# Early development of central mudminnow *Umbra limi* (Kirtland)

J.K. Leslie and C.A. Timmins

Great Lakes Laboratory for Fisheries and Aquatic Sciences
867 Lakeshore Road
Burlington, Ontario L7R 4A6

1997

**Canadian Technical Report of Fisheries and Aquatic Sciences No. 2183**

Fisheries and Oceans Pêches et Océans

Canada

## Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1–456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457–714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715–924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

## Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 456 de cette série ont été publiés à titre de rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Technical Report of
Fisheies and Aquatic Sciences No. 2183

1997

# Early development of central mudminnow *Umbra limi* (Kirtland)

by

J.K. Leslie and C.A. Timmins

Department of Fisheries and Oceans
Great Lakes Laboratory for Fisheries and Aquatic Sciences
867 Lakeshore Road
Burlington, Ontario L7R 4A6

Cat. No. Fs 97-6/2183E ISSN 0706-6457

**Correct citation for this publication:**

**Leslie, J.K., and C.A. Timmins. 1997. Early development of central mudminnow *Umbra limi* (Kirtland). Can. Tech. Rept. Fish. Aquat. Sci. No. 2183**

## ABSTRACT

Leslie, J.K., and C.A. Timmins. 1997. Early development of central mudminnow *Umbra limi* (Kirtland). Can. Tech. Rept. Fish. Aquat. Sci. No. 2183.

Eggs of the central mudminnow *Umbra limi* were incubated and larvae reared in the laboratory. Additionally, small mesh (0.4 mm) beach seines and illuminated static traps were used to collect fish larvae in various locations in southern Ontario. Early development of the central mudminnow is described and compared with larvae of sympatric common carp *Cyprinus carpio* and grass pickerel *Esox americanus vermiculatus*. Eggs were pale yellow or amber and averaged 1.6 mm. in diameter .Embryos hatch at about 5 mm and have a stout body dominated by a large yolk sac containing numerous oil globules. Melanophores are especially evident on anterior epaxial myomeres. Larger larvae are characterized by a flexed urostyle, notched round caudal fin, deep caudal peduncle, and a dark bar at the base of the caudal fin. Central mudminnow larvae have 20-22 preanal and 12-15 postanal myomeres; preanal length is about 60%. The dorsal and anal fins are situated on the posterior third of the body. Squamation is first evident at about 12 mm and complete at about 20 mm, when the full complement of fin rays is acquired.



## RESUME

Leslie, J.K., and C. A. Timmins. 1997. Early development of central mudminnow *Umbra limi* (Kirtland). Can. Tech. Rept. Fish. Aquat. Sci. No. 2183.

Nous avons élevé en laboratoire des oeufs et des larves d'umbre de vase, *Umbra limi*. De plus, des sennes de plage à petit maillage (0,4 mm) et des pièges statiques éclairés on servi à prélever des larves de poissons à plusieurs endroits du sud de l'Ontario. Nous décrivons les premières phases du développement de l'umbre de vase et nous les comparons à celles de larves d'espèces sympatriques, la carpe, *Cyprinus carpio*, et le brochet vermiculé, *Esox americanus vermiculatus*. Les oeufs sont jaune pâle ou ambre et mesurent en moyenne 1,6 mm de diamètre. Les embryons éclosent à une taille d'environ 5 mm et possèdent un corps trapu surmonté par une grosse vésicule vitelline contenant de nombreux globules d'huile. Les mélanophores sont particulièrement évidents sur les myomères épaxiaux anterieurs. Les larves de grande taille se caractérisent par un urostyle recourbé, une nageoire caudale arrondie et échancrée, un pédoncule caudal haut et une barre sombre à la base de la nageoire caudale. Les larves d'umbre de vase possèdent 20-22 myomeres preanaux et 12-15 myomeres postanaux; la longueur préanale représente environ 60% de la longueur totale. Les nageoires dorsale et anale sont situées dans le tiers postérieur du corps. L'écaillure commence à apparaître vers 12 mm, et elle est complète à une longueur de 20 mm environ, étape où l'ensemble de nageoires rayonnées est acquis.

## INTRODUCTION

Class Osteichthyes
Subclass Neopterygii
Order Salmoniformes
Suborder Esocoidei
Family Umbridae
Genus ***Umbra***
Species ***limi*** Etymology: *Umbra*-dark *limi*-mud

The central mudminnow *Umbra limi* (Kirtland) is a small fish found in sheltered, densely vegetated areas of steams, ponds, and lakes. Its geographic distribution is extensive in Ontario south of the 46$^{th}$ parallel (Mandrak and Crossman 1992), but occurrence is not well known elsewhere in the province. Specific studies of adult fish have been published (see, for example, Gee 1980; Colgan and Silburt 1984; Paszkowski 1984; Martin-Bergmann and Gee 1985), however, its early development has been ignored, as will attest representative data on a single fish (25-mm) from Lake Erie (Fish 1932).

The present study intends to offer a more thorough description of central mudminnow by presenting morphologic, morphometric, meristic, and pigmentary characteristics of larvae and small juveniles. This information is needed in order to identify this species as well as improve knowledge of its life history and relationship with other fishes. In any case, the central mudminnow should be known simply because it has a role in our national heritage.

Several early developmental stages of the exotic common carp *Cyprinus carpio*, and native grass pickerel *Esox americanus vermiculatus* are compared with central mudminnow, because on occasion, these three species co-occur. Since they most resemble each other superficially in early ontogeny, their identification may be problematic. Descriptions employing to a large extent the so-called "static" approach (Berry and Richards 1973), are presented mainly for field workers who must identify fish larvae efficiently, and thus economically.

## METHODS

Central mudminnow adults (maximum length 135 mm) were obtained from various locations in southern Ontario from 1982 to 1997. In late April 1982 and 1984, adults were collected with a siene (3 m long, 1 m wide, 6 mm diamond mesh opening) on floodplains of Forty Mile Creek and Twenty Mile Creek, near Hamilton. Floodplain water temperatures at time of collection were 9-11°C. Eggs were fertilized *in situ*, and placed immediately in a 30-L aquarium, in which aerated water was kept at 11.0-13.5°C. Incubation proceeded in a darkened room at the Great Lakes Laboratory for Fisheries and Aquatic Sciences, Burlington. Larvae were removed in lots of 10-15 until all had died, about 100 h post-hatch. All fish were preserved with Davidson's B solution.

Descriptions of central mudminnow natural larvae are based on fish collected from mid-March (6°C) to mid-July (21°C), 1983 and 1984 at the St. Clair National Wildlife Centre (SCNWC), in southwestern Ontario (Leslie and Timmins 1990), Long Point (Lake Erie) in June-August, 1985 (Leslie and Timmins 1997), and Wainfleet Peat Bog drainage ditches, near Port Colborne, May-June, 1997. At SCNWC, fish were collected in wide-mouth glass jars (3.6-L) with an attached plastic funnel (6-mm aperture). These "activity" traps were set on the substrate amongst plant litter and macrophytes at a depth of ~1 m and illuminated with an automobile lamp suspended about 2 m from the surface of the water. Traps were placed in the water just after sunset and retrieved about 3 hr later. Co-occurring species of fish larvae included gizzard shad *Dorosoma cepedianum*, pumpkinseed *Lepomis gibbosus*, common carp, black crappie *Pomoxis nigromaculatus*, brook silverside *Labidesthes sicculus*, banded killifish *Fundulus diaphanus*, yellow perch *Perca flavescens, Ameiurus* spp., green sunfish *Lepomis cyanellus*, golden shiner *Notemigonus crysoleucas*, and spottail shiner *Notropis hudsonius*.

In Long Point, fish were collected with a larval fish beach seine (length 4 m, width 1 m, mesh opening 0.4 mm) in drainage ditches and shallow ponds. Sampling took place from June to October. All central mudminnows caught at Long Point were juveniles, 20-40 mm total length (TL). Co-occurring species included blackchin shiner *Notropis heterodon*, blacknose shiner *Notropis heterolepis*, brook silverside, bluntnose minnow *Pimephales notatus*, bluegill *Lepomis macrochirus*, pumpkinseed, grass pickerel,

Iowa darter *Etheostoma exile*, and tadpole madtom *Noturus gyrinus*. Fish in Wainfleet ditches were collected with a larval fish beach seine in dense *Cladophora, Elodea canadensis*, and sparse stands of *Potamogeton* sp. in water about 30 cm deep. Water in the ditches occupied a width of about 2 m; temperature ranged from 14°C to 22°C in mid-May to mid-June. Adult central mudminnows in Wainfleet ditches were 70-100 mm total length (TL), and co-occurred with their own larvae as well as those of golden shiner, brook stickleback *Culaea inconstans*, pumpkinseed, and juvenile goldfish *Carassius auratus*.

