under study were seined.

Abundance

Seining rates for the bluestripe darter at 48 stations are presented in Appendix 2, and are summarized in Table 3 for stream reaches known to support the bluestripe darter. Rates were computed separately for pools and riffles at most stations to determine habitat preferences, and also because different seining techniques were used in the two habitats. The time expended in seining averaged 2.7 hours per station, of which 0.6 hours was expended kick-seining riffles and 2.1 hours was expended drag-seining pools.

All bluestripe darters were collected from pools, and the catch rate in the pools of stream reaches known to support *P. cymatotaenia* averaged 2.3 individuals per hour. Catch rates were highest in Whetstone Creek, Niangua River, and Gasconade River.

The density of bluestripe darters was estimated by seining two stream sections intensively until no more bluestripe darters could be captured (Table 4). Density estimates achieved during censuses of the same area on different dates were fairly consistent when only bluestripe darter habitat was seined. Most of the variability that did occur was in the numbers of juveniles captured. The drastic difference in this estimate for the Roubidoux Creek station in 1981 and 1982 was largely determined by the substantial number of juveniles captured in 1981. The rate of capture for adults was actually greater in 1982 than in 1981.

Figure 5. Roubidoux Creek, Texas County (Station 16). Bluestripe darters were captured along the shore on the left of this photograph.

Behavior

The bluestripe darter is one of the most cryptically colored and secretive Missouri darters, and is less easily approached for observation than other darters I have studied. Individuals observed in the open and unalarmed were generally moving about near but not on the bottom, picking food items from the substrate or submerged objects such as sticks or the stems of aquatic plants. When slightly alarmed they sank to the bottom and remained quiet, taking advantage of any available cover for partial or complete concealment.

When thoroughly alarmed they dashed off or plunged into thick growths of aquatic vegetation if any was present. Mr. Harold Kerns called my attention to the close resemblance of the color pattern of *P. cymatotaenia* to the "skeleton" structures of dead stems of the *Justicia* with which this species is often associated. When viewed from above, the predominate color pattern of *P. cymatotaenia is* of alternating light and dark lengthwise parallel stripes.

Table 5. Occurrence of fish species at stations where bluestripe darters were seined. Faunal groups are: Ozark (0), Ozark-Lowland (O-L), Ozark-Prairie (O-P), and wide-ranging (WR). Only species present at 10 or more bluestripe darter localities are listed. Total occurrences are based on 248 localities from the Ozark section of the Osage and Gasconade stream systems.

Species	Constancy* (%)	Fidelity** (%)	Number of occurrences: With bluestripe darter	Number of occurrences: Total	Faunal group
Large Fishes					
Longear sunfish	100.0	15.8	28	190	O-L
Green sunfish	96.7	16.1	27	180	WR
Northern rockbass	90.0	31.0	26	84	O
Bluegill	93.3	19.2	26	146	WR
Northern hog sucker	83.3	16.8	23	149	O
Golden redhorse	83.3	21.0	23	119	O
Black redhorse	80.0	20.5	22	117	O
Smallmouth bass	80.0	17.1	22	140	O
Largemouth bass	80.0	18.9	22	127	WR
Yellow bullhead	40.0	23.5	10	51	WR
Nektonic Fishes					
Largescale stoneroller	100.0	16.7	28	180	O
Bleeding shiner	100.0	14.3	28	210	O
Bluntnose minnow	100.0	16.1	28	186	WR
Hornyhead chub	96.7	16.0	27	181	O
Brook silverside	93.3	18.5	26	151	O-L
Central stoneroller	90.0	12.0	25	225	O-P
Ozark minnow	86.7	13.8	25	188	O
Northern studfish	86.7	16.4	25	159	O
Blackspotted topminnow	90.0	15.4	25	175	O-L
Rosyface shiner	83.3	22.1	23	113	O
Wedgespot shiner	66.7	32.2	19	62	O
Striped shiner	56.7	21.2	16	80	O
Spotfin shiner	56.7	40.5	16	42	O
Redfin shiner	60.0	15.1	16	119	WR
Bigeye shiner	53.3	44.4	15	36	O
Creek chub	50.0	11.4	15	132	O-P
Southern redbelly dace	36.7	12.8	11	86	O
Plains topminnow	36.7	24.4	10	45	O
Benthic Fishes					
Greenside darter	96.7	18.8	27	154	O
Rainbow darter	93.3	15.2	27	184	O
Banded darter	90.0	26.0	25	104	O
Log perch	90.0	23.7	25	114	O
Orangethroat darter	86.7	11.0	24	217	O
Slender madtom	83.3	16.0	23	156	O
Missouri saddled darter	80.0	24.2	22	99	O
Mottled sculpin	63.3	18.6	17	102	O
Banded sculpin	53.3	18.8	16	85	O
Gravel chub	56.7	26.6	15	64	O
Fantail darter	56.7	10.2	15	167	O
Stippled darter	43.3	13.0	12	93	O
Gilt darter	40.0	31.6	11	38	O

*Constancy (%) = Number of occurrences with the bluestripe darter as a percent of total bluestripe darter occurrences.

**Fidelity (%) = Number of occurrences with the bluestripe darter as a percent of total occurrences of the species.

Associated Species

Some 78 species of fishes were identified at stations where bluestriped darters were collected. The number of species recorded per station ranged from 22 to 53, averaging 37.2. The fauna was decidedly Ozarkian in character. Species assigned by Pflieger (1971) to the Ozark, Ozark-lowland, and Ozark-prairie faunal groups comprised 85.4% of the species that occurred at 10 or more bluestripe darter localities (Table 5).

I used the concepts of dominance, constancy and fidelity to characterize fish populations at stations where bluestripe darters occurred. In the context of this study, dominance was the relative numerical abundance of fish species in seine collections from bluestripe darter localities. Constancy was the number of occurrences of a species with the bluestripe darter as a percentage of total bluestripe darter occurrences. Fidelity was the number of occurrences of the species with the bluestripe darter as a percentage of total occurrences of the species at 248 localities within the Ozark section of the Osage and Gasconade drainages.

The species ranking differed for each of the three parameters (dominance, constancy, and fidelity), but together they adequately characterized fish populations at localities where bluestripe darters were collected (Fig. 6, Table 5).

Centrarchids (longear sunfish, green sunfish, rock bass, smallmouth bass, and bluegill), and suckers (black redhorse, golden redhorse, and northern hog sucker) were the dominant and characteristic groups of large fishes. The longear sunfish occurred at all bluestripe darter localities.

Three species of nektonic fishes (bleeding shiner, largescale stoneroller, and bluntnose minnow) occurred at all bluestripe darter stations. Two of these (bleeding shiner and largescale stoneroller) and the Ozark minnow were the numerically dominant nektonic species. Benthic fishes exhibiting the highest constancy at bluestripe darter localities were greenside darter, rainbow darter, banded darter, log perch, and orangethroat darter. The rainbow darter and orangethroat darter comprised 65.9% of all the benthic fishes collected. The bluestripe darter ranked 10th in numerical abundance among benthic fishes at these localitities.

Figure 6. Relative numerical abundance of fish species at 22 localities where bluestripe darters were collected.

