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State of the Art of Identification for Cyprinid Fish Larvae from Eastern North America

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Abstract

Morphological characteristics are known for 62 species of cyprinid larvae in 22 genera occupying waters of North America east of the Continental Divide. Currently known diagnostic characters are presented for most of these species. Species are arranged into groups according to their relative preanal length, eye shape, preanal myomere number, and ventral pigmentation. Descriptive literature is noted, as are errors in the literature. Practical considerations for making identifications, species in need of description, and characters to be investigated are discussed.

Identification of North American cyprinid fishes at any stage in their life histories is an intimidating task. The combination of a high number of species and their great morphological similarity is a source of aggravation to many taxonomists. The problem of identification is magnified for larvae because of even greater morphological similarity, lack of knowledge of many species' larvae, lack of comparative literature, and errors in existing literature. A "state-of-the-art" paper such as this can do little to alleviate the first two problems. However, we do present the current state of knowledge in a comparative framework so as to assist identifications of larvae and preparations of future descriptive and comparative studies. We identify descriptive literature and errors in that literature. Finally, we indicate taxa in need of description. Although we present current diagnoses (which may falter as the remaining species become known), it is not our intent to provide a taxonomic key. Such an undertaking would be premature given that larvae of two-thirds of the species are unknown.

Scope and Organization

Robins et al. (1980) listed 221 species and 43 genera of cyprinids from the United States and Canada. Given that taxonomic literature on lar-

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TABLE 1.—*Species of eastern North American cyprinids known in their larval forms, grouped by selected character states. A species may belong to more than one group but it is listed in only the first group that describes it (read left to right, then top to bottom). TL is total length.*

High preanal length (>65% of TL)	***Flattened eye***	***High preanal myomere number (>25)***	***Midventral stripe***
Carassius auratus	*Hybopsis aestivalis*	*Campostoma anomalum*	*Clinostomus funduloides*
Ctenopharyngodon idella	*Hybopsis storeriana*	*Couesius plumbeus*	*Hybognathus regius*
Cyprinus carpio	*Hybopsis winchelli*	*Gila atraria*	*Notemigonus crysoleucas*
Rhodeus sericeus	*Notropis cerasinus*	*Hybognathus hankinsoni*	*Notropis amoenus*
Tinca tinca	*Notropis emiliae*	*Hybognathus nuchalis*	*Notropis ardens*
	Notropis stramineus	*Nocomis biguttatus*	*Notropis atherinoides*
	Phenacobius mirabilis	*Nocomis leptocephalus*	*Notropis rubellus*
	Pimephales notatus	*Nocomis micropogon*	*Notropis shumardi*
	Pimephales vigilax	*Nocomis raneyi* (?)	*Notropis telescopus*
		Notropis chrysocephalus	*Notropis volucellus*
		Notropis cornutus	*Pimephales promelas*
		Semotilus atromaculatus	
		Semotilus corporalis	

Scattered breast melanophores	***Outlined gut***	***Unassigned species***
Notropis chalybaeus	*Exoglossum maxillingua*	*Campostoma oligolepis*
Notropis dorsalis	*Notropis analostanus*	*Leuciscus idus*
Notropis hudsonius	*Notropis blennius*	*Notropis bifrenatus*
Notropis leuciodus	*Notropis longirostris*	*Notropis girardi*
Notropis lutipinnis	*Notropis lutrensis*	*Notropis leedsi*
Phoxinus oreas	*Notropis maculatus*	*Notropis niveus*
	Notropis procne	*Scardinius erythrophthalmus*
	Notropis spilopterus	
	Notropis venustus	
	Rhinichthys atratulus	
	Rhinichthys cataractae	

vae is nearly restricted to species of eastern North America, we limited our work to the species occurring east of the Continental Divide. Lee et al. (1980 and supplements) compiled 179 species in 25 genera in this study area, which represent 78% of the species and 58% of the genera listed by Robins et al. (1980).

In the following sections, species are discussed within groups defined by selected character states. A particular species may fit into several groups, but it is discussed only in the first one that describes it. In this way, the presentation is roughly similar to a taxonomic key. Diagnostic characters, as currently known or suspected, and references containing new (at that time) information are cited. An additional paragraph discussing published errors or information on geographic variation is included whenever possible. Most characteristics of species were taken from the literature and comparisons were based on this information combined with personal experiences of the authors. Wherever we contributed our own original descriptive data, the respective author's initials are given in parentheses. Preanal myomere numbers are presented in figures for most groups or subgroups and species are discussed in the text in approximately the same sequence in which they are presented in these figures. Preanal myomeres include all segments anterior to, and transected by, a vertical line drawn from the anus. Myomere data were taken from the literature cited in the text, but those from Fish (1932) were not included because of doubt that she was able to observe all myomeres present in a given specimen. This is based on discordance of her reports with those of more recent studies on larvae and with vertebra counts of adults. Lengths of specimens are reported as mm total length (TL).

Diagnoses

Four major characters are useful in segregating all cyprinid larvae into distinct, though unrelated, groups. These include relative preanal length, eye shape, preanal myomere number, and midventral pigmentation (Table 1).

