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Life-History Traits of the Bluenose Shiner, *Pteronotropis welaka* (Cypriniformes: Cyprinidae)

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Life-history aspects and behavioral ecology of the bluenose shiner (*Pteronotropis welaka*) were investigated from May 1993 to June 1994 in a small tributary of the lower Pearl River in Marion County, Mississippi. Samples were taken monthly or biweekly to provide information about preferred habitat, reproductive biology, and demography. Observations were made during the breeding season to determine spawning strategy. Except during peak spawning periods, bluenose shiners were located in schools of more than 25 individuals in areas of sluggish flow (0–4 cm/sec) near submerged vegetation. Based on gonadal condition, bluenose shiners have a protracted breeding season, lasting from May to August and including two major spawning bouts. Although the spawning act was not observed, aggregations of adults over sunfish nests and the presence of bluenose shiner eggs and fry in nests indicates that this species is a nest associate. Unlike male bluehead shiners (*Pteronotropis hubbsi*), male bluenose shiners show an increase in gonadal weight and a gradual increase in the development of secondary sexual characteristics with increased length. Length frequency data and the absence of adults from the study site in the fall and winter indicate that adults die after the breeding season.

PTERONOTROPIS welaka Evermann and Kendall, the bluenose shiner, inhabits clear, vegetated coastal streams on the Gulf slope and occurs in a disjunct population in the St. Johns River, Florida (Page and Burr, 1991). The species is known for striking sexual dimorphism; males are generally larger than females and develop bright blue snouts and elongated pelvic, dorsal, and anal fins during the breeding season. Males also develop black pigment in the dorsal fin and black and yellow pigment in the pelvic and anal fins. Due to their attractive appearance, these males are highly prized as aquarium fish. In spite of the popularity of the fish, the life history and ecology of the species remain poorly known. Even the systematics of the bluenose shiner is unclear; some authors suggest a close relationship with the bluehead shiner, *Pteronotropis hubbsi* (Bailey and Robison, 1978; Amemiya and Gold, 1990), whereas others question this relationship (Dimmick, 1987). This paper describes the development and expression of sexual dimorphism and patterns of reproductive allocation (resources devoted to sexual characteristics or gonads) in the bluenose shiner. Other aspects of life history are also presented and compared to those of the bluehead shiner.

MATERIALS AND METHODS

Our study site is a tributary to the Pearl River, at highway 587, Marion County Mississippi (T4N, R19W, sec. 21). The water in the first-order stream is clear, with sand and silt substrata and dense patches of aquatic vegetation. Water velocity is low in expanded pool areas and moderate in the stream channel.

Samples of bluenose shiners were collected by seine monthly from May 1993 through June 1994. Two samples per month were taken in July 1993 and May 1994 (16 total samples). A total of 822 fish was collected during the course of the study (State of Mississippi collecting permits issued to CEJ and CLK). Specimens were fixed in a solution of 5% buffered formalin, and those not used for gonadal analysis were later vouchered at the Mississippi Museum of Natural Science, where they were transferred to alcohol. During the winter of 1993, the entire stream to the confluence with the Pearl River was sampled for bluenose shiners.

Three hundred seventy-six adults were examined for sexual dimorphism and reproductive characteristics, and 822 individuals were measured (standard length to 0.01 mm) with dial calipers and sexed. Measures of sexual dimorphism (differences between sexes and development of secondary sexual characteristics in males) included size (SL), length of dorsal and anal fins (length of longest ray, from base, mm), degree of tuberculation (categorical, 1 = low; 2 = medium; 3 = high), development of blue nose (present or absent), and degree of dorsal fin pigmentation (categorical, 1 = low; 2 = medium; 3 = high). These data were taken for in-

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dividuals collected during the breeding season only (May, June, and July).

Seasonal changes in gonad mass for adults of both sexes were examined using gonadosomatic index (GSI). Gonads and eviscerated specimens were air dried for 2 h and weighed to the nearest 0.01 gm. Air drying served to standarize the procedure and remove surface moisture; essentially the measurements were wet weights. Gonadosomatic index was calculated by dividing gonad mass by adjusted somatic mass (mass of eviscerated specimen) and multiplying by 1000. The reproductive condition of males was classified as latent or mature by examination of testes. Mature testes were opaque and large, whereas latent testes were small strands of clear tissue. The reproductive condition of females (n = 157) was determined by examination of ovaries and their classification into one of six categories (Heins and Baker, 1993): latent (LA), early maturing (EM), late maturing (LM), mature (MA), ripening (MR), or ripe (RE). Ova in the three largest size classes were counted, and the diameter of five ova in each size class was measured for 35 females from seven samples taken during the breeding season. The ova were easily separated into these three size classes, which differ in size by 0.1–0.2 mm. Measurements were made with a dissecting microscope and ocular micrometer. Data were analyzed using the SYSTAT software package (Evanston, IL, 1990, unpubl.).