Illustrations of common carp were of fish collected in Hamilton Harbour in 1985 (Leslie and Timmins 1992) at 18°C and in Big Creek marsh, western Lake Erie in 1994 at 22-26°C. Fish were fixed with 10% formalin and transferred to Davidson's B solution within 3 mo. Measurements and illustrations of common carp follow procedures described above. Grass pickerel larvae were obtained from fish cultured in the laboratory in Burlington (Leslie and Gorrie 1985). Eggs were incubated at room temperature (23°C) in dimmed artificial light.

Linear measurements of the left side of body components were accurate to ±0.02 to 0.2 mm, depending on size of object observed, using a Wild M5 dissecting microscope. A *camera lucida* was used to assist with illustrations of specimens. Most measurements follow methods in Leslie et al. (1986). Additional measurements included predorsal length, i.e., the distance between tip of snout and origin of dorsal fin; greatest body depth, which is the maximum depth between dorsal and ventral surfaces, and dorsal and fin base lengths. Swim bladder length is the linear distance between anterior and posterior margins, as observed with transmitted light. Standard length is defined as the linear distance from tip of snout to definable hypurals, discernible in fish at about 10 mm TL. Preanal myomere counts included the deltoid-shaped, anterior-most segment, whereas postanal myomere counts excluded the final, incomplete segment, the precise location of which is usually uncertain.

## RESULTS

### DIAGNOSIS

As a rule, the type of littoral ecotone occupied by central mudminnow isolates this fish. In early spring, adult central mudminnows move from backwaters of streams or margins of lakes to reproduce in floodplains. Deposited eggs adhere to the remains of plants or new growth. In summer, these shallow areas become densely vegetated, stagnant, and in many cases, dry. Sheltered bays, ditches (e.g. Fig. 1), bogs, swamps, and coastal ponds, are usual nursery habitats for this species. Based on numerous searches for central mudminnow, we conclude that ecotones that have abundant submersed vascular plants and moving (although not necessarily flowing) water connected to larger sheltered bodies of water are basic requirements for spawning and nursery habitat.

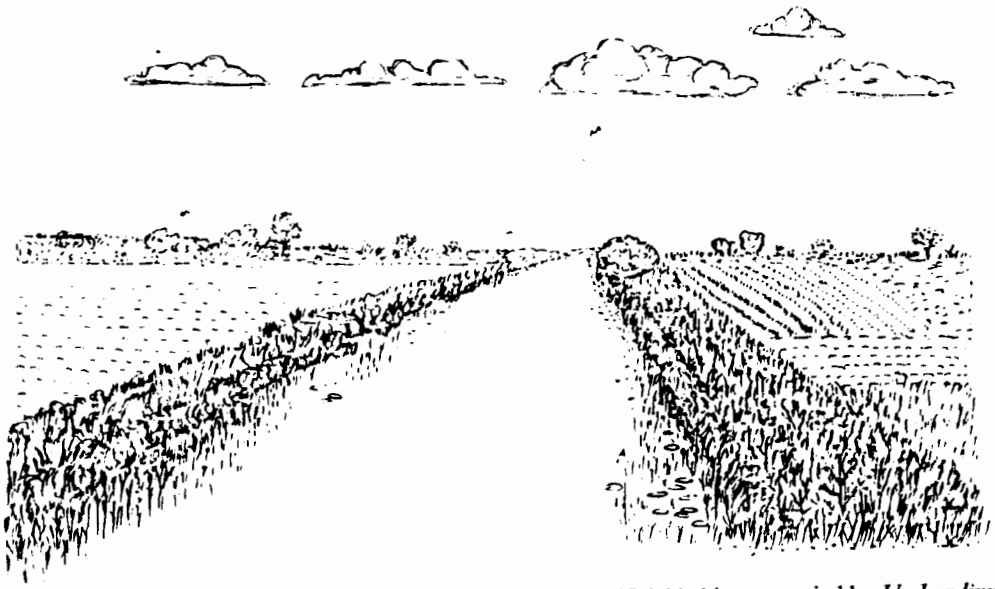

Figure 1. Drainage ditch in southern Ontario, showing artificial habitat occupied by *Umbra limi*.

Hatched larvae have a stout body dominated by a large oval yolk sac with numerous clusters of sub-surface oil globules. Preanal length is about 59% TL, and melanophores are dispersed over epaxial myotomes. Central mudminnows typically have 21 to 22 preanal, 13-15 postanal, and 34-37 total myomeres. Generally, larvae >9 mm have a medium-size head, short snout, large black eyes, and stout body; pigment is uniform on dorsal and lateral surfaces. A black bar at the distal margin of the caudal peduncle is characteristic of the species. There is a single swim bladder.

DESCRIPTIONS

## EGGS

Preserved, unfertilized eggs are slightly oval and light yellow. Mean diameter of mature eggs extruded from a 98-mm fish in Forty Mile Creek was 1.5 ± 0.09 mm (range = 1.3-1.6 mm; N = 131). A 60 mm-fish contained a total of 3482 eggs light amber in colour and whose mean diameter was 1.6 ± 0.19 mm (range = 1.4-1.7 mm; N = 85).

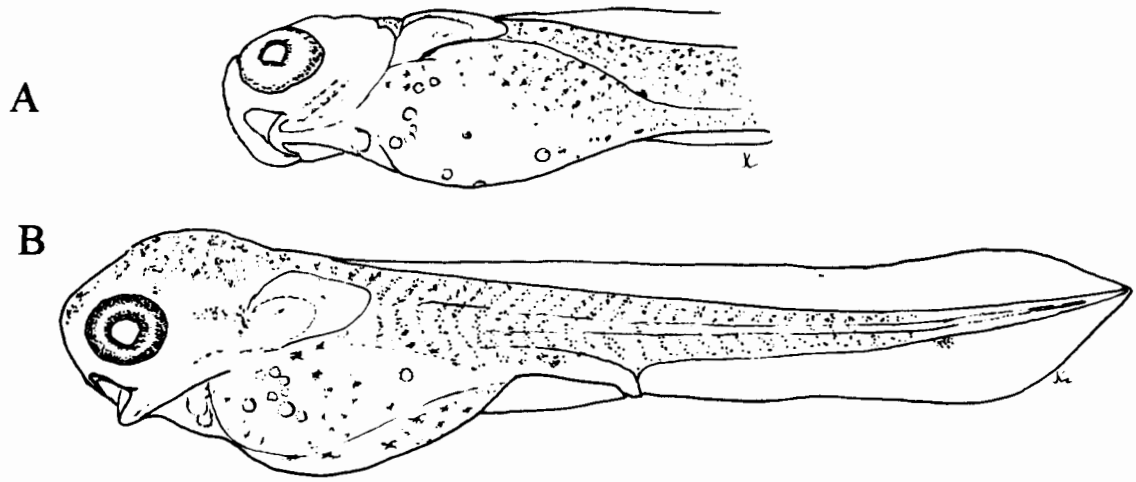


Figure 2. (A): anterior half of central mudminnow *Umbra limi* free embryo; (B): lateral aspect; both illustrated at 7 mm TL Fish reared in laboratory. Source: Forty Mile Creek (near Hamilton), 1986.

## SIZE CLASS 5-8 mm TL

**Morphology**: Large pale yellow yolk in smallest specimens (Fig. 2); remnant yolk present in some fish at 8-mm. Head deflected over yolk sac, mouth incomplete, agape; urostyle straight; fin fold circumbody, origin at first or second myomere, terminates near centre of yolk sac. Anus deflected downward; pectoral base prominent, fin short, fan-shaped; caudal fin ray single, incipient at 8 mm.

**Morphometry and meristics** (Table 1): Standard length and total length equal. Yolk sac length 28% TL. Diameter of largest oil globule approximately 0.2 mm. Pectoral fin length 0.7 mm. Embryos have 20-22 preanal and 14-15 postanal myomeres.

