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Ontogeny of Larval Greater Redhorse (Moxostoma valenciennesi)

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ABSTRACT.—Adult greater redhorse *Moxostoma valenciennesi*, were seined from the Grand River, Ontario, and artificially spawned in May 1997 and May 1998. Eggs hatched after 6–8 d at a mean temperature of 19 C. Eggs and larval development of 9–22-mm specimens are described. Ontogeny of larval greater redhorse was compared to that of other syntopic *Moxostoma* species from previously published studies, including river redhorse (*M. carinatum*), black redhorse (*M. duquesnei*), golden redhorse (*M. erythrurum*), shorthead redhorse (*M. macrolepidotum*), copper redhorse (*M. hubbsi*) and spotted sucker (*Minytrema melanops*). There was significant overlap between most meristic variables that were compared. However, the majority of greater redhorse (up to 18-mm) have myomere counts (27–33 pre-anal myomeres, 9–10 postanal myomeres and 39–42 total myomeres) that are different from other sympatric redhorse species and spotted suckers and may allow identification of greater redhorse as small as 9-mm.

INTRODUCTION

Ontogenetic development of the catostomid fishes has received increased attention since the publication of comprehensive studies by Buynak and Mohr (1977, 1978a, b, c, 1979), Fuiman (1979) and Fuiman and Whitman (1979). Kay *et al.* (1994) reviewed the early life history of catostomids in the Ohio River drainage, but reported no descriptions of early life history of greater redhorse *Moxostoma valenciennesi*. They noted that this species has not been included in early-stage taxonomic keys due to a general lack of information. With the exception of a report by Gendron and Branchaud (1991) that compares eggs, larvae and juveniles of greater redhorse with those of copper redhorse (*M. hubbsi*), very little information exists on early life history of this species. The greater redhorse is found in lakes and rivers of the Great Lakes—St. Lawrence River basin (with the exception of Lake Superior), as well as the northern portion of the Ohio River, upper Mississippi River, the Red River of the North drainages, the upper Illinois River and the upper Iroquois River in Indiana (Kay *et al.*, 1994; R. E. Jenkins, pers. comm.). Greater redhorse are a targeted food fish by some anglers and an important component in fluvial fish communities (Bunt and Cooke, 2001).

The Grand River, a tributary of Lake Erie in Ontario, supports large populations of greater redhorse along with at least six other catostomid species. Descriptions of early life history are available for white sucker (*Catostomus commersoni*, Manuseti and Hardy, 1967; Fuiman and Whitman, 1979; Buynak and Mohr, 1978c), northern hog sucker (*Hypentelium nigricans*, Buynak and Mohr, 1978a; Fuiman, 1979), shorthead redhorse (*Moxostoma macrolepidotum*, Buynak and Mohr, 1979), golden redhorse (*M. erythrurum*, Fuiman and Whitman, 1979), black redhorse (*M. duquesnei*, Kay *et al.*, 1994) and river redhorse (*M. carinatum*, Kay *et al.*, 1994), but not for greater redhorse. Life history aspects of adult greater redhorse, including

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TABLE 1.—Morphometric data for protolarval and mesolarval greater redhorse (mean and range) expressed as percent TL. Abbreviations: PreAL = pre-anal length, PreDFL = predorsal fin length, HD = head depth, BDA = body depth at anus, ED = eye diameter, and HW = head width

			Percent TL					
	TL (mm)	N	PreAL	PreDFL	HD	BDA	ED	HW
Protolarvae	13.2	12	74.8	32.1	10.8	10.7	6.5	9.3
	12.6–13.8		70.5–77.6	26.9–39.9	9.4–15.0	7.6–13.2	5.7–7.3	7.8–12.5
Mesolarvae	14.8	11	71.6	39.0	12.3	8.1	7.1	9.6
	14.2–16.4		70.0–75.8	23.9–45.9	10.3–13.8	5.8–11.3	6.0–7.9	7.6–11.1

spawning habitat and behavior and post-spawn movement, habitat and behavior, have been recently described (Cooke and Bunt, 1999; Bunt and Cooke, 2001). These studies complement earlier descriptions of greater redhorse reproductive behaviour in the St. Lawrence River by Jenkins and Jenkins (1980). The aim of this study is to describe the early stages of development of greater redhorse and to identify diagnostic characters to distinguish larvae of this species from other syntopic catostomids.

