HARRY VAN METER

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GREAT LAKES FISH EGG AND LARVAE IDENTIFICATION

HARRY VAN METER

National Power Plant Team

Power Plant Project

Office of Biological Services

Fish and Wildlife Service

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GREAT LAKES FISH EGG AND LARVAE IDENTIFICATION:

PROCEEDINGS OF A WORKSHOP

HARRY VAN [illegible]

edited by:

JOHN BOREMAN

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Preface

A workshop sponsored by the National Power Plant Team, U. S. Fish and Wildlife Service, was held in Ann Arbor, Michigan on April 19-21, 1976. The objectives of the workshop were: (1) assess the state-of-the-art of Great Lakes fish egg and larvae identification, and (2) develop a strategy for future larval taxonomic work in the Great Lakes Region. The workshop consisted of both plenary and laboratory sessions.

The accompanying proceedings are papers and working group reports presented at the workshop. Some of the papers were adapted from edited transcripts, while others were written independently of the transcripts. In all cases the content of the papers reflect material presented at the workshop.

The editor wishes to acknowledge Dr. James McFadden for use of University of Michigan facilities, Dr. Jack Watson for Mitre Corporation assistance in the workshop planning, Sally Vreeland for typing the manuscript of the entire proceedings, and Dr. Roy Irwin for support throughout the project. The editor especially acknowledges the participants, who came to work, and were primarily responsible for the workshop's success.

John Boreman

The opinions expressed herein do not necessarily reflect those of the Office of Biological Services, U. S. Fish and Wildlife Service.

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WELCOME ADDRESS

Roy J. Irwin*

Good morning ladies and gentlemen. My name is Roy Irwin and I am the Team Leader of the National Power Plant Team, the group sponsoring this workshop. It is my distinct pleasure this morning to welcome you to Ann Arbor and to welcome you to our first technical workshop. I don't want to spend much time this morning talking about the Team, because that is not why we are here. Our brochure fairly well describes who we are and what we do.

We look forward to a productive workshop. I understand that we have some of the finest people in the country present here today to address the issues at hand. I think this might be a good time to have everybody stand and introduce themselves and tell us who you are working for, and just very briefly what your involvement in fish egg and larvae indentification is.

(Whereupon the introduction of those present occurred).

It looks like we have a good group to tackle this problem, and I understand you have all come ready to share ideas and do a lot of thinking, brain-storming, identifying problems, and proposing solutions to the problems. We are hoping that the proceedings of the workshop will be a summary document which will be useful to a lot of people.

I would like to emphasize that we are trying to encourage not only the identification of problems, but also the identification of possible solutions to those problems. I had the experience last year of going to a conference in which just about every speaker stood up and said: "Well, you know, I didn't come here with any solutions, I came here with a whole set of problems and I was hoping that by coming to this conference I could sit down and listen to everybody else's paper and thereby gain insight into the solutions". This would have been fine except for the fact that almost every speaker stood up and said that same thing. So we encourage you to suggest possible solutions, new ideas, new hypotheses, and so on. Each one of you probably have some of the answers to some of the problems. If we can get these ideas down on paper in the form of a summary document, we will be ahead of the game.

*Team Leader, National Power Plant Team
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Some people have asked why the National Power Plant Team is interested in the identification of fish eggs and larvae. The answer is very simply that there is an information gap; there is a gap of knowledge in identification of fish eggs and larvae. We can not identify some of them, or at least we can not identify some of them readily. In turn it is difficult to know what impact power plants are having on fishery resources in cases where no one knows the degree to which individual species are being impacted.

The scope of the workshop focuses on the Great Lakes. However, we are not interested just in the Great Lakes, and this is the reason why we invited people from other parts of the country.

We are interested in such questions as: is it possible to come up with a summary document, technical manual, or an atlas for larger geographical areas? Is it true that many of the species entrained in power plants along the Mississippi and Ohio Rivers are the same species being frequently entrained in the Great Lakes? If so, is there so much variation among specimens from these areas that trying to come up with a summary document to cover more that one region is beyond the state-of-the-art? Answers to these kinds of questions will help us decide "where to go from here".

The Team members who are here will be glad to assist you in any manner we can to make this workshop a success and to make your stay in Ann Arbor a pleasant one. Again, welcome to Ann Arbor. Good luck and bon voyage.

I would now like to introduce John Boreman. He is the Team's Aquatic Ecologist, and has been in charge of setting this workshop up, organizing it, and so on. We did have some help with logistics from Mitre Corporation, but to a large degree the design and construction of this workshop is John's doing.

INTRODUCTION

John Boreman*

Welcome to your workshop. The National Power Plant Team is serving as an intermediary to provide the place and the opportunity for experts to assemble and address the problem of Great Lakes fish eggs and larvae identification. With the new 316(b) requirements of Public Law 92-500 and National Environmental Policy Act (NEPA) requirements, the field biologist is forced to identify fish eggs and larvae. He has no choice. Many field biologists are not ichthyologists. Therefore, the long-term goal of this workshop is to develop a document that a field biologist can use to identify fish eggs and larvae; the simplest, easiest to understand, basic document. It may currently be an impossible dream but this goal should always be kept in mind.

Another obvious goal of the workshop is to bring all the current expertise together in one place to discuss common problems, help each other out, and hopefully come up with some common solutions. This leads to the third goal: answer some tough questions that I will pose to the assembled expertise. Hopefully we will develop a strategy from this workshop which we can follow to a logical conclusion-a simple guide to the fish eggs and larvae of the Great Lakes.

Last summer, when the Team was established here in Ann Arbor, we received numerous unsolicated proposals dealing with identification and delineation of Great Lakes fishery resources. In order to evaluate the technical merits of these proposals, we asked numerous resource workers in the region if the expertise existed to do the type of work being proposed. The general concensus was either "I don't know" or, "Why don't we have a meeting to find out?"

For this workshop we attempted to assemble as many people as possible associated with Great Lakes fish egg and larvae identification. We have representatives from Federal and State agencies, utilities, utility consultants, academia and independent research organizations.

This morning the workshop will assess the state-of-the-art. The National Power Plant Team has assisted in the preparation of documentation for this part of the workshop. Dr. Werner prepared, revised, and updated

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his annotated bibliography of references relating to Great Lakes fish egg and larvae identification. Lee Emery from the U. S. Fish and Wildlife Service Great Lakes Fishery Laboratory in Ann Arbor worked on a Great Lakes fish species list. Alice Lippson from Martin-Marietta Corporation was gracious enough to prepare a generalized key to the families of the Great Lakes.

We will have four working groups. I will briefly read questions I want each group to address for orientation purposes. Keep these questions in the back of your mind as these papers are being presented.

In "Determination of Highest Priority Gaps" (Working Group No. 1), we want to know where the gaps are and what priority should be placed on filling them. For example, should we worry about Coregonus larvae? It is more important to work on Cyprinodontidae larvae identification or Centrarchidae larvae, keeping in mind what answers are needed from the field studies.

After determining the priorities of filling the gaps, we want to know which strategy should be used, what should be the method of approach, what types of studies are needed, who should conduct the studies, who should sponsor the studies, and how soon can this information be available?

It is a common habit to say "Well, we need 10 years to study this, we need 20 years, we need a whole lifetime," etc. We need the answers now. In fact, we needed the answers yesterday, and those answers were not there, and that is why the decisions on power plants have been made.

The last question in the determination of highest priority information gaps is what is the importance of filling these gaps in light of the Coastal Zone Management Act, 316 requirements, NEPA-related studies, and also developing Great Lakes fishery management strategies?

The second working group is "Identification Tools; What is available and What Could Be Developed?" We are looking for the alternative types of guides currently available for identification of fish eggs and larvae. What are the ambiguities or inconsistencies in terminology in classification? How can they be resolved? This group, I hope, will recommend a certain guide to use that is simple and easy for the field biologist, who is not an ichthyologist, to understand and follow. What additional studies are needed before this tool can be developed?

The third group is "Variability of Characteristics Appearing in Keys, Regionwide and Nationwide". Roy Irwin touched on this in his opening remarks. We are interested in what key characters are vulnerable to variability. Can local conditions such as thermal discharges, chemical discharges, or geographical location vary these characteristics? Are studies needed to look at this problem, or should we even concern ourselves with this problem?

How specific a region should identification tools be geared? That is, can we develop one guide, one massive volume, that will be a guide to every larval fish in the United States, or do we have to be more specific? Do we have to be specific to Lake Ontario, or to the Great Lakes, or the Northeast United States, or to the Eastern United States?

Finally, the fourth working group is "Identification of Reference Collections and Expertise in the Region." Where are the experts now? Are there people who are good at identification in one family? Who are they? Who has the appropriate reference collections? Once again, who are the specific sources of expertise on different taxonomic groups? How can these sources be made available to use by everybody in the region? Should we develop a reference library some place, a museum? What strategy is needed? What studies are needed in order to accomplish the task of making the expertise and information available to everybody in the Great Lakes?

Remember, it is the state of <u>your</u> art. It is going to save <u>you</u> money in the long run. When a new group comes into the Great Lakes and is faced with identification of fish eggs and larvae, they will not have to re-invent the wheel. Hopefully we will have one document that is going to cover the current status of information, as well as a suggested strategy for resolution of associated problems.

CURRENT LEVEL OF TAXONOMIC INFORMATION ON GREAT LAKES FISH EGGS AND LARVAE

Robert G. Werner*

Before we begin a concerted effort to solve the problem of identifying egg and larval stages of fishes of the Great Lakes, it is appropriate to assess the work that has already been accomplished. If we can restrict the scope of our concerns by eliminating those species already described the task will be greatly diminished. Thus, it is the purpose of this paper to bring together and briefly describe the literature which can aide identification of egg and larval stages of Great Lakes fishes. To that end I have assembled an annotated bibliography which makes up the bulk of this report (Appendix I).

This project began as a personal working list of references. It was then expanded by making a thorough search of Dean's Bibliography of Fishes and the Pisces section of Zoological Record. Recent work was assembled by searching Biological Abstracts, Sport Fisheries Abstracts, and contacting active investigators. Eventually, nearly seven hundred references were compiled which, based on their title, appeared to be relevant. An attempt was made to locate each paper and extract the pertinent information for annotation. Of particular interest were studies which included line drawings, photographs, and verbal descriptions of early life history stages or keys. In addition, since clues to identification can come from knowledge of spawning: spawning time, site, and behavior was also included. As a result of this search the original list was substantially reduced to less than 400 references.

The bibliography is arranged taxonomically so that all of the papers dealing with a particular taxon are listed under that group. This should make it more useful to investigators in the field since in most cases the unknown specimen can be narrowed down to one of just a few alternatives. The descriptions of each alternative can then be consulted and the identification made. The species included are primarily those listed for the entire Great Lakes watershed by Hubbs and Lagler (1964).

As with most efforts of this type the bibliography is not complete and will always require updating. It is, however, a starting point that will hopefully help guide our efforts along the most productive channels.

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If, for sake of argument, we assume that the bibliography is reasonably complete we can then locate those references which include descriptions adequate for making an identification, and eliminate references to peripheral aspects (such as spawning). By compiling this list taxonmically the gaps in information become immediately apparent (Table 1). What this table demonstrates is that only about 34% of the species of fish in the Great Lakes have descriptions developed for both egg and larval stages. Approximately another 28% have had either the egg or larval stages described, but not both. That leaves 38% of the species essentially undescribed. Thus, only 34% of the species have had both egg and larval stages described, while 66% are either partially described or not described at all. I think this clearly illustrates our problem. If the fact is added that, of the existing descriptions, many are sketchy and incomplete, it is easy to see why we have had difficulty identifying larval fishes taken in the field.

Secondly, we are also faced with the problem of lack of comparability of descriptions. One investigator may have prepared detailed verbal descriptions of prolarval stages; another may have illustrated just a single larval stage by sketching an outline drawing; while a third may have several photographs of postlarval stages. If we are faced with an unknown specimen which could be any of the three described above, the lack of comparability of studies makes the identification more difficult.

Another problem with utilizing isolated descriptions is determining that the unknown specimen is not one of the closely related but undescribed species. For example, the larval stages of Fundulus diaphanus have been well described. Unfortunately, the larval stages of F. notatus and F. notti have not. If an investigator had an unknown Fundulus and all three species were known to be in the area, it would be extremely difficult to prove that it was not F. notti or F. notatus, even though the specimen bore a close resemblance to the description of F. diaphanus. If the investigator had descriptions of all three species then he would stand a much better chance of making the appropriate identification.

How are we to overcome these problems? To me the answer is obvious. We must develop a two-tier strategy in which an effort is made to compile descriptive material from the literature, as was done so well for Chesapeake Bay fishes (Mansueti & Hardy, 1967). Such a compilation would be designed as a short term aid to the field investigator. This should ultimately be replaced by complete descriptions of egg and larval stages of whole taxonomic groups such as large genera of families. We need to encourage investigations that will encompass all of the species of a taxon in an integrated fashion. The descriptions should be made from material of known parentage, wherever possible, and they should follow a standard format so that one species can be easily compared to another. Eventually, after enough descriptions have been developed, we should then prepare a key.

The task facing this workshop is large and difficult. We have been able to reduce it somewhat by identifying descriptions in the literature. The use of the literature, however, has its own unique problems, such as a

Table 1. A summary of studies describing egg and larval stages of Great Lakes fishes.

Species	Descriptions	
	Egg	Larva
Ichthyomyzon castaneus *I. fossor* *I. unicuspis*	Smith, Howell & Piavis 1968	
Lampetra lamottei		
Petromyzon marinus	Piavis 1966 & 1961 Gage 1893	Gage 1893
Acipenser fulvescens	Harkness & Dymond 1961	Harkness & Dymond 1961
Polyodon spathula	Purkett 1961 Ballard & Needham 1964	Purkett 1961 Ballard & Needham 1964
Lepisosteus oculatus *L. osseus*	Dean 1895 Lippson & Moran 1974 Balfour & Parker 1882 Vert 1924 Mansueti & Hardy 1967	Dean 1895 Fish 1929,1932 Balfour & Parker 1882 Lippson & Moran 1974 Mansueti & Hardy 1967
Amia calva	Eycleshymer & Wilson 1906 Mansueti & Hardy 1967 Whitman & Eycleshymer 1897	Dean 1896 Mansueti & Hardy 1967
Alosa pseudoharengus	Oldmixon 1964? Mansueti & Hardy 1967 Norden 1967 Bigelow & Schroeder 1953 Lippson & Moran 1974	Oldmixon 1964? Mansueti & Hardy 1967 Ryder 1887 Bigelow & Schroeder 1953 Norden 1967 Wang 1970 Lippson & Moran 1974
A. sapidissima	Oldmixon 1964? Mansueti & Hardy 1967 Bigelow & Schroeder 1953 Lippson & Moran	Oldmixon 1964? Mansueti & Hardy 1967 Ryder 1887 Wang 1970 Lippson & Moran 1974

Table 1 (cont.)

Species	Descriptions: Egg	Descriptions: Larva
Dorosoma cepedianum	Miller 1960 Mansueti & Hardy 1967 Lippson & Moran 1974	Miller 1960, Wang 1970 Mansueti & Hardy 1967 Lippson & Moran 1974
Hiodon tergisus		Fish 1932
Coregonus alpenae		
C. artedii		Faber 1970 Pritchard 1930 Fish 1929, 1932
C. clupeaformis	Price 1934 Fish 1932	Hart 1930 Fish 1929, 1932 Faber 1970
C. hoyi		Faber 1970
C. johannae		
C. kiyi		
C. nigripinnis		
C. nipigon		
C. reighardi		
C. zenithicus		
Oncorhynchus gorbuscha		Foerster & Pritchard 1935
O. kisutch		Foerster & Pritchard 1935
O. nerka		Foerster & Pritchard 1935
O. tshawytsch		Foerster & Pritchard 1935
Prosopium coulteri		
P. cylindraceum		Faber 1970
Salmo clarki		
S. gairdneri	Wales 1941 Knight 1963 Ballard 1973	Knight 1963
S. salar	Fryer 1873 Pelluet 1944 Battle 1944	Fryer 1873 Pelluet 1944 Battle 1944
S. trutta	Klein 1876 Goronowitsch 1885 Luther 1935 Taning 1952	Klein 1876 Taning 1952
Salvelinus fontinalis	Ballard 1973	Schindler 1938
S. namaycush	Garside 1959	Garside 1959 Fish 1932
Thymallus arcticus	Watling & Brown 1955?	

Table 1 (cont.)

Species	Descriptions: Egg	Descriptions: Larva
Osmerus mordax	Cunningham 1887	Cunningham 1887
Umbra limi	Ryder 1886	Ryder 1886 Fish 1932
Esox americanus	Kleinert & Mraz 1966 Crossman 1962	Kleinert & Mraz 1966 Mansueti & Hardy 1967 Lippson & Moran 1974
E. lucius	Frost & Kipling 1967 Gihr 1957 Kotlyarevskaya 1969 Kennedy 1969 Fish 1932 Schwarz 1889 Brown 1907	Frost & Kipling 1967 Gihr 1957 Franklin & Smith 1960 Kotlyarevskaya 1969 Kennedy 1969 Brown 1907 Fish 1932
E. masquinongy	Galat 1973 Fish 1932	Fish 1932
E. niger	Lippson & Moran 1974 Mansueti & Hardy 1967	Lippson & Moran 1974 Mansueti & Hardy 1967
Campostoma anomalum		Fish 1932
Carassius auratus	Hamid Khan 1929 Battle 1940 Mansueti & Hardy 1967 Kajishima 1960 Lippson & Moran 1974	Hamid Khan 1929 Battle 1940 Mansueti & Hardy 1967 Kajishima 1960 Lippson & Moran 1974
Clinostomus elongatus		Fish 1932
Couesius plumbeus		
Cyprinus carpio	Ramakrishna et al 1967 Verma 1970 Lippson & Moran 1974 Mansueti & Hardy 1967	Balon 1958 Fish 1932 Ramakrishna et al 1967 Smallwood & Smallwood 1931 Verma 1970 Lippson & Moran 1974 Mansueti & Hardy 1967 Nordquist 1915
Ericymba buccata		
Exoglossum laurae		
E. maxillingua	VanDuzer 1939	VanDuzer 1939

Table 1 (cont.)

Species	Descriptions: Egg	Descriptions: Larva
Hybognathus hankinsoni		
H. nuchalis		Raney 1939 Lippson & Moran 1974 Mansueti & Hardy 1967
Hybopsis amblops		
H. storeriana		Fish 1932
H. x-punctata		
Nocomis biguttas		
N. micropogon		Fish 1932
Notemigonus crysoleucas	Manseuti & Hardy 1967	Lippson & Moran 1974 Fish 1932
Notropis analostanus	Lippson & Moran 1974 Stone 1940 Mansueti & Hardy 1967	Stone 1940 Lippson & Moran 1974 Mansueti & Hardy 1967
N. anogenus		
N. atherinoides		
N. bifrenatus	Harrington 1947b Mansueti & Hardy 1967	Harrington 1947b Fish 1929, 1932 Mansueti & Hardy 1967
N. blennius		
N. boops		
N. chalybeus	Nelson 1947 Mansueti & Hardy 1967	Nelson 1947 Mansueti & Hardy 1967
N. chrysocephalus	Fish 1932	Fish 1932
N. cornutus		
N. dorsalis		
N. emiliae		
N. heterodon		
N. heterolepis		
N. hudsonius		Fish 1932 Fish 1929, 1932 Lippson & Moran 1974 Mansueti & Hardy 1967
N. lutrensis		Saksena 1962
N. photogenis		
N. procne		
N. rubellus		Pfeiffer 1955 Fish 1932 Reed 1958
N. spilopterus		Stone 1940
N. stramineus		Fish 1932
N. texanus		
N. umbratilis		
N. volucellus		

Table 1 (cont.)

Species	Descriptions: Egg	Descriptions: Larva
Phenacobius mirabilis		
Phoxinus eos		
P. erythrogaster		
P. neogaeus		
Pimephales notatus	Fish 1929, 1932 Wynne-Edwards 1932	Fish 1929, 1932 Markus 1934 Fish 1932
P. promelas		
P. vigilax		
Rhinichthys atratulus	Noble 1965	Fish 1932 Bartnik 1970
R. cataractae		Fish 1932 Bartnik 1970
Semotilus atromaculatus		Fish 1932
S. corporalis	Reed 1971	Reed 1971
S. margarita	Langlois 1929	
Carpiodes carpio	Bucholz 1957	
C. cyprinus	Gerlack 1973?	Gerlack 1973? Fish 1932 Mansueti & Hardy 1967 Lippson & Moran 1974
C. velifer		
Catostomus catostomus	Harris 1962	
C. commersoni	Stewart 1926 Lippson & Moran 1974 Mansueti & Hardy 1967	Stewart 1926 Fish 1929, 1932 Lippson & Moran 1974 Mansueti & Hardy 1967 Crawford 1923
Erimyzon oblongus	Carnes 1958 Lippson & Moran 1974 Wagner & Cooper 1963 Mansueti & Hardy 1967	Lippson & Moran 1974 Carnes 1958 Mansueti & Hardy 1967
E. sucetta		
Hypentelium nigricans		Fish 1932
Ictiobus bubalus	Wrenn & Grinstead 1968	Wrenn & Grinstead 1968
I. cyprinellus		
I. niger		
Lagochila lacera		

Table 1 (cont.)

Species	Descriptions: Egg	Descriptions: Larva
Minytrema melanops		
Moxostoma anisurum		Fish 1932
M. carinatum		
M. duquesnei		
M. erythrurum		
M. hubbsi		
M. macrolepidotum		Fish 1932
M. valenciennesi		
Misgurnus anguillicaudatus		
Ictalurus catus	Ryder 1887 Mansueti & Hardy 1967 Lippson & Moran 1974	Ryder 1887 Mansueti & Hardy 1967 Lippson & Moran 1974
I. melas		
I. natalis		Fish 1932
I. nebulosus	Breder 1935 Armstrong 1962 Mansueti & Hardy 1967 Lippson & Moran 1974	Breder 1935 Armstrong 1962 Fish 1932 Mansueti & Hardy 1967 Lippson & Moran 1974
I. punctatus	Saksena et al 1961 Mansueti & Hardy 1967	Fish 1932 Lippson & Moran 1974 Mansueti & Hardy 1967
Noturus exilis		
N. flavus		Fish 1932
N. furiosus		
N. gyrinus		
N. insignis	Mansueti & Hardy 1967 Lippson & Moran 1974	Mansueti & Hardy 1967 Lippson & Moran 1974
N. miurus		
Pylodictus olivaris		
Aphredoderus sayanus		Mansueti 1963
Percopsis omiscomaycus		Fish 1929, 1932
Lota lota		Kanonsky 1928 Europeizeva 1947? Fish 1929, 1932
Fundulus diaphanus		Fish 1929, 1932 Lippson & Moran 1974
F. notatus		
F. notti		

Table 1 (cont.)

Species	Descriptions	
	Egg	Larva
Gambusia affinis	Kuntz 1913 Krumholz 1948	Kuntz 1913 Lippson & Moran 1974 Krumholz 1948
Labidesthes sicculus		Fish 1932
Culaea inconstans		Fish 1932
Gasterosteus aculeatus	Kuntz & Radcliffe 1918 Jacobs 1948 Vrat 1949 Lippson & Moran 1974 Swarup 1958 Thomopoulos 1953	Vrat 1949 Krutz & Radcliffe 1918 Swarup 1958 Fish 1932 Lippson & Moran 1974
Pungitius pungitius		
Morone americana	Mansueti 1964 Lippson & Moran 1974	Mansueti 1964 Lippson & Moran 1974
M. chrysops M. mississippiensis		Fish 1932
Ambloplites rupestris		Snyder 1970 Fish 1932
Lepomis cyanellus	Meyer 1970	Meyer 1970 Snyder 1970
L. gibbosus	Balon 1959 Lippson & Moran 1974	Balon 1959 Werner 1966 Fish 1932 Lippson & Moran 1974
L. gulosus	Carr 1939	Larimore 1957 Carr 1939
L. humilis L. macrochirus	Meyer 1970 Lippson & Moran 1974	Meyer 1970 Lippson & Moran 1974 Werner 1966
L. megalotis L. microlophus	Meyer 1970	Lipson & Moran 1974 Meyer 1970 Werner 1966
Micropterus dolomieui	Meyer 1970 Lippson & Moran 1974 Doan 1939	Meyer 1970 Lippson & Moran 1974 Snyder 1970 Fish 1929, 1932 Doan 1939

Table 1 (cont.)

Species	Descriptions: Egg	Descriptions: Larva
M. salmoides	Chew 1974 Carr 1942 Kelley 1962 Meyer 1970	Chew 1974 Carr 1942 Snyder 1970 Meyer 1970
Pomoxis annularis		Snyder 1970 Morgan 1954 Lippson & Moran 1974
P. nigromaculatus		Snyder 1970 Lippson & Moran 1974
Ammocrypta pellucida		
Etheostoma blennioides	Fahy 1954	Fahy 1954
E. caeruleum		Fish 1932
E. chlorosomum		
E. exile		Fish 1932
E. flabellare	Lake 1936	Lake 1936 Fish 1932
E. microperca		
E. nigrum		Fish 1929, 1932
E. olmstedi	Lippson & Moran 1974	Lippson & Moran 1974
E. spectabile	Linder 1958	Linder 1958
E. zonale		
Perca flavescens	Mansueti 1964 Lippson & Moran 1974	Norden 1961 Fish 1929, 1932 Mansueti 1964 Lippson & Moran 1974
Percina caprodes	Cooper 1976	Fish 1932 Cooper 1976
P. copelandi		Fish 1932
P. evides		
P. maculata	Raney & Lachner 1939 Petravicz 1938	Raney & Lachner 1939 Petravicz 1938
P. phoxocephala		
P. shumardi		
Stizostedion canadense		Nelson 1968a Fish 1929, 1932
S. vitreum	Olson 1966 Carpenter 1939	Norden 1961 Nelson 1968b
Aplodinotus grunniens	Davis 1959 Swedberg & Walburg 1970	Fish 1932 Swedberg & Walburg 1970

Table 1 (cont.)

Species	Descriptions	
	Egg	Larva
Cottus bairdi	Lugwig & Norden 1969	Fish 1932
	Koster 1936	Koster 1936
C. cognatus	Koster 1936	Fish 1932
		Koster 1936
C. ricei		Fish 1932
Myoxocephalus quadricornis		Kahn & Faber 1974

lack of comparability between descriptions, an inability to make positive identifications when not all species of a taxon are described, and a lack of complete descriptions for more than 60% of the species. The best strategy to overcome the problem of identifying egg and larval stages of Great Lakes fishes seems to be a dual one; in the short term compilations of existing literature are made and distributed, and in the long term a program is established to encourage comprehensive investigations into limited taxonomic groups.

Literature Cited

Hubbs, C. L., and K. F. Lagler. 1964. Fishes of the Great Lakes Region. Univ. of Michigan Press, Ann Arbor. 213 pp.

Mansueti, A. J., and J. D. Hardy. 1967. Development of fishes of the Chesapeake Bay region. An atlas of egg, larval and juvenile stages. Part 1. Univ. of Maryland. Baltimore. 202 pp.; 90 figs.

Discussion

UNIDENTIFIED PERSON: Will the final bibliography be sent out?

MR. BOREMAN: What we plan to do is include the bibliography as part of the proceedings of the workshop. We are going to try and get a copy to everybody who is here.

MR. FETTEROLF: Bob, do these two documents (annotated bibliography and Table 1) go together?

DR. WERNER: Yes.

MR. FETTEROLF: And when you start off on the thin one (Table 1)--and come down to the Ichthyomyzon--you say there is nothing available for Ichthyomyzon. Then in your bibliography we have a paper on comparative embryology. Yet you felt that this was inadequate to provide you with descriptions?

DR. WERNER: Yes. That paper deals only with the egg and figures that are provided only for Petromyzon and Ichthyomyzon unicuspis in one stage. I felt it was probably inadequate. This is, of course, a subjective judgement. In preparing Table 1, it was my feeling that we needed fairly detailed descriptions, not just a key or a limited embryological study. Keys work, if you have a limited array of species or a limited geographic region. One can then make the comparison, and by the process of elimination work on down. All that is needed is to have one or two key characters to allow one to separate each species. But since the descriptions are incomplete we can hardly have a key. We need fairly detailed, complete descriptions. I went through this bibliography and tried to find those species that had primary descriptions developed on them. I should emphasize that the purpose of Table 1

was just to get some rough idea of the percentage of completely described species. The information is in the bibliography. That is the point to work from.

