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OFF-PRINT:

Snyder, D.E. 1980. Standardized format, counts, measures, and illustrations for a series of Larval Fish Identification Circulars (Abstract Only). Page 168 in L.A. Fuiman (ed.). Proceedings of the Fourth Annual Larval Fish Conference (Feb. 27-28, 1980; Univ. MS, Oxford). U.S. Fish. Wildl. Serv., Office Biol. Serv. FWS/OBS-80/43. 179 p.

STANDARDIZED FORMAT, COUNTS, MEASURES, AND ILLUSTRATIONS FOR A SERIES OF LARVAL FISH IDENTIFICATION CIRCULARS

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Abstract.- The Laboratory for the Identification and Study of North America's Freshwater Larval Fishes, otherwise known as the Larval Fish Laboratory, is planning the preparation and publication of a major series of larval fish identification circulars. The objective is to provide a standard format of standardized information for species accounts that con be utilized or prepared by any interested party. Since the same species accounts can be used in any and all appropriate regional guides, duplication of effort in preparation of larval descriptions will be minimized and the time and effort to assemble guides will be ultimately much reduced. As more species are covered, regional guides can be made more complete with respect to species coverage and expanded or combined for greater geographical coverage. Eventually, this accumulative approach could result in a guide to the freshwater fish larvae of North America and perhaps one or more for our coastal fishes as well. The circulars are designed for loose-leaf binding and intended to be updated as sufficient additional information becomes available, an activity in which all can participate.

The circulars consist of eight pages. Background information including general distribution, habitat, and reproduction is provided on the first page along with drawings of the adult and an egg with late embryo. Pages two and three provide brief descriptions by developmental period or phase and emphasize diagnostic characters. Eight sets of dorsal, lateral, and ventral view drawings, two for each larval phase and the early juveniles, occupy pages four and five. Page six consists of three tables of standardized data: the means and ranges of selected morphometrics and myomere counts summarized for each larval phase and the early juvenile, selected adult meristics, and sizes at apparent onset of selected developmental events. Morphometric length data in terms of percent standard length are graphed for a full range of individual specimens on transparencies associated with page seven. The use of transparencies allows data for one species to be lain over that for another for quick and easy comparison. The final page includes source citations, credits, acknowledgements, and perhaps additional space for user notes.

Unpublished Manuscript, 1982. Concept described is still being worked on but has yet to be realized, DES 6/11/83

8-page version LFL ID. CIR.

STANDARDIZED FORMAT, COUNTS, MEASURES AND ILLUSTRATIONS FOR A SERIES OF LARVAL FISH IDENTIFICATION CIRCULARS

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This manuscript represents the presented orally the abstract was published in the proceedings [illegible]

ABSTRACT

The Laboratory for the Identification and Study of North America's Freshwater Larval Fishes, otherwise known as the Larval Fish Laboratory of Colorado State University, is planning the preparation and publication of a series of larval fish identification circulars. The objective is to provide a standard format of standardized information for species accounts of the early developmental phases that can be utilized or prepared by any interested party. Since the same species accounts can be used in any and all appropriate regional guides, personal or publishable, duplication of effort in larval descriptions will be minimized and the time and effort to prepare a guide will ultimately be much reduced. As more species are covered, these initial regional guides can be made more comprehensive with respect to species coverage or expanded or combined for greater geographical coverage. Eventually we could have a *Guide to the Freshwater Fish Larvae of North America* and perhaps one or more for our coastal fishes as well. The circulars are designed for loose-leaf binding and intended to be up-dated as sufficient additional information becomes available -- an activity in which all can participate.

The format and information included in these circulars is still subject to some modification. Accordingly an incomplete prototype circular, a morphometric and meristic data form, and an explanation are provided for reader consideration.

The circulars consist of eight pages. Background information including general distribution, habitat and reproduction is provided on the first page along with drawings of the adult and an egg with late embryo. Pages two and three provide brief descriptions by developmental period or phase and emphasize diagnostic characters. Eight sets of dorsal, lateral and ventral view drawings, two for each larval phase and the early juveniles, occupy pages four and five. Page six consists of three tables of standardized data: the means and ranges of selected morphometrics and myomere counts summarized for each larval phase and the early juvenile, selected adult meristics, and sizes at apparent onset of selected developmental events. Morphometric length data in terms of percent standard length is graphed for a full range of individual specimens on transparencies associated with page seven. The use of transparencies allows data for one species to be layed over that for another for quick and easy comparison. The final page includes source citations, credits, acknowledgments, and perhaps space for user notes.

The Laboratory for the Identification and Study of North America's Freshwater Larval Fishes -- *alias* Larval Fish Laboratory, Colorado State University -- is planning the preparation and publication of a series of Larval Fish Identification Circulars. The first circulars produced will be part of a "Guide to the Cypriniform Fish Larvae of the Upper Colorado River System in Colorado," which should be finished this year. The objective in developing these circulars is to provide a standardized format for species accounts of the early developmental phases that can be utilized or prepared by anyone at any location, and that will be directly comparable to similar accounts on other species regardless of the author or authors. To assure peer review quality, the circulars would be reviewed by appropriate individuals, if possible by others familiar with the fish, then edited and published via the Larval Fish Laboratory, possibly in cooperation with the Early Life History Section of the American Fisheries Society and/or with other larval fish centers. Funds will be sought for this purpose.

Perhaps the major contribution of these circulars to work on fish eggs and larvae will be to facilitate the preparation of guides or keys, both personal and for publication. Since the same species accounts can be used in any and all appropriate regional guides, duplication of effort in larval descriptions and account preparation will be minimized and the time and effort to prepare a guide will ultimately be much reduced. As more species are covered, these initial regional guides can be made more comprehensive with respect to species coverage for the region or expanded or combined for a larger geographical area. Eventually we could have a Guide to the Freshwater Fish Larvae of North America, and perhaps one or more for our coastal fishes as well. It is recommended that major guides utilizing these circulars follow the basic layout suggested by Snyder (1976a). In many cases it might be useful to provide additional previously published illustrations as an appendix to individual circulars or

to the guide as a whole. Loose-leaf assemblage of these circulars, and the published guides which utilize them, will facilitate up-dating as sufficient additional information and corrections accumulate for the species covered.

The format and information included in these identification circulars is still subject to some modification. Accordingly, a prototype circular and a copy of the morphometric and meristic data forms currently used by the Larval Fish Laboratory are appended to this paper for consideration by all potential users. Comments and suggestions for improvement are solicited.

