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New Dace of the Genus *Phoxinus* (Cyprinidae: Cypriniformes) from the Tennessee River Drainage, Tennessee

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***Phoxinus saylori* is a new cyprinid described from the Tennessee River drainage. This distinctive minnow is one of seven described North American *Phoxinus* species and one of four that occurs in Tennessee. It differs from all congeners by the combination of two uninterrupted black lateral stripes and development of black pigment on the underside of the head of nuptial males. Based on coloration and tuberculation patterns, *P. saylori* is hypothesized to be part of a monophyletic group comprised of *P. oreas, P. tennesseensis,* and *P. cumberlandensis. Phoxinus saylori* appears to be very rare; it is currently known from only six localities on the Walden Ridge portion of the Cumberland Plateau. Human activities such as agriculture and timbering threaten its future existence.**

THE North American members of the cyprinid genus *Phoxinus* are widely distributed throughout the Mississippi and Ohio River basins of the northeastern, central, and southeastern United States (Etnier and Starnes, 1993). The most northerly species, *Phoxinus neogaeus*, can be found as far north as the Mackenzie River system of the Northwest Territories (Scott and Crossman, 1973), and a single species, *P. oreas*, inhabits rivers and streams draining to the Atlantic Ocean.

There are six described North American *Phoxinus* species (Robins et al., 1991) and at least one undescribed species. Of the six named species, *P. erythrogaster, P. tennesseensis*, and *P. cumberlandensis* are native to Tennessee (Etnier and Starnes, 1993). The wide-ranging *P. erythrogaster* is found throughout much of middle and west Tennessee, whereas *P. tennesseensis* and *P. cumberlandensis* are confined to upper portions of the Tennessee and Cumberland River drainages, respectively. The last two species have restricted ranges, and *P. cumberlandensis* is federally listed as threatened.

The new *Phoxinus* was first collected in July 1976 by the Tennessee Valley Authority (TVA) in two small Tennessee River tributaries on the Walden Ridge portion of the Cumberland Plateau (C. Saylor, TVA, pers. comm.). Because nonbreeding individuals of the new species look like the common *P. erythrogaster*, the collection remained in storage at TVA until 1990. At that time, the specimens were donated to the University of Tennessee Research Collection of Fishes (UT). When D. Etnier (UT) examined the specimens, he remarked that the dace probably represented an undescribed species (D. Etnier, pers. comm.). Subsequent collections of breeding individuals revealed a unique combination of breeding colors that provided strong evidence the fish was undescribed.

Herein, the new dace is formally described. The new species has nuptial coloration characteristics intermediate between its geographically proximate congeners, *P. tennesseensis* and *P. erythrogaster,* and is thus compared with and differentiated from them.

MATERIALS AND METHODS

Methods of counts and measurements generally follow Hubbs and Lagler (1964) except that gape width was measured at the corner of the mouth, and the fleshy margin of the operculum was excluded from head length. Additionally, transverse scale rows were counted diagonally from the third anal ray to the third dorsal ray because of the difficulty met when counting the very small scales near the origin of the dorsal and anal fins. To design a truss (Humphries et al., 1981), several measurements that were not described by Hubbs and Lagler (1964) were used in this analysis (Table 1). Measurements were made using a needle-point digital caliper and were taken to the nearest 0.1 mm. To reduce the confounding effects of sexual dimorphism, among-species shape comparisons were made using only adult males. Overall size effects were minimized with sheared principal components analysis (SPCA, Humphries et al., 1981; Bookstein et al., 1985) with a program written for SAS by D. Swofford (Statistical Analysis Systems Institute, Inc., Cary, NC). SPCA was also used to assess shape dimorphism between nonbreeding males and females and intraspecific shape variation among males. A two-sample *t*-test (PROC TTEST) was used to compare distance measurements between males and females. One-way analysis of variance (PROC AN-

TABLE 1. MEANS AND RANGES OF PROPORTIONAL MEASUREMENTS (EXPRESSED IN THOUSANDTHS OF STANDARD LENGTH) FOR THE HOLOTYPE AND MALES OF *Phoxinus saylori*, *Phoxinus tennesseensis*, and *Phoxinus erythrogaster*. Holotype not included in mean. Significant differences indicated with an asterisk.

