

12-1-1987

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Peterson, Mark S. and Ross, Stephen T. (1987) "Morphometric and Meristic Characteristics of a Peripheral Population of *Enneacanthus*," *Southeastern Fishes Council Proceedings*: No. 17.

<https://doi.org/10.7290/sfcp173gx5>

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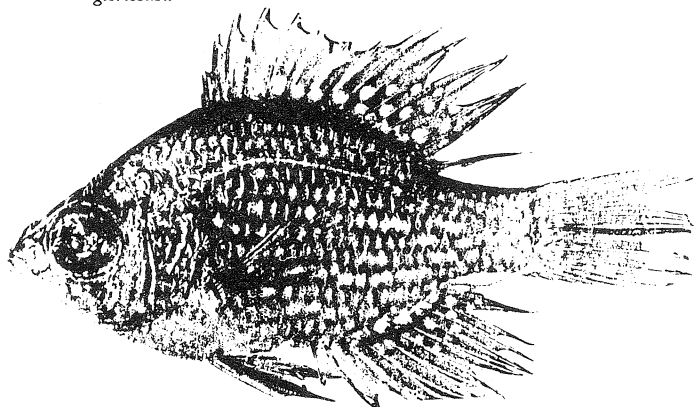
December 1987

Morphometric and Meristic Characteristics of a Peripheral Population of *Enneacanthus*

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Figure 1. Photograph of a 27.8 mm SL specimen of an Old Fort Bayou *Enneacanthus gloriosus*..



The bluespotted sunfish, *Enneacanthus gloriosus* (Holbrook), is a small centrarchid native to coastal drainages of the eastern United States from southeastern New York through peninsular Florida (Carr and Goin 1955; Lee and Gilbert 1980a; b). It has also been recorded from Alabama (Smith-Vaniz 1968) and Bluff Creek, a tributary of the Pascagoula River, Mississippi (Clemmer et al. 1975; Miller and Clemmer 1980), *Enneacanthus gloriosus* and *E. obesus* (Girard) have been introduced into ponds off the Big Black River, Mississippi, where they have established breeding populations (Mike Stegall, Miss. Game and Fish Comm., Jackson, per. comm. 1987), and *E. gloriosus* has been introduced and apparently established in the Lake Ontario drainage of New York (Werner 1972).

Enneacanthus gloriosus is sympatric with *E. obesus* (Girard) (Lee and Gilbert 1980a; b), both species typically inhabiting acidic, black water drainages that are highly vegetated (Hardy 1978; Guillory et al. 1979). All *Enneacanthus* species have been collected in habitats where the pH was as low as 4.1 (Graham and Hastings 1984), and *gloriosus* has been reported to occur in salinities up to 12.9 ppt (Hildebrand and Schroeder 1928; Raney and Massman 1953).

Although unquestionably distinct species, *E. gloriosus* and *E. obesus* sometimes are not easily distinguished. Graham (1985) indicated that individuals of both species less than 9mm SL are morphologically more similar to each other than they are to their respective adults. Lee and Gilbert (1980a; b) suggested that hybrids might occur near the periphery of the western range in Florida and Alabama. Recently, hybrids between the two species have been identified from Connecticut and New Jersey populations (Graham and Felley 1985). Miller and Clemmer (1980) indicated that *E. gloriosus* from Bluff Creek, Mississippi varied from more eastern populations in head length and orbit dimensions, suggesting a clinal pattern.

Herein we: 1) document the westernmost range of *Enneacanthus gloriosus* in the Biloxi Bay system; and 2) examine the variation in morphometric and meristic characters presently used to describe and identify *E. gloriosus* and *E. obesus*.. In our analysis we compared Old Fort Bayou specimens of *E. gloriosus* with specimens of *E. gloriosus* and *E. obesus* from Florida, South Carolina and Maryland.

MATERIALS AND METHODS

Between 29 June 1985 and 20 September 1986, 105 specimens of *E. gloriosus* were collected with a 4.57 X 1.87 m, 3.17 mm mesh bag seine from the headwaters of Old Fort Bayou, Jackson County, Mississippi. Old Fort Bayou is an eastern tributary of Biloxi Bay. Specimens ranged from 12.1-37.5 mm SL. Habitat characteristics were those described as typical for the species.