The first page of this eight-page circular is intended to provide general background information on taxonomy; size, weight, and age; current general distribution; habitat; and reproduction. The latter two sections should be particularly useful in delimiting the probable candidates for species identification, or in helping to acquire spawn or ripe adults for culture purposes. Most of the information on this page is summarized from the published literature with sources here and on subsequent pages denoted by superscripts and listed on the last or eighth page. Detailed regional distribution is relinquished to an appropriate section in the guides utilizing these circulars. All measures are reported in metric units. Illustrations on this first page include a generalized map of current North American distribution and drawings of a typical adult and egg with late embryo. Habitat includes separate subsections for the adult, juvenile and larval periods. Reproductive information includes reproductive guild as per Balon (1975), maturation in terms of both size and age, breeding colors and structures, fecundity, and more importantly summarizations of spawning season and temperatures, spawning areas and behavior, and incubation period.

Pages two and three include brief descriptions of the eggs and embryos, protolarvae, mesolarvae, metalarvae and early juveniles emphasizing potentially useful characters not presented or obvious in the subsequent illustrations,

tables, or graph. Also included are brief discussions of behavior, previous descriptions, and known diagnostic characters for distinguishing the species described from very similar or closely related species. Unused space, here, as elsewhere, is intended for user notes or future additions.

Since original publication by Snyder (1976b), the definitions for the larval phases used as a framework on these and subsequent pages (protolarva, mesolarva and metalarva), have not been strictly adhered to by all authors utilizing the terminology. In some cases this was due to a misunderstanding of the definitions. Accordingly, the definitions have been reworded and are appended to this paper. If a terminology is to be considered as a standard, the definitions should be understood and adhered to.

Pages four and five consist of eight sets of dorsal, lateral, and ventral view illustrations, one set for the beginning and middle of each larval phase, the beginning of the juvenile period and a later juvenile stage. Illustrations should be accurate and of high quality, otherwise they will be of limited use. Sharp, high quality photographs with sufficient depth of field and advantageous lighting can be used, but few have been published that are as good as quality drawings. If original drawings are to be used, it is recommended that they be constructed by a direct projection technique (e.g. camera lucida, or a micro-projector as described by Buynak and Mohr, 1977), or the tracing of photographs to assure proper proportions and position of structures. Details should be verified or completed while observing the specimen drawn under a low powered microscope. Specimens selected for drawings (or photographs) should be straight with open undamaged fins, and typical of the species in body form and size relative to developmental stage. Myomeres should be accurately illustrated for at least the protolarvae and mesolarvae. Fin rays should be accurately illustrated for all stages drawn. Drawings should emphasize typical pigmentation patterns based on the examination of numerous specimens. Significant

variation in pigmentation, whether for local populations or representative of regional differences should be discussed in the text on pages two and three. Drawings should be produced in a manner that will minimize potential confusion of pigmentation with shading or body and fin structure. Continuous tone drawings can be particularly effective in this respect, especially if use of black ink is restricted largely to melanophores. The latter approach is recommended; good examples of continuous tone drawings are provided by many authors -- scan Lippson and Moran (1974) or the recently published (1978), the multi-authored, six volume guide, *Development of Fishes of the Mid-Atlantic Bight*. Final drawings should be somewhat idealized to eliminate any specimen specific flaws. Both total length (TL) and standardized length (SL) should be given in the legend to each set of drawings.

Page six is composed of three tables of standardized data, much of which might have diagnostic value. The first table consists of the means ($\pm$ standard deviation) and ranges of selected morphometrics and myomere counts for each larval phase and the early juvenile. Table two summarizes adult meristics with whole unit mean or modal values underlined. The third table gives the ranges of sizes (nearest whole millimeter in both SL and TL) at the apparent onset of selected developmental events based on structures observable under low power magnification. Rare or questionable extremes in tables two and three are enclosed in parentheses.

Page seven is a graph of selected morphometric length data for a full size range of individual specimens up to about 45 mm SL. Most, but not all, of the data is included in the summarization table on the preceding page. In final form, the graph will be printed in separate parts on two transparencies allowing the data points for one species to be layed over those of another for direct comparison. Use of two rather than a single transparency allows the plotting of data for most characters with overlapping values to be segregated.

Graphing the characters as percent SL on the horizontal axis versus SL on the vertical axis allows the relative position of various structures for each individual specimen to be readily visualized with the tip of the snout at 0% and the posterior margin of the notochord or hypural plates at 100%. To avoid vertical overlap among data points, only data for one specimen within each half millimeter unit is plotted. If a choice of specimens is possible for any particular half millimeter interval, and one is confident of the data, the specimen with values deviating most from the norm should be selected to impart a sense of observed variation. Use of means and ranges for so many characters would make the graph too complicated to be used with ease.

Morphometric data in both the table and the graph is expressed as percent SL rather than TL to avoid the allometric influence of caudal fin growth. However, since SL in protolarvae and mesolarvae prior to sufficient hypural plate formation is actually notochord length and since the end of that notochord in most species flexs upward dramatically, usually early in the mesolarval phase, be aware that allometric differences in vicinity of this transition will appear greater than if a relatively unchanging point or structure were used consistently throughout early development. Such a point or structure has yet to be identified that can be applied universally to nearly all fish. For those requiring or preferring the data in terms of TL, conversion is readily accomplished by simply dividing the length of interest in terms of %SL by TL (AS to PC) in terms of %SL, and multiplying by 100 (i.e. 100 x X%/TL%). In the morphometric table, standard length is reported to the nearest tenth of a millimeter and the morphometric data to the nearest whole percentile. Greater resolution is unnecessary and may imply more precision in obtaining the original measurements than actually existed; measurements much finer than to nearest tenth of a millimeter may be difficult to repeat with any amount of consistency.

All but a few counts and measures included on pages six and seven are specified and defined on the back of the basic data form provided in the appendix. Most of these counts and measures are identical or correspond closely to those typically used in the taxonomic study of juvenile and adult fishes. However, there are some significant differences necessitated by measurement under a scope with ocular micrometer and the need for consistency. For example, all measurements except fin lengths are measured from one point of reference to another along a straight line parallel (lengths) or perpendicular (depths and widths) to the horizontal axis of the fish. Another example is head length which in juveniles and adults is typically measured to the posterior margin of the operculum, a structure which may be absent or incomplete throughout much of the larval period in some fishes. Accordingly, many larval fish biologists have redefined head length as the measurement from the tip of the snout to the posterior margin of the auditory vesicle, anterior or posterior margin of the cleithrum (Berry and Richards, 1973), or to the origin or anterior base of the pectoral fin or fin bud (OP1) (Snyder, et al. 1977). The latter closely corresponds to the ultimate posterior margin of the operculum in many fish, and is readily observed throughout all but perhaps the earliest larval stages of some fishes. Accordingly, it is used here for all larval and juvenile specimens (often most accurately measured from the dorsal or ventral perspective). To avoid unnecessary repetition of measurements, all lengths, except fins, are measured from the anterior margin of the anout to a specific structure. Values for commonly measured characters such as eye diameter, base lengths of dorsal and anal fins, and postanal lengths can be obtained by simple substraction. For purposes of comparability and consistency, depths and widths are measured at five precise locations rather than as greatest or least measures of the head, body or caudal peduncle. Any diagnostic measurements or counts

not included or obtainable from the data on pages six or seven, can be documented in the descriptive text on pages two or three. Many additional morphometrics can be approximated from the illustrations on pages four and five.