Spawning aggregations of bluenose shiners were observed over longear sunfish (*Lepomis megalotis*) nests on 10 May 1994, 26 May 1994, and 9 June 1994. Observation periods ranged from 30 min to 1 h. Eggs from five nests were brought back to the laboratory, raised to larvae, and preserved; and eggs from five additional nests were preserved and counted. Sunfish eggs could be distinguished from bluenose shiner eggs because the sunfish eggs were larger (2.0 m diameter vs 1.0 mm diameter for bluenose shiners). Samples of larvae raised from nests and older larvae collected in the field were sent to T. Slack, University of Southern Mississippi to verify identification.

Results

Examination of length-frequency histograms for *P. welaka* collected during this study indicates that large (≥ = 40 mm SL) individuals are present in the spring but disappear from the population by fall (Fig. 1). Recruitment into the larger sizes classes begins in late winter. Recruitment of young of the year is evident in the summer months. The size range for all males was

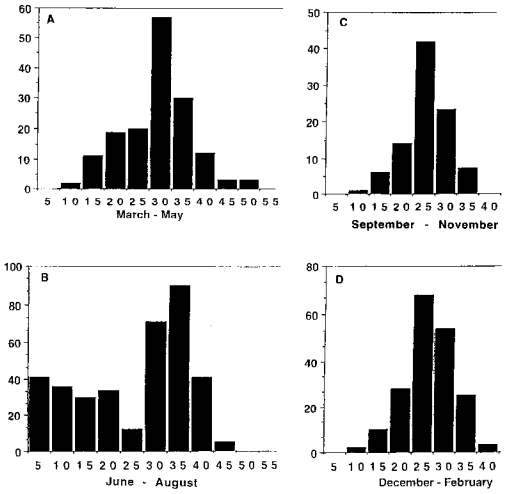
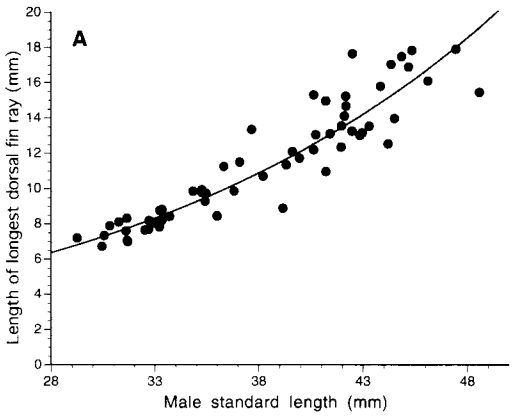


Fig. 1. Length-frequency histograms for *Pteronotropis welaka*. Samples are combined by season. (A) represents spring; (B) represents summer; (C) represents fall; and (D) represents winter.

21.7–51.0 mm SL and for females was 5.2–44.1 mm SL. Male *P. welaka* are larger than females (males: mean SL = 36.1, SD = 5.8, n = 147; females: mean SL = 34.7, SD = 4.6, n = 229; t = 2.4, P = 0.01). The sex ratio was skewed toward females (1.5 females: 1.0 males; χ^2 = 17.88, P = 0.001).

Virtually all males collected during the breeding season had a blue snout. Only eight of 147 males (5%) did not have this characteristic. The mean length of males that did not have a blue snout was 35.7 mm (SD = 4.5); all of these males had undeveloped gonads but were collected during the breeding season. The mean length of males that had blue snouts was 36.1 mm (SD = 5.9). These lengths were not significantly different (t = 0.77; P = 0.44). Both the degree of cephalic tuberculation and dorsal fin pigmentation increased gradually with length for males, as did the length of the dorsal and anal fins (Fig. 2). Although there was overlap in the standard length of males categorized as having high to low values for tuberculation and dorsal fin pigmentation, the mean standard length of males in these categories was significantly different (tuberculation: SL males in high category = 45.7 mm, SD = 2.8; medium = 39.2, SD = 3.2; low = 33.1, SD = 3.1; F = 99.9, P = 0.0001, SNK = all means different; dorsal fin pigmentation: SL males in high category = 43.5 mm, SD = 3.6; medium = 37.4, SD = 3.2; low = 32.5, SD = 2.7; F = 90.1, P = 0.0001, SNK = all means different). Females did not develop a blue nose, elongated dorsal and