Relative Preanal Length (As % of TL)

Nearly all North American cyprinid larvae have a relative preanal length between 45 and 65% throughout development, usually 55 to 62%. However, five species (all Eurasian intro-

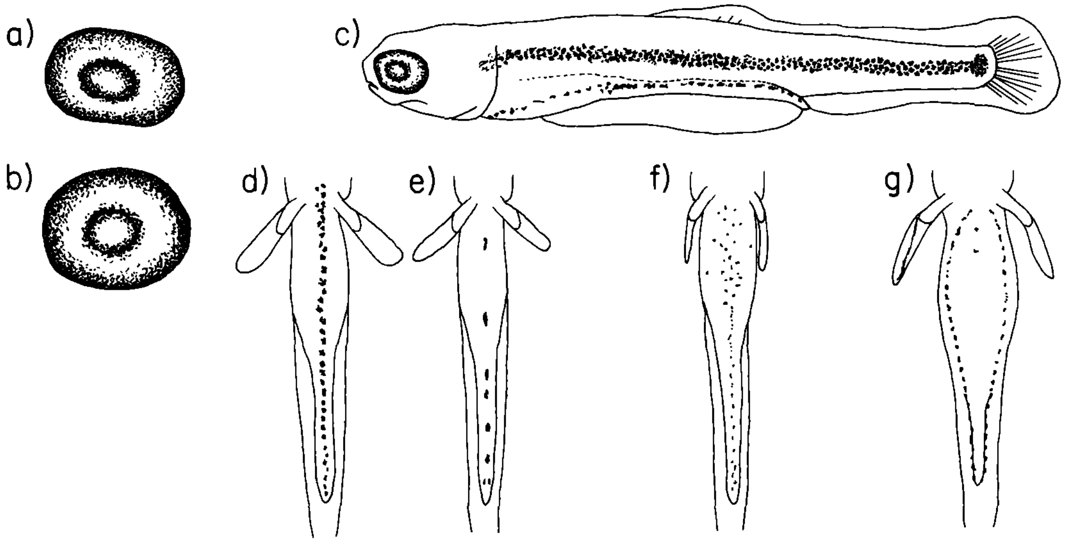

FIGURE 1.—*Characters for distinguishing groups of cyprinid larvae. (a) flattened eye; (b) rounded eye; (c) high preanal myomere number associated with broad midlateral stripe, caudal spot, and ventrolateral stripe; (d, e) midventral stripe as in* Notemigonus crysoleucas *(d) and* Notropis atherinoides *(e); (f) scattered breast pigment; (g) outlined gut.*

ductions, Table 1) exhibit a large relative preanal length (65–74%). Usually, however, allometry causes the relative preanal length to decrease with growth. Recognition of this trend ameliorates the difficulty imposed by the overlap at 65%.

Ctenopharyngodon idella is easily distinguished from the others of this group by the presence of 30 to 33 preanal myomeres. Larger larvae develop only 7 to 9 dorsal fin rays; *Carassius auratus* and *Cyprinus carpio* develop more than 15. References (in part): Nakamura (1969), Soin and Sukhanova (1972), Conner et al. (1980).

Carassius auratus and *Cyprinus carpio* are robust and often darkly pigmented (especially on the dorsum). Both possess a dark, internal band of pigment that tracks the dorsum of the gut and swim bladder. This band bifurcates dorsoventrally anteriad, at the pectoral buds. The dorsal branch of this "Y" pattern extends beyond the anterior edge of the auditory vesicle in *Carassius auratus*. Further, this species has fewer preanal myomeres (17 to 20 whole myomeres anterior to the anus, add 1 or 2 to conform to our conventional count). *Cyprinus carpio* has more preanal myomeres (21 to 24 whole myomeres) and the dorsal branch of the "Y" pattern terminates at the anterior edge of the auditory vesicle (Gerlach 1983). References (in part): *Carassius auratus*—Battle (1940), Kajishima (1960), Nakamura (1969), Taber (1969), Lippson and Moran (1974), Loos et al. (1979), Wang and Kernehan (1979); *Cyprinus carpio*—Smallwood and Smallwood (1931), Fish (1932), Nakamura (1969), Lippson and Moran (1974), Hogue et al. (1976), Jones et al. (1978), Loos et al. (1979), Wang and Kernehan (1979), Conner et al. (1980), Snyder (1981).

Fish (1932) illustrated a 7.5-mm *Cyprinus carpio* but identified it as *Moxostoma aureolum* (=*M. macrolepidotum*) (Snyder and Douglas 1978). Fish's error was transcribed by Mansueti and Hardy (1967). Fish also described a 10.0- and a 30.75-mm *C. carpio* with 18 and 19 preanal myomeres and a 13.3-mm specimen with "21(22)" preanal myomeres. Combined with the unexpectedly advanced state of development illustrated in the 10.0-mm specimen, these counts indicate that only the 13.3-mm description and illustration are that of *Cyprinus carpio*. The remaining information probably relates to *Carassius auratus*. Fish's illustration of a 10.0-mm "*Cyprinus carpio*" and associated descriptive data were reproduced by Mansueti and Hardy (1967), Lippson and Moran (1974), Jones et al. (1978), Wang and Kernehan (1979), and Heufelder and Fuiman (1982).

