Sexual Dimorphism in Plains Minnow, *Hybognathus placitus*

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*Hybognathus placitus* collected from several west Texas streams exhibit sexual dimorphism in body form, which is unusual in cyprinids. Seventeen morphological measurements, including standard length, were made on 62 specimens and analyzed for sexual dimorphism. Partial warp scores were used to describe sexual dimorphism in body shape. There was no difference in standard length between males and females (ANOVA, $P = 0.9038$, $F_{1,60} = 0.0147$), but there was a highly significant (MANOVA, $F_{1,60} = 4.78$, $P < 0.001$) sexual dimorphism in body shape. Overall, males have relatively longer first dorsal fin rays, larger heads, and caudal peduncles, whereas females are deeper bodied and have relatively longer trunks, from the pelvic fin insertion to the anal vent. Differences between male and female *H. placitus* in length of the first dorsal fin ray are readily apparent and can potentially be used for field identification.

The plains minnow (*Hybognathus placitus*) has a wide geographic range extending from Texas through the Great Plains to Montana and North Dakota (Taylor and Miller, 1990). In Texas, *H. placitus* ranges from the Colorado and Brazos River basins northward to the Red and Canadian Rivers (Hubbs et al., 1991). While examining fish collections from west Texas (Brazos, Canadian, Pease, and Wichita rivers), we noted an apparent sexual dimorphism in the length of the first dorsal fin ray in specimens of *H. placitus*.

Sexual dimorphism in body size, coloration, fin length, nuptial tubercles, and intermittent organs has been observed in many fish families (Scott and Grossman, 1973). In cyprinids, sexual dimorphism in morphological characteristics other than coloration or presence of nuptial tubercles is uncommon (e.g., Scott and Grossman, 1973). Occasionally, sexual dimorphism in fin lengths, with males possessing longer fins, has been noted in some species such as the speckled dace, *Rhinichthys osculus*, tui chub, *Gila bicolor*, relict dace, *Relictus solitarius* (Hubbs et al., 1974; Sigler and Sigler, 1987), and bluehead shiner, *Notropis hubbsi* (Bailey and Robison, 1978). However, such sexual differences have not been noted in the genus *Hybognathus*. Herein, we present an analysis of this dimorphism and test the hypothesis that specimens of *H. placitus* with longer first dorsal fin rays are males.

**Materials and methods**

*Study animals.*—Morphological analyses were conducted on 62 specimens of *H. placitus* collected 7 July 1996 from the Brazos River basin. Specimens were preserved in 10% buffered formalin and stored in 70% ethanol and are housed in the Texas Tech University Museum (TTU Museum), Lubbock, Texas (TTU-2134).

*Morphological analyses.*—All specimens were photographed (with metric scale) in lateral projection using an Olympus OM-4T SLR camera fitted with a macro-zoom lens. Measurements were obtained by digitizing coordinates of 16 anatomical landmarks (Fig. 1A) judged to be homologous from form to form (Bookstein et al., 1985). We also measured standard length on each specimen.

Sexual dimorphism in shape was described using geometric morphometric methods (Bookstein, 1991; Rohlf and Marcus, 1993). Shape variables were extracted from the landmark data and visualized using tpsSplit (vers. 1.15, F. J. Rohlf, unpubl.). Multivariate analysis of variance (MANOVA; Scheiner and Gurevitch, 1993) was used to assess differences in male and female shape using tpsRegr (vers. 1.19, F. J. Rohlf, unpubl.). Because dorsal and pectoral fins could not be positioned in precisely the same three-dimensional orientation in all study specimens, we omitted landmarks 6 and 7 (dorsal fin) and 15 and 16 (pectoral fin) from this analysis.

Sexual dimorphism in morphology, including length of the first dorsal fin ray and pectoral fin length, also was assessed using discriminant analysis (DA) and MANOVA of interlandmark distances. Interlandmark distances were estimated as linear (Euclidean) distances among selected pairs of landmarks and were selected to form triangles and trusses (Strauss and Bookstein, 1982), geometric arrangements that are highly sensitive to changes in size and shape among forms. In some instances distances were estimated through helping points (landmarks 2,
4, 6, 15) chosen to approximate the outline of the body or fin (Fig. 1B). Because DA and MANOVA assume that samples of males and females were drawn from multivariate normal populations having equal covariance matrices, significance of the MANOVA probability and confidence intervals for discriminant coefficients were estimated by bootstrapping (Dagleish, 1994) using 999 bootstrap iterations.

The entire procedure, from digitizing landmarks through calculation of interlandmark distances, was repeated three times for each specimen to estimate measurement error. Measurement error was estimated separately for each interlandmark distance, per specimen, as the coefficient of variation (CV) on the untransformed interlandmark distances.

After measurements were completed, but before statistical analyses were performed, specimens were classified as to sex, based on length of the first dorsal-fin ray. Dissection of gonads and histology analysis were later used to verify the classifications. Accuracy of classification based on length of the first dorsal-fin ray was estimated by comparing external classifications with internal confirmation (i.e., dissection and histology).

Results

There was no significant difference in SL among males and females used for morphometric analyses (ANOVA, $P = 0.9038, F_{1,60} = 0.0147$). Average SL for males was 55.5 mm (SE = 3.7; $n = 30$) and for females 56.1 mm (SE 3.3; $n = 32$).

Discussion

Our analyses demonstrate the presence of sexual dimorphism in *H. plancius*, which has not been previously described in any member of the genus *Hybognathus*. Dimorphisms occur in head, trunk, and caudal peduncle size, as well as in the length of the first dorsal fin ray. This latter difference is quite distinct. Sexual dimorphism is a widespread phenomenon in fishes and may occur for a variety of reasons including, mate selection, male to male competition for mates, differences in sexual roles, predator avoidance, territoriality and ecological processes (Hubbs et
There is no obvious explanation for sexual dimorphism in H. placitus, but one could advance testable hypotheses for some of the previously mentioned reasons.

Studies exploring the reproductive biology of H. placitus (Lehtinen and Layzer, 1988) and its reproductive ecology and population structure (Taylor and Miller, 1990) used large numbers of specimens (n = 4345 and 4080, respectively). Large numbers of H. placitus were, in part, collected to ensure adequate sample sizes of males and females. The dimorphism in the first dorsal fin ray that we document is sufficiently obvious to reliably sex fish in situ, by holding a fish and depressing the dorsal fin. If the posterior margin of the dorsal fin forms a more or less vertical edge, the specimen is a female. If the first dorsal-fin ray extends past the vertical edge of the depressed dorsal fin, forming a fingerlike projection, the specimen is a male. We found this technique to be 99% effective. Sex identification has an obvious practical utility and potential conservation use because of documented declines in abundance and distribution of H. placitus (Cross and Moss, 1987; Pigg, 1987; Taylor and Miller, 1990).

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