FISH INHABITING U. S. WATERS OF THE GREAT LAKES, WITH INDICATIONS OF THEIR RELATIVE ABUNDANCE AND OF THEIR IMPORTANCE AS COMMERCIAL, SPORT, OR FORAGE SPECIES

Lee Emery *

Knowledge of the abundance, distribution, and importance of Great Lakes fishes is a prerequisite for making intelligent decisions relative to the siting of power plants on the lakes; as well as to the development of other water-use projects that threaten to impair the lakes as fish habitat. A first step in providing this knowledge is a checklist of the species in each lake; with some general indication of their ecological and economic value, and of the size as well as extent of their populations.

Species lists for Lakes Superior, Michigan , Huron, Erie, and Ontario are presented as Appendix II. Only common names are used, in accordance with the American Fisheries Society Special Publication No. 6. (1970); although scientific names for each species may be found in the same publication.

The preparation of these lists was considerably more difficult than might be supposed. For instance, the two most comprehensive reports of fish distribution in the Great Lakes (Hubbs and Lagler, 1958; Scott and Crossman, 1973) relate to entire watersheds and do not always clearly indicate whether a species described for the drainage basin of one of the lakes actually occurs in the lake proper. Moreover, data from some recent fish collections in the Great Lakes are as yet unobtainable. Nevertheless, a fairly substantial body of reference material was avaiable. The more formal fish-distribution reports used in the compilation of the lists, in addition to the two references cited above, were: for Lake Superior--Underhill (1974); for Lake Michigan--Wells (1968); for Lake Ontario--Christie (1973), and Crossman and Van Meter (MS). In addition to these references, I consulted commerical catch records for each of the lakes; various documents of the Great Lakes Fishery Laboratory (U. S. Fish and Wildlife Service), such as research vessel cruise reports and reports to the Great Lakes Fishery Commission for each of the lakes; and data from studies at power-plant sites for all lakes except Superior.

For purposes of this report, each species abundance has been classified as (1) common; (2) uncommon, although formerly common; and (3) uncommon, present and past. A species must have been recorded during

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the past 10 years for the lake in question to be included in the lists at all. Thus the blue pike (actually only a subspecies), which is on the Federal Endangered Species List for Lakes Erie and Ontario, and the longjaw cisco, which is on the Federal List for Lakes Michigan, Huron, and Erie, are excluded. (A single longjaw cisco was recorded from Canadian waters of Lake Huron in 1975). A species was categorized as common if it occurs in any substantial portion of the lake (e. g., Green Bay of Lake Michigan). The category-1 species include all those which are important commercially, and most which are important as sport or forage fish. The category-2 species are primarily those which were once important in one or more of the above aspects (most of them as commercial fish), but have subsequently experienced a radical reduction in abundance. Some, however, could become common again under proper management. The category-3 fish are for the most part only marginal Great Lakes inhabitants, residing primarily in tributary streams. They are ordinarily found in the lakes only in very shallow areas, and are usually (but not invariably) scarcer than the category-2 species. The likelihood of category-3 fish becoming common in the lakes in the foreseeable future (with perhaps one or two exceptions) is small.

The lists also contain designations indicating the species which are important as commerical, sport, or forage fish. A species was considered to be commercial if its commerical production in U. S. waters of the lake in question was at least 5,000 pounds in 1974. In some cases the designation was conjectural; because the catches of certain closely related species, e.g., suckers and ciscoes, are customarily reported as a group rather than individually. The decision as to which species should be considered commercially important was based on knowledge of the relative abundance in the lake of the various species in the group. For example, among the species in the rather substantial cisco catches reported in Lake Michigan, only bloater is designated as commercially important, because the other species are known to be rare. The designation of species as sport or forage in Lakes Superior, Michigan, Huron, and Erie generally followed the classification of fishes as sport or forage in the State of Michigan's guidance manual for thermal and intake studies (Section 316, Public Law 92-500). The corresponding designations for Lake Ontario were based on inferences from Michigan's manual, together with a knowledge of the abundance of various species in the lake.

An orginal intent of this report was to include data on the relative vulnerability of the various species in the lists to impingement and entrainment. After investigation into the matter, I concluded that the subject was too involved to be considered in detail here. Nearly all fish species in the Great Lakes, because they may be found in shallow water during one or more of their life stages, are vulnerable to impingement/entrainment to some degree. Among the few exceptions are the pygmy whitefish (present in Lake Superior only) and the fourhorn sculpin (present in all lakes except Erie)--both of which occupy deep waters throughout their lives. Some species are obviously highly vulnerable to impingement/entrainment (e.g., alewives in Lake Michigan and gizzard

shad in Lake Erie), but any detailed analysis of the vulnerability of the various species would require a comprehensive review of data from power plant studies.

I wish to express my appreciation to Drs. Robert S. Benda, Aquinas College, and David Jude, University of Michigan, and Vincent Kranz, NUS Corporation, for providing information on species collected at various power plants.

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Discussion

DR. WERNER: I was curious about your criteria in that you included the American eel, for example, which isn't going to spawn in the area.

MR. EMERY: Right.

DR. WERNER: You wouldn't have any larvae. I in turn left it off of the bibliography on that basis.

MR. EMERY: I think that would be a valid reason.

DR. WERNER: Also some of the other fish may not have larval stages in the lake. It seems to me that we may need to establish some sort of of a constant pattern for the species that we are interested in, in the Great Lakes. I think your approach is good in many ways, but I see some places --

MR. EMERY: As I say, this is a working document. I tried to show what was there. I realize I left out a lot of species that, were found in the streams, very near the lake itself.

MR. BOREMAN: What do you see as the next logical step?

MR. EMERY: I think that you have made a good point here. Some of these species, for example, the 3's, one's chances of sampling them are not as great as for 1's or 2's. I think through talking to people involved in sampling at various power plants; we are more likely to come up with the more accurate species list. They are dealing with these things all the time and conduct scientific studies frequently at these sites. I think they might have a better handle on what species are more important in terms of the larval entrainment because they are the people who are going to be catching larval fishes.

This list isn't oriented only toward larval fishes; it includes all species, as indicated.

MR. BOREMAN: Any other questions?

MR. EMERY: I thought of something. In a couple of the reports I saw a yellow bass listed for Lake Ontario. To my knowledge it wasn't in the Great Lakes except for one rare stray back in the 40's in a Chicage drainage canal. I didn't include it. I didn't know if it was a misidentification or exactly what to do with it.

Has anybody working in Lake Ontario seen any yellow bass? (No response).

UNIDENTIFIED PERSON: I wondered why you eliminated the spoonhead from Lake Michigan. Has it not been found?

MR. EMERY: There are recent references. Tex Wells, a fellow laboratory worker, saw one about 20 years ago but I have not seen any reports from anyone. Has your group seen any?

UNIDENTIFIED PERSON: No.

MR. EMERY: I tried to put some kind of limitation on species found in the lake. Otherwise, we would have about 200 species.

DR. WANG: Did you have lists concerning the endangered species?

MR. EMERY: I tried to stay away from threatened and endangered species. There were plenty of problems trying to put this together. When one talks about threatened and endangered, it varies from state to state within a lake. For example in Lake Erie, Ohio calls one fish threatened, while in Canadian waters a different term is used. To solve these problems I thought the Federal Government's list of threatened and endangered species would be most useful to cover all the lakes. The Register only listed the blue pike and the longjaw cisco. The longjaw hasn't been seen in about 40 years, and the blue pike, as I said, disappeared in '65 Michigan just recently put out state list of threatened and endangered fishes. Michigan's list has about 15 species on it. I think most states are going to compile their own lists too.

MR. FETTEROLF: This is the part of the program where we are going to talk about relative importance in power plant decisions.

MR. EMERY: Yes.

MR. FETTEROLF: I haven't heard you say an awful lot about that.

MR. EMERY: Yes. I said a couple of things. Number one, it is extremely difficult to put together a list saying which species are likely to be entrained and impinged without going to each power plant on the lakes and asking them what variety and number of species they had caught. I hinted that Clupeids were the most common family of fishes in the Great Lakes, and are entrained and impinged at various power plants.

It would be nice to come up with a list of the top 10 species of fish most susceptable to entrainment impingement in each of the Great Lakes. Given the short time that I had to prepare the paper, I couldn't get all the information from all the power plants on each of the lakes, but it could be done in the future. I think it is a very important question. I also said that the location of the power plants, let's say located in a bay as opposed to the lake proper, cause different types of fish entrained or impinged.

Also, the list does not deal entirely with larval fishes, it includes all stages of the fish species. The fish which are presently within the lake, and actually spawn naturally as opposed to stocked fishes. That was one of the most difficult of all.

MR. FETTEROLF: As John Boreman said earlier, the decisions on these are being made. And I think maybe you are playing around now with something for the future, because when 316(a) and 316(b) came down in the states, my goodness, that's like two or more years ago now. We immediately had to interpret what the Federal Government meant by important species. They provided us with something like three categories, which we felt were inadequate.

The State of Michigan included other criteria. We had to do this because our consultants were involved in these demonstrations. Now I

understand that several entities put off 316(b). Michigan didn't. Michigan said do it now, and we made up our own guide and manual for 316(b).

But it certainly seems that one can't expect a contractor, or a consultant for a utility to investigate every species that is found at a particular site. And when the group gets together this afternoon and starts talking about determination of highest priority information gaps, one of the areas that has to be decided is what are your criteria for what is an important species?

MR. EMERY: Yes.

DR. WERNER: I want to ask Carlos a question. Why can't you study every species at the site?

MR. FETTEROLF: Because I think that is putting an unfair burden on the public utility. I think it is up to a biologist to say what is important.

MR. BOREMAN: Would it be worthwhile to include on these lists those species whose eggs and/or larva are pelagic, relatively pelagic and, therefore, more susceptible to entrainment, such as in terms of entrainment of water mass alone. If these fishes are up in the water column at any particular life stage, would they be more susceptible then were they not suspended in the water column?

MR. EMERY: Yes, I think a list of that nature -- as I said, some of the species we don't know a lot about. But the list is coming fairly close to representing important species. Some species are more important commercially or as a sport or a forage than others.

MR. BOREMAN: I was speaking of susceptibility to entrainment. Not necessarily important. You cannot study them all. Time and money wouldn't allow that. But those that are in the water column and close to the intake, I think those are worth considering.

If that was marked on these lists, then number one, you would know what species not to concern yourself with to a great extent; and those species, as you say, the Clupeids, with their pelagic nature, which would be of principal concern.

MR. EMERY: Of course, a lot of species in the list have actually been taken by the various power plants at one life stage or another. And that was not indicated. I want the species as such that were reported, but probably a list could be put together of that nature.

MR. FETTEROLF: Michigan did this with their 316(b) guidelines. When we were picking out sport species, we did not say that we need to know all of the life history process that is affected by this plant; but we tried to pick out that aspect of their life history which would be affected. So for a certain species, we would say we want you to look at the adult here;

and with the other species, we want you to look at the spawning requirements and habitats; and then we would say for this we are interested here in egg. And other species, we would say look at larva. So we didn't say look at the whole spectrum. We tried to pick out and make it a little easier or make it more practical for everyone involved.

MR. EMERY: Michigan is one of the few states to put together this particular representative important species list. Any species that Carlos is referring to is also found within the list. It is not indicated as which stage, larval, eggs, or what have you.

MR. FETTEROLF: If anyone has any questions on that list, they can talk to Dr. Jude; or if there are any Consumers Power people here, they can tell you what they're looking at.

DEVELOPMENT OF A KEY TO THE FAMILIES OF GREAT LAKES FISH LARVAE

Alice J. Lippson*

When John Boreman called to ask whether it was possible for me to put together a family pictorial key for Great Lakes fish larvae similar to the one I had done for the Potomac ichthyoplankton manual, my initial response was "I have never even been to the Great Lakes." But on second thought, my response was "well, there are so many families already included in the Potomac manual that would, of course, be found in the Great Lakes that I'll attempt it."

The resulting key (Appendix III) is preliminary. It has been compiled primarily as a work sheet for this workshop and is presented to the participants for scrutiny and refinement just as both Bob Werner and Lee Emery have presented their bibliography and species lists. Because the key has been written to be "picked apart" so to speak, I went ahead even though in compiling it, I ran into a lot of problems.

One of my biggest problems was that I had to use only references at hand, as there was not sufficient time for a thorough literature survey involving interlibrary loans. Bob Werner's bibliography was not accessible at the time. Likewise, Lee Emery's species list was not available and, as it turns out, there is one more family in the pictorial key than on his list. This is Poeciliidae. He excluded this family because his list intended to encompass only those species inhabiting the Great Lakes proper not the entire watershed. Other than this, our families coincide.

My objective is not to provide species-specific descriptions, but a quick guide to the identifier so that he can feel confident in identifying at least to the family level. Once you get to the family, in many instances, your battle is won because out of the 26 families in the Great Lakes region half or 13 have only a single species. These single species families include Acipenseridae, sturgeons; Amiidae, bowfins; and Anguillidae, eel. (By the way, the eel is listed because of adult distribution within the Great Lakes. In the key it is noted that larvae or leptocephalus stages would not occur there. Similarly, with other species, trouts and salmon for example, adults are present within the Great Lakes proper but egg and larval stages are absent being found instead up the streams. However

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inclusion in the key is based on adult distribution.) Other families with one species are Hiodontidae, the mooneyes; Aphredoderidae, pirate perches; Osmeridae, smelt; Umbridae, mud minnows; Percopsidae, trout-perches; Gadidae, cods; Cyprinodontidae, killifishes; Poeciliidae, live-bearers; Atherinidae, silversides; and Sciaenidae, drums.

In the key, for single species families the description and illustration is specific for that species if early developmental stages have been portrayed in the literature. Otherwise reference is to another species of the family from a different geographical area. In multi-species families, the description is of generalized family characteristics and the illustration is a hypothetical or "typical" larva.

In trying to identify a fish larva there is no substitute for the visual experience of observing a known specimen. Even the best pictures do not show what a larva actually looks like. Does a photograph show this better to the uninitiated? Or does a drawing give more needed details? One can see from the literature that authors widely differ in viewpoint (or perhaps, availability of an artist or photographer). Some prefering photographs; others drawings which might be half-tones, line drawings, simple outlines, or extremely detailed. The most helpful methodology, for presenting the visualization of morphology is a combination of photographs and drawings. There are many technical problems to solve before arriving at the stage where one has the ability to get good photographs showing all details of fin ray development, etc. But, if drawings accompanied pahotgraphs, they would provide the reader with a more accurate identification source.

The problems a person has relying solely on published illustrations and descriptions become really apparent to me in preparing the key. For instance, in the case of the mooneye, I had seen pictures of various larval stages with detailed descriptions; and, on this basis, having no access to specimens the description in the key was written. Yesterday in the laboratory session I saw a series of mooneye larvae and my immediate response was "WOW! There is no question, one would never mistake a Hiodontidae for anything else." Having had the opportunity to examine the specimens, I can now go back to the preliminary key and provide a more adequate description and refine the drawings to emphasize the most important identifying characteristics which were not evident from the original published sources. This is a good example of what should evolve out of this workshop.

One can take the moment now to add an addendum to the mooneye description in the key on page 209 as follows: Larva - very large with a dense opaqueness or heaviness; body sparsely pigmented except for a mid-ventral line beginning at vent and passing around tail to dorsal fin in later stages; snout projecting and squarely blunted.

In developing the key, I have tried to keep in mind the progressive steps one follows in attempting to identify an unknown larva. There are

certain basic characteristics which you look at before anything else. First of all, the size. Is it a small or large larva? These obviously are very subjective and relative terms. But certain species have very small hatching larvae -- two, three or four millimeters, others hatch at seven or eight millimeters. One does not even need to look at them under the microscope to know right away that he can eliminate certain families on the basis of size alone.

The next step is looking at general body shape. Is it a very elongate, slender larvae, or does it have a bulkiness to it? Is it short and stubby in appearance? These are characteristics which are apparent immediately. Not all larvae fit these extremes. Rather they tend to be moderately proportioned larvae, and other identifying characteristics must be used.

The next step is to observe more specific body proportions or relationships. I find one of the most useful proportions to identify a specimen at least to its family is the position of the vent. In other words, ratio of the preanal length to total length or preanal to postanal lengths.

I should emphasize here again that what is stresssed in the key are typical family features. Sometimes one gets into problems when identifying a family with many species and much variation among the species. A good example is the Centrarchids. Generally they have very short preanal lengths; and yet, if one compares crappies to largemouth bass there is quite a bit of difference in the relative position of the vent. What has to be done is use a combination of different characteristics. Centrarchids have, along with the generally short gut, a characteristically large bulky-appearing head that with experience one can recognize easily: In some multi-species families, larval morphology differs to such an extent at the genus level that a family key is unapplicable and sub-family descriptions must be provided. Salmons and whitings are examples of this.

Another body proportion that is often a good identification guide is the relative size of the head. Head shape, by the way, can also be important, particularly in the slightly older larvae after yolk absorption.

The presence or absence and position of oil globules is often used as criteria for identification, and comment on such is utilized in the present key. Perhaps this is a mistake. In preserved specimens the position of the oil globule can be very inconsistent. In the literature it may be described as being in the posterior of the yolk, yet in many specimens on hand it may very well be forward. Furthermore, in some specimens, the oil globule cannot be discerned. Whether such discrepancies are due to mechanical damage in preservation or are within normal variability is uncertain.

Another major feature to observe is fin structure. Relative position and developmental sequence of fins are often an extremely useful guide. In other words, is the origin of the anal fin posterior to

the dorsal fin or anterior? Is it located mid-body? Are the pectorals large? For example, if a Great Lakes specimen is examined and extremely large, stiff, pectoral fins are its most predominately noticeable structures, and its vent is anterior; then it has almost got to be a sculpin. Reference to available literature on sculpin development could then verify family identification.

Pigmentation is a creditable identification character. It is highly variable not only among individuals of the same species; but also among specimens collected from different geographical regions. As a definitive character it must be approached with caution. There are certain families that, in spite of tremendous variation in pigmentation among species, have a characteristic family pattern which dominates. Most cyprinids, for example, have a four-rowed pattern that is persistant and consists of dorsal, lateral, ventral and abdominal rows of melanophores.

In summary, usually no single characteristic will take you to a family identification but a combination can and will, more times than not, be definitive. There are many species-specific characteristics which must be considered before a final evaluation is made.

I would like to stress that this preliminary family key is not in any way a substitute for a species identification manual or guide which, hopefully, will soon be compiled for the Great Lakes Region. It is hoped that it will provide, after refinement, an immediate tool to aid in identification to the family level. If specimens are initially sorted to this level further perusal of existing literature will in most cases lead to species identification.

DISCUSSION

MR. NELSON: When you were talking about basic family characteristics, you didn't say anything about myomere counts.

MS. LIPPSON: I am sorry, I simply neglected to mention them. Certainly myomere counts are valuable, and they are included in the key where they are a definitive aid to identification. For example, certain Percidae and Percichthyidae species are similar in general appearance and body proportion, but the differences in myomere count allows an immediate differentiation. You can visually see this difference even without making an actual count because of the relative differences in appearance of the higher to lower numbered counts.

DR. JOHNSON: I think it could be much more helpful if this thing was actually written as a dichotomy key rather than a pictorial guide.

MS. LIPPSON: The orginial intent for this preliminary key was to attempt only a pictorial guide in a format following that provided in the

Potomac manual. We had this quandary with the Potomac Manual about whether to attempt a dichotomous key or resort to the pictorial guide. But in writing the Potomac book we found there were so many gaps in our knowledge that a dichotomous key including all species was virtually impossible. The pictorial key allows us to get to the family. Once you get family, that is the point where you may start a useful dichotomous key.

DR. JOHNSON: It might be important then to put in here a note that families are illustrated from species other than Great Lakes species.

MS. LIPPSON: Yes, I agree that was a comment I omitted, but it is stated in the introduction to the key. One other point which I debated was whether to approach the key in the manner I did, or whether to attempt an entirely different format which would separate and group (or list) larvae according to morphological details such as larvae with oil globules vs those without; elongate vs stubby; short fins vs long fin, etc. What I tried to do is place myself in the position of someone who knows nothing about fish larvae. In other words what are the most obviously noticeable characters. I tried to be as practical as possible.

I have juggled all kinds of approaches in my mind and I think that one thing that should be determined at this workshop is what is the best methodology for practical laboratory guides.

DR. JOHNSON: One thing that is important that you didn't bring out is that relative time of development of the different fins. That can help.

MS. LIPPSON: I didn't have the literature to do this.

DR. FABER: I think that the family is not really a good level to provide a key for. I think you have got to look at the ichthyologies of the sub-families or groups within families, which I think you found out yesterday.

MS. LIPPSON: For some specific families, yes.

DR. FABER: Consequently, the family is not a good level to make a key.

MS. LIPPSON: That is what I have mentioned previously and is what we also found with the Potomac manual. The picture key takes you to a family, then you have to go to a species key.

DR. FABER: You infer that you shouldn't go to family, you should go to a sub-family or the groups that are homogeneous or icthyological homogeneous within a family. In the Salmonids, you can separate the salmons and trout, and the Coregonus artedii, which is really a sub-family. You cannot combine the two groups because the larvae are so different

MS. LIPPSON: That was the exception I made in the key.

DR. FABER: There are others, too.

DR. JUDE: I would like to bring up a whole new can of worms, that is with regard to fish eggs. Do you think it is feasible to fool with trying to identify the different species and different families of fish eggs?

MS. LIPPSON: Well, you know my answer is no.

DR. JUDE: Good. Right.

MR. SNYDER: On the topic of fish eggs, it is significant to point out there are very distinct fish eggs that you are likely to come across, such as the salmon.

MS. LIPPSON: Yes, that is true.

MR. SNYDER: These freshwater eggs are quite distinctive. Smelt eggs are very distinctive, and in many fish you get an egg with late embryo. You can often identify if based on similar characteristics reached fairly early.

MS. LIPPSON: True. I think the question Dave Jude was talking about is trying to do it on the same level as you would the larvae.

FISH EGG AND LARVAE STUDIES: SOME PROBLEMS AND RECOMMENDED SOLUTIONS

J. D. Hardy, Jr.*

Today I am going to discuss certain aspects of the use of literature in fish egg and larvae studies, as well as other problems involved in this kind of study.

Initially, I was asked to discuss only those "problems" dealing specifically with the literature. A question immediately arose, however: Is literature really a problem area? It seems to me that the only problem in dealing with literature is that there are a lot of biologists, myself sometimes included, who sometimes just do not want to take the time and trouble to use the literature as the basic excellent tool that it is. We tend to fudge over our literature search as quickly as we can so that we can get on with doing our own thing; and we are missing the use of one of the best research tools available to us. To say that you have trouble using the literature is like saying you have trouble using a microscope. A microscope can have lots of idiosyncrasies that take getting used to, and the literature can sometimes seem totally impossible to deal with; but both are excellent research tools.

In our lab we deal pretty much with literature. We send a technician off to look up references on one fish or another, and it all seems pretty simple. But we all know how this works. One reference leads to other references, and these in turn lead to even more references and pretty soon your desk is under a mountain of books. I have been known to get my desk in this kind of shape and have someone walk in and say "Dave Hardy, your problem is that you just can't see the forest for the trees." It must be very nice indeed to be the kind of biologist who can sit up in an ivory tower and look at the forest and say, "My, my, isn't that pretty?" But we are talking about using the literature, and the only way to effectively use the literature is to get down in the forest and touch every tree that one can. Basically, all I am saying is dig deep, dig an lot deeper that one might think he has to.

For the sake of argument, I will agree to the use of the term "problems" in dealing with the literature. I have consequently defined nine such "problems". They are very basic and very simple.

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The first "problem" is the missed reference. We all miss references. We put things together. We are kind of in a hurry. We wind up missing some very important references.

When I was working on Volume I of the Fish Atlas, I was preparing the text for Trachinocephalus myops. I said to myself "Here's a fish that isn't too abundant around Chesapeake Bay, so I'll just go through Zoological Record and Biological Abstracts and let it go at that." Now this is one good way to miss references. We published a plate showing several juveniles of Trachinocephalus myops, and I made the unfortunate mistake of saying that the eggs and larvae are undescribed.

We have a fellow at Solomons, Phil Jones, who is updating some of the material in Volume I, and he is burning midnight oil. He is going through piles and piles of papers and getting very tired of doing it, but he recently found a paper which I had missed. It was published in Russia in 1965, and contains excellent descriptions of the eggs and larvae of Trachynocephalus myops. I missed it because I wan not digging deep enough.

The second "problem" is the thing I call the "razzle dazzle rumor mill." We all know how rumors work. One writer says hag fish; the next writer says hog fish; the next writer says hake fish; and the last writer does not have the foggiest notion what the first guy was talking about. This sort of thing pops up in very serious ways in ichthyological literature. One has to be particularly cautious about using review papers for basic data. Review papers are good guideposts.

In actual cases we have found statements of the diameter of "fertilized eggs" when, in fact, the original author had presented data on ovarian egg size. We have data on what is presented as total fecundity, when, in fact, the original investigator was stating the number of eggs in one ovary. A lot of "hatching lengths" are based on measurements of yolk-sac larvae which have been allowed to grow until the yolk-sac is essentially absorbed. There also are a number of published "spawning seasons" based on the presence of ripe males in a population. In numerous kinds of fishes, the males remain ripe throughout most of the year, but this has nothing to do with the actual spawning season of the species. There are two morals to this story. One is: Just because one happens to find a ripe male, it does not necessarily follow that he is going to get to spawn. The other is that if one is dealing with the literature he had better take the trouble to go back to the original source. One can not depend exclusively on review type papers.

Problem number 3 is what I call "expansion of parameters." Let us talk for a minute about the spawning season of the codfish in the Northwest Atlantic Ocean. One can pull out all the information from a couple of good review papers and say "O.K., this is all I need to know about the spawning season of the codfish in the Northwest Atlantic." Now I do not mean to knock the authors of the papers I am going to cite (they

are excellent reviews), but let us look, for example at Breder (1948), and Leim and Scott (1969). Using these sources one finds a big gap in the middle of the year when the codfish is not spawning. Doing an in depth study of this same subject, using about fifty sources which give data on seasonal occurrence of codfish eggs in the Northwest Atlantic Ocean, we find that the codfish spawns there throughout the year.

One might ask "Why go to all the trouble to dig all this stuff out of the literature?" Well, the other alternative is to spend an awful lot of time and money trying to resolve a problem which was long ago resolved.

Problem number 4: The incorrect citation. I am not going to be boring with the fact that one will sometimes get a citation saying something is in Volume 6 when it is really in Volume 16, or something was written in 1950, when it was actually 1940. If one can not handle this kind of little problem, he should not be in the library in the first place. I am talking about another kind of incorrect citation. For example, in 1963 an Australian review of the life history of Mugil cephalus gave the egg diameter as 0.6 to 0.73 mm. The authors of this paper cited a paper published in Russia in 1954. A few years later (1970) another review of Mugil cephalus appeared in Israel. They also cited a paper published in Russia in 1954, but gave the egg size as 0.72 to 0.78 mm. The problem was that both reviewers were citing exactly the same Russian paper. Now, in a case like this, one only has a couple of choices: One can pay his penny and take his pick and hope that one of the reviewers was right; or one can do what we are doing at Solomons, dig out the original Russian paper and go through all the agony of having it translated and see what the author actually said. I think that is the key to the whole business: go back to the original source.

Another example of the same thing. Two reviewers gave completely different spawning seasons for Mugil cephalus although both were citing the exact same source, a paper published in France in 1938. And that is why my colleague George Drewry is sitting around these nights reading French. He is trying to find out what that Frenchman really said.

The fifth problem: Misidentifications. A lot of people say one can not use old illustrations of fish eggs and larvae because they are frequently misidentified. And, indeed, they frequently are. But if one knows egg and larval taxonomy, he can probably identify the species anyhow. A couple of examples: Agassiz and Whitman presented a series of eggs and larvae which they identified as bluefish. In point of fact, most of these figures have been clearly identified as larval needlefish; yet in fact, they are larval halfbeaks. This sort of thing should not really bother the researcher if he knows fish eggs and larvae. These misidentifications can be looked at as a very positive thing. Agassiz and Whitman have given us the best color illustrations of the eggs and larvae of the butterfish currently available, and the

misidentified halfbeak larvae is one of the very few halfbeak larva illustrations in the world literature. There is a lot of good stuff hidden among misidentification.

Problem number 6 I call "the life-history study that isn't" I will not dwell on this one long. It is just something that really gripes me. We get lots of papers which begin with the "the life history of..." but do not seem to deal with life history at all. Frequently they discuss growth, feeding habits, parasites, or response to a single environmental variable. The other day I got a "life history study" which was nothing more than a computer read-out. I could not figure out what it was supposed to be saying, and I doubt that the computer that wrote it could have explained it either. In short, we need to define the term "life history" and stick to that definition.

