Description of Larval and Juvenile Robust Redhorse, *Moxostoma robustum*

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ABSTRACT: Looney, Gregory L., Cecil A. Jennings. 2002. Description of Larval and Juvenile Robust Redhorse, *Moxostoma robustum*. Bulletin Alabama Museum of Natural History, Number 23: 1–8. 4 Tables, 5 Figures. Robust redhorse, *Moxostoma robustum*, is a large riverine catostomid that until recently was known only from museum and archeological specimens. A population was discovered in a 60-km reach of the Oconee River, GA during summer 1991. Efforts to locate or to verify continuity of known populations were unsuccessful until individuals were captured at scattered locations in the Savannah River, GA/SC, during 1997–2000; Ocmulgee River, GA, in 1999; and three specimens from the Pee Dee River, NC, during 2000–2001. Little is known about the biology, ecology, and population dynamics of this species, but intensive research in these areas has yielded new information. We describe the morphological development of larval and early juvenile robust redhorse. Newly hatched larvae ranged from 7.2 to 8.1 mm total length (TL). Absorption of yolk is complete at about 14.0 mm TL. Fin development is complete or nearly so by about 22.5 mm TL, at which time scale formation is visible midlaterally on the body from the caudal peduncle to the head. Fin ray development is complete by 23.5 mm TL. Juveniles 72–100 mm TL have acquired most of the morphological characteristics of adults. Of the morphological characters examined, length at hatching was the only morphological characteristic that can be used reliably to distinguish *M. robustum* from *M. collapsum*, a sympatric congener.

Introduction

Robust redhorse, *Moxostoma robustum*, are large (maximum size approximately 760–mm TL) catostomids that were discovered near the mouth of Commissioner Creek in the Oconee River, Georgia, on 8 August 1991. Edward Cope originally described the species in 1870; however, Cope's original specimens were mislabeled and later lost, thereby erasing any scientific knowledge of the species (Jenkins and Freeman, unpubl.). A detailed account of this resolution can be found in Jenkins and Burkhead (1993). After discovery of robust redhorse in 1991, a review of archaeological records showed robust redhorse (RRH) remains collected from the Savannah River, Georgia, and Yadkin River, North Carolina. Currently, the Oconee River contains the largest known population. Systematic attempts to locate other populations in the his-

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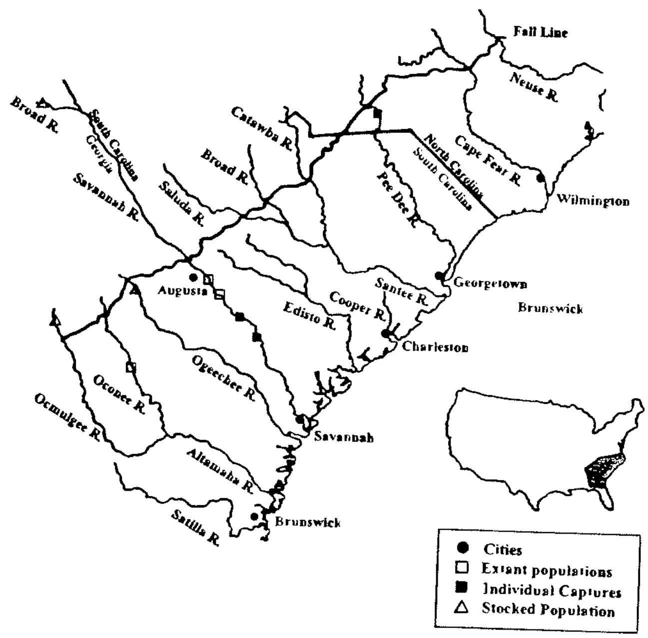

Fig. 1. Current locations of extant (wild individuals, wild populations, and stocked populations) robust redhorse, *Moxostoma robustum*, in the major drainages of the South Atlantic.

torical range (i.e., Atlantic Slope drainages from the Pee Dee River in North Carolina to the Altamaha River in Georgia, Figure 1) were unsuccessful until recently, when at least 24 individuals were captured at scattered locations in the Savannah River, GA/SC, two adults from the Ocmulgee River, GA, and three specimen from the Pee Dee River, NC.