Tinca tinca is 4 to 5 mm long at hatching with a preanal length of about 72% TL (from figure in Muus 1967). It possesses an adhesive organ

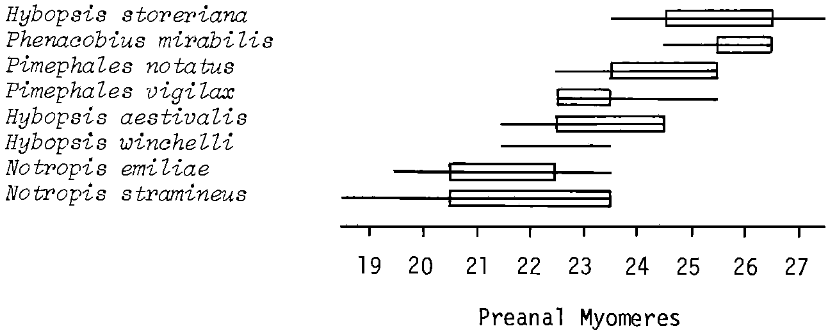

FIGURE 2.—*Preanal myomere distributions for cyprinid larvae with a flattened eye. Lines are ranges; boxes enclose common values.*

on the head by which it attaches to vegetation. Diagnostic pigmentation consists of a dark internal stripe that covers the dorsum of the yolk sac, continuing posteriad along the postanal venter. Other pigmentation is lacking. Larger larvae develop a conspicuous black patch on the end of the caudal peduncle. Pelvic buds develop at about 11 mm. The 11 dorsal fin rays (three are spine-like) and single pair of barbels may be present in larvae. References: Kazansky (cited in Berg 1949), Kryzhanovsky (1947, 1949), Berg (1949), Bracken and Kennedy (1967), Muus (1967).

Rhodeus sericeus may belong to this group. Available illustrations show relative preanal lengths of 79, 67, and 64% at 5, 6, and 8 mm, respectively. Small larvae (about 5–8 mm) have a pair of horny lateral protruberances of the yolk sac that secures them among the gills of molluscs in which the eggs are deposited. Yolk is absorbed after 8 mm. Larger larvae develop 12 to 13 dorsal fin rays (three are spine-like). Pelvic buds develop anterior to the dorsal fin origin. Larvae probably are collected rarely because they remain in the mantle cavity of a mollusc until about 20 mm (juveniles). References: Kryzhanovsky (1949), Kryzhanovsky et al. (1951), Nikolsky (1954), Muus (1967), Wheeler (1969).

Eye Shape

A few species have eyes with distinctly flattened dorsal and ventral borders (Fig. 1). This characteristic appears very early in many species but disappears rapidly. In some species it persists, is consistent within the species, and is not an artifact of preservation. In these instances, the eyes appear circular by the end of the larval period (this may be merely a result of further development of the overlying circumorbital bones). Myomere number is useful for separating some of these larvae (Fig. 2).

Phenacobius mirabilis is known only from 6.6 to 7.2 mm. Dorsal melanophores are restricted to a few on the occiput. The venter shows the outlined-gut pattern described in a later section. The mouth is inferior and horizontal and the snout blunt and projecting. Internal melanophores develop immediately above the vertebral column. Yolk is absorbed by 8.0 mm. Reference: Perry (1979).

Pimephales notatus has small larvae (for example, hatch, 5–6 mm; yolk absorption, about 6.0 mm; pelvic-bud formation, 8–9 mm). The venter shows the outlined-gut pattern. The mouth is subterminal to inferior once yolk is absorbed. Larger larvae develop a caudal spot and a concentration of melanophores at the dorsal fin base. References: Fish (1932), Buynak and Mohr (1979c), Loos et al. (1979), Perry and Menzel (1979), Heufelder and Fuiman (1982).

Pimephales vigilax is similar to *P. notatus* but somewhat smaller. There is an intermittent midventral row of melanophores (similar to that of *Notropis atherinoides*) after yolk absorption. A caudal spot and a concentration of melanophores develop at the dorsal-fin base and, on late larvae, a spot develops on the anterior part of the dorsal fin itself. The mouth is subterminal to inferior once yolk is absorbed (all comparative characters here are from JVC). References: Taber (1969), Conner et al. (1980), Heufelder and Fuiman (1982).

Hybopsis aestivalis, H. storeriana, and at least older larvae of *H. winchelli* (JVC) exhibit a small, subterminal to nearly inferior mouth that is overhung by a fleshy snout at larger sizes. Pectoral buds or fins are long and expansive and usually placed ventrolaterally. Nares develop early and are rather large. Differentiation of *Hybopsis* species is difficult but myomere number is of some aid (Fig. 2). References: *H. aestivalis*—Bottrell et al. (1964), Conner et al. (1980); *H. storeriana*—Taber (1969), Conner et al. (1980).

Fish (1932) described larvae of *Erinemus storerianus* (=*Hybopsis storeriana*) but her identifications were doubted by Snyder and Douglas (1978) and Heufelder and Fuiman (1982). The presence of an oil globule, anterior placement of the anus, size of the mouth, and other characters indicate that all stages she described, except the juvenile, were those of a darter (Percidae). Her 21-mm juvenile is a cyprinid and may or may not be *H. storeriana,* but we cannot justify an alternative identification.

Taber (1969) illustrated a developmental series of *Hybopsis storeriana* and Heufelder and Fuiman (1982) reproduced these. At least the 6.5-, 7.6-, and 8.7-mm specimens were probably *Pimephales vigilax,* based on head shape and size at given stages of development when compared to data in Conner et al. (1980).

Hogue et al. (1976) depict their "group B, subgroups 1, 2, and 3" larvae and offer tentative identifications. We suggest that at least the photograph of group B, subgroup 1 represents *Hybopsis storeriana* and that of group B, subgroup 2 represents *H. aestivalis.* Hogue et al. tentatively identified their group B, subgroup 3 as *H. insignis.* Low total myomere counts reported by them (34+) disagrees with that expected from vertebra counts (38 to 40).

Notropis emiliae is very similar to *Pimephales vigilax,* but it tends to have fewer preanal myomeres (Fig. 2). Further, it attains a ninth dorsal fin ray by the time pelvic buds appear, and no spot develops in the anterior part of the dorsal fin. Reference: Millard (1981).