The basic morphometric and meristic data form used by the Larval Fish Laboratory (appendix), is provided as a model or for direct use (via photocopy) by other researchers. If possible, at least one specimen should be measured within each half millimeter length interval (SL) throughout the larval period, except possibly for species with exceptionally large larvae. Fewer specimens need to be measured for exceptionally large larvae or early juveniles. Space is sufficient in each of the nine columns to record actual measurements on the left side and percent SL on the right side, perhaps in a different color. Experienced technicians can complete all measurements and counts for one specimen in about 1/2 to 3/4 hr.

The final page of the identification circular includes source citations (literature and personal communications), credits, and acknowledgments. Literature with potentially useful illustrations of eggs and embryos, larvae, or early juveniles is identified with an asterisk. In the event that any section of text on pages one, two, or three requires more space than is allotted, those sections can be continued on this page. Any remaining space is for user notes.

Literature Cited

Balon, E. K. 1975. Reproductive guilds of fishes: a proposal and definition. J. Fish. Res. Board Can. 32(6):821-864.

Berry, F. H. and W. J. Richards. 1973. Characters useful to the study of larval fishes. Pages 48-65 in A. L. Pacheco (ed.). Proceedings of a workshop on egg, larval, and juvenile stages of fish in Atlantic coast estuaries. NMFS Middle Atlantic Coastal Fisheries Center, Tech. Publ. 1. 338 p.

Buynak, G. L. and H. W. Mohr, Jr. 1977. Micro-projector for drawing larval fishes. Progressive Fish Culturist 40(1):37-38.

Lippson, A. J. and R. L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River estuary. Martin Marietta Corp., Spec. Publ. PPSP-MP-13. 282 p.

Snyder, D. E. 1976a. Identification tools: what's available and what could be developed [Report of working group two]. Pages 88-96 in J. Boreman (ed.). Great Lakes fish egg and larvae identification: proceedings of a workshop. USFWS, OBS National Power Plant Team (Ann Arbor, Michigan), FWS/OBS - 76/23. 220 p.

Snyder, D. E. 1976b. Terminologies for intervals of larval fish development. Pages 41-58 in J. Boreman (ed.). Great Lakes fish egg and larvae identification: proceedings of a workshop. USFWS, OBS National Power Plant Team (Ann Arbor, Michigan), FWS/OBS - 76/23. 220 p.

Snyder, D. E., M. B. M. Snyder and S. C. Douglas. 1977. Identification of golden shiner, Notomigonus crysoleucas, spotfin shiner, Notropis spilopterus, and fathead minnow, Pimephales promelas, larvae. J. Fish. Res. Board Can. 34(9):1397-1409.

APPENDIX:

Prototype mockup of a typical Identification Circular. Pages 2 and 3, the descriptive text for the eggs and embryos, protolarvae, mesolarvae, metalarvae and early juveniles, and page 8, the source citations, credits and acknowledgments have not yet been prepared. Page 7 is a combined photocopy of two transparencies (7a and 7b) and the backing page (7c) less a fine grid for more precisely locating each point. Characters OPAF, ODF, OD, ID, P1 and D are plotted on transparency 7b and the remainder on 7a

. . .

Basic data form for recording morphometric and meristic data by the Larval Fish Laboratory. Also definitions of abbreviations and notes on procedure. Permission is granted to copy and use this form.

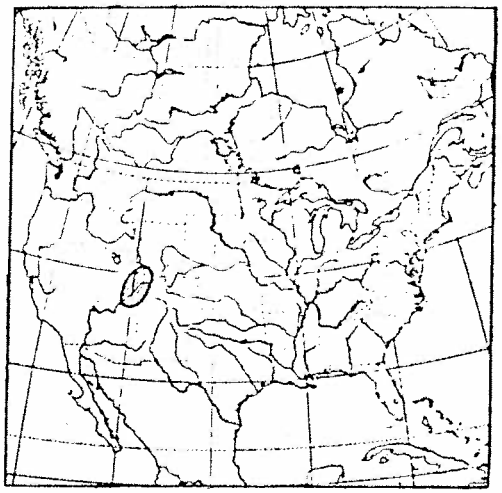
. . .

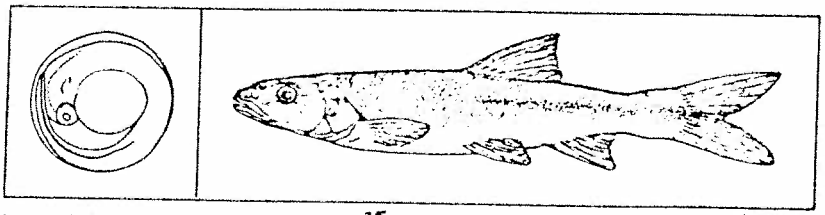
Protolarva, mesolarva and metalarva + definitions reworded.

IDENTIFICATION CIRCULAR 7

PTYCHOCHEILUS LUCIUS

LABORATORY FOR THE IDENTIFICATION AND STUDY OF NORTH AMERICA'S FRESHWATER FISH LARVAE
Colorado State University, Fort Collins, Colorado 80523 December 1979





Late Embryo, 2.0 mm diameter;[25] Adult, mm TL.

COMMON NAME: Colorado Squawfish

TAXONOMY: Order Cypriniformes, Family Cyprinidae, Subfamily Leuciscinae

SIZE, WEIGHT, AGE - *Maximum*: 150-180 cm, 35-45 kg, age unknown. North America's largest cyprinid.[5,6,7,8,9,10,16,23]

Typical Adult: 43-90 cm, 1.0-6.5 kg, 6-15 yrs.[25,26,27,32]

GENERAL DISTRIBUTION: Endemic to the Colorado River System. Although historically abundant in large and intermediate rivers throughout the system, the fish is now rare and endangered, and is restricted to accessible portions of the upper basin.[2,5,6,7,8,25,26,27,28,29,30]

HABITAT - *Adults*: As probing, wandering, opportunistic, top carnivores, adults (and larger juveniles) can be found in a wide variety of riverine and backwater habitats. However, they are usually found in greater numbers in river reaches in or near deep-water canyons.[25,26,27,28,32,29,30,31]

Juveniles: The smaller juveniles are usually found in backwaters and pools over almost any type of bottom where currents are slight or absent; typically in deeper water than the young-of-the-year.[6,7,25,31,32]

Larvae: As is typical of most riverine fish larvae, these fish usually inhabit the quiet shallow backwaters, with an apparent tendency towards those with firm silt bottoms.[25,31,32]

REPRODUCTION - *Guild*[33]: A.1.3; Open substrate, non-guarding lithophils.