The estimated 1,000 – 3,000 robust redhorse in the Oconee River (Evans, unpubl.) occur in about a 60 km reach between Milledgeville and Dublin, Georgia. Most individuals are 10 – 26 years (Jenkins et al. 1999, AFS, abstract), and recruitment over the past several years seems to have been negligible. Accordingly, studies have been undertaken to estimate the abundance and distribution of larval robust redhorse in the Oconee River. Because descriptions of larval robust redhorse were unavailable to help identify wild-caught specimens, our objectives were 1) to describe the development of hatchery-reared robust redhorse, and 2) identify morpho-metric and meristic characters that would aid in distinguishing of wild-caught *M. robustum* and its sympatric congener notchlip redhorse *M. collapsum*.

Materials and Methods

The larval and juvenile specimens used were produced from the mating of one male and one female robust redhorse collected from the Oconee River between RM 85.5 and 87.7 on 25 May, 1993, when water temperature was 23° C. The female was stripped and the dry fertilization technique was used to fertilize the eggs. Fertilized eggs and larvae were incubated in a closed, recirculating system at a water temperature of 23° C ± 1.5° C from 25 May until 23 July. Intensively cultured post yolk-sac larvae were fed a combination of *Artemia* napulii, chopped blackworms, and commercially prepared diets. Samples were collected periodically (every six to eight hours for yolk sac larvae and every 24 hours for post yolk-sac larvae) from the culture system and preserved in unbuffered 10% formalin solution. Juveniles were pond-reared siblings.

Larval specimens were examined with a stereo-binocular microscope equipped with polarizing filters. Total length (TL) was measured to the nearest 0.1 mm. Measurements of individuals less than 30.0 mm TL were made with an ocular micrometer at magnifications of 6X and 10X. Measurements on juveniles greater than 70 mm TL were made with a ruler graduated in millimeters. Descriptive counts, measurements, and terminology follow Wallus et al. (1990). The described larvae are typical, morphologically, to RRH larvae produced since 1993. The study specimens are currently housed at the Warm Springs Fish Technology Center, Warm Springs, Georgia.

Results

The following descriptions are based on preserved specimens and emphasize developmental state, morphology, and pigmentation. Morphometric data are summarized in Table 1. Table 2 contains the numbers of individuals in each size range examined. Myomere count frequencies are in Table 3.

Description

Yolk sac Larvae Morphology.— Robust redhorse eggs hatched about 3.5 days after fertilization. Newly-hatched larvae were 7.2–8.1 mm TL and had a large, bright yellow yolk sac. The anterior 40–45% of the yolk-sac was bulbous (appearing almost round); and the remainder was cylindrical or tubular. The head was small and slightly curved around the anterior end of the bulbous portion of the yolk sac. Anterior and posterior myomere development was incomplete, thus accurate myomere counts were not possible for this size range.

At six days post-fertilization, larvae were 9.7–10.5 mm TL. Yolk material was visibly reduced. The yolk sac was no longer bulbous anteriorly; its cylindrical or tubular form along the entire length was retained. The head had lifted and was no longer curved around the yolk sac. The stomodeum was forming, but the mouth was not open.

Larvae at eight days post-fertilization were 11.2–11.7 mm TL (Fig. 2). The yolk-sac was still tubular, but not as thick anteriorly as posteriorly. Depth of the yolk was greater than the depth of the myomeres directly above. The mouth opening was apparent, gill arches had begun to form, and the heart was developing just anterior to the yolk sac.

Table 1. Morphometry of Robust Redhorse *(Moxostoma robustum)* larvae and juveniles (n=sample size). The range is given in parentheses. (Standard length [SL] - distance from anterior-most part of the head to most posterior point of the notochord or hypural complex; preanal length [PreAL] - distance from anterior-most part of the head to posterior edge of margin of anus; head length [HL] - distance from anterior-most tip of head to the posterior-most part of opercular membrane; eye diameter [ED] - horizontal measurement of the iris of the eye).