**Pigmentation**: Eyes dark brown, snout and occiput pigmented lightly; minute, stellate melanophores scattered laterally from head to caudal peduncle. Punctate melanophores on much of yolk sac, except ventral surface. Body-length mid-dorsal stripe unpigmented. Margin of anterior epaxial myomeres vaguely outlined by melanophores

## SIZE CLASS 9-13 mm TL

Length 8.5 mm

**Morphology**: Mouth terminal, complete; teeth small, evident more on upper than lower jaw; lower jaw projects slightly; maxillary extends to anterior margin of orbit. Branchiostegal rays observed (with transmitted light), incomplete; gut coiled. Urostyle straight, hypurals barely discernible, incipient rays (4) ventrad of caudal fin fold.

**Morphometry and meristics** (refer Table 1): At 8.5 mm - preanal length 56% TL; head 22% TL; eye diameter 9% TL (32% HL); greatest body depth 17% TL; swim bladder 14% TL; peduncle depth 3% TL. Myomeres: preanal 21-22, postanal 13. Length 9.5-10.0 mm - swim bladder 12% TL; caudal fin rays 5, incipient. 11.8 mm - preanal length 59%, snout 22% HL, pectoral fin length 1.3 mm, pelvic buds 0.6 mm.

**Pigmentation**: Melanophores dense over most of snout, premaxillary; occiput densely-pigmented; sub-surface stripe commences at posterior margin of orbit, extends upward to swim bladder. In some specimens, margin of first 10-11 preanal myomeres delineated by series of 5-8 punctate melanophores. Pectoral fin base, gut, and most of intestine unpigmented; body pigmentation otherwise diffuse. Dark spot at posterior margin of anus and centre of caudal fin base; unpigmented median stripe from nape to caudal peduncle more obvious than at smaller sizes. Throat patch triangular; ventral of head typically sparsely pigmented, if at all. Most of ventral surface unpigmented. Fin fold unpigmented.

Length 12.3 mm

**Morphology**: Eyes situated slightly above centre-line of body. Dorsal fin fold origin near 6$^{th}$ preanal myomere, continuous to mid-gut. Urostyle flexed, forms notch on caudal fin; fin otherwise round. Incipient rays in pelvic fin. Scales on mid-body.

**Morphometry and meristics**: Standard length 85% TL; preanal 58%; head (HL) 29%; eye 10% TL or 33% HL; greatest body depth 19%; peduncle depth 8%; predorsal length 51-53% TL; ratio dorsal to anal fin base length 1.7-1.9. Branchiostegal rays 4-5. Myomeres: preanal 22, postanal 13. Fin rays: anal 7, dorsal 12, caudal 10, incomplete. Pelvic fin rays not developed; pectoral fin length 1.3 mm, rays not developed. At 13 mm (Fig. 3) - preanal 59%; predorsal length 52%; snout 17% HL; prepelvic length 47%.

Table 1. Morphometry and meristics for *Umbra limi* larvae collected in southern Ontario. Lengths expressed as percentage mean TL; N = number of specimens measured. In parentheses: modal value for meristics. N/A = not applicable; inc = incipient.

| Size class | 5-8 mm | 9-13 mm | 14-18 mm | 19-24 mm | 25-30 mm |
|---|---|---|---|---|---|
| N | 21 | 28 | 58 | 17 | 9 |
| Total length | 6.6 | 10.2 | 16.2 | 20.4 | 28.5 |
| Standard length | 100 | 100 | 85-100 | 83.4 | 80.4 |
| Preanal | 58.2 | 59.2 | 58.6 | 58.9 | 57.9 |
| Head | 16.9 | 25.5 | 27.7 | 27.1 | 26.6 |
| Eye | 8.8 | 8.7 | 8.5 | 7.7 | 7.1 |
| Predorsal | N/A | ~50 | 51.9 | 50.7 | 49.2 |
| >body depth | | 16.2 | 19.8 | 19.4 | 21.3 |
| Peduncle | | 4.0 | 9.4 | 9.9 | 11.0 |
| Myomeres | | | | | |
| Preanal | 20.8 (21) | 21.2 (21) | 21.1 (21) | 20.8 (21) | 20.8 (21) |
| Postanal | 14.2 (14) | 12.7 (13) | 12.4 (12) | 12.3 (12) | 12.4 (12) |
| Total | 34-36 | 33-35 | 33-35 | 32-35 | 32-34 |
| Fin rays | N/A | | | | |
| Dorsal | | ~6 (inc) | 12.4 (12) | 12.3 (12) | 12.6 (13) |
| Anal | | 3.5 (inc) | 7.0 (7) | 7.3 (7) | 6.8 (7) |
| Pectoral | | inc | 4.0 (0) | 13.4 (15) | 13.2 (13) |
| Pelvic | | inc | 2.8 (5) | 5.1 (5) | 6 |
| Caudal | | 7.5 (inc) | 10.3 (11) | 11.3 (11) | 11.8 (12) |

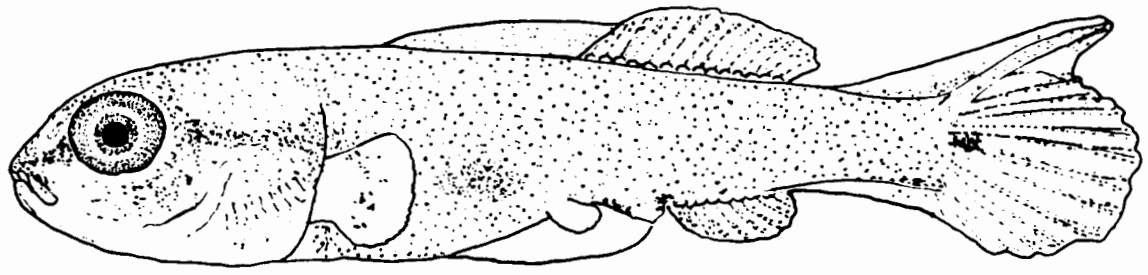

Figure 3. Lateral aspect of central mudminnow *Umbra limi* at 13 mm TL. Specimen collected at St. Clair National Wildlife marsh, Lake St. Clair, 1983.

**Pigmentation**: Minute spots scattered on snout, jaws, below and behind orbit. Several black "dashes" posterior of isthmus; pigment sparse on gut and venter. Dorsal body-length, clear stripe much diminished; melanophores concentrated on posterior margin of anus; margins of all fin rays pigmented.

Length 13.4 mm

General description: Full complement of rays in anal, dorsal fins; pectoral rays, 2-5; caudal fin ray complement incomplete. Dorsal stripe no longer evident.

## SIZE CLASS 14-18 mm

Length 15.1 mm

**Morphology**: Teeth villiform on both jaws. Lateral scales on most of body, head. Origin of pelvic fins precedes origin of dorsal fin; fin fold remnant continuous (or not) between dorsal fin insertion and caudal fin and between caudal and anal fins. Remnant fin fold obvious between mid-gut and anus. Hypurals formed. Full complement of rays in pelvic, caudal fins. Caudal fin notch much reduced, urostyle extension half length of homocercal fin .

**Morphometry and meristics**: Head length 26% eye 8% TL (30% HL); swim bladder 20% TL. Preanal and postanal myomeres as for 12.3 mm. Number of dorsal, anal fin rays as above; caudal fin rays 13, articulated; pelvic fin rays 6 incipient; pectoral fin rays 8, less developed than pelvic fin rays.

**Pigmentation:** Snout densely pigmented, suborbital blotch; cheek unpigmented. Main features: lateral body pigmented uniformly; posterior margin of anus darkly pigmented; dark bar on base of caudal fin. Melanophores outline scales; dorsum of head, nape darkly pigmented; no obvious pigmentation pattern on dorsum of body.

Length 17.0 mm

**Morphology**: Body fusiform (Fig. 4A); mouth terminal; jaws articulate below anterior margin of pupil; maxilla antrorse (Fig. 4B). Body scaled dorsally and laterally. Remnant of ventral fin fold prevails just before pelvic fin; dorsal fin fold absorbed. Origin of dorsal fin corresponds with pelvic fin insertion, whilst anal fin origin corresponds with centre of dorsal fin base. Depressed pelvic fins extend to anterior margin of anus. Caudal fin rounded, not obviously notched. Pelvic fin ray complement incomplete in some specimens.

