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LIFE HISTORY PATTERN OF *NOTROPIS SABINAE* (PISCES: CYPRINIDAE) IN THE LOWER SABINE RIVER DRAINAGE OF LOUISIANA AND TEXAS

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ABSTRACT

The life history of *Notropis sabinae* in two tributary streams of the lower Sabine River drainage system (Bayou Anacoco, Beauregard-Vernon Parish line, Louisiana; Big Cow Creek, Newton County, Texas) was studied from 1972 to 1977. The life history pattern observed for the two streams was similar. In Bayou Anacoco, the reproductive season extended from early April through late September; it was similar in Big Cow Creek except that reproduction ended earlier in September 1973. Counts of unovulated mature ova in females ranged from 113 to 423 for females 35-48 mm SL and were significantly correlated with female size. There was a low but significant correlation between the ovary weight-somatic weight ratio and body size among Bayou Anacoco females, but not among Big Cow Creek females. A low but significant correlation was found between mean mature ovum size and body size among females from both localities. The size of unovulated mature ova ranged from 0.55 to 0.88 mm diameter. There were no significant differences in slope or elevation of regression lines fitted to either fecundity or ova size data for each of the two localities. Sex ratios did not differ significantly from 1:1. Females matured at a slightly larger size than males; all females were mature by 32 mm in Bayou Anacoco and 33 mm in Big Cow Creek. Mean sizes of adult males and females did not differ significantly. Maximum age for most individuals of *Notropis sabinae* was about 1½ to 2 years. Maximum size was 49 and 47 mm SL for Big Cow Creek and Bayou Anacoco, respectively.

INTRODUCTION

Information on the life history of the Sabine shiner, *Notropis sabinae* Jordan and Gilbert, is almost completely lacking. Except for data on habitat and distribution, only ancillary comments are available (cf. Moore, 1944; Douglas, 1974; Pflieger, 1975). The reproduction, age and growth of *N. sabinae* are considered herein.

This species is a member of the *Notropis longirostris* species group (subgenus *Alburnops*; Swift, 1970), which also includes *N. longirostris* and an undescribed species in the Mobile Bay drainage system. The species in this group are common inhabitants of clear, small to moderate sized sand-bottomed streams of Gulf coastal plain drainages. *N. sabinae* occurs in such streams of the Calcasieu, Sabine and Neches river drainages of southwestern Louisiana and southeastern Texas; it is also present in the White and St. Francis river systems of Arkansas and Missouri (Moore, 1968; Pflieger, 1971, 1975; Buchanan, 1973; Douglas,1974). Douglas, (1974) also reported an isolated population in the Little River system of east-central Louisiana.

MATERIALS AND METHODS

Monthly collections were obtained from Bayou Anacoco below State Hwy. 111, Beauregard-Vernon Parish line, Louisiana (T. 2 S., R. 11 W., SE ¼ sec. 20). The stream receives Kraft papermill effluent above this locality; therefore,

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another stream was sampled to provide a "check" on data from Bayou Anacoco. The second locality consisted of access points along Big Cow Creek for ca. 0.8 - 1.2 km from Farm Road 1416, Newton County, Texas. The sampling locality in Big Cow Creek was about 39 km SSW of that in Bayou Anacoco. Collections were made from December 1972 (March 1973 at Big Cow Creek) through November 1973 with 3-m long, 4.8-mm and 3.2-mm Ace mesh seines. Supplementary collections were made during the springs of 1974, 1976 and 1977. Fishes were initially preserved in 10% formalin and stored in 43% isopropyl alcohol. Specimens were deposited in the Tulane University Museum of Natural History.

Stream flow records were obtained from local offices of the United States Geological Survey (Baton Rouge, LA; Austin, TX). The gauging station on Bayou Anacoco was located at my sampling locality; however, the gauging station on Big Cow Creek was located at State Hwy. 87 ca. 35 km upstream from my sampling point. Water quality data for Bayou Anacoco were also secured; no such data were available for Big Cow Creek. Climatological and daylength data for nearby recording stations were obtained from the National Climatic Center, Asheville, North Carolina, and the Naval Obsrvatory, Washington, D.C., respectively.

Periodic changes in the reproductive condition of females were determined by measurements of ova, determination of ovarian weights, and gross examinations of ovaries of females in the monthly samples. Both ovaries were removed from each of 10 adult females (when available) chosen at random from each collection examined. The diameter of one of the larger eggs from each female was measured. Preserved ova were not spherical; thus diameters were estimated by averaging measurements of the largest and smallest dimensions. Measurements were made to the nearest 0.05 mm using an ocular micrometer in a dissecting microscope. Ovaries and specimens were dried to a constant weight at 100-105°C and weighed to the nearest 0.001 g; ovarian weight was calculated as a percentage of total body weight. Contents of the digestive tract were removed before drying to eliminate a possible source of variation in data. Gross assessments of reproductive condition were based on the classification of females into one of the following stages of ovarian condition: (1) Immature (IM) – ovaries very small, thin, transparent to slightly translucent. Larger, developing ova, if present, yolkless with nucleus visible. (2) Early maturing (EM) – ovaries small to moderate size, translucent to white in color. Larger eggs relatively small with nucleus obscured by yolk deposition, often numerous, and becoming white in color. (3) Late maturing (LM) – ovaries greatly enlarged, filling a large portion of the body cavity, white to cream color. Larger maturing ova often as large as mature ova but not easily differentiated from smaller maturing ova, usually cream colored. (4) Mature (MA) – ovaries greatly enlarged, filling a major portion of the body cavity and usually distending the abdomen, cream to yellow. Mature ova present, cream to yellow in color, easily differentiated from maturing ova on the basis of size and color, and relatively numerous. (5) Partially spent (PS) – ovary noticeably smaller than mature ovary, relatively small number of mature ova present, often translucent areas and/or areas of small maturing ova easily distinguishable among larger mature ova. All individuals capable of producing gametes were considered sexually mature adults. More specifically, females were considered sexually mature if they had at least three enlarged eggs with the nuclei obscured by yolk deposition in one ovary (usually left) examined from each specimen. Individuals classified as MA or PS were considered reproductive. Breeding coloration, tuberculation and enlargement of urogenital papillae were also noted.