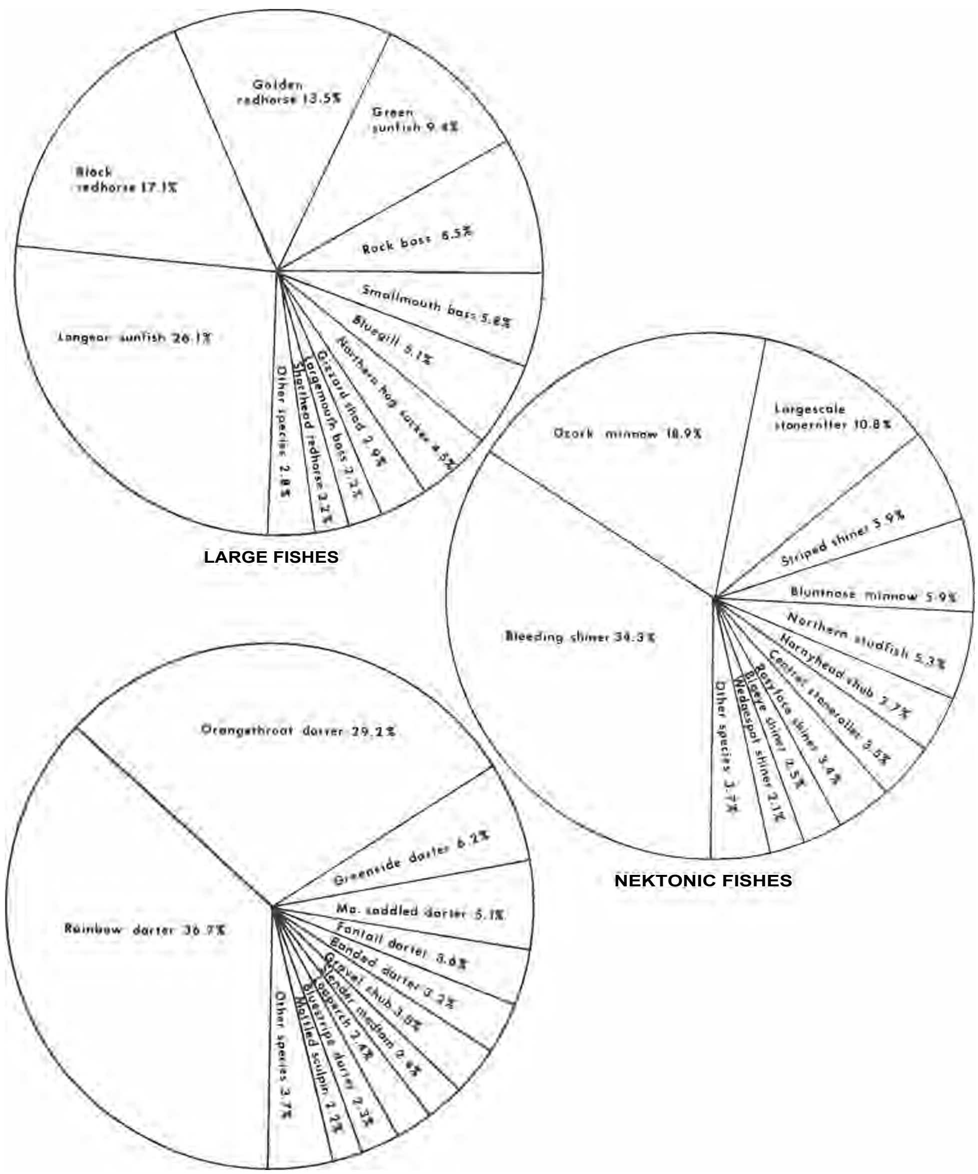


Table 6. Percent frequency of occurrence and percent composition by number of items in the stomachs of 56 bluestripe darters during four time periods.

	Feb.-March		April-May		July-August		Sept.-Oct.	
Item	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.
Microcrustacea	44.0	16.2	37.5	26.0	77.8	22.8	66.7	22.7
Amphipoda	8.0	1.1	0		22.2	2.6	50.0	11.3
Ephemeroptera								
Baetidae	4.0	0.2	68.8	37.0	44.4	17.5	50.0	3.5
Heptageniidae	4.0	0.2	31.3	2.9	0	0	0	0
Ephemerellidae	20.0	1.1	18.8	5.0	0	0	0	0
Other Ephemeroptera	12.0	2.3	37.5	3.8	44.4	2.6	33.3	4.3
Odonata	0	0	6.3	0.4	77.8	11.4	50.0	8.7
Plecoptera	24.0	11.9	6.3	0.4			0	
Trichoptera	4.0	0.2		0	55.6	19.3	50.0	35.7
Diptera	76.0	65.0	81.3	23.1	77.8	14.9	50.0	11.3
Misc. Invertebrates	16.0	1.0	12.5	1.2	33.3	7.9	16.7	2.6
Unidentified (organic)	12.0	0.6	0	0	0	0	0	0
Sand	0	0	0	0	11.1	0.9	0	0
Sample size	25		16		9		6	

Table 7. Percent frequency of occurrence and percent composition by number of items in the stomachs of 56 bluestripe darters of three length groups.

	36mm-51mm		54mm-64mm		66mm-82mm		All length groups	
Item	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.
Microcrustacea	68.0	34.5	26.7	7.1	37.5	17.5	44.6	4.9
Amphipoda	8.0	0.9	20.0	6.1	12.5	1.4	12.5	3.0
Ephemeroptera								
Baetidae	28.0	9.1	26.7	11.3	50.0	5.4	33.9	11.2
Heptageniidae	0	0	6.7	0.5	31.3	2.0	10.7	6.0
Ephemerellidae	12.0	0.9	20.0	2.8	12.5	2.3	14.3	8.0
Other Ephemeroptera	4.0	0.3	20.0	2.8	56.3	5.9	23.2	23.8
Odonata	12.0	3.4	13.3	4.2	18.8	1.1	14.3	5.3
Plecoptera	20.0	16.8	6.7	0.5	6.3	0.3	12.5	7.4
Trichoptera	20.0	5.8	20.0	15.0	6.3	3.7	16.1	3.8
Diptera	64.0	24.7	66.7	47.4	100.0	58.6	75.0	24.4
Misc. invertebrates	12.0	3.6	20.0	1.8	18.8	1.2	16.1	1.7
Unidentified (organic)		0	6.7	0.5	12.5	0.6	5.4	0.3
Sand	0	0	0	0	6.3	0.3	1.8	0.1
Sample size	25		15		16		56	

Food and Feeding

The food of 56 bluestripe darters was mostly immature aquatic insects, supplemented by lesser quantities of microcrustacea, amphipods, and other aquatic invertebrates (Table 6 and 7; Figs. 7 and 8). Some 35 taxa were among the food items recorded (Appendix 3). No items of terrestrial origin were found in digestive tracts. Ephemeroptera (principally Baetidae, Heptageniidae, and Ephemerellidae) and Diptera (principally Chironomidae) were the most important aquatic insects, but Odonata, Plecoptera, and Trichoptera were also present. Cladocera and Copepoda were the most important microcrustacea; *Hyallela azteca* was the only species of amphipod identified. The sand found in one stomach was probably ingested accidentally.