Problem number 7 is the opposite of this: "the non-life history study that is." One has to look at a lot of things which he may thing are not useful. For example, who would go to McClanes Fishing Encyclopedia and expect to find information of the fecundity of certain centrarchid fishes which is not otherwise available? But there it is. Who would expect an article in a popular magazine to contain the only picture in the world literature of the larva of the white marlin? I do not remember whether it was my associate Dave Johnson or Ron Fritzsche who found this, but I remember there was a real shout of joy. This was a major find. Or would you expect to look at an article like "Induced Spawning of the Striped Mullet by Hormone Injection" and expect to find excellent descriptions of egg and larval stages? But, there they are. It seems to me that one has got to track down every title he gets, no matter how unimportant it may seem; or one is going to lose some useful information.

Problem number 8 is the problem of what to call various life history stages of fishes. This can be a real headache in dealing with old illustrations. There is currently a great deal of emphasis on re-defining early life-history stages of fishes, and I welcome this interest. Most of the new definitions, however, are based on fine details of development; and these details were generally overlooked by earlier investigators. In consequence, whether we like it or not, we have to use the simplist approach to this problem as possible. As in volume I of the Fish Atlas, we still recognize three basic life history stages: yolk-sac larva, larva, and juvenile. We can take most of the illustrations out of the old literature and put them in one of these catagories. While we are talking about life history stages, I would like to say that we are still debating about the use of the term prejuvenile. I think it is a useful term for those species which go through radical changes in pigmentation, morphology, or ecology following the normal larval period. The codfish is a good example. Larvae of this species live at the surface and are generally pale in color. At the end of the larval stage they turn bright blue and begin a slow descent to the bottom, where there is again a profound change in pigmentation. I regard this transitional period as a prejuvenile stage. I would welcome any debate about the use of this term.

That about covers the "problems" involved in dealing with literature. I guess that if I am saying anything about literature, it is that one simply has to live under that big mountain of literature I have been talking about. And one has got to accept the fact that this will demand a great deal of his time and that there is no simple way out of it. Otherwise literature will not be a useful tool; it will merely be a "problem."

This is enough about literature. Let us talk for a while about some other problems in fish egg and larval studies. Take a biologist and put him to work somewhere in the Great Lakes, or down on the Chesapeake, or out in San Diego Bay and say "O.K., fella, tell us something about the life history of all of the fishes in this area."

Well, there are hundreds of kinds of fishes in the area and the poor fellow panics. He just can not do it. He does not have the money or the time. He does not want to spend all his weekends and nights doing it. Then he says "Man, have I got an idea. I will just study the money fishes." So he pulls out a big handful of fishes and puts them over in a special pile and says, "These are the money fishes. These are the ones I am going to concentrate on."

If my use of the term "money fish" sounds a little bit derogatory, that's good: because that is exactly how I want it to sound. We have invented some fancy terms to describe these fishes. We call them the "commerically important species" or the species which are "important to the sport fishery" or the species which might be a "potentially good protein source for man"; but what we are really talking about are the kinds of fishes from which we can make money. In actual fact I am persuaded that there is no such thing as one fish which is any more important than any other fish.

Take for example the lanternfish, one of the Myctophiform fishes. These sort of fish are generally thought of as being exotic; the thing one would expect to see in an old, William Beebe book; or sometimes may be seen Saturday night after a particularly good cocktail party. They certainly are not the kinds of fishes one would want to spend a great deal of time and money on. But, maybe the lanterfishes are more important than they seem. Think for a minute about a kind of abstract biological concept called a food web. Food webs are supposed to come in two varieties: structured and unstructured. There are thought to be a number of types of structured food webs. One begins with prickly pears, which are eaten by pack rats, which are eaten by snakes, which are eaten by road-runners. The food web ends with bobcats eating the road-runners. But I am not sure I believe in structured food webs at all. In fact the only structured food web in which I have any faith at all is the one that took place in the stomach of the lady that swallowed the fly, then swallowed a spider to catch the fly; and then a frog, and a cat, and a dog, and maybe a goat, and then a cow, and then a horse; and she's dead of course. Now that is a structured food web, and if she had omitted just one predator she probably would not be dead.

In the ocean food webs just do not work that way. My colleague, Doug Martin, has been doing a lot of research in marine waters of Puerto Rico. He has put together a partial food web of Jobos Bay, Puerto Rico. It is a very complex food web and completely non-structured. A non-structured food web works like this: if one likes a particular kind of food and suddenly its all gone, one simply moves over and eats something else. This can result in a lot of changes throughout the food web. What happens, then, if we take away a part of an unstructured food web. Will the changes that take place be subtle or catostrophic? At this point we can not predict. We simply do not know.

Now let's consider again the lanternfishes. If one has been reading that big mountain of literature I have been talking about, he will have learned two things about the lanternfishes: they are the most abundant fishes in the world, and they are probably the most important forage fishes in the world's oceans. I am willing to bet, however, that when we begin to study the effects of offshore drilling we will spend a lot of time and money on things like cod, and haddock, and tuna - the money fishes - and we will look at the lanternfishes and say "My, my, aren't they cute? They look like something out of an old, William Beebe book".

What I am really saying is, I think that any one kind of fish is not any more important to a system than any other kind. My friend Dr. Ahlstrom made the comment in class one day that we tend to become specialists before we become generalists. He was speaking of systematic work, but I think the idea is equally appropriate here. We have a lot of people who are specialists on the "commercially important species" - the money fishes - and we are consequently missing the boat on a lot of very useful data. I think we have to accept the entire ichthyofauna of an area and work it through. I just do not see any other solution to the problem. At Solomons, the people working with me would be just as willing to get up at 3:00 A. M. to illustrate the egg of a lanterfish as they would be to get up at 3:00 A. M. to illustrate a striped bass egg. We consider them all important.

We are planning to develop a center for the study of fish eggs and larvae at Chesapeake Biological Laboratory. We feel that work at such a center should be divided equally into four areas: (1) Library research, (2) Rearing of fish eggs and larvae, (3) Maintaining a well-organized collection of fish eggs and larvae, and (4) Publication.

We have already talked about library-related problems. Let's talk for a while about rearing. If one considers the work being done by Ed Houde in Florida and John Hunter in California, it becomes evident that there is great potential for new information in this area.

At Solomons, we have a new Controlled Environment Laboratory. At this point, our project does not have any space in the present building, but we plan to officially move in within the next year or so. Even now we manage to sneak into the Controlled Environment Lab. We have a couple

of pretty girls on our staff; so whenever we fertilize some eggs, we send one of the girls over and she says, "Gee, Sir, could I have some space in your lab?"

Using this technique, we have fish eggs all over that building and nobody knows how they got there. We are also inventive, which is one of the things one has to be if he is going to have much luck rearing fish eggs and larvae. We developed the circular constant flow embroyological module. It consists of a kiddie wading pool with a trash can in the middle of it, a pump, and some water. It is the best artificial stream we have ever used.

We are committed to the belief that rearing efforts should not be restricted to narrow geographic areas. Clark Hubbs works with live fish and developing fish eggs at his laboratory at Austin, Texas. But his normal work area extends to within a 600 mile radius of Austin. We would like to work within a similar radius of Solomons, Maryland. This would give us a 1200 mile stretch of coast line, plus access to a great variety of both marine and fresh water species. We are currently planning a mobile unit - a van - equipped with circulating water, temperature controls, a microscope, and a camera. With such a unit, and given what we now know about the spawning seasons of the fishes in the area, we could keep a fish egg and larvae rearing team busy throughout the year.

A good rearing facility has a lot of potential for spin-off projects. There is no reason not to take advantage of this potential. I know a lot of good behaviorists who bring fish into the laboratory and watch them spawn, but do not keep the eggs or attempt to hatch them. There are ichtyoplanktologists who get eggs through laboratory spawnings, but do not make observations on behavior. These people are missing important spin-off. In attempting to get eggs of Fundulus confluentus we have been fortunate enough to see courtship and spawning behavior in this species, and having photographed this activity. This is all new information. George Drewry has been observing spawning behavior in a number of species of Fundulus. He routinely hangs a hydrophone in his observation tanks and has gotten some excellent information on acoustic behavior in these species.

The point is a rearing facility should not be oriented exclusively to obtaining fish eggs and larvae. It should move in as many useful directions as possible.

Let us talk for a while about the collection we are attempting to build. It seems to me that to be most useful a collection has to have a broad base. One can not make any general statements about the larvae of a family of fishes based on the larvae of one locally available species. One has to look at the larvae of as many members of that family as possible. To build such a collection, we see three sources of material: the rearing facility, old time plankton collecting, and an exchange program with other institutions throughout the country, or for that matter, throughout the world.

What can you do with a bunch of fish eggs? One can illustrate them and preserve them in a variety of fixatives. I am rapidly coming to the conclusion that fish eggs are best illustrated in life. Now I can not draw, but in my attempts to draw, I find that when I draw a preserved egg it comes out 50% fact and 50% imagination. When I use a living egg, it comes out 85% fact and only 15% imagination.

Of course, there are other ways to illustrate. We have developed a rather fantastic photographic technique involving a system of mirrors and strobe lights, and, using this technique, we have gotten excellent photographs of living embryos. As my friend Alice Lippson has pointed out, a combination of art and photography is extremely useful. It is a good direction to move in.

Electron scanning is another very useful illustrative technique; yet, there have been few efforts made to use this tool in the identification of fish eggs. This brings us to the use of a variety of fixatives other than the old stand-by, buffered formalin. To be scanned, eggs should be preserved in gluteraldehyde. It is a simple thing to do. It takes as a minimum a single egg out of a series, and we plan to use this preservative in every series we rear. We may not ever scan all of the eggs preserved in gluteraldehyde; but on the other hand, look at the small percentage of conventionally preserved eggs which are ever really used in research. We also plan to preserve eggs, as they become available to us, in 2-phenoxyethanol for use in electrophoresis. This is an excellent tool for distinguishing any life history stages of closely similar species; yet, it has seldom been used with fish eggs. There is a great potential there.

What can one do with a collection of larvae? Again one can illustrate them; one can preserve them in 2-phenoxyethanol (as well as conventional fixatives); and one can clear and stain them. We think that it is important that all of these techniques are used as specimens become available.

For reasons which I do not understand, we have gotten away from the use of color in illustrating fish larvae; although, the value of such illustrations is strikingly apparent in the works of Agassiz and Whitman, and in the excellent monograph on fish eggs and larvae of the Bay of Naples.

The use of color notes is especially important in identifying the larvae of tunas. These larvae simply can not be properly identified without knowledge of the distribution or red and yellow pigment - all of which is lost after preservation. Pigment is also probably useful as an indicator of systematic relationships: The white, yellow, gold, and red pigments seen in a number of species of Fundulus are good examples.

Color, of course, is best seen in living specimens. The problem is that we have developed a crazy notion that a microscope is somehow sacred. Boats are not sacred. Expensive nets are not sacred. So why a microscope? It seems to me that a good microscope should become a piece of field equipment

A biologist should be able to sit there on shipboard and scan his fresh-caught larvae for significant pigment before dropping them in formalin.

I mentioned preserving in a variety of fixatives. Larvae should be preserved in 2-phenoxyethanol as they become available. The use of electrophoresis in distinguishing similar kinds of larvae is a excellent tool. At Solomons, Ray Morgan has been able to distinguish larvae of white perch from larvae of striped bass using this technique. To my knowledge there is no way to distinguish certain size groups of these larvae using morphological of pigmentary characters. But people are afraid to use electrophoresis. It really is not that complicated and will eventually become one of our most useful tools in studying larval fishes.

We also plan to clear and stain larvae as they become available. Staining and clearing make available a great variety of characters which are not otherwise available. Furthermore, a broad based collection of cleared and stained specimens would be of excellent value in making studies of systematic relationships of fishes.

Now let us talk about publication. If one is not publishing, he should not be in the fish egg and larvae business. At the moment we are presenting our data in the form of a six-volume series of books. We are persuaded, however, that in the future we would like to switch to a loose-leaf format. A loose-leaf format gives greater flexibility, disseminates knowledge much more quickly, and allows for convenient up-dating as new information becomes available in the future.

Basically I have said that we want to establish a center for the study of fish eggs and larvae at Chesapeake Biological Laboratory; and that we envision such a facility dividing its time, money, and personnel equally between four major areas: library research, rearing, collection, and publication. I think if we follow this format we will very quickly come up with many good answers to some of the current questions regarding fish eggs and larvae. We will have also lots of information available for a wide variety of spin-off projects which can be pursued either by our own staff or by visiting investigators. Such a program, in a very few years, would also make it possible for us to teach courses in fish eggs and larvae at Solomons. This is something well worth thinking about in future planning.

TERMINOLOGIES FOR INTERVALS OF LARVAL FISH DEVELOPMENT

Darrel E. Snyder*

Although fish are often the principal focus of aquatic studies; conspicuously little is known of the early life history of most fishes including their early development and identifying characteristics. Information on larval fish distribution, abundance, and biology, as well as the reproductive biology of various fishes, is critical to the determination or prediction of the effects of man's activities on the aquatic environment. Those workers conducting these studies have the responsibility of providing the most accurate and valid information possible. One of the more critical problems is accurate identification of the collected fish eggs and larvae. The conclusions drawn from larval studies cannot be any more valid than the identifications of the specimens on which the data is based.

Need and Criteria for a Standard Terminology

Fish, to paraphrase Grace Onton in one of her 1953 papers, commonly have a definite and more or less prolonged larval period characterized by distinctive early phases in the development of morphological structures and pigmentation. The morphological development of fish is a continuous and usually gradual process. However, developmental patterns vary considerably and some fish, particularly among the marine species, exhibit striking morphological characters unique to the early developmental intervals and undergo more or less abrupt morphological transformations.

In the study of larval fish ecology, biology, and development, and in the preparation of formal descriptions and keys to larval identity, it is most convenient and useful to divide the larval period into a number of smaller intervals or distinct phases. The literature provides us with an amazing variety of terms and definitions applied to intervals of early fish development following hatching or birth. In a survey of only about 360 literary sources concerning fish larvae, Maryann Mulhall Snyder and I have found and listed in Table 1, over 60 different, but often synonomous terms. Others probably exist in published literature, but, like many of the terms listed, have not found their way into common usage in North America. Unfortunately, many of these terms have several

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Table 1. Terms for the early developmental intervals (periods and phases) of bony fishes after hatching, percentage of sources using them, and references for definitions. Based on over 360 literary sources.

Terms	%Usage	Definitions[a]
Larva	54	1,3,4,6,9,11,12,14,18,19,23, 24,25,26,30,32,34,35,36,37.
Early larva	1	37.
Late larva	1	37.
Postlarva	18	1,4,5,7,11,14,15,17,18,1,9 30,32,35,36.
Early postlarva	2	26,27,32.
Mid-postlarva	1	27.
Late postlarva	2	26,27,32.
Transforming postlarva	<1	Undefined.
(Pre)prolarva	16	1,4,5,6,7,11,14,17,18,19,22, 24,26,27,29,30,32,35,36.
Early prolarva	1	Undefined.
Late prolarva	1	Undefined.
Yolk-sac larva	5	25,33,34,36,38.
Late yolk-sac larva	<1	Undefined.
Newly hatched larva	3	Undefined.
Leptocephalus	2	7,13,28.
Post yolk-sac larva	1	Undefined.
Metamorphic larva	1	16,20,30.
Early metamorphic larva	1	16,20,30.
Late metamorphic larva	<1	13.
Mid-metamorphic larva	1	9,13.
(Pre)Prometamorphic larva	1	9,16.
Postmetamorphic larva	<1	9.
Metamorphosizing larva	1	Undefined.
Active larva	1	Undefined.
Inactive larva	1	Undefined.
Feeding larva	<1	3.
Non-feeding larva	<1	3.
Formed larva	<1	30.
Unformed larva	<1	30.
Free swimming larva	1	Undefined.
Just hatched larva	<1	Undefined.
Larva I	<1	30.
Larva II	<1	30.
Eleutheroembryo	<1	30.
Protopterygiolarva	<1	30.
Ptergiolarva	<1	30.
Transitional larva	1	36.
Transforming larva	<1	Undefined.
Yolk larva	<1	37.
Young larva	<1	Undefined.

Table 1, (cont.)

Terms	% Usage	Definitions[a]
Straight notochord stage	<1	21.
Caudal fin stage	<1	21.
Pelvic bud stage	<1	21.
Pelvic ray stage	<1	21.
Preflexion	b.	38.
Flexion	b.	38.
Postflexion	b.	38.
Fry	38	2,4,7,14,18,19,30.
Sac-fry	6	4.
Advanced fry	3	2,7,8,19.
Yolk-sac fry	1	Undefined.
Post-yolk sac fry	<1	Undefined.
Yolk fry	<1	Undefined.
Newly hatched fry	1	Undefined.
Young fry	1	Undefined.
Young (and young-of-year)	33	1,4,7,11,14,26,30.
Transforming young	1	Undefined.
Very young	<1	Undefined.
Juvenile	22	1,4,9,13,14,15,18,19,21,22, 25,26,30,32,34,36,37.
Prejuvenile	4	10,25,30,31,33,34.
Early juvenile	2	31.
Late juvenile	1	Undefined.
Fully transformed juvenile	1	Undefined.
Postlarval juvenile	1	Undefined.
Hatchling	1	4.
Fingerling	14	2,4,7,8,14,18.
Alevin	3	1,4,14,18,19,22.
Parr	1	18.
Smolt	1	18.
Immature organism	1	24.

[a]Key to sources of definitions: 1-Hubbs, 1943; 2-Rodd, 1947; 3-Balinsky, 1948; 4-Jones, 1950; 5-Winn and Miller, 1954; 6-Kryzhanovsky, 1956; 7-Lagler, 1956; 8-Hartman, 1957; 9-Ahlstrom and Counts, 1958; 10-Hubbs, 1958; 11-Mansueti, 1958; 12-Swarup, 1958; 13-Gehringer, 1959; 14-Raney, 1959; 15-MacPhee, 1960; 16-Alexander, 1961; 17-Norden, 1961; 18-Gove, 1961; 19-Lagler, et al., 1962; 20-Wade, 1962; 21-Faber, 1963, 22-Franklin and Smith, 1963; 23-Kenneth, 1963; 24-Nikolsky, 1963; 25-Mansueti and Hardy, 1967; 26-May and Gasaway, 1967; 27-Norden, 1967; 28-Faber and McAllister, 1968; 29-Priegel, 1969; 30-Balon, 1971 and 1975; 31-Dawson, 1971; 32-Snyder, 1971; 33-Young, 1971; 34-Berry and Richards, 1973; 35-Gerlach, 1973; 36-Scotton, et al., 1973; 37-Unpublished definitions utilized in the ichthyoplankton programs of the Ecological Sciences Divison, NUS Corporation through 1975; 38-Ahlstrom, personal comm. Undefined means that a specific definition was not found by the authors.

Term not found in literature upon which this table is based, but provided for consideration by the reader.

different definitions; others have none. Most are insufficiently defined; that is, so vague that the precise characters used to distinquish one interval from another are unknown. A few are more precisely defined but apply only to certain groups of bony fishes, or require intricate or time consuming techniques such as clearing and staining or partial dissection to determine the developmental interval under study. The same problems also exist with definitions of the larval period itself.

To better facilitate comparability of descriptions, keys, and the many reports of studies of larval fishes either underway or planned, it would obviously be most useful to standardize the terms and definitions used with respect to the larval period and its phases of development. This need has been expressed many times in the past, and still no real effort has apparently been made by most workers to agree to one terminology for consistent use by all.

The published literature provides us with many candidates for a standard terminology. I will briefly discuss thirteen of these, plus two unpublished terminologies. Some are presented because of their more common use by various groups of fisheries workers; others are less well known but are of such a nature that they should certainly be considered in selecting or developing a terminology for standard use.

However, before I proceed we should consider our criteria for a standard set of terms and definitions for the larval period and its phases. We suggest at least the following. First, a standard terminology should be practical, precise, and easy to use without requiring intricate or time consuming techniques. Technicians, or aides, as well as fishery biologists or larval fish specialists, should be able to use the terminology. In processing samples, time is critical and so we need a terminology that can be rapidly applied upon simple examination. Accordingly, the boundaries between each developmental period or phase must be very precise and easy to determine. Second, the terminology should provide intervals indicative of relative age and state of development. It should therefore be based on a sequence of developmental characters which follow nearly the same course in all fishes. And third, the intervals must facilitate the production of comparable formal descriptions of fish larvae, keys to their identity, and reports of pertinent field and laboratory studies, particularly those associated with environmental impact. We must bear in mind that while fishery biologists and larval fish specialists may be able to compare data that utilize various terminologies, this may not be the case for many of the people who must read and use these reports in making critical environmental decisions.

Review of Terminologies

In this discussion, I utilize 3 of the 4 types of developmental intervals suggested by Dr. Eugen Balon in his 1971 and 1975 papers - period, phase, and stage, The periods are the major and largest intervals. In fish, we usually refer the the embryonic, larval, juvenile, and adult

periods. Dr. Balon also suggests a senescent period - an interval usually considered a part of the adult period. Each period then can be subdivided into two or more phases. Stage is defined as the smallest just observed moment of development and, in this sense, is misused by many fisheries biologists.

Of the fifteen terminologies, all but two utilize the transitions from endogenous to exogenous nutruition as a phase or period boundary, usually on the basis of the presence or absence of the yolk sac, yolk material, oil globules, or food organisms in the gut. This transition is of tremendous physiological, ecological, and behavioral significance. A larva with a large amount of yolk often looks quite different from one with little or no yolk. Unfortunately, yolk absorption is often very gradual, and somewhat temperature dependent. The yolk sac, so obvious in most recently hatched larvae, often becomes very indistinct as yolk absorption proceeds. Yolk material and/or oil globules occassionally remain long after active feeding begins; and sometimes, they also become very indistinct or difficult to determine. Like the completion of yolk sac or yolk absorption, the use of the presence of food organisms also presents many problems. The small size and rapid digestion of some prey organisms often makes their determination nearly impossible. In addition, fish larvae ready to feed may have been taken at the wrong time of day for food to be present, or food may simply not have been available. Lack of food organisms could also be a result of capture, handling, or preservation. The ingested organisms may have been regurgitated or forced through the gut and out the vent. None of the terminologies about to be discussed provide a practical means for simply and precisely separating larvae using the transition form internal to external feeding. Accordingly, if precision and ease are desired, this transition poses some serious problems. In addition, it should be noted that the general state of morphological development at this transition varies considerably among the many different groups of fishes that might be compared.

Fry-fingerling terminologies- The following three terminologies are commonly used by fish culturists, some to whom the term "larva" means nothing with respect to fish.

Titcomb (1910)

Fry: "fish up to the time the yolk sac is absorbed and feeding begins."
Advanced fry: "fish from the end of the fry period until they have reached a length of 1 inch."
Fingerlings: "fish between the length of 1 inch and the yearling..."

Rodd (1947)

Fry: "Fish from the time they are hatched until complete absorption of the yolk sac."
Advanced fry: "Fish for a period of two weeks from complete absorption of the yolk sac."
Fingerlings: "Fish from two weeks after complete absorption of the yolk sac until they are one year old from date of hatch."

Jones (1950)

Hatchling: "The stage within 24 hours after hatching."
Sac-fry: "A term generally used in hatcheries to denote the prolarvae and alevins."
Fry: "Post larvae and juveniles up to a length of about 1.5 inches."
Fingerling: "May be used when the length of specimens ranges from about 1.5-5 inches. Should be applied only to young of those species that grow to a fairly large size and not to those whose maximum size falls within or near the range given above."

The first two, Titcomb and Rodd, use identical terms but entirely different definitions for the last two intervals, one based on length and the other on time. Jones adds the term hatchling and substitutes sac-fry for fry and fry for advanced fry. Note that Jones defines these intervals in terms of Hubbs terminology - prolarva, postlarva, etc. These terminologies appear to be quite adequate for their purposes in fish culture. However, the published definitions are often considerably modified in various ways by many fisheries workers and other terms such as swim-up fry and feeding fry are not uncommon.

We have already discussed the problem with using yolk absorption as a phase boundary. The use of length or time since hatching is certainly the most precise and easiest to use as a phase or period boundary. Unfortunately, there is no direct correlation with the development of morphological characters that is consistant when comparing various species. Some fish may appear very adult-like well before the end of the advanced fry phase while others may not have all their fins developed until well into the fingerling interval which is often considered synonomous with young-of-the-year juvenile. In addition, use of time to determine interval boundaries is usually not possible with field collected specimens since time of hatching is usually not known.

Larval terminologies - The remaining terminologies define a "larval" period and usually provide for two or more phases within that period. The following seven terminologies utilize yolk or yolk-sac absorption in separating two phases defined within their larval period.

Hubbs (1943)

Larva: "Developmental stages well differentiated from the juvenile and intervening between the times of hatching and of transformation; commonly divisible into prolarva and postlarva."
Prolarva: "Larva still bearing yolk."
Postlarva: "Larva following the time of absorption of yolk; applied only when the structure and form continues to be strikingly unlike that of the juvenile."
Alevin: "Larva of species in which postlarval stages are not recognized; that is, in which the yolk-bearing larva transforms directly into the juvenile...."
Juvenile: "Young essentially similar to adult."

Balinsky (1948)

Non-feeding larvae: Interval following hatching through stage 32.
Feeding larvae: "stages 33-39."
"Stage 32. The assimilation of the yolk has proceeded so far that the liver reaches the mid-ventral line. The cleithrum is ossified."
"Stage 33. The assimilation of the yolk is accomplished. There is as yet no trace of fin-rays in the caudal fin..."
"Stage 39. The pelvic fins are in the form of paddles. No trace of fin-rays is visible in them."
"Stage 40. In the pelvic fins rudiments of rays, not yet ossified, have appeared."

Winn and Miller (1954)

Larva: See Hubbs (1943).
Prolarva: See Hubbs (1943).
Postlarva: "...the period after the absorption of the yolk to a stage when the fish resembles the juvenile." "...it seems the prolarva when (1) a continuous finfold is present, (2) there are pigment characters different from those of the juvenile, or (3) the fins are absent, unossified, or developed to various degrees."

May and Gasaway (1967)

Larva: "The young stages of fishes from hatching until acquisition of a full complement of juvenile characters."
Prolarva: "Larva still bearing yolk, regardless of the degree of development of other characters."

Early Postlarva: "Larva after the time of absorption of yolk to a stage when all the soft rays in the vertical fins have developed."

Late Postlarva: "Fishes whose soft vertical fin rays have developed to a point where they are identical in count with those of the adult, and with any combination or degree of development of juvenile or larval characters and extending until the time that all rays are developed and the spines, or in some cases rays, are ossified."

Mansueti and Hardy (1967)

Yolk-sac larva: "The yolk-sac larva stage begins at time of hatching and continues until the yolk sac is no longer visible. Specimens in this stage are essentially dependent upon yolk for nourishment, but gradually begin feeding by mouth prior to disappearance of the yolk sac."

Larva: "The larva stage begins with disappearance of the yolk sac, although vestiges of the yolk may remain in the gut region during the early parts of the stage." "...we equate termination of the larval stage with acquisition of the adult fin-ray complement. These counts are frequently attained before the rays are fully ossified."

Prejuvenile: "The prejuvenile stage is the intermediate stage between larval and juvenile forms which begins with acquisition of the adult fin-ray complement and continues, with rapid metamorphosis, until the more adult-like form of juvenile is attained."

Berry and Richards (1973)

Larva: "from hatching to completion of formation of the adult complement of rays in all fins (usually determined by red staining of the rays in alizarin)."

Yolk-sac larva: "is recommended if a term is desired to describe the larva before complete absorption of the yolk."

Prejuvenile: "...refers to forms that are not appropriately termed larval (or postlarval) or juvenile; it is commonly characterized by strong spines, bony plates, and peculiar body form. Transformation into the juvenile stage is usually very rapid, and often associated with movement from a pelagic to a benthic habitat."

Scotton et al. (1973)

Larva: "stage from hatching to completion of formation of the adult complement of rays in all fins (Berry and Richards, in press)."

Yolk-sac larva: "'begins at the time of hatching and continues until the yolk-sac is no longer visible' (from Mansueti and Hardy, 1967) (also called prolarva by Hubbs, 1943)."

Postlarva: "larva following the time of absorption of yolk; to be applied only when the structure and form continues to be unlike that of the juvenile (from Hubbs, 1943) (also called larva by Mansueti and Hardy, 1967)."

Transitional (or metamorphic) larva: "the period in which the larva is acquiring the juvenile shape, structure, and pigmentation (Moser and Ahlstrom, 1970; Ahlstrom, 1968; Bertelsen, 1951); does not occur in the life history of many fish species, i.e., developement may proceed directly from the larva to the juvenile."

The best known of these terminologies and the basis for many modifications is the terminology recommended by Hubbs in 1943. Note, however, the illogical names for phases of the larval period - prolarva or preceeding larva and postlarva or after larva. What happened to larva? Note also the use of the special term alevin for fishes that transform directly from prolarvae to juveniles, and the very generalized boundary between the larval and juvenile periods.

