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BURBOT - LARVAL EVIDENCE FOR MORE THAN ONE NORTH AMERICAN SPECIES

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ABSTRACT

Historically, the burbot of North America had been described as more than one species, but by the latter part of the 19th century all, including the Eurasian burbot, were generally recognized as one circumpolar holarctic species. During the last few decades, the burbot has been considered by some authorities to exist as three subspecies: Lota lota lota in Eurasia, L. l. leptura in eastern Siberia and northwestern North America, and L. l. lacustris (= maculosa) in central and northeastern North America. However, the more recent literature suggests that recognition of these subspecies may be unwarranted. Most systematic work to date has been restricted to adult forms, but we have dramatic evidence based on burbot larvae that, with further study, might lead to the recognition of more than one species, or subspecies, but not corresponding to the aforementioned subspecific designations. There appear to be two distinct larval forms. One is well pigmented with melanophores even as a late embryo and appears to be common to both Europe and North America. The other is without any melanophore pigmentation during the protolarval phase, except for the eyes and dorsal surface of the air bladder, and appears to be restricted to the lower Great Lakes and their tributaries.

INTRODUCTION

Lota lota, commonly known as the burbot, ling, lush, lake lawyer, metling, dogfish, eelpout, mother-of-eels, *etc.*, is the only freshwater member of the Gadidae or cod family (Figure 1). It is a circumpolar holarctic species typically inhabiting the depths of lakes and cooler rivers and streams. In North America it is found as far south as the

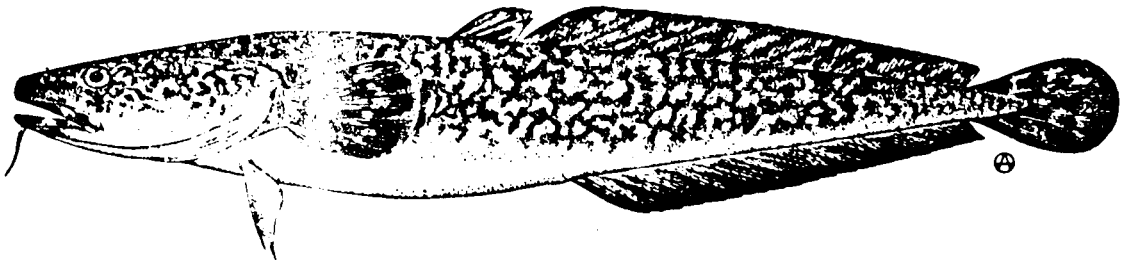

Figure 1. *Lota lota* a , 510 mm TL from Lake Opeonge, Ontario. Reproduced from Scott and Crossma 973, page 641.

Missouri and Ohio River systems. The species can be characterized as a relatively large, negatively phototropic, piscivorous carnivore. It is valued by many, when caught during the winter or in cold waters, for its firm, white, delicately flavored flesh (similar to lobster when boiled), and for the exceptionally rich Vitamin A and D content of its liver oil. (Baxter and Simon 1970, Clay 1975, Eddy and Underhill 1974, Hubbs and Lagler 1958), Lindsey 1956, Lo-Chai 1969, McPhail and Lindsey 1970, Moore 1917, Pflieger 1975, and Scott and Crossman 1973).

The burbot is most frequently reported to spawn at twilight or during the night from January to mid-April in the shallows of lakes, usually under ice, and to a lesser extent in streams. It is also suspected to spawn in the depths of lakes. The fish have been observed to spawn as individual pairs but more frequently in large, relatively dense, spawning aggregations, and occasionally in a very compact "withering ball" of about a dozen fish. During the spawning season large females may, based on fecundity studies, scatter more than a million eggs over gravel or sand substrates. The eggs are semibuoyant, clear with a large oil globule, and, when water hardened, typically measure 0.9 to 1.3 mm in diameter, with a with a reported range of 0.8 to 1.9 mm or more. Incubation requires about four to six weeks at 6 to 2 C (Bailey 1972, Baxter and Simon 1970, Bjorn 1939, Breder and Rosen 1966, Cahn 1936, Fabricius 1954, Hewson 1955, Lo-Chai 1969, McCrimmon 1959, McPhail and Lindsey 1970, Miller 1970, Prince and Halkett 1906, and Scott and Crossman 1973).