Notropis stramineus from 4 to 7 mm may show scattered breast pigmentation, but smallest larvae may lack pigment entirely. Larger larvae sometimes develop the outlined-gut pattern. Late in the larval period, melanophores develop in the nasal pit and along the dorsal-fin base. Juveniles develop a dusky midlateral stripe. References: Fish (1932), Loos and Fuiman (1978), Perry and Menzel (1979), Snyder (1981), Heufelder and Fuiman (1982).

Notropis cerasinus is poorly known. One illustration depicts a flattened eye. Reference: Loos and Fuiman (1978).

Preanal Myomere Number

Generally, myomere frequency distributions are symmetrical around a single (or double) heavily weighted mode (that is, they are positively kurtotic). Therefore, overlap at the extremes of two distributions usually represents a small proportion of either population. Preanal myomere number ranges approximately from 18 to 33 among cyprinids and a small group of genera have modal values greater than 25 (Table 1). Preanal myomere number is also a useful character for species within this group (Fig. 3). Many of these fishes also have the following characteristics in common: a broad, dark midlateral stripe, a caudal spot, and a less prominent ventrolateral stripe that crosses the length of the gut, descending to the heart anteriad (Fig. 1).

Ctenopharyngodon idella and *Semotilus corporalis* have the highest preanal myomere counts; the former was discussed in the previous section. *Semotilus corporalis* is larger than other cyprinids (hatch, 6.8–7.5 mm; yolk absorption, about 10.6 mm; pelvic-bud formation, 15.6 mm). The caudal spot and midlateral stripe form by 15 mm. The ventrolateral stripe tends to be well defined and complete (without gaps). Pelvic buds develop below the dorsal fin origin. References: Reed (1971), Jones et al. (1978), Buynak and Mohr (1979b), Loos et al. (1979), Heufelder and Fuiman (1982).

Semotilus atromaculatus is smaller than *S. corporalis* (hatch, 5.3–6.2 mm; yolk absorption, 8.9–9.3 mm; pelvic-bud formation, 14–15 mm), yet larger than most cyprinids. The midlateral stripe and confluent caudal spot form between 11 and 14 mm. The ventrolateral stripe has gaps in the sequence of melanophores. The ventral edge of the operculum is marked with melanophores by about 9 mm. Pelvic buds develop anterior to the dorsal fin origin. Predorsal length is 46 to 48% TL at 12 to 15 mm. References: Fish (1932), Buynak and Mohr (1979b), Kranz et al. (1979), Loos et al. (1979), Perry and Menzel (1979).

Campostoma anomalum is very similar to *S.*

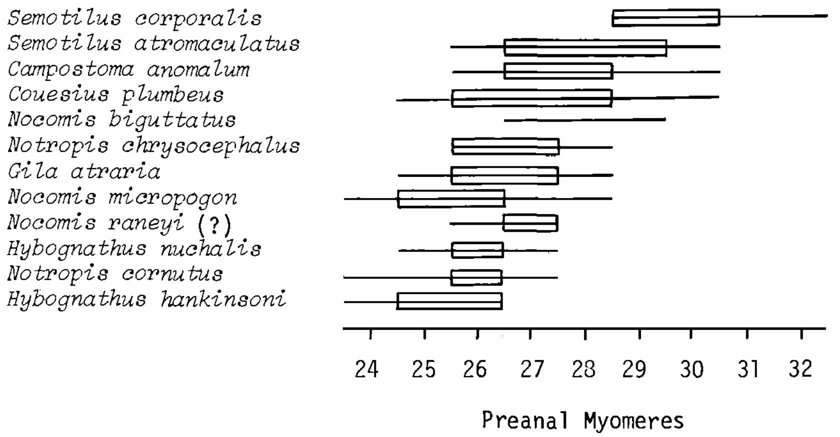

FIGURE 3.—*Preanal myomere distributions for cyprinid larvae with many preanal myomeres. Lines are ranges; boxes enclose common values.*

atromaculatus after caudal fin ray formation (until that time, the former is much darker [BFL]). Sizes at various stages are similar. The caudal spot of *C. anomalum* usually is separated from the midlateral stripe (forming at 9.3 mm). Pelvic buds develop below the dorsal fin origin and the predorsal length is 43–45% TL at 12–13 mm. By 20 mm, the diagnostic subterminal mouth and black peritoneum develop. References: Fish (1932), Reed (1958), Hogue et al. (1976), Loos et al. (1979), Perry and Menzel (1979), Buynak and Mohr (1980a), Heufelder and Fuiman (1982).

Couesius plumbeus is one of the smallest of this group, excepting *Ctenopharyngodon idella* (hatch, 5.8–6.4 mm; yolk absorption, about 7.5 mm; pelvic-bud formation, 11.3 mm). The midlateral stripe is very narrow and the caudal spot is reduced. A second, smaller, hypaxial, caudal spot develops by 9.2–10.0 mm. The ventrolateral stripe descends across the breast anteriorly, converging with its counterpart midventrally. Pelvic buds develop anterior to the dorsal fin origin. Unlike others of this group, *Couesius plumbeus* is usually lacustrine and enters the mouths of streams only to spawn. Reference: Fuiman and Baker (1981).

A trident-shaped pattern on the ventral foregut is described for *Notropis chrysocephalus* by Yeager (1979) but not illustrated. The outer tines of the trident ascend posteriad to become the ventrolateral stripes along the gut. Larvae are of moderate size (hatch, 5.6–6.0 mm; yolk absorption, 7.8 mm; pelvic-bud formation, 11.3–12.2 mm). The caudal spot is absent. References: Loos and Fuiman (1978), Yeager (1979).