Some seasonal differences were evident in the food habitats of P. *cymatotaenia*. Stoneflies (Plecoptera) occurred only in the February-March and April-May periods, and were third in volumetric abundance in February-March. Odonata (dragonflies and damselflies) were one of the dominant food items in the July-August and September-October periods, but were of only minor importance in other time periods. Ephemeroptera (mayflies) appeared to show a pattern of declining importance from the July-August period through the September-October period, increasing again in February-March and reaching a peak in the April-May period.

Trichoptera (caddisflies) increased in importance from the July-August period to the September-October period, in which it was first in volumetric abundance, but was scarcely represented in the February-March and April-May periods. Diptera (true flies) increased in volumetric abundance from the July-August period to the September-October period and peaked in the February-March period.

Few consistent trends were evident in the changes in food habits of the bluestripe darter with increasing size. Ephemeroptera (mayflies) appeared to be of increasing importance from the smallest to the largest length group, and Plecoptera (stoneflies) exhibited the opposite trend.

Figure 7. Percent composition by volume of food items in stomachs of 56 bluestripe darters during four time periods.

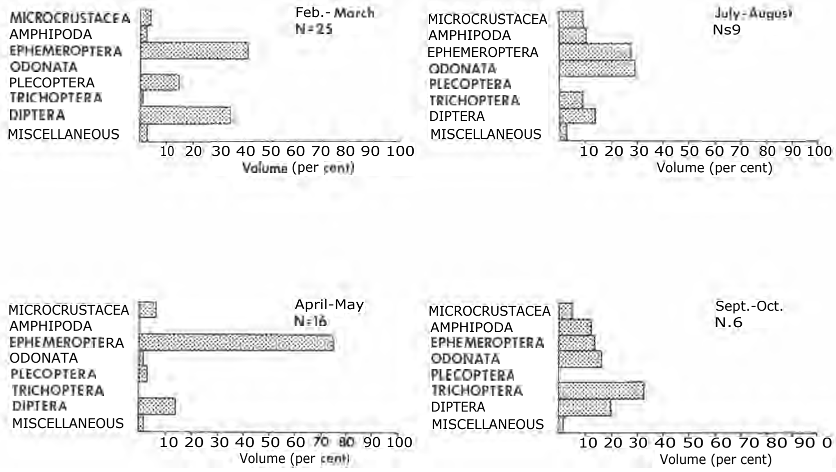
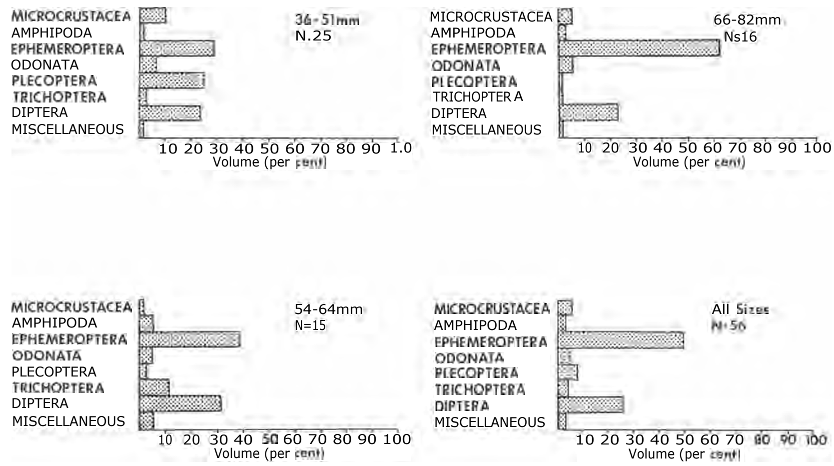


Figure 8. Percent composition by volume of food items in stomachs of 56 bluestripe darters of three length groups, and in all specimens combined Length is standard length.



Age and Growth

Scales of 79 bluestripe darters were used for studies of age and growth. Of these, 32.9% were age-group 0, 24.1% were age-group I, 29.1% were age-group II, 10.1% were age-group III, and 3.8% were age-group IV (Table 8). Since spawning in this species occurs in late March and early April, I designated April 1 as the birthdate for purposes of aging.

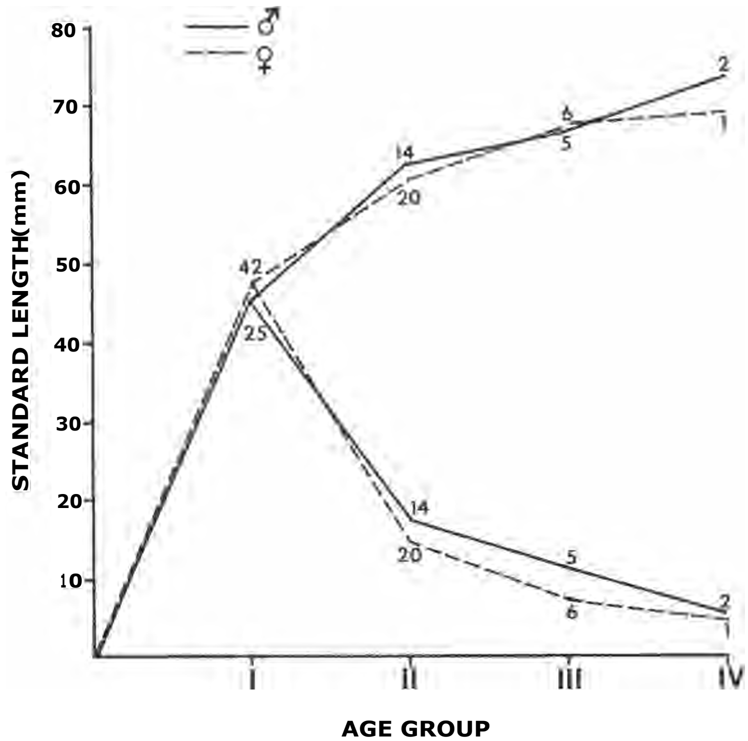
I used a binomial test to determine if the sex ratio for various age classes or the total sample exhibited a significant departure from 1 to 1. Although females predominated in all age groups except IV, only the ratio for age-group I tested as significant.

Table 8. Numbers of individuals by age-group and sex in samples of the bluestripe darter.

			Age group			
Sex			II	III	IV	Total
Male	12	5	9	3	2	31
Female	14	14	14	5	1	48
Total	26	19	23	8	3	79

AGE GROUP

Figure 9. Average back-calculated lengths and average growth increments for 79 bluestripe darters. The number of specimens used in calculating each length and length increment are given.