Temperatures ranged from 32.0°C in August 1985 to 12.0°C in January 1986; pH values from 4.75 in January 1986 to 3.25 in July 1985; and dissolved oxygen from a low of 1.0 ppm in September 1985 to a high of 8.1 ppm in January 1986. The salinity at the site was 0 ppt when specimens were collected; however, beginning in May 1986, salinities increased to a maximum surface value of 5.5 ppt in June 1986.

We selected a suite of 20 morphometric and meristic characters (Table 1) from taxonomic keys (Carr and Goin 1955; Smith-Vaniz 1968; Sweeney 1972; Wang and Kernehan 1979) and/or species descriptions (Hardy 1978; Lee and Gilbert 1980a; b; Miller and Clemmer 1980;

Graham and Felley 1985). Counts and measurements follow Hubbs and Lagler (1958). All measurements were made with Helios dial calipers to the nearest 0.1 mm. Specimens were borrowed from: The Florida State Museum, University of Florida (UF); the Savannah River Ecology Laboratory (SREL); and the University of Southern Mississippi (USM). The number of specimens is given in parentheses after the catalogue number of each lot (Table 1).

STATISTICAL ANALYSES

To determine natural groupings of specimens, we ran a principle components analysis (PCA) on meristic and coded variables. Variables were transformed to z-scores (Sokal and Rohlf 1981) and ordination was done on a correlation matrix using the SPSSX 1.1 program package (SPSS 1985; Norusus 1985) with varimax rotation. We used a scree test (Kim and Mueller 1978) to determine the number of meaningful factors. Following ordination, we plotted standardized factor scores of each specimen on combinations of components I-IV.

RESULTS AND DISCUSSION

With a few exceptions, the majority of morphometric and meristic characteristics of Old Fort Bayou *Enneacanthus* compare favorably to those attributed to *E. gloriosus* (See Hardy 1978; Graham and Felley 1985); thus, we consider these specimens to be *E. gloriosus* (Fig.1). The only significant differences are: 1) the completeness of the lateral line; and 2) a reduction in many of the morphometric/meristic characters used in this analysis, most notably the opercular spot diameter and the caudal peduncle scale count (Tables 1 and 2). There was no significant difference in either the dorsal or anal spine counts or the dorsal or anal ray counts between population samples of *Enneacanthus* (ANOVA, $P > 0.05$). However, the caudal peduncle scale counts were significantly different (ANOVA, $P > 0.0001$; Table 1). Scheffe's multiple comparison test indicates that not only are museum specimens of *E. obesus* and *E. gloriosus* significantly different ($P < 0.05$), but Old Fort Bayou *E. gloriosus* specimens have significantly fewer scales than the other two groups (Table 1). In Werner's (1972) documentation of an isolated, northern population of *E. gloriosus*, he indicated that the caudal penduncle scale counts were: $16.4 \pm 0.07(X \pm SE)$. This is slightly lower than the mean of 17 but within the range of 15-19 reported in Sweeney (1972). Old Fort Bayou populations of *E. gloriosus* have the lowest mean scale count reported.

The majority of *E. obesus*, and *E. gloriosus* from Old Fort Bayou, possess incomplete lateral lines (Tables 2). In contrast, less than 32.6% of the museum specimens of *E. gloriosus* have incomplete lateral lines. The reported completeness of the lateral line found in the literature suggests that *E. obesus* either have an interrupted or incomplete lateral line whereas *E. gloriosus* possess a complete lateral line. Hildebrand and Schroeder (1928) indicated that the lateral line of *E. gloriosus* is "usually wanting on several scales posteriorly" suggesting that some *E. gloriosus* individuals may possess an incomplete lateral line (See Table 2; *E. gloriosus* (MU)). We suggest that the most parsimonious explanation for all Old Fort Bayou specimens having incomplete lateral lines is either the founder effect or genetic drift.

TABLE 1. Meristic and morphometric characteristics ($X \pm SE$) of *Enneacanthus*. LV=Literature values; OFB= Old Fort Bayou; MU=Museum specimens. Coded variable meanings are listed in LV columns.