Fish (1932) described and illustrated *Notropis cornutus chrysocephalus* eggs and larvae. The specimens were incorrectly identified (Snyder et al. 1977; Loos and Fuiman 1978) and were probably a percid, perhaps *Etheostoma* sp.

Gila atraria is another small species in this group (hatch, about 4 mm; yolk absorption, about 7 mm; pelvic-bud formation, about 10 mm). It is darkly pigmented with a short row of melanophores descending posteriad from the pectoral region. Melanophores also outline the caudal peduncle in lateral view. Reference: Snyder (1981).

Members of *Nocomis* belong to this group. Larvae of *N. biguttatus* and *N. micropogon* have been described and a 9.1-mm *N. leptocephalus* has been illustrated (Loos et al. 1979). A description of *N. raneyi* (Potter et al. 1980), based on a reared series from artificially fertilized eggs, is probably that of *N. leptocephalus. Nocomis raneyi* had not been identified from the stated locality for 15 years (R. E. Jenkins, personal communication with LAF) and the specimens from which gametes were taken were lost. All known *Nocomis* larvae were about the same size and similarly pigmented. The caudal spot of *N. biguttatus* is much larger and the caudal fin is reddish in living and freshly preserved material (LAF). References: *N. biguttatus*—Heufelder and Fuiman (1982); *N. micropogon*—Loos et al. (1979), Buynak and Mohr (1980a), Cooper (1980).

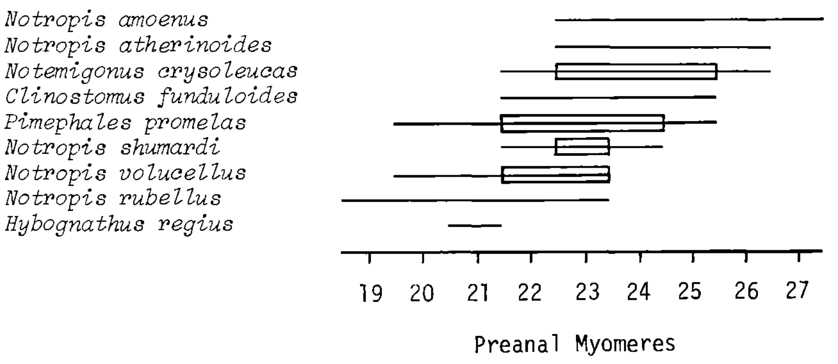

FIGURE 4.—*Preanal myomere distributions for cyprinid larvae with a midventral stripe. Lines are ranges; boxes enclose common values.*

Notropis cornutus is similar to *Notropis chrysocephalus* as larva and adult. Some populations do not exhibit the midventral stripe, which is usually present. Most specimens have a concentration of melanin at the tip of the urostyle. References: Loos and Fuiman (1978), Perry and Menzel (1979), Buynak and Mohr (1980a).

Hybognathus nuchalis is indistinguishable from others of its genus on the basis of qualitative characters. It is unique among southern Mississippi River cyprinids in that it has many preanal myomeres (24–27, usually 25 or 26) but few postanal myomeres (9–13, usually 11 or 12) (JVC). Ecologically, these larvae (in Louisiana) are restricted to marginal areas of the inundated floodplain (where *Ictiobus* and *Notemigonus* larvae are abundant) and rarely are encountered in open-water collections (JVC).

Hybognathus hankinsoni does not develop ventrolateral stripes, but it does possess prominent melanophores on the pectoral fin base shortly after caudal fin-ray formation. There is a prominent midventral stripe anterior to the anus and the ventral edge of the operculum is lined with melanophores, as on *Semotilus atromaculatus*. Larger larvae lack a midlateral stripe and caudal spot. The pectoral and opercular pigmentation may not be present in other members of the genus. References: Perry and Menzel (1979), Snyder (1981), Heufelder and Fuiman (1982).

Ventral Pigmentation

A variety of melanophore patterns are found in cyprinids; the ventral pattern between the head and anus is helpful in grouping larvae (Fig. 1). The pattern of melanophores, rather than their number, size, or intensity, appears to be a useful taxonomic character.

Midventral Stripe

Perhaps the most common arrangement of melanophores is in a median line between the head and anus. The stripe is usually developed by 4.6 mm and may vary in intensity due to the size or number of melanophores (Fig. 1). It is usually most linear along the base of the preanal fin fold. Anteriorly, it may be slightly more dispersed. Preanal myomere number is helpful to separate some species within this group (Fig. 4).

Notropis amoenus contains midventral pigment at hatching. Late larvae are similar to *Notemigonus crysoleucas* in that they develop pelvic buds anterior to the dorsal fin origin, have at least 11 anal fin rays, and have a pointed snout with a superior mouth. However, *Notropis amoenus* has fewer anal fin rays and is more slender than *Notemigonus crysoleucas*. References: Loos and Fuiman (1978), Buynak and Mohr (1980b).

Notropis atherinoides is more elongate than other cyprinids, superficially resembling clupeids. Pigment is sparse and the midventral stripe is intermittent, consisting of 5 to 10 melanophores. Pelvic buds develop anterior to the dorsal-fin origin and the anal fin develops at least 10 rays. References: Fish (1932), Flittner (1964), Hogue et al. (1976), Loos and Fuiman (1978), Conner et al. (1980).

Notemigonus crysoleucas is characterized by a concentration of melanophores around the tip of the urostyle (sometimes absent at hatching).