The young hatch as protolarvae (Snyder 1976) at about 3 to 4 mm total length (TL) and transform to the mesolarval phase at about 8 to 9 mm TL. Protolarvae and early mesolarvae are most readily identified by a large myomere count of about 55 to 65, 14 to 21 of which are preanal, and

a ventral finfold that continues unbroken below the vent region (Figures 2, 3, and 5). The earlier stages typically carry a large oil globule with the yolk, while later stages exhibit pelvic buds below or anterior to the pectoral fins and a bulky coil in the gut. Later mesolarvae, metalarvae and juveniles can be easily distinguished by a single medium chin barbel, a short first dorsal fin, long second dorsal and anal fins (over 60 rays each) which extend onto the caudal peduncle, and a proterocercal (diphycercal) caudal fin (Figure 4).

Historically, the burbot has been described as more than one species. LeSueur in 1817 described what he believed to be two species of burbot from the Connecticut River in Massachusetts. These were similar to but considered distinct from the European species. Additional descriptions and species designations followed but in 1862 Gunther concluded that all, including Old and New World forms, were indeed but one universal species. Thereafter it was generally accepted that only one species inhabited North America. But, since the American burbot differs in vertebra counts and predorsal lengths, not all ichthyologists agreed that the burbot should be considered one holarctic species. This difference of opinion was sustained well into the 20th century (Fish 1930). In 1941, Hubbs and Schultz, though recognizing one species, described and designated three subspecies: *Lota lota lota* of Eurasia, *L. l. leptura* of northwestern North America and eastern Siberia, and *L. l. maculosa* (*L. l. lacustris*, Speirs 1952) of central and eastern North America. Lo-Chai (1969) agreed with the designations. Differentiation was based on the shape of the caudal peduncle, predorsal length, and various meristic values. However, since these characters appear to be clinal with relatively broad areas of integradation,

Berg (1949) and Pivnicka (1970) considered *L. l. leptura* as a form of *L. l. lota* and Lindsey (1956), Lawler (1963), McPhail and Lindsey (1970), and Scott and Crossman (1973) considered recognition of any subspecies unwarranted without more intensive taxonomic study.

LARVAL EVIDENCE

Most systematic work to date has been restricted to the adult forms. But we have dramatic evidence based on burbot eggs and larvae that, with further study, might lead again t the recognition of more than one species, or at least subspecies, but not corresponding to the aforementioned subspecific designations. Fish (1930) recognized and pointed out the potential significance of this larval evidence, but the evidence seems to have been ignored. She found that the melanophore pigmentation of the eggs and larvae of the European burbot, as described by Sundevall (1855) and Ehrenbaum (1911), differed markedly from that of the American form. The late embryos and recently hatched protolarvae of the European burbot were described and illustrated as having considerable pigmentation along the dorsal surface of the head and body, over the dorsal surface of the gut, and on the lateral and ventral surfaces in the stomach or yolk region (Figure 2). Subsequent descriptions and illustrations of European protolarvae and mesolarvae by Nordqvist (1915) and Kasansky (1928) were similar but included additional pigmentation along the mid-ventral surface posterior to the vent. In contrast to the European larvae, Fish (1929, 1930 and 1932) found burbot protolarvae from Lake Erie to be totally without melanophore pigmentation except in the eyes and, in later protolarvae, over the air bladder (Figure 3). The only additional melanophores on a

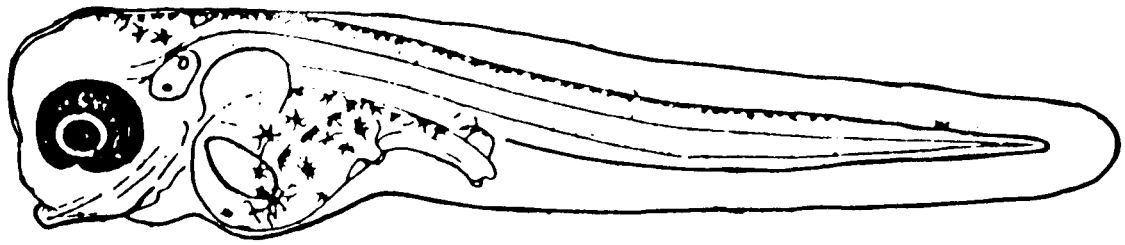

Figure 2. *Lota lota* protolarva, 5 mm TL from Europe. Reproduced from Ehrenbaum 1909, Figure 98, page 274.