Balinsky defined intervals similar to Hubbs prolarva and postlarva but used different, more descriptive terms and provided a very precise boundary for the end of the larval period for cyprinids. Winn and Miller essentially adopted Hubb's terminology but suggested a set of characters for the postlarval interval which also provides a more specific end to the larval period. May and Gasaway divided Hubb's later phase into early and late postlarvae based on the presence or absence of the adult count of soft rays in the vertical fins. They also defined a more specific end to the larval period including, as did Winn and Miller, a requirement for ossification of certain fin elements. Staining may be needed to determine this condition with precision.

The last three terminologies define the larval period to end upon acquisition of the adult fin-ray complements in all fins. Mansueti and Hardy specifically note that "these counts are frequently attained before the rays are fully ossified." All three substitute yolk-sac larva for Hubbs' prolarva. Mansueti and Hardy also substitute larva for postlarva. This however, may present another problem; if larva is used both to name the period and a phase within that period, there is considerable potential for confusion. Scotton et al., apparently recognizing this problem, retained the term postlarva. Mansueti and Hardy, and Berry and Richards define a separate interval between the larval and juvenile periods which they call prejuvenile, a term introduced by Hubbs in 1958. Scotton, et al., as have certain other authors, consider this interval as a phase of the larval period and call it transitional (or metamorphic) larva. They also note that this phase does not occur in the life history of many fishes.

Dr. Ahlstrom and his associates at the Southwest Fisheries Center of the National Marine Fisheries Service consider the larval period to consist of five phases: yolk-sac, preflexion, flexion, postflexion and transitional (personal communication). The first and last phases of their unpublished terminology are considered transitional or connecting intervals (Ahlstrom, 1968) and are essentially as previously defined. Preflexion is characterized by a straight notochord. Flexion begins upon the formation of the first caudal rays and postflexion begins with the completion of notochord flexion and caudal fin formation. These three intervals were originally used to group morphometric data based on types of length measurements (Moser and Ahlstrom, 1970), i.e. notochord length for preflexion and flexion larvae, and standard length for postflexion larvae. The flexion sequence is quite attractive; although, a more precise and easily observed transition is needed between flexion and postflexion. Unforturnately, retention of the yolk-sac phase poses the problem of what to do about specimens that except for the presence of yolk or yolk-sac would be considered preflexion, flexion, postflexion, or transitional larvae. Another relatively minor problem with this terminology is that the three flexion based phases cannot be applied, as defined, to the few fishes lacking caudal fins and may be difficult to apply to some fishes with unusual caudal fin form and development.

The next two terminologies utilize yolk or yolk-sac absorption in separating the embryonic and larval periods.

Kryzhanovsky (1956)
(from Nikolsky, 1963)

Prelarva: "Free-living embryo...., when development continues outside the membrane." This is considered part of the embryonic period which continues to the beginning of external feeding.

Larva: period during which the fish feeds on external food and "the external appearance and internal structure have not yet taken on the characteristics of the adult organism".

Balon (1975)

Eleutheroembryonic phase: "(from Greek eleutheros = free) commences with hatching and lasts until most or all of the yolk is digested and the fish begin to feed externally, or until feeding on the ovarian secretion is terminated by parturition or by predation on siblings in the case of livebearers." This is a phase of the embryonic period.

Larval period: "commences when the transition to exogenous nutrition takes place and usually lasts until the formation or ossification of the axial skeletion and until the undifferentiated (embryonic) median fin fold is differentiated or no longer apparent."

Protopterygiolarval phase: "encompasses the interval between the transition to exogenous feeding and the commencement of differentiation of the embryonic median fin fold - the first appearance of mesenchymatic buds of lepiodotrichia and dorsal and anal fin outlines within the fin fold."

Pterygiolarval phase: "lasts from the beginning of the differentiation of the unpaired fins until the embryonic median fin fold is entirely differentiated or no longer apparent."

Alevin Phase: "exists is species that do not have a larval period and lasts until the development of complete scalation or ossified spines."

Unlike all previously discussed terminologies, these consider the interval from hatching to yolk absorption or the beginning of exogenous feeding as the last phase of the embryonic period. The transition between Balon's protopterygiolarva and pterygiolarvae is frequently difficult to discern and should be refined for ease of determination. Although only a minor problem, the terms for Balon's larval phases are considered by many to be too difficult to pronounce. Note that the provision for the alevin phase is totally unnecessary as fish which lack a larval period would simply pass from the embryonic to juvenile period. In an illustration of developmental intervals of salmon in his 1975 paper, Balon labeled one drawing, in which the specimen illustrated possessed an obvious preanal finfold, as representing an alevin; but, by his own definitions, it would properly be designated as a larva in the pterygiolarval phase.

Due to the various problems associated with determination of the transition from endogenenous to exogenous nutrition, a terminology not utilizing this transition might be more suitable for comparative studies of larval development, keys, data tabulation, and reports. The following terminology is based essentially on a specific sequence of fin development. Note the misuse of the word stage according to Balon's (1971) definition.

Faber (1963)

Straight-notochord stage: "The beginning of the SNS begins at hatching (breaking of the chorion). The duration of the stage is characterized by a straight notochord extending out into the caudal region of the finfold."

Caudal-fin stage: "The transistion into the CFS occurs when two rays of the caudal fin appear. Shortly before the ventral portion of the caudal finfold becomes opaque actinotrichia radiate from the notochord toward the edge of the finfold. CFS larvae are characterized by numberous rays developing in the caudal fin and a dorsal bending of the notochord."

Pelvic bud stage: "The appearance of the pelvic buds heralds the next stage..." "The local reduction of the embryonic

finfold and the gradual appearance of fins occuring in this stage constitute a great transformation."

Pelvic ray stage: "The appearance of rays in the pelvic bud and the accompanying loss of bluntness mark the start of the PRS. The larvae begin to resemble the adult in fins and in morphometric characteristics. A good objective morphological feature marking the end of the PRS could not be found, so the end of this stage is based entirely on the total length of the larva (a predetermined length)."

Aside from not providing a morphologically based end to the larval period, the specific characters on which this terminology is based vary considerably in sequence, particularly among marine fishes. For those species to which it can be applied; it is an attractive, easy to use terminology.

A Practical Alternative Terminology

My wife, Maryann Mulhall Snyder, and I have found that none of the reviewed terminologies adequately fulfill the criteria established for standard use in our work. Accordingly, we have spent years devising and experimenting with various modifications of existing terminologies and have finally settled on the version I am about to present. We offer it, along with the other terminologies I have presented, for your critical evaluation and consideration.

In developing this terminology we sought at least three consistent sequential intervals of significant duration in most fish. One of the most consistent and obvious sequences of developmental characters in all bony fishes is the morphogenesis of the median finfold and fin elements (spines and rays). Accordingly, we utilize this as the basis for our derived terminology. In addition, paired fins are included in the definition of the last phase. All other, often less consistent characters, including morphogensis of the paired fins in the earlier phases, can be described in terms of the framework provided by these phases. To avoid confusion with the phases (stages) of other authors, and the use of illogical, inappropriate, or difficult to pronounce terms, new terms are applied to the larval phases.

Snyder and Snyder

Larva: The period of bony fish development characterized by obvious fin morphogenesis following hatching or parturition; the period terminated immediately before: 1) the last of the finfold and atrophying fins, if any, are absorded beyond recognition, 2) the full complement of distinct fin elements (spines and rays) becomes apparent in all fins, and 3) segmentation of principal rays in all fins becomes apparent.

Fish in which all the latter conditions exist before or upon hatching or parturition do not have a larval period and transform directly from the embryonic to the juvenile period.

Protolarva: The larval phase in which distinct median fin elements (dorsal, anal, or caudal spines or rays) are not yet apparent.

Mesolarva: The larval phase in which at least one but not the full complement of distinct principal rays in the median fins is apparent; or, if the full complement is present and the adult possesses pelvic fins, the pelvic buds or fins are not yet apparent.

Metalarva: The larval phase in which the full complement of distinct principal rays in the median fins and, if the adult possess pelvic fins, the pelvic buds or fins are apparent.

The protolarval phase includes all larval stages prior to the appearance of the first median fin elements. For most fishes these elements first appear in the caudal portion of the finfold, and for these species, the protolarval phase is essentially synonymous to Ahlstrom's preflexion phase (except when overlapped by the yolk-sac phase) and Faber's straight-notochord phase. For the remaining fishes, the first median fin elements usually appear in the dorsal portion of the finfold, for example, the single elongated anterior dorsal ray of the larvae of the 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 soft ray counts of the dorsal, anal, and caudal fins, as well as the relative positions of these fins and the pelvic fins. Accordingly, the presence of the full complement of distinct principal median fin rays and the pelvic fins or fin buds (except in fishes lacking these fins) is required for transition from the mesolarval to the metalarval phase. In many fishes the pelvic buds form as or after the full complement of distinct principal median fin rays is attained and therby make the distinction between mesolarvae and metalarvae exceedingly simple. However, in some fishes the pelvic fin buds make their appearance during the mesolarval phase prior to the appearance of all principal median fin rays or may be even more precocious and appear during the protolorval phase as in a lanternfish, Symbolophorus californiensis, described by Moser and Ahlstrom (1970).

The transition from the metalarval phase to the juvenile period requires the presence of the full complement of distinct fin elements in all fins and segmentation of principal rays in those fins, as well as the absence of the finfold and any atrophying fins. For fishes in which the finfold is still apparent upon attainment of the former two characters, distinction between the larval and juvenile periods is particularly easy. Please note that 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.

Not all fish pass through all three larval phases; salmon, catfishes, and certain killifishes, for example, lack a protolarval phase and hatch as mesolarvae. Some fishes, such as the mosquitofish, Gambusia affinis, lack a larval period entirely, and hatch or are born as juveniles.

Let us return one final time to comments on the presence of yolk. In most fishes yolk absorption is completed during the protolarval phase. However, in some fishes such as the salmon and catfishes, yolk is still present in the metalarval phase. Some fish may still possess yolk as recently transformed juveniles. If it is desirable to indicate the presence of yolk we suggest modifying the phase name with the preposition "with yolk", e.g., mesolarva with yolk, as per Faber (1963).

Figure 1 illustrates the application of these terms to drawings of various stages of the fathead minnow, Pimephales promelas. To date, I have not found any body fish, marine or freshwater, to which this terminology cannot be applied. However, depending on the development and size of various structures and the condition of the larvae under study, the ease with which it may be applied varies considerably. For most fishes we find the terminology as easy or easier to apply and more precise than any of the other terminologies considered in this paper.

A Standard Terminology?

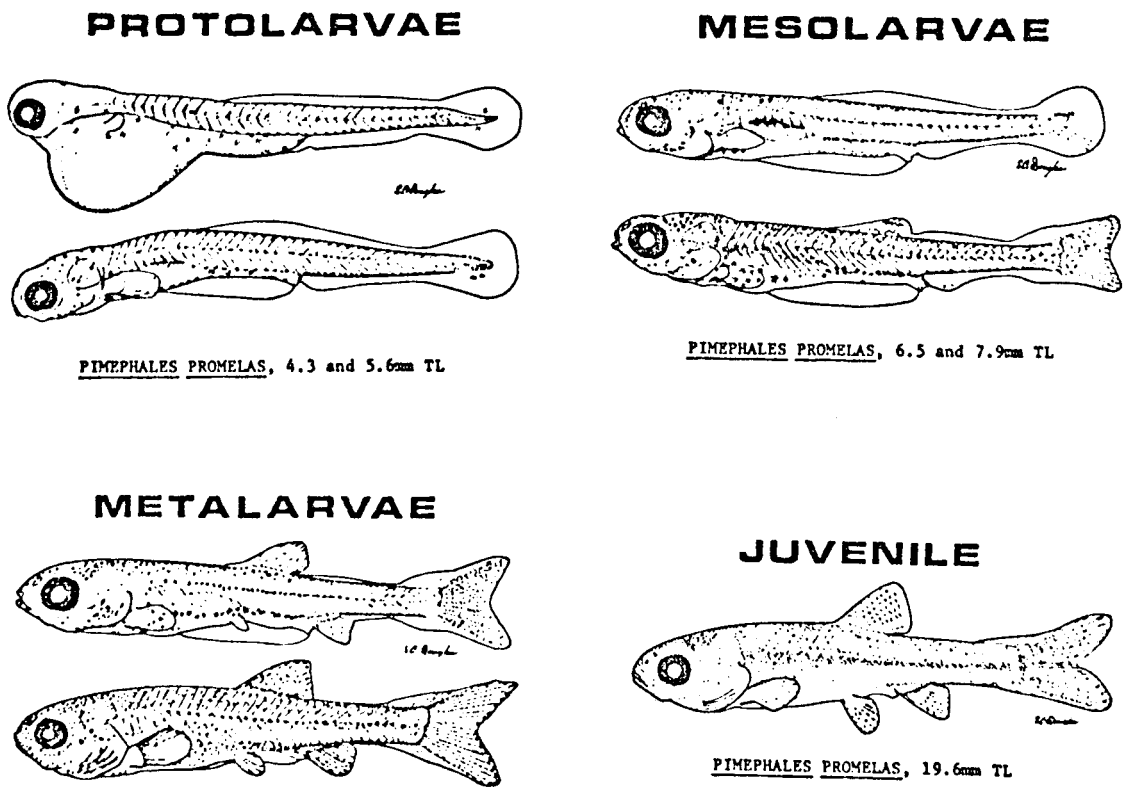
I will close my presentation by again asking you to consider the need for a standardized larval terminology. Many of you have adopted one of the terminologies we have discussed, or a modification of one or more of them. I believe the time has come to get together, discuss advantages and disadvantages, and select or devise a terminology suitable to all. In this way we can better facilitate future communication by making descriptions, keys, data, and reports readily comparable. If you agree that a standard terminology is needed, we have the opportunity at this workshop to begin the process. We should be able to at least come to terms on an agreeable definition for the larval period. Once selected, it would be our responsibility to promote the agreed upon terminology among our various agencies, universities, and private organizations.

Which terminology? Of course I recommend Snyder and Snyder, but the decision belongs to all of us. Only by consistent use can any terminology become standardized. The time to decide is now while so much of our work lies before us.

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Figure 1. The larval phases of the fathead minnow, Pimephales promelas.



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Discussion

DR. MARTIN: I would like to suggest that one of the problems with a standard terminology is that we are trying to put all the fishes into a single system - and there is no single system. For example, the system that you suggest, protolarva, meolarva, and metalarva, seems to work much better with freshwater fish than with a lot of marine species which waver on the borderline between one phase or the other. I would suggest that we are always going to have this problem.

MR. SNYDER: This is a comment that has been brought up a number of times in the past. I disagree and feel that a single terminology is possible. Following very strictly the definitions that my wife and I have derived; I find I can distinguish with relative ease the larval phase from any fish in reasonably good condition, regardless of where it is from. There are some fish that are certainly more difficult to categorize than others, but I maintain that the terminology is applicable to almost if not all bony fish.

DR. MARTIN: One other point I would like to make. Whatever system we use, let's look at what the definition is and stick within the definition - not wander all over the board.

MR. SNYDER: Precisely.

DR: FRITZSCHE: When you talk about fin rays, you are talking about --

MR. SNYDER: I am talking about distinct rays.

DR. FRITZSCHE: You are talking about lepidotricha, true bony rays?

MR. SNYDER: Yes.

MR. FOBES: Are copies of your terms and definitions available for this meeting?

MR. SNYDER: Only in the form of my notes. I can provide you with a copy of the original manuscript after the workshop.

MR. FOBES: For the purposes of this workshop, I would suggest that the working group that would handle this particular subject be provided a copy to work with and consider.

MR. SNYDER: I can make it available.

DR. FABER: Terminology is a very sensitive issue with me as well. I have been thinking about this for over 10 years. It is very difficult to decide how to go at it or what to do. I think for ecologists, for data and reports, it is a very good concept; but I fear its misuse, particularly in orginial descriptions and illustrations. There may be a tendency to jump too many gaps.

I recently reviewed a manuscript using Darrel's system. In their description they used one stage, one illustration, for each phase. There was no data or information for intervening stages, no justification for connecting one stage to the other, or for considering them to be the same species. This could lead to errors in the original descriptions as well as errors in identifications based on those descriptions. We should be cautious of a similar fault I've found in working with a couple of guides put out on the east coast. This is the placement of single illustrations of three or four species on one page as representative of an entire developmental phase. This could be a serious problem for those trying to use such guides. When first looking at a species and describing its development, do not use this method; but later after one has established identity by describing a detailed series of larvae, this method may be good to use. From my own experience, I would start the way Ahlstrom does - don't use any terms. By using Ahlstrom's system I found two species where I think if I had used Darrel's, I would have thought I had only one.

MR. SNYDER: I agree that there is often a tendency to skip important connecting stages in the description of fish larvae and that this can lead to critical errors. I, myself, have perhaps been guilty of this. However, I don't believe the use of a particular terminology is the cause of the problem. The terminologies I discussed in my presentation are not methods of description, but rather convenient frameworks within which description can take place and keys can be developed. For instance, several individual stages might be illustrated and described as protolarvae, several more relatively distinct stages as mesolarvae and so on. In this way we can describe, as you suggest, a whole continuum of stages from hatching through recently transformed juveniles without missing any significant connecting stages. The number of stages used for each phase would, of course, vary from species to species, depending on the degree of change in morphology or pigmentation.

IDENTIFICATION OF LARVAL FISHES TAKEN FORM THE INSHORE WATERS OF SOUTHEASTERN LAKE MICHIGAN NEAR THE DONALD C. COOK NUCLEAR PLANT, 1973-1975*

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Introduction

The Donald C. Cook Nuclear Plant is a 2-unit, 2200 megawatt nuclear generating facility located near Bridgman, Michigan; Unit 1 went "on-line" in January 1975. Environmental studies in southeastern Lake Michigan near the Cook Plant began in 1966 and continue to the present. As the scope of the Cook Plant study expanded, more specific sections of investigation (benthos, phytoplankton, zooplankton, fish, etc.) evolved. Preliminary fishery investigations conducted during 1972 (Jude et al. 1973) recognized the need to expand studies of both the adult and larval fish populations. Also, environmental technical specifications for the Cook Plant, established in 1974, outlined a minimum sampling regime to be conducted to monitor larval fish populations. Analysis of field (open lake) and entrainment samples of fish larvae revealed the seasonal presence of tremendous numbers of larvae; with a water circulation rate of 1.6 million gpm, periodic entrainment of fish larvae by the Cook Plant is high. Since the larval period represents a critical and perhaps particularly vulnerable stage during the life cycle of a fish, study of this period is necessary to understand and to predict how factors such as entrainment affect larval development and population recruitment.

As with many fishery biologists, we did not have extensive prior training or experience in the process of identifying larval fish, and the original design of the general ecological study at the Cook Plant had not anticipated evolution of a comprehensive larval fish monitoring program. It was necessary for us to both learn and develop methodologies for identifying larval fishes. It is the objective of this paper to illustrate these methodologies with a description of how we initially identified seven species of fish larvae, and to describe characteristics we use to distinguish one species from another. Characterisitics of

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larvae at early stages of development were emphasized because it is felt that the inexperienced investigator will have the most difficulty identifying larvae at early rather than later stages of development.

Methods

Fish larvae samples were collected at field (open lake) stations and from the intake and discharge forebays of the plant. Between 1973 and 1975 approximately 2000 samples were collected, of which 1450 have been examined. Studies of the adult fish populations in the area were conducted concurrently using seines, gill nets, and trawls (see Jude et al. 1975).

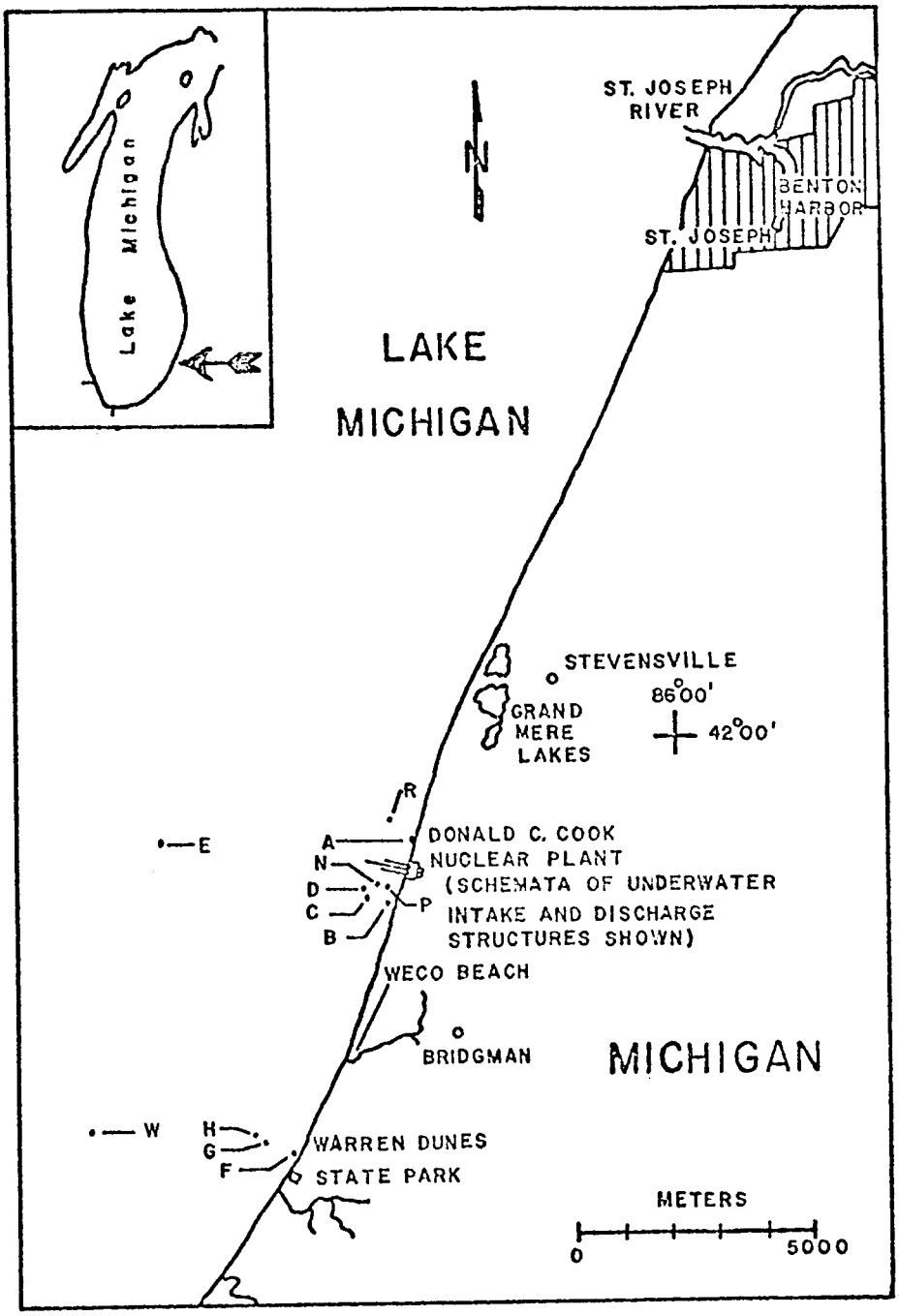
Field sampling for fish larvae was conducted once per month from April through November with a No. 2 (361 micron mesh), 0.5 m diameter, Nitex plankton net towed horizontally at 12 stations in the vicinity of the Cook Plant (Figure 1). Samples were collected at a number of discrete depths depending on station, once during the day and once during the night. Sampling for entrained larvae was conducted by pumping water from different depths (2, 5, and 8 m) at two locations at the common intake forebay and from a single location (depth = 5 m) at the Unit 1 discharge forebay. A 303 l/min (80 gal/min) Hale diaphragm pump with a 7.5 cm (3 in) diameter hose pumped water into a 0.5 m diameter, No. 2 plankton net suspended in a 208 l (55 gal) drum. Samples were usually collected every 6 hr during a 24-hr period about once per month during 1974, a preoperational year. During 1975, entrainment sampling was performed twice per month during all months except June, July, and August when sampling was done once per week.

All samples were concentrated into 0.5 l (1 pt) mason jars and preserved in approximately 10% formalin. Several weeks to several months later, all fish larvae and fish eggs were removed from samples with the aid of a binocular microscope and a lighted sorting chamber (Dorr 1974). All larvae removed were identified, when possible, and total length was measured to the nearest millimeter; all fish eggs were enumerated but not identified.

Fish larvae were identified through one or more of the following processes: 1) knowledge of the seasonal abundance and distribution, spawning habits (temporal, geographical and enviornmental conditions), and gonad condition of adult fish frequenting the study area; 2) use of keys and descriptive literature including drawings and photographs; 3) comparison of unidentified larvae with specimens of known identity; 4) fertilization of eggs and rearing of larvae of fish species most common to the study area; and 5) identification of collected larvae by outside investigators.

Characteristics of seven species of fish larvae were compiled from selected literature and analysis of specimens collected during our studies in southeastern Lake Michigan. The sub-heading "larvae" generally

Figure 1. Map of the Cook Plant and Warren Dunes study areas in southeastern Lake Michigan, 1973-1975. Letters indicate sampling stations for fish larvae.



refers to stages of development from hatching to and shortly following yolk-sac absorption. Whenever possible, length stages at which particular characteristics occured were indicated. The sub-heading "late larvae" refers to stages of development well beyond yolk-sac absorption and approaching that of the juvenile condition (e.g., development of ful fin-ray complement or scales). If yolk extended through the gut to the vent the yolk-sac was said to be "entire."

Photographs of fish larvae were taken with a Bausch and Lomb Stereo-Zoom 7 binocular microscope with camera adapter, 35 mm, 3 X camera kit and three Nicholas illuminators. Formalinized, unstained larvae were mounted in water, without cover slips, on either opaque or transparent glass slides to which a scale (mm) was affixed. Larvae were photographed with Kodak High-Speed Ektachrome film (tungsten, 3200 K, EHB 135-36). Black and white negatives were developed from the Ektachrome slides by a local photographic laboratory. Light microscope photography of fish larvae was difficult; proper equipment, experience, experimentation, staining, and use of polarizing filters improved the quality of photographs.

Observations

Alewife (Alosa pseudoharengus)

Distinguishing characteristics of alewife (Table 1) include: extremely small size at hatching (2.5-3.5 mm); pre-anal to post-anal length ratio of 3.2-3.8 to 1 (4.1-5.1 to 1 at hatching); filiform shape, long gut with very posterior vent, terminal oblique (upturned) mouth, weakly developed pectoral fins; and ventro-posterior flexing of the head over the yolk-sac at hatching. Pigmentation varies and has not proved to be a particularly reliable characteristic.

With the exception of rainbow smelt, the above characteristics clearly separate larval alewives from the other species discussed. Hatching length, pre-anal to post-anal length ratio and yolk-sac position distinguish newly hatched alewives from rainbow smelt. Separation of older larvae (10-20 mm length stages) is more difficult, requiring myomere counts, examination of pigmentation and late larvae characteristics (if present) and applied knowledge of seasonal abundance, distribution and growth rates.

Spottail shiner (Notropis hudsonius)

Spottail shiner larvae hatch at lengths between 4.7-5.3 mm and have a pre-anal to post-anal length ratio of 1.4-1.6 to 1 (Table 2). The horizontally oval gas bladder, located slightly anterior of the mid-point between the pectoral fins and the vent, is usually evident by the 6-7 mm length stage; occasionally the peritoneum above the dorsal surface of the gas bladder is pigmented with several round chromatophores.

Table 1. Characteristics of alewife (Alosa pseudoharengus) larvae compiled from literature (see selected references) and from analysis of specimens collected from the inshore waters of southeastern Lake Michigan, 1973-1975.

Larvae

1) Approximate length at hatching: 2.5-3.5 mm TL (total length).

2) Myomere count: pre-anal 37-39; post-anal 8-10.

3) Post-anal length enters pre-anal length 3.2-3.8 times; 4.1-5.1 times for larvae less than 24 hr. old.

4) Mouth: non-functional and barely evident at hatching, becomes large terminal and oblique (upturned).

   Gut: yolk-sac small and not entire, no oil globule.

   Body: long and very slender (filiform). Larvae very small and fragile at hatching; head small, snout blunt.

   Fins: pectoral fins barely evident at hatching, remaining weakly developed well into later larval stages.

   Other: head flexed ventro-posteriorly closely over yolk-sac at hatching, remaining so for approximately 24 hr. following hatching.

5) Pigmentation: paired row of elongate chromatophores on ventral aspect of larva between pectoral fins and pelvic fin buds, constricting to a narrowly spaced, paired row between pelvic fin buds and vent. Pigmentation often not evident at or immediately following hatching.