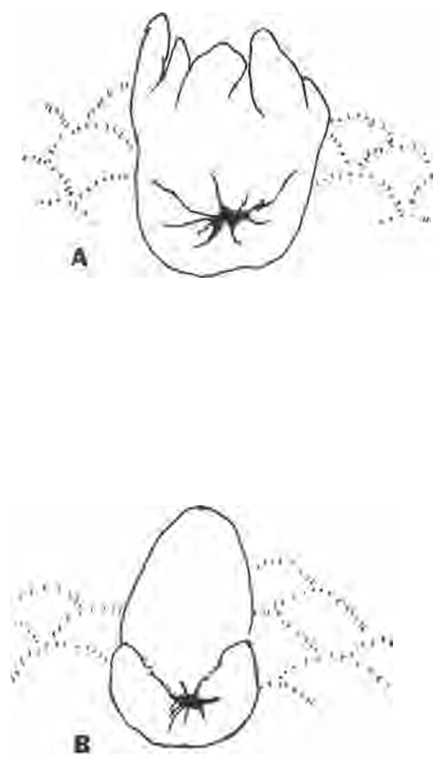
Growth and longevity were nearly the same in males and females (Fig. 9). A t-test was used to compare the average lengths attained by males and females at each annulus, and none were found to be significant at the .01 level of confidence. The largest specimen of *P. cymatotaenia* examined in this study was an 81.8 mm female captured in July of her third summer of life. The smallest individual, also a female, measured 36.1 mm SL and was captured in February of her first year of life. The youngest individual examined was a 42.4 mm female captured on July 29, at an age of about four months. The bluestripe darter achieves approximately 55% of its maximum adult length by the end of its first year of life. At that age, males and females averaged 46.0 mm and 47.9 mm SL, respectively.

A total-length to standard-length conversion was computed emperically from preserved specimens for use in converting the total length of specimens measured in the field to standard length. The formula for this conversion was:

SL (standard length) = -0.8395 + 0.8706 TL (total length)

The correlation coefficient (r) of 0.997 was significantly different from 0 ($P<0.01$).

Figure 10. Genital papilla of sexually mature female (A) and male (B) of the bluestripe darter.



Reproduction

Sexual dimorphism—Sexually mature males and females of the bluestripe darter differ in the size of the soft dorsal and soft anal fins, the shape of the genital papilla, the distention of the abdomen in females, and the presence of a prominent keel on the caudal peduncle in males. The soft dorsal and soft anal fins reach much closer to the base of the caudal fin in males than in females, and when depressed these fins comprise about 30% and 20% of the standard length, respectively, in the two sexes.

The genital papilla of males is a smooth, triangular-shaped structure, while that of females is prominently lobed and truncated on its distal margin (Fig. 10). Bailey (1948) was first to note the presence of a prominent median keel on the lower edge of the caudal peduncle in *P. cymatotaenia*. This structure, bearing strongly ctenoid scales on its lateral surfaces, is present only in males (Fig. 11), and is unique to this species and its underscribed relative in Kentucky.

Figure 11. Ventral surface of caudal region of sexually mature female (A) and male (B) of the bluestripe darter, showing development of the keel in the male.

A

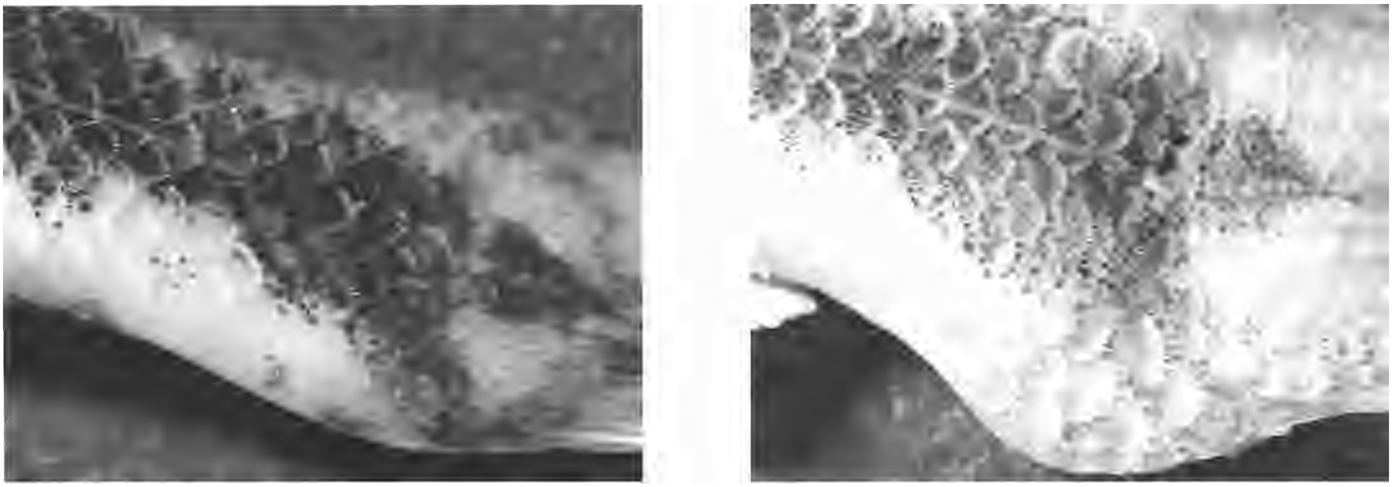


Figure 12. Color pattern of sexually mature adults of the bluestripe darter. Pattern of male not engaged in breeding behavior (A) and engaged in breeding behavior (B). Pattern of female (B), lower fish.

A

The only color difference between males and females was the greater development in males of a narrow dark band along the distal margin of the spinous dorsal. However, males engaged in breeding activity underwent a dramatic color change (Fig. 12). This change was quite rapid, and males could go from the usual color to breeding color or back again in a few minutes.

During the change to breeding color the midlateral and middorsal stripes blanch, and are replaced by a series of black bars. The midlateral bars number 10, and they result from intensification and elongation of the blotches that overlay the lateral stripe in the usual color phase. The smaller bars along the dorsum also number about 10.

In some males a narrow longitudinal stripe was present along the upper sides, touching the margins of the dorsal bars, but separated from the lateral bars. In some more highly colored males this stripe was indistinct or absent. The ventral surface of the head and body in breeding males is splotched with black pigment. Some males that engaged in breeding activity exhibit the color change described above to only a slight degree (Fig. 14b).

Females of the bluestripe darter undergo only a slight color change when engaged in breeding activity, involving a blanching of the basic color pattern they have at other times (Fig. 12b).

Age and size at maturity —Slightly more than half (52%) of 25 age I bluestripe darters were sexually mature when captured in early spring. The proportion of sexually mature individuals was higher in females (64.7%) than in males (25.0%). Immature age I females were 36-52 mm SL, averaging 43.8 mm, while mature age I females were 44-62 mm SL, averaging 51.0 mm. Immature age I males were 42-53 mm SL, averaging 45.5 mm SL, while two mature age I males were 48-51 mm SL. All age II or older bluestripe darters captured in February and March were sexually mature.

Fecundity -Fecundity determinations were made on 12 females collected in February 1977 and March 1980 (Table 9). Mature ova were distinguished from immature ova on the basis of appearance and size. Mature ova were dark yellow and translucent, and ranged in diameter from 1.0 to 2.0 mm. Immature eggs were pale yellow or white and opaque, and ranged in diameter from 0.1 to 1.4 mm.

The number of mature ova are plotted against female standard length in Fig. 13. The regression line was fitted by the least squares method. The logarithmic regression which described this line was:

Log F (fecundity) = -2.2777 + 2.5635 Log L (standard length)

The correlation coefficient (r) of 0.7749 was not significantly different from 0 ($P = 0.15$), indicating that for these females the number of mature ova was not significantly related to standard length.