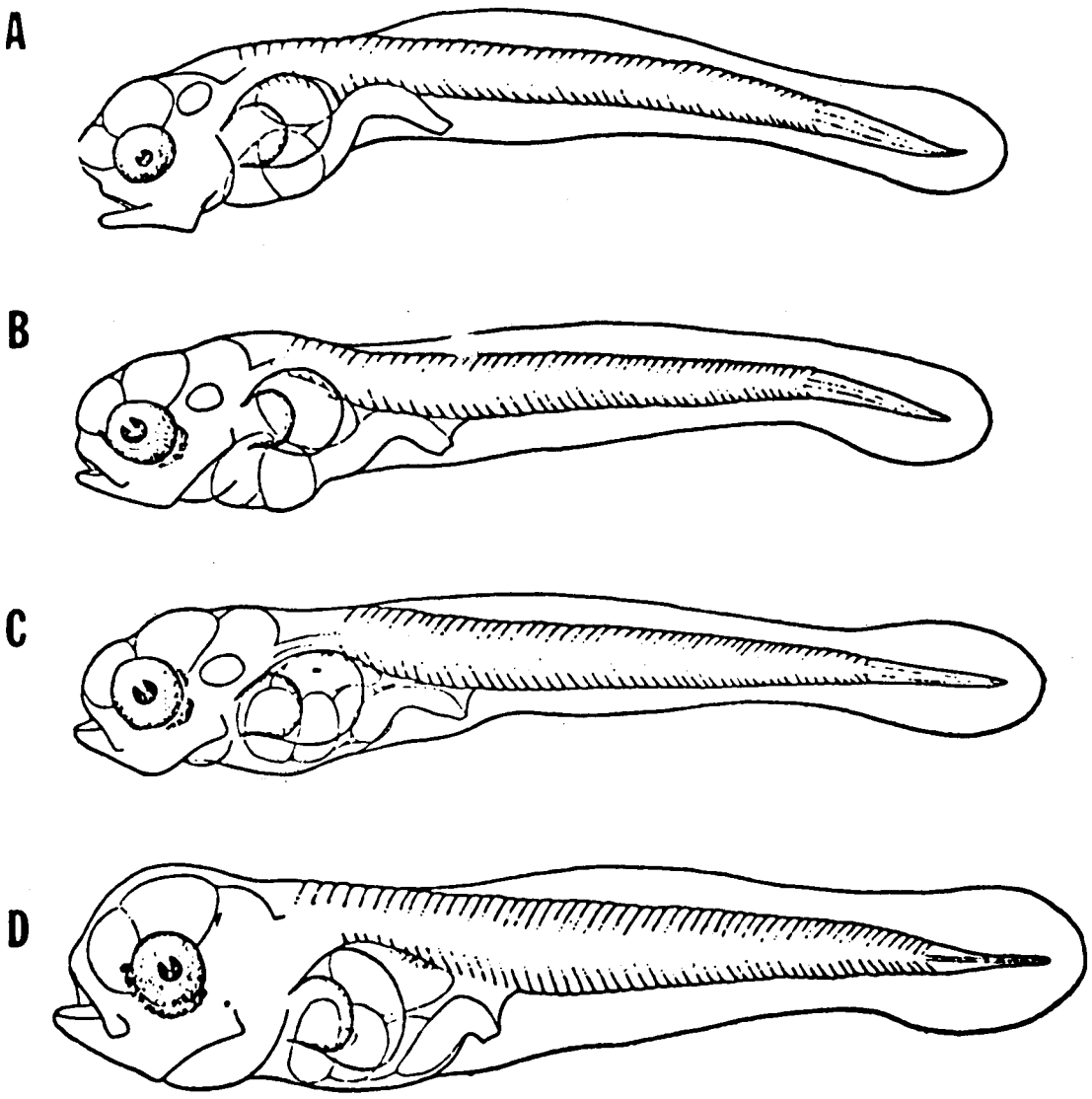

Figure 3. *Lota lota* protolarva, 3.5 (A), 4.5 (B), 6.0 (C), and 6.8 mm TL (D) from Lake Erie. Reproduced from Fish 1932, Figures 138-141, pages 393 and 394.