Late larvae

1) Post-anal length may enter pre-anal length only 2.1 times (approximately).

2) Base of anal fin relatively long. Anal fin rays approximately 18.

3) Dorsal fin inserts behind pelvic fins. Dorsal fin rays 12-16.

4) Scutes may or may not be evident at 22-25 mm TL.

Table 2. Characteristics of spottail shiner (Notropis hudsonius) larvae compiled from literature (see selected references) and from analysis of specimens collected from the inshore waters of southeastern Lake Michigan, 1973-1975.

Larvae

1) Approximate length at hatching: 4.7-5.3 mm TL.

2) Myomere count: pre-anal 18-22; post-anal 15-18.

3) Post-anal length enters pre-anal length 1.4-1.6 times.

4) Mouth: non-functional at hatching, becomes small inferior and slightly oblique.

   Gut: yolk-sac entire and constricted in middle at hatching. No oil globule.

   Body: slender, head of medium size, snout blunt.

   Fins: pectoral fins very weakly developed at hatching.

5) Pigmentation: numerous small, stellate chromatophores on ventral aspect of yolk-sac and on ventral aspect of larva proceeding from posterior end of yolk-sac to base of caudal fin. Peritoneum above dorsal surface of gas bladder sometimes bearing several round chromatophores.

Late larvae

1) Gas bladder evident by 6-7 mm.

2) Spot at base of caudal fin appears relatively early in juvenile development.

3) Base of anal fin relatively short. Anal rays 7-9.

Of the species identified, only yellow perch and trout-perch larvae even closely resemble larval spottails. An entire yolk-sac, absence of an oil globule, pre-anal length distinctly greater than post-anal length, and less robust appearance clearly separate spottail shiner larvae from larval yellow perch and trout-perch.

Rainbow smelt (Osmerus mordax)

Larval rainbow smelt (Table 3) may be distinguished from alewife by: larger hatching size (4.5 mm); higher pre-anal and post-anal myomere counts; a hatching pre-anal to post-anal length ratio of 2.0-2.9 to 1; and the small yolk-sac located well to the posterior of the pectoral fins which contains an oil globule. The head of the newly hatched rainbow smelt is not closely flexed over the yolk-sac like that of an alewife. Several (often three) widely spaced elongate chromatophores may be present on the ventral aspect of smelt larvae between the vent and the base of the caudal fin. These chromatophores were not observed in alewife larvae and often not in newly hatched rainbow smelt larvae. Using characteristics in Table 3, larval smelt are easily separated from the other five species.

Yellow perch (Perca flavescens)

Yellow perch larvae (Table 4) are characterized by a nonentrie yolk-sac containing a large anterior oil globule, and by a prominent decurved vent. A large terminal oblique mouth with well-developed jaws appears early in development. The larvae are large and robust at hatching with pectoral fins that become well developed at early length stages. The nearly equal pre-anal to post-anal length ratio clearly separates yellow perch larvae from the other six species.

Trout-perch (Percopsis omiscomaycus)

Relatively little information and only a few specimens of trout-perch (Table 5) larvae were available. Characteristics which help to distinguish this species from the other six include a large yolk-sac, the ventral aspect of which is covered by numerous large prominent stellate chromatophores. An oil globule is present at hatching but is barely discernible in larvae 3 days old. The larva is large, robust, and strongly fusiform (torpedo-shaped) with a large head, projecting snout, and small (sometimes horizontally elliptical) eyes. Pectoral fins are weakly developed at hatching and the urostyle is oblique.

Trout-perch most closely resemble, but are easily separated from, spottail shiner and yellow perch larvae because the post-anal length enters the pre-anal length less than one time. Trout-perch larvae are probably more robust than larval Johnny darters.

Table 3. Characteristics of rainbow smelt (Osmerus mordax) larvae compiled from literature (see selected references) and from analysis of specimens collected from the inshore waters of southeastern Lake Michigan, 1973-1975.

Larvae

1) Approximate length at hatching: 4.5 mm TL.

2) Myomere count: pre-anal 40-42 (range in literature 35-42): post-anal 18-21 (range in literature 11-16).

3) Post-anal length enters pre-anal length 2.0-2.9 times.

4) Mouth: non-functional at hatching, becomes large terminal and oblique.

   Gut: yolk-sac small and containing an anterior oil globule. Yolk-sac located well posterior to pectoral fins (nearly at the mid-point of the larva).

   Body: long and very slender (filiform). Head small, snout blunt.

   Fins: pectoral fins very weakly developed at hatching.

5) Pigmentation: paired row of elongate chromatophores on ventral aspect of larva between pectoral fins and pelvic fin buds, becoming a single row between pelvic fin buds and vent. Several (often three) widely-spaced elongate chromatophores may be present on ventral aspect between vent and base of caudal fin.

Late larvae

1) Pelvic fin buds quite obvious as a distant swelling on ventral aspect at nearly the midpoint of the larva.

2) Base of anal fin relatively long. Anal fin rays 13-16.

3) Dorsal fin inserts almost directly over pelvic fins. Dorsal fin rays 8-11.

4) Teeth may become evident on pre-maxillary and mandible.

5) Adipose fin may not become evident until after 20-35 mm length stage.

Table 4. Characteristics of yellow perch (Perca flavescens) larvae compiles from literature (see selected references) and from analysis of specimens collected from the inshore waters of southeastern Lake Michigan, 1973-1975.

Larvae

1) Approximate length at hatching: 5.0 mm TL.

2) Myomere count: pre-anal 16-18 (range in literature 16-24); post-anal 19-21 (range in literature 16-21).

3) Post-anal length enters pre-anal length approximately one time.

4) Mouth: readily apparent at hatching, becomes large terminal and slightly oblique. Jaws prominent and well developed early in larval development.

   Gut: yolk-sac not entire and containing a large anterior oil globule. Vent very prominent and strongly decurved.

   Body: robust. Head large and triangular, snout blunt.

   Fins: pectoral fins moderately well-developed at hatching, becoming large and rayed early in larval development.

   Other: yolk-sac absorbed by 8-mm length stage.

5) Pigmentation: a few small, round chromatophores on lateral aspects of larva (often concentrated along myoseptums). A few small, stellate chromatophores on vent.

Late larvae

1) Base of anal fin relatively short. Anal spines 2, anal rays 6-8.

Table 5. Characteristics of trout-perch (Percopsis omiscomaycus) larvae compiled from literature (Fish 1932 and selected references) and from analysis of specimens collected from the inshore waters of southeastern Lake Michigan, 1974-1975.

Larvae

1) Approximate length at hatching: 5.5 mm TL.

2) Myomere count: pre-anal 14 (range in literature 12-19); post-anal 21 (range in literature 18-22).

3) Post-anal length enters pre-anal length 0.8 times.

4) Mouth: non-functional at hatching, becomes large terminal and oblique.

   Gut: yolk-sac large not entire and containing an oil globule at hatching; vent prominent.

   Body: robust and fusiform (torpedo-shaped). Head large, snout projecting, eye small relative to size of head.

   Fins: pectoral fins weakly developed at hatching, remaining so through at least the 8-mm length stage.

   Other: urostyle oblique at 6-mm and 8-mm length stages.

5) Pigmentation: numerous large, prominent, stellate chromatophores on ventral aspect of yolk-sac. Single row of small, round chromatophores on ventral aspect of larva from vent to base of caudal fin. Dorsal aspect of stomach covered with a dense mat of small, subsurface chromatophores.

Late larvae

1) Base of anal fin short. Anal rays 5-8.

Johnny darter (Etheostoma nigrum)

Descriptive literature pertaining to larval development of the Johnny darter is scant. In addition we captured only three specimens, all of which were at advanced stages of larval development. A few characteristics of larval Johnny darters are summarized in Table 6, including those of the 10.3 mm length stage. Pre-anal to post-anal length ratio and myomere counts may separate this species from the other six.

Slimy sculpin (Cottus cognatus)

Characteristics of slimy sculpin larvae (Table 7) include: large size at hatching (8.0-8.5 mm); pre-anal myomeres 9-11, post-anal myomeres 20; pre-anal length less than post-anal length (ratio = 0.7-0.9 to 1); yolk-sac is large, entire, and contains an oil globule. The body is robust, thick, and wide, with a large head, blunt snout, and large eyes. Pectoral fins are well developed at hatching and become rayed by the 8.9 mm length stage before yolk-sac absorption is complete.

Larval slimy sculpins are large, robust, and well developed at hatching. Assumption of juvenile characteristics occurs with no more than a 1.2-mm increase in total length. The size, advanced development at hatching, and assumption of juvenile characteristics between the 9.0-9.5 mm length stage, along with its distinctive appearance, clearly separate this species from the other six discussed.

Discussion and Summary

Fish larvae were identified through one or more of five general processes. Knowledge of seasonal abundance and distribution of adult fish frequenting the study area enables the investigator to anticipate those species which should appear in the larval fish catch. We have found that the species composition expressed as percentage total catch of larval fish roughly parallels that of the adult fish catch (Table 8). Species which appeared only incidentally as adults were rarely or never captured as larvae. Consequently, the potential occurrence in a study area of larvae of many species of fish may be extremely low. Spawning habits of adults, as well as incubation time of eggs, may indicate when various species of fish larvae should appear. Rainbow smelt spawn in abundance inshore during April or May in our study area, and we expect the larvae to appear by late April or early May, peak during May and move offshore by June. This pattern has been observed by Jude et al. (1975). Similar predictions can be made for the other six larval species discussed. Scott and Crossman (1973) indicate bloaters (Coregonus hoyi) spawn at depths between 36.5-91.4 m (120-300 ft) and that white suckers (Catostomus commersoni) usually spawn in streams, tributaries, and bays of deep lakes. Considering this, these two species probably spawn outside our study area. The incidence of adult fish in our catch is low and

Table 6. Characteristics of Johnny darter (Etheostoma nigrum) larvae compiled from literature (see selected references) and from analysis of specimens collected from the inshore waters of southeastern Lake Michigan, 1974-1975.

Larvae

1) Approximate length at hatching: 5.0 mm TL.

2) Myomere count: pre-anal 15; post-anal 20-22.

3) Post-anal length enters pre-anal length 1.2 times.

4) Mouth: becomes small inferior and slightly oblique.

   Gut: yolk-sac entire, oil globule present.

   Body: slender. Head small, snout protruding.

   Fins; pectoral fins rayed by 10.3 mm length stage.

5) Pigmentation: numerous small, round chromatophores on dorsal aspect of head. A few, elongate chromatophores on ventral aspect of larva between vent and base of caudal fin.

Table 7. Characteristics of slimy sculpin (Cottus cognatus) larvae compiled from literature (see selected references) and from analysis of specimens collected from the inshore waters of southeastern Lake Michigan, 1974-1975.

Larvae

1) Approximate length at hatching: 8.0 mm TL.

2) Myomere count: pre-anal 9-11; post-anal 20.

3) Post-anal length enters pre-anal length 0.7-0.9 times.

4) Mouth: well developed at hatching, becomes large inferior and horizontal.

   Gut: large, entire yolk-sac containing an oil globule.

   Body: robust, thick and wide. Head large, snout blunt.

   Fins: pectoral fins well developed at hatching; ray development occurs shortly after hatching.

   Other: larvae is large and well developed at hatching; assumption of juvenile characteristics occurs with only a 1.2 mm TL increase.

5) Pigmentation: a few small, round, scattered chromatophores are evident at hatching.

therefore we would not expect (nor did we capture) any larval bloaters or white suckers (Table 8).

Keys and descriptive literature, including photographs and drawings, often provide a means for identifying certain species of larval fish. Special references which were useful to us are listed at the end of this paper. However, as with the genus Notropis, keys or literature may be incomplete or nonexistent, making identification to species difficult or impossible if methods for larval fish identification rely entirely upon the use of descriptive literature.

Examination of identified larvae and comparison with unidentified specimens can be helpful, especially if the investigator is unfamiliar with the species and requires a reference specimen to clarify his interpretation of the species description. Rearing larvae of the fish species commonly found in the study area provides an excellent source of identified specimens and will enhance the investigator's familiarity with the larval features of fish he may expect to find in his area. Rearing eggs and larvae to hatching and through early stages of larval development may sometimes be accomplished without great difficulty or complicated equipment. Larvae may also be obtained from other workers.

If identification is particularly difficult, identification of specimens and a second opinion by outside investigators may be desirable. The reliability of the identification will vary with the expertise of the outside investigator. In addition, finding other workers familiar with the species under investigation may be difficult and time-consuming.

Alewives constituted approximately 73% by number of the 1973-1974 adult fish catch and 72% of the total larval catch (Table 8). Peak larval fish catch occurred during June followed by July and August, correlating closely with hatching periods anticipated from our concurrent studies of adult alewives and their spawning habits. Initially we identified specimens with identified alewife larvae obtained from other workers. Identifications were confirmed with keys and descriptive literature and supported by the close correlation of seasonal abundance of the larvae with the alewife hatching period that we predicted. Alewives are common in Lake Michigan and the other Great Lakes and occur in much of the Atlantic coastal drainage of eastern North America (Scott and Crossman 1973); consequently much information is available.

Approximately 15% of the adult fish catch and 21% of the larval catch was made up of spottail shiners. Spottail larvae were captured June through August, with June the month of maximum abundance. Initial identification of larval spottails was accomplished by predicting when they should appear and what proportion of the total larval catch they would comprise. Identifications were confirmed with keys, descriptive literature and experience. Spottail shiners were observed spawning in the area of the Cook Plant and samples of eggs were collected by SCUBA divers (Dorr

Table 8. Adult fish and total larval fish catch from the inshore waters of southeastern Lake Michigan near the D. C. Cook Nuclear Plant, 1973-1974.

Species	Adult fish catch		Larval fish catch	
	Percent	Total	Percent	Total
Alewife	72.81	224677	71.99	5904
Spottail shiner	14.59	45015	20.66	1694
Rainbow smelt	7.24	22348	4.98	408
Yellow perch	2.73	8411	1.62	133
Trout-perch	1.66	5120	.16	13
Johnny darter	.16	500	.04	3
Coregonus sp.	.12	373	.00	0
Slimy sculpin	.11	352	.09	7
White sucker	.11	325	.00	0
Lake trout	.10	316	.00	0
Ninespine stickleback	.01	43	.01	1
Other species	.36	1108	-	-
Unidentified species	.00	0	.46	38
Total		308588		8163

Includes "chubs" (*C. hoyi*, *C. artedii*, etc.); excludes Lake whitefish (*C. clupeaformis*).

Specimen misplaced prior to final identification.

Includes 36 additonal species each of which comprised less than .10% of the total adult fish catch.

and Miller 1975) and reared, supplying us with a few identified larvae to compare with field-caught specimens.

Rainbow smelt comprised approximately 7% of the adult fish catch and 5% of the larval catch. The correlation of adult fish spawning and larval catch provided an excellent means for identifying larval smelt and tentatively separating them from the larval alewife catch on a temporal basis, since alewives appear to hatch several weeks later than smelt. Specimens of smelt were tentatively identified using keys, and later were confirmed by other investigators. During 1974 smelt eggs were fertilized, reared, and a series of larval developmental stages obtained and compared with field-caught specimens.

Yellow perch constituted approximately 3% of the adult fish catch and 2% of the larval catch. Jude et al. (1975) indicated that peak spawning of yellow perch in the Cook Plant area in 1973 occurred within a very short time span, 1.5 weeks, beginning around mid-June. Additional data indicates spawning takes place primarily during June; our seasonal catch of larval perch closely correlates with predicted spawning. Larval stages of yellow perch have been studied frequently, and since information and expertise were readily available our specimens were initially identified by outside investigators. Later, with field and laboratory experience and familiarity with the literature, we were able to support the identifications.

Little is known about spawning of trout-perch or their larval distribution or identification, particularly in Lake Michigan. They comprised about 2% of the adult fish catch and 0.2% of the larval catch. We caught relatively few larvae and based our identifications primarily on descriptons of larval trout-perch by Fish (1932).

Only 0.2% of the adult fish catch and less than 0.1% of the larval catch was comprised of Johnny darters. Only three larvae were collected; all were at advanced stages of larval development and were easily recognizable as darters. Since no other darter species have been collected near the Cook Plant, the larvae were assumed to be Johnny darters (Etheostoma nigrum).

Slimy sculpin occurred regularly in our catch, but were rare (approximately 0.1% of both the adult and larval fish catch) when compared with numbers of other species captured. Our data (Jude et al. 1975) suggest a hatching period from late April through early May. During May 1974, SCUBA divers collected two clumps of 300-600 suspected sculpin eggs from rip-ap near the Cook Plant (Dorr and Miller 1975). Eggs were incubated in our laboratory and larvae reared to the stage at which they could be identified with keys and characteristics of adult fish. A series of developmental stages was compared with field-caught larvae suspected to be sculpins. Also, a few descriptions of larval stages of Cottus sp. were available; larvae of this genus are very distinctive.

Unidentified specimens comprised approximately 0.5% of the larval fish catch. Poor physical condition and loss of identifying characteristics, usually the result of decay or physical damage sustained prior to capture, were most often the factors preventing identification. The few remaining larvae were unidentified because we had neither the experience nor enough information to identify them.

Each species of fish was assigned a two-letter code to facilitate computerized processing of adult and larval fish catch data. For example, alewives were coded AL; a 4.5-mm alewife was enumerated as AL 4.5. The two-letter code for unidentified fish was as follows: if poor condition prevented the identification of a specimen it was coded XP (unidentified-poor condition). Specimens which could only be tentatively identified were coded with a question mark preceding the two-letter species code (e.g., ?AL - Questionable alewife). Damaged rainbow smelt and alewife larvae were difficult to separate but other factors such as catch date, size, etc. occasionally permitted tentative identification and coding as above. Finally, specimens that were in good condition but which we were unable to identify were coded XX (unidentified-good condition).

This method of coding unidentified specimens facilitates the handling, recording, and selective incorporation or exclusion of these specimens into computerized data processing programs. When processing data, unidentified larvae may be included or ignored depending upon the level of species certainty required. For example, all larvae would be included when calculating total numbers entrained during a given time period. However, if the vertical, diel, and seasonal distribution of larval alewives is to be studied, unidentified larvae may be ignored (although those tentatively identified as alewives might be included). In addition to facilitating data processing, classification status of each unidentified larva is clearly defined and easily changed as additional information and expertise for later identification become available.

Characteristics of seven species of larval fish were summarized in Tables 1-7 so that features such as hatching size, morphometric proportions, physical appearance, and other characteristics could be presented in a consistent, comparable order. Myomere counts represent an excellent diagnostic characteristic, but accurate counting requires great care and experience. Although the total count for a given species should vary by only a few myomeres, the range that has been recorded in the literature may be very wide (e.g., yellow perch 32-45) and confusing to an inexperienced investigator.

We have not attempted to develop a key to the species of fish larvae exclusive to our study area because we have not examined specimens of, nor do we know, all the species or their stages of development which could possibly appear in southeastern Lake Michigan. Rather, we have attempted to develop a means for separating and recognizing species of larval fish that we can identify, categorizing each unidentified specimen with a code that reflects the particular identification problem incurred.

Financial and temporal constraints dictate that methods for larval fish identification be reliable, fast, and easily learned, since we have a rapid turnover of students and temporary help aiding in the sorting and enumerating of several thousand samples of larvae. Generally, samples are sorted and easily recognizable larvae are identified by a number of individuals capable of performing simple, routine identifications. Doubtful specimens are set aside for identification by more experienced personnel. Although a few larvae may be misidentified, they probably do not represent a significant portion of the total catch to bias our calculations or conclusions. Every attempt is made to identify all larval species caught. However, efforts and desire to recognize and enumerate even the most incidental species must be balanced with expenditure of time and money required, and the significance of such enumeration to the total larval fish catch and populations.

Fish eggs are often collected in large numbers during sampling. Early attempts to identify eggs to species using egg diameter measurements were not totally reliable because of size overlap among the most common species, alewife, spottail shiner, and rainbow smelt (Figure 2). Spawning periods also overlap (Figure 3), and other characteristics such as spawning habits and physical description of eggs did not provide complete species separation.

Adult fish studies, egg and larvae catch data, and occasional identification of eggs suggest periods when eggs of various fish species may appear in the area. Burbot (Lota lota) eggs have been observed in samples collected between January and March. Rainbow smelt eggs have been tentatively identified in April and May samples, and sculpin eggs were taken from the rip-rap during May by divers. Yellow perch eggs have been observed during June by divers examining the rip-rap near the Cook Plant. Eggs tentatively designated as alewife and spottail shiner have also been observed during June by divers and have been collected in May-July samples. Most eggs are collected between April and July, with rainbow smelt probably comprising much of the April catch and alewives the May-July catch, along with a relatively small percentage of spottail shiner eggs. The extent to which other, incidental species contribute to the total egg catch is not known but is undoubtedly small.

As many as 19,000 eggs have been collected in a single sample. Jude (in press) has calculated that approximately 20 million eggs were entrained once during a single 24-hr. period during 1974 operation of Unit 1 of the Cook Plant. Given the periodically tremendous number of eggs present and samples, operational constraints, and the fact that complete identification cannot be assured, we enumerate all fish eggs but do not attempt to identify them.

Figure 2. Egg diameter ranges of seven species of fish common to the inshore waters of southeastern Lake Michigan as determined from the literature (see Selected References and Scott and Crossman, 1973) and measurements of samples.

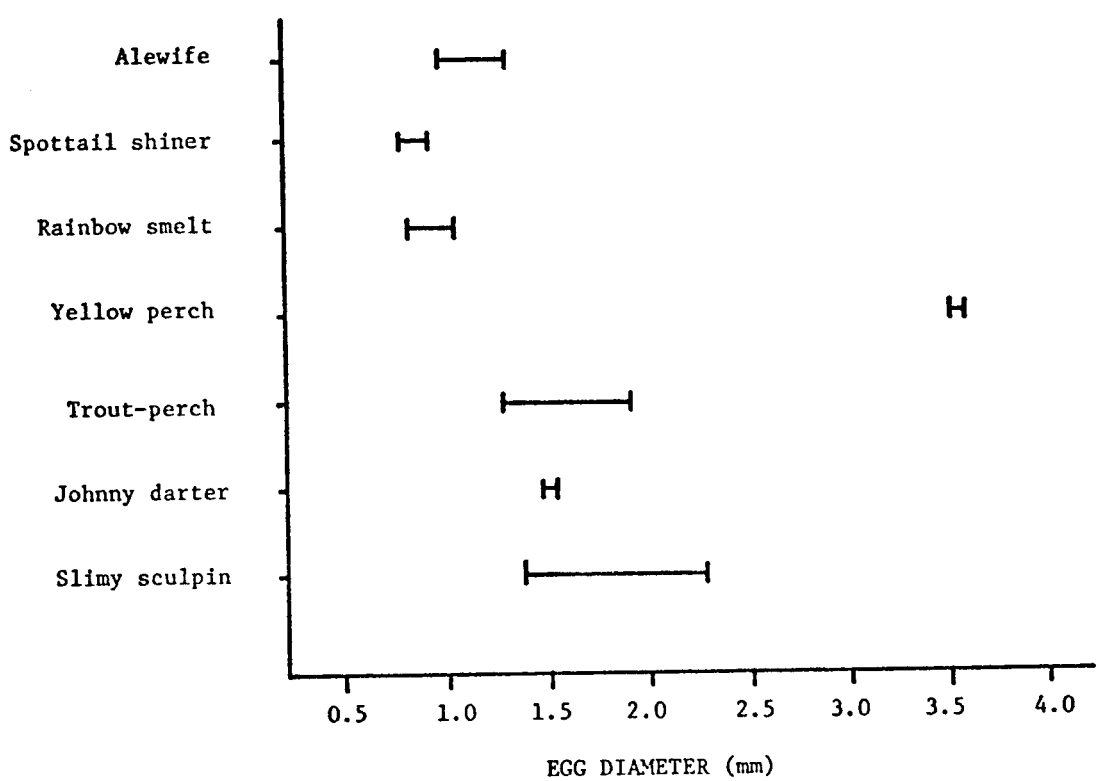
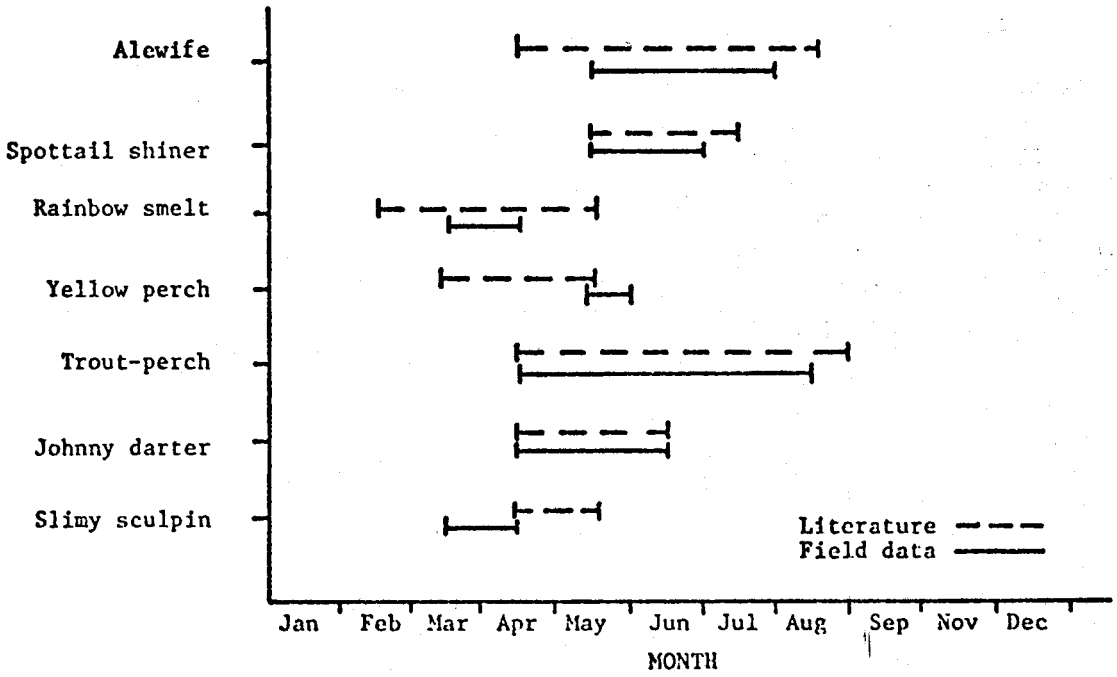


Figure 3. Spawning periods of seven species of fish common to the inshore waters of southeastern Lake Michigan as determined from the literature (see Selected References and Scott and Crossman, 1973) and field data (Jude, et al., 1975).



Acknowledgments

These studies were funded through a grant from the Indiana and Michigan Power Company to the Great Lakes Research Division, University of Michigan. We are grateful to Dr. John C. Ayers, Project Director, for his continued support of our research activities, and to Dr. Ayers and Dr. Erwin Seibel for review of this paper.

All larval samples were collected and picked by members of the Fisheries Investigation group, including Jane Tomlinson and Timothy Miller. Special thanks are extended to Bruce Pollard for his assistance in the compilation of Tables 9 and 10 and to Gregory Godun for the statistical considerations.

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WORKING GROUP NO. 1

DETERMINATION OF HIGHEST PRIORITY INFORMATION GAPS

Robert Werner
Chairperson

Participants: Cynthia Cook, John Dorr, James Edmunds, Ronald Fobes, Jerry Hardy, David Jude, Lawrence Lubbers, Donald Nelson, Eileen Setzler, and John Shauver

The objective of Working Group No. 1 was to identify those species of Great Lakes fishes whose egg and larval stages have not been described and to place them in an order of priority. The approach taken was to systematically proceed through the species list for the Great Lakes drainage, checking it against the literature in the bibliography to determine what was already available in terms of descriptions. We then assigned a priority rating to each undescribed species. The criteria for assigning priority ratings was a subjective judgement based on the following factors: (1) Was it a rare, endangered or threatened species? (2) Was it a sport species? (3) Was it a commerical species? (4) Was it an important forage species? (5) Was it a predator that might have some impact on one of the categories above? or (6) Was it simply a species that was commonly taken in field studies of larval fish distribution?

Three priority ratings were established: high, moderate, and low. High priority ratings indicated that work on descriptions of those species should begin immediately. Moderate priority ratings were assigned to important species for which the need was not quite as pressing. Low priority ratings were assigned to forms that are present, but are either not as likely to be impacted or are a less significant component of the fish fauna. The ratings of Great Lakes fish species are presented in Table 1.

The working group also addressed the question of implementing this effort. Ultimately there should be complete descriptions for egg and larval stages of all Great Lakes species. Since this would require a major effort and would probably not be completed for many years, loose leaf notebook format should be established in the interim. As each description is developed it could be quickly disseminated to subscribers. They could add each description to their notebook as it came out and thus maintain an up-to-date file of descriptions. The notebook might also contain a key to the families.