A logarithmic regression was also computed for describing the relationship between number of mature ova and female age as follows:

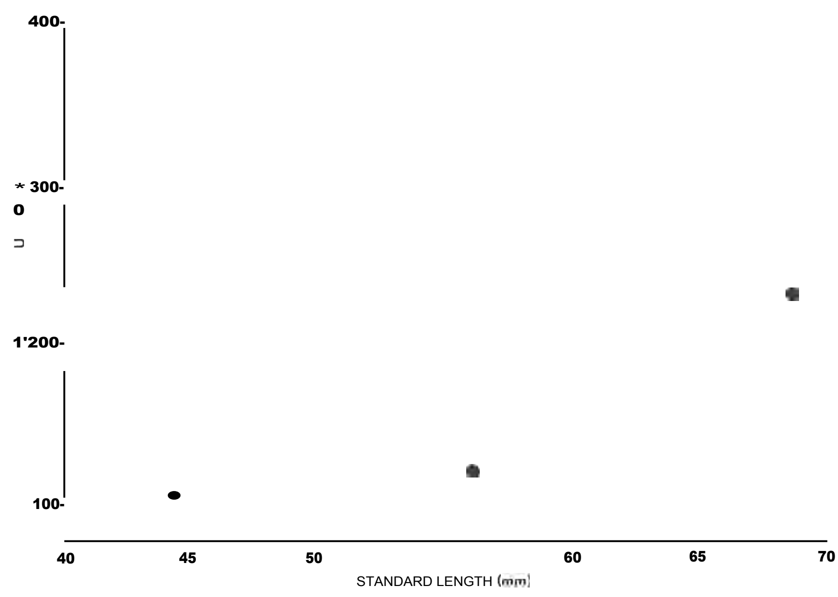
Log F (fecundity) = 0.7718 + 1.0845 Log A (age in months)

The correlation coefficient (r) of 0.7974 was not significantly different from 0 ($P = 0.14$), indicating that for these females the number of mature ova was not significantly related to female age.

Table 9. Number of ova in twelve female bluestripe darters collected in February 1977 and March 1980.

Collection date	Standard length	Age group	Mature	Immature	Total
24 Feb. 1977	44.3		104	244	348
24 Feb. 1977	45.6		81	281	362
24 Feb. 1977	55.8	II	290	509	799
24 March 1980	56.1	II	122	43	165
24 March 1980	58.1	II	213	256	469
24 March 1980	59.0	II	126	245	371
24 March 1980	60.6	II	184	169	353
24 March 1980	62.3	II	126	329	455
25 March 1980	66.2	II	267	277	544
25 March 1980	68.7	III	233	297	530
25 March 1980	69.1	III	351	271	622
25 March 1980	69.3	III	344	175	519

Figure 13. Number of mature ova in 12 female bluestripe darters collected in February and March.



In the Niangua darter (Pflieger 1978), I found a significant relationship between fecundity and female age and length. The reasons for the poor correlation between these parameters in the bluestripe darter are unclear. Possibly, spawning was already in progress when these females were collected and the ova counts that we obtained resulted because some females had already deposited part of their eggs. If this is correct, spawning may have occurred earlier in the year than I suspect.

Spawning period —The timing and duration of spawning in the bluestripe darter were not adequately documented in this study, but I did establish that spawning occurred in early spring, with the peak occurring in March and April. In 1980, 10 females collected in Roubidoux Creek and Whetstone Creek on March 24 and 25 were gravid but not ripe, while two of four males collected with them were ripe. Stream temperatures on those dates were 46°-48°F, and stream flows were near seasonal base levels.

Heavy rain on April 8 and snow on April 14 resulted in the postponement of further observations until April 18. On that date, eight bluestripe darters were collected in Roubidoux Creek (two age I and six age II or older). None of these specimens were gravid or ripe. Three specimens were preserved and the gonads were subsequently examined. One, an age I female, contained mature eggs, while the others, an age II female and an age II male were spent.

February and March were unseasonably warm in 1981, and this may have resulted in earlier spawning by the bluestripe darter. On March 11, three of four males collected in Big Piney River were ripe, and five females collected with them were gravid. The water temperature was 53°F. On March 15, four females were collected along with 23 juveniles in Roubidoux Creek. One of these females was judged to be ripe, since she released a few eggs when pressure was applied to her abdomen. The other three females were gravid but not ripe. No males were collected, and I surmised that they might be in different habitat and perhaps were spawning. The water temperature was 49°F.

On March 24, 14 male and three female bluestripe darters were collected from the Niangua River. One of the males was checked and was found to be ripe, and another that was preserved had mature testes. The females were all slightly gravid but were not ripe. On March 26, two of five females collected in the Osage Fork appeared to be spent, and another appeared to be partly spent.

Spawning was observed only in the laboratory tank. In 1981, seven bluestripe darters (one male, two females, and four juveniles) were placed in the tank on March 2 and 3. Two more males were added March 11, and another female was added March 15. The water temperature was maintained at about 45°F until March 12, 48°F until March 19, and 54°F until March 27 when the adults were removed from the tank. Spawning was observed on March 16 and March 21.

In 1982, six male and seven female *P. cymatotaenia* were placed in the tank on March 11. The water temperature was maintained at about 33°F. until March 15, 37°F until March 17, 43°F until March 18, and 50°F until March 19 when spawning was first observed. Between March 19 and April 10 spawning was observed on six days, at temperatures ranging from 50°F to 56°F. Temperatures during this period were not held constant, fluctuating from 36°F to 59°F. Males were observed in breeding color until April 16, at temperatures as high as 64°F. Spawning may have occurred during this period, but was not observed because observations were too infrequent. The darters were released on April 23.

Spawning behavior—Females indicated readiness to spawn by swimming slowly over the substrate, with the caudal region elevated slightly higher than the head. Females were very passive and exhibited no overt aggression. Approach by a male occasionally elicited a side-to-side head-jerking behavior in females. The female usually settled into a slight depression just before spawning. The eggs were released a few at a time during repeated spawning bouts over a period of hours or days. One female spawned a minimum of 47 times with two different males over a period of $2^1/3$ hours. Another female spawned repeatedly over a period of more than eight hours on March 19 and then spawned several more times on April 6, 18 days later.

Males usually maintained breeding colors (see sexual dimorphism) only while actively engaged in breeding behavior, but one male was in color each time he was observed over a period of several days. Males in breeding color were quite agressive, particularly towards other males in breeding color. Generally, each male confined his activities to a particular part of the tank, and attempted to exclude other males in breeding color from the area.

Males not in color and even females were occasionally chased, but usually their presence in the defended area was tolerated. Once a male in breeding color attempted to elicit spawning behavior in a male that was not in color, as he foraged in the breeding males area. Typically, the smaller males did not develop breeding color and did not defend an area, although they frequently engaged in spawning behavior. Males not in spawning color often spawned within the area defended by territorial males without eliciting a strong aggressive response.

Males followed females as they swam over the substrate, mounting them and attempting to elicit spawning by pressing against the female and vibrating. If the female responded by vibrating, the spawning pair vibrated in unison, creating a shallow furrow in the gravel substrate as they moved forward for an inch or more (Fig. 14A). During spawning, the posterior one-third of the female's body was pressed into the substrate, and the anterior two-thirds of both fish were curved upward at about a 45-degree angle. The caudal peduncle of the male was curved downward on one side of the female, and his anal fin was pressed against the female on the other side. All of his fins except the caudal were fully spread, and the pectoral fins were curved forward. The pectoral and pelvic fins of the female were also spread and fully extended.