Larvae are among the smallest cyprinids (hatch, 3.0 mm; yolk absorption, 4.6 mm; pelvic-bud formation, about 10.2 mm). The mouth is always small and by 6 mm it is superior. Pelvic buds develop anterior to the dorsal-fin origin. The anal fin is falcate, usually with 12 to 13 rays when complete. Eggs are spawned among vegetation and newly hatched larvae attach to plants by means of an adhesive organ or gland on the top of the head. References: Lippson and Moran (1974), Hogue et al. (1976), Snyder et al. (1977), Loos et al. (1979), Wang and Kernehan (1979).

Fish (1932) described and illustrated an 18-mm larva. The description appears to be that of *Notemigonus crysoleucas,* but the illustration differs on several points (Snyder et al. 1977). The placement of the pelvic fins, the shape of the anal fin, and the few anal-fin rays leads us to believe that the illustration is of *Notropis cornutus* or *Notropis chrysocephalus.*

Clinostomus funduloides may belong to this group. The best description available (Hogue et al. 1976) indicates the presence of a midventral stripe; however, an illustration in Loos et al. (1979) shows a scattering of melanophores between the heart and preanal fin fold. Hogue et al. (1976) described ventrolateral stripes (as in the high preanal myomere group) that cross the breast anteriorly to join midventrally near the heart, and pelvic buds anterior to the dorsal-fin origin. The mouth of older larvae is large and oblique. Dorsal-fin rays may be 8 or 9. Pigmentary differences between the specimens in the two studies cited above may indicate great geographic variability in larvae of this species. At least three subspecies have been recognized and the specimens from these two studies were of different subspecies.

Pimephales promelas shows a midventral row of melanophores along, but usually not anterior to, the preanal fin fold. The mouth is terminal until the juvenile phase. Larger larvae develop a midlateral stripe and lack a caudal spot. In many respects, *P. promelas* resembles *Notropis chrysocephalus* and *Notropis cornutus.* References: Fish (1932), Hogue et al. (1976), Snyder et al. (1977), Buynak and Mohr (1979c), Perry and Menzel (1979).

Notropis shumardi is very similar to *N. atherinoides,* but in the lower Mississippi River, the former has an even weaker midventral stripe (3–7 melanophores), fewer preanal myomeres and anal-fin rays, and more posteriorly placed pelvic buds (JVC).

Notropis volucellus is most similar to, but is thinner, more delicate, and less pigmented throughout development than, *Notropis amoenus* (BFL). Midventral pigment is sometimes absent at hatching, but develops soon afterward. Pelvic buds develop below the dorsal-fin origin, the snout is blunt, and the anal fin contains 8 or 9 rays. References: Potter and Potter (1981), Heufelder and Fuiman (1982).

Notropis rubellus is darkly pigmented, with a sharply pointed snout. Pelvic buds develop anterior to the dorsal-fin origin and there are 9 to 11 anal-fin rays. Reference: Heufelder and Fuiman (1982).

A 15-mm *Notropis rubrifrons* (=*N. rubellus*) illustrated by Fish (1932) is probably misidentified (Heufelder and Fuiman 1982), based on the position of the pelvic fins as illustrated.

Hybognathus regius larvae are known from descriptions under the name of *H. nuchalis.* However, the northern populations sampled in those descriptive studies subsequently were assigned to *H. regius.* Larvae are virtually indistinguishable from *H. hankinsoni* (see Preanal Myomere Number) except for having fewer preanal myomeres. References: Raney (1939), Mansueti and Hardy (1967), Lippson and Moran (1974), Jones et al. (1978), Wang and Kernehan (1979).

Notropis ardens is very similar to *Notropis rubellus*; it is darkly pigmented and has a pointed snout. Pelvic buds form posterior to the dorsal-fin origin and 9 to 11 anal-fin rays develop. Reference: Loos and Fuiman (1978).

Notropis telescopus is not well known. Adults have 11 anal-fin rays which may be a useful character for older larvae. Reference: Loos and Fuiman (1978).

Scattered Breast Melanophores

When it occurs, a broad scatter of melanophores develops on the breast between the heart and the preanal fin fold (Fig. 1) by the time of yolk absorption. The pigment along the base of the preanal fin fold may be in the form of a stripe or entirely lacking.

Notropis hudsonius and *N. dorsalis* possess the broad scatter of melanophores from the breast to anus, which fades and eventually disappears by the juvenile period. One illustration of *N. hudsonius* (Loos and Fuiman 1978) depicts a flattened eye, which would place this species in

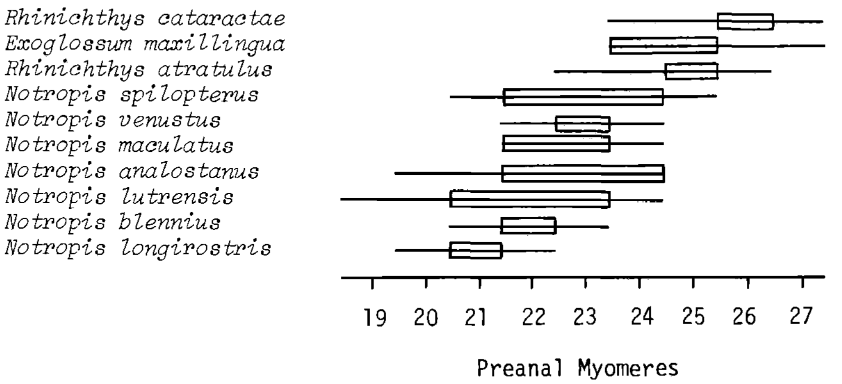

FIGURE 5.—*Preanal myomere distributions for cyprinid larvae with the outlined-gut pigment pattern. Lines are ranges; boxes enclose common values.*

a different group according to our scheme; however, numerous other published figures do not support this illustration. *Notropis hudsonius* has 22–25 preanal myomeres, usually 23–25. *Notropis dorsalis* develops a prominent melanophore in the nasal pit by about 7 mm and has 20–22 preanal myomeres, usually 21 or 22. References: *N. hudsonius*—Lippson and Moran (1974), Jones et al. (1978), Loos and Fuiman (1978), Loos et al. (1979), Wang and Kernehan (1979), Heufelder and Fuiman (1982); *N. dorsalis*—Loos and Fuiman (1978), Perry and Menzel (1979).