		P. saylori (*n* = 41)		*P. tennesseensis* (*n* = 43)		*P. erythrogaster* (*n* = 50)	
Measurement	Holotype	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range
Standard length	50.5	45.7	39.7–54.6	49.53	42.3–60.7	49.6	44.3–56.4
Pectoral fin length	205	206	185–225	201	181–231	232	207–266
Pelvic fin length	177	168	153–180	170	158–193	162	146–178
Dorsal fin length*	219	230	216–259	216	195–254	220	193–243
Anal fin length*	209	203	186–217	196	174–223	194	180–208
Interorbital distance*	83	90	82–100	83	75–91	83	74–96
Head width*	147	151	132–171	136	118–153	141	122–155
Body width at dorsal fin origin	140	138	120–165	130	106–162	137	101–173
Body width at anal fin origin	116	107	89–133	99	82–128	104	78–127
Snout length*	77	78	69–88	75	66–90	75	62–86
Head length*	262	258	245–289	247	236–270	248	229–274
Snout–occiput	205	211	192–271	207	193–219	203	181–224
Occiput–dorsal origin*	340	350	314–377	334	318–359	342	316–365
Dorsal fin base*	104	106	93–120	109	93–126	110	100–131
Dorsal end–caudal base*	360	375	358–395	385	338–421	382	358–411
Caudal peduncle depth	127	126	118–138	110	97–131	122	110–136
Anal end–caudal base*	234	249	233–266	260	229–277	255	232–278
Anal fin base	110	107	97–118	106	86–117	106	96–115
Anal origin–pelvic origin*	170	174	155–192	185	163–215	181	154–205
Pectoral origin–pelvic origin*	216	218	197–239	212	188–234	228	210–250
Snout–isthmus	175	172	154–183	169	130–198	168	155–183
Gape width*	65	67	54–74	57	41–77	59	47–73
Upper jaw length*	82	82	70–93	67	60–77	73	63–85
Head depth*	164	174	163–189	164	152–182	167	153–182
Occiput–pectoral origin*	182	175	155–189	168	158–181	170	154–186
Dorsal origin–pectoral origin	327	341	324–367	332	306–364	345	326–372
Dorsal origin–pelvic origin	231	230	208–256	220	194–272	234	207–264
Dorsal origin–anal origin	234	233	216–248	229	196–253	t243	223–263
Dorsal end–pelvic origin	243	248	220–269	243	216–272	249	228–277
Dorsal end–anal origin	171	173	152–190	164	145–192	176	162–198
Dorsal end–anal end	193	189	169–205	180	161–202	190	175–210
Orbit diameter*	67	71	62–87	66	58–78	67	60–81
Pectoral origin–isthmus*	141	132	116–146	121	107–139	112	100–126
Pectoral origin–pectoral origin	166	167	149–186	147	127–172	149	123–166

OVA) was used to assess distance measurements among species. Variables that exhibited significant differences were further evaluated with the Tukey posthoc test to determine which groups differed from one another. Differences were considered significant for $P < 0.05$. Statistical analyses were conducted with SAS (vers. 6.12, 1996, Cary, NC). Institutional abbreviations follow Leviton et al. (1985) and Leviton and Gibbs (1988).

Vertebral counts were made from cleared-and-stained specimens with the Weberian apparatus counted as four elements and the hypural as one element. Pharyngeal tooth formulae, shape of the pharyngeal arch, and basioccipital shape were described from skeletal material prepared by macerating specimens in water.

Phoxinus saylori n. sp.
Laurel Dace
Figure 1

Phoxinus sp. cf. *erythrogaster* Etnier and Starnes, 1993:246

Phoxinus sp. cf. *tennesseensis* Warren et al., 1997: 146.

Holotype.—UMMZ 236817, ex. UT 44.7710, a nuptial male, 50.5 mm SL, Bumbee Creek at only road crossing, 10.0 air km west-southwest of Spring City, Rhea County, Tennessee,

Fig. 1. *Phoxinus saylori* Holotype, UMMZ 236817, nuptial male, 50.5 mm SL, Bumbee Creek, Rhea County Tennessee. Photo by C. Williams.

35°39′46″N, 84°58′09″W, 6 June 1997, R. D. Bivens, B. D. Carter, C. E. Skelton, C. E. Williams.

Allotype.—UMMZ 236818, ex. UT 44.7709, female, 46.5 mm SL, same locality as holotype, 15 March 1997, C. E. Skelton.

Paratypes.—UT 44.7710 (5, 45.0–54.0 mm SL), collected with holotype; UT 44.7293 (6, 22.0–38.0 mm SL), same locality as holotype, 10 May 1996, C. E. Skelton; UT 44.7305 (5, 42.0–50.0 mm SL), same locality as holotype, 24 October 1996, C. E. Skelton; USNM 360019 (2, 43.4–47.2 mm SL), OSUM 90895 (2, 43.9–44.7 mm SL), CU 81096 (2, 39.5–45.0 mm SL), TU 189962 (2, 44.4–46.4 mm SL), UAIC 12364.01 (2, 44.0–44.2 mm SL), and NLU 76157 (2, 42.5–44.3 mm SL), same locality as holotype, 23 May 1998, C. E. Skelton; INHS 53769 (2, 43.6–53.2 mm SL), Cupp Creek, approximately 14.6 air km west of Dayton, Bledsoe County, Tennessee, 27 June 1996, C. E. Skelton, C. J. Paxton, ex. UT 44.7300; NCSM 28473 (2, 47.2–48.1 mm SL) and JFBM 32313 (2, 45.7–48.3 mm SL), Soddy Creek below Wolf Branch Road, approximately 25.7 air km south of Pikeville, Bledsoe County, Tennessee, 4 December 1993, C. E. Skelton, C. F. Saylor, ex. UT 44.7340; UT 44.4789 (47, 29.0–47.0 mm SL), Horn Branch at only road crossing, 21.9 air km south-southwest of Pikeville, 29 July 1976, C. F. Saylor et al.; CAS 210943 (2, 40.8–42.9 mm SL) and AMNH 229529 (2, 40.6–46.8 mm SL), ex. UT 44.4789; UT 44.7295 (7, 25.0–43.0 mm SL), Moccasin Creek at first Summer City Road crossing, 1.6 km southwest of Milo and 19.6 air km northwest of Pikeville, 14 May 1996; UT 44.7320 (9, 39.0–54.0), Youngs Creek, 4 July 1996, C. E. Skelton and C. J. Paxton; SIUC 38000 (2, 44.5–51.7) ex. UT 44.7320.