CHARACTERS*	E. OBESES	E. GLOR(MU)	E. GLOR(OFB)	E. OBESES(LV)	E. GLOR(LV)
DSPINES	8.97 $\pm$ 0.03	9.00 $\pm$ 0.05	8.97 $\pm$ 0.03	9	8-9
DRAYS	10.71 $\pm$ 0.18	10.93 $\pm$ 0.06	10.97 $\pm$ 0.09	12	10-11
ASPINES	3.00 $\pm$ 0.00	3.00 $\pm$ 0.00	3.00 $\pm$ 0.00	3-4	3
ARAYS	10.68 $\pm$ 0.08	10.63 $\pm$ 0.09	10.70 $\pm$ 0.09	10	11
CFSR	21.69 $\pm$ 0.17	17.89 $\pm$ 0.13	15.60 $\pm$ 0.11	X=19(18-22)	X=17(15-19)
OSD	60.49 $\pm$ 3.11	44.23 $\pm$ 1.67	24.88 $\pm$ 1.96	>50%	<50%
GD	45.38 $\pm$ 0.60	45.04 $\pm$ 0.55	42.05 $\pm$ 0.50	40-51%	37-59%
DFB	47.09 $\pm$ 0.89	45.28 $\pm$ 0.44	42.29 $\pm$ 0.58	37-49%	—
PDL	43.95 $\pm$ 0.44	43.96 $\pm$ 0.30	45.64 $\pm$ 0.32	40-51%	39-53%
AFB	28.22 $\pm$ 0.65	27.93 $\pm$ 0.47	25.62 $\pm$ 0.36	20-33%	22-34%
CPD	17.25 $\pm$ 0.26	16.04 $\pm$ 0.22	14.10 $\pm$ 0.19	13-20%	13-20%
OCD	13.49 $\pm$ 0.16	11.43 $\pm$ 0.12	10.92 $\pm$ 0.12	16%(14-18)	14%(12-16)
NOS	2.00 $\pm$ 0.00	1.95 $\pm$ 0.21	2.00 $\pm$ 0.00	No (1=no, 2=yes)	Yes
NOR	1.00 $\pm$ 0.00	1.040 $\pm$ 0.21	1.00 $\pm$ 0.00	Yes	No
SL	36.92 $\pm$ 2.61	37.07 $\pm$ 1.43	23.85 $\pm$ 1.20		
N	35	46	30		

ENNEACANTHUS OBESES = UF 26370(25), UF 29175(2), UF 35258(8).

ENNEACANTHUS GLORIOSUS (MU) = UF 7539(22), UF 29179(5), UF 43080(3), SREL 102(3), SREL 103(1), SREL 104(2), SREL 105(2), USM 1191(5), USM 1962(2), USM 1963(1).

ENNEACANTHUS GLORIOSUS (OFB) = USM 2289(23), USM 2290(30), USM 2291(39), USM 2292(8), USM 2293(2), USM 2294(3).

*Character codes: DSPINES= DORSAL SPINES; DRAYS= DORSAL RAYS; ASPINES= ANAL SPINES; ARAYS= ANAL RAYS; CFSR= CIRCUMFERENTIAL SCALE ROWS; OSD= OPERCULAR SPOT DIAMETER; GD=GREATEST DEPTH; DFB= DORSAL FIN BASE; PDL= PRE-DORSAL LENGTH; AFB= ANAL FIN BASE; CPD= CAUDAL PEDUNCLE DEPTH; OCD= OPERCLE TO CHEEK DISTANCE; NOS= NARES OVAL/SLIT; NOR= NARES OVAL/ROUND; SL= STANDARD LENGTH; N= NUMBER OF INDIVIDUALS.

Opercular spots of all Old Fort Bayou specimens were clearly distinct in individuals ranging in size from 12.1-37.5 mm SL. Scatterplots of opercular spot diameter (as % of eye diameter) vs SL, in general, resulted in the separation of *E. obesus* and *E. gloriosus* specimens greater than 25 mm SL; however, those specimens smaller than 25 mm SL have proportionally smaller opercular spot diameters (Fig. 2). This ontogenetic change in spot diameter is not clearly indicated in the literature, particularly for *E. obesus*. Werner (1972) indicated that the opercular spot diameter of New York specimens was about 50% of eye length. Anjard's (1974) illustration of *E. gloriosus* does not show an opercular spot in a 15.5 mm TL specimen, while Hardy (1978) indicated that at 25 mm the spot is well-developed. Graham (1985) indicated that specimens < 9mm SL of both species were morphologically more similar to each other than they were to their respective adults, although pigmentation was not specifically mentioned. It is interesting that Breder and Redmond (1929) indicated that one 10.5 mm SL *E. gloriosus* specimen was "...fundamentally similar to the adults except in the proportions of the body, depth, eye, head, etc." suggesting that juvenile pigmentation patterns are similar to adults. Wang and Kernehan (1979) further indicated that young (>10.0 mm) *E. gloriosus* morphologically resemble adults. This suggests that some individuals obtain adult pigmentation patterns at a smaller size.