A standard format for descriptions should be followed, so that reports by different investigators will contain comparable material. At a minimum, the format should consist of:

Table 1. List of species of Great Lakes Fishes that need descriptions of egg and larval stages. Groupings indicate species that should be studied as a unit with a special effort to develop distinguishing characteristics.

Highest Priority	
Grass pickerel	*Esox americanus*
Muskellunge	*E. masquinongy*
Gizzard shad[1]	*Dorosoma cepedianum*
Goldfish[2]	*Carassius auratus*
Carp	*Cyprinus carpio*
Troutperch	*Percopsis omiscomaycus*
Emerald shiner	*Notropis atherinoides*
Spottail shiner	*N. hudsonius*
Threespine stickleback	*Gasterosteus aculeatus*
Ninespine stickleback	*Pungitius pungitius*
Brook stickleback	*Culaea inconstans*
Mottled sculpin	*Cottus bairdi*
Slimy sculpin	*C. cognatus*
Spoonhead sculpin	*C. ricei*
Moderate Priority	
Ciscos[3]	*Coregonus* sp.
Round whitefish	*Prosopium* sp.
Arctic grayling	*Thymallus arcticus*
Central mudminnow	*Umbra limi*
Stoneroller	*Campostoma anomalum*
Redside dace	*Clinostomus elongatus*
Gravel chub	*Hybopsis x-punctata*
Bigeye chub	*H. amblops*
Silver chub	*H. storeriana*
Mimic shiner	*Notropis volucellus*

Table 1 (Cont.)

Bluntnose minnow	Pimephales notatus
Fathead minnow [4]	P. promelas
Bullhead minnow	P. vigilax
Creek chub	Semotilus atromaculatus
Fallfish	S. corporalis
Pearl dace	S. margarita
River carpsucker	Carpiodes carpio
Highfin carpsucker	C. velifer
Longnose sucker	Catostomus catostomus
Lake chubsucker	Erimyzon sucetta
Northern hog sucker	Hypentelium nigricans
Black buffalo	Ictiobus niger
Redhorses	Moxostoma sp.
Yellow bullhead	Ictalurus natalis
Black bullhead	I. melas
Madtoms	Noturus sp.
Flathead catfish	Pylodictus olivaris
Banded killifish	Fundulus diaphanus
Blackstripe topminnow	F. notatus
Starhead topminnow	F. notti
Brook silversides	Labidesthes sicculus
Yellow bass	Morone mississippiensis
Rock bass	Ambloplites rupestris
Sunfish	Lepomis sp.
Black crappie	Pomoxis nigromaculatus
White crappie	P. annularis
Sand darter	Amocrypta pelucida
Darters	Etheostoma sp.
Darters	Percina sp.

Table 1 (Cont.)

Lower Priority

Remaining undescribed species

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[1]The gizzard shad should be done concurrent with the alewife, so that characters separating these two species can be developed.

[2]Although the goldfish and carp have both been well described, separation of these two species from Great Lakes specimens is still difficult. Thus, the committee felt that carp and goldfish should be done again using Great Lakes parents.

[3]Includes all members of the genus except C. artedii and C. clupeaformis.

[4]Although the fathead minnow has been done it should be included when the entire genus is done.

(1) Range of species

(2) A complete description of adult characters

(3) Time of spawning-seasonal and daily

(4) Spawning habitat

(5) Pertinent aspects of spawning behavior

(6) Fecundity

(7) Egg discriptions, verbal and illustrated (as appropriate) with line drawings or photographs. Illustrations should include unfertilized egg, recently fertilized egg (early clevage stages), blastopore closure stage, tail-free stage, and hatching stage, at a minimum.

(8) Larval descriptions, verbal and illustrated (as appropriate) with line drawings or photographs showing dorsal, ventral, and lateral views. Illustrations should show larvae at frequent enough intervals so that all changes are easily followed.

(9) Summary of diagnostic characters useful in separating the species from all species with a close resemblance.

(10) Methods - Notation of origin of the parents, and where voucher specimens are maintained. Preservation and staining techniques, etc., should also be included.

To initiate such a program we suggest that a review board be established. The board would be responsible for reviewing manuscripts, printing the descriptions, and distributing appropriate information to subscribers.

WORKING GROUP NO. 2

IDENTIFICATION TOOLS: WHAT'S AVAILABLE AND WHAT COULD BE DEVELOPED

Darrel E. Snyder
Chairperson

Participants: John Cooper, John Dorr, Ronald Fritzsche, Joseph Geis, G. David Johnson, R. Lynn Moran, Joel Schaeffer, Richard Siefert, and W. Waldo Wakefield.

Fish eggs and larvae are a principal focus of many ecological studies. Their sensitivity to environmental changes and susceptibility to entrainment are major concerns of siting, environmental impact, and monitoring surveys now required of many industries and utilities. Their distributions and densities are indicative of spawning and nursery areas, spawning seasons, larval behavior, and year-class strength. Larval fish collections also provide information on growth rates, morphological development, food habits, and various other ecological relationships. Accurate identifications are essential. The data generated from studies of fish eggs and larvae can be no more valid than the identifications of the specimens on which they are based.

The Problem

Of over 700 species of fish found in North America's freshwaters, the eggs or larvae of only about 15% have been described and illustrated. Over 170 of these freshwater and anadromous fishes have been reported in the Great Lakes and its drainages. There are indications that at least minor descriptive notes exist for the eggs or larvae of about 30% of these Great Lakes fishes. Considerably fewer have been adequately described and illustrated for identification purposes. Confidence in identification is often limited, even for specimens matching the better descriptions, due to the presence in the study area of related species with undescribed but potentially similar larvae. Resolution of this problem requires that we know as much as possible about the early development of most, if not all, species within the study area. Much remains to be learned about the identifying characteristics of the vast majority of fishes.

Existing Conditions

At present, the freshwater larval fish taxonomist must depend on the limited literature he is aware of or able to obtain; reference specimens he has borrowed, cultured, or positively identified from collections;

and/or the aid of fellow taxonomists. Unlike biologists working with most other groups of organisms, freshwater larval fish taxonomists have no comprehensive keys or guides to aid in identification.

Few regional guides and keys have been published. "Contributions to the Early Life History of Sixty-two Species of Fishes from Lake Erie and its Tributary Waters" by Fish (1932) is (with the exception of its predecessors, Fish 1929 a & b) the earliest major aid to freshwater larval fish identification. In spite of its errors and inadequacies, it remains one of the basic illustrated guides. Winn and Miller (1954) assembled a key, with photographs, for the "postlarvae" of cyprinids and catostomids of the Lower Colorado River Basin. A preliminary key, with photographs, to the larval fishes of Oklahoma by May and Gasaway (1967) and descriptions and drawings by Taber (1969) of Lake Texoma (Oklahoma) fish larvae are also valuable aids to the larval fish taxonomist. Snyder (1971) produced a preliminary family key to the larvae of the lower Susquehanna River. Nelson and Cole (1975) have recently published a key to larval fishes found near the west shore of Lake Erie. Lippson has prepared a preliminary pictoral guide to the families of Great Lake's fish larvae for this workshop.

Unfortunately, the usefulness of these regional keys and guides is limited, usually due to incomplete coverage; scattered descriptions and illustrations in journals, bulletins, reports, and theses are needed to complement them. Mansueti and Hardy (1967) collected information from some of these papers in part I of their guide, "Development of the Fishes of the Chesapeake Bay Region". The book, while marine and estuarine oriented, presents most of what was known on a few families of freshwater and anadromous fishes in the vicinity. In the near future this volume will be updated and included as part of a relatively comprehensive guide for the Mid-Atlantic Bight. The latest most useful and most comprehensive regional guide presently in existence is the "Manual for Identification of Early Developmental Stages of Fishes of the Potomac River Estuary" by Lippson and Moran (1974). In addition to consolidating much of the literature on the species covered, the manual includes many original descriptive notes, keys to certain species, and illustrations.

Aside from the bibliographies of the previously mentioned guides and keys, the only "published" (distributed in memo form) bibliography on fish eggs and larvae that includes references to a substantial number of freshwater species is that by Mansueti (1954). An extensive bibliography of most of the literature on fish eggs and larvae for species of the Great Lakes region is being assembled by Dr. Werner for this workshop. Unfortunately, much of the literature, even when its existence is known, is difficult to obtain.

Research in the behavior, ecology, development, and identification of freshwater fish eggs and larvae is quite limited and largely uncoordinated. Researchers are frequently unaware of others doing similar work and communication is often non-existent. Tens of thousands of fish

eggs and larvae are processed each year through temporary baseline, environmental impact, and monitoring studies. Unfortunately, no permanent facilities exist in which most of these specimens might be deposited for future study and reference, and some of this valuable material is discarded and lost forever. Ideally there should exist permanent centers to serve as depositories and clearing houses for these specimens, to coordinate larval fish studies throughout the country, and to encourage and facilitate communication and the exchange of material and information. These would seem to be logical activities for museums of natural history, universities, or other institutions with strong fish-related programs. Unforturnately, few, if any of these institutions, appear to be sufficiently interested.

Suggested Solutions

In view of the urgent need for additional information on the identification of freshwater (and anadromous) fish eggs and larvae, we considered both short-term and long-term solutions. In the short-term we recommend: 1) the production of a manual of guide to the identification of Great Lakes fish eggs and larvae; 2) the production of a "complete and comprehensive" bibliography to descriptive information on the freshwater (and anadromous) fish eggs and larvae of North America, coupled with a central file of all listed publications from which copies could be made available to interested parties; 3) the establishment of a center for the study of these organisms to serve both the Great Lakes Region and, temporarily, the nation; and 4) organization of annual regional workshops or courses in larval fish identification. In the long-term we recommend: 1) the establishment of either a permanent national center or, as preferred by the majority of participants, additional regional centers for the study of freshwater and anadromous fish eggs and larvae, 2) periodic up-dating of the previously mentioned bibliography, literature file, and guide; and 3) the production of additional regional identification guides for other parts of the country, and/or a single guide for all North America, to be periodically updated.

The "Manual for the Identification of Great Lakes Fish Eggs and Larvae" is envisioned as a compilation of existing information based largely on the references cited in the Werner bibliography and including any original contributions offered in the way of descriptive notes, keys, illustrations, or other pertinent information. It would include many concepts suggested by two of the other working groups. The manual should be designed for pericdic up-dating (two to five year intervals, perhaps more frequently) by simple insertion of revised of additional pages. Such up-dating would include correction of errors, clarification of misleading information, new useful information obtained from older literature previously overlooked, recent publications, and any original

information made available. The guide should accordingly utilize a "take-apart" type binding. Such a binding also permits ease in copying pages and allows the user to rearrange according to his own needs. Based on the experience of Lippson and Moran with their Potomac River Estuary manual, assembly and production should require no more than a year to a year and a half. Consideration should also be given to a very rapidly produced (several weeks) preliminary or rough version for immmediate use by those presently working with fish eggs and larvae of the Great Lakes region.

We recommend that the manual be developed and assembled through a coordinated and well directed effort by several groups or individuals, each working on a specific group of fishes and using identical formats. Coordination and direction could be maintained either by agreement of all parties involved or by the supervision of a single group or individual given that responsibility. Such an arrangement should expedite production of the manual, permit the inclusion of distinctive characters as seen by those most familar with the species of concern, and facilitate the inclusion of differences between examined Great Lakes specimens and published descriptions and illustrations.

The manuals by Mansueti and Hardy (1967) and Lippson and Moran (1974) provide useful models for the proposed guide. However, we suggest several modifications or additions as presented in the following outline of potential format and content:

I. Title page.

II. Acknowledgements.

III. Contents.

IV. Introductions.

V. Definitions.

VI. Family (and where appropriate, subfamily) key to the larvae with simple sketches of typical larvae of each family. The key should be in three parts according to phase of development (see discussion of terminologies elsewhere in these proceedings.)

VII. Table of pertinent information phylogenetically by family and alphabetically by species within each family for all species in the Great Lakes and their drainages.

A. General distribution and typical habitat-coded.

B. Spawning behavior and habitat-coded, perhaps using Balon's (1975) "Guilds in Fish Reproduction."
C. Spawning seasons and temperatures including both typical and extreme ranges.
D. Incubation periods.
E. Selected adult meristics useful in larval and early juvenile identification.
    1. Fin spine and ray counts.
    2. Vertebral counts, trunk and caudal.
    3. Others such as branchiostegial rays, caudal structure, etc., might be considered for inclusion.
F. Egg size, total length at hatching, preanal and postanal myomeres; etc.
G. Existence of descriptions and/or illustrations of eggs or larvae.
H. Reference to pages in following compendeum if described or illustrated.
I. References for parts A-F, footnoted by author and date.

VIII. Compendeum of egg and larval descriptions and illustrations.

A. Phylogenetically by family and where appropriate by subfamily.
    1. Introductory comments.
    2. Family (and subfamily) characteristics.
        a. Distinctive characters of adults.
        b. Distinctive characteristics of eggs.
        c. Distinctive characteristics of larvae.
    3. References.
        a. Numbered in text.
        b. Listed by author and date (full bibliographic entry in literature cited, or readers might be referred to Werner bibliography).
B. Key to species, if sufficient information is available. It should be in three parts according to phase of development.
C. Alphabetically by species within each family (only species for which information or illustrations are available).
    1. Eggs.
        a. Description.
        b. Characters used to distinguish from other species in family.
        c. Illustrations.

2. Larvae by phase of development (see discussion on terminologies by Snyder elsewhere in these proceedings.)
   a. Descriptions.
   b. Characters used to distinguish from other species in the family.
   c. Illustrations, dorsal and ventral views included if available.
3. Illustrations of recently transformed juveniles and adults for comparative purposes.
4. References.
   a. Numbered in text.
   b. Listed by author and date (full bibliographic entry in literature cited, or readers might be referred to Werner's bibliography).
5. Space for personal notes of the user.

XI. Laboratory tools and techniques useful in sorting fish eggs and larvae from collected samples, identification of specimens, and culture and preparation of material for developmental studies.

X. Literature cited.

The final format for this manual must be most carefully selected. If done properly and with sufficient foresight, this format could be exactly duplicated for the additional regional or North American manuals recommended as part of the long-term solutions to larval fish identification problems. In future guides, regional or otherwise, sections from the Great Lakes manual for species found in both regions would already be completed and ready to insert in the new guide. Some modifications may, however, be needed (if the information is available) to account for regional differences in larval characters, and pertinent spawning and distribution information. Using the same format and larval terminology, specific keys for families (where sufficient information is available) may be readily modified and incorporated into new or more comprehensive manuals.

The assemblage and production of a complete and comprehensive "Bibliography to Descriptions of Freshwater and Anadromous Fish Eggs and Larvae of North America" should also be considered a priority project. Such a bibliography, up-dated on a regular basis, will eliminate the extensive time and effort repeatedly required each time a study is conducted or planned, or a manual or manuals are assembled. It should also minimize the unnecessary repetition of work that has long since been completed and prevent the nagging doubt held by many researchers of having overlooked some important literature.

In the interests of time, efficiency, and thoroughness, this bibliography should be restricted to descriptive information on the eggs, larvae,

and early juveniles only. Supplimentary bibliographies on other aspects of early life history and fish reproduction should be considered separately. The bibliography should indeed be as complete as possible; partial or incomplete bibliographies usually leave one wondering if some important papers were missed. The bibliography should be arranged alphabetically by author with each entry coded for detailed content, and indexed alphabetically by species

The corresponding central file of all literature listed in the bibliography will make all papers readily available to all researchers, again saving tremendous amounts of time and effort. Accordingly, this file and bibliography will help assure more accurate and valid identifications of collected specimens prior to the production and distribution of relevant guides. The file could be housed and maintained at one of the proposed regional centers, or under special contract by the Fish and Wildlife Reference Service in Denver or some similar organization. Individuals needing certain papers listed in the bibliography would then write to this facility and request either photocopies or microfiche copies of the desired literature. Inexpensive replicate microfiche copies of the entire file might be made readily available to various museums, universities, research groups, and larval fish taxonomists.

The "Center for the Study of Freshwater and Anadromous Fish Eggs and Larvae" could immediately concentrate on serving the needs of the Great Lakes Region, and could also temporarily serve on a national basis. Our working group envisions the eventual organization of a well coordinated network of regional centers, based on major drainage systems, throughout the United States. These regional centers should be of a "permanent" nature, similar to that of the U. S. National Museum, and should be funded and supported as such by the federal government. The relationship with the National Museum and similar institutions should be close. These centers might eventually evolve into broader based "National Centers for the Study of Living Fishes", a concept discussed with Mr. Snyder by a prominent member of the National Museum.

The centers would provide facilities for the deposition, maintenance, and storage of eggs, larvae and early juveniles no longer needed by various organizations or individuals collecting or rearing them. Deposited specimens would be verified as to identity and stored along with any related collection data provided by the depositor. These valuable specimens would then be available both internally and to outside groups or individuals for reference purposes (for taxonomic, developmental, or related studies), and for use in larval fish courses or workshops.

Each center would be responsible for the development of well organized comprehensive reference collections, emphasizing the species within its own region. Replicate collections would be provided to other regional centers, museums, universities, or similar organizations. Individual series might be exchanged with various outside researchers. In this way destruction of a reference collection at one center would not result in complete loss of the valuable resource. Collections with specimens from various

parts of the country would be more readily available to more people, thus facilitating more and better comparative studies and more accurate identifications. Master lists of the holdings of all regional centers and outside groups and individuals should be maintained at each center.

The centers would also conduct developmental studies on problem species or on fishes as yet undescribed or inadequately discribed as eggs or larvae. Both deposited specimens and in-house cultured material could be used. Spin-off studies including fish reproduction, behavior, and systematics, as mentioned in the discussion by Dave Hardy, should not be neglected. In addition to coordinated in-house research, these centers might facilitate communication and coordination or activities with and among outside groups and individuals; thus minimizing replication of on-going or planned work and encouraging joint ventures and cooperation. These centers might also be responsible for the periodic up-dating of the manuals, bibliography, and central literature file mentioned previously.

Although manuals or guides are primary identification tools, nothing substitutes for examining the actual specimens. We strongly recommend regular, perhaps annual, regional workshops or courses on larval fish identification at which the participants would study specimens and receive instruction. These courses, or workshops, ideally held at each regional center, would be particularly valuable to newcomers to larval fish work and at the same time provide an opportunity for workers to exchange new information.

The proposed manuals and bibliography are necessary to both draw together the greatest amount of useful information in the shortest possible time and provide a firm foundation for all future work. The proposed regional centers are necessary to gather together and distribute valuable specimens and expertise, to rapidly add to our present state of knowledge, and to facilitate the ever important communication among larval fish taxonomist, researchers, and others. Well organized courses or workshops are the most expedient and efficient means for training new larval fish workers. The solutions recommended in this report should rapidly increase our knowledge of early fish development and assure ever increasing accuracy in specimen identification which is essential in studies concerning changes or potential changes in our aquatic ecosystems.

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WORKING GROUP NO. 3

VARIABILITY IN CHARACTERISTICS APPEARING IN KEYS REGIONWIDE AND NATIONWIDE

Alice J. Lippson
Chairperson

Participants: Charles Anjard, George Drewry, H. W. Mohr, Jr., George Boronow, Lee Fuiman, Johnson Wang, Bruce Bushweiler, Jules Loos, and Ron Kernehan

Our group took a broader approach than what the subject title for our group implied. In our opinion, this report, in essence, should be directed towards answering three questions: (1) What characteristics in existing identification keys, manuals guidebooks, etc., are most useful for rapid and accurate identification of samples? (2) Of these characteristics, what is their variability or reliability, and how does this affect their usefulness in identification guides? (3) What are the regional limits that should be set for an identification guide? This latter question should be answered in the light of its practicality and the availability of adequate reference materials.

Characteristics Most Useful to a Practical Identification Guide

To address this problem we reviewed one by one those characters consistently employed in description of early developmental stages of fishes. We then sorted and chose those which, in our opinion, are most universally reliable as distinguishing characteristics. We recommend characteristics primarily for identification guides directed toward the investigator or laboratory technician who must efficiently sort and identify large numbers of field collected specimens. These characteristics are not necessarily the same as those historically used in more academically oriented descriptive or taxonomic works. The characters enumerated below relate to all species. Species-specific descriptions may include additional features important to identification.

Ecological Information: The geographical distribution of adults, spawning season, habitat, and location should be included. Brief summations are all that are necessary but the range of selectivity for each factor should be emphasized. We have omitted certain particulars that Bob Werner listed as inclusions for ichthyoplankton literature. For instance, in his report he mentions fecundity. Fecundity is not the most important information for guides designed primarily for specimen identification. In our discussion, we felt this kind of information could be presented in tabular form to widen the usefulness of the doucment, but it is not critical to species identification.

Meristics: The most important meristics for laboratory guides are myomere counts, number of fins, and fin ray counts. Many authors include vertebral counts, but these are generally an impractical tool when working with large numbers of specimens. Beyond these basic requirements, species of family-specific taxonomy might require that additional data be stated on such meristics as teeth counts, gill raker counts, etc. We stress that when meristics are presented, the method of counting should be clearly explained.

Morphometrics: Certain morphometric measurements or proportions are extremely important in the initial examination of a specimen. These proportions form the basis of the general appearance of any species. However, we do not consider the listing of highly specific numerical ratios as essential because they may change so radically from one developmental stage to the next. Statements on generalized proportional relationships (such as "head large, 1/4 body length," or "pectorals large, extending to or beyond origin of dorsal fin") are more useful. The best example of a proportion is the pre- to postanal length measurement. The relative position of the vent along the body can change with growth, so a statement such as "vent well posterior, about 3/4 back on body" is preferable to "preanal length .753 of total length". In some cases good sequential measurements of a species are a matter of record and the latter alternative is acceptable.

Description of Developmental Stages: Emphasis should be on diagnostic characteristics, comparative differences among families and species, and sequences of development. Verbal descriptions in detail of every morphological structure are unnecessary. Illustrations show morphology.

The problems of standardizing terminology for developmental stages of fishes are unresolved at this time. This committee reviewed alternatives and recommends that simplicity should prevail in a practical ichthyoplankton identification manual for the Great Lakes Region. We suggest that the post-hatching stages of freshwater species be divided into not more than four categories: yolk-bearing larva, either one or two intermediate stages designating larva before and after fin ray development, and juveniles.

Our list of the most useful diagnostic characteristics by stage are as follows:

- Eggs

  Measurements: capsule diameter of both unfertilized and fertilized eggs; proportion of perivitilline space to egg size; yolk diameter; and the number and size of oil globules.

  A verbal discription of the basic character and shape of the capsule and yolk including special structures (filaments, adhesive discs, etc.) should be given, as well as whether the

egg is pelagic, demersal, or attached. A general discussion of developmental morphology should be provided, but is not necessary for every embroylogical sequence. Descriptions of early cleavage stage and late embryonic stages would generally suffice. (There are always exceptions, but where a more detailed sequential series is needed, referenced bibliographic sources will lead the taxonomically oriented investigator or more serious student to more comprehensive papers.)

- Yolk-sac Larvae

  Measurements: hatching size, range of hatching size, and size at end of stage if known. Both total length and urostyle length should be included.

  Shape, relative position, and length of yolk should be noted. The discussion should also document number, size, presence or absence, and location of oil globules; and origin of dorsal finfold, its width and indentations. A brief description of body shape and any special structures should be presented. Good illustrations are a must and a combination of both drawings and photographs are ideal, but not always possible.

  Finally, pigmentation can be an extremely valuable aid to species identification. However, pigmentation as a definitive identifying character must be used with caution as it is highly variable and subject to fading under preservation.

- Larval Stages (after yolk absorption and including juveniles)

  Measurements should include: size and range of each stage; total length; and urostyle or standard length, depending upon stage. The development of fins, their sequence, relative position, and size are also important. (Number of fins would have previously been stated under meristic counts.) Body shape, its general characteristics, and any special structures should be described. Mention should be made of such features as mouth, its shape and position; teeth; position of eyes; presence or absence of preopercle spines; internal organs, etc. Although all the above should be described if possible, the importance of each depends on the species under discussion. Consistent use of all features for every species description is not expected.

Our group decided not to discuss the multiple variables which could be encountered in each listed key character.

Variability in Diagnostic Characteristics and How This Affects Their Usefulness in Identification Guides

Most key characteristics vary at least to some degree among individuals from the same geographic region and from different regions. They also vary between cultured and field samples. Local conditions and man-made perturbations may also cause changes in morphology and meristics. Morphometric properties are perhaps somewhat less vulnerable to change than meristic counts. There is, nevertheless, a consistency in the combination of identifying features which allows for reliable identification. It is assumed that descriptions in a guide would include discussion of the possible inconsistencies in pigmentation patterns, myomere counts, etc., to make the identifier aware of the caution he must exercise.

There was one question in our instruction sheet for Group III about whether special studies were needed to determine the parameters and/or causes of deviations from the norm. Although studies of the factors which may cause variability in these characters are certainly indicated, we do not feel they are necessary for the immediate production of a viable identification guide.

Regional Limits for Identification Guides

The committee concluded that for optimum effectiveness ichthyoplankton guides should be kept to limit geographical regions rather than the entire United States or to arbitrary regions as the eastern United States. They should be confined to basins or major drainage systems. In this way the problems of variability in identifying features will be minimized. Furthermore, we feel that a useful document can be developed for the Great Lakes Region with the existing state of knowledge. Top priority should be given to a guide for the Great Lakes proper covering species as listed by Lee Emery in his report to this workshop. Of second priority is a guide that would cover additional species found in the headwaters of the Great Lakes. We feel there is not sufficient information at this time to compile a guide which would encompass this broader region. Before an extensive guide is possible, additional research is necessary, particularly with regard to stream surveys and rearing studies.

The Mississippi River drainage system is another region in which critical ichthyoplankton assessments are ongoing, and methodologies for identifying samples are lacking. A series of sub-drainage manuals should be designed, rather than a single compendium for the entire Mississippi drainage system. With the current "state-of-the-art" preliminary keys to families and to certain species could be prepared for the Mississippi. If Regional Ichthyoplankton Centers are established they could direct development of keys and guides as research progresses.

MR. SNYDER: No questions. Just comments. You mentioned about vertebral counts not possibly being as useful as myomere counts. Since vertebral counts very closely correspond to myomere counts, you have a very good idea what the myomere count is based on the vertebral count. This is particularly helpful in fishes where early stages have not yet been described.

MS. LIPPSON: We discussed this at some length, but in the end we went by the original criteria we had set up because of its practicality. In most instances considering the problems of working with large numbers of specimens, vertebral counts would not be used except for the very serious student. I might be wrong. These are just our preliminary suggestions and I am sure a lot of people would support you in this.

MR. SNYDER: One other comment in respect to illustrations. I would like to point out the extreme usefulness of including dorsal and ventral views, not just lateral views.

MS. LIPPSON: I agree. That is a good addition.

WORKING GROUP NO. 4

IDENTIFICATION OF REFERENCE COLLECTIONS AND RECOMMENDATIONS FOR FUTURE DEVELOPMENT

Dan Faber, Chairperson

Participants: Ralph Barr, Leslie Knapp, Doug Martin, Paul Bradfield, and Ken Mueller

In the short term we feel that there is an immediate need for a coordination center for the Great Lakes Region. The most important feature of this proposed center of coordination is an individual desiring the responsibility. Second, space would have to be arranged to handle the developing reference collections. Duties of the coordinator will include curating, coordinating, and mailing of specimens for loan purposes.

We recommend that the center be located in the Great Lakes Region. The coordinator should send a questionnaire about availability of specimens and establish an ichthyoplankton newsletter immediately after the survey is accomplished. Reference material could be maintained at this coordinating center with the specimens both tank-raised and collected in nature. Also, photographs, drawings, and an index of specimens in personal reference collections elsewhere in the United States should be maintained.

Current collections and individuals willing to donate specimens in the future are Charles Anjard (Ichthyological Associates), Ralph Barr (NUS Corporation), Lee Emery (Great Lakes Fishery Lab, USFWS), Dan Faber (National Museum of Natural Science, Canada), Alice Lippson (Martin-Marietta Corporation), Jules Loos (Academy of Natural Sciences), Joel Schafer (Michigan Department of Natural Resources), Ken Mueller (Northern States Power Company), Darrel Snyder (Colorado State University) and Kathryn Wood (University of Maryland, Chesapeake Biological Lab.).

Table 1 is a list of expertise on the taxonomic groups of Great Lakes Fish eggs and larvae. It is a preliminary list, established in a matter of hours. This list would be extended or reduced as a function of the Newsletter.