Figure 14. Spawning act of the bluestripe darter. Male in breeding color (A), and male not in breeding color (B). A territorial male in breeding color is shown in the background of B.

A

Spawning habitat—Although spawning was observed only in the laboratory, a few generalizations can be made about the spawning habitat of the bluestripe darter, based on the laboratory observations of spawning and the distribution of sexually mature adults in the field. In the laboratory, this species selected fine gravel for spawning when provided a variety of other substrates, including coarse gravel, rock, aquatic vegetation, and water-soaked tree leaves.

One male established a spawning territory over coarse gravel, but this apparently occurred because he was excluded from fine gravel substrate by another dominant male that spawned more frequently. Gravelly riffles and chutes with slow or moderate current were commonly present adjacent to the backwaters where sexually mature adults were captured, and on two occasions a ripe male was seined or observed in this habitat. The only ripe female ever captured in the field was also captured in this habitat. These observations lead me to believe that the bluestripe darter spawns over fine gravel in slow, deep riffles and chutes adjacent to the quiet backwater areas it inhabits throughout the year.

Early development—In 1981, males and females of the bluestripe darter from the laboratory tank were stripped, and 21 eggs were obtained. The eggs were incubated with aeration at temperatures ranging from 53°F to 56°F. Most of these eggs were dead within 36 hours, but five survived more more than 48 hours. They were not checked again for three days, by which time all were dead.

In 1982, eggs were collected from the substrate of the tank after spawning was observed. All of four eggs collected on March 25 hatched, and about 50% of 32 eggs collected on March 30 hatched. These eggs were incubated with aeration at temperatures ranging from 54°F to 68°F.

Newly fertilized eggs were about 2 mm in diameter, with a prominent oil globule adjacent to the blastodisc. By the 4th or 5th day following fertilization the larva was actively moving in the egg membrane, and the eye was clearly visible. The larvae hatched nine or 10 days after spawning, at which time they averaged 8.5 mm TL, and the yolk sac was 4.2 mm in length.

Although plankton was provided as food, the darters never fed, and all were dead about 10 days after hatching.

Parasites

Bluestripe darters dissected for studies of food habits and fecundity were found to contain flukes (trematodes) in the digestive tract (four specimens), in the fat surrounding the digestive tract (four specimens), and in the ovaries (one specimen). The number of flukes observed ranged from one to four per specimen.

STATUS AND THREATS TO SURVIVAL

The bluestripe darter evidently underwent a fairly drastic decline in distribution and abundance between the 1880s when it was initially discovered and the 1930s and 1940s when the first general survey of Missouri fishes was made. Collectors in 1884 and 1889 recorded *P. cymatotaenia* from five of 13 localities sampled within its general range and reported it as "abundant" in three streams. This species has not subsequently been collected from any of these localities, and I would not judge it to be "abundant" in any collection made since 1930.

The principal feature of this decline appears to have been a withdrawal from headwater habitats. Perhaps this decline resulted from rapid deforestation and repeated burning of Ozark watersheds during the early part of this century. These factors probably resulted in the influx of chert gravel into the streams, eliminating pool habitat and reducing surface flow across riffles. Headwater streams would become more intermittent or dry up entirely as a result of these changes.

Collections made over the period from 1930 to the present suggest that populations of the bluestripe darter have remained relatively stable, but possibly with a recent decline in the upper Big Piney River and Woods Fork of the Gasconade River. In collections made in the upper Big Piney River in the 1930s and 1940s *P. cymatotaenia* was recorded at Highway 17 west of Houston, Texas County and at another locality 10 miles upstream. It was also recorded at the Highway 17 locality in 1967.

In 1980 I made two collections at Highway 17 and one collection 8 miles upstream without finding the bluestripe darter. In 1969 I recorded *P. cymatotaenia* from the Woods Fork at Highway 38 east of Hartville, Wright County. This species was not present in my 1980 collection from that locality. Two other darters (greenside darter and least darter) that were common at this locality in 1969 were also absent from the 1980 collection.

The changes noted above suggest that the bluestripe darter may still be declining at a slower, less detectable rate than occurred in the early part of this century. The gradual deterioration of stream habitat, involving changes such as increased sedimentation, channel instability, and nutrient enrichment, could be instrumental in such a decline. For the streams under consideration, little documentation exists for these changes and their causes, but I believe that urbanization and the continuing conversion of woodlands to pasture are implicated by one recent study (Smart 1980).

This investigator found higher concentrations of certain nutrients (nitrogen and phosphorus) and greater algal biomass in Ozark streams draining watersheds with urban development and those draining watersheds with a high proportion of pasture than in streams draining watersheds that were still mostly in forest. It seems likely that stream fish communities that evolved in the low-nutrient, forested watersheds of the Ozarks would be affected by the nutrient enrichment associated with urbanization and the conversion of forest to pasture.

The decline previously noted in abundance of the bluestripe darter, greenside darter, and least darter in Woods Fork of the Gasconade River between 1969 and 1980 may have resulted from nutrient enrichment. During the time span between these dates a sewage lagoon constructed by the city of Hartville began discharging into the Woods Fork upstream from the sampling site. Decline of the bluestripe darter in the upper Big Piney River between 1940 and 1980 may indicate a similar response, since that stream receives sewage effluent from the town of Cabool.

In assessing the status of the bluestripe darter it is useful to compare its distribution and abundance with the Niangua darter, since the two species have overlapping distributions and have both been subject to recent surveys using comparable methods.

In terms of general distribution the bluestripe darter is the more widely distributed of the two. It occurs in at least 240 miles of stream in two major drainages (Osage and Gasconade), compared with at least 128 miles of stream in one major drainage (Osage) for the Niangua darter. The range of the Niangua darter is more fragmented than that of the bluestripe darter. This is due in part to its tendency to occur in smaller streams (mostly orders III-V) than the bluestripe darter (mostly orders V-VI), but more importantly is due to the presence of several man-made impoundments within its range in the Osage Basin. The bluestripe darter, on the other hand, has its distribution centered in the Gasconade drainage, where no major impoundments have been constructed and none are planned.

The bluestripe darter seems to occur in somewhat higher population densities than the Niangua darter. This is suggested by the higher seining rate for the bluestripe darter (2.3 per hour) compared with the Niangua darter (1.1 per hour). The bluestripe darter may be more readily seined than the Niangua darter, but I would expect the opposite because of the tendency for the bluestripe darter to occur in or near cover.

Although both species are quiet-water darters except when spawning, they occupy different habitats. The bluestripe darter generally occurs along the channel margin and exhibits a definite affinity for detritus and aquatic vegetation. The Niangua darter occurs in the main channel, generally over a substrate of gravel and rubble that is largely free of silt.

I judge that the bluestripe darter is less vulnerable to extinction than the Niangua darter. Its wider distribution and occurrence in two major drainages reduces the likelihood that a localized natural or man-induced disaster could result in a drastic reduction in all populations. Because the bluestripe darter has a more continuous distribution, there is less likelihood of the permanent extirpation of populations. If the bluestripe darter were eliminated from a stream reach by some temporary condition such as pollution or drought, it would be reestablished from nearby habitable areas. Local extirpation of Niangua darter populations, however, would be more permanent, because the high dams and reservoirs that isolate most populations of this species are effective barriers to dispersal from other habitable areas.