Life stage	n	Total length (mm)	% of total length			
			SL	PreAL	HL	ED
Yolk-sac Larvae	12	7.67 (7.2-8.1)	97.5 (97.2-98)	84.7 (82.9-87.2	10.8 (9.7-11.5)	4.9 (3.8-5.7)
Yolk-sac Larvae	20	9.99 (9.7-10.45)	96.3 (95.8-97)	79.3 (75.8-81.6)	12.7 (11.2-14.1)	5.3 (4.8-5.8)
Yolk-sac Larvae	10	11.45 (11.2-11.7)	95.6 (94.5-96.5)	76.2 (74.8-77.3)	13.9 (13.0-14.3)	5.5 (5.1-5.8)
Yolk-sac Larvae	10	12.53 (12.1-12.9)	94.8 (94.4-95.9)	74.8 (73.6-76.0)	15.1 (13.8-17.1)	5.9 (5.5-6.3)
Yolk-sac Larvae	17	13.71 (13.0-14.3)	93.9 (89.5-95.7)	70.5 (67.8-73.5)	16.0 (14.8-17.5)	6.4 (5.9-7.0)
Post Yolk-sac Larvae	12	15.26 (14.5-15.9)	87.6 (86.0-89.7)	66.8 (65.6-67.7)	18.2 (17.2-19.1)	6.9 (6.5-7.2)
Post Yolk-sac Larvae	13	16.65 (16.0-17.2)	86.4 (85.2-87.5)	65.7 (65.1-67.5)	19.2 (18.5-20.0)	7.1 (6.8-7.5)
Post Yolk-sac Larvae	10	19.57 (17.7-22.5)	83.3 (82.2-84.7)	62.4 (60.0-63.3)	20.0 (18.7-20.5)	7.2 (6.8-7.6)
Juveniles	6	25.55 (23.5-28.8)	82.3 (81.0-83.0)	60.0 (59.5-60.4)	20.2 (19.8-20.5)	7.0 (6.7-7.2)
Juveniles	5	74.6 (72.0-77.0)	82.3 (81.5-83.1)	61.5 (60.3-62.5)	17.3 (17.1-19.3)	5.6 (5.3-6.0)
Juveniles	5	95.8 (92-100.0)	83.5 (82.0-84.9)	62.2 (61.2-63.0)	17.3 (17.0-17.7)	5.2 (5.0-5.4)

Larvae at 10–12 days post-fertilization were 12.2–12.9 mm TL. Yolk was reduced but still tubular and was about equal to the depth of the myomeres directly above. Branchiostegal development was visible, and opercular flaps were forming.

Larvae at 14–18 days post-fertilization were 13.0–14.0 mm TL (Fig. 3). Opercular development continued until the opercular flap covered the gills. Nares were visible, and the optic chamber had formed. The head profile and eyes were slightly flattened. The mouth was subterminal and oblique. The digestive tract was functional in some individuals by 13.6 mm TL. The remaining yolk was still tubular at 13.0 mm TL, its depth about equal to half the depth of the myomeres directly above. Complete absorption of the yolk, which marked the beginning of the post yolk sac period, occurred at about 14.0 mm TL, although yolk was present on some specimens up to 14.3 mm TL.

Yolk sac Larvae Fin Development.— Newly-hatched yolk sac larvae (7.2–8.1 mm TL) had a median finfold that began dorsally near midbody, extended posteriorly around the notochord, and ended ventrally at the posterior margin of the yolk sac. Other fin development was not apparent.

Larvae of 9.7 mm TL had pectoral flaps present. Median finfold dorsal origin was at an anterior position about 25% the TL. The tip of the notochord was flexed slightly dorsal.

Table 2. Robust redhorse (n-120) larvae and juveniles, by length increment.

Life Stage	Size Range	Number (mm TL)
Yolk-sac	7.2-7.9	10
	8.0-8.1	2
	9.7-9.95	10
	10.0-10.45	10
	11.2-11.7	10
	12.2-12.9	10
	13.0-13.8	10
Post Yolk-sac	14.0-14.8	10
	15.2-15.9	9
	16.0-16.9	10
	17.1-17.7	4
	18.3-18.6	2
	19.0-19.2	4
	20.3	1
	21.9	1
	22.5	1
Juvenile	23.5-23.8	3
	25.3	1
	28.2-28	2
	72.0-77.0	5
	92.0-100.0	5
	Total	120