METHODS

Greater redhorse spawning was observed in the Grand River, Ontario, during May of each year from 1995–1998. Ripe greater redhorse were seined from known spawning locations, 800 m downstream from the Mannheim Weir (43°25′N, 80°25′W) and then artificially spawned on 31 May 1997 (river temperature 15 C) and 5 May 1998 (river temperature 16 C). Details of greater redhorse spawning sites in the Grand River are reported in Bunt *et al.* (1998) and Cooke and Bunt (1999). Eggs and larvae were reared in an aerated aquarium with gravel substrate, similar to that found on spawning riffles, at temperatures between 16 and 19 C. Larvae were fed *Artemia* sp. nauplii (Fuiman, 1979). Larger larvae (>15 mm TL) were also fed copepods and small cladocerans collected from the Grand River. Observations of larval feeding behavior, swimming behavior, yolk-sac absorption and pigmentation were recorded daily and descriptions are included where appropriate.

Approximately weekly, three or four larval fish were removed from the rearing tank and were examined under a stereo microscope. Following length measurements (mm TL) and descriptions of general morphology and pigmentation, larval fish were preserved in 4% buffered formalin. Morphometric and meristic characters as listed were examined from the preserved series within 1 y (Table 1). Morphometric data are reported as percent TL to alleviate problems with shrinkage. Definitions of larval phases follow Fuiman (1979). All morphometric features, except postanal length, were defined in Snyder (1976). The definition of postanal length that we used was taken from Hogue and Buchanan (1977). All measurements were made to the nearest 0.1 mm with a digital caliper. Postanal myomeres are those posterior, but not intersected (Siefert, 1969) by an imaginary vertical line through the body at the posterior margin of the anus (Kay *et al.*, 1994). Images of preserved larvae were projected and traced; some details were added following microscopic examination (Buynak and Mohr, 1978b).

GREATER REDHORSE ONTOGENY

Eggs and hatching.—Fertilized and water-hardened eggs are yellow, 3.0–3.5-mm in diameter, demersal and nonadhesive. On spawning riffles, substrate is cleared by spawning actions (*i.e.,* anal fin and caudal fin sweeps) of adults (Cooke and Bunt, 1999) and eggs settle into interstitial spaces between unembedded cobble and pebble. In 1998 we used a drift net and a rod to agitate substrate and dislodge fertilized eggs from riffles where spawning occurred. Naturally deposited eggs were located as deep as 25-cm into the river bed. Under laboratory conditions, artificially spawned eggs hatched in 6 to 8 d at 16–19 C. Upon hatching, larvae remained generally quiescent on the bottom of the rearing tank and became free-swimming after about 5 d.

Protolarvae (9–14 mm TL)—Figure 1

Morphology.—Protolarvae lack caudal fin rays (Fuiman, 1979), but incipient rays begin forming by about 14-mm. The postanal finfold and urostyle are upcurved. The head is deflected over the anterior end of the yolk-sac and eyes are not fully developed and pigmented. Two chambers of the heart are visible as are the branchial arches and notocord. The yolk-sac is bulbous anteriorly and yolk is finely granular. Otoliths and nares become apparent in individuals >12-mm, at which stage the head is no longer decurved. The pre-anal myomere count ranged from 27 to 33, but most protolarvae (67%) have between 28 and 30 pre-anal myomeres (Table 2). Most protolarvae (50%) have 10 postanal myomeres (range 6–12) and 50% of protolarvae have 39–40 total myomeres (range 34–43).

Pigmentation.—Retinal pigmentation is lacking in protolarvae and pigmentation is slight in and around the eyes of individuals <12 mm. Larvae larger than 11-mm have well-developed lenses and retinal pigmentation and the eyes are black. Sparse expanded melanophores are sometimes present along the ventral midline of specimens >11-mm; those >12-mm have stellate melanophores along the ventral midline and sparse pigmentation along the dorsal midline and postanal finfold. An incomplete row of melanophores is present along the horizontal myosepta of the myomeres. Stellate melanophores are scattered anteriorly, behind the eyes and on the occiput.

Mesolarvae (14 mm–18 mm TL)—Figure 2

Morphology.—Mesolarvae have at least one distinct caudal fin ray (Fuiman, 1979). Specimens that are about 14.5-mm have pectoral fin buds with rays and 19–20 total caudal fin rays. Yolk is finely granular, but diminished somewhat, and the yolk sac is no longer bulbous. Eyes are fully developed, the mouth is slightly sub-terminal at eye level and the opercula and two of the three lobes of the gas bladder are apparent. The yolk sac is completely absorbed by about 15-mm. The digestive tract is complete by 14.5-mm and begins to coil anteriorly by about 16.5-mm. The pectoral fin has 12 rays. The anal fin begins forming in the anal finfold and 5–6 incipient rays are visible in specimens >16-mm. Pelvic fin buds begin to develop by about 15.5-mm. Larvae >16-mm begin to assume a benthic feeding habit and the mouth becomes subterminal by about 16.5-mm. Most specimens (91%) had between 27 and 33 pre-anal myomeres (range 26–33, Table 2). Postanal and total myomere counts are 9–10 for 64% of specimens (range 8–14), and 39–42 for 82% of specimens (range 37–43), respectively.