Nontype material.—Tennessee River drainage, Tennessee, Bledsoe County: UT 44.5884 (23), Horn Branch at only road crossing, 21.9 air km south-southwest of Pikeville, 19 June 1991; UT 44.7304 (2), same locality, 31 May 1994; UT 44.7306 (1) same locality, 10 June 1994; UT 44.7339 (21), same locality, 29 August 1993; UT 44.7341 (2), Cupp Creek, approximately 0.8 km north-northeast of intersection of Hendon and Brayton roads, approximately 14.6 air km west of Dayton, 31 March 1995; UT 44.7300 (6), same locality, 27 June 1996; UT 44.6003 (30), Soddy Creek below Wolf Branch Road, approximately 25.7 air km south of Pikeville, 19 November 1993; UT 44.7294 (2), same locality, 1 June 1996; UT 44.7303 (2), same locality, 31 May 1994; UT 44.7307 (2), same locality, 10 June 1994; UT 44.7340 (18), same locality, 4 December 1993. Rhea County: UT 44.7322 (1), Bumbee Creek at only road crossing, 10.0 air km west-southwest of Spring City, 5 June 1996; UT 44.7301 (2), same locality, 1 June 1996; UT 44.7292 (2), same locality, 23 May 1996; UT 44.7902 (3), Youngs Creek 0.6 km upstream of confluence with Moccasin Creek, approximately 11.7 air km southwest of Spring City, 16 May 1997; UT 44.7705 (2) same locality, 15 March 1997.

Diagnosis.—Coloration and tuberculation patterns align the new species with the genus *Phoxinus*. Differs from all congeners by the combination of two uninterrupted black lateral stripes and black pigment covering breast and underside of head nuptial males. Further differentiated from all congeners (except *P. erythrogaster* and *P. eos* occasionally) by 0,5–4,0 pharyngeal tooth formula; from all congeners except *P. neogaeus* by S-shaped (or loosely coiled) gut configuration and winged rather than rounded basioccipital pharyngeal pad.

Description.—General shape and coloration of new species shown in Figure 1 and proportional measurements in Table 1. The largest specimen examined was a female, 62 mm SL. Pectoral fins of nonbreeding males broadly rounded; fins of females narrow and taper to broad point. Nuptial males develop distinctly thickened pectoral rays and distal edges of these fins appear almost straight. Anterior rays of the dorsal and anal fins extend slightly past the posterior rays when depressed. Rear margins of dorsal and anal fins slightly convex and dorsal fin inserted just behind pelvic fin origin. Modal number of dorsal, anal, and pelvic rays 8. Number of pectoral rays modally 16 (14–17).

Entire body except head covered with tiny cycloid scales. Scales in lateral series 72–90 ($\bar{x}$ = 78.5, n = 55); transverse scale rows usually 24–26 ($\bar{x}$ = 25.2, n = 55); belly scales somewhat embedded, but outline visible with magnification (40×); breast scales very small (approximately 0.5 mm in diameter) and deeply embedded. Lateral line incomplete with 13–36 pored scales ($\bar{x}$ = 24, n = 47). All portions of cephalic lateralis system usually incomplete with varying numbers of external pores. Infraorbital canal pores usually 17 or 18 (14–19), preoperculomandibular canal pores modally 12 (9–13), supraorbital pores usually 9–11 (7–11), supratemporal pores broadly interrupted at midline of nape and usually 3 + 2 or 3 + 3.

Pharyngeal tooth formulae 0,5–4,0 (n = 22). Pharyngeal arch moderately heavy and teeth laterally compressed. The fifth tooth (ventral) on the left arch one-third to one-half the length of other teeth, bladelike, and tapers abruptly to sharp point. Remaining teeth hooked with poorly developed grinding surfaces. Instead, they have shallow angled furrows with sharp edges. Total gillrakers on first arch bimodal at 8 or 9 (8–10, n=23) and vertebrae modally 38 (36–39, n = 14). Gut is S-shaped (or nearly so) and peritoneum light brown or gray with scattered melanophores.

Coloration.—As with three other species in the genus (*P. erythrogaster, P. eos, P. tennesseensis*), *Phoxinus saylori* possess two black lateral stripes. In life, these stripes vary from dark black to barely discernible. The upper stripe originates near the junction of the occiput and the posterodorsal portion of the operculum. Anteriorly the stripe is approximately three scale rows deep and gradually narrows caudally. This stripe differs from the upper stripe of other *Phoxinus* species because it is usually persistent from beginning to end rather than breaking into discrete spots on the caudal peduncle. The lower stripe begins on the snout and passes through the eye and onto the body. It angles downward from the shoulder girdle toward the belly, and often dips slightly but abruptly over the anal fin, creating a small notch. The stripe then narrows somewhat and continues uninterrupted to the base of the caudal fin. There is usually a continuation of diffuse black pigment down the middle of the caudal fin. At the caudal fin base, there is often a small black spot or narrow bar about the same depth as the lower black stripe.

A black line of varying completeness and intensity runs along the midline of the dorsum, and a row of small (smaller than the pupil) irregular spots lies on either side of the midline. The number of these spots varies from less than five to approximately 20.

The dorsum of *P. saylori* varies from dark olive to a very pale tan. The area between the lateral stripes has a silvery-white sheen. The lower caudal peduncle is typically the same color as the dorsum. The belly, breast, and lower half of the head are whitish-silvery. At any time during the year, however, *P. saylori* may develop red coloration below the lower lateral stripe from the insertion of the pectoral fins to the base of the caudal fin.