Maturation: Usually at or beyond 43 cm and 6 years of age; it is not known whether the fish spawns every year after reaching maturity.[25]

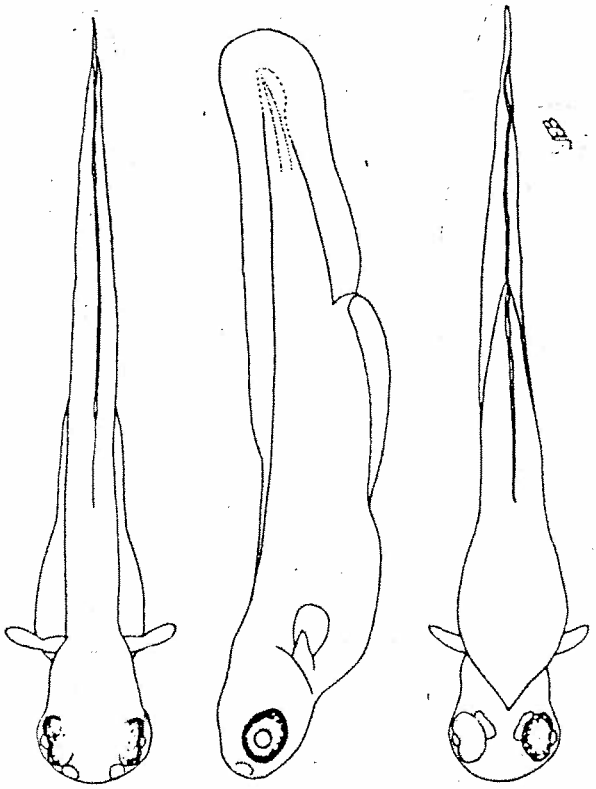
Breeding Colors and Structures: No special coloration reported. Males, when ripe, exhibit tubercles over the entire body except the abdominal area; tuberculation is particularly heavy on the head and the dorsal surface of the pectoral fin.[25,34]

Spawning Season and Temperatures: In present range, from early July through mid-August at about 22-24 C after temperatures have exceeded 18 C for about a month; possibly triggered by increasing temperatures and receding water levels.[5,6,25,27,32,34]

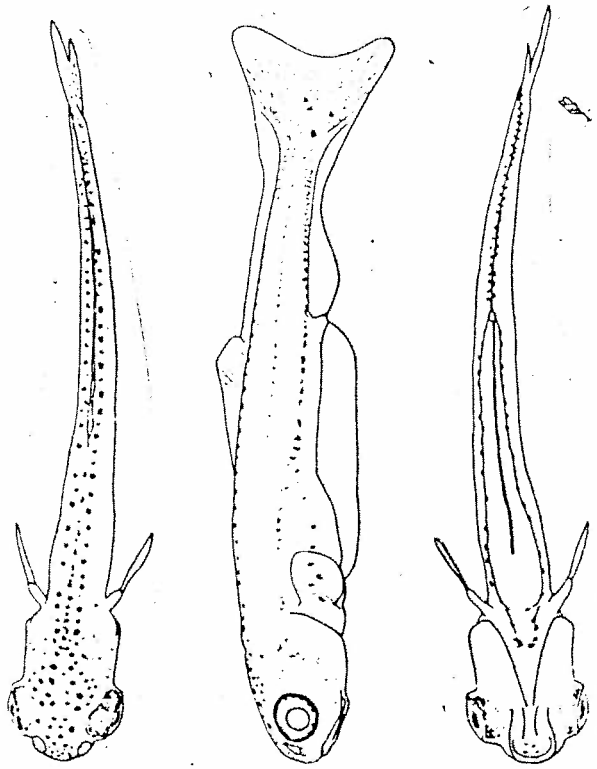
Spawning Area and Behavior: Presumed to spawn in riffle areas of coarse gravel and rubble, especially where deep pools are nearby. Ripe males probably aggregate on or near the riffles and await the females which probably remain in the deeper pools until they are ready to spawn. The spawning act is presumed similar to that of *P. oregonensis* - the female elicites a chase response from the males; a few males then join the female on either side and slightly behind as she dips to within 3 cm of the bottom and broadcasts eggs over and into the rubble.[25,32,35]

Fecundity: Unknown.

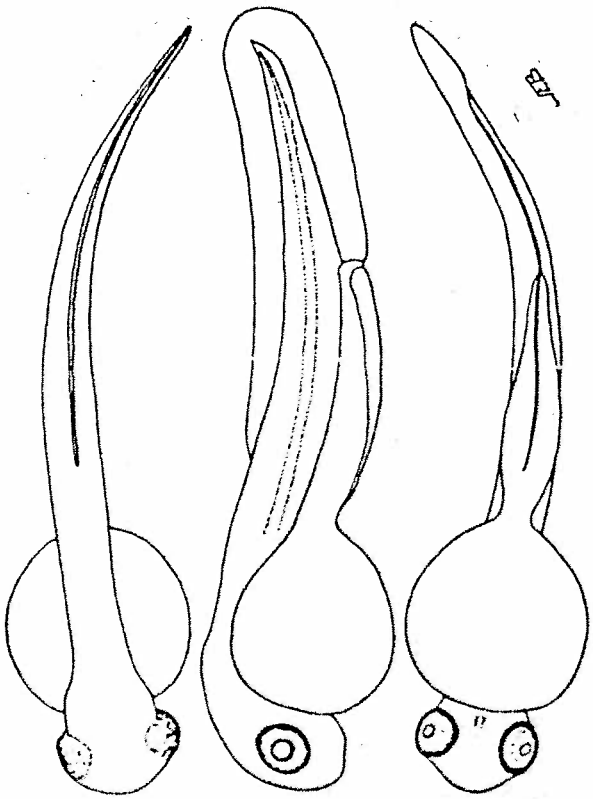
Incubation Period: About 90-120 degree days, 4-5 days at 22-24 C.[25,34]



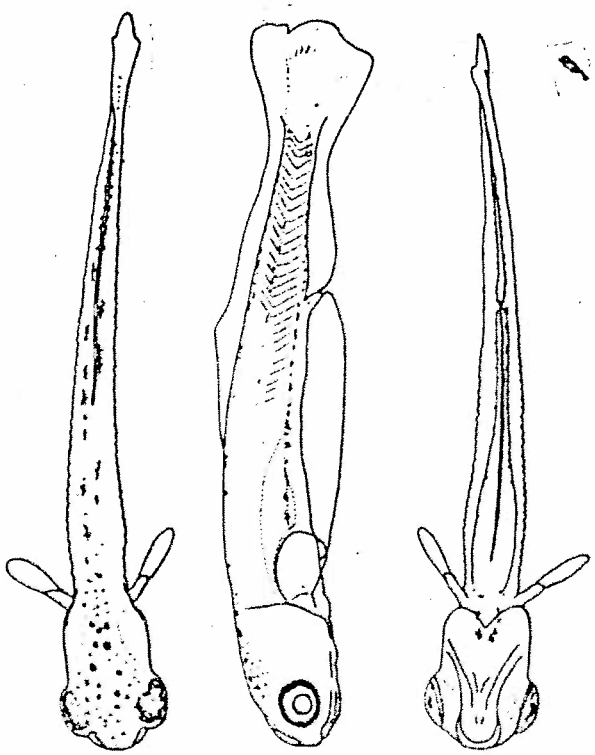
Protolarva, 7.3 mm TL, 7.0 mm SL.