To illustrate the ova development pattern in *N. sabinae*, an ova diameter histogram was prepared using a mature female. All eggs in one ovary with the nuclei obscured by yolk deposition were measured. The number in each 0.05 mm size group was plotted as a percentage of the total number measured.

Analysis of reproductive condition in males was based on tuberculation and gross examination of the testes. Maturity was assessed primarily on the basis of increased size and development of opaque white testes in comparison to the smaller transparent/translucent testes of immature males.

Fecundity was determined by direct counts of mature ova in ovaries of reproductively mature females. Generally the specimens examined were only those with abdomens distended as a result of the ovaries filling the body cavity. Mature ova were easily separated from maturing ova on the basis of size and color. For each of the females examined for the analysis of fecundity, ten mature ova were chosen at random and their diameters measured to determine mean mature ovum diameter. Ovaries and specimens were dried and weights determined for calculation of ovarian weight-somatic weight ratios. Covariance analyses of these data were conducted following Snedecor and Cochran (1967).

Analyses of size at sexual maturity, sex ratio and mean size of sexually mature males and females were based on a number of collections. Chi-square tests (X^2) were used in replicated tests for goodness of fit to determine if there were significant deviations from a 1:1 sex ratio ; average sizes of adult males and females were compared using the unweighted means analysis in a two-way analysis of variance (Steel and Torrie, 1960; Snedecor and Cochran, 1967; Sokal and Rohlf, 1969).

Estimates of age were made on the basis of length frequency and scale analyses. All individuals in each collection analyzed were measured to the nearest 0.1 mm standard length (SL) and length frequency histograms prepared by plotting the percentage frequency for each 1-mm size group. For scale analyses, about 10-20 scales were removed from the area above the lateral line and anterior to the dorsal fin insertion of each specimen examined. Scales were cleaned by rubbing between two fingers moistened with water, mounted between two glass slides, and observed by microprojection at 50X. Annuli were identified by various combinations of the following: cutting over of circuli in dorsal and ventral fields, discontinuity of circuli or ridge-spacing in the posterior field, thickening of circuli and bending of radii.

STUDY AREAS

The stream at the Bayou Anacoco locality normally ranged from ca. 15-38 m in width. The area consisted of flowing runs and/or riffles 0.6m or greater in depth; they stretched between sandbars which constituted about 30-40% of the total shoreline, the remainder being heavily wooded. The bottom was primarily comprised of white sand with some gravel intermixed in patches; at times it became covered with a light layer of silt and/or detritus. With a gradient of 0.5 m/km in the immediate area, stream flow was usually moderate or slightly greater. The average discharge for the period of August 1969 – September 1973 was 0.013 m^3/s/km with an average annual runoff of 401 mm.

Bayou Anacoco was typically dark brown in color, presumably resulting largely from the papermill effluents. For example, monthly measurements of color for 1972-76 (excepting October 1972 – May 1973, August – October and December 1976) averaged 100 platinum cobalt color units, range from 20-400 units. Other physicochemical characteristics recorded over the same time period were as follows (mean followed by (range): dissolved oxygen, 7.4

ppm (5.3-10.0); pH, 6.9 (6.2-7.8); alkalinity 29 mg/1 (8-87); and specific conductance, 206 micromhos/cm(41-629).

The stream section sampled in Big Cow Creek was narrower and sandbars were much less extensive and more intermittent. This area probably represents the upper reaches of the tributary in which *N. sabinae* occurs in relatively large numbers. The stream usually ranged from ca. 15-24 m in width with a section of this area divided into two channels normally ca. 9-12 m wide. The stream bed was similar to that in Bayou Anacoco. Stream flow was usually moderate; the gradient in the immediate area was 0.5 m/km. Average discharge for the 24 year period April 1952 – September 1976 was 0.009 $m^3/s/km^2$, the average annual runoff 296 mm.

Mean annual temperature in the area (Kirbyville Forest Service, TX. and Elizabeth, LA, stations) was 19°C. Mean temperature in January was 10°C and in July 28°C. Average annual rainfall was 150 cm.

RESULTS

Species Associates — A total of 45 species was taken from Bayou Anacoco; 38 were taken from Big Cow Creek. *Notropis sabinae* was the second most abundant species in each area, constituting 31% and 23% of all specimens collected from Bayou Anacoco and Big Cow Creek, respectively. *Notropis venustus* was the most abundant species; it composed 37% and 33% of all samples from the two respective stations. An association similar to that of *Notropis longirostris, Notropis venustus* and *Ammocrypta beani* (Heins and Clemmer, 1975) existed between *N. sabinae, N. venustus* and *Ammocrypta vivax* in these streams. *Notropis sabinae* and *N. venustus* were always taken together; and although *A. vivax* was not as abundant (3% of all samples from each locality), it was taken frequently (94 and 92 percent frequency of occurrence, n=16, 13, respectively). Both *N. sabinae* and *A. vivax* occupied the same open sand bottoms along sandbars, although *A. vivax* tended to be more abundant in areas of mixed sand and gravel. Other species collected were not closely associated nor commonly taken with *N. sabinae*. A complete list of species taken at each locality (including relative abundance and frequency of occurrence) is available in Heins (1979).

Reproduction – Secondary sexual characteristics: The extent of tubercle development may vary considerably in reproductively mature *N. sabinae* males. Weakly tuberculate males had small to moderately large, fine tubercles scattered over the sides of the snout (separated by wide hiatus at the tip of the snout) and lateral areas of the head posteriorally from the anterior edge of the lacrimal to the anterior suborbital area; small widely scattered tubercles often extended to the angle of the preopercle. Tubercles on the side of the head were separated from those on the snout by a sometimes poorly defined hiatus along the anterior edge of the lacrimal. Highly tuberculate males (Fig. 1) had concentrations of large, slightly retrorse to erect tubercles on each side of the snout which were separated by a hiatus of variable size at the tip of the snout. Tubercles on the lateral areas of the head extended from the anterior edge of the lacrimal (large to moderately large, erect to slightly retrorse) posteroventrally to the angle of the preopercle, generally becoming smaller and erect and at times sparsely scattered. Tubercles in the anterior suborbital area also tended to be smaller. Small to moderate size tubercles occurred between the orbit and nares and were separated from the anterior suborbital tubercles; they extended to the antero-dorsal aspect of the orbital margin and were occasionally absent. Small to moderate size tubercles were variably developed in two small groups medial and slightly anterior to the nostrils; at times the groups were poorly