Loos and Fuiman (1978) and Snyder and Douglas (1978) stated that Fish's (1932) description and illustration of a 5.0-mm *Notropis hudsonius* were incorrectly identified. This figure was reproduced by Mansueti and Hardy (1967). The body form and the presence of an oil globule suggest that the specimen may have been a percid. It is also possible that the 14.25-mm specimen (reproduced by Mansueti and Hardy 1967; Lippson and Moran 1974; Jones et al. 1978) was misidentified, based on the position and angle of the mouth as illustrated.

Notropis chalybaeus has a single dense stripe of melanophores on the dorsum, unlike the two parallel rows found in most other cyprinids. A dense caudal spot develops early (before 7.0 mm). Larvae are small (hatch, 2.3 mm; yolk absorption, about 3–4 mm; pelvic-bud formation, 9.2 mm) with only 19 or 20 preanal myomeres. References: Marshall (1947), Jones et al. (1978), Loos and Fuiman (1978).

Notropis leuciodus and *N. lutipinnis* are poorly known. They hatch between 4.4 and 5.1 mm. Pigment along the preanal fin fold is lacking. The anal fin ultimately contains 9 rays. Reference: Loos and Fuiman (1978).

Phoxinus oreas is also poorly known. It has several scattered melanophores on the venter of the breast. The pigment is less scattered than in the previous species of this group. Pigment along the preanal fin fold is lacking. Melanophores are aligned in diagonal rows along the myosepta. Reference: Loos et al. (1979).

Outlined Gut

Several species develop the ventrolateral stripe as described for the high-preanal-myomere group. When viewed from below, these stripes outline the visceral cavity (Fig. 1). Preanal myomere number may be of use within this group (Fig. 5).

Exoglossum maxillingua and two species of *Rhinichthys* are in this group. All are relatively larger than the other members (hatch, 5–6 mm; yolk absorption, 7–9 mm; pelvic-bud formation, 11–14 mm), have uniformly scattered dorsal pigment by 7 mm, and develop a frenum in late larval stages.

Exoglossum maxillingua tends to be more heavily pigmented than the *Rhinichthys* species. Prior to yolk absorption it develops a distinct caudal spot that nearly is separated from the midlateral stripe. The spot in both *Rhinichthys* species develops after yolk absorption as a widening of the midlateral stripe. Later, *E. maxillingua* develops pelvic buds below the dorsal-fin origin (*Rhinichthys* species develop them anteriorly) and lacks maxillary barbels (*Rhinichthys* species develop small barbels). References: Fuiman and Loos (1978), Loos et al. (1979), Buynak and Mohr (1980a).

Rhinichthys atratulus and *R. cataractae* are very similar to one another. The former tends to have 25 preanal myomeres, the latter 26. *Rhinichthys cataractae* develops a subterminal to inferior mouth in the latter half of the larval period, whereas *R. atratulus* has a terminal mouth. A broad midlateral stripe develops by 9 mm in *R. atratulus* and the caudal spot extends into the caudal fin. In the congener, the broad stripe forms later (about 15 mm) and the spot is almost confined to the peduncle. Dorsal pigmentation extends laterally to the midlateral stripe on *R. cataractae,* but does not reach the stripe on *R. atratulus.* References: *R. atratulus*—Fish (1932), Bartnik (1970), Fuiman and Loos (1977), Buynak and Mohr (1979a), Loos et al. (1979), Wang and Kernehan (1979); *R. cataractae*—Fish (1932), Bartnik (1970), Fuiman and Loos (1977), Buynak and Mohr (1979a), Loos et al. (1979), Cooper (1980).

Bartnik (1970) and Fuiman and Loos (1977) discussed characteristics of *Rhinichthys atratulus meleagris,* a subspecies occurring west of the Appalachian Mountains; other descriptions deal with the eastern form *R. a. atratulus.* Characteristics of these subspecies had little effect on the characters used for separating the species from *R. cataractae.* A comparison of the two subspecies showed a few pigmentary differences (Fuiman and Loos 1977). An illustration of a 13.7-mm *R. cataractae* (Fish 1932) has the characters of *R. atratulus,* as described by more recent studies, and, therefore, may be misidentified. Further, a preanal fin fold should have been present at that developmental stage, regardless of the species. It was probably inadvertently neglected by the artist.

Notropis spilopterus and *N. analostanus* are small (hatch, 4–5 mm; yolk absorption, about 6 mm; pelvic-bud formation, about 9.3 mm). The outlined gut develops early but may fade late in the larval period. Dorsal pigmentation is particularly sparse. A broad, but light, midlateral stripe without a caudal spot develops on juveniles. References: *N. spilopterus*—Hogue et al. (1976), Snyder et al. (1977), Loos and Fuiman (1978), Heufelder and Fuiman (1982); *N. analostanus*—Stone (1940), Mansueti and Hardy (1967), Lippson and Moran (1974), Jones et al. (1978), Loos and Fuiman (1978).