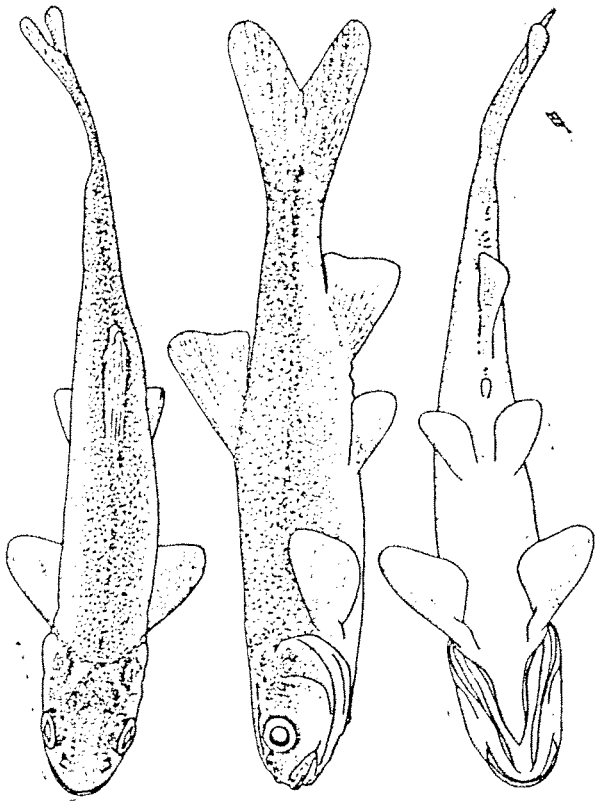
Mesolarva, 9.4 mm TL, 8.0 mm SL.



Protolarva, recently hatched, 5.7 mm TL, 5.5 mm SL.

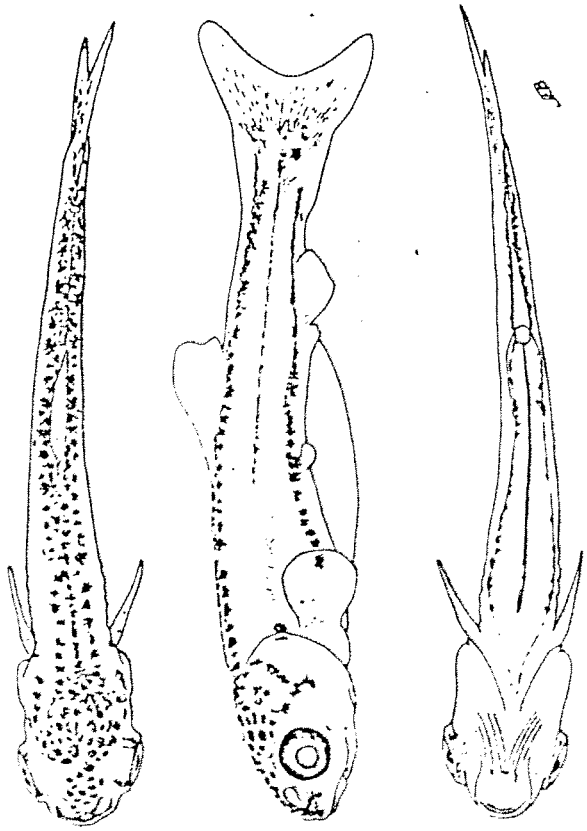


Mesolarva, recently transformed, 8.3 mm TL, 7.2 mm SL

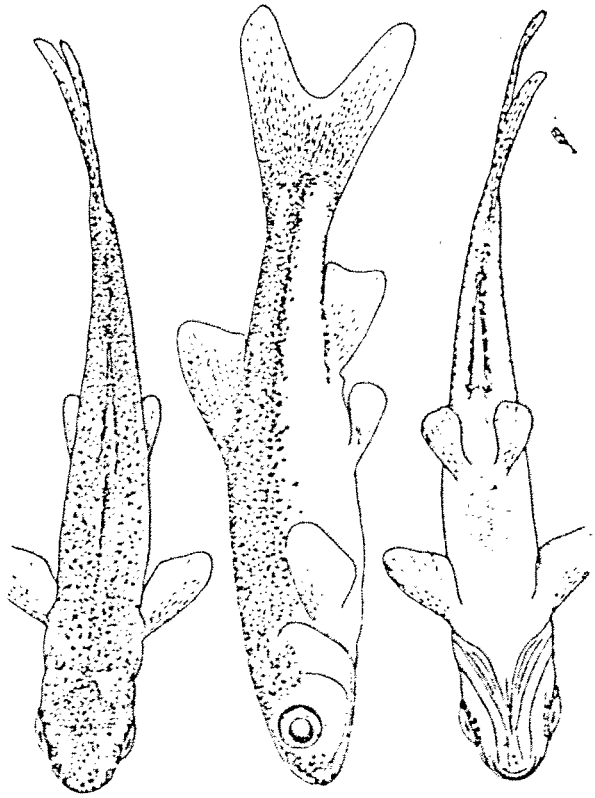


Metalarva, mm TL, mm SL.

Juvenile, 51.4 mm TL, 39.8 mm SL.



Metalarva, recently transformed, 11.3 mm TL, 9.4 mm SL.



Juvenile, recently transformed, 23.8 mm TL, 18.2 mm SL.