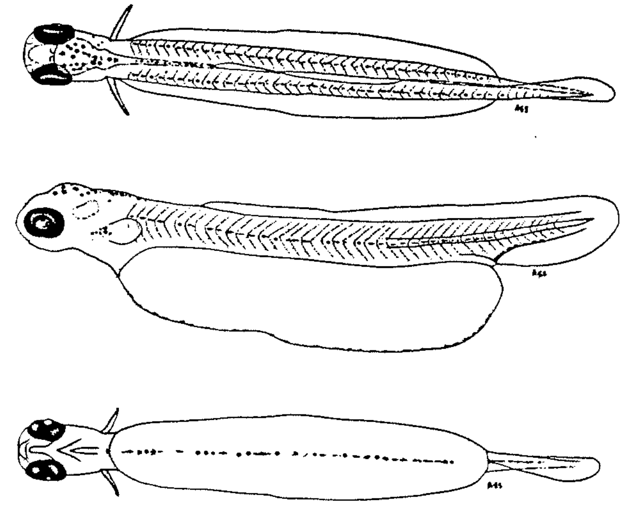

Fig. 2. Robust redhorse, *Moxostoma robustum,* 11.2–11.7 mm TL.

Larvae of 11.2–11.7 mm TL (Fig. 2) showed slight flexing of the notochord, but differentiation of the caudal fin had begun. Rays were not visible in the caudal fin, but basal elements of the hypural complex were forming. Developing pectoral fins were about 0.5 mm long. Dorsal origin of the median finfold was between myomeres 8–10. Ventrally, the finfold was beginning to form on the posterior margin of the yolk sac.

Larvae of 12.2–12.9 mm TL showed more obvious flexion of the notochord posteriorly, and basal elements of the caudal fin were well formed. Incipient rays were forming in the caudal fin; 8–12 rays were visible in the caudal fins of 12.9 mm TL fish. The ventral finfold was present anteriorly on the yolk sac to about the position of the pectoral fins. The dorsal profile of the median finfold was beginning to elevate at the future position of the dorsal fin.

Larvae of 13.6–14.3 mm TL (Fig. 3) had pectoral fins about 1.3 mm long. The caudal fin was becoming bilobed. The urostyle extended to the dorsal margin of the caudal fin. The dorsal fin profile was forming in the dorsal finfold, which was much reduced anteriorly. Differentiation in the forming dorsal fin was obvious on some 13.8 mm TL individuals. The anterior and posterior margins of the dorsal fin were nearly defined for fish of 14.0–14.3 mm TL, and incipient rays were forming. The ventral finfold

Table 3. Myomere count frequencies related to TL (mm) for robust redhorse.

		Preanal myomeres						Postanal myomeres					Total myomeres					
Life Stage	TL Range	33	34	35	36	37	38	5	6	7	8	9	40	41	42	43	44	45
Yolk-sac	9.7-9.95				3	7			3	7						6	4	
	10.0-10.45				2	7			6	3					1	7	2	
	11.2-11.7				5	3	1	1	2	8					1	7	1	1
	12.2-12.9			1	6	3	2		2	8					2	6	2	
	13.0-13.8		1	7	2				1	7	2			1	6	3		
Post Yolk-sac	14.0-14.8		5	4	1				2	6	2			4	6			
	15.2-15.9	2	6	1						8	1		1	7	1			
	16.0-16.9	2	8							2	7	1		3	7			
	17.1-17.7	2	2								4			2	2			
	18.3-18.6	1	1								2			1	1			
	19.0-19.2	1	3								3	1		1	2			

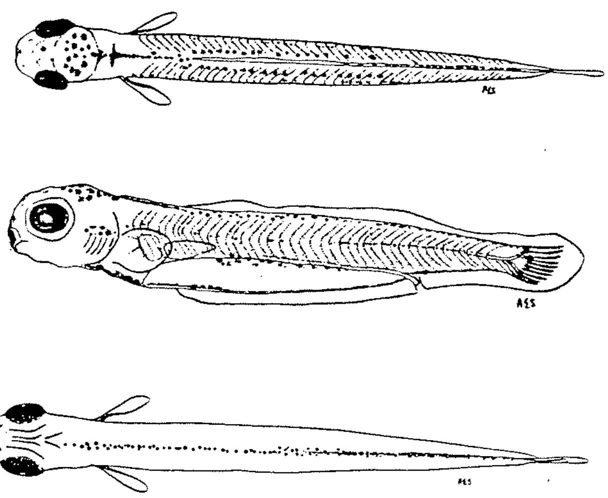

Fig. 3. Robust redhorse, *Moxostoma robustum*, larvae 13.0–14.0 mm TL.

was decreasing in width and extended anteriorly to a position near mid-length of the abdominal cavity. On 14.0–14.3 mm TL fish, pelvic fins appear as narrow flaps positioned ventrolaterally beneath the anterior half of the developing dorsal fin and at the juncture of the gut and the torso.