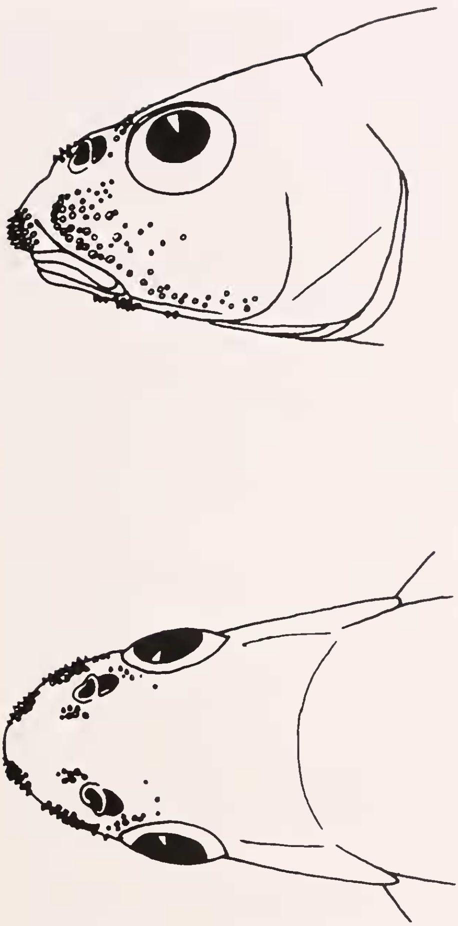

Figure 1. Head tuberculation of highly tuberculate *Notropis sabinae* males. The drawing is a composite of a number of specimens.

separated. Occasionally small scattered tubercles occurred between the orbits. Small to moderately large tubercles were variably developed on the posterior half of the mandibles of most males, forming one or two poorly defined rows in highly tuberculate males; occasionally a few also developed on the lower arm of the interopercle. Minute tubercles formed a shagreen on the pectoral rays of most males, the greatest development was generally on rays 2-6, less so on 7; they usually originated about one-fourth of the distance from the proximal end of the rays and extended to just past the first, major branching. Tubercles were occasionally scattered on other rays and the dital ends of hevily tuberculated rays. Tubercles also occured on dorsal, pelvic and anal fins but were poorly developed. No tubercles were noted on body scales.

Tuberculation in reproductively mature females was generally very weak. Some females developed small to fine tubercles that were scattered over the sides of the snout and head posteriorly to the suborbital areas. Tubercles occasionally extended to the angle of the preopercle or were on the mandible. Minute tubercles occasionally were also scattered along rays of the pectoral fins.

Reproductive coloration is poorly developed in both sexes, particularly in females. A faint lemon yellow color often develops in the dorsal and caudal rays of males, being strongest antero-basally. White pigmentation is also variably present in these and other fins, particularly the pectoral and anal. Breeding females have enlarged urogenital papillae which are absent in males.

Reproductive periodicity in females: Periodic changes in ova diameters and ovarian weights (Fig. 2) and gross ovarian examinations demonstrated a reproductive season extending from early April through late September in Bayou Anacoco. Diameters of ova and ovary weights were small from December 1972 through mid-March 1973 ($\overline{X}$ = 0.17—0.27 mm, 0.9-1.2% body weight). These measurements were slightly greater in late March 1976, but all females examined (n = 21) were still maturing as they were in 1973 (n = 18). No sample was available from April 1973 due to flooding during the scheduled sampling period. Females were in reproductive condition in early April of 1974 (93% MA&PS, n = 30) and 1976 (32% MA&PS, n = 37); diameters of ova averaged 0.71 and 0.53 mm and ovarian weights 6.1% and 3.7% of body weight, respectively. These data also indicate that reproductive activities began somewhat later in 1976. Females were in re-

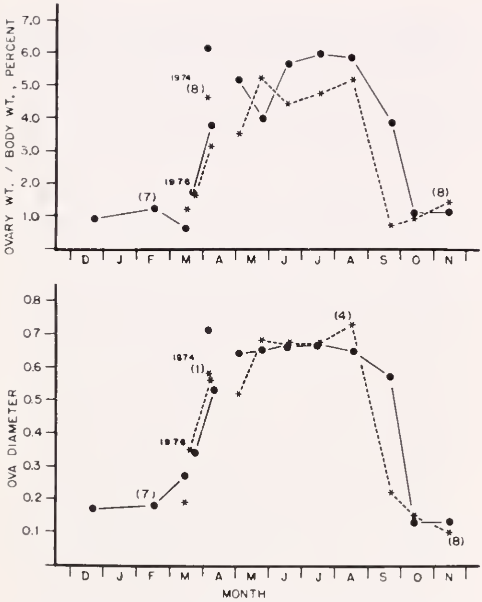

Figure 2. Mean diameter of largest ova (lower graph) and mean percentage ovary weight (upper graph) for *Notropis sabinae* from Big Cow Creek, Texas (dashed lines), and Bayou Anacoco, Louisiana (solid lines), 1972-73 (no April sample), April 1974, and March-April 1976. Lines connect only data points for sequential samples within the same year. Numbers in parentheses indicate the number of observations on the mean when less than ten. Statistics of variability are available in Heins (1979).

productive condition in early May 1973, (63% MA&PS, n = 30). Ova diameters and ovarian weights remained large from May through late September 1973 ($\overline{X}$ = 0.57 - 0.67 mm, 3.8% - 5.9% body weight). In September, 77% (n = 26) of the females were reproductive. Ova diameters and ovarian weights decreased to an average of 0.13 mm and 1.0% of body weight by mid-October, and almost all females were considered non-reproductive (98% IM&EM, n = 55). The reproductive periodicity of females in Big Cow Creek was similar to that in Bayou Anacoco (Fig. 2), but reproduction ended somewhat earlier in 1973. Diameters of ova and ovarian weights decreased to 0.22 mm and 0.7% of body weight by late September, and only 2 of 32 females (6%) were considered reproductive. The periodicity and variability in temperature, photoperiod and stream flow accompanying these cycles are shown in Figure 3.