IDENTIFICATION CIRCULAR 7 — PTYCHOCHEILUS LUCIUS

MEANS AND RANGES OF SELECTED MORPHOMETRICS, EXPRESSED AS PERCENT STANDARD LENGTH, AND MYOMERE COUNTS for each larval phase and the early juveniles. See diagram on next page for explaination of length measurements and abbreviations (MPM = most posterior myomere, AMPM = anterior margin of MPM). Body depths and widths are measured perpendicular to the horizontal axis. Superscripts in the table indicate the number of specimens on which the value is based if less than the number given in the column heading.[25 32]

	Protolarvae N = 8		Mesolarvae N = 15		Metalarvae N = 5		Juveniles N = 14	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Size, mmSL -	7.0 ± 0.7	5.5-7.8	8.0 ± 0.5	7.4-9.1	15.5 ± 3.5	9.7-18.8	26.7 ± 5.3	20.5-41.9
Lengths, anterior margin of the snout to:								
AE -	3 ± 1	2-4	3 ± 1	3-5	6 ± 1	5-6	7 ± 1	5-8
PE -	9 ± 2	7-11	11 ± 1	10-13	13 ± 1	12-14	14 ± 1	12-16
OP1 -	19^{7} ± 1	17-20	21 ± 1	20-24	26 ± 2	25-28	28 ± 1	25-30
OP2 -					52 ± 1	50-53	52 ± 1	50-54
OD -			55^{8} ± 1	53-57	55 ± 1	54-57	55 ± 1	53-56
ID -			66^{3} ± 1	66-67	67 ± 1	66-68	67 ± 1	66-68
PV -	68 ± 2	66-71	69 ± 1	67-71	69 ± 2	67-72	68 ± 1	66-69
IA -					80 ± 1	78-81	80 ± 1	79-82
AFC -			107^{11} ± 2	105-111	112 ± 3	108-115	114 ± 1	111-116
PC -	105 ± 1	104-106	111 ± 3	106-115	125 ± 5	117-130	129^{9} ± 3	126-133
Fin lengths:								
P1 -	8 ± 4	0^{1}-12	13 ± 1	11-13	15 ± 1	14-16	17^{12} ± 1	16-18
P2 -					10 ± 4	4-14	16 ± 1	14-17
D -					20 ± 3	16-23	23 ± 1	22-25
A -					15 ± 2	11-17	19 ± 1	18-21
Body depths at or just behind (B-):								
BPE -	14 ± 2	11-18	13 ± 1	12-15	15 ± 1	14-17	15 ± 1	14-16
OP1 -	17 ± 4	13-26	14 ± 1	13-17	18 ± 1	16-20	18 ± 1	17-19
OD -	12 ± 1	8-15	11 ± 1	10-14	16 ± 2	14-19	19 ± 1	17-21
BPV -	8 ± 0	8-9	8 ± 1	7-9	13 ± 2	10-15	15 ± 1	14-17
AMPM -	4 ± 1	3-4	5 ± 1	4-7	8 ± 2	5-9	9 ± 1	8-9
Body widths at or just behind (B-):								
BPE -	13 ± 0	12-13	13 ± 1	12-14	15 ± 1	13-16	14 ± 1	13-16
OP1 -	12 ± 5	9-23	10 ± 1	9-12	13 ± 1	12-15	14 ± 1	12-17
OD -	7 ± 2	5-10	6 ± 1	5-7	9 ± 2	8-12	13 ± 1	10-15
BPV -	5 ± 1	4-6	5 ± 0	4-5	8 ± 1	6-9	10 ± 1	8-12
AMPM -	2 ± 1	1-3	3 ± 1	2-3	4 ± 1	3-5	3 ± 0	2-4
Myomere counts:								
to OP2-					20^{3} ± 1	19-20	20^{12} ± 1	19-20
to OD -					23^{3} ± 1	23-24	22^{12} ± 1	22-23
to PV -	33^{4} ± 1	32-33	34^{12} ± 1	33-35	33^{3} ± 2	31-34	32^{12} ± 1	31-33
PV-MPM-	17^{4} ± 0	17-17	15^{12} ± 1	14-17	16^{3} ± 1	16-17	17^{12} ± 1	17-18
total -	50^{4} ± 1	49-50	49^{12} ± 1	48-51	49^{3} ± 1	48-50	49^{12} ± 1	48-50

SELECTED ADULT MERISTICS. Mean or modal values are underlined and rare or questionable extremes are enclosed by parentheses.[2 5 6 8 9 23 24 25 32]

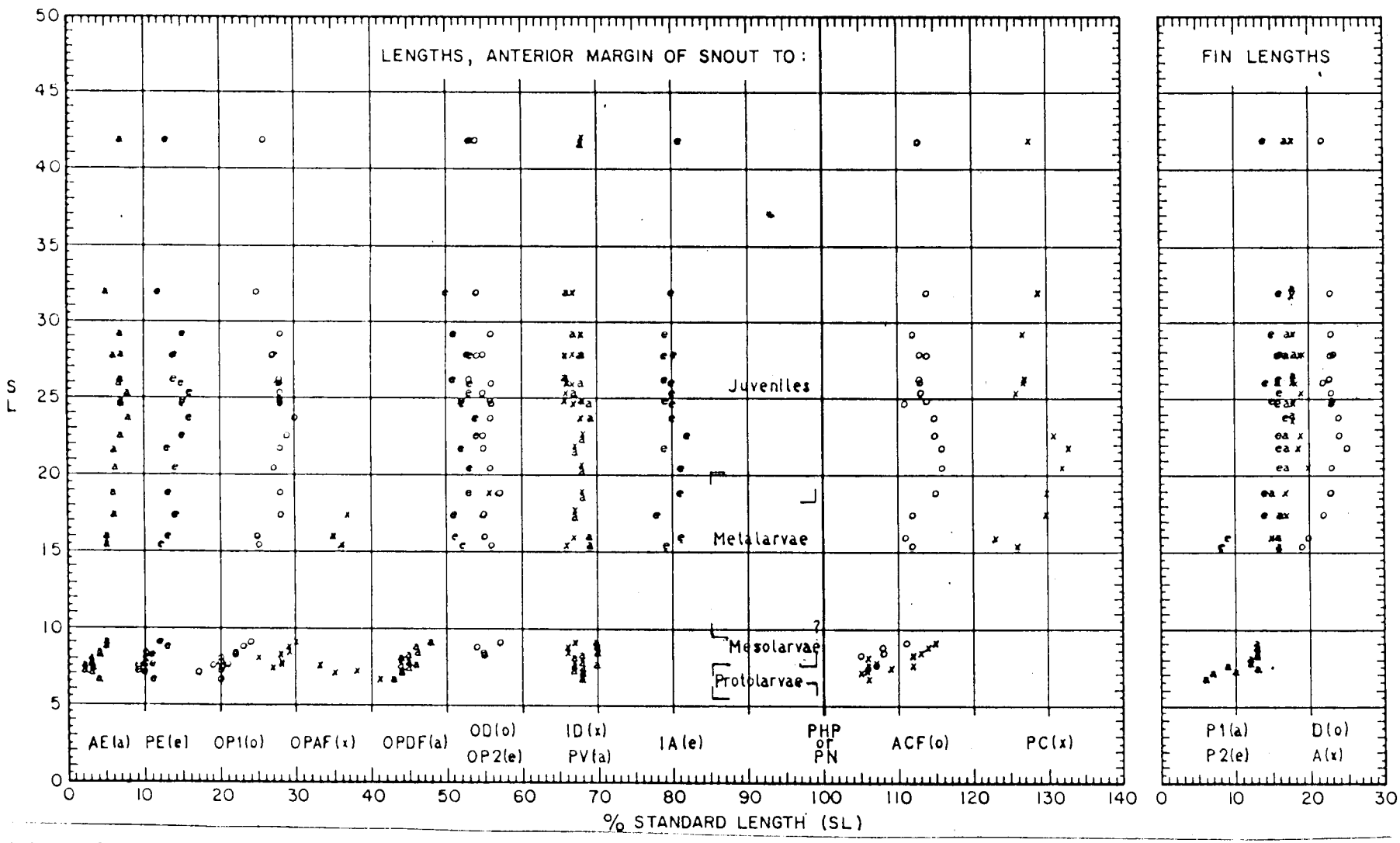
D rays - ii,9
A rays - ii,9(10)
C rays - (viii)ix-x,19,ix-x
P2 rays - 9(10)
P1 rays - 14?-18
Branchiostegal rays - 3
Gill rakers -
Phargngeal teeth - 2,5/4,2
Vertebrae - 47-48
Scales, lateral series - (79)83-90-95(98)