The bluestripe darter occurs in larger streams than the Niangua darter, and these larger streams are less affected by droughts and other factors that might lead to extirpation of populations. Also, the bluestripe darter occurs in somewhat higher population densities than the Niangua darter, and this would seem to render its populations less subject to extirpation.

RECOMMENDATIONS

1. I do not recommend listing of the bluestripe darter as a nationally threatened species at this time. Although it occurs in low population densities, it has a fairly wide and continuous distribution, and for the present its habitat seems relatively secure.

2. Populations of this species should be sampled periodically to determine trends in distribution and abundance. In particular, additional sampling is needed in the upper Big Piney River and Woods Fork to determine if the bluestripe darter is still present.

3. Studies should be conducted to define changes in habitat quality that are responsible for the decline or disappearance of the bluestripe darter from certain stream sections.

4. Habitat quality within the range of the bluestripe darter should be maintained and improved. The water quality standards for Missouri streams should be vigorously monitored and enforced. If these standards are found to be insufficient to maintain habitat quality, efforts should be made to obtain more stringent standards. Landowners should be encouraged to adopt land-use practices that are consistent with the maintenance of stream habitat quality through education, cost-sharing on approved soil-conservation practices, and the leasing of easements along reaches of prime stream habitat.

ACKNOWLEDGMENTS

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REFERENCES

Bailey, R. M. 1948. Status, relationships, and characters of the percid fish, *Poecilichthys sagitta* Jordan and Swain. Copeia, 1948(2):77-85.

Gilbert, C. H. 1888. Description of new and little known etheostomids. Proceedings of U.S. National Museum 10:47-64.

Horton, R. E. 1945. Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. Bull. Geol. Soc. Amer. 56:275-370.

Meek, S. E. 1891. Report of explorations made in Missouri and Arkansas during 1889, with an account of fishes observed in each of the river basins examined. Bulletin of U.S. Fish Commission 9:113-141.

Page, L. M. 1974. The subgenera of Percina (Percidae: Etheostomatini). Copeia, 1974(1):66-86.

Pflieger, W. L. 1971. A distributional study of Missouri fishes. Museum of Natural History, University of Kansas, Publication 20(3)225-570.

Pflieger, W. L. 1978. Distribution, status, and life history of the Niangua darter, *Etheostoma nianguae*. Missouri Department of Conservation Aquatic Series No. 16, 25 pp.

Robins, C. R. and R. W. Crawford. 1954. A method of estimating volume of stream flow. Journal of Wildlife Management 18(4):366-369.

Robins, C. R., et *al.* 1980. A list of common and scientific names of fishes from the United States and Canada. Amer. Fish. Soc. Spec. Publ. No. 12 (Fourth edition), 174 pp.

Smart, M. M. 1980. Stream-watershed relationships in the Missouri Ozark Plateau Province. Ph. D. dissertation, Univ. Missouri-Columbia, 171 pp.

APPENDICES

Appendix 1

Sampling stations selected for more intensive studies of bluestripe darter habitat, abundance, and life history. The dates listed are those on which collections or observations were made. Asterisks denote stations where bluestripe darters were found.

1. Little Piney Cr. at mouth of Mill Creek; T37N, R9W, S20, SE 1/4; Phelps Co. — April 18, 1980.

2. Little Piney Cr. at Newburg; T37N, R9W, S22, SE 1/4; Phelps Co. — July 29, 1980.

3. Little Piney Cr. at Lane Spring; T36N, R8W, S32; Phelps Co. — July 28, 1980.

4. Big Piney R. 2 1/2 mi. E of Big Piney; T34N, R10W, S8; Pulaski Co. — July 28, 1980.

*5. Big Piney R. at Slabtown; T33N, R10W, S15; Texas Co. — April 17, 1980; July 28, 1980; July 29, 1980; March 11, 1981.

6. Big Piney R. at end of Rt. BB (Boiling Spring); T32N, R10W, S24, SW 1/4; Texas Co. — April 17, 1980 and July 28, 1980.

7. Paddy Cr. at Paddy Creek Campground; T33N, R10W, S21; Texas Co. — April 17, 1980.

8. Arthur-Bender Cr. near end of Rt. "0," 6 mi. N of Houston; T31N, R9W, S9, NW 1/4; Texas Co. — May 19, 1980.

9. Arthur Cr. at Hwy. 63, 51/2 mi. NE of Houston; T31N, R9W, S15, Texas Co. — May 19, 1980.

10. Big Piney R. at Dogs Bluff; T30N, R10W, S2; Texas Co. — May 20, 1980.

11. West Piney Cr. 23/4 mi. WSW of Houston; T30N, R10W, S16; Texas Co. — March 25, 1980.

12. Big Piney R. at Rt. "Z" (above West Piney Cr.); T30N, R10W, S11, NW 1/4; Texas Co. — July 28, 1980.

13. Big Piney R. at Baptist Camp; T30N, R10W, S34; Texas Co. — May 19, 1980.

14. Big Piney R. at Hwy. 63, 5 3/4 mi. NE of Cabool; T29N, R10W, S16; Texas Co. — May 19, 1980.

15. Roubidoux Cr. 1 1/4 mi. N of Waynesville; T36N, R11W, S13; Pulaski Co. — March 26, 1981.

*16. Roubidoux Cr. at Hwy. 17, just above Ft. Leonard Wood; T33N, R12W, S3, NE 1/4; Texas Co. — March 24, 1980; March 15, 1981; April 30, 1981.

*17. Roubidoux Cr. at 1st crossing above Hwy. 17 (Forest Service Picnic Ground); T33N, R12W, S10, E 1/2; Texas Co. — September 11, 1980, October 30, 1980, and February 21, 1981.

*18. Roubidoux Cr. 4 1/4 mi. NW of Plato; T33N, R12W, S15, SW 1/4; Texas Co. — April 18, 1980 and February 21, 1981.

19. Roubidoux Cr. at Hwy. 32 near Plato; T32N, R12W, S2, SW 1/4; Texas Co. — March 24, 1980.

20. West Fork Roubidoux Cr. at Roubidoux; T31N, R11W, S4; Texas Co. — March 24, 1980.

*21. Gasconade R. at Hazelgreen Access (Hwy. 44); T35N, R14W, S23, NW 1/4; Laclede Co. — May 28, 1980.

22. Gasconade R. just above mouth of Osage Fork; T35N, R14W, S23; Laclede Co. — May 21, 1980.

*23. Gasconade R. 4 mi. N of Nebo; T34N, R13W, S26; Laclede Co. — May 21, 1980 and February 28, 1981.

*24. Gasconade R. 2 mi. NE of Competition; T32N, R13W, S6, SW 1/4; Laclede Co. — March 10, 1982.

*25. Gasconade R. on Rt. "0," 11/4 mi. E of Competition; T32N, R13W, S7; Laclede Co. — May 21, 1980.

26. Beaver Cr. at Hwy. 95, 31/2 mi. N of Manes; T31N, R13W, S3, NW 1/4; Wright Co. — March 26, 1980.

27. Beaver Cr. 1 1/4 mi. ENE of Hartville (1st crossing above Hwy. 38); T30N, R12W, S20; Wright Co. — March 25, 1980.

*28. Gasconade R. on Rt. "H," 13/4 mi. SW of Manes; T31N, R13W, S29; Wright Co. — May 20, 1980.