Notropis lutrensis and *N. venustus* occasionally develop a short midventral row of melanophores in the heart region to complement the outlined gut pattern. Larvae are small (hatch, 4–5 mm; yolk absorption, about 5.0 mm; pelvic-bud formation, 8–9 mm). *Notropis venustus* develops a caudal spot from the time pelvic buds appear. In the lower Mississippi River, *N. venustus* tends to have one or two more preanal myomeres than *N. lutrensis* (JVC). References: *N. lutrensis*—Saksena (1962), Taber (1969), Loos and Fuiman (1978), Perry and Menzel (1979), Snyder (1981); *N. venustus*—Taber (1969).

Notropis maculatus has the outlined-gut pattern but the ventrolateral lines are incomplete. The snout is attenuate and the large mouth is terminal. Late larvae develop a narrow midlateral stripe and a prominent caudal spot. Reference: Millard (1981).

Notropis procne develops an outlined-gut pattern after caudal fin-ray formation and is somewhat similar to *N. hudsonius* at this time. A few melanophores may develop midventrally anterior to the preanal fin fold. Internal melanophores form chevron-shaped patterns along the notochord that are not found in *N. hudsonius.* Only seven anal-fin rays develop. Reference: Loos and Fuiman (1978).

Although undescribed as larvae, *Notropis blennius* and *N. longirostris* are known in sufficient detail to assign them to this group. They ultimately develop seven anal-fin rays and larvae are qualitatively alike. Myomere counts differ (Fig. 5). They seldom are encountered together; the former is riverine and the latter prefers upland creeks (JVC). A single illustration of *N. blennius* is available (Conner et al. 1980).

Unassigned Species

Some details are known for larvae of a few species, but not enough to place them in the foregoing classification: *Campostoma oligolepis* (Heufelder and Fuiman 1982); *Leuciscus idus* (=*Idus melanotus,* Ryder 1887); *Notropis bifrenatus* (Harrington 1947); *Notropis girardi* (Moore 1944); *Notropis leedsi* and *N. niveus* (Loos and Fuiman 1978); and *Scardinius erythrophthalmus* (Kazansky, cited in Berg 1949; Bracken and Kennedy 1967; Wheeler 1969).

Discussion

We caution again that these diagnoses are based on barely more than a third of the cyprinid species east of the Continental Divide. The larvae of some species among the 62 covered here remain poorly known. Our diagnostic criteria may falter as the remaining two-thirds of the species become known. However, the task of identification need not be based entirely upon morphological data. Distributions of many species discussed here, such as several of *Notropis,* do not overlap. Species with overlapping ranges may not be syntopic, thereby also eliminating comparisons. (This lack of syntopy may need to be demonstrated for larvae as well as adults.) Spawning season is an important clue to which larvae should be present at a given time and place. If two species have consecutive spawning seasons, the age of a larva (reflected by size, developmental stage, or otolith rings) is a useful character. Finally, adult characters, such as fin-ray number and fin position, can be applied to older larvae.

Morphological characters chosen here to separate groups of larvae were based upon their consistency and ease of application. Although these groups do not correspond to phyletic groups as defined by systematic schemes devised for the adults, all of the species grouped according to high relative preanal length are Eurasian introductions. Morphometric characters such as this have been of little value in larval-cyprinid taxonomy because of the difficulty in dealing with allometry in a practical fashion. Stable meristic characters are few in cyprinid larvae. Of these, myomere counts are taxonomically useful. The inclusion of caudal (postanal) myomeres may cause difficulties because their number may vary as a result of environmental factors or, in rare cases, posthatching development. However, total myomere number can be predicted from adults as total vertebra number (including four Weberian vertebrae) minus one (Fuiman 1982). Pigmentary characters can be valuable but one must recognize the great range of intensity to be found in these patterns. Wild-caught specimens are often pale, whereas laboratory-reared larvae are usually quite dark. Melanophore number in a certain area is seldom diagnostic as it is in some marine species. Gross patterns, such as preanal ventral pigmentation, appear to be consistent within species but may undergo ontogenetic changes, thereby rendering the patterns of transient importance. It is possible that dorsal pigmentation will be taxonomically useful. General larva size frequently is used in our diagnoses, based on size at three selected events (hatching, yolk absorption, and pelvic-bud formation). Many other events occur during development for which size is known and these data should be extracted from the literature for a more complete representation of general larval size. This type of character is often very useful but size has not been quantified for numerous stages of many species, and so detailed comparisons from the literature are difficult to make.

Descriptions of currently unknown larvae are needed for many purposes. Although larvae do not always form morphologically similar groups that correspond to established taxa (as demonstrated by Loos and Fuiman 1978), it is not unreasonable to expect some degree of diversity among genera. Larvae are unknown for three genera (*Dionda, Ericymba, Hemitremia*); they may be distinctive and thus important to a better understanding of the diversity of cyprinid larvae. A few species are quite common and have a widespread distribution (for example, *Hybognathus placitus, Notropis buchanani, N. heterolepis, N. umbratilis, Phoxinus erythrogaster, Semotilus margarita*), yet their larvae are unknown. Such common species should be described for more complete management of the communities in which they live. A few species (such as *Gila nigrescens, Hybopsis cahni, Notropis callitaenia,* and *Phoxinus cumberlandensis*) currently are endangered or threatened (Deacon et al. 1979). Descriptions of their larvae are necessary for proper analyses of reproductive success and early-life-history requirements; such analyses, in turn, are needed to support subsequent recovery of the species.

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