**Morphometry and meristics** (Table 1): Standard length 84%; preanal length 59%; snout 15-18% HL; pectoral fin length 1.7 mm; peduncle depth 10% TL; predorsal length 53% TL. Ratio dorsal to anal fin base length, 2.0. Myomeres, preanal 20-22, postanal 11-13. Fin rays: dorsal 12 or 13; anal 7; caudal 13; pelvic 6; pectoral 10.

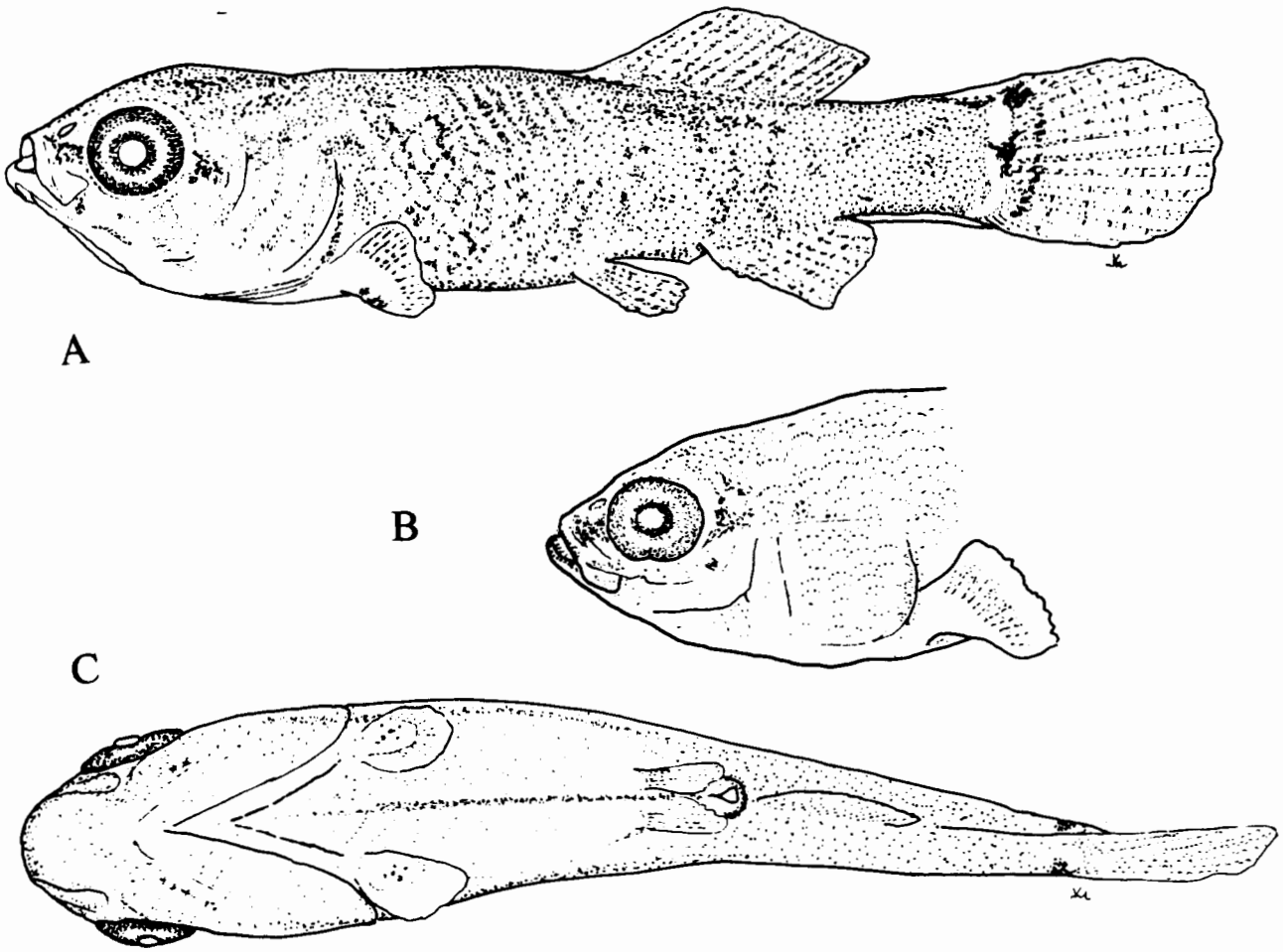


Figure 4. (A): lateral aspect of cental mudminnow *Umbra limi*, collected at Long Point, Lake Erie, 1985; (B): head and (C) ventral aspect of same specimen (17 mm TL).

**Pigmentation**: Melanophores concentrated between premaxillary and orbit. Lateral pigment dispersed over body, although slight disruptive pattern; scales outlined; dark-brown or black spot expanding on caudal peduncle (Fig. 4A). Interradials generally devoid of pigment. Head and body pigmentation more diffuse than in smaller fish. Pigment on snout and opercle forming vague stripe. Ventral series of sub-surface melanophores between base of pectoral fins and pelvic fins (Fig. 4C); melanophores diffuse between anus and caudal peduncle.

Table 2. Comparison of developmental events in *Umbra limi* and *Cyprinus carpio*.

| Event | Approximate total length (mm) *Umbra limi* | *Cyprinus carpio* |
|---|---|---|
| Hatch | 5 | 4-5(a) 3-6(c) |
| Cleithrum visible | 7 | 6(a) |
| Branchiostegals formed | 7 | 6(a) |
| Swim bladder inflated | 7 | 6(a) |
| Yolk completely absorbed | 8-9 | 6(a) 8(b) |
| Appearance of pelvic fin bud | 11 | 10-12(a) 10-15(c) |
| First hypural formed | 9 | 12-15 (a) |
| First fin rays caudal | 8 | 8(a) 6-8(c) |
| dorsal | 11 | 8(a) 11(c) |
| anal | 11 | 10(a) |
| pectoral | 10-14 | 10-11(a) |
| pelvic | 12 | 14(a) |
| All hypurals formed | 15 | 13(a) |
| Full complement of fin rays | | |
| caudal | 15 | 8-10(a) 18(b) |
| dorsal | 14 | 16(a) 21(b) |
| anal | 13-16 | 13(a) 21(b) |
| pectoral | 18-22 | 15(a) 13(b) 12-13 (c) |
| pelvic | 15-18 | 15(a) 21(b) |
| Postanal fin fold absorbed | 16 | 15(a) 21(b) |
| Preanal fin fold absorbed | 18 | 19(a) 21(b) |
| Squamation first evident | 12 | 18(a) 22(b) |
| Squamation complete | 21 | 21-25(a) 26-33(b) |

a: this study; b: McCrimmon and Swee (1967); c: Heufelder and Fuiman (1982).

## SIZE CLASS 19-24 mm TL

Length 21.0 mm

**Morphology:** Eyes large, situated in upper third of head; maxilla extends slightly beyond posterior margin of orbit. Pectoral fins fan-shaped, short; depressed pelvic fins extend to first ray of anal fin; dorsal fin rays more or less equal in length; anal, caudal fins round. Squamation increasingly developed on mid-lateral of body. Scales cycloid, pattern unique (Fig. 5).

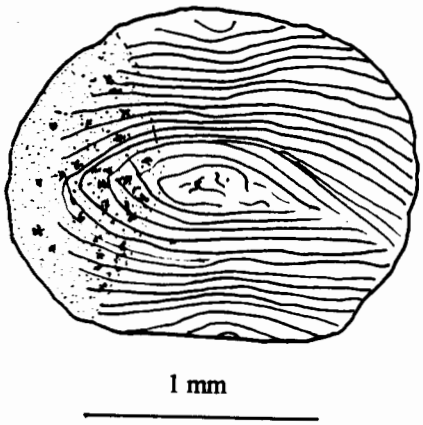


Figure 5. Central mudminnow (35 mm TL) scale, showing longitudinal circuli.

**Morphometry and meristics**: Standard length 82% TL; preanal length 57%, head 27%, eye 8% TL or 30% HL; snout 18% HL; predorsal length 49% TL; greatest body depth 17% TL; peduncle depth 10%; prepelvic length 46% TL; ratio dorsal to anal fin base, 1.9-2.0; pectoral fin length 2.0 mm; swim bladder 19% TL. Myomeres, preanal 20-22, postanal 12-13; fin rays: dorsal 12-13, anal 6-8, caudal 11-12, pelvic 5-6, pectoral 13-15.