Vertical bars are very common in *E. obesus* but rare in *E. gloriosus* (Table 1). However, juvenile *E. gloriosus* (15.5-45.0 mm TL) have variable bar development (Breder and Redmond 1929; Breder 1936; Anjard 1974; Wang and Kernehan 1979). Vertical bars were common in both *E. obesus* and all *E. gloriosus* populations; however 28.3% of the museum specimens of *E. gloriosus* lacked vertical bars (Table 2).

TABLE 2. Frequencies of selected diagnostic characters for *E. obesus* (N=35), *E. gloriosus* (MU) (N=46) and *E. gloriosus* (OFB) (N=30), LLL=left lateral line completeness; RLL=right lateral line completeness; Vbars=vertical bars; Sob=suborbital bar; IS=iridescent spot; MU=museum; OFB=Old fort bayou; INC=incomplete; INT=interrupted; COMP=complete.

CHARACTERS	E.OBESUS	E.GLOR(MU)	E.GLOR(OFB)	E.OBESUS(LV)	E.GLOR(LV)
LLL	88.6% INC. 5.7% INT. 5.7% COMP.	67.4% COMP. 32.6% INC.	96.7% INC. 3.3% COMP.	INC./INT.	COMP.
RLL	88.6% INC. 5.7% INT. 5.7% COMP.	78.3% COMP. 21.7% INC.	100.0% INC.	INC./INT.	COMP.
VBARs	97.1% YES 2.9% NO	71.7% YES 28.3% NO	96.7% YES 3.3% NO	VERY COMMON	RARE
SOB	100.0% YES	95.7% YES 4.3% NO	100.0% YES	YES	FAIRLY COMMON
IS	100.0% NO	63.0% YES 37.0% NO	100.0% NO	VERY RARE	COMMON

Iridescent spots were absent on *E. obesus* and the Old Fort Bayou populations of *E. gloriosus* (Table 2); however, 63.0% of the *E. gloriosus* museum specimens possessed iridescent spots. Iridescent spots are common for *E. gloriosus* but sparse or absent in *E. obesus* (Werner 1972; Sweeney 1972; Hardy 1978; Wang and Kernehan 1979). Anjard (1974), Hardy (1978) and Wang and Kernehan (1979) indicated that there is a marked iridescence in live or freshly killed specimens of *E. gloriosus* ranging in size from 6.0 to 11.08 mm TL. Variation in spots might also reflect differential preservation. The suborbital bar was present in all groups and is thus not a good character to separate *Enneacanthus* species (Table 1). Nares shape can be drastically altered due to handling and preservation techniques rendering it useless for species distinction as well.

PCA of meristic variables resulted in five meaningful components (eigenvalues > 1.0), which explained 79% of the variance (Table 3). Populations and species of *Enneacanthus* were best separated by scatterplots of standardized scores on PC I & IV, which are interpreted as: I) lateral line completeness and IV) caudal peduncle scale rows (Fig. 3). Species showed broad overlap on PC II, III, and V, interpreted as: II) banding pattern; III) median fin counts; and V) nares shape. Old Fort Bayou specimens of *Enneacanthus gloriosus* are well separated from *E. obesus* especially along PC-IV, and broadly overlap with other specimens of *E. gloriosus* from the southeast. However, the Old Fort Bayou material is more extreme than the other *E. gloriosus* in showing a tendency for an incomplete lateral line.

Another character that is clearly distinct between these two species is the shape and slope of the forehead (see Figs. 39 and 40; Branson and Moore 1962). Although this is a difficult character to quantify, current technologies exist to examine this character.

TABLE 3. Loadings (correlations) of meristic and coded variables from *Enneacanthus gloriosus* (N=76) and *Enneacanthus obesus* (N=35) of five principal components following varimax rotation. Variables with the highest loadings on each component are grouped together. Character abbreviations can be found in Tables 1 and 2.