As seen in other species of the genus (Etnier and Starnes, 1993), nuptial males may acquire brilliant colors during the breeding season (Fig. 1). The two lateral stripes become intensely black as does the entire underside of the head and breast. The pigment covers from one-half to all of the breast and can occasionally be found on portions of the belly.

The entire ventral portion of the body becomes intense scarlet and is contiguous with the lower black stripe and black breast. However, a narrow strip of red pigment passes obliquely through the lower black stripe behind the insertion of the pectoral fin and follows the gill opening to the upper connection of the opercular cover and the head. The red pigment is most intense on the caudal peduncle. Except for the first ray, the basal 20–30% of the dorsal fin turns red. Red pigment develops around the black caudal spot (bar) and radiates out toward the fin edges. The lips also become red.

The cheek, the area between the two lateral stripes, and the upper and lower halves of the operculum become metallic gold as do the upper and lower portions of the iris. This color is most intense in the area between the lateral stripes. The bases of the paired fins develop a small pearly-white patch of pigment. The pigment at the base of the pectoral fin is about the size of the eye, whereas the spot at the base of the pelvic fin is about the size of the pupil. The paired fins become bright yellow and the dorsal (above basal red band) and anal fins somewhat less so. The caudal fin acquires a yellow wash. Females develop all of these colors, but they are usually less intense. A diffuse widening of the anterior portion of the upper lateral stripe is sometimes present on females.

In preservative, all of the red, white, yellow, and iridescent colors fade quickly. Black pigment persists after preservation but fades slightly. Fins become translucent, and areas that were white or yellowish become cream colored. The dorsum color varies from light brown to pale tan.

Tuberculation.—Male *P. saylori* develop nuptial tubercles on the head and the posterior edge of every scale except for the belly and breast scales, where tubercles are reduced or absent. Most tubercles are uniconic on the front half of the body but become increasingly multiconic posteriad. Multiconic tubercles (up to six or seven points) are most evident around the anal fin and the ventral half of the caudal peduncle. As with other species in the genus (Howes, 1985), *P. saylori* develop 7–10 rows of comblike breast tubercles anterior to each pectoral fin. The dorsal portion of pectoral rays two to five or two to six develops one or two rows of uniconic tubercles.

Head tubercles are small and uniconic and are dispersed over the entire surface. They appear to be randomly distributed except for a dense patch of retrorse tubercles on the posterodorsal portion of the opercle. Additionally, a row of tubercles is sometimes present along the posterior edges of the opercle and subopercle. Tuberculation patterns of females are similar, but tubercles are not as well developed.

In addition to tubercles, there is another apparently cornified structure found on *P. saylori* that develops during the breeding season. To the naked eye, they appear to be small raised dots. They are found in the center of each scale, along the dorsal, pelvic, anal, and caudal rays and scattered randomly all over the head. They are probably some type of sensory structure.

Variation.—SPCA of morphological measurements of *P. saylori* males indicates broad overlap of body shape among the five populations examined (Fig. 2). There is no apparent separation along SPC3 and limited separation along SPC2. Based on the SPC2 loadings (Table 2), it appears that the variation described by this axis is related primarily to body width. Other measurements that loaded heavily on SPC2 were anal fin length and distance from pectoral fin origin to isthmus. The heaviest loadings on the

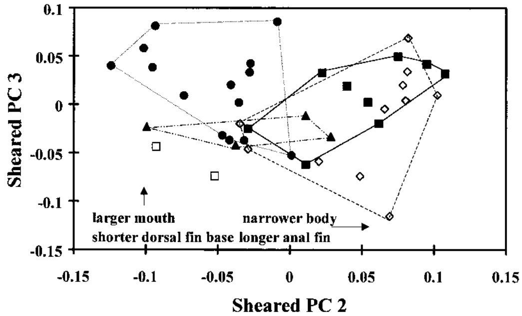

Fig. 2. Sheared principal component scores for male *Phoxinus saylori* from Horn Branch of Rock Creek (diamonds), Soddy Creek (closed squares), Bumbee Creek (circles), Cupp Creek (triangles), and Youngs Creek (open squares), Bledsoe and Rhea Counties, Tennessee.

SPC3 axis were dorsal fin base length, upper jaw length, and gape width.

Gut length is consistently S-shaped in all populations except for Soddy Creek. The gut configuration of this population varies from a nearly double looped configuration like *P. erythrogaster* (Starnes and Starnes, 1978) to a simple S-shape.

Sexual dimorphism in *P. saylori* is similar to that seen in other *Phoxinus* species (Smith, 1908; Starnes and Starnes, 1978). Secondary sexual characteristics such as coloration and tuberculation patterns develop on both males and females; however, these characteristics are almost always more fully developed in males. Proportional measurements indicate that males have longer fins and a wider breast than females (Table 3). The broadly rounded pectoral fins of males versus broadly pointed fins of females allows for easy separation of male and female *P. saylori* at any time during the year. SPCA of nonbreeding males and females from Soddy Creek and Horn Branch shows complete separation along the SPC2 axis (Fig. 3). The heaviest loadings on the SPC2 axis are eye diameter, gape width, dorsal fin length, and pelvic fin length. There is wide overlap between males of both populations and Horn Branch females on the SPC3 axis. Females from Soddy Creek are almost completely separated from all three groups. Heaviest loadings for SPC3 are snout length, distance between pectoral fin origin and pelvic fin origin, orbit diameter, pectoral fin origin to isthmus, and pectoral fin origin to pectoral fin origin.