**Pigmentation**: Two horizontal lines (vermiculated) extend from posterior margin of orbit to cleithrum; caudal bars: one distinct at posterior margin of peduncle, one less distinct near base of caudal fin rays. Dorsal pigmentation on scales progressively more diffuse posterior to head; mid-gut unpigmented, venter otherwise pigmented. Narrow, sub-surface series of melanophores between pectoral and pelvic fins.

## SIZE CLASS 25-30 mm TL

**Morphometry and meristics**: Standard length 76-82% TL; predorsal length 47-51%; snout 18% HL. Ratio dorsal to anal fin base length 2.0-2.2. Myomeres 20-21 preanal, 12-13 postanal; fin rays: dorsal 12-13, anal 6-7, caudal 11-13, pelvic 6, pectoral 13-14.

**Pigmentation**: Similar to adult stage; body colouration blended. Upper body darker than lower, notably on scales. Dorsal fins pigmented mainly along length of rays. Vague median stripe from nape to origin of dorsal fin.

## SIZE CLASS 35-40 mm TL

**Morphometry and meristics**: Predorsal length 49-52% TL. Ratio dorsal to anal fin base length, 2.0-2.3. Preanal myomeres 21-22, postanal myomeres 12; fin rays: dorsal 12-13 (articulated), anal 7 (8 articulated), caudal 12 branched + 5 unbranched, pelvic 5 articulated, pectoral 12-13 branched.

### *Cyprinus carpio*

Length 5-6 mm

**Morphology**: Head deflection slight over yolk sac; mouth open, incomplete; cleithrum visible; notochord straight; anterior swim bladder inflated at 6 mm. Orange-coloured yolk conspicuous in club-shaped yolk sac; fin fold present, irregular on some specimens; myomeres prominent.

**Morphometry and meristics**: Preanal length 67-71% TL (modally 69%); head length 16-22% TL (modally 21%); eye diameter 7-8 (modally 7%). Myomeres: preanal 25-26 (modally 26), postanal 11-13 (modally 12).

**Pigmentation:** Eye dark brown or black; series of melanophores extend from orbit to base of pectoral fin, then joins similar series on dorsal margin of intestine. These, and a band on anterior of yolk sac, form a horizontal fork, characteristic of the species (see Fig. 6). About 10-15 large melanophores on intestine; body length, uniform, widely-spaced melanophores. Pigment on distal margin of notochord. Several large melanophores on dorsum of head, not in pattern; two irregular lines of punctate melanophores extend from occiput to peduncle. Ventral region essentially unpigmented, except for series of discrete punctate melanophores from posterior margin of anus to peduncle.

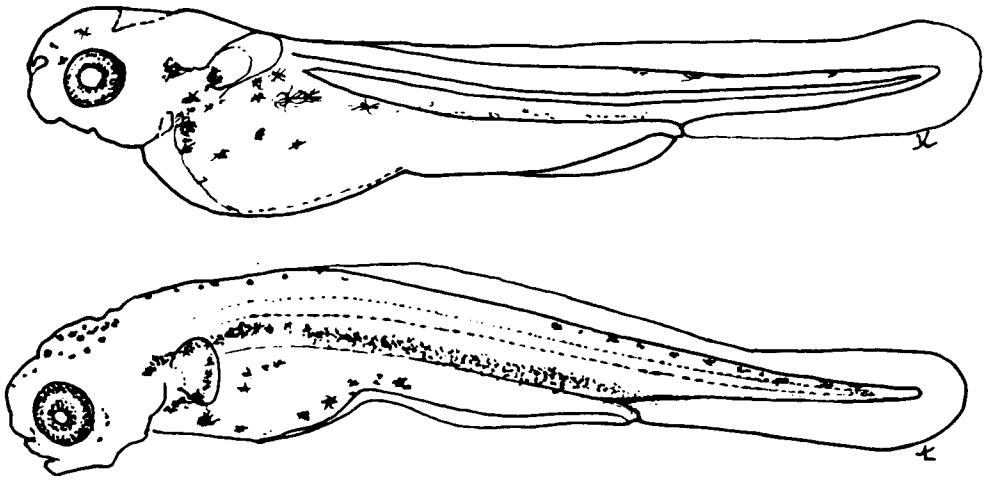

Figure 6. Lateral aspect of two common carp *Cyprinus carpio* at 5 mm TL. Natural fish collected in Michell Bay, Lake St. Clair, 1983 (upper figure). Natural fish (lower figure) collected in Holiday Beach, Lake Erie, 1994.

Length 10.0 mm

**Morphology**: Body large anterior to anus; eye situated above centre line of head; mouth oblique, terminates just anterior to margin of orbit; premaxillaries protracted, nares large. Notochord flexed. Dorsal fin fold originates 6$^{th}$ or 7$^{th}$ preanal myomere, continuous to mid-gut, irregular in outline.

**Morphometry and meristics**: (these, and following, lengths refer to percent TL or head length HL) Standard length 89-93%; preanal length 69-73%; snout 21-23% HL; head length 25-29%; eye diameter 7-9% (29% HL); peduncle depth 7%; swim bladder (2) lengths: anterior 7%; posterior 12%; greatest body depth 20%. Myomeres: preanal 26-28, postanal 10-12; incipient dorsal rays 7; caudal 19; anal 3 incipient; pectoral 2, incipient; pelvic, no rays.

**Pigmentation**: Melanophores diffuse on snout, postorbital, preopercle, base of pectoral fin. Hypaxial stellate melanophores dispersed over swim bladder, most of gut and intestine. Posterior half of intestine unpigmented. Margin of caudal fin rays pigmented. Mixture of large dark and small punctate melanophores prevail between occiput and dorsal fin. Venter of body anterior to anus unpigmented; venter posterior to anus covered with small punctate melanophores.

Length 13.0 mm

**Morphology**: Body stout anterior to anus, elongate posteriorly (Fig. 7); gut bulbous; caudal fin relatively large; corner of oblique mouth terminates below nare; dorsal and ventral fin fold remnant at caudal peduncle.

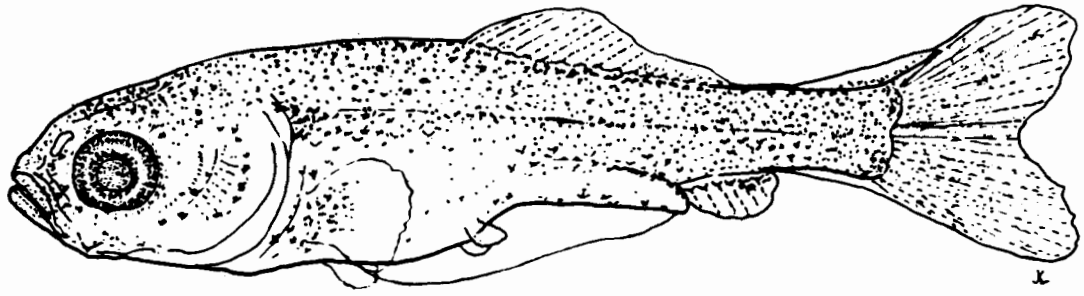

Figure 7. Lateral aspect of common carp *Cyprinus carpio* at 13 mm TL.
Natural specimen collected at St. Clair National Wildlife marsh, Lake St. Clair 1984.

**Morphometry and meristics**: Standard length 84-89%; preanal length 65-68%; predorsal length 43-46%; eye diameter 9% (32% HL); peduncle depth 8%; greatest body depth 22%; swim bladder lengths: anterior 9%, posterior 13%; pelvic buds 0.5 mm; snout to origin of ventral fin fold 32%. Myomeres: preanal 26-27, postanal 10-11. Fin ray complement: dorsal 13, incomplete; anal 5, incipient; caudal 19 (10 hypaxial, 9 epaxial), plus 2 procurrent each side; pectoral 5, incipient; pelvic, no rays.

**Pigmentation**: Dorsum of head pigmented; small melanophores on margins of rays of developing fins; caudal spot much reduced; large melanophores on nape becoming two irregular lines extending to dorsal fin. Head essentially unpigmented ventrally; series of spots diverging on each side of gut.