After attaining reproductive condition, individual females remained reproductive throughout the spawning season. Maturing ova were present in reproducing females throughout the season. The ova development pattern of this species exhibits two complements of yolk-bearing ova, a stock of smaller maturing ova and a differentiated group of larger mature ova (Fig. 4). Such a bimodal distributions is indicative of a variable series of spawnings with complements of ova released periodically over an extended reproductive season (Hickling and Rutenberg, 1936; Prabhu, 1956; Qasim and Qayyum, 1961; MacGregor, 1970).

Reproductive periodicity in males: The cycles of testis and tubercle development were similar for both areas. Males taken in December and February had no tubercles although there were scars on a few; testes were small and cloudy to white in color. In March samples testicular activity was indicated by enlargement of the testes; tubercles also developed in March. Testes and tubercles were generally well developed from April into September; however, there was a decline of testis and particularly tubercle development in Big Cow Creek males in September, coincident with the decline of reproductive activity in females. Testes were small in October and November. Very small degenerating tubercles were still present in October but were generally absent in November, excepting tubercle scars in some males.

Reproductive effort and ovum size: There was a highly significant correlation between number of mature ova and standard length among females from both localities (Table 1). Regression lines expressing the relationship between counts of mature ova and body size did not differ in slope ($F = 0.14$; $df = 1, 60$; $p > .05$) or elevation ($F = 2.20$; df =

1, 61; p > .05) when tested by analyses of covariance; therefore, the data from both localities were combined. Counts of mature ova ranged from 113 to 423 for females 35.4 - 47.8 mm SL. The intercept, regression coefficient and correlation coefficient for the linear relationship between fecundity and standard length among females in the combined sample (Fig. 5, $r^2 = 0.57$) are also given in Table 1. Log-log and semi-logarithmic transformations yielded similar r^2 values, indicating that any of the three models adequately defined the relationship. However, logarithmic transformation of both variables stabilizes the variance along the regression line (Bagenal, 1967) and is important for use in prediction; the resulting equation is ($r^2 = 0.53$; F = fecundity, SL = standard length):

$$\log_{10}F = -2.8297 + 3.1953(\log_{10}SL).$$

There was a low but significant correlation between ovarian weight-somatic weight ratio and body size among females from Bayou Anacoco, but there was no significant correlation among females from Big Cow Creek (Table 1, Fig. 6). This notwithstanding, there was a low but highly significant correlation between ovarian weight-somatic weight ratio and body size among females in the combined samples. In general, these ratios ranged from 4.8 -15.2%.

There was a low but significant correlation between mean mature ovum size

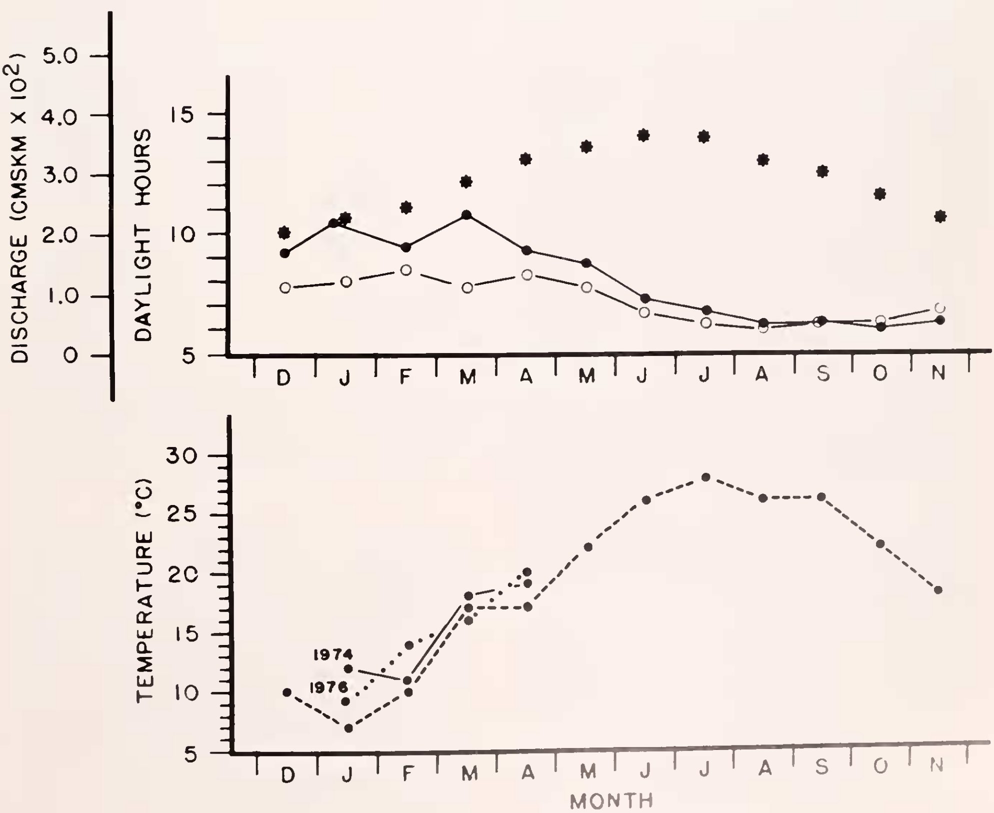

Figure 3. Environmental variability and periodicity for Big Cow Creek, Texas, and Bayou Anacoco, Louisiana. Upper graph: mean monthly number of daylight hours (bold asterisks, Lake Charles, LA) and mean monthly discharge as cubic meters per second per square kilometer for Big Cow Creek (1952-76, open circles, solid line) and Bayou Anacoco (1969-73, solid circles, solid line). Lower graph: mean monthly air temperature for 1973 (dashed line, DeRidder, LA), early 1974 (solid line), early 1976 (dotted line).