Comparisons.—The color pattern of nuptial *P. saylori* is unique among all North American cyprinids. The combination of two uninterrupted

TABLE 2. SHEARED PRINCIPAL COMPONENT LOADINGS FOR MALES OF *Phoxinus saylori*, *Phoxinus tennesseensis*, AND *Phoxinus erythrogaster*; MALES OF *Phoxinus saylori* FROM SODDY CREEK, HORN BRANCH, CUPP CREEK, YOUNGS CREEK, AND BUMBEE CREEK; AND MALES AND FEMALES OF *Phoxinus saylori* FROM SODDY CREEK AND HORN BRANCH.

	Males-interspecific		Males-*P. saylori*		Males and females-*P. saylori*	
Measurement	SPC2	SPC3	SPC2	SPC3	SPC2	SPC3
Standard length	−0.144	0.057	0.084	−0.092	0.050	−0.048
Pectoral fin length	−0.304	−0.183	0.166	−0.009	−0.217	0.091
Pelvic fin length	−0.145	0.183	0.139	0.000	−0.334	0.233
Dorsal fin length	−0.067	0.116	0.213	0.019	−0.277	0.093
Anal fin length	−0.095	0.188	0.273	−0.004	−0.114	0.075
Interorbital distance	0.054	0.080	0.035	−0.018	0.084	0.093
Head width	0.201	0.000	−0.102	0.231	0.170	0.195
Body width at dorsal origin	0.278	−0.300	−0.371	0.135	−0.075	−0.211
Body width at anal origin	0.352	−0.306	−0.461	0.224	0.031	−0.070
Snout length	0.078	0.137	−0.203	0.109	0.202	−0.279
Head length	−0.025	0.159	0.146	0.077	0.152	0.177
Snout–occiput	−0.060	0.148	0.067	−0.072	−0.020	−0.023
Occiput–dorsal origin	−0.111	0.080	0.180	0.015	0.086	−0.060
Dorsal fin base	−0.180	0.019	0.041	−0.288	−0.182	−0.053
Dorsal base end–hypural	−0.222	−0.009	0.034	−0.186	0.006	−0.064
Caudal peduncle depth	0.111	−0.176	−0.107	0.009	−0.009	0.079
Anal base end–hypural	−0.252	0.027	0.042	−0.188	−0.099	−0.028
Anal fin base	−0.026	0.038	−0.107	−0.037	0.019	−0.151
Anal origin–pelvic origin	−0.318	0.105	0.244	−0.259	0.102	−0.210
Pectoral origin–pelvic origin	−0.076	−0.153	−0.067	0.064	0.227	−0.289
Snout–isthmus	−0.037	0.154	0.039	−0.060	0.019	0.060
Gape width	0.360	0.230	0.129	0.509	0.278	0.087
Upper jaw length	0.230	0.244	0.058	0.336	0.154	−0.067
Head depth	0.028	0.036	0.028	0.009	0.008	0.024
Occiput–pectoral origin	0.016	0.039	−0.025	−0.055	−0.089	0.053
Dorsal origin–pectoral origin	−0.087	−0.048	0.042	−0.006	0.128	−0.131
Dorsal origin–pelvic origin	−0.037	−0.235	−0.171	−0.200	−0.88	−0.172
Dorsal origin–anal origin	−0.128	−0.168	−0.075	−0.210	−0.007	0.047
Dorsal base end–pelvic origin	−0.069	−0.124	−0.108	−0.154	−0.063	−0.229
Dorsal base end–anal origin	−0.019	−0.220	−0.218	−0.125	0.018	0.005
Dorsal base end–anal base end	−0.054	−0.160	−0.137	−0.144	0.049	0.089
Orbit diameter	−0.022	0.219	0.233	0.223	0.425	0.558
Pectoral origin–isthmus	0.129	0.432	0.271	0.175	−0.239	0.313
Pectoral origin–pectoral origin	0.285	0.056	−0.076	0.132	−0.376	−0.035

black lateral stripes and the development of black pigment on the underside of the head of breeding males separates *P. saylori* from all congeners. It is sometimes difficult to differentiate small *P. saylori* from *Semotilus atromaculatus* in the field, but they are easily separated using magnification.

Phoxinus saylori has significantly fewer scales in lateral series than either *P. erythrogaster* or *P. tennesseensis*. There is considerable overlap in number of transverse scale rows; however, *P. saylori* usually has one or two fewer rows than the other species.

Phoxinus saylori differs significantly from *P. erythrogaster* and *P. tennesseensis* in several morphometric measurements (Table 1). The scatterplot of SPCA scores shows some separation along the SPC2 axis between *P. saylori* and the other two species (Fig. 4). Heaviest loadings on this axis were body width, gape width, pectoral fin length, and distance from anal fin origin to pelvic fin origin (Table 2). All three species overlap broadly on the SPC3 axis.

Relationships and biogeography.—Starnes and Jenkins (1988) hypothesized that *P. tennesseensis* and *P. oreas* formed a closely related pair based on three putative synapomorphies: an interrupted and decurved lower black lateral stripe, red pigment on the lower operculum, and black pigment covering the underside of the head of nuptial males. They further suggested that this pair was sister to *P. cumberlandensis* based on opercular tuberculation, dorsolateral speckling,

TABLE 3. MEANS AND RANGES OF PROPORTIONAL MEASUREMENTS (EXPRESSED IN THOUSANDTHS OF STANDARD LENGTH) FOR *Phoxinus saylori* MALES AND FEMALES FROM HORN BRANCH OF ROCK CREEK AND SODDY CREEK. Measurements that differ significantly marked with an asterisk.