Length 17.0 mm

**Morphology**: Body robust, caudal peduncle increasingly deep, mouth terminal, posterior margin of maxillary extends to centre of nare (Fig. 8A, B); terminal barbel barely discernible; body scaled on anterior lateral line; anal fin small, pointed; origin of dorsal fin barely anterior to origin of pelvic fin; origin of anal fin slightly posterior of centre of dorsal fin base; trace of ventral fin fold between anus and pelvic fins; dorsal fin falcate; caudal fin large, fork deep; pectoral fin medium, tip round.

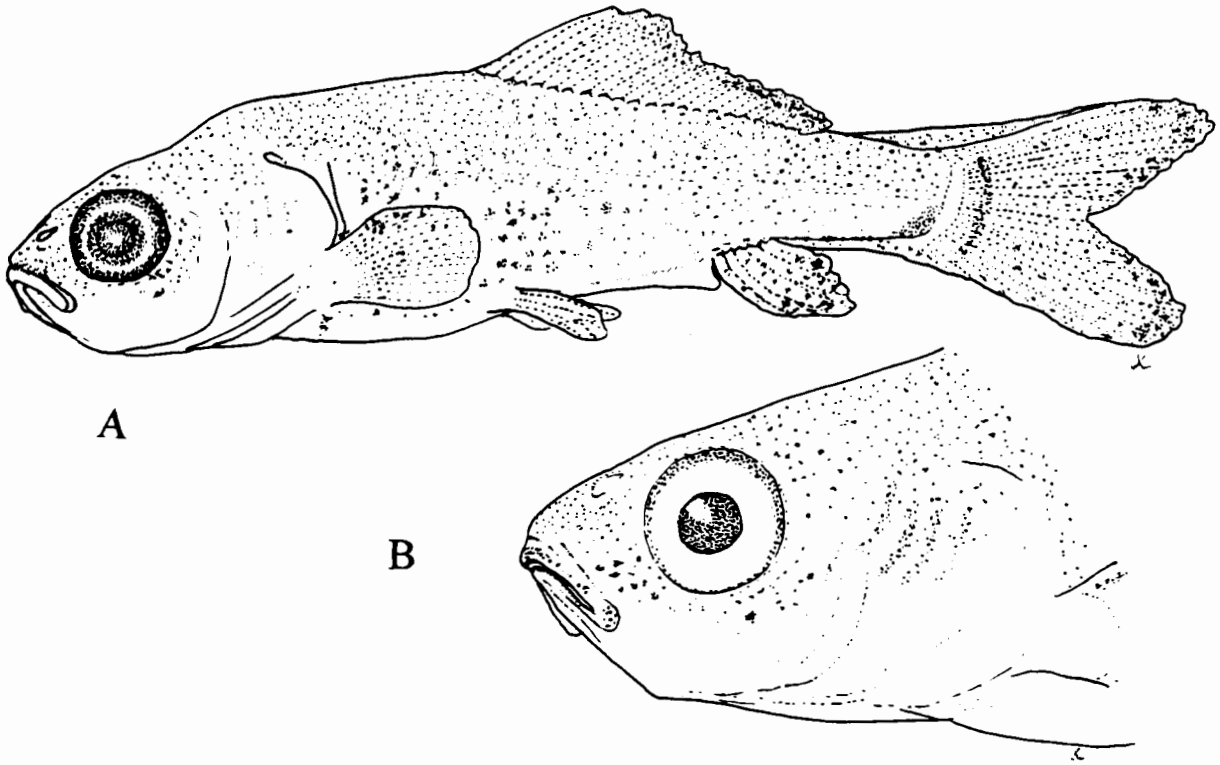


Figure 8. (A): lateral aspect; (B): head of common carp *Cyprinus carpio* at 17 mm TL, collected in western Lake Erie, 1994.

**Morphometry and meristics**: Standard length 79%; preanal length 61-63%; head 30%; eye 8% (28% HL); predorsal length 42%; peduncle 10%; greatest body depth 22%; snout 24% HL; branchiostegal rays 4 each side. Ratio dorsal to anal fin base length: 4.5. Myomeres, preanal 26-28, postanal 9-11; fin ray complement: dorsal 1 spine, 19 soft, anal 5 incomplete, caudal 19, pelvic 6, pectoral 14.

**Pigmentation**: Body slightly countershaded; snout pigmented uniformly; small stellate melanophores on maxilla and orbit; postorbit, epaxial body densely covered with small melanophores. Large sub-surface

stellate melanophores on intestine; slight concentration of melanophores at caudal fin base; dark sub-surface patch on ventral hypurals. Margin of scales pigmented. Dorsal fin rays darkest near distal margin; interradials of anal fin blotched; pelvic fins generally unpigmented; pectoral fins pigmented on dorsal margin. Dorsally, heart-shaped pattern present on snout, interorbit; occiput. Nape to caudal peduncle pigmented uniformly. Ventrally, head and gut to pelvic fin origin unpigmented; single series each side of anal fin, converge at caudal fin base.

Table 3. Basic characteristics for rapid taxonomic separation of YOY *Umbra limi* and *Cyprinus carpio*. Figures underlined indicate largest discrepancies.

| Total length (mm) | 5 | 10 | 13 | 17 |
|---|---|---|---|---|
| | | ***Umbra limi*** | | |
| Lengths (%TL) | | | | |
| standard | 100 | 85 | 85 | 85 |
| preanal | 60 | 61 | 59 | 59 |
| predorsal | | | 52 | 52 |
| Dorsal:anal fin base | | | 1.9 | 2.1 |
| Myomeres | | | | |
| Preanal | 20-22 | 21-22 | 22 | 20-22 |
| Postanal | 14-15 | 12-13 | 13 | 11-13 |
| | | ***Cyprinus carpio*** | | |
| Lengths (%TL) | | | | |
| standard | 96 | 85 | 84-89 | 79 |
| preanal | 69 | 69-73 | 65-69 | 61-63 |
| predorsal | | 46 | 43-46 | 43 |
| Dorsal:anal fin base | | | 3.8 | 4.5 |
| Myomeres | | | | |
| Preanal | 26 | 26-28 | 26-27 | 26-28 |
| Postanal | 12 | 10-12 | 10-11 | 9-11 |

*Esox americanus vermiculatus*

Length 6-8 mm (Fig. 9A)

**Morphology**: At 6 mm - head decurved over oval yolk sac; body elongate, slender, dominated by large yolk sac containing light-yellow yolk; notochord straight; paired adhesive glands immediately anterior to orbits. Fin fold (wide) origin at nape, circumbody, terminating near mid-yolk sac. Oil globules profuse, dispersed but clustered in groups of approximately 5, lateral, ventrad of yolk. Anus thin, decurved, extends to margin of fin fold. Eye with choroid fissure. Mouth incomplete. Pectoral fins formed. At 8 mm - head not decurved; cleithrum formed; gas bladder visible (transmitted light); mouth open.

**Morphometry and meristics**: At 6 mm - preanal length 68%, head 19%, yolk sac length 37%, eye 37% HL, pectoral fin length 0.4 mm. Myomeres 47: preanal 27-30 (modal 29), postanal 16-22 (modal 18).

**Pigmentation**: At 6 mm - eyes light-brown; punctate melanophores posterior of orbit, minute stellate melanophores scattered on head; small round spots and stellate melanophores on dorsum and lateral of body. Irregular stripe forming between body and dorsal margin of intestine; melanophores concentrated on posterior margin of anus, ventrad of caudal fin fold (Fig. 9A). This pattern increased in intensity at 8 mm. Intestine unpigmented ventrally.