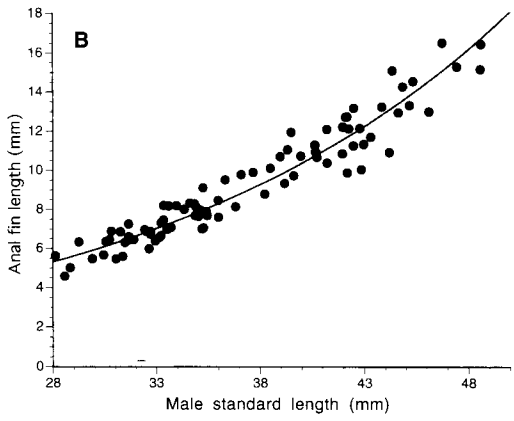


Fig. 2. (A) The relationship between standard length and the length of the longest dorsal fin ray of male *Pteronotropis welaka*. Y = exp(1.41 + 0.054x), r^2 = 0.88; $F_{1,90}$ = 464.61, P = 0.0001. (B) The relationship between standard length and the length of the longest anal fin ray of male *P. welaka*. Y = exp(1.11 + 0.055x), r^2 = 0.92, $F_{1,90}$ = 1231.69, P = 0.0001.

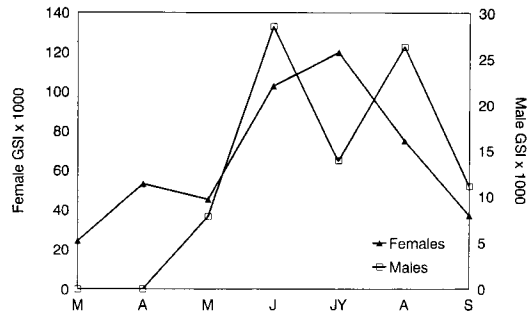


Fig. 3. Gonadosomatic index of male and female *Pteronotropis welaka* by month.

anal fins, or pigmented dorsal and anal fins. Females also did not develop elongated pelvic fins (unpubl. data).

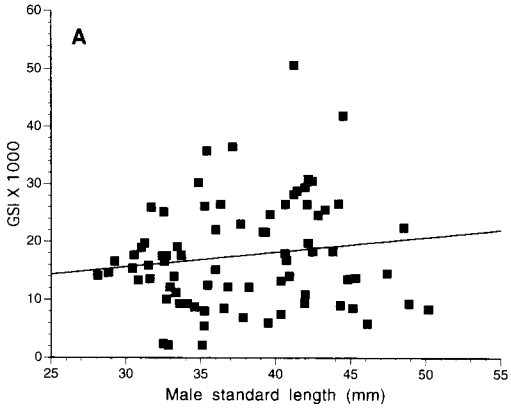
The GSI values for males and females (Fig. 3) indicate that *P. welaka* prepare for spawning in April and spawn from May through July. This is supported by the data for gonad stage for females (Table 1). Ovaries are latent in March, begin maturing in April, have a relatively high percentage of mature stages in May to July, and by September are all latent (Table 1). The proportion of individual males of each testes stage was 100% mature in May, June, and July; 73% mature and 27% latent in August; and 100% latent by September. The regression of GSI and standard length for males (Fig. 4) suggests that gonads increase in size with an increase in length, although this is not a statistically significant relationship ($F_{1,76}$ = 1.67, P = 0.19), due to individual variability. The somatic weight of males increases with increased length (Fig. 4).

The mean number of ova counted from females collected during the breeding season in the largest size class ranged from 55–183, in the next largest size class from 83–130, and the smallest size class 104–190. Corresponding ova diameters were 0.6–0.8 in the largest size class, 0.3–0.4 in the next largest size class, and 0.1–0.2 in the smallest size class.

Aggregations of breeding male and female *P. welaka* were observed over active (guarding male present), longear sunfish (*L. megalotis*) nests on 10 May 1994 (one of three active nests), 26 May 1994 (six of eight active nests), and 9 June 1994 (four of five active nests). Each nest was observed for 15–30 min. Male *P. welaka* were aggressive, and circle swims and lateral displays between pairs of males were common. Males also chased other males and females from their immediate area. No one male dominated the area over nests. Two sizes of eggs were found in these nests, suggesting that *P. welaka* were spawning, even though no actual spawning events were observed. Larvae raised in the lab-

TABLE 1. PROPORTION OF INDIVIDUALS OF EACH OVARY STAGE FOR FEMALE *Pteronotropis welaka*. RE = ripe, MR = ripening, MA = mature, LM = late maturing, EM = early maturing, and LA = latent.