Measurement	Males (n = 15)		Females (n = 19)	
	$\bar{x}$	Range	$\bar{x}$	Range
Standard length	43.9	39.7–48.5	44.3	39.8–50.9
Pectoral fin length*	211	195–225	192	175–200
Pelvic fin length*	170	153–180	148	139–161
Dorsal fin length*	237	223–259	213	200–228
Anal fin length	208	191–217	196	189–206
Interorbital distance	91	87–96	92	85–99
Head width	147	136–160	150	138–165
Body width at dorsal origin	129	120–137	126	108–141
Body width at anal origin	97	89–102	96	90–104
Snout length*	74	69–81	78	68–87
Head length	262	246–289	266	247–285
Snout–occiput*	211	194–221	206	196–220
Occiput–dorsal origin	355	340–377	362	322–383
Dorsal fin base*	104	93–117	96	82–108
Dorsal base end–hypural*	374	360–389	370	342–383
Caudal peduncle depth	121	118–124	118	106–128
Anal base end–hypural	247	233–266	235	217–251
Anal fin base	102	97–111	103	83–109
Anal origin–pelvic origin	180	164–192	184	168–201
Pectoral origin–pelvic origin*	215	200–230	233	218–253
Snout–isthmus	170	166–181	168	152–181
Gape width*	68	61–72	72	64–83
Upper jaw length	81	74–90	84	67–97
Head depth	174	163–183	171	148–186
Occiput–pectoral origin*	173	161–187	164	154–181
Dorsal origin–pectoral origin*	339	324–367	349	334–369
Dorsal origin–pelvic origin*	222	208–246	214	192–240
Dorsal origin–anal origin	227	216–242	221	201–237
Dorsal base end–pelvic origin	241	220–255	235	216–264
Dorsal base end–anal origin	164	152–174	161	147–179
Dorsal base end–anal base end	183	169–194	180	167–198
Orbit diameter*	74	64–87	80	65–96
Pectoral origin–isthmus*	137	123–146	122	105–134
Pectoral origin–pectoral origin*	161	149–173	141	125–150

and shape of the opercular bone. *Phoxinus saylori* shares with *oreas* + *tennesseensis* the hypothesized synapomorphy of black pigment on the underside of the head of nuptial males, and with all three species, a dense triangular patch of breeding tubercles on the posterodorsal portion of the operculum. Thus, *P. saylori, P. tennesseensis, P. oreas*, and *P. cumberlandensis* are hypothesized to form a monophyletic group within the Nearctic *Phoxinus*. Based solely on morphological characters, placement of *P. saylori* within this group is problematic. However, recent genetic evidence suggests that *P. saylori* is a distinctive taxon sister to *P. cumberlandensis* and that this pair is sister to *oreas* + *tennesseensis* (R. Mayden, pers. comm.). An alternative hypothesis places *P. saylori* as sister to the hypothesized sister pair of *P. eos* and *P. erythrogaster*. These three species possess two uninterrupted lateral black stripes. If this character is a synapomorphy, these three species may be sister to *P. cumberlandensis* plus the sister pair of *P. oreas* + *P. tennesseensis*. *Phoxinus neogaeus* is the hypothesized sister to the entire group.

A hypothesized biogeographic scenario explaining the distributions of *P. tennesseensis, P. oreas*, and *P. cumberlandensis* was described in detail by Starnes and Jenkins (1988). They suggested that the ancestor (similar to *P. oreas*) to these three species was widespread in the upper Teays River drainage. *Phoxinus cumberlandensis* was likely derived from a portion of this stock that dispersed into the upper Cumberland River drainage through a capture of upper Teays

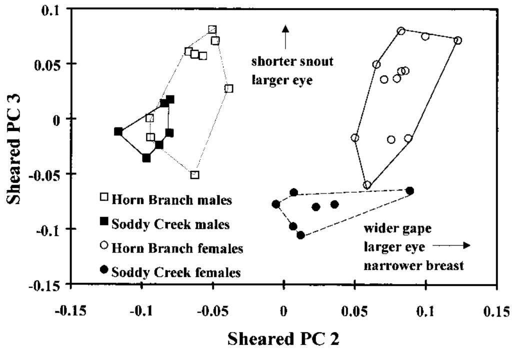

Fig. 3. Sheared principal components score for nonbreeding male and female *Phoxinus saylori* from Horn Branch of Rock Creek and Soddy Creek, Bledsoe County, Tennessee.