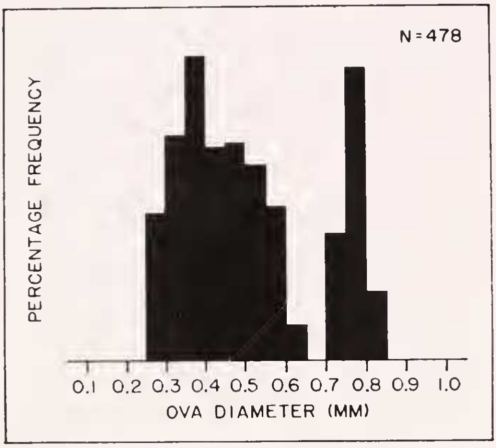

Figure 4. Size frequency distribution for vitellogenic ova in a reproductive *Notropis sabinae* female, indicating the typical pattern of ova maturation and recruitment.

and body size among females from both localities (Table 1, Fig. 7), indicating a tendency for larger females to produce larger ova. Data are missing for one specimen fromBayou Anacoco; the ovary was not well preserved and many eggs broke when teased from the follicles. Analysis of covariance showed that regression lines fitted to the data for each locality did not differ in slope ($F = 0.53$; df = 1, 59; $p > .05$) or elevation ($F = 2.03$; df = 1, 60; $p > .05$); therefore, data for both localities can be combined. The mean sizes of the mature ova measured ranged from 0.63 to 0.81 mm diameter and averaged 0.72 mm ($S = 0.0452$). Addition of mean mature ovum diameter to the linear equation for fecundity did not significantly increase the r^2 value ($F = 2.260$; df = 1, 60; $p > 0.05$).

Sex ratio, size at maturity and mean size of adult males and females: Chi-square tests indicated that there were no significant differences from a 1:1 sex ratio at either locality. The heterogeneity χ^2 was not significant ($p > .05$) for either Big Cow Creek (0.7485, df = 4) or Bayou Anacoco (5.3745, df = 4); similar results were obtained for the pooled χ^2 at the two respective stations (2.9823, df = 1; 1.6864, df = 1).

The number of specimens originally examined from Big Cow Creek to determine size at sexual maturity was insufficient; therefore, supplemental specimens taken in August 1973 and a portion of those taken in May 1977 were also examined. The supplemental specimens appeared to differ somewhat from those initially examined (May–July 1973) in that individuals seemed to mature at a

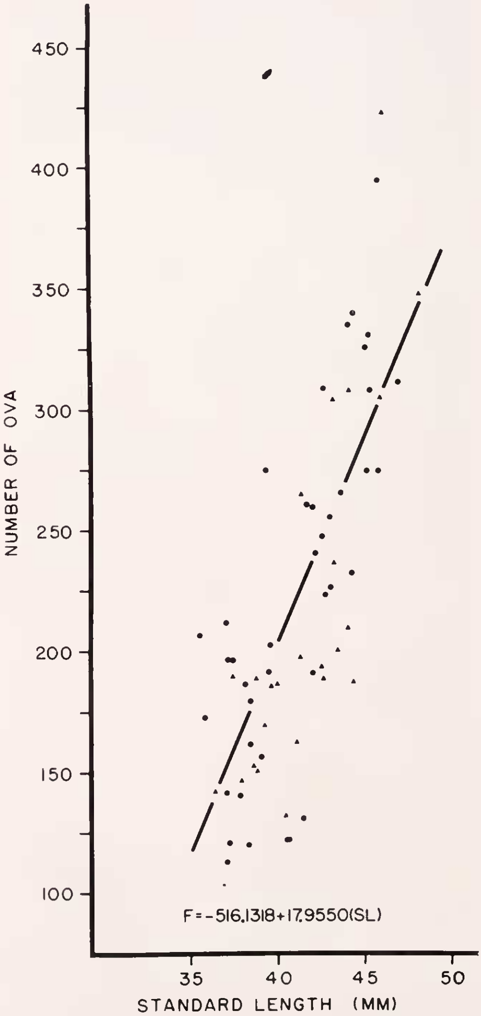

Figure 5. Relationship between number of mature ova and standard length for *Notropis sabinae* females from Big Cow Creek (triangles), Texas, and Bayou Anacoco (dots), Louisiana, 1973-74 and 1976-77.

Table 1. Summary of linear regression analyses of ova number-body size, ovary weight-somatic weight ratio--body size, and ova diameter-body size relationships for samples of *Notropis sabinae* from Big Cow Creek, Texas, and Bayou Anacoco, Louisiana, 1973-1974 and 1976-1977; ns = non-significant difference, * = significant difference at .05 level, ** = significant difference at .01 level.

Locality	n	Intercept	Regression Coefficient	r
Ova number-body size (SL)				
Big Cow	24	−581.3956	19.2567	.772**
Anacoco	40	−497.7474	17.6721	.758**
COMBINED	64	−516.1318	17.9550	.753**
Ovary weight-somatic weight ratio--body size (SL)				
Big Cow	24			.362^{ns}
Anacoco	40	−3.3558	0.3003	.364*
COMBINED	64	−4.3164	0.3282	.368**
Ova diameter-body size (SL)				
Big Cow	24	0.4200	0.0075	.443*
Anacoco	39	0.5136	0.0049	.377*
COMBINED	63	0.4735	0.0060	.409**

smaller size. Despite this complication the data are useful for a approximate comparison of size at sexual maturity in the two populations. Males matured at a smaller size than females at both localities,completing maturation by 29 mm SL in Bayou Anacoco and 30 mm SL in Big Cow Creek. Females were not completely mature until 32 mm in Bayou Anacoco and 33 mm in Big Cow Creek.

The analysis of variance performed to test for significant differences in mean size of adult males and females from Big Cow Creek indicated a significant interaction between the effects of sex and month (Table 2); therefore, a test of simple effects was performed to determine when there were differences in mean size. This procedure indicated that females were significantly larger than males in July ($p < .05$); all other differences were non-significant. The F-value for interaction was non-significant for the Bayou Anacoco samples, as was the F-value for sex, indicating that there were no significant differences in the mean sizes of adult males and females. Significant differences between monthly samples were indicated for both localities but were not analyzed. The results for the July sample from Big Cow Creek are unexplained; however, they may be due to sampling error. It seems reasonable to conclude that there were generally no significant differences in the mean sizes of adult males and females at either locality.