Pigmentation.—Stellate melanophores are present on the horizontal myoseptum of the myomeres, dorsal midline, ventral midline from head to anus and along the dorsal and ventral midlines of the yolk sac. Caudal fin rays and the leading edge of the dorsal fin have small stellate melanophores. The gas bladder becomes increasingly pigmented by about 15.5-mm. In living larvae, yellow chromatophores are visible on the dorsum and above the lateral line.

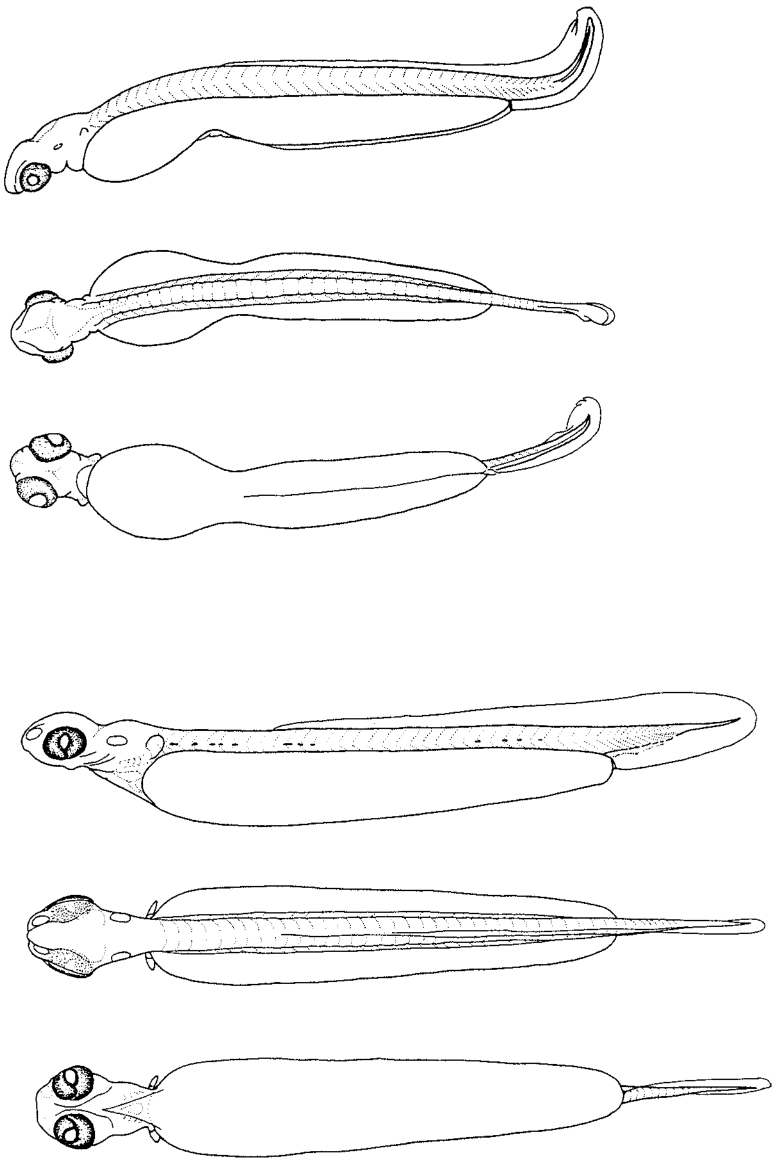

FIG. 1.—Lateral, dorsal and ventral views of greater redhorse protolarvae (top—10.4 mm, bottom—11.3 mm)

Metalarvae (18 mm–22 mm TL)—Figure 3

Morphology.—The pelvic fin is developed with 8 rays, principal caudal fin rays 18, total anal fin rays 8, dorsal fin rays 15 and pectoral fin rays 12 by 18-mm. All fin margins are distinct and the pre-anal finfold is not entirely absorbed. The mouth is fully subterminal with well developed lips by 19-mm. The head is large and box-like with well developed nares and a very