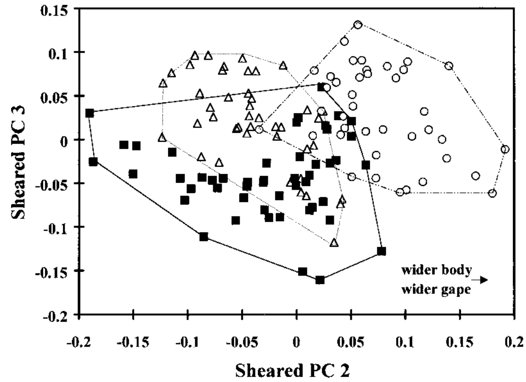

Fig. 4. Sheared principal components scores for males of *Phoxinus saylori* (circles), *Phoxinus tennesseensis* (triangles), and *Phoxinus erythrogaster* (squares).

drainage tributaries (Starnes and Starnes, 1978). The *oreas*-like form may have then dispersed into the upper Tennessee River (Holston), giving rise to *P. saylori*. *Phoxinus tennesseensis* would have then been derived from a second invasion into the Tennessee River system from the upper New River by an *oreas*-like form. *Phoxinus oreas* has subsequently dispersed into several Atlantic Slope drainages (Starnes and Jenkins, 1988)

Distribution.—*Phoxinus saylori* is known to occur in six streams on the Walden Ridge portion of the Cumberland Plateau in Tennessee (Fig. 5). The drainages on Walden Ridge are comprised of eastward flowing, meandering streams that drop abruptly off the edge of the plateau and then enter the Tennessee River. The streams where *P. saylori* has been collected are found in three independent systems on Walden Ridge: the Soddy Creek system, the Sale Creek system, and the Piney River system. In the Soddy Creek system, one population is known from Soddy Creek proper. In the Sale Creek system, there are populations in Horn Branch of Rock Creek and Cupp Creek. In the Piney River system, populations are known from Youngs, Moccasin, and Bumbee Creeks (Fig. 5).

Phoxinus saylori is fairly common to abundant where it occurs, but known populations are extremely localized. All populations, except Cupp Creek, have been determined to inhabit reaches of only 1–3 km. The Cupp Creek population also appears to be sharply localized, but further sampling is required for a confident assessment.

Behavior, ecology, and life history.—Although a detailed life-history study of *P. saylori* has not been completed, the species appears to have ecological requirements similar to those of other species in the genus. *Phoxinus saylori* is most often collected in pools or slow runs from undercut banks or beneath slab boulders. The creeks that they inhabit are first or second order, clear and cool (maximum about 26 C), and typically have a substrate consisting of a mixture of cobble,

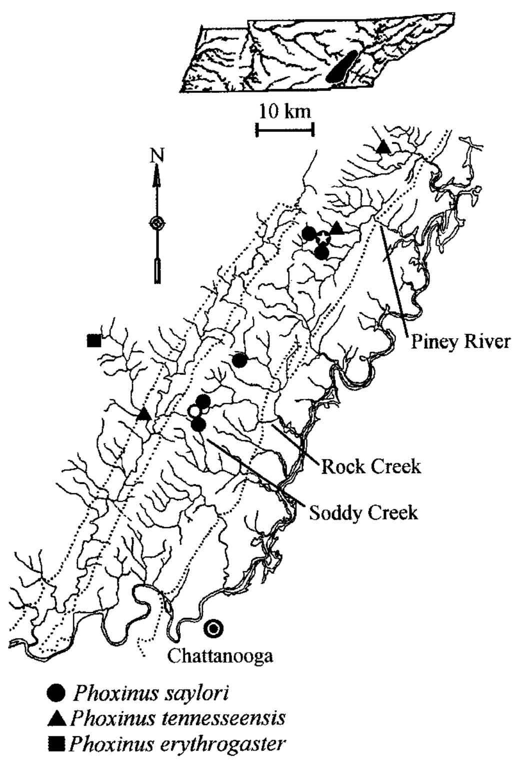

Fig. 5. Distribution of *Phoxinus saylori* with proximate populations of *Phoxinus tennesseenis* and *Phoxinus erythrogaster*. The open circle is an extirpated population of *P. saylori*, and the star is the type locality. The dotted line represents the Cumberland Escarpment.

rubble, and boulders. Most streams have a dense riparian zone, of which mountain laurel (*Kalmia* sp.) is often the main component.

Three year classes are found in some collections, although it is often difficult to find young-of-year fish. Nuptial individuals have been collected from late March until mid-June.

Several studies have documented *Phoxinus* spp. as being nest associates (e.g. Raney, 1947; Starnes and Starnes, 1981). I witnessed behavior of *P. saylori* that suggests it is also a nest associate where syntopic with a nest-building minnow species. In late May 1994, I observed a school of approximately 20 *P. saylori* moving over a stoneroller (*Campostoma oligolepis*) nest in Soddy Creek. The males were at peak coloration and tuberculation, and I expected to witness spawning; however, they were periodically burying their noses between gravel in the nest, possibly trying to eat eggs. Soddy Creek is the only locality where a nest-building minnow has been collected with *P. saylori*. In Horn Branch and Bumbee Creek, behavior I assumed to be associated with spawning was observed, but again, spawning did not occur. At both sites, several nuptial *P. saylori* were moving in and out of a shallow riffle that contained small gravel. Unfortunately, the fish were disturbed on both occasions, and further observations were not made. Smith (1908) observed *P. erythrogaster* spawning in a shallow gravel riffle.

Qualitative analysis of intestinal tracts (n = 12) indicates that *P. saylori* eats a mixture of food items but relies heavily on animal material. A variety of benthic invertebrates including larva from the insect orders Trichoptera, Plecoptera, and Diptera, were found. Plant material and sand grains were present in some intestines. The animal-based diet of *P. saylori* reflects its morphological feeding traits. Relative to congeners, they have a large mouth, short digestive tract, reduced number of pharyngeal teeth, and a primitively shaped basioccipital bone. During the spring I have observed them in loose schools picking at insects and surface materials.