SIZE (mm SL / TL) AT THE APPARENT ONSET OF SELECTED DEVELOPMENTAL EVENTS. Based on structures observable under low power magnification; rare or questionable extremes are enclosed in parentheses.[25 32]

Hatching - 6 / 6-7
Eyes pigmented - prior to hatching
P1 bud formation -
P2 bud formation - ? 9-10 / 11
Yolk completely absorbed - 7-8 / 8
Finfold completely absorbed - (18)19-20/24-25
Gut coil or loop formation, as evidenced by at least a 90° bend -
Segmentation evident in the principal rays of all fins -

Fin rays	First observed	Adult complement
Principal C -	7-8 / 8	(7)8 / 8-9
Secondary C -	7-8 / 8-9	? 17 / 22
Principal D -	8 / 9	9 / 11
Principal A -	9 / 10	9-10 / 11
All P1 -	? 9 / 10-11	16 / 20
All P2 -	9-10 / 11	15 / 19

Scales: initial appearance - ? 27-31 / 35-40
full coverage -



Selected length measurements of individual larval and early juvenile specimens expressed as percent standard length. Lengths documented in the left diagram are of the horizontal distance from the anterior margin of the snout (0%) to an intersecting verticle from the point of interest: AE - anterior margin of the eye (snout length), PE - posterior margin of the eye, OP1 - origin (anterior insertion) of the pectoral fin (head length), OPAF - origin of the preanal finfold, OPDF - origin of the predorsal finfold, OP2 - origin of the pelvic fin, OD - origin of the dorsal fin, ID - insertion (posterior insertion) of the dorsal fin, PV - posterior margin of the vent (snout-to-vent length; also approximates OA, origin of the anal fin, in most fishes), IA - insertion of the anal fin, PHP - posterior margin of the hypural plates (standard length, 100%), PN - posterior margin of the notochord (standard length prior to acquisition of the adult complement of principal caudal fin rays), ACF - anterior margin of the caudal fin fork (fork length), PC - posterior margin of the caudal fin (total length). Lengths documented in the right diagram are the greatest length from the origin of the indicated fin to the most distal margin of its rays: P1 - pectoral fin, P2 - pelvic fin, D - dorsal fin, A - anal fin. The size range of larval phases is indicated for reference.

LARVAL FISH LABORATORY
COLORADO STATE UNIVERSITY

DEVELOPMENTAL STUDIES
MORPHOMETRIC AND MERISTIC DATA

ABBREVIATIONS AND
NOTES ON PROCEDURE

ABBREVIATIONS

AS - Anterior margin of Snout
AE - Anterior margin of Eye
PE - Posterior margin of Eye
OP1 - Origin of Pectoral fin(s) (anterior-most junction or insertion)
OP2 - Origin of Pelvic fin(s)
PY - Posterior margin of Yolk (not necessarily same as yolk sac)
OPAF - Origin of PreAnal Finfold
ODF - Origin of Dorsal Finfold
OD - Origin of Dorsal fin
ID - Insertion of Dorsal fin (posterior-most junction or insertion)
PV - Posterior margin of Vent (anus)
OA - Origin of Anal fin (delete if essentially same as PV)
IA - Insertion of Anal fin
PHP - Posterior margin of Hypural Plates or, prior to acquisition of adult count of principal caudal rays, of notochord
AFC - Anterior margin of fork of caudal fin
PC - Posterior margin of caudal fin
Y - Yolk
P1 - Pectoral fin(s), 1st paired fins
P2 - Pelvic fin(s), 2nd paired fins
D - Dorsal fin
A - Anal fin
BPE - immediately Behind Posterior margin of Eye
BPV - immediately Behind Posterior margin of Vent
AMPM - Anterior margin of Most Posterior Myomere

NOTES ON PROCEDURE

1. Specimens are typically measured in a horizontal position, with left lateral, dorsal, or ventral sides up, and with the head to the left.
2. Measurements are from one specified point to another along a straight line parallel (length, except fins) or perpendicular to the horizontal axis of the fish. Depths do not include fins or finfolds.
3. Fin lengths are the greatest length from the origin to the most distal margin (not to insertion). Left pectoral and pelvic fins are measured and counted unless damaged or much more difficult to use than those on the right side. If right side, precede with a slash; if both give left first, then slash, then right measurement or count (i.e. L/R).
4. Position OD for depth and width measurements on protolarvae and early mesolarvae should be approximated based on measurements of AS to OD (as % of length) or myomere counts on late mesolarvae or early metalarvae.
5. Record all measurements on the left side of the appropriate column. Percentage of standard length (AS to PHP) can then be recorded (using a different color ink or pencil) on the right side of the column.
6. Myomeres are counted beginning with the first, typically deltoid shaped myomere immediately behind the occiput, and ending with the last myomere transected by an imaginary vertical line from the point of reference (Siefert 1969 method). The first few myomeres are typically apparent only on the dorsal half of the body and the myosepta may be difficult to distinguish without polarizing filters, special lighting or other aids. The latter also applies to the myosepta of the last myomere(s); the most posterior myosepta may appear incomplete.
7. Fin ray counts are given as large case Roman numerals for the true spines, small case Roman numerals for the secondary or procurrent rays which often precede the most anterior or leading principal rays, and Arabic numerals for the principal rays including the hardened spine-like rays. The different types of rays, when present in the same fin, are separated by commas. In fins with two or more separate portions the portions are separated by a plus. Examples: D:XI+II,9; D:iii,9; P1: 17 (left only); P1: /14 (right only); P2: i,5/i,5 (left/right); C: ix,19,viii (dorsal procurrent rays, principal caudal rays, ventral procurrent or secondary rays).
8. If desired, the observable pterygiophores (basal structures to the fin rays) can also be counted and recorded in Arabic numerals but must be enclosed in parentheses and precede actual ray counts if any.
9. Rays are counted as soon as they are sufficiently well formed so as not to be mistaken for folds or striations in the finfold or fin membranes.