Yolk sac Larvae Pigmentation.—Newly-hatched larvae lacked pigment in the eyes, head or body. The yolk was yellowish.

Eye pigment first appeared in larvae 9.7–10.5 mm TL. The only body pigmentation consisted of thin dark dashes along the median myosepta, dorsal to the yolk sac, on some specimens.

Larvae 11.2–11.7 mm TL had dark brown eyes. Dorsally, pigmentation was scattered on the head over the brain; this pigmentation narrowed on the occipit to a single middorsal row along the body to about the origin of the dorsal finfold. Scattered melanophores were present dorsally and ventrally at the base of the finfold on the caudal peduncle. Melanophores were present in one midventral row on the yolk sac from the pectoral fin base area to the anus. Lateral pigmentation consisted of a dashed line along the median myosepeta from the head to about mid-length of the caudal peduncle.

Larvae 12.2–12.9 mm TL (Fig. 2) had black eyes. Dorsal pigmentation on the head posterior to the eyes, on the occipit, and in a middorsal row on the body anterior to the finfold, consisted of large, black melanophores. Indistinct rows of small melanophores appeared along each side of the dorsal finfold at about mid-length of the body. The pigmentation outlining the caudal peduncle was darker, and internal pigmentation appeared scattered on the dorsal margin of the yolk sac.

In addition to the previously described pigmentation patterns, larvae 13.0–14.3 mm TL (Fig. 3) had melanophores present on the head around the tip of the snout at the anterior margins of the nares. A few large melanophores were scattered dorsally on the head between the eyes. Lateral rows of dorsal pigmentation were distinct over the middle of the body and fused posteriorly with the dense, scattered pigmentation on the caudal peduncle. Three to four melanophores in a row were present on the side of the head between the eyes and the pectoral fins, ventral to the optic chamber. This row of pigmentation curved downward anteriorly from about the height of the dorsal margin to the pectoral fin base. Ventral pigmentation on the yolk sac was a wide band of melanophores. Internally, the dorsal margin of the abdominal cavity was covered with melanophores. Scattered pigmentation was present on the caudal fin and by 14.0–14.3 mm TL at the base of the caudal fin. On some individuals, two or three melanophores were present on the chin.

Post Yolk sac Larvae (TL Range=14–23 mm) Morphology.— Larvae at 23.5–30.5 days post-hatch were 14.3–16.0 mm TL (Fig. 4) with a ventrally flattened head. The mouth was ventral and had progressed from subterminal-oblique to subterminal-horizontal. Operculum was present to the base of the pectoral fins on larvae 16.0 mm TL. Larvae 18.6–20.0 mm TL had a slightly concave dorsal head profile posterior to the eyes. Larvae at 20.3 mm TL had squamation on the caudal peduncle. Larvae 21.9–22.5 mm TL (Fig. 5) had scales midlaterally from the caudal peduncle to the head.

Post Yolk sac Larvae (TL Range=14–23 mm) Fin Development.—Larvae 14.3–14.5 mm TL had a distinctly bilobed, well-developed caudal fin with 18 primary rays, some of which were segmented. The urostyle, positioned immediately dorsal to the most anterior primary caudal

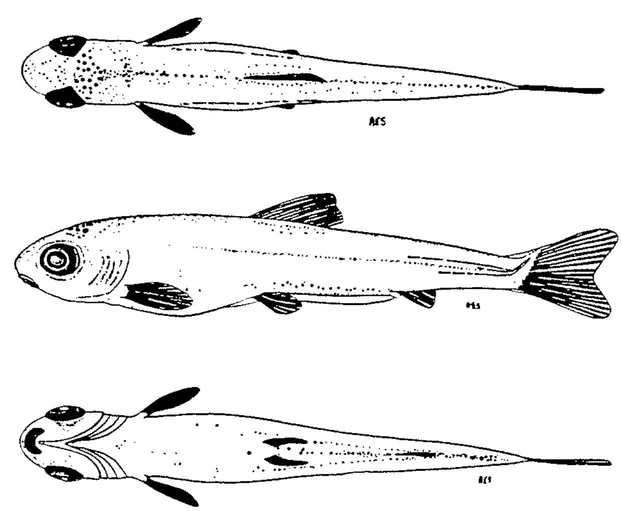

Fig. 4. Robust redhorse, *Moxostoma robustum*, post yolk-sac larvae 14.3–16.0 mm TL.