10.9 mm total length (TL) mesolarva were found on top of the head, followed by barely discernable subsurface pigmentation over the anterior portion of the notochord, and possibly continuing for its entire length (Figure 4). Melanophore pigmentation was considerable over the dorsal and lateral surfaces of 14- and 19-mm TL specimens, but Fish neither described nor illustrated pigmentation on the ventro-lateral and ventral surfaces. The ventral surface of a 30.5-mm TL specimen remained "unmarked except for a double series of about 20 chromatophores along the base of the anal fin." Fish apparently assumed th : the numerous Lake Erie specimens she examined were representative of the early developmental stages of all American burbot. This is not the case.

Other biologists working with larvae of the American burbot have either ignored pigmentation or failed to note it in published form. Faber (1967 and 1970) and Clady (1976) published on the distribution of burbot larvae in Wisconsin Lakes, Lake Huron and Oneida Lake, respectively, but neither described the larvae or mentioned pigmentation. Miller (1970) noted that burbot larvae he collected in Wyoming were comparable to those described by Fish from Lake Erie, but in a personal communication to me, he related that he failed to mention pigmentation and that melanophore distribution was similar to that illustrated in Figure 5. Grant Hagen provided several photographs of burbot eggs and larvae in 1952 in an unpublished report to the Wyoming Game and Fish Commission, "Ling hatching experiment, Cokeville." All were pigmented in a manner similar to that illustrated in Figure 5.

During the past few years, I have had an opportunity to examine cultered burbot embryos and protolarvae from Wyoming and collected protolarvae and