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Species: _____ Page__of__
Source: _____

DEVELOPMENTAL STUDIES
MORPHOMETRIC AND MERISTIC DATA

Measured and recorded by: _____
_____, Dates: _____

	1	2	3	4	5	6	7	8	9
LENGTHS									
AS to:AE									
PE									
OP1									
OP2									
PY									
OPAF									
ODF									
OD									
ID									
PV									
OA									
IA									
PHP									
AFC									
PC									
Y									
P1									
P2									
D									
A									
DEPTHS									
at:BPE									
OP1									
OD									
BPV									
AMPM									
max. Y									
WIDTHS									
at:BPE									
OP1									
OD									
BPV									
AMPM									
max. Y									
MYOMERES									
to:PY									
OPAF									
OP2									
ODF									
OD									
PV									
total									
FIN RAYS									
C									
D									
A									
P1									
P2									

Optional comments by specimen on back (presence of structures, pigmentation, etc.).

SNYDER TERMINOLOGY CLARIFIED

The following discussion is taken directly from the draft text for the *Guide to the Cypriniform Fish Larvae of the Upper Colorado River System in Colorado* which is being prepared by Darrel E. Snyder. In it the definitions for protolarva, mesolarva, and metalarva are reworded (not redefined) for purposes of clarification. Bibliographic information for the literature citations are deleted herein for purposes of brevity.

"The larval period is defined arbitrarily as consisting of three distinct sequential phases: protolarva, mesolarva, and metalarva. These phases, and therefore the period, are based on one of the most consistent and obvious sequences of development in all, or nearly all, bony fishes - the morphogenesis of the median finfold and fin elements (spines and rays). In addition, paired fins (pectoral and pelvic) are included in defining the last or metalarval phase. The definitions are based on structures or features readily observed under low-range magnification (less than 30x) and do not require dissection, clearing, or staining. Not all fish pass through all three phases; salmon (Salmonidae), catfish (Ictaluridae), and certain killifish (Cyprinodontidae), for example, hatch as mesolarvae. It is likely that some fish may hatch or be born as juveniles, lacking a larval period entirely. However, no examples of such are known among North America's freshwater or anadromous fishes (Snyder 1976b erroneously gave the mosquitofish, *Gambusia affinis*, as an example; since that fish lacks pelvic fins at birth, it by definition has both a mesolarval and a metalarval phase).

"The specific definitions of the larval period and its phases are as follows (from Snyder 1976b, but reworded for purposes of clarity):

> *Larval Period* - The period of bony fish development characterized by obvious fin morphogenesis following hatching or parturition. Transition to the juvenile period is based on the following three criteria, each of which must be met: 1) finfolds and atrophing fins, if any (very rare), must be absorbed beyond recognition; 2) the full adult complement of fin spines (actinotrichia) and rays (lepidotrichia), including secondary rays, must be distinctly formed (visually well defined) in all fins; and 3) segmentation must be evident in at least a few of the rays of each fin that is characterized by segmented rays in the adult.
>
> *Protolarval Phase* - The larval phase of bony fish development characterized by the absence of distinct spines or rays associated with the future median fins (dorsal, anal or caudal fins). Transition to the mesolarval phase is based on the appearance of at least one such distinct spine or ray in any of the future median fins. Pectoral and pelvic fins or fin buds may or may not be present.
>
> *Mesolarval Phase* - The larval phase of bony fish development characterized by the morphogenesis of distinct principal rays (Hubbs and Lagler 1958) in the median fins. Transition to the metalarval phase is based on the following two criteria, each of which must be met, except in species lacking pelvic fins as adults: 1) the full adult complement of principal rays must be distinctly formed in each of the median fins; and 2) the pelvic fins or fin buds must be evident.

Metalarval Phase - The larval phase of bony fish development characterized by the full adult complement of principal rays in each of the median fins and by the presence of pelvic fins or fin buds (except in species lacking pelvic fins). Transition to the juvenile period is as defined for the larval period.

"The median fin elements in most fishes appear first in the caudal portion of the finfold. For these species, the protolarval phase is essentially synonymous with Ahlstrom's (1968) preflexion phase (except when a yolk sac is present) and Faber's (1963) straight-notochord phase. For the remaining fishes, those in which the first median fin elements usually appear in the developing dorsal or anal fin, the protolarval phase terminates before the preflexion or straight notochord phase would (e.g., the larvae of lined sole, *Achirus lineatus*, described by Houde et al. 1970).

"The metalarval phase is defined so as to allow in description and key preparation the use of principal ray counts of the dorsal, anal, and caudal fins, as well as the relative positions of these fins and the pelvic fins, assuming the species has pelvic fins. In some fishes, the pelvic buds form as or after the full adult complement of distinct principal rays in the median fins is attained and for these the distinction between mesolarvae and metalarvae is exceedingly simple. In other fishes, the pelvic fin buds make their appearance during the mesolarval phase, prior to the appearance of the full complement of principal median fin rays, or they may be even more precocious and appear during or before the protolarval phase (e.g., the lanternfish, *Symbolophorus californiensis*, described by Moser and Ahlstrom 1970).

"For fishes in which part of the finfold is still present upon attainment of the other two criteria for transition to the juvenile period, distinction between the larval and juvenile periods is particularly easy. Recently-transformed juvenile fish, based on this terminology, may or may not yet resemble the adult. However, for most fishes, the appearance will be very adult-like.

"In meeting the three criteria suggested for a standard terminology [discussed elsewhere in the guide and in Snyder 1976], this terminology, unlike most others, avoids the difficulties inherent in using the transition from endogenous to exogenous nutrition as a phase or period boundary. Although this transition is of tremendous physiological, ecological, and behavioral significance, the various criteria previously used for determining a boundary between intervals based on it are frequently difficult to discern with precision on preserved material and are no less arbitrary than criteria for other interval boundaries. Like hatching or parturition, the transition from endogenous to exogenous feeding, largely a physiological change, does not correlate well with the more obvious morphological features of larval development such as fin morphogenesis. In many fishes, yolk absorption is completed during the protolarval phase; in others, such as salmon and catfishes, yolk is still present in the metalarval phase. If it is desirable to indicate the presence of yolk, modification of the phase name with the prepositional phrase "with yolk", is suggested (as per Faber 1963; e.g. mesolarva with yolk)."

Submitted to the ELHS Newsletter
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