ray, extended beyond the hypural plate. The anterior and posterior margins of the dorsal fin that originated at myomere 12–13 were defined. Rays were visible in the dorsal fin. The remainder of the dorsal finfold was restricted between the dorsal fin and caudal fin; its depth was less than half the body depth. The ventral finfold also was reduced and extended anterior to the anus to a position near the pectoral fin bases at about the point of the greatest body depth. The anal fin was forming (pterygiophores were present on 14.3 mm TL larvae but rays were not present) posterior to the anus. Rays were visible in the pectoral fins, which were about 1.5 mm long.

Larvae 15.2–15.9 mm TL had rays forming in the anal fin. There were 10–11 rays present in the developing dorsal fin. The pelvic flaps were about half the width of the remaining ventral finfold. The urostyle extended past the hypural plate.

The margin of the anal fin of 16.0–16.9 mm TL larvae (Fig. 4) was rounded and had a defined insertion with five or six rays visible in the fin. Pelvic fins extended to the margin of the remaining ventral finfold. A small amount of dorsal finfold was still present between the dorsal and caudal fins. The ventral finfold was present from the anus anteriorly to about midway between the pectoral and pelvic fins.

Larvae 17.7–19.2 mm TL had lost the dorsal finfold. The ventral finfold was restricted between the pelvic fins and the anus. Fin development was nearing completion in all fins with well developed rays and profiles; however, the urostyle still extended beyond the margin of the hypural plate. The distal margin of the dorsal fin was concave with at least 13 rays visible in the fin. The anal fin had seven or eight rays and; eight or more rays were visible in each pelvic fin. The pectoral fins were well developed and at least 12–14 rays were present.

Larvae 20.0–22.5 mm TL (Fig. 5) had a remnant of finfold immediately anterior to the anus. The finfold was completely gone and fin development was complete on larvae 22.5 mm TL.

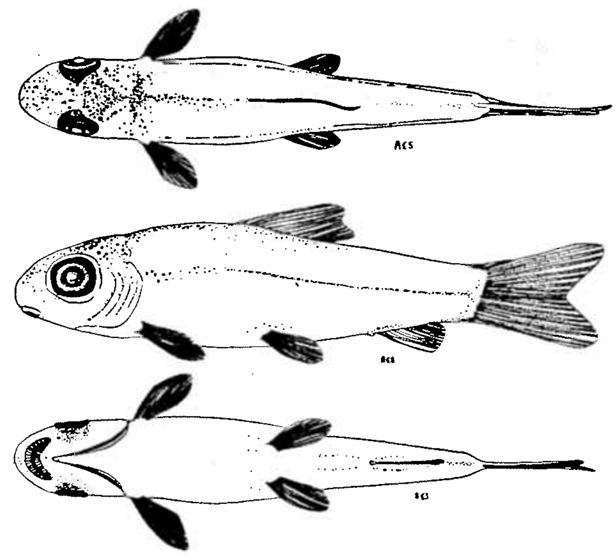

Fig. 5. Robust redhorse, *Moxostoma robustum*, post yolk-sac larvae 21.9–22.5 mm TL.

Post Yolk sac Larvae (TL Range=14–23 mm TL) Pigmentation.— Larvae 14.3–15.9 mm TL were heavily pigmented ventrally. Anterior to the pectoral base, the pigmentation pattern appeared as an arrow with its point near the isthmus. This scattered pigmentation narrowed at the base of the pectoral fins to a double row of melanophores that extended posteriorly to about the anterior margin of the ventral finfold. Dense pigmentation was scattered at the base of the finfold to the anus. Chin pigmentation was present. Pigmentation patterns outlined the gill arches, and pigmentation appeared on the upper lip and snout. Internally, melanophores were scattered dorsally on the gut posterior to the air chambers.