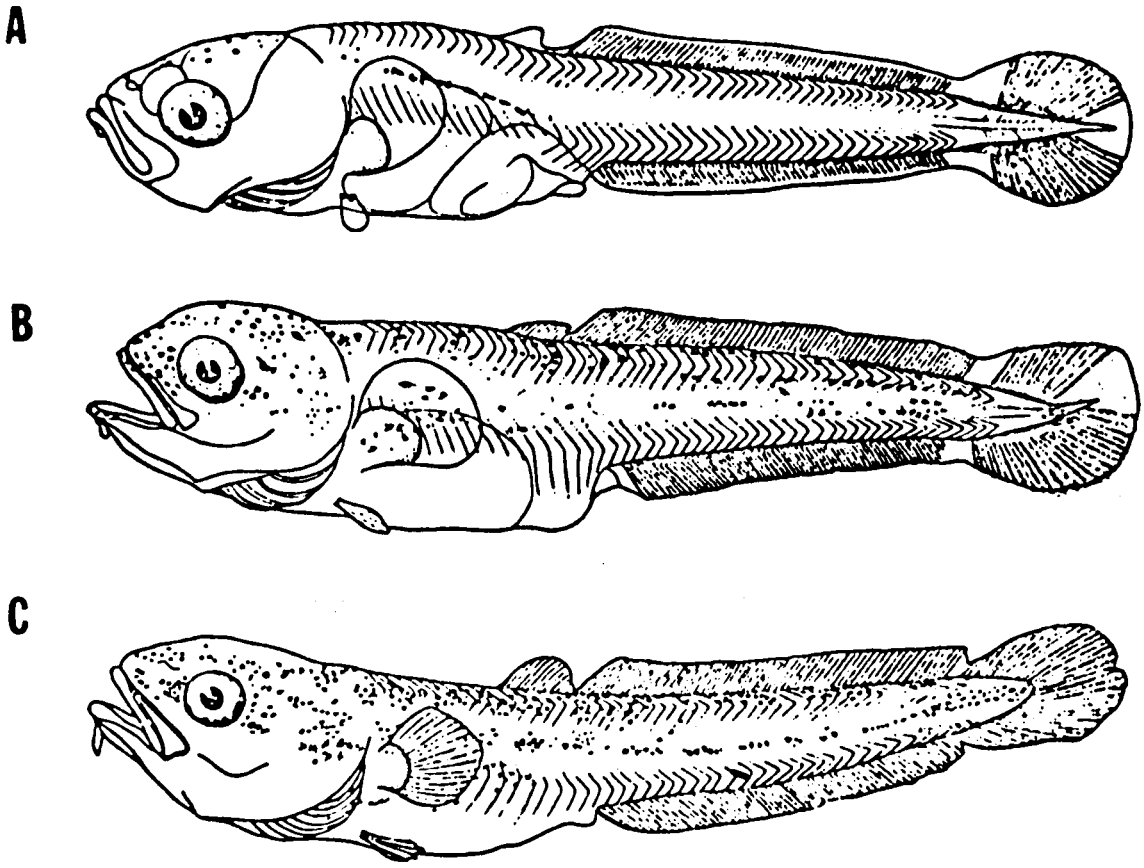

Figure 4. *Lota lota* mesolarvae, 10.9 (A) and 14 mm TL (B), and metalarva (?), 19 mm TL (C) from Lake Erie. Reproduced from Fish 1932, Figures 142-144, pages 395 and 396.