A preliminary list of possible locations for the coordination center are the: Great Lakes Research Division, University of Michigan; Great Lakes Laboratory, Ann Arbor; Great Lakes Institute, Milwaukee; Smithsonian Institute, Washington; Buffalo Museum; Cleveland Museum; University of Michigan; University of Minnesota; Ohio State University; Michigan State

Table 1. Preliminary List of Expertise
on Families of Great Lakes Ichthyoplankton

Family	Experts
Petromyzontidae	Vladykov, Hubbs, Piavis, Lagler
Acipenseridae	(unknown)
Polyodontidae	(unknown)
Lepisosteidae	Suttkus
Amiidae	Wang, Miller, Whitehead, Norden, Wakefield
Hiodontidae	Snyder, Miller
Salmonidae	Frye, Faber
Osmeridae	Batt, Richardson, Able, Cooper, Snyder
Umbridae	(unknown)
Esocidae	Balon, Loos, Miller, Raney, Jenkins, Lachner, F. Nelson, Gilbert, Bailey, Snyder, Anjard
Catostomidae	Loos, Jenkins, Raney, Snyder, Mohr
Ictaluridae	Taylor, Jenkins, Snyder, Miller
Aphredoderidae	Martin, Lippson
Percopsidae	Snyder
Gadidae	Faber, Snyder
Cyprinodontidae	Hardy, Foster, Thompson, Able, Miller
Poeciliidae	Hardy, Hubbs, Miller
Atherinidae	Wang, Foster, J. Nelson
Gasterosteidae	Kruger, Faber, J. Nelson
Percichthyidae	Lippson, C. Wood, Mihursky, Cooper, Snyder
Centrarchidae	Werner, Anjard, Snyder, Balon, Siefert
Percidae	Straun, Hubbs, Taber, Stevenson, Norden, Dressler, Jenkins, Knapp, Forney, Cooper, Snyder, Anjard
Sciaenidae	Swedberg, Wahlburg, G. Johnson, Setzler, Snyder
Cottidae	Robbins, Faber

University; Michigan Department of Natural Resources; and Chesapeake Biological Laboratory. We do not feel that universities are particularly good places for a center because the individuals come and go, and the collections are not handled properly.

There is a need for a national center of concern for ichthyoplankton like the one Rass established in the U.S.S.R. in the 1940's. We are only 30 years behind.

Discussion

MR. WAKEFIELD: You mentioned a lot of large universities and museums. I was wondering if you considered the Field Museum in Chicago, that is a very stable museum with quite a staff.

MR. FABER: I agree, the Chicago Field Museum should be added.

MR. DORR: This response will be informal and I will try to keep it brief, because I am sure Dave Hardy will want to put in his two cents. I will try to summarize this as best as possible.

I want to address the problem of regional centers because it is one of the four topics that was listed on the itinerary, and we feel very strongly that the development of a reference collection which could be used immediately by researchers in the Great Lakes Region is of paramount importance.

Some of the reasons we feel that our department would be a good place to start the initial respository are as follows:

First of all, Dr. Jude and I have a very strong interest in fish larvae, and we are actively studying larvae in the Great Lakes Region. We have communication with other investigators who are also operating in the region. We maintain our own collection, small as it is, so we have some experience in handling specimens.

Second, our Department is located here in Ann Arbor, which geographically is a rather centralized location for the Great Lakes. In terms of individuals who would like to come and review the collections collections in person rather than just corresponding by mail (which can be a rather slow procedure), this would facilitate workers in the Great Lakes Region.

Third, there are a number of agencies in the Ann Arbor area that are actively doing research and studying the adult fish distributions in the Great Lakes Area. Some of these agencies are the U. S. Fish and Wildlife Service; The Great Lakes Fishery Commission; Great Lakes Basin Commission; one of the regional branches of NOAA with its associated lab; The Fisheries Research Insitute, which is affiliated with the Michigan DNR;

and, finally, the University of Michigan Ichthyological Museum, which is curated by Robert Miller, Reeve Bailey, and Gerald Smith.

I have left the University of Michigan Museum until last because I think it is important to point out that I spoke to Dr. Gerald Smith several months ago about the possibility of establishing a larvae collection, and at that time he expressed a strong interest in establishing a reference collection. To absolve any fears any of you have expressed concerning continuity in where the specimens are going to be maintained, our Department could set up a cooperative effort with the University of Michigan Museum. If any of the personnel operating or maintaining the collection in our Department were to leave, this collection would then be turned over to the University of Michigan Museum until its position could be relocated, rather than be lost.

I think that when we look at this on a formative basis, we are going to have a talk about a lot of free gratis time and effort. It is not going to be something that would be funded on a large scale basis right away. The University situation provides a number of students who would be anxious to get their foot in the door and help with some of the mundane tasks such as writing mailing lists, and cataloging and sorting specimens. They would be willing to do it for free, and would not be a particular financial burden to any agency.

Finally, our Department has close access to the University computing facility (which is next door to us) so that we are familiar with the computing complex and the procedures for computerizing such things as references on a species-specific basis, who and where in the country references could be maintained or obtained, and computerizing mailing lists.

Also, the University of Michigan has its formal printing facility next door to us. In terms of the reproducing and cataloging of material and references, we are in a good position to do so.

MR. BOREMAN: Do I hear a rebuttal from Dave Hardy?

MR. HARDY: No, I think it is beautiful. We volunteered because nobody else did it. But that sounds great.

MR. WERNER: Mr. Dorr, is it possible that you could serve as a large clearing house for these descriptive sheets I was talking about earlier? Is that a function you envision?

MR. DORR: I think we would like to do that, and I agree with you that I can see there would be a great advantage to maintaining both the specimen collection and the clearing house for publications. I think that having had only an opportunity to think about this for an hour and a half, we need a little bit more time to say yes. We would like the opportunity to think about something like that.

We might be able to computerize a list of references on a species basis and maintain the collection, but we might not be able to take on the process of printing or publishing all the circulars as they came in. We might evolve into it or in a year, if the operation has gotten too big, somebody else might have to take it over. We would serve as a immediate repository until something better comes along.

MR. SNYDER: Do you think you might have facilities to accept collections from other parts of the country at all?

MR. DORR: I think initially we could. On a long-term storage basis, I can not answer that question. Even my massive collection would not fill more than one wall of shelves within the first six months period, which would get the Great Lakes Region workers off the ground. At least for the summer season of 1976 people would have a place to write to and say I need specimens of alewife, shiner, and so on. This would get us off the ground. From there on, I can not make any promises because I do not know how big the operation would become.

DR. JUDE: I would like to add we do not have the facilities to take this on for more than a couple of years. I stress the temporary aspect.

APPENDIX I

A PRELIMINARY ANNOTATED BIBLIOGRAPHY OF THE LITERATURE RELEVANT TO DESCRIPTIONS OF EGGS AND LARVAL STAGES OF FISHES OF THE GREAT LAKES

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INTRODUCTION

The ability to correctly identify organisms is a cornerstone to good ecological work. Unfortunately for those interested in the early life history stages of fishes, this cornerstone has not been firmly established. Most ecological studies on larval fishes encounter great difficulties when identification of field collections are attempted. In recent years, as a result of the demands of environmental impact analysis, more and more investigators are confronted with this difficulty. In order to begin the process of solving this problem, I have developed a bibliography to some of the works that might be useful to investigators trying to identify egg and larval stages of Great Lakes fishes.

The bibliography focuses primarily on papers which describe egg and larval stages. References applicable to associated aspects such as fecundity, spawning season, spawning locality or spawning behavior are also included. No effort was made, however, to conduct an exhaustive search of the literature on these secondary aspects.

The scope of the bibliography encompasses the fishes of the Great Lakes drainage as developed by Hubbs and Lagler (1964) with the addition of Oncorhynchus kisutch and O. nerka. The catadromous eel is not included.

The search for references utilized A Bibliography of Fishes (Dean, 1917), Zoological Record, Vol. 1-107, and selected journals and paper published since 1970.

In order to make the bibliography more useful to active investigators, the references are arranged taxonomically. In addition, a brief annotation to every reference that we were able to peruse is also included. The annotation indicates whether the paper discusses fecundity, spawning biology, egg descriptions, larval descriptions, or presents figures or keys. In a few instances references are included which I did not review, but which, based on their titles, appeared to be particularly pertinent. For those species with no references cited useful information can often be obtained by reading faunal studies such as Scott and Crossman (1973) or Breder and Rosen (1966).

Several people participated actively in this work, particularly Dorothy Shafer and John Boreman. Both spent many long hours in the library locating references. Their assistance is gratefully acknowledged. In addition, many larval fish ecologists shared references with me. I am grateful to R. Cole, J. Cooper, L. Emerey, D. Faber, C. Herdendorf, V. Kranz, J. Loos, D. Nelson, J. Simmonds, D. Snyder, and J.C.S. Wang.

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   Covers general teleostan embryology.

2. Balon, E.K. 1975. Terminology of intervals in fish development. J. Fish. Res. Bd. Can. 32:1663-1670.

   Divides life of fish into 5 periods of which 2 (embryonic and larval) are of significance to this work. Then he subdivides embryonic period into 3 phases (cleavage, embryonic, and eleutheroembryonic) and larval into 2 phases (protopterygiolarval and pterygiolarval).

3. Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. Fishery Bull. No. 74, Vol. 53. 577 pp.

   Basically marine fishes, but included are Petromyzon marinus, Alosa pseudoharengus, A. sapidissima, Salvelinus fontinalis, Salmo salar, Oncorhynchus gorbuscha, O. kisutch, Osmerus mordax, Pungitius pungitius, Gasterosteus aculeatus, Apeltes quadracus and Morone americana. Includes life history information and descriptions of egg and larval stages usually from literature.

4. Breder, C.M. Jr. and D.E. Rosen. 1966. Modes of reproduction in fishes. Natural History Press, Garden City, New York. 941 pp.

   Summarizes spawning information on fishes, including all Great Lakes species for which information was available.

5. Brinley, J.F. 1938. Eggs of Fishes. Tab. Biol. Junk. 16:51-59.

   A classification of eggs with characteristics of 44 common fish eggs.

6. Brook, George. 1887. The formation of the germinal layers in Teleostei. Trans. Roy. Soc. Edinb. 133:199-239.

   Discusses general ideas regarding germ layer formation. There are no species described or drawn, however.

7. Carlander, K.D. 1969. Handbook of Freshwater Fishery Biology. Iowa State Univ. Press, Ames, Iowa. 752 pp.

Extensive life history information on all species of freshwater fishes of U.S. except the Perciformes.

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Not seen.

9. Eigenmann, Carl H. 1890. On the egg membrane and micropyle of some osseus fishes. Mus. Comp. Zool., Bull. 19:129-154. 3 pls.

Egg membrane of Perca sp., Morone americana, Esox niger and Notemigonus crysoleucas discussed.

10. Fish, M.P. 1929a. Contributions to the early life histories of Lake Erie fishes. N.Y. Conserv. Dept. 18th Ann. Rep. 1928 Suppl. 76-95 pp.

Line drawings and descriptions of Coregonus artedii, C. clupeaformis, Perca flavescens, Stizostedion canadense, and Micropterus dolomieui.

11. Fish, M.P. 1929b. Contributions to the early life histories of Lake Erie fishes. Buffalo Soc. Nat. Sci., Bull. 14(3):136-187.

Line drawings and descriptions of Lepisosteus osseus, Coregonus artedii, C. clupeaformis, Catostomus commersonii, Moxostoma aureolum, Notropis hudsonius, N. atherinoides, N. cornutus, Pimephales notatus, Fundulus diaphanus, Percopsis omiscomaycus, Perca flavescens, Stizostedion canadense, Etheostoma nigrum, Cottus bairdii, Triglopsis thompsoni, Micropterus dolomieui, and Lota lota.

12. Fish, M.P. 1932. Contributions to the early life histories of sixty-two species of fish from Lake Erie and its tributary waters. U.S. Bur. Fish., Bull. 47:293-398. Fig. 144, 4 tables.

Egg and larval descriptions with many drawings and plates. Families include: Percopsidae, Serranidae, Percidae, Centrarchidae, Atherinidae, Sciaenidae, Cottidae, Gasterosteidae, Gadidae, Lepisosteidae, Hiodontidae, Coregonidae, Salmonidae, Catostomidae, Cyprinidae, Ameiuridae, Umbridae, Esocidae, Cyprinodontidae.

13. Galat, D.L. 1972. Preparing Teleost Embryos for Study. The Progressive Fish Culturist. 34:43-48.

Good review of fixing, clearing and staining techniques for studies of embryos.

14. Hubbs, C.L. 1943. Terminology of early stages of fishes. Copeia:260.

Defines early stages as follows:

Embryo - developmental stages to hatching or birth.
Larva

a. Prolarva - with yolk sac.
b. Postlarva - after yolk sac absorption.
c. Alevin - larva in which postlarval stages are not recognized. Yolk sac larva transform directly into juveniles.

Juvenile - young fish before sexual maturity, which are morphologically similar to adult.

Young-of-year - age-group 0 from time of transformation into juvenile until January 1 of 1st year.

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

A thorough treatment of egg and larval stages of the Potomac estuary including the following Great Lakes species: Lepisosteus osseus, Anguilla rostrata, Alosa pseudoharengus, A. sapidissima, Dorosoma cepedianum, Esox americanus, E. niger, Carassius auratus, Cyprinus carpio, Hybognathus nuchalis, Notemigonus crysoleucas, Notropis analostanus, N. hudsonius, Carpiodes cyprinus, Catostomus commersonii, Erimyzon oblongus, Ictalurus catus, I. nebulosus, I. punctatus, Noturus insignis, Fundulus diaphanus, Gambusia affinis, Gasterosteus aculeatus, Morone americana, Lepomis gibbosus, L. macrochirus, L. megalotis, Micropterus dolomieui, M. salmoides, Pomoxis annularis, P. nigromaculatus, Etheostoma olmstedi, and Perca flavescens.

16. Mansueti, A.J. and J.D. Hardy. 1967. Development of fishes of the Chesapeake Bay region. An atlas of egg, larval and juvenile stages. Pt. 1. University of Maryland, Baltimore. 1-202 pp. 90 figs.

A thorough treatment of egg and larval stages of Chesapeake Bay fishes, including the following Great Lakes species:

Lepisosteus osseus, Amia calva, Alosa pseudoharengus, A. sapidissima, Dorosoma cepedianum, Esox americanus, E. niger, Carassius auratus, Cyprinus carpio, Hybognathus nuchalis, Notemigonus crysoleucas, Notropis analostanus, N. bifrenatus, N. chalybaeus, N. hudsonius, Semotilus corporalis, Carpiodes cyprinus, Catostomus commersoni, Erimyzon oblongus, Moxostoma macrolepidotum, Ictalurus catus, I. natalis, I. nebulosus, I. punctatus, Noturus gyrinus and N. insignis.

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18. May, E.B. and C.R. Gasaway. 1967. A preliminary key to the identification of larval fishes of Oklahoma, with particular reference to Canton Reservoir, including a selected bibliography. Oklahoma Fish. Res. Lab. Bull. #5. Norman, Oklahoma. 42 pp.

Contains key and photographs of 43 species of larval Oklahoma fishes including the following Great Lakes species: Morone chrysops, Percina caprodes, Perca flavescens, Amia calva, Cyprinus carpio, Carassius auratus, Aplodinotus grunniens, Labidesthes sicculus, Dorosoma cepedianum, Ictalurus punctatus, I. melas, I. nebulosus, I. natalis, Stizostedion vitreum, S. canadense, Micropterus salmoides, M. dolomieui, Campostoma anomalum, Esox lucius, E. americana, Pomoxis sp. and Lepomis sp.

19. Nelson, D.D. and R.A. Cole. 1975. The distribution and abundance of larval fishes along the western shore of Lake Erie at Monroe, Michigan. Mich. State Univ. Inst. Water Res. Tech. Rep. No. 32.4. 66 pp.

Key to prolarval and early post larval stages of several dozen species of fish in Lake Erie including: Ictalurus punctatus, Ictalurus sp., Lepisosteus sp., Dorosoma cepedianum, Alosa pseudoharengus, Osmerus mordax, Catostomus commersoni, Esox lucius, Stizostedion vitreum, Percina caprodes, Perca flavescens, Notropis cornutus, Cyprinus carpio, Carassius auratus, Aplodinotus grunniens, Micropterus dolomieui, Ambloplites rupestris, Pomoxis sp., Lepomis sp., Micropterus salmoides, Percopsis omiscomaycus and Morone chrysops.

20. Norden, C.R. Undated. A key to larval fishes from Lake Erie. Unpublished Mimeo. 4 pp.

Provides key to larvae of Salvelinus namaycush, Coregonus clupeaformis, C. sp., Catostomus commersoni, Osmerus mordax, Alosa pseudoharengus, Dorosoma cepedianum, Carassius auratus, Notropis atherinoides, N. hudsonius, Ictalurus punctatus, Percopsis omiscomaycus, Percina caprodes, Perca flavescens, Stizostedion vitreum, Aplodinotes grunniens, Morone chrysops, and Pomoxis annularis.

21. Nordqvist, H. 1915. Bidrag till Kännedomen om vara sötvattens-fiskars larvstadier (Contributions to the knowledge of the larval stage in our freshwater fish). (Eng. trans. in Lib. Nat. Museum Can., Ottawa.) Arkiv for Zoologi. 9:1-49.

Discusses European species, but figures of Cyprinus carpio from 5-10 mm, Lota vulgaris from 4.5-9 mm, Perca fluviatilis from 6-11.5 mm, and Cottus quadricornis 10.5-15.5 mm may be useful.

22. Raney, E.C. 1959. Some young fresh-water fishes of New York. N.Y. Conservationist. Aug.-Sept., 1959. pp. 22-28.

Brief descriptions of spawning and egg and early life history stages of Esox lucius, E. niger, E. americanus, E. masquinongy, Anguilla rostrata, Ictalurus nebulosus, Catostomus commersoni, Morone americana, M. saxatilis, Alosa sapidissima, Cyprinus carpio Perca flavescens, Stizostedion vitreum, Micropterus dolomieui, Salvelinus fontinalis, S. namaycush, Salmo trutta, S. gairdneri. Also includes a centerfold plate showing juveniles of each species in color, shad, smelt and sheepshead are not shown, however.

23. Ryder, J.A. 1887. On the development of osseous fishes, including marine and freshwater forms. Rept. U.S. Fish Comm. 13:488-604.

Deals primarily with marine fishes but does include Ictalurus catus.

24. Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bull. 184. Fisheries Research Board of Canada, Ottawa. 966 p.

Summarizes life history information including spawning location, behavior, time fecundity, and egg size where known, for most of the fishes of the Great Lakes. In addition, contains detailed morphological information on adults.

25. Scotton, L.N., R.E. Smith, M.S. Smith, K.S. Price and D.P. DeSylva. 1973. Pictorial guide to the fish larvae of Delaware Bay, with information and bibliographies useful for the study of fish larvae. Delaware Bay Rep. Series. Vol. 7. College Marine Studies, University of Delaware. 206 pp.

Includes descriptions and line drawings of Alosa pseudoharengus, A. sapidissima, Fundulus diaphanus, plus 53 other marine forms.

26. Snyder, D.E. 1971. Studies of larval fishes in Muddy Run Pumped Storage Reservoir near Holtwood, Pennsylvania. M.S. Thesis. Cornell University. 351 pp.

Includes a key to 6 families of Conowingo Reservoir fishes (pike, minnow, suckers, catfish, sunfish and perch families) as prolarvae, early postlarvae, and late postlarvae. Also presents information from the literature and his own collections on larval characteristics used to make identifications in study.

27. Summer, Francis B. 1899. Observations on the germ layers of teleost fishes. Science. 9:718.

A classification of Teleost eggs based on their approach to holoblastic cleavage and derivation of hypoblast.

28. Taber, C.A. 1969. Distribution and identification of larval fishes in the Buncombe Creek Arm of Lake Texoma with observations on spawning habits and relative abundance. Ph.D. Thesis. University of Oklahoma. 106 pp.

Not seen.

29. Taning, A.V. 1952. Experimental study of meristic characters in fishes. Biol. Revs. 27:169-193.

Discusses influence of temperature and other environmental factors on meristic characters. Includes line drawing of egg and embryo of Salmo trutta.

30. Winn, H.E. and R.R. Miller. 1954. Native postlarval fishes of the lower Colorado River Basin, with a key to their identification. Cal. Fish and Game. 40:273-285.

Artificial key to description of post larval fishes of the lower Colorado. Does not include any of the Great Lakes fauna.

31. Smith, Allen J., John H. Howell, and George W. Piavis. 1968. Comparative Embryology of Five Species of Lampreys of the Upper Great Lakes. Copeia 461-469.

Embryology of Lampetra lamottei, Ichthyomyzon castaneus, I. unicuspis, I. fossor compared to Petromyzon marinus with diagrams of Petromyzon and Ichthyomyzon unicuspis in stage 11.

Ichthyomzon castaneus

Ichthyomyzon fossor

Ichthyomyzon unicuspis

Lampetra lamottei

32. Hyman, L.H. 1926. The metabolic gradients of vertebrate embryos II. The Brook Lamprey. J. Morph. 43:111-133.

Description of egg and early larval stages with crude figures showing how the death gradient proceeds over body of Lampetra lamottei.

Petromyzon marinus

33. Applegate, V.C. 1951. Sea lamprey investigations. II Egg development, maturity, egg production and percent of unspawned eggs of sea lampreys, Petromyzon marinus, captured in several Lake Huron tributaries. Pap. Mich. Acad. Sci. 35:71-90.

Information on fecundity/weight of female, description of egg, and frequency distribution of egg diameter is presented.

34. Coventry, A.F. 1922. Breeding habits of the landlocked Sea Lamprey (Petromyzon marinus var dorsatus Wilder). Univ. Toronto Stud. Biol. Ser. 20. 129-136 pp.

Information on length of spawning season and nesting season as well as a description of lamprey nests is presented.

35. Gage, Simon H. 1893. The lake and brook lampreys of New York, especially those of Cayuga and Seneca lakes. In Wilder Quart.-Cent. Book. Ithaca, New York. 421-493 pp.

Descriptions and drawings of egg and larval stages.

36. Gage, Simon H. 1894. Transformation of the brook and sea lamprey. Proc. Amer. Assoc. Adv. Sci. 43 meet. 254-255 pp.

Discusses landlocked and sea run Petromyzon marinus in terms of habitat, larvae and adult size.

37. Hardisty, M.W. 1969. Information on the growth of the ammocoete larva of the anadromous sea lamprey, Petromyzon marinus in British waters. J. Zool. 159:139-144.

Study of the duration of ammocoetes stage. Concludes that it must last for at least 5 years. Description of ammocoetes included.

38. Hardisty, M.W. and J. Cosh. 1966. Primordial germ cells and fecundity. Nature 210(5043):1370-1371.

Fecundity only.

39. Howell, J.H. 1966. The life cycle of the sea lamprey and a toxicological approach to its control. In R.T. Smith, P.A. Miescher, and R.A. Goode, eds. Phylogeny of immunity. Univ. Florida Press, Gainsville. 263-270 pp.

Information on spawning, particularly nests, behavior, and fecundity is presented. Description of egg and metamorphosis also included.

40. Hussakof, L. 1912. The spawning habits of the Sea Lamprey P. marinus. Amer. Nat. 46:729-740.

A description of spawning behavior and nests.

41. Manion, P.J. and A.L. McLain. 1971. Biology of larval sea lampreys (Petromyzon marinus) of the 1960 year class, isolated in the Big Garlic River, Michigan 1960-65. Great Lakes Fish. Comm. Tech. Rep. No. 16. 1-35 pp.

A study concerned with lamprey control at larval stage. Fecundity, nest descriptions and larval ecology are covered.

42. Manion, P.J. and T.M. Stauffer. 1970. Metamorphosis of the landlocked sea lamprey, Petromyzon marinus. J. Fish. Res. Bd. Canada. 27:1735-1746.

Describes larvae, four stages of metamorphosis, and newly transformed adults. Includes tables and photographs.

43. McCauley, R.W. 1963. Lethal temperatures of the developmental stages of the sea lamprey, Petromyzon marinus. J. Fish. Res. Bd. Canada. 20:483-490.

Discusses role of temperature in development of eggs of sea lamprey.

44. Muller, August. 1856. Ueber die Entwickelung der Neunaugen. Arch. Anat. 1856. 323-339 pp. Also in Ann. Mag. Nat. Hist. 2 Ser. 18. 298-301 pp.

This paper is concerned with demonstrating that ammocoetes are lampreys. Includes a discussion of spawning, description of eggs, and early embryology of Petromyzon.

45. Ovsyannikov, F.V. 1892. Fur Entwickelungsgeschichte des Flussneunanges. Abstract in J. Roy. Micr. Soc. 1892-460.

Discusses early embryology through gastrulation. Only abstract was seen.

46. Piavis, G.W. 1961. Embryonic stages in the sea lamprey and effects of temperature on development. U.S. Bur. Fish. Bull. 61:111-143.

Divides embryology of sea lamprey into 19 stages with descriptions and photographs.

47. Piavis, George W. 1966. Embryology of the Sea Lamprey. In R.T. Smith, P.A. Miescher, and R.A. Goode, eds. Phylogeny of immunity. Univ. Florida Press, Gainsville. 271-273 pp.

A description of the following stages is presented: ovulated/ unfertilized egg-zygote, 2 cell, 4 cell, 8 cell, 16, 32, 64 cell, Blastula, Gastrula, and Hatching.

48. Schneider, Anton F. 1873. On the developmental history of Petromyzon. Ann. Mag. Nat. Hist. 4 Ser. 11. 236-238.

Explain morphological changes during metamorphosis.

49. Scott, W.B. 1881. Preliminary Account of the Development of the Lampreys. Q. J. Micr. Sci. 21:146-153.

Includes a description of formation of germinal layers of early differentiation of Petromyzon.

50. Scott, W.B. 1887. Notes on the Embryology of Petromyzon. J. Morph. 1:253-310.

Deals exclusively with embryology of Petromyzon sp. Figures are all sections showing internal organs. Good figures though.

See also references, 3, 4, 7, 24.

Acipenseridae

Acipenser fulvescens

51. Dean, B. 1893. Notes on the spawning conditions of the sturgeon. Zool. Anz. 16:473-475. Also in Forest & Stream. Vol. 41. 525 p. Also in Allgem. Fischerei Zert. 1893. 388-390 pp.

Notes on movements of fish during spawning and conditions under which eggs are deposited and hatched.

52. Dean, B. 1895. The early development of garpike and sturgeon. J. Morph. 11:1-62.

A description of Lepisosteus osseus and Acipenser sp. development from egg to hatching with rough sketches. Also discusses spawning behavior.

53. Harkness, W.J.K. and J.R. Dymond. 1961. The lake sturgeon, the history of its fishery and problems of conservation. Ontario Dept. of Lands and Forests. 121 pp.

Includes information on fecundity, descriptions of egg and larval stages with photographs, and growth notes during first month.

54. Magnin, E. 1966. Quelque donnees biologigues sur la reproduction des esturgeons Acipenser fulvescens Raf. de la riviere Notaway, tributaire de la Baie James. Can. J. Zool. 44:257-263.

Notes on spawning conditions, spawning behavior and egg descriptions.

See also references 4, 7, 24, 73.

Polyodontidae

Polyodon spathula

55. Allen, W.F. 1911. Notes on the breeding season and young of Polyodon spathula. J. Washington Acad. Sci. 1:280-282.

Some spawning information of Mississippi River spoonbills. Author was attempting to rear Polyodon embryo but was unable to mature eggs.

56. Ballard, W.W. and R.G. Needam. 1964. Normal embryonic stages of Polyodon spathula (Walbaum). J. Morph. 114:465-478.

Description of development from fertilization to 15 mm. (26 days) with crude drawings.

57. Barbour, Thomas. 1911. The smallest Polyodon. Biol. Bull. 21:207-208.

Drawing of 37 mm. specimen, drawing of 80 mm. specimen.

58. Danforth, C.H. 1911. A 74 mm. Polyodon. Biol. Bull. 20:201-204.

Study of 74 mm. Polyodon embryo and comparison with adult fish. Three views of the 74 mm. specimen. Table of measurements of 74-1300 mm. specimens.

59. Purkett, C.A. 1961. Reproduction and early development of the paddlefish. Trans. Amer. Fish. Soc. 90:125-129.

External features of the egg, prolarvae, hatching and early behavior of the larvae are discussed. Spawning site and activity briefly described. Figure containing various stages of development including: (1) egg; (2) prolarva, newly hatched; (3) prolarva 48 hrs. old; (4) larvae, 29 days old is presented.

60. Thompson, David H. 1933. The finding of very young Polyodon. Copeia 31-33.

Line drawing of 17 and 200 mm. specimens.

See also references 4, 7, 24.

Lepisosteidae

Lepisosteus oculatus

61. Echelle, A.A. and C.D. Riggs. 1972. Aspects of the early life history of gars (Lepisosteus) in Lake Texoma. Trans. Amer. Fish Soc. 101:106-112.