Growth and Population Age Structure

Temperatures in the study area varied considerably over short periods (daily, weekly); but mean monthly temperature variation was moderate (Fig. 3). Therefore, annulus formation in this warm temperate region is quite variable. Further, annulus formation may be especially weak for smaller individuals experiencing their first winter. Thus, scale analyses were combined with length frequency analyses to obtain the most reliable age estimates. These analyses (Figs. 8, 9) indicate that the maximum age for most *N.sabinae* is about 1½ to 2 years. None of the scales examined from March or September 1973 Big Cow Creek samples (Fig. 8; n = 50, 54, respectively) had more than two annual marks. Some specimens examined from March appeared to be forming an annulus. These data, and examinations of a few larger specimens in April and May collections (a time of active annulus formation), suggest that some of the larger individuals (particularly those 44 mm SL) may enter a fourth growing season as three-year olds. Analysis of the length

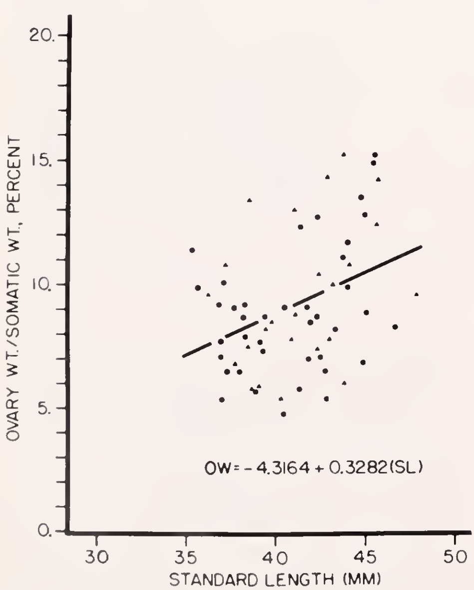

Figure 6. Relationship between ovary weight-somatic weight ratio and standard length for *Notropis sabinae* females from Big Cow Creek (triangles), Texas, and Bayou Anacoco (dots), Louisiana, 1973-74 and 1976-77.

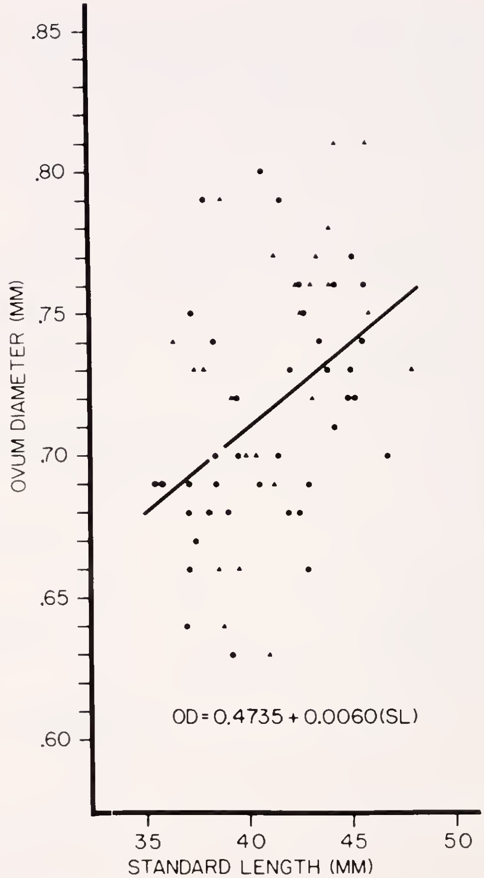

Figure 7. Relationship between mean size of unovulated, mature ova and standard length for *Notropis sabinae* females from Big Cow Creek (triangles), Texas, and Bayou Anacoco (dots), Louisiana, 1973-74 and 1976-77.

Big Cow Creek						
Sex	Date of Collection					Mean
	21 Mar 1976	2 May 1973	17 Jul 1973	21 Sep 1973	12 Oct 1973	
Male	36.834 (41)	37.225 (24)	38.673 (15)	39.796 (23)	39.943 (23)	38.5
Female	35.864 (50)	37.347 (32)	40.475 (16)	38.873 (33)	38.604 (25)	38.2

Analysis of Variance of Unweighted Means

Source	df	SS	MS	F-value
Sex	1	4.23760	4.23760	
Month	4	418.86419	104.71605	
Interaction	4	80.56889	20.14222	2.67303*
Error	272	2049.6125	7.53534	
Total	281			

Bayou Anacoco						
Sex	Date of Collection					Mean
	21 Mar 1976	2 May 1973	17 Jul 1973	21 Sep 1973	14 Nov 1973	
Male	38.670 (27)	37.942 (24)	37.782 (17)	34.929 (42)	37.053 (45)	37.3
Female	38.371 (21)	38.797 (31)	38.350 (18)	35.858 (24)	37.213 (38)	37.7

Analysis of Variance of Unweighted Means

Source	df	SS	MS	F-value
Sex	1	12.65552	12.65552	1.66072^{ns}
Month	4	345.74802	86.43701	11.34271**
Interaction	4	13.59546	3.39887	0.44602^{ns}
Error	277	2110.8763	7.62049	
Total	286			

Table 2. Mean size (mm SL), number of observations on the mean (in parentheses), and summary table for analysis of variance to test for presence of significant differences between mean size of adult (33 mm SL) male and female *Notropis sabinae* in various collections from Big Cow Creek, Texas, and Bayou Anacoco, Louisiana; ns = non-significant difference, * = significant difference at 0.05 level, ** = significant difference at 0.01 level. Adjustment of sums of squares for unequal numbers in the unweighted means analysis of variance was made to sums of squares for sex, month, and interaction.