Conservation status.—Phoxinus saylori is a former Category 2 candidate as recognized by the U.S. Fish and Wildlife Service (USFWS). Although *P. saylori* is currently afforded no federal protection, the species is considered endangered by the state of Tennessee (P. Shute, TVA Nat. Heritage, pers. comm.).

Phoxinus saylori was first collected in Horn and Laurel branches of Rock Creek in 1976 during a TVA rotenone survey (C. Saylor, pers. comm.). The species was not collected again until 1991 when C. Saylor revisited Horn and Laurel branches. Additional specimens were collected in Horn Branch; however, they have not been taken again in Laurel Branch, and I suspect that they are now extirpated. *Phoxinus saylori* was subsequently discovered in Soddy Creek in 1993. When it became apparent that the dace represented an undescribed species, a status survey was funded by USFWS to determine the species distribution. During the next three years, over 100 sites on Walden Ridge and surrounding areas were sampled. As a result of these surveys, four additional populations were discovered. Other than the apparent extirpation of the Laurel Branch population, it is difficult to say whether *P. saylori* has declined in recent years. Examination of range maps in Etnier and Starnes (1993) indicates that little collecting has taken place on Walden Ridge; thus, there is no historical information to draw from. Agriculture, mining, and timbering have been widespread on Walden Ridge, and it is likely that additional populations may have existed before these types of human activities began. Extensive timber harvesting and some agriculture are ongoing in the vicinity of some *P. saylori* populations. A large area surrounding the headwaters of Horn Branch of Rock Creek has recently been clearcut, as has an approximately 200 m stretch adjacent to the type locality. Further cutting is proposed near the type locality in the next four years (W. Boyd, Bowater Newsprint, pers. comm.). Increased siltation from these activities is already evident and has the potential of destroying available spawning areas.

An encouraging note about *P. saylori* is that the species seems to be fairly tolerant of a wide range of physical conditions. They are apparently tolerant of low pH values (lowest recorded was 5.4 in Horn Branch) and presumably tolerant of some siltation. Most of the areas adjacent to streams where *P. saylori* occurs have been clearcut at one time or another and at least some of the populations have survived. Currently, the individual populations appear to be fairly secure. However, since there are only six known populations, a single catastrophic event could significantly reduce the species range.

Because of the isolated nature of many of the streams on Walden Ridge, it will likely be difficult for a population of *P. saylori* to recolonize new areas should one be eliminated. Evidence of this is the fact that *P. saylori* has probably been extirpated from Laurel Branch since at least 1991. Although the mouth of Laurel Branch is close to the Horn Branch population, *P. saylori* has not recolonized the creek. Some of the other creeks have no source population for recolonization should they become extirpated (i.e., Cupp Creek, Soddy Creek). Based solely on the limited number of populations of *P. saylori*, this species warrants federal protection minimally at the threatened level.

As part of any protection efforts, the known populations should be monitored on a regular basis and surveys should be conducted to determine whether additional populations exist. Also, artificial propagation protocols should be established and stream reaches identified for possible introductions. Finally, to protect sensitive spawning areas, efforts should be made to increase and maintain riparian buffers adjacent to and upstream of reaches that harbor *P. saylori* populations.

Etymology.—It is with pleasure that I name this minnow in honor of TVA ichthyologist Charles F. Saylor, who was part of the crew that first collected this species. He has contributed greatly to our knowledge of the fishes of Tennessee and the Southeast. The suggested common name, laurel dace, refers to the presence of mountain laurel at most of the localities where this species occurs.

Material Examined

Phoxinus tennesseensis.—Tennessee River Drainage, Tennessee: Duskin Creek: UT 44.6784 (6) and UT 44.7708 (3); Sandy Creek: UT 44.6779 (4). Holston River system: Brice Branch: UT 44.5266 (19); Beaverdam Creek: UT 44.2693 (1); R. Prong Hatcher Creek: UT 44.5820 (3). Clinch River system: Flatfork Creek: UT 44.3037 (11); Pinhook Branch of E. Fork Poplar Creek: UT 44.5748 (18). Little Tennessee River system: Tributary to Nine-mile Creek: UT 44.4045 (8). Sequatchie River system: Little Brush Creek: UT 44.7119 (3). French Broad River system: Cove Creek: UT 44.5450 (2). Little River system: Reed Creek: UT 44.1070 (1).

Phoxinus erythrogaster.—Tennessee River Drainage, Tennessee, Elk River system: Dry Creek (3), Anderson Creek (2), and Dry Weakly Creek (1): UT 44.7882. Duck River system: Bobo Creek: UT 44.7110 (4); Anderton Branch: UT 44.6064 (2). Cumberland River Drainage, Kentucky, Rockcastle River system: Clear Creek: UT 44.7790 (10); Dry Fork of Skeggs Creek: UT 44.7796 (2). Tennessee, Harpeth River system: Kelly Creek: UT 44.7607 (7). Caney Fork River system: Big Indian Creek: UT 44.1513 (8); Indian Creek: UT 44.6897 (9). Ohio River Drainage: Tennessee, Barren River system: Little Salt Lick Creek: UT 44.5745 (4); Trammel Creek: UT 44.5756 (11). Ohio, Hocking River system: Wolf Pen Creek: UT 44.5571 (6). Kentucky, Kentucky River system: Long Branch: UT 44.7784 (11); unnamed trib. to Boone Fork: UT 44.7788 (7); Red Lick Creek: UT 44.7706 (8) and UT 44.7598 (35); Possum Run: UT 44.7602 (9).

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