TABLE 2.—Frequency distribution of number of myomeres of greater redhorse protolarvae and mesolarvae as a function of total length

		Pre-anal myomeres									
	TL Range (mm)	26	27	28	29	30	31	32	33		
Protolarvae	9–14		1	3	1	4	1	1	1		
Mesolarvae	14–18	1	2	2	1		2		3		
		Postanal myomeres									
		6	7	8	9	10	11	12	13	14	
Protolarvae	9–14	1	1	1	2	6		1			
Mesolarvae	14–18			1	5	2		2		1	
		Total myomeres									
		34	35	36	37	38	39	40	41	42	43
Protolarvae	9–14	1		1	1	1	3	3		1	1
Mesolarvae	14–18				1		2	1	3	3	1

large eye (compared to the size of the head) in a well-developed orbit. The pre-opercula are transparent in living specimens.

Pigmentation.—By 19-mm, fewer large melanophores are present posteriorly. Numerous large melanophores remain above the lateral midline. A line of pigmentation is present along the lateral myoseptum, along the ventral midline and on the dorsal aspect of the head. Melanophores on the occiput have coalesced into a heart shape. Guanine is sparsely present on the operculum. The iris is golden/silver and the top of the orbit and upper maxillary are densely pigmented. Individuals remain yellow dorsally.

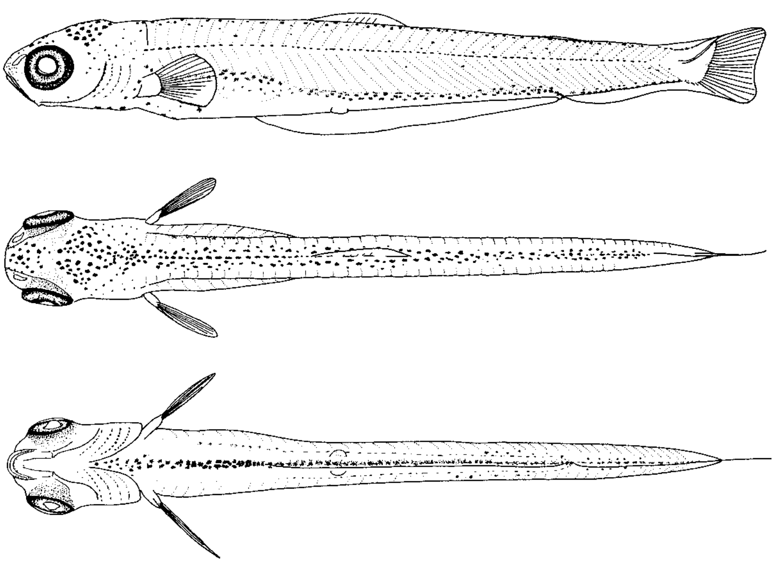

FIG. 2.—Lateral, dorsal and ventral views of greater redhorse mesolarvae (15.3 mm)

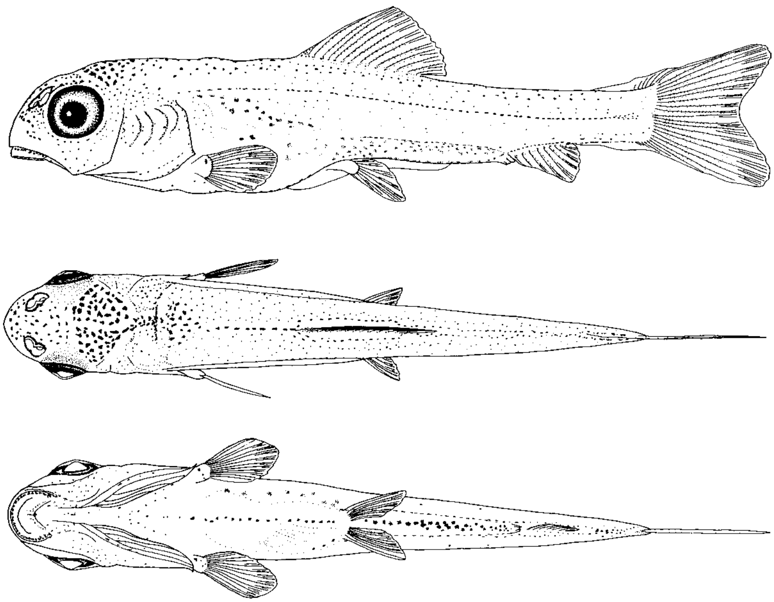

FIG. 3.—Lateral, dorsal and ventral views of greater redhorse metalarvae (17.6 mm)