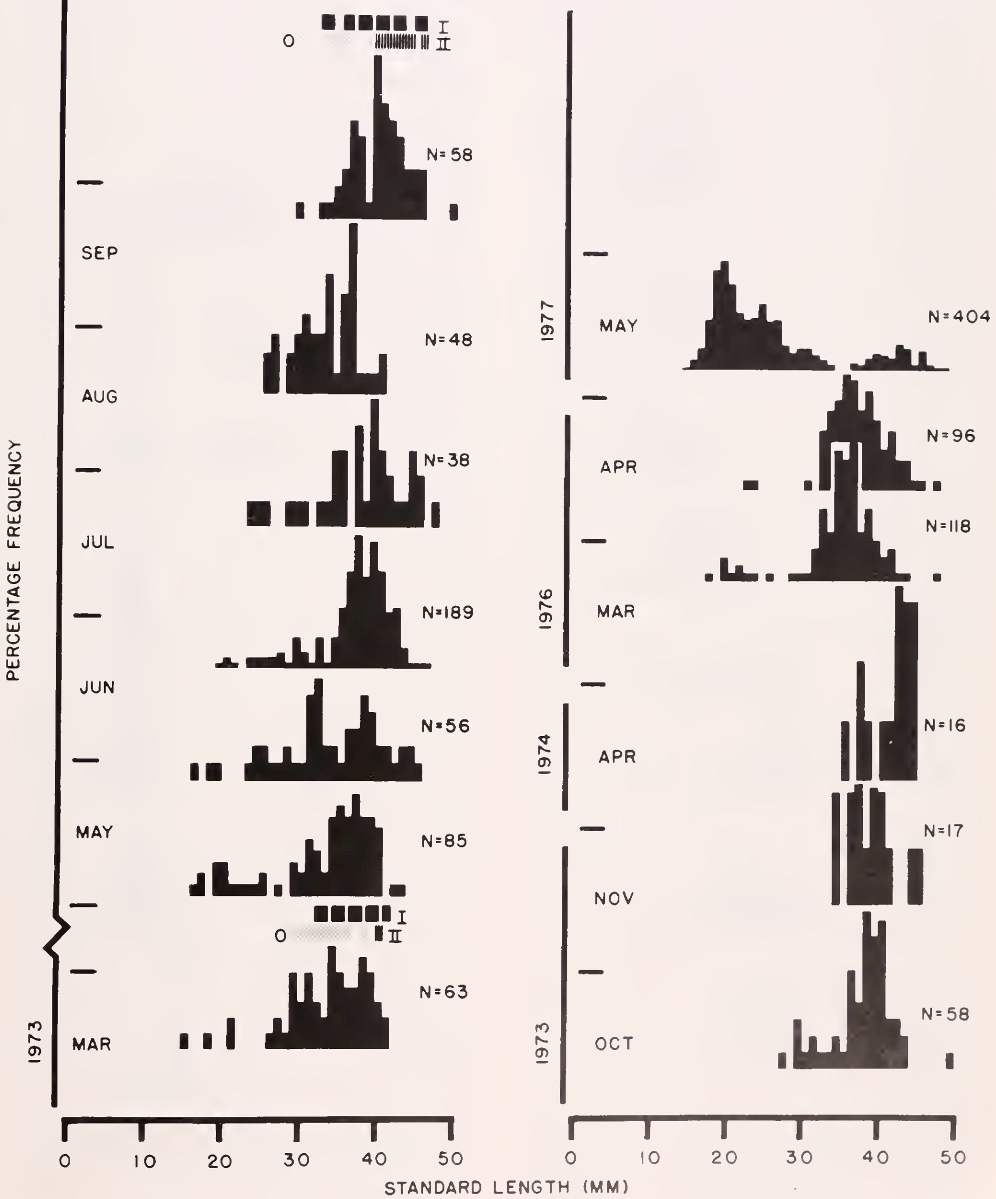

Figure 8. Length frequency histograms for collections of Notropis sabinae from Big Cow Creek, Texas. Horizontal bars are placed at beginning of each month; histogram bases are set at date of collection. Results of scale analyses are shown for March and September, 1973, collections. (0 = no annulus, I = 1 annulus, II = 2 annuli).

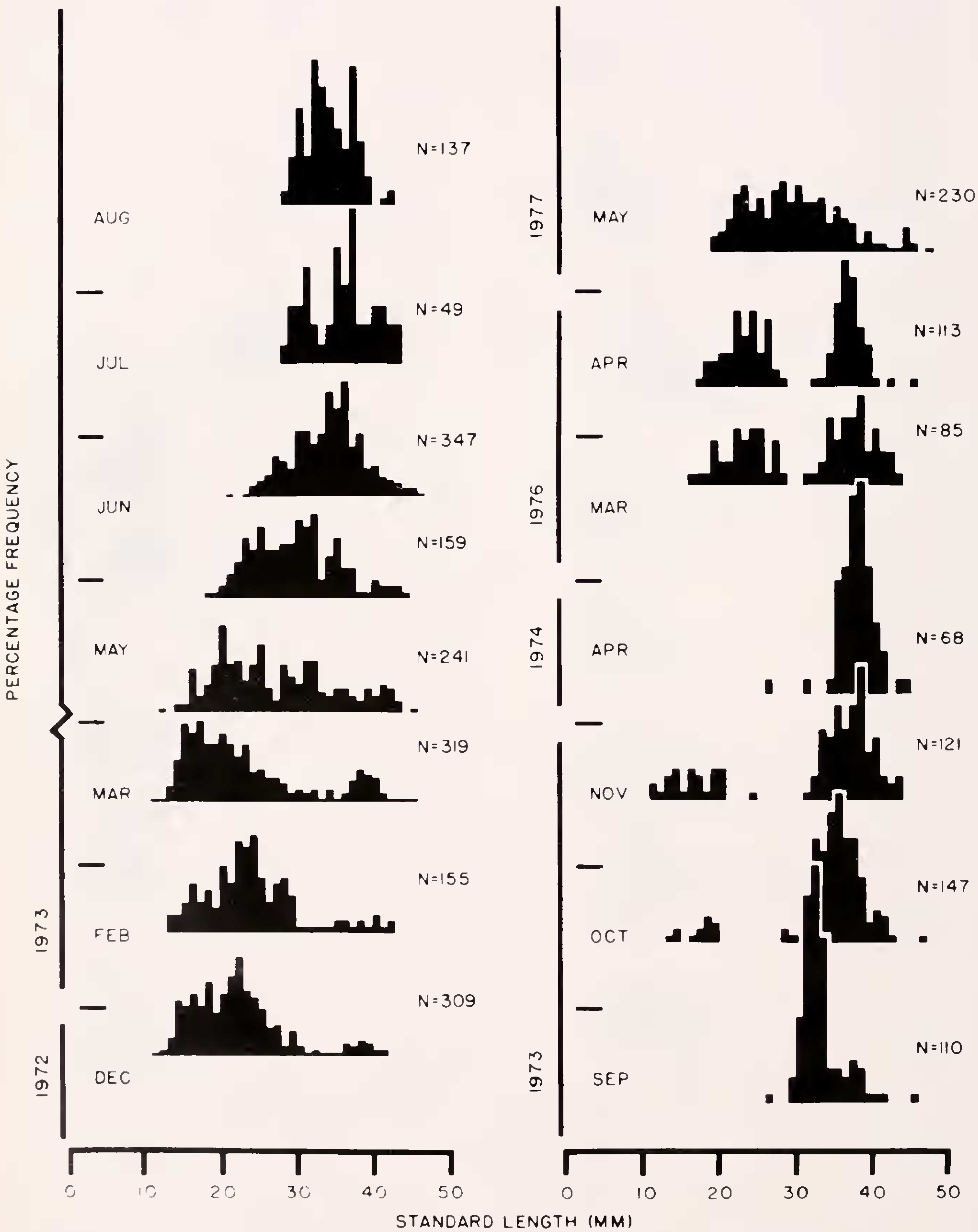

Figure 9. Length frequency histograms for collections of *Notropis sabinae* from Bayou Anacoco, Louisiana. Horizontal bars are placed at beginning of each month; histogram bases are set at date of collection.