	March	April	May	June	July	August	September
RE	0	0	0	0	0	0	0
MR	0	0	16	23	13	4	0
MA	0	17	49	69	78	66	0
LM	0	33	10	0	7	6	0
EM	0	50	23	0	0	0	0
LA	100	0	3	8	2	23	100



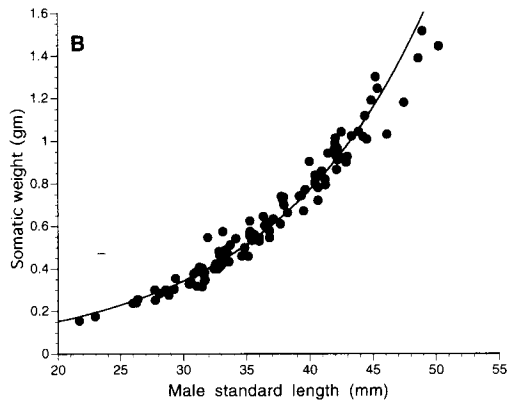


Fig. 4. (A) Relationship between male gonadosomatic index and standard length. Y = 0.26x + 7.58, $r^2 = 0.02$, $F_{1,76} = 1.67$, $P = 0.19$. (B) The relationship between somatic weight and standard length of male *Pteronotropis welaka*. Y = exp(0.023 + 0.081x), $r^2 = 0.96$, $F_{1,105} = 2774.81$, $P = 0.0001$.

oratory from these nests were identified as sunfish and as *P. welaka*. The composition of five nests sampled for eggs ranged from 2–46% sunfish and 54–98% shiner. When parental male sunfish left nests, *P. welaka* entered the nests and fed on eggs and larvae.

Discussion

Our data suggest that *P. welaka* have a relatively short lifespan, with most individuals dying during their second summer, after their first spawning season. This is similar to field data taken for *P. hubbsi* (Taylor and Norris, 1992). Fletcher and Burr (1992) suggest that *P. hubbsi* have two distinct year classes, but their data for length frequencies, based only on males, was from only one season (April and May) and for very few individuals (125 males), perhaps providing a misleading representation of the population they studied.

According to Fletcher and Burr (1992), two distinct classes of male *P. hubbsi* exist in the breeding population and are termed secondary and terminal males (based on data from 53 secondary males and 11 terminal males). Secondary males are smaller than terminal males and can also be characterized by the presence of blue pigment on the head. These males are more numerous in the population and as they grow longer turn into terminal males. Terminal males lose the blue coloration on the head; have greatly expanded dorsal, anal, and pelvic fins; and are deeper bodied than secondary males. Secondary males invest more in gonad weight than do terminal males, which invest more in somatic growth (Fletcher and Burr, 1992). Terminal males are the dominant individuals during the breeding season, and apparently large body size is linked to this breeding system. Male *P. welaka* do not have this pattern of reproductive allocation. Our data show that, for male *P. welaka*, somatic weight increases gradually with standard length, as gonadal investment does, in general (illustrated by GSI). A statistically significant relationship between male length and GSI was not found due to variation, presumably in individual condition.

Our results also suggest that the secondary sex characteristics of male *P. welaka* develop gradually, unlike what Fletcher and Burr (1992) found for *P. hubbsi*. As male *P. welaka* get larger (length and weight), fin length and pigmentation increase, as does relative testes weight and somatic weight. Males displaying all stages of the development of secondary sexual characteristics could be found at the same time during the breeding season, unlike the two morphologically distinct classes of males found at the same time in *P. hubbsi* (Fletcher and Burr, 1991). Almost all males examined had blue snouts, however, and there appeared to be no difference in the amount of blue pigmentation observed on any individuals. The gradual development of these traits and the presence of males with all stages of development at the same time suggests that there are not two morphologically distinct classes of males in *P. welaka*, as in *P. hubbsi* (Fletcher and Burr, 1992; Taylor and Norris, 1992). Our conclusions are based on data from 147 breeding males (eight samples during the breeding season) versus data for 64 males taken

from three samples (April and May) for *P. hubbsi*; and we followed the population for 14 months (16 total samples, 822 total fish examined). Whether the patterns found for *P. hubbsi* by Fletcher and Burr (1992) would be seen if more individuals were studied over a greater period of time is not known but is of interest.