Larvae mm 16.0–16.9 mm TL (Fig. 4) had uniformly scattered pigmentation covering the head, occipit, and optic chamber, dorsally. The large melanophores over the brain and in the single row from the occipit to the dorsal fin origin were still present. Scattered small melanophores covered the remainder of the dorsum. This pigmentation consisted of dorsolateral rows of small melanophores with scattered pigmentation between the rows from the dorsal fin origin to the middle of the caudal peduncle. The dark, tightly scattered pigmentation on the middle of the caudal peduncle to the base of the caudal fin remained. Lateral pigmentation was mostly unchanged compared to previous developmental stages. Small melanophores were scattered around the snout with pigmentation on the upper lip and, on some specimens, on the lower lip. Pigmentation was still visible on the chin. There were fewer melanophores ventrally, especially on the gut, anterior to the developing pelvic fins, and the anus was dark. Tightly scattered pigmentation was present on the ventral caudal peduncle between the anal and caudal fins. The arrow pattern anterior to the pectoral fin bases was still present.

Larvae 17.0–19.2 mm TL had small melanophores that increased in number dorso-laterally. In larvae 18.3 mm TL, ventral pigmentation anterior to the pelvic fins was reduced, but there was still dark, tightly scattered pigmentation posterior to the pelvic fins along the gut and posterior to the anal fin. Small melanophores were scattered throughout the caudal fin and on the anterior half of the dorsal fin. Some pigmentation was present in the anal fin on 19.0 mm TL larvae.

Larvae 19.2–22.5 mm TL (Fig. 5) had lateral pigmentation that was continuing to expand. On larvae 19.2 mm TL, pigmentation was scattered laterally to just above the median myosepta; but on larvae 20.3 mm TL, pigment had expanded past the median myosepta on the sides of the body anterior to the anal fin, and small melanophores out-

Table 4. Characters for separating, eggs, yolk-sac larvae, post yolk-sac larvae, and juveniles of *Moxostoma robustum*, *M. carinatum*, and *M. collapsum* (Kay et al., 1994).

Characteristic	*Moxostoma robustum*	*M. carinatum*	*M. collapsum*
Eggs	Demersal; nonadhesive	Demersal; nonadhesive	Demersal; adhesive
Length at Hatching	7.2 to 8.1 mm TL	8.7 to 11.7 mm TL	9.0 to 10.2 mm TL
Preanal myomeres	36–37 at 9.7–10.45 mm* 35–38 at 11.2–12.9 mm 33–36 at 13.0–16.9 mm	33–38 at 10.2–14.7 mm 29–35 at 15.0–16.8 mm	34–37 at 9.0–10.2 mm 34–38 at 10.1–13.8 mm 31–35 at 14.0–16.7 mm
Postanal myomeres	6–7 at 9.7–10.45 mm* 5–7 at 11.2–12.9 mm 6–9 at 13.0–16.9 mm	5–9 at 10.2–14.7 mm 5–7 at 15.0–16.8 mm	6–7 at 9.0–10.2 mm 6–8 at 10.1–13.8 mm 6–8 at 14.0–16.7 mm
Total myomeres	42–44 at 9.7–10.45 mm* 42–45 at 11.2–12.9 mm 40–43 at 13.0–16.9 mm	40–45 at 10.2–14.7 mm 35–42 at 15.0–16.8 mm	40–43 at 9.0–10.2 mm 41–45 at 10.1–13.8 mm 38–42 at 14.0–16.7 mm

* Myomeres unobservable until 9.7 mm TL.

lined scales on the caudal peduncle. Scales were outlined from the caudal fin to the head on larvae 21.9–22.5 mm TL.

JUVENILE (TL RANGE=23 MM AND GREATER) MORPHOLOGY.—Juveniles 23.5–28.8 mm TL showed squamation progressing. Body, head, and fin morphology was typical of other redhorses. Mouth was ventral, subterminal, horizontal, and small. The snout was rounded, about as long as the width of the eye. The anterior tip of the snout was at a position about equal to the lower margin of the eye.

Juveniles 72–100 mm TL had a mouth that was still ventral, subterminal, horizontal, and small. The body was elongate. Squamation was complete and a complete lateral line was apparent on 92 mm TL juveniles.

JUVENILE (TL RANGE=23 MM AND GREATER) FIN DEVELOPMENT.—Juveniles 23.5–28.8 mm TL had fin ray development apparently complete in all fins by 23.5 mm TL. The caudal fin was deeply forked and typical of redhorses. The anterior five or six rays of the dorsal fin were longer than the rest. On juveniles 28.8 mm TL, the urostyle still extended beyond the hypural plate. Juveniles 72–100 mm TL had 13 dorsal fin rays, 7 anal fin rays, and 18 caudal (primary) rays.