	I	II	III	IV	V
LLL	.930	.054	.072	.039	-.065
RLL	.915	.118	.009	-.019	-.108
SOB	.107	.885	-.016	.093	.011
VBARs	.298	.519	-.183	-.264	.273
DRAYS	.025	.011	.809	-.214	-.157
ARAYS	.174	-.346	.641	.227	.366
DSPINES	-.078	.626	.637	.067	-.099
CPSR	.020	.034	-.085	.938	-.019
NARES	-.175	.068	-.057	-.029	.890
%variance extracted	20.8	17.7	16.9	11.8	11.7

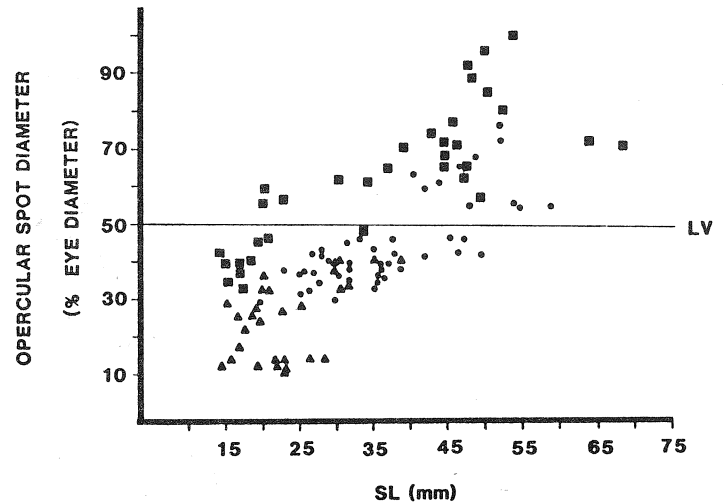


Figure 2. Scatterplot of opercular spot diameter vs SL for all *Enneacanthus* species. ■ = *Enneacanthus obesus*; ● = *Enneacanthus gloriosus* (MU); ▲ = *Enneacanthus gloriosus* (OFB). LV= literature value separation point.

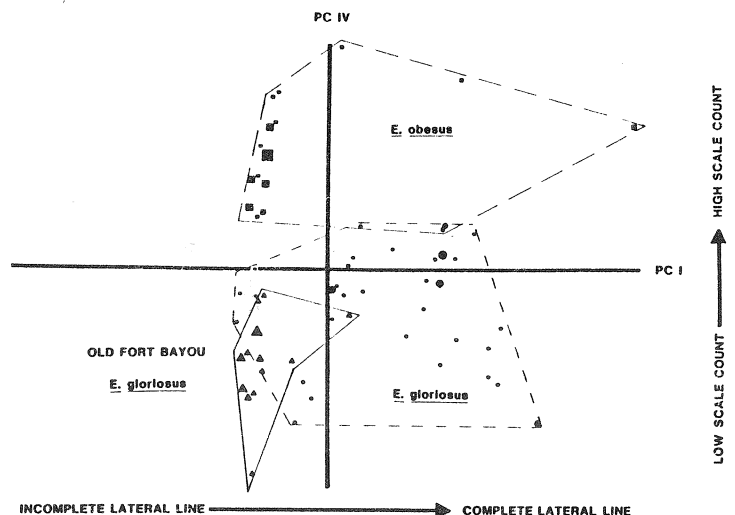


Figure 3. Scatterplot of standardized scores on PC I and PC IV for all *Enneacanthus* species. ■ = *Enneacanthus obesus*; ● = *Enneacanthus gloriosus* (MU); ▲ = *Enneacanthus gloriosus* (OFB). Size of symbols indicates multiple occurrences at that point (e.g., ▲ = one occurrences; ▲ = 2-5 occurrences; ▲ = > 5 occurrences).

We suggest that caudal peduncle scale counts, lateral line completeness and opercular spot diameter are presently the characters most helpful in distinguishing *Enneacanthus* species.

ACKNOWLEDGEMENTS

We are grateful to Daniel Gustafson for his help with field work. Tom Rogge and Daniel Gustafson assisted in producing Figure 1. Special thanks to John Aho (Savannah River Ecology Laboratory) and Carter Gilbert (Florida State Museum) for loaning us specimens for study.

Nancy J. Brown Peterson kindly reviewed the manuscript. This project was partially supported by a Mississippi/Alabama Sea Grant. Fellowship NABSAA-D-SGOOS and a pre-doctoral Fellowship from the Slocum-Lunz Foundation, Inc to M.S.P.

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ERRATUM

SFC PROCEEDINGS Vol. 4 no. 4p. 11 ("Fishes of the Buttahatchee River System of Alabama and Mississippi" by Pierson, et al.) Introduction, first sentence - the terms lentic and lotic were accidentally reversed. The sentence should read : Construction of the Tennessee-Tombigbee Waterway (TTW) has resulted in change of the Tombigbee River proper from a lotic environment with firm substrate to a lentic environment with a mud-silt bottom.

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