frequency histograms for Big Cow Creek prior to and during the early part of the annual reproductive season demonstrates a bi-modal distribution. The origins and fates of these two groups suggest that the larger group is primarily comprised of one-year old individuals entering their third growth season as two-year olds. The number in this group dwindles considerably by the end of this season, suggesting that most individuals die by the age of two years. The group of smaller fish thus represents individuals having just completed a first winter and entering a second growth season as one year olds. Maximum size was about 49 mm and 47 mm SL in Big Cow Creek and Bayou Anacoco, respectively. Finally, these data and the data on size at maturity suggests that a small percentage of individuals might mature within their first growth season. However, at least the majority mature in their second season, at or within one year.

DISCUSSION

Notropis sabinae, along with other members of the *Notropis longirostris* species group (Heins and Clemmer, 1976; Heins, 1979; Heins et al., in press), has an extended reproductive season during which it seems a number of clutches of eggs are spawned. The long annual period of high temperatures and long photoperiods in the area (Fig. 3) probably facilitates the protracted reproductive season; temperature and photoperiod are two proximal factors that activate neuroendocrine centers controlling reproductive cycles in fishes (Schwassman, 1971; DeVlaming, 1972, 1974). Nevertheless, extended reproduction may be adaptive to a variable environment in that distributing reproductive activity over a long period of time may reduce the chance of losing a large portion of the annual recruitment (Starret, 1951; Tanyolac, 1973; Wallace,, 1973; Heins and Bresnick, 1975; Heins and Clemmer, 1976; Heins et al., in press). Protracted reproduction has also been observed in a number of southern species of *Notropis* (Mathur and Ramsey, 1974; Cowell and barnett, 1974; Beach, 1974; Cowell and Resico, 1975; Heins and Bresnick, 1975).

The protracted reproductive season and presumed production of multiple clutches of eggs indicates a relatively high seasonal reproductive effort for *Notropis sabinae*. Further, *N. sabinae* is a relatively small, short-lived member of the genus *Notropis* as are other members of the *N. longirostris* species group (cf. Hubbs and Hubbs, 1958; Carlander, 1969; Snelson and Jenkins, 1973; Hubbs and Miller, 1975; Heins and Clemmer, 1976; Heins, 1979; Heins et al., in press). *N. sabinae* also matures early, at about one year. Williams (1966) suggested that a small, short-lived species with high annual mortality should invest a greater effort in reproduction in a given season, as compared to a large, long-lived species. Additionally, strong selection for early maturity, that is within one year, should result from a short life expectancy (Tinkle, 1969).

The spawning of *N. sabinae* was not observed during this study; however, it presumably occurs over open sand as in *Notropis longirostris* (Hubbs and Walker, 1942). If this is so, *N. sabinae* would belong to the ecological guild of psammophilous fishes delineated by Balon (1975), as do other members of the *N. longirostris* species group.

Notropis sabinae, as with other members of the *N. longirostris* species group, exhibits life history traits conventionally considered characteristic of a relatively r-selected species (cf. Stearns, 1976; Balon et al., 1977). Nevertheless, some interspecific variation was observed among the life history patterns of members of the *N. longirostris* species group; variation was also noted among populations of *N. longirostris* which was more widely studied (Heins, 1979). This intra- and inter-specific life history variation will be considered in a forthcoming report. However, I will consider a distinctive difference between *N. sabinae* and other members of the *N. longirostris* species group herein. Among those populations studied thus far, *N. sabinae* produces smaller mature, unovulated ova (cf. Heins and Clemmer, 1976; Heins, 1979; Heins et al., in press). The inter- and intra-specific variation observed in egg size appears to be related,at least in part, to stream flow patterns in southern North America (Fig. 10). Larger egg sizes were found in populations inhabiting areas of higher annual stream runoff (Heins, 1979). I postulate that there has been a selective advantage to larger egg size in those streams where average annual runoff is greater. Thus annual stream runoff values may indicate the relative severity of this factor in the respective stream environments. Svardson (1949) and Williams (1959) have argued that a reduction in fecundity could not be favored by natural selection unless it was a necessary consequence of some advantageous development such as increased egg size. Larger ova generally result in larger larvae that can be expected to be stronger, able to swim better, and less susceptible to damage (Blaxter, 1969). Thus, larger ova may

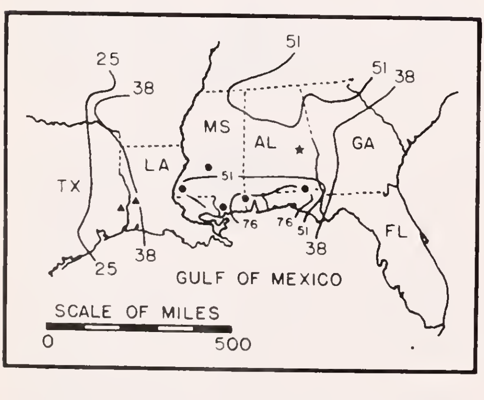

Figure 10. Map showing locations of various populations of *Notropis sabinae* (triangles), *Notropis longirostris* (dots), and *Notropis* species (cf. *N. longirostris*) (star) studied by Heins (1979) in relation to amount of annual stream runoff (cm). (After Geraghty et al. (1973), by permission.)

result in larger larvae better able to survive in streams with greater average annual runoff. Heins and Clemmer (1976) had intimated this in their report on *N. longirostris*. This notion will be treated more fully along with other inter- and intra-specific variations in the life histories of members of the *Notropis longirostris* species group in a forthcoming paper.

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