These different patterns of male reproductive investment are particularly interesting because both species share the nest association breeding strategy. In our observations, numerous male *P. welaka* maintained positions over sunfish nests. Aggressive encounters were common and similar to those described for *P. hubbsi* by Fletcher and Burr (1992). No one male defended the area over a sunfish nest, however, as Fletcher and Burr (1992) observed for terminal male *P. hubbsi*. Fletcher and Burr (1992) suggested that secondary male *P. hubbsi*, which have enlarged testes, may act as sneakers in the breeding system, although this has not been confirmed. Whether the differences in male reproductive strategies have driven the evolution of different patterns of male secondary sex characteristics and reproductive allocation in these two species is not known but is certainly worthy of further investigation.

Individuals in breeding aggregations of *P. welaka* over sunfish nests were observed entering nests and preying on brood when the guarding male sunfish was not present. This behavior is similar to that of *Notropis cummingsae* (Fletcher, 1993). Fletcher (1993) provided evidence for selective predation of host (sunfish) brood by *N. cummingsae*. Preliminary experiments from this study suggest that *P. welaka* will prey on both their own and host brood but feed on the larger host eggs first (CEJ, unpubl. data). The impact of this type of behavior on the reproductive success of both hosts and nest associates is unknown but is probably directly related to the number of opportunities available to associates for entering nests and preying on brood.

Both *P. welaka* and *P. hubbsi* have peak spawning seasons of May to July (Taylor and Norris, 1992). Ovum sizes and fecundity are also similar for the two species (Taylor and Norris, 1992). Ova in several distinct size classes suggests that females spawn more than once during the breeding season, which is common for minnows (Heins and Rabito, 1986).

Although *P. welaka* and *P. hubbsi* show some similarity in several life-history traits, the patterns of male reproductive allocation, expression of secondary sex characteristics, and male reproductive behavior appear to be very different for the two species. More observations of the breeding behavior are needed to determine whether the observed behaviors are artifacts of variable breeding systems or are real differences in breeding systems for the two species. A more thorough investigation of reproductive investment in *P. hubbsi*, using specimens gathered over a greater period of time, is also needed to verify the patterns of gonadal investment of males reported in Fletcher and Burr (1992). If *P. welaka* and *P. hubbsi* are sister species, as proposed by some authors (Bailey and Robison, 1978; Amemiya and Gold, 1990), a comparative study of the reproductive strategies of these two species will provide insight into the evolution of alternative male reproductive behaviors.

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Literature Cited

Amemiya, C. T., and J. R. Gold. 1990. Chromosomal NOR phenotypes of seven species of North American Cyprinidae, with comments on cytosystematic relationships of the *Notropis volucellus* species-group, *Opsopeoedus emilae*, and the genus *Pteronotropis*. Copeia 1990:68–78.

Bailey, R. M., and H. W. Robison. 1978. *Notropis hubbsi*, a new cyprinid fish from the Mississippi River basin, with comments on *Notropis welaka*. Occ. Pap. Mus. Zool. Univ. Mich. 683:1– 21.

Dimmick, W. W. 1987. Phylogenetic relationships of *Notropis hubbsi*, *N. welaka* and *N. emiliae* (Cypriniformes: Cyprinidae). Copeia 1987:316–325.

Fletcher, D. E. 1993. Nest association of dusky shiners (*Notropis cummingsae*) and redbreast sunfish (*Lepomis auritus*), a potentially parasitic relationship. *Ibid.* 1993:159–167.

———, and B. M. Burr. 1992. Reproductive biology, larval description, and diet of the North American bluehead shiner, *Pteronotropis hubbsi* (Cypriniformes: Cyprinidae), with comments on conservation status. Ichthyol. Explor. Freshwaters 3:193–218.

Heins, D. C., and J. A. Baker. 1993. Reproductive biology of the brighteye darter, *Etheostoma lynceum* (Teleostei: Percidae), from the Homochitto River, Mississippi. *Ibid.* 4:11–20.

———, and F. G. Rabito Jr. 1986. Spawning performance in North American minnows: direct evidence of the occurrence of multiple clutches in the genus *Notropis*. J. Fish Biol. 28:343–357.

Page, L. M., and B. M. Burr. 1991. A field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin, Boston, MA.

Taylor, C. M., and S. M. Norris. 1992. Notes on the reproductive cycle of *Notropis hubbsi* (bluehead shiner) in southeastern Oklahoma. Southwest. Nat. 37: 89–92.

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