DISCUSSION

The literature on early life history, in particular egg and larval development, of greater redhorse is scant. One report supports our observations that mesolarval greater redhorse have a linear pattern of pigmentation along the lateral line on each myomere, that distinguishes it from mesolarval copper redhorse (*Moxostoma hubbsi*), that has a triangular pattern of pigmentation on each myomere along the horizontal myoseptum (Gendron and Branchaud, 1991). River redhorse lack pigmentation until 12.8-mm, after which pigment covers the occiput and nape and narrows to a median row extending to the origin of the dorsal finfold (Kay *et al.*, 1994). Black redhorse >11.2-mm have scattered pigment over the head and occiput that narrows to a predorsal stripe and lateral melanophores in median myosepta that form a stripe from the pectoral fins to the posterior margin of the yolk sac (Kay *et al.*, 1994). Golden redhorse >10.8-mm have median predorsal melanophores and pigmentation increases on the head, occiput and nape until larvae are darkly pigmented by 12–14-mm (Kay *et al.*, 1994). Shorthead redhorse between 10.2 and 12.2-mm have melanophores on the occiput, a single mid-dorsal row of pigment and an intermittent mid-lateral stripe (Kay *et al.*, 1994). By 13.2-mm, shorthead redhorse have three dorsal stripes that merge into a dark band over the caudal peduncle (Kay *et al.*, 1994). Spotted suckers have pigmentation along median myosepta at 9.5-mm and a single row of pigmentation dorsally, ventrally and mid-laterally by 10–11-mm (Kay *et al.*, 1994). Pigmentation differences are usually easy to observe, but should be examined cautiously because significant intraspecific variation may exist and pigmentation changes can occur depending on method of preservation and age of specimens. Furthermore, artificially reared specimens may be atypical in terms of some pigmentation and anatomical characteristics relative to specimens that are fertilized and develop naturally (R. E. Jenkins, pers. comm.).

TABLE 3.—Comparison of typical myomere counts and selected morphometric features of larval greater redhorse, river redhorse, black redhorse, golden redhorse, shorthead redhorse, spotted sucker and copper redhorse

	Myomere counts			Percent TL						
	Pre-anal	Postanal	Total	PreAL	PreDFL	HD	BDA	ED	HW	Source
Greater redhorse (9–16 mm)	27–33	9–10	39–42	72–75	32–39	11–12	8–11	7	9–10	This study
River redhorse (12–15 mm)	35	7	42	72–78	—	—	9–10	5–6	—	Kay et al., 1994
Black redhorse (13–15 mm)	37	7	44	73–76	—	—	8–9	5–6	—	Kay et al., 1994
Golden redhorse (13–15 mm)	34	6	40	72–74	—	—	9–13	7–10	—	Kay et al., 1994
Shorthead redhorse (8–17 mm)	36	8	44	69–79	32–39	9–13	8–10	6–7	8–12	Fuiman, 1979
Spotted sucker (10–15 mm)	33	8	41	69–76	—	—	—	6–8	—	Hogue and Buchanan, 1977
Copper redhorse	—	—	—	—	—	—	—	—	—	Data not available

Greater redhorse from the Chambly basin of the Richelieu River in Quebec (Gendron and Branchaud, 1991) and the Grand River in Ontario have similar numbers of dorsal, anal and caudal fin rays. The fin ray counts for greater redhorse generally overlap with those of shorthead redhorse, golden redhorse, black redhorse, river redhorse, but differ from those of spotted sucker (Kay *et al.*, 1994). Morphometric and developmental data of larval greater redhorse are similar to those of syntopic species, such as shorthead redhorse, golden redhorse, black redhorse, river redhorse and spotted sucker (Table 3). There is significant nondiscriminatory overlap between most meristic variables that may preclude their usefulness for identifying larval moxostomid fishes. According to Kay *et al.* (1994), *Moxostoma* specimens from the Ohio R. basin cannot be reliably distinguished as larvae. However, myomere counts for the majority of greater redhorse are unique compared to other redhorse species with the exception that total numbers of myomeres for greater redhorse overlap with those of the river redhorse. There was very limited overlap in numbers of pre-anal or postanal myomeres among any of the species that were compared. Pre-anal and postanal myomere counts may therefore be used to identify and distinguish larval greater redhorse as small as 9-mm, but further work is necessary to determine if myomere counts alone can be reliably used to separate different species of syntopic *Moxostoma* over a greater geographical range.

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