JUVENILE (TL RANGE=23 MM AND GREATER) PIGMENTATION.—Juveniles 23.5–28.8 mm TL had scattered pigmentation covering the dorsum of the head and the body. The head had scattered pigmentation laterally to the lower margin of the eye and on the snout to the mouth. The ventrolateral and ventral aspect of the head had little, if any, pigmentation. The body also had very little pigmentation ventrolaterally and ventrally anterior to the anus. The pigmentation pattern consisted of small melanophores that outlined scales occurring mid-laterally and dorsolaterally, anterior to the anus, and laterally on the caudal peduncle.

Juveniles 30.0 mm TL had scales on the sides of the body that were outlined boldly with pigment. Very little body pigmentation was present ventrally from the ventral margin of the eye posteriorly to the anal fin. Pigment was scarce or lacking on the mouth or ventral surface of the head.

Juveniles 30.0–40.0 mm TL appeared to have about four or five bands of dark pigmentation forming dorsally and extending laterally down the side of the body; one or two anterior to the dorsal fin and two or three posterior to the dorsal fin.

Juveniles 72–100 mm TL were dusky dorsally and laterally, with four or five dark bands apparent laterally. The ventrum lacked pigmentation.

Discussion

The spawning repertoire and early life history of *M. robustum* are similar to that of other redhorse species (Jennings et al., unpubl.). The ability to reliably distinguish *M. robustum* from sympatric congeners is critical to obtaining meaningful data about the reproductive success of this imperiled fish. Our results provide a description of larval *M. robustum* and identify morphological characters by which it can be distinguished from a sympatric congener. Of the morphological characters examined, length-at-hatching was the only morphological characteristic that can be used reliably to distinguish *M. robustum*, 7.2 to 8.1 mm TL, from *M. collapsum*, 9.0 to 10.2 mm TL

(Table 4). *Moxostoma collapsum* usually spawns much earlier in the year—March and April—and at much cooler temperatures, 11–15° C (Jenkins and Burkhead, 1993) than does *M. robustum,* which spawns from late April to early June at 19–24° C (Jennings et al., unpubl.). This difference and length at hatching are the best methods for differentiating these two species. Difference in length at hatching suggest that there also may be differences in morphological development at a given length (e.g. length at which yolk is absorbed). These differences may help to distinguish between the two species.

Moxostoma carinatum and *M. robustum* are the two largest species of *Moxostoma* found in the Southeast and both occur in Georgia, albeit in separate drainages. We include a distinguishing characteristic between these two species to alleviate any potential misidentification. *Moxostoma carinatum* can be distinguished from *M. robustum* primarily by geographical location and length at hatching. *Moxostoma robustum* has been found only in south Atlantic slope drainages whereas *M. carinatum* are restricted to Gulf of Mexico drainages. *M. robustum* are 7.2–8.1 mm TL at hatching, whereas *M. carinatum* are 8.7–11.7 mm TL at hatching (Table 4). Both species spawn at similar water temperatures though *M. carinatum* spawn from mid-April to mid-May (Jenkins and Burkhead, 1993), whereas *M. robustum* spawn from late April to early June (Evans et al., unpubl.).

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Literature Cited

Hogue, J. J. Jr., R. Wallus, and L. K. Kay. 1976. Preliminary Guide to the Identification of Larval Fishes in the Tennessee River. Technical Note B19, December 1976. Tennessee Valley Authority, Chattanooga, Tennessee.

Jenkins, R.E., and N.M. Burkhead. 1993. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Jenkins, R.E., 1999. American Fisheries Society, Abstracts, 129th Annual Meeting, 1999, Charlotte, North Carolina.

Kay, L.K., R. Wallus, and B.L. Yeager. 1994. Reproductive biology and early life history of fishes in the Ohio River drainage. Volume 2: Catostomidae. Tennessee Valley Authority, Chattanooga, Tennessee.

Leviton, A. E., R. H. Gibbs Jr., E. Heal, and C. E. Dawson. 1985. Standards in herpetology and ichthyology: Part I. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. Copeia 1985:802–832.

Wallus, R., T. P. Simon, and B. L. Yeager, 1990. Reproductive biology and early life history of fishes in the Ohio River drainage. Volume 1: Acipenseridae through Esocidae. Tennessee Valley Authority, Chattanooga, Tennessee.

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