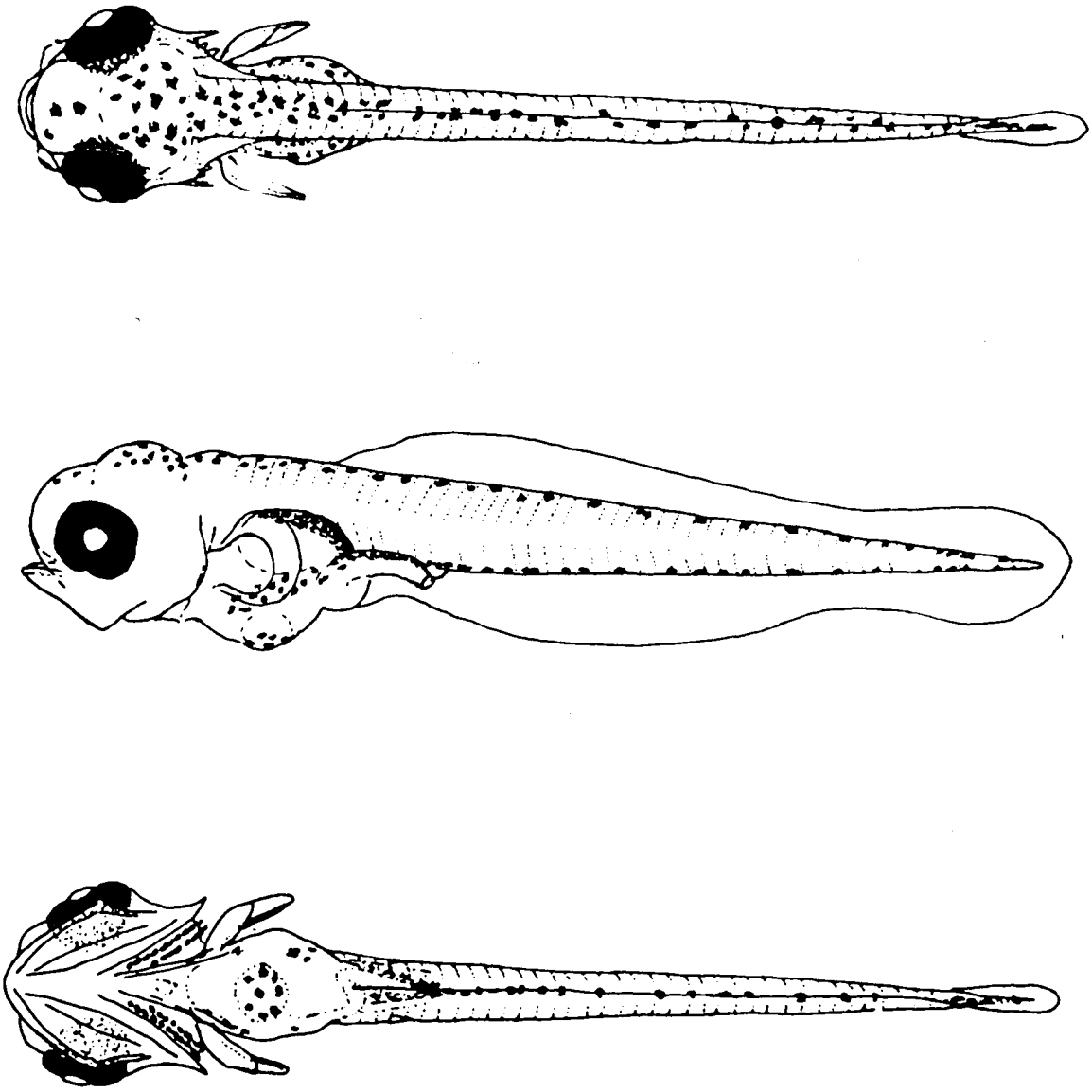

Figure 5. *Lota lota* protolarva, 4.7 mm TL from Mississippi River, Minnesota.

mesolarvae from the Missouri River in North Dakota, Mississippi River in Minnesota, Chippewa River in Wisconsin, Genessee River and Oneida Lake in New York, and Lakes Superior, Michigan, Erie, and Ontario. Of these, only a protolarva from the Lake Ontario tributary, the Genessee River, was of the unpigmented form described by Fish. All others were pigmented with most approximating the form of the upper Mississippi River protolarva illustrated in Figure 5 and described for the European burbot by Nordqvist (1915) and Kasansky (1928). Some exhibited reduced pigmentation on the ventral surface posterior to the vent, approaching the condition described and illustrated by Ehrenbaum (1905) (Figure 2). Pigmentation on recently collected specimens from Lake Erie was generally reduced to a state somewhat intermediate to the typical pigmented and unpigmented forms.

CONCLUSIONS

It appears that there are at least two distinct larval forms of burbot. One form is well pigmented, even as a late embryo, and appears to be common in Europe and North America (I have not yet seen larvae or descriptions of burbot from northwestern North America or the Soviet Union). The other form remains essentially unpigmented until well into the mesolarval phase and has been observed thus far only in Lake Erie and the Genessee River (tributary to Lake Ontario). Specimens recently collected in Lake Erie are somewhat intermediate.

Do the two extreme forms represent distinct species or subspecies? Are the recently collected "intermediate" specimens from Lake Erie a variation of the unpigmented form described for the Lake Erie burbot by Fish (1930)? Or do they represent hybridization between the two forms

and/or the near loss of the unpigmented form? Is the unpigmented form, apparently common throughout Lake Erie half a century ago, approaching extinction due to man's activities, as is (or was) the case for the blue pike (*Stizostedion vitreum glaucum*)?

Or do we simply have one species which exhibits unprecendented variation in embryonic and larval pigmentation? The larvae of the burbot's many marine relatives are often distinguished by relatively subtle differences in pigmentation (Hardy 1978).

To answer the above questions, and others, it will be necessary to examine many more larvae from throughout North America, Europe, and northern Asia, to study in detail other larval characters, and to try to correlate differences in the larvae with differences in the adults. Emphasis on the systematics of the burbot should focus immediately on both the adults and larvae in the Great Lakes region of North America. If there are two distinct genetic forms and one is restricted to the lower Great Lakes, we may lose the latter form to man-caused extinction before we know it exists.

ACKNOWLEDGEMENTS

I thank Ken Mueller, Northern States Power; Don Miller and Chuck Viox, Wyoming Fish and Game; Kathleen Hadley, BioSystems Research; John Dorr, Great Lakes Research Institute; Lee Fuiman, Cornell University; Vince Kranz, NUS Corporation; Steve Dennis, Stearns-Ruger; Ross Rasmussen, Texas Instruments; George Kandler, Swanson Environmental; and Tony Pekovitch and Daniel Patulski, Hazleton Environmental Sciences, for the loan or donation of study specimens or comments on the pigmentation of specimens they have encountered.