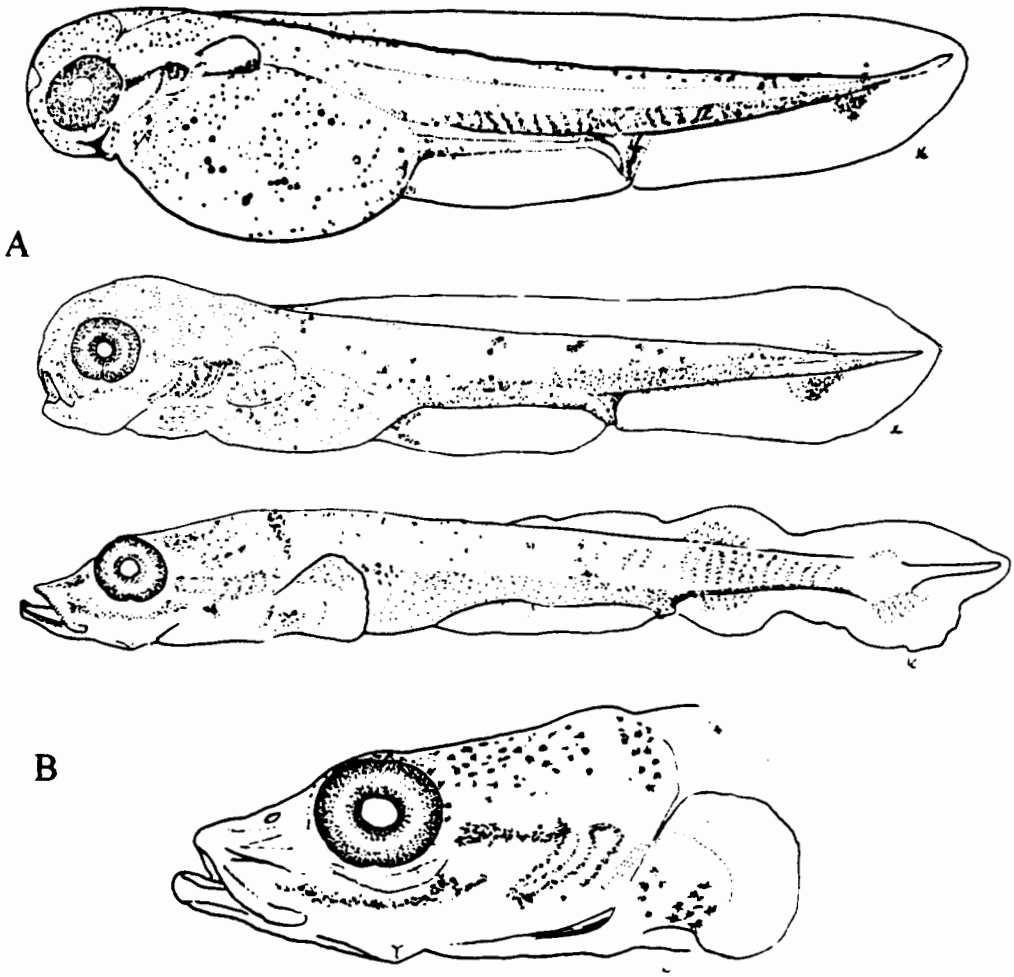




Figure 9. (A): lateral aspect of grass pickerel *Esox americanus vermiculatus* at 7 mm and 9 mm; (B): lateral and head at 13 mm TL.

Length 9-11 mm (Fig. 9)

**Morphology**: At 9 mm - yolk sac bi-lobed laterally; mouth large, terminal; eyes oval; gas bladder functional. At 10 mm - first feeding; lower jaw protruding, anterior to upper; yolk greatly reduced. At 11 mm - anal fin pterigiophores developing.

**Morphometry and meristics**: Standard length 98%; preanal length 65%; head 22-25%; eye 31-38% HL; pectoral fin length 1.0 mm. Myomeres 47: preanal 26-30 (modal 29), postanal 17-22 (modal 18). 11 mm - snout length 22-24% HL.

**Pigmentation**: Punctate melanophores on dorsum of head, head scarcely pigmented ventrally; gill arches, suborbitals light brown; hypaxial pigmentation intense (Fig. 9B), epaxial region lightly (or not) pigmented. Large stellate melanophores at base of pectoral fins.

Lengths 13 mm, 17 mm (Fig. 9B, Fig. 10)

**Morphology**: At 13 mm, larvae assuming general body form of adult, body elongate, snout pointed and slightly concave in profile. Fin fold present dorsally and ventrally, median fins forming (actinotrichia in dorsal and anal fins) on posterior third of body, hypurals forming, pelvic fin buds formed; jaws articulated below anterior of orbit; notochord straight. At 17 mm, head pointed, dominated by large eye ; body longitudinally compressed, "arrow"-shaped; ventral fin fold remnant between posterior of gut to anus, thence to caudal fin; dorsal fin fold remnant much reduced, exists anterior to dorsal fin; caudal fin notched on dorsal margin (Fig. 10).

**Morphometry and meristics**: At 13 mm, head 28%; eye 28% HL, caudal peduncle 4%. Myomeres: preanal 30, postanal 17. At 17 mm, preanal length 69-70%; prepelvic length 49-50%; predorsal 68-69%; ratio, dorsal fin base to anal fin base 1.2; head 28-31%; eye 24-26% HL; snout 30% HL; caudal peduncle 5%. Fin ray complement: dorsal 16 incipient, anal 13 incipient, caudal 19 incipient, 8 procurrent; pectoral not formed, pelvic 5-6 incipient.

**Pigmentation**: At 17 mm, dorsolateral stripe on snout, posterior margin of eye to cleithrum; suborbital stripe from anterior of orbit to preopercle; large sub-surface stellate melanophores on dorsum of gut, intestine; lateral of body otherwise covered with small dark spots. Dorsally, indefinite clear stripe extending from nape to caudal peduncle. Ventrally, body and intestine mainly pigment-free.

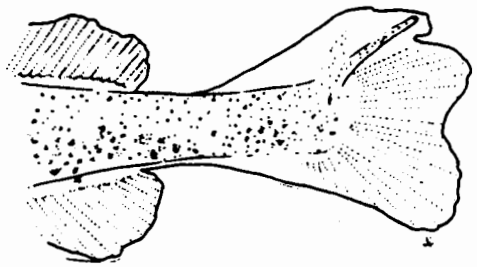

Figure 10. Caudal region of grass pickerel *Esox americanus vermiculatus* at 17 mm TL, showing remnant notched fin, typical of the Esocoidei in early ontogeny.

## DISCUSSION

The central mudminnow occurs in ecotopes tolerable to few fishes. Thus, problems in the identification of its larvae may be reduced in consideration of environmental cues (e.g., water quality, temperature, and habitat type utilized for spawning). Whereas identification of smallest stages may be problematic, fish larger than about 8 mm, or nearly twice hatch size, are quite distinctive. At this stage of development, the form of larvae of each species diverges, so that as organogenesis proceeds, various combinations of morphometric and pigmentary attributes taxonomically separate the central mudminnow.

Although size, form, and colour of central mudminnow eggs resemble those of numerous fishes, asynchronous temporal and spatial reproductive activities differentiate them from all but a few species. Spawning usually proceeds shortly after ice leaves in April or May and eggs are deposited on submersed or flooded vegetation. Separation of eggs of sympatric fishes (see "Methods") may be effected on the basis of differences in yolk colour, capsule diameter, and the number and size of oil globules. Eggs of small esocids, such as grass pickerel, co-occur with those of central mudminnow. However, esocid eggs are larger (1.6-2.5 mm), embryos densely-pigmented, and oil globules smaller, more clustered and numerous. Common carp and goldfish eggs most resemble those of central mudminnow. However, reproduction in these taxa usually takes place as much as one month later and embryonic development is correspondingly delayed.

General characteristics distinguishing recently-hatched central mudminnows from co-occurring larvae include a small head, dark eyes, large bulbous yolk sac, melanophores dispersed over the lateral surface of the body, and a postorbital patch and a caudal spot. There is also a narrow, unpigmented stripe extending from the nape to the caudal region. This stripe is also characteristic of grass pickerel. Due to similarity and overlap in numbers, myomere counts (21, 14 in central mudminnow) are not often useful for separating many fishes. In larger larvae, additional diagnostic attributes include high preanal length (~58% TL), predorsal and prepelvic lengths about 50% TL, pectoral fins situated low on the body, long dorsal fin base, flexed urostyle, round caudal fin, and deep caudal peduncle. The ratio of dorsal to anal fin base (ca. 2.0) in fish >20 mm is one of the largest in sympatric fishes.

This ratio is higher for common carp, goldfish, and bowfin *Amia calva* (>4.0), however, their anal and dorsal fin ray and myomere counts differ considerably. Notwithstanding these differences, bowfin larvae could be mistaken for central mudminnow on the basis of a similar robust body, deep caudal peduncle, flexed urostyle, and a round, notched caudal fin accentuated by a large, round, black spot. Development and persistence of a notochordal lobe is peculiar only to two other species in the study area: grass pickerel and longnose gar *Lepisosteus osseus*. The latter occupies a different ecotope niche and hatches later in the spring. In any case, larvae of central mudminnow and longnose gar do not resemble each other. Although grass pickerel larvae have an epaxially notched caudal fin (Fig. 10), an hypochordal notch is formed.

Prevailing differential and fragmentary data on central mudminnow larvae fosters uncertainty in identification of the species. For example, morphometry of 5-mm central mudminnow reported in Auer (1982) differs from Ontario fish in respect of preanal length ("just greater than 50%"), rather than 58% TL. A difference of >5% in this variable will induce doubt in the taxonomic separation of species of fish larvae.that are similar in body form and colouration. Length at first appearance of rays in fins is a key diagnostic character for separating fish larvae (Taubert 1977). An illustration of a 6.0-mm fish (Jones et al. 1978) indicates formation of initial incipient caudal rays as well as a lack of the full complement of preanal myomeres. Ontario fish did not develop rays before they were at least 8 mm.

The sequence of initiation and completion of fin ray development (pelvic precedes pectoral) in central mudminnow is the reverse of that in many littoral fishes. It is also the reverse of ray formation in the congenor pigmy mudminnow *Umbra pygmaea* (Martin 1984). Scott and Crossman (1973) noted urostylar deflection and extension in central mudminnow until 25 mm, effectively notching the caudal fin. Notching was not generally discernible in fish from southern Ontario at lengths >18 mm, although urostyle extension was observed in fish as long as 21 mm. In contrast to these anomalies and differences, Fish's (1932) description of a 25-mm specimen agrees with our observations in all respects.

Comparative developmental events in central mudminnow and common carp larvae separate these habitually sympatric species (Table 2, Table 3). Central mudminnow have at least five fewer preanal myomeres and shorter preanal length than common carp. Similarly, the ratio of dorsal to anal fin base length in common carp is twice that in central mudminnow. Initiation and completion of morphologic attributes differ in many respects (Table 2), especially with regard to initiation of squamation, length at loss of fin fold, and completion of full complement of fin rays. Squamation occurs in both central mudminnow and common carp at similar lengths (about 16 mm and 22 mm, respectively), but at different age. Full complement of rays in all fins (except pectoral) in central mudminnow are attained at smaller sizes than common carp (Table 2), although at about the same age. Also, the two species complete pectoral and pelvic ray complement in reverse order, i.e., in central mudminnow, rays in pectoral fins develop last.

During early development, central mudminnow and grass pickerel larvae resemble each other morphologically (compare Fig. 2B and Fig. 9A), as do the eastern mudminnow (*Umbra pygmaea*) and redfin pickerel *(Esox americanus americanus*) (Malloy and Martin (1982). Morphologic differences increase with length (e.g., Fig. 3 and Fig. 9B; Table 3). For example, at 14 mm, central mudminnow had developed median fins and initiated body scalation; the peduncle was twice the depth of grass pickerel, and snout length much shorter. Moreover, central mudminnow larvae have fewer (~10) myomeres, and pigmentation was more prominent epaxially, i.e., the reverse of the pigmentation pattern in grass pickerel.

## ACKNOWLEDGEMENTS

Thanks are due especially to J.Fraser Gorrie, who cultured progeny of central mudminnow, common carp, and grass pickerel. Steve King reared common carp and helped with field work, as did Lester Son Hing, Chris Blanche, James Moore, and Matthew Timmins. We thank Dr. R. Randall for his comments and those of an anonymous reviewer.

## REFERENCES


Auer, N.A. 1982. Family Umbridae, mudminnows, pp. 152-154. *In* N.A. Auer [ed.]. 1982. Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. Great Lakes Fishery Comm., Ann Arbor MI. Spec. Pub. 82-3: 744 p.

Berry, F.H., and W.J. Richards. 1973. Characters useful to the study of larval fishes, pp. 48-65. *In* A.L. Pacheco [ed.]. Proc. workshop on egg, larval, and juvenile stages of fishes in Atlantic coast estuaries. Tech. Publ. No. 1, NMFS Mid Atl. Coast Fish. Cent., Highlands, N.J. 338 pp.

Colgan, P., and B. Silburt. 1984. Feeding behaviour of the central mudminnow, *Umbra limi*, in the field and laboratory. Environ. Biol. Fishes 10: 209-214.

Fish, M.P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. U.S. Bur. Fish. Bull. 47: 293-398.

Gee, J.H. 1980. Respiratory patterns and anipredator responses in the central mudminnow, *Umbra limi*, a continuous facultative, air-breathing fish. Can. J. Zool. 58: 819-827.

Heufelder, G.R., and L.A. Fuiman. 1982. Family Cyprinidae, carps and minnows, pp. 174-344. *In* N.A. Auer [ed.]. 1982. Identification of larval fishes of Great Lakes basin with emphasis on the Lake Michigan drainage. Great Lakes Fishery Comm., Ann Arbor MI. Spec. Pub. 82-3: 744 p.

Jones, P.W., F.D. Martin and J.D. Hardy, Jr. 1978. Development of fishes of the mid-Atlantic bight. An atlas of egg, larval and juvenile stages. Vol. 1. Acipenseridae through Ictaluridae. U.S. Fish Wildl. Serv. FWS/OBS-78/1

Leslie, J.K., and J.F. Gorrie. 1985. Distinguishing features for separating protolarvae of three species of esocids. *In* Descriptions of early life history stages of selected fishes: from the 3rd International Symposium on the Early Life History of Fishes and 8th Annual Larval Fish Conference, May, 1984, Univ. British Columbia, Vancouver. Can. Tech. Rep. Fish. Aquat. Sci. 1359.

Leslie, J.K., J.L. Metcalfe, and K.M. Ralph. 1986. Early development of the common shiner, *Notropis cornutus* (Mitchill), in southern Ontario. Can. Tech. Rep. Fish. Aquat. Sci. 1455.

Leslie, J.K., and C.A. Timmins. 1990. The community of young fish in drainage ditches in southwestern Ontario. Arch. Hydrobiol. 118: 227-240.

Leslie, J.K., and C.A. Timmins. 1992. Distribution and abundance of larval fish in Hamilton Harbour, a severely degraded embayment of Lake Ontario. J. Great Lakes Res. 18: 700-702.

Leslie, J.K., and C.A. Timmins. 1997. Early life history of fishes in Long Point inner bay, Lake Erie. Can. Tech. Rept. Fish. Aquat. Sci. 2150.

Malloy, R., and F.D. Martin. 1982. Comparative development of redfin pickerel (*Esox americanus americanus*) and the eastern mudminnow (*Umbra pygmaea*). pp. 70-72. *In* Bryan, C.F., J.V.

Conner, and F.M. Truesdale (eds.), Fifth Ann. Larval Fish Conf., La. Coop. Fish. Res. Unit, Baton Rouge, La.

Mandrak, N.E., and E.J. Crossman. 1992. A checklist of Ontario freshwater fishes annotated with distribution maps. Royal Ontario Museum, Toronto. ISBN 0-88854-402-2.

Martin, F.D. 1984. Esocoidei: development and relations, pp. 140-141. In Moser, H.G., and W.J. Richards (eds.) Ontogeny and systematics of fishes. Spec. Publ. ASIH No. 1.

Martin-Bergmann, K.A., and J.H. Gee. 1985. The central mudminnow, *Umbra limi* (Kirtland), a habitat specialist and resource generalist. Can. J. Zool. 63: 1753-1764.

McCrimmon, H.R., and U.B. Swee. 1967. Scale formation as related to growth and development of young carp, *Cyprinus carpio* L. J. Fish. Res. Bd. Canada 24: 47-51.

Paszkowski, C.A. 1984. The foraging behavior of a generalist feeder, the central mudminnow (*Umbra limi*). Can. J. Zool. 62: 457-462.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. No. 184.

Taubert, B.D. 1977. Early development of the green sunfish *Lepomis cyanellus*, and its separation from other larval *Lepomis* species. Trans. Am. Fish. Soc. 106: 445-448.