Some discussion of spawning times. Of little value for identification. Includes: L. osseus, L. platostomus, L. oculatus, L. spatula.

Lepisosteus osseus

62. Agassiz, J.L.R. 1856. On some young gar pikes from Lake Ontario. Proc. Boston Soc. Nat. Hist. 6:47-48. Also in Amer. Journ. Sci. 1857. 2 Ser. 23. 284-285 pp.

Brief description of embryonic characters.

63. Balfour, F.M. and W.N. Parker. 1881. On the structure and development of Lepidosteus. Royal Soc. London Proc. 33:112-119.

Not seen.

64. Balfour, F.M. and W.N. Parker. 1882. On the Structure and Development of Lepidosteus. Royal Soc. London. Trans. 173:359-442.

First part of paper devoted to segmentation, formation of germinal layers, and general development of embryo. Second part deals with structure and development of organs. Excellent plates of segmentation of ovum, embryo to time of hatching and larva. Transverse sections of embryo after impregnation.

65. Beard, J. 1889. On the early development of Lepidosteus osseus. Preliminary notice. Royal Soc. London Proc. 45:108-118.

Description of egg and embryo, but no figures.

66. Eycleshymer, A.C. 1903. The early development of Lepidosteus osseus. Univ. Chicago Sec. Publ. Vol. 10. 17 pp.

Not seen.

67. Lanzi, Luigi. 1909. Richerche sui primi momenti di sviluppo degli. Olostei (od Euganoidi) Amia calva Bonap. e Lepidosteus osseus L. Con speciale riguardo al cosi detlo ispessimento prostomale. Arch. Ital. Anat. Embreol. 8:292-306. Also in Arch. Ital. Biol. 53:123-125.

Covers embryology only with no figures or descriptions.

68. Mark, E.L. 1890. Studies on Lepisosteus, Part I. Mus. Comp. Zool. Bull. 19:1-127.

Habits of young fishes and some embryology is discussed.

69. Netsch, Norval F. and Arthur Witt, Jr. 1962. Contributions to the life history of the longnose gar, (Lepisosteus osseus) in Missouri. Trans. Amer. Fish. Soc. 91:251-262.

Brief discussion of fecundity and spawning habits.

70. Vert, O. 1924. Beitrage zur Kenntnis des Kopfes der Wirbeltiere. II. Fruhstadien der Entwicklung des Kopfes von Lepidosteus osseus und ihre prinzipielle Bedeutung fur die Kephalogenese der Wirkeltiere. Morph. Jahrb. Leipzig. 53:319-390.

Excellent drawings and photos of developing embryo with an extensive bibliography.

71. Wilder, Burt Green. 1877. Garpikes, old and young. Pop. Sci. Monthly. 11:186-195.

Drawing of 18 mm. garpike.

72. Wright, Edward P. 1879. On the development of the garpike (Lepidosteus osseus). Nature. 19:100-101.

Account of an expedition to collect eggs for fertilization and rearing. Brief description of eggs and newly hatched embryo with an account of the growth of young fish.

See also references 4, 7, 11, 12, 15, 16, 24, 52, 61, 74.

Amiidae

Amia calva

73. Allis, E.P. 1889. Anatomy and development of the lateral line system in *Amia calva*. J. Morph. 2:463-568.

Discussion of lateral canals, (topography), and surface pores in adults. Discusses post larval forms (primary pores), number and position of canal organs, sense organs and innervation. Discusses formation of canals and origin of canal organs in larval forms. Excellent drawings (plates) of larval/embryonic forms with many figures of larvae.

74. Dean, B. 1895. Notes on the early development of the Ganoids, Lepidosteus, Acipenser, and Amia. Rept. Brit. Assoc. Adv. Sci. 65. Meet. 734 pp.

Notes on segmentation, blastula and gastrula stage. General mode of the formation of the embryo discussed.

75. Dean, B. 1895. The early development of Amia. Quart. Journ. Micro. Sci. 38:413-444. Abst. in Journ. Roy. Micro. Soc. 2 Ser. Vol. 16. 173-4 pp.

An account of spawning habits, the early appearance of embryo and differentiation of germ layers. Embryological differences between Ganoids and Teleosteans discussed.

76. Dean, B. 1896. On the larval development of *Amia calva*. Zool. Jahrb. (Syst. Abth.). 9:639-672. Abstract in Journ. Roy. Micro. Soc. 2 Ser. 17:20-21.

Description of larvae with excellent drawings.

77. DeBruine, H. 1936. Embryology of the spleen in *Amia calva*. Pap. Mich. Acad. Sci. Arts and Lett. 22:573-592.

Descriptions of spleen in various larval stages.

78. Eycleshymer, A.C. and J.M. Wilson. 1906. The gastrulation and embryo formation in Amia calva. Amer. J. Anat. 5:133-162.

Embryology with drawings of eggs.

79. Forbes, Stephen A. 1878. Notes on the early development of Amia. Proc. Amer. Assoc. Adv. Sci. 27:296-298.

Brief description of the form and structure of specimens from 20-30 mm. long.

80. Whitman, C.O. and A.C. Eycleshymer. 1897. The egg of Amia and its cleavage. J. Morphol. 12:309-354.

Describes cleavage of egg with many line drawings. Also discusses spawning behavior.

See also references 4, 7, 16, 18, 24, 67.

Anguillidae

Anguilla rostrata - Catadromous

Clupeidae

81. Oldmixon, E. 1964. Valid criteria for distinguishing the young stages of five Chesapeake Bay clupeids. Summer Student Proj. Rept. Chesapeake Biol. Laboratory. Univ. of Maryland. Aug. 1964.

Not seen.

82. Wang, J. 1970. Characters of, and keys to, young clupeids collected in the Delaware River in the vicinity of Artificial Island. Pages 154-172 in V.J. Schuler et al. An ecological study of the Delaware River in the vicinity of Artificial Island. Ichthyological Associates. Delaware Project Report. 426 pp.

Provides a description of gill raker spines and a key to Dorosoma cepedianum, Alosa sapidissima, A. pseudoharengus, A. mediocris, A. aestivalis, and Brevoortia tyrannus derived from field caught specimens from 15 to 130 mm. standard length.

Alosa pseudoharengus

83. Chambers, J.R. 1969. Methods of distinguishing larval alewife (Alosa pseudoharengus) from larval blueback herring (A. aestivalis). M.S. Thesis. William and Mary College. 30 pp.

Not seen.

84. Cianci, J.M. 1969. Larval development of alewife, Alosa pseudoharengus, and the glut herring, Alosa aestivalis. M.S. Thesis. Univ. of Connecticut. 62 pp.

Not seen.

85. Mansueti, R.J. 1956. Alewife herring eggs and larvae reared successfully in lab. Md. Tidewater News. 13:2-3.

Not seen.

86. Norden, C.R. 1967. Development and identification of the larval alewife, Alosa pseudoharengus (Wilson) in Lake Michigan. Proc., 10th Conference on Great Lakes Research. p. 70-78.

Detailed descriptions supplemented by line drawings of egg to postlarvae stages. Also includes a summary of characters useful in distinguishing alewives from emerald shiner, smelt and gizzard shad.

87. Odell, T.T. 1934. The life history and ecological relationships of the alewife (Pomolobus pseudoharengus (Wilson)) in Seneca Lake, New York. Trans. Amer. Fish. Soc. 64:118-124.

Includes fecundity information and a brief discussion of hatching time in relation to temperature.

88. Ryder, J.A. 1887. On the development of osseus fishes, including marine and freshwater forms. U.S. Fish Comm. Rep. (1885). 13:489-604.

Includes figures of Alosa pseudoharengus and A. sapidissima.

See also references 3, 4, 7, 15, 16, 19, 20, 24, 25, 81, 82.

Alosa sapidissima

89. Chittenden, M.E., Jr. 1970. Life history and ecology of the American shad, Alosa sapidissima in the Delaware River. Diss. Abstr. Int. 30B:3431-3432.

Gonad development and spawning behavior is described. Habitat preferences of young shad discussed.

90. Lehman, B.A. 1953. Fecundity of Hudson River shad. Res. Rep. U.S. Fish. Serv. 33:1-8.

Fecundity only.

91. Miller, G.L. and S.C. Jorgensen. 1973. Meristic characters of some marine fishes of the western Atlantic Ocean. Fish. Bull. 71:301-317.

Includes vertebral counts and anal, dorsal and caudal fin, spine and ray counts for Gambusia affinis, Alosa sapidissima and Dorosoma cepedianum.

92. Nichols, P.R. 1966. Comparative study of juvenile American shad populations by fin ray and scute counts. U.S. Fish and Wildl. Serv. Spec. Sci. Rept. Fisheries. #525. 10 pp.

Comparisons of fin ray and scute counts of 10 major shad producing rivers along Atlantic coast.

93. Nichols, P.R. and W.H. Massmann. 1963. Abundance, age and fecundity of shad, York River, Va. 1953-1959. Fish. Bull. 63:179-188.

A brief study of the life history of shad including fecundity is presented.

94. Senior, H.D. 1909. The development of the heart in shad, with a note on the classification of Teleostean embryos from a morphological standpoint. Amer. J. Anat. Philadelphia. 9:211-262.

Very little information useful for identification.

95. Worth, S.G. 1893. Observations on the spawning habits of the shad. Bull. U.S. Fish. Comm. 11:201-206.

A brief description of conditions suitable for spawning.

See also references 3, 4, 7, 15, 16, 24, 25, 81, 82, 88.

Dorosoma cepedianum

96. Bodola, Anthony. 1955. The life history of the gizzard shad, Dorosoma cepedianum (Le Sueur), in western Lake Erie. Ph.D. Thesis. Ohio State University. 130 pp.

Not seen.

97. Bodola, Anthony. 1966. Life history of the gizzard shad, Dorosoma cepedianum (Le Sueur), in Western Lake Erie. Fish. Bull. 65:391-425.

No drawings except of gut of 18, 19, 22.5, 27.5, 33, and 51 mm. fish. Some spawning information and some larval behavior included.

98. Hubbs, C.L. and S.C. Whitlock. 1929. Diverse types of young in a single species of fish, the Gizzard shad. Pap. Mich. Acad. Sci. Arts and Lett. 10:461-482.

A figure of normal and abnormal young Gizzard shad, Dorosoma cepedianum is presented. Differences in appearance between young of separate regions in Oklahoma discussed.

99. Miller, R.R. 1960. Systematics and biology of the Gizzard shad (Dorosoma cepedianum) and related fishes. Fish. Bull. 60:371-392.

A thorough life history study including information on fecundity, reproduction, and egg and larval stages is presented. Excellent line drawings of embryos at 33, 38, 43, 48, 52, 60 and 70 hours, and larvae at hatching, 1 day, 3 day, 10.8 mm., 17.5 mm., and 22.0 mm. is presented.

100. Miller, R.R. 1963. Genus Dorosoma Rafinesque 1820 Gizzard shads, Threadin shad. In Fishes of the Western North Atlantic. Sears Foundation for Marine Research, Mem. 1:443-451.

Description of larvae. Discussion of spawning season.

101. Warner, Edward M. 1940. Studies on the embryology and early life history of the Gizzard shad, Dorosoma cepedianum Le Sueur. Ph.D. Thesis. Ohio State University. 28 pp.

Not seen.

See also references 4, 7, 15, 16, 18, 19, 20, 24, 81, 82.

Hiodontidae

Hiodon tergisus

102. Battle, H.I. and W.M. Sprules. 1960. A description of the semi-buoyant eggs and early developmental stages of the Goldeye, Hiodon alosoides (Rafinesque). J. Fish. Res. Bd. Com. 17:245-266.

Description of development from egg to 33 mm. with good drawings. Could serve temporarily as an aid to the identification of H. tergisus in the absence of descriptions.

Salmonidae

103. Bacon, E.H. 1954. Field characters of prolarvae and alevins of brook, brown and rainbow trout in Michigan. Copeia: 232.

Photographs and diagnostic characters useful in separating fry 20 mm. and larger.

104. Bosley, C. 1969. Trout Egg Development. Wyo. Wildl. 34:4-7.

Describes development of trout eggs including photographs of egg stages.

105. Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. Fish. Bull. 52:97-110.

The spawning habits of Oncorhynchus tshawytscha, O. kisutch, O. keta and O. nerka are described.

106. Crawford, D.R. 1925. Field characters identifying young salmonoid fishes in freshwaters of Washington. Univ. Washington Pub. Fish. 1:64-76.

Not seen.

107. Foerster, R.E. and A.L. Pritchard. 1935. The identification of the young of the five species of Pacific salmon, with notes on the fresh-water phase of their life history. Brit. Col. Comm. Fish. Rept. 1934. K106-K116 pp.

Species descriptions for young of Oncorhynchus gorbuscha, O. keta, O. nerka, O. tschawytscha, O. kisutch. Includes key for identification of young salmon.

108. Ignat'evov, G.M. 1969. Relative duration of certain process of early embryogenesis in salmonoid fish. (In Russian). Dokl. Akad. Nauk. SSSR. 188:1412-1421. Translated in Dokl. (Proc.) Acad. Sci. USSR Biol. 188:661-663.

Concerned with cleavage and gastrulation as related to temperature in brown and rainbow trout. No descriptions or figures.

109. Neave, F. 1946. Development of the lateral line organs in salmonids. Trans. Roy. Soc. Can. Section 5. 113-118 pp.

A study of Oncorhynchus tschawytscha, Salmo clarkii, S. trutta, and Salvelinus fontinalis embryos beginning 50 days after fertilization. Brief descriptions.

110. Rounsefell, G.A. 1957. Fecundity of the North American Salmonidae. Fish. Bull. 57:451-468.

Relationship of fecundity and egg size to a number of parental variables is described for Salvelinus fontinalis, Oncorhynchus gorbuscha and O. keta.

111. Weisel, G.F. 1966. Young salmonoid fishes of western Montana. Proc. Mont. Acad. Sci. 26:1-21.

Not seen.

Coregonus alpenae

Coregonus artedii

112. Brown, C.J. and J.W. Moffett. 1942. Observations on the number of eggs and feeding habits of the Cisco (Leucichthys artedi) in Swains Lake, Jackson County, Mich. Copeia: 149-152.

Mean egg counts for ciscos presented.

113. Colby, P.J. and L.T. Brooke. 1970. Survival and development of Lake herring (Coregonus artedii) eggs at various incubation temperatures. Pages 417-428. In Lindsey, C.C. and C.S. Woods (Eds.). Biology of Coregonid Fishes. Univ. Manitoba Press. Winnipeg. 560 pp.

Includes size at hatching and photographs of one normal and three deformed yolk sac fry. Eggs taken from known parents.

114. Hogman, W.J. 1970. Early scale development on the Great Lakes coregonids, Coregonus artedii and C. kiyi. Pages 429-436. In Lindsey, C.C. and C.S. Woods (Eds.). Biology of Coregonid Fishes. Univ. Manitoba Press. Winnipeg. 560 pp.

Scale development only.

115. Pritchard, A.L. 1930. Spawning habits and fry of the Cisco (Leucichthys artedi) in Lake Ontario. Contrib. Can. Biol. Sta. of Can. 6:227-240.

A study of the ecology of cisco, but included are descriptions of the larvae, from 10 mm. to 20 mm. with photographs. Fry were captured with a collander. Smaller sizes were not described.

See also references 4, 7, 10, 11, 12, 24, 116.

Coregonus clupeaformis

116. Faber, D.J. 1970. Ecological observations on newly hatched lake whitefish in South Bay, Lake Huron. Pages 481-500. In Lindsey, C.C. and C.S. Woods (Eds.). Biology of Coregonid Fishes. Univ. Manitoba Press. Winnipeg. 560 pp.

Includes discussion of lake whitefish spawning habitat; line drawings of dorsal, ventral and lateral views of late prolarval Coregonus clupeaformis, C. artedii, C. hoyi and Prosopium cylindraceum and verbal descriptions of the larvae of each species.

117. Hall, A.R. 1925. Effects of O_2 and CO_2 on the development of the whitefish. Ecology. 6:104-116.

Data on egg mortality and growth range of various body parts with varying O_2 concentrations is presented.

118. Hart, John L. 1930. The spawning and early life history of the whitefish, Coregonus clupeaformis (Mitchell), in the Bay of Quinte, Ontario. Contrib. Can. Biol. and Fish., being studies from the Biol. Sta. of Can. 6:167-214.

A study of the ecology of larval whitefish. Includes descriptions, line drawings, and photographs of stages from prolarvae to 84 mm.

119. Lawler, G.H. 1961. Egg counts of Lake Erie whitefish. J. Fish Res. Bd. Can. 18:293-294.

Gives fecundity and egg diameter for Lake Erie whitefish.

120. Price, J.W. 1931. The embryology of the whitefish, Coregonus clupeaformis (Mitchell). Ohio J. Sci. 31:268.

Abstract of Part I and II.

121. Price, J.W. 1934. The embryology of the whitefish, Coregonus clupeaformis (Mitchell). Pt. I. Ohio J. Sci. 34:287-305.

A general survey of development from fertilization to hatching, tracing segmentation and germ layer formation and development through closure of blastopore. Includes 2 good plates showing 27 figures of various stages.

122. Price, J.W. 1934. The embryology of the whitefish, Coregonus clupeaformis. Part II. Organogenesis. Ohio J. Sci. 34:399-414.

A continuation of previous paper with emphasis on development of organs.

123. Price, J.W. 1935. The embryology of the whitefish, Coregonus clupeaformis (Mitchell). Part III. The second half of the incubation period. Ohio J. Sci. 35:40-53.

Brief descriptions given (in table form) of the embryo from 1 day to 134 days old.

124. Quadri, S.U. 1968. Growth and reproduction of the lake whitefish, Coregonus clupeaformis in Lac la Ronge, Saskatchewan. J. Fish. Res. Bd. Canada. 25:2091-2100.

Spawning is briefly described with fecundity data.

125. Richards, A. and Shumacher, B.L. 1935. Analysis of early development of fish embryos by means of the mitotic index. III. The mitotic index of young embryos of Coregonus clupeaformis. Amer. J. Anat. 56:395-408.

Embryology only.

See also refrences 4, 7, 11, 12, 20, 24.

Coregonus hoyi

126. Dryer, W.R. and J. Beil. 1968. Growth changes of the bloater (Coregonus hoyi) of the Apostle Islands region of Lake Superior. Trans. Amer. Fish. Soc. 97:146-158.

Information on fecundity of bloater is presented.

See also references 4, 7, 24, 116.

Coregonus johannae

Coregonus kiyi

See reference 114

Coregonus nigripinnis

Coregonus nipigon

Coregonus reighardi

Coregonus zenithicus

Oncorhynchus gorbuscha

127. Foerster, R.E. and A.L. Pritchard. 1941. Observations on the relation of egg content to total length and weight of sockeye salmon (Oncorhynchus nerka) and the pink salmon (O. gorbuscha). Trans. Roy. Soc. Can. Sec. 5. 51-60 pp.

The correlation between number of eggs and length and weight of females is discussed.

See also references 3, 4, 7, 24, 106, 107, 110.

Oncorhynchus kisutch

128. Allen, G.H. 1958. Notes on the fecundity of silver salmon (Oncorhynchus kisutch). Prog. Fish-Cult. 20:163-169.

Fecundity as it relates to size of female and progression of run is discussed. Information on egg diameters is also presented.

129. Zeitoun, I.H. and P.I. Tack. 1974. The embryology of the coho salmon, Oncorhynchus kisutch (Walbaum). Trans. Amer. Fish Soc. 103:371-375.

Only photographs of sections of developing embryos are presented. There are no illustrations of whole embryos.

See also references 3, 4, 7, 24, 105, 106, 107.

Oncorhynchus nerka

130. Clarke, W.C. and H.D. Smith. 1972. Observations on the migration of sockeye salmon fry (Oncorhynchus nerka) in the Lower Babine River. J. Fish. Res. Bd. Canada. 29:151-159.

Contains line drawings of young beginning with large yolk sac and following through until yolk is completely absorbed.

131. Hartman, W.L., T.R. Merrell, Jr., and R. Painter. 1964. Mass spawning behavior of sockeye salmon in Brooks River, Alaska. Copeia: 362-368.

Spawning behavior and nest building of sockeye salmon are described.

See also references 4, 7, 24, 105, 106, 107, 127.

Oncorhynchus tshawytscha

132. Galbreath, J.L. and R.L. Ridenhour. 1964. Fecundity of the Columbia Chinook Salmon. Fish Comm. Ore. Res. Briefs. 10:16-27.

Information on fecundity changes during the spawning season.

133. Major, R.L. and J.L. Mighell. 1969. Egg-to-migrant survival of spring Chinook salmon (Oncorhynchus tshawytscha) in the Yakima River, Wash. Fish. Bull. 67:347-359.

The distribution and abundance of redds; size, age and fecundity of spawners; and number of eggs retained by females is discussed as well as subsequent migration of progeny and survival.

134. Riddle, M.C. 1917. Early development of the Chinook salmon. Puget Sound Mar. Stat. Publ. 1:319-338.

Not seen.

135. Welander, A.D., L.R. Donaldson, R.F. Foster, K. Bonham, and A.H. Seymour. 1948. The effects of roentgen rays on the embryos and larvae of the Chinook salmon. Growth. 12:203-244.

Photos of 44 day old control larvae and photomicrographs through heads of larvae of 37 days are presented.

See also references 4, 7, 24, 105, 106, 107, 109.

Prosopium coulteri

136. Stalnaker, C.B. and R.E. Gresswell. 1974. Early life history and feeding of young mountain whitefish. Environmental Protection Agency. Ecological Research Series. EPA-660/3-73-019.

Deals primarily with ecology, but does discuss spawning. No descriptions or illustrations. May be helpful for Great Lakes Prosopium.

Prosopium cylindraceum

See references 116 and 136.

Salmo clarki

137. Jahn, L.A. 1972. Development of the olfactory apparatus of the cutthroat trout. Trans. Amer. Fish. Soc. 101:284-289.

Describes development of olfactory apparatus in 20 day old embryos to adult. Includes photographs of microscopic sections.

See also references 4, 7, 24, 109.

138. Allen, G.H. and G.A. Sanger. 1960. Fecundity of rainbow trout from actual count of eggs. Copeia: 260-261.

Estimated egg counts from 17 female individuals is presented.

139. Ballard, W.W. 1973. Normal embryonic stages for salmonid fishes, based on Salmo gairdneri Richardson and Salvelinus fontinalis (Mitchell). J. Exp. Zool. 184:7-26.

An excellent detailed account of development from fertilization to hatching supplemented with photographs and line drawings.

140. Ballard, W.W. 1973. Morphogenetic movements in Salmo gairdneri Richardson. J. Exp. Zool. 184:27-48.

Concerned primarily with movements and ultimate fate of blastomeres in rainbow trout embryology.

141. Ballard, W.W. 1973. A new fate map for Salmo gairdneri. J. Exp. Zool. 184:49-74.

Detailed map showing fate of blastomeres.

142. Bulkley, Ross V. 1967. Fecundity of steelhead trout, Salmo gairdneri, from Alsea River, Oregon. J. Fish Res. Board Can. 24:917-926.

Seventy-three females were sampled from 1965-66 spawning run and egg size and number were correlated with body length.

143. Foster, R.F., L.R. Donaldson, A.D. Welander, K. Bonham and A.H. Seymour. 1949. The effect on embryos and young of rainbow trout from exposing the parent fish to x-rays. Growth. 13:119-142.

Study includes photos of normal and abnormal eggs, embryos and fry.

144. Gras, J., R. Reyhand, J. Frey and J.C. Henry. 1966. Biochemical modifications during development of eggs and fry of the Rainbow trout (Salmo gairdnerii Rich). Soc. Biol. (Paris). C.R. Seances. 160(6):1262-1264.

Discusses factors effecting egg development and presents a table of percent of composition of substances in various age trout. (In French).

145. Knight, A.E. 1963. The embryonic and larval development of the rainbow trout. Trans. Amer. Fish. Soc. 92:344-355.

Description and photos of egg and larval stages of rainbow trout.

146. Wales, J.H. 1941. Development of steelhead trout eggs. Calif. Fish & Game. 27:250-260.

Describes development to hatching supplemented by line drawings.

See also references 4, 7, 22, 24, 103, 106, 108.

Salmo salar

147. Battle, H.I. 1944. The embrology of the Atlantic salmon, Salmo salar. Canadian J. Res. 22D:105-125.

Development from fertilization to hatching is described including 13 plates of various stages.

148. Belding, D.L., M.J. Pender and J.A. Rodd. 1932. The early growth of salmon parr in Canadian hatcheries. Trans. Amer. Fish. Soc. 62:211-223.

Primarily discusses rate of development in relation to temperature No descriptions.

149. Fryer, Charles E. 1873. The growth of salmon. Nature. 8:285-286.

Development from fertilization to early post hatching stages described with sketchy drawings.

150. Gardiner, W.R. 1974. An electrophoretic method for distinguishing the young fry of salmon Salmo salar (L.) from those of trout Salmo trutta (L.). J. Fish. Biol. 1974:517-519.

Distinguishes brown trout from salmon by electrophoresis.

151. Jones, J.W. and G.M. King. 1949. Experimental observations on the spawning behavior of the Atlantic salmon (Salmo salar Linn.). Proc. Zool. Soc. London. 119:33-48.

Discusses spawning behavior in Salmo salar.

152. Jones, J.W. and G.M. King. 1950. Further experimental observations on the spawning behavior of the Atlantic salmon (Salmo salar Linn.). Proc. Zool. Soc. Lond. 120:317-323.

Spawning behavior described.

153. Jones, J.W. 1959. The spawning behavior of the salmon. New Scientist. 6:122-123.

Spawning behavior described.

154. Pelluet, D. 1944. Criteria for the recognition of developmental stages in the Salmon (Salmo salar). J. Morph. 74:395-407.

Development from fertilization to 210 days post fertilization is described with excellent line drawings.

155. Schwarze, Daniel. 1889. Untersuchungen des Schwanzendes bei den Embryonder Wirbeltiere. Nach Beobachtungen an Selachiun, Knockenfischen und Vogeln vergleichend dangestellt. Z. Wiss. Zool. 48:191-223.

Includes figures and descriptions of Salmo salar and Esox lucius embryos.

156. Shaw, John. 1840. Account of experimental observations on the development of the salmon-fry from the exclusion of the ova to the age of 2 years. Trans. Roy. Soc. Edinburgh. 14:547-566.

General description of early development with plates showing general stages of development from egg to two years old.

See also references 3, 4, 7, 24.

Salmo trutta

157. Brown, C.J. and G.C. Kamp. 1941. Gonad measurements and egg counts of brown trout (Salmo trutta) from the Madison River, Montana. Trans. Amer. Fish. Soc. 71:195-200.

Fecundity data only.

158. Chichewicz, M. 1961. Embryonic development of Lake trout (Salmo trutta m. lacustris L.). Polish Agric. Annual. 93D:557-594.

Not seen.

159. Demoll and Wohlgemuth. 1921. Einiges uber die hebensbedingunger der Forellenbrut in Freian. Biol. Zbl. Leipzig 41:165-172.

Text in German; photographs of eggs also.

160. Goronowitsch, N. 1885. Studien uber die Entwicklung des Medullarstranges bei Knochenfischen, nebst Beobachtungen uber die erste Analage der Keimblatter und der Chorda bei Salmoniden. Morphol. Jahrb. 10:376-445.

Text in German; 4 plates with 42 figures of embryos and eggs are presented.

161. Klein, Edward E. 1872. Researches on the first stages of the development of the common trout, Salmo fario. Monthly Micr. Journ. 7:193-200.

Not seen.

162. Klein, Edward E. 1876. Observations on the early development of the common trout, Salmo fario. Quart. Journ. Micr. Sci. 16:113-131.

Development from fertilization to 12 day old embryo is described with illustrations of sections showing various stages up to 14 days after fertilization.

163. Luther, Wolfgang. 1935. Entwicklungs - physiologische Untersuchungen am Forellankeim: Die Rolle des Organisationszentrums bei der Entstehung der Embryonalanlage. Biol. Zbl. Leipzig. 55:114-137.

Embryonic development of salmonid described and many line drawings and photographs included.

164. Oellacher, Josef. 1873. Beitrage zur Entwicklungsgeschichte der Knocherfischen nach Beobachtungen am Bachforelleneie. Z. Wiss. Zool. 23:1-116.

Descriptions and figures of embryo, primarily cross-sections of egg, however.

165. Stuart, T.A. 1954. Spawning sites of trout. Nature. 173:354.

A short account of spawning sites in relation to subsurface currents is presented.

See also references 4, 7, 22, 24, 103, 108, 109.

Salvelinus fontinalis

166. Schindler, O. 1938. Uber Larven und Jungfische der Kreuzungen zwischen Seesaibling und Bachsaibling. Int. Rev