I also thank Dr. Robert Behnke, Dr. Clarence Carlson, Edmund Wick and Maryann Snyder, all of Colorado State University, for critically reviewing the manuscript.

ADDENDUM

At the end of this paper is a special form entitled "*Lota lota*, burbot. Contributed notes on early developmental stages." I am maintaining a file of these "notes" on larvae from all locations. Individuals who have collected burbot larvae and wish to contribute their observations should make photocopies of the blank form and supply as much of the requested information as possible. The sources of all information used in publications will of course be duly acknowledged.

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Lota lota, Burbot
Contributed notes on
early developmental stages

Please print clearly and use a separate photocopy of this form for each developmental phase (Snyder 1976) and/or general location.

Specimen Data

Developmental Phase:_____
Number:_____ Size Range:_____mm TL

If time permits, any of the following information for one or more specimens would be appreciated.

Lengths (mm)

Total	___	___	___
Standard	___	___	___
Snout (Sn)* to Eye*	___	___	___
Sn* to Pectoral bud or fin*	___	___	___
Sn* to Pelvic bud or fin*	___	___	___
Sn* to Dorsal finfold*	___	___	___
Sn* to Dorsal fin*	___	___	___
Sn* to Preanal finfold*	___	___	___
Sn* to Air bladder*	___	___	___
Sn* to Vent'	___	___	___
Eye	___	___	___
Yolk	___	___	___
Oil Globule	___	___	___
Pectoral bud or fin	___	___	___
Pelvic bud or fin	___	___	___

Body Depths (mm)

Posterior margin of eye"	___	___	___
Posterior margin of vent"	___	___	___

Myomeres

Preanal (as per Siefert '69)	___	___	___
Postanal	___	___	___

*origin or anterior margin.
'posterior margin.
"just posterior to, excluding finfold or fin.

(Place any additional notes on reverse side.)

Illust. typical pigmentation by completing the generalized drawings regardless of developmental stage. Atypical pigmentation should be illustrated on separate forms.

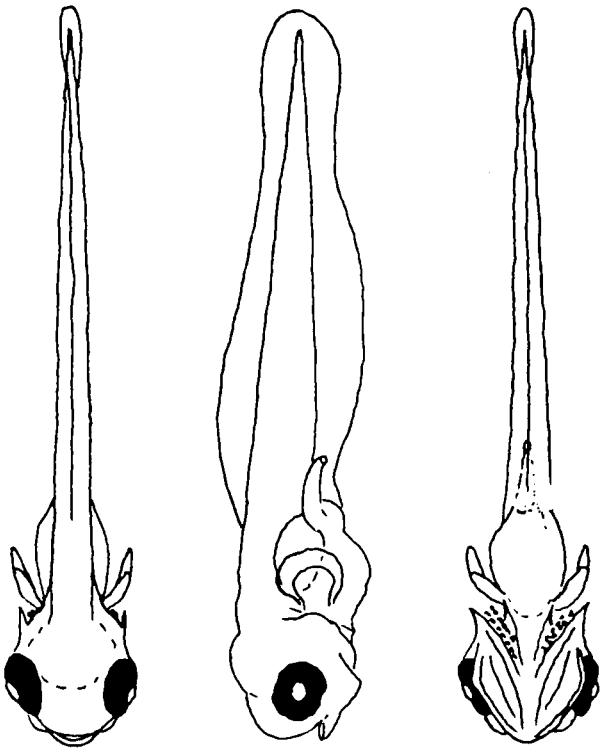
Collection Data

State:_____ County:_____
Body of water:_____

Specific location:_____

Distribution within study area:_____

Dates:_____
Water temperatures:_____



Contributor (Name, affiliation, address and phone):_____

Specimens available for study via loan (___) or donation (___).
Mail form(s) to above address c/o Darrel E. Snyder. Sources of data or specimens used for publication will be duly acknowledged.