*29. Gasconade R. at Rt. "E," 1 mi. N of junction with Hwy. 38; T30N, R13W, S17, NW 1/4; Wright Co. — February 28, 1981.

*30. Whetstone Cr. above Hwy. 38, 7 mi. NE of Hartville; T30N, R13W, S20; Wright Co. — March 25, 1980 and February 28, 1981.

31. Lick Fork Gasconade R. at Hwy. 5, 31/2 mi. SSW of Hartville; T29N, R15W, S13, NW 1/4; Wright Co. — March 26, 1980.

32. Woods Fork of Gasconade R. 1 1/2 mi. E of Hartville on Hwy. 38; T29N, R14W, S6, NE 1/4; Wright Co. — May 20, 1980.

33. Osage Fork 2 mi. SSW of Hazelgreen; T35N, R14W, S26; Laclede Co. — May 28, 1980.

34. Osage Fork on Hwy. 32 at Dry Knob Access; T34N, R12W, S27, NE 1/4; Laclede Co. — May 20, 1980.

35. Osage Fork at Orla; T33N, R15W, S26, SE 1/4; Laclede Co. — July 30, 1980.

*36. Osage Fork on Rt. "J" 23/4 mi. ESE of Morgan; T32N, R15W, S7, SW 1/4; Laclede Co. — July 30, 1980.

*37. Osage Fork on Rt. "F," 5 3/4 mi. NE of Niangua; T31N, R17W, S12; Webster Co. — March 26, 1981.

38. Osage Fork at 1st crossing above Rt. "M," 2¾ miles SE of Niangua; T31N, R17W, S34; Webster Co. — April 8, 1976.

39. Niangua R. 1 1/2 mi. ENE of Celt; T36N, R18W, S11, NW 1/4; Dallas Co. — February 24, 1977.

40. Niangua R. 1/2 mi. SE of Halsey Hollow Creek (Corkery); T35N, R18W, S1, NW 1/4; Dallas Co. — February 24, 1977.

41. Niangua R. below Bennett Spring; T35N, R18W, S25; Dallas Co. — February 24, 1977.

*42. Niangua R. SW of Windyville; T34N, R18W, S6, Dallas Co. — April 10, 1975 and February 24, 1977.

*43. Niangua R. 4 mi. NE of Buffalo; T34N, R19W, S17, NW 1/4; Dallas Co. — March 24, 1981.

*44. Niangua R. at slab crossing 2 3/4 mi. E of Buffalo; T34N, R19W, S29; Dallas Co. — February 23, 1977.

45. Greasy Cr. 2 1/2 mi. SSE of Buffalo; T33N, R19W, S6; Dallas Co. — October 5, 1976 and February 23, 1977.

*46. Niangua R. 3 3/4 mi. N of Charity; T33N, R19W, S22, NW 1/4; Dallas Co. — March 24, 1981.

47. Niangua R. on Rt. "M," 2 mi. E of Charity; T32N, R19W, S2; Dallas Co. — April 7, 1976 and October 5, 1976.

48. Niangua R. 9 1/2 mi. NNW of Marshfield; T32N, R18W, S30; Webster Co. — April 7, 1976.

49. Niangua R. on Rt. "Y," 7 1/2 mi. N of Marshfield; T32N, R18W, S33; Webster Co. — April 7, 1976; October 6, 1976; March 15, 1977.

Appendix 2

Number of bluestripe darters and number per hour at selected stations.

		Bluestripe Darters				Sampling effort	
		Number collected		Number per hour		(hours)	
Station number	Stream	Riffle	Pool	Riffle	Pool	Riffle	Pool
1	L. Piney Cr.	0	0	0.0	0.0	0.5	1.3
2	L. Piney Cr.	0	0	0.0	0.0	0.3	0.9
3	L. Piney Cr.	0	0	0.0	0.0	0.5	0.8
4	Big Piney R.	0	0	0.0	0.0	0.7	1.3
5	Big Piney R.	0	18	0.0	4.5	2.1	4.0
6	Big Piney R.	0	0	0.0	0.0	0.6	1.6
7	Paddy Cr.	0	0	0.0	0.0	0.7	1.1
8	Arthur-Bender Cr.	0	0	0.0	0.0	0.5	1.2
9	Arthur Cr.	0	0	0.0	0.0	0.5	1.5
10	Big Piney R.		0		0.0		1.3
11	West Piney Cr.	0	0	0.0	0.0	0.6	1.2
12	Big Piney R.	0	0	0.0	0.0	0.4	1.2
13	Big Piney R.	0	0	0.0	0.0	0.5	1.6
14	Big Piney R.	0	0	0.0	0.0	0.7	1.2
15	Roubidoux Cr.	0	0	0.0	0.0	0.3	1.1
16	Roubidoux Cr.	0	7	0.0	4.1	0.6	1.7
17	Roubidoux Cr.		7	-	1.1		6.5
18	Roubidoux Cr.		1	0.0	0.3		3.3
19	Roubidoux Cr.	0	0	0.0	0.0	0.4	1.3
20	West Fork Roubidoux Cr.	0	0	0.0	0.0	0.5	1.6
21	Gasconade R.	0	3	0.0	2.7	0.8	1.1
22	Gasconade R.	0	0	0.0	0.0	0.6	1.2
23	Gasconade R.	0	6	0.0	2.7	0.5	2.2
24	Gasconade R.	0	8	0.0	5.7	0.6	1.4
25	Gasconade R.	0	1	0.0	0.7	0.3	1.4
26	Beaver Cr.	0	0	0.0	0.0	0.5	0.8
27	Beaver Cr.	0	0	0.0	0.0	0.5	1.3
28	Gasconade R.	0	3	0.0	3.8	0.7	0.8
29	Gasconade R.	-	13		7.6	-	1.7
30	Whetstone Cr.	0	11	0.0	4.1	0.6	2.7
31	Lick Fork	0	0	0.0	0.0	0.3	1.0
32	Woods Fork	0	0	0.0	0.0	0.5	1.2
33	Osage Fork	0	0	0.0	0.0	0.9	1.4
34	Osage Fork	0	0	0.0	0.0	0.4	1.1
35	Osage Fork	0	0	0.0	0.0	0.7	1.2
36	Osage Fork	0	2	0.0	2.0	0.8	1.0
37	Osage Fork	0	8	0.0	10.0	0.5	0.8
39	Niangua R.	0	0	0.0	0.0	0.5	1.2
40	Niangua R.	0	0	0.0	0.0	0.3	0.5
41	Niangua R.	0	0	0.0	0.0	0.3	0.4
42	Niangua R.	0	7	0.0	5.8	1.6	1.2
42	Niangua R.	0	18	0.0	13.8	0.4	1.3
44	Niangua R.	0	3	0.0	5.0	0.3	0.6
45	Greasy Cr.	0	0	0.0	0.0	0.9	2.0
46	Niangua R.	0	1	0.0	0.8	0.4	1.3
47	Niangua R.	0	0	0.0	0.0	0.3	0.9
49	Niangua R.	0	0	0.0	0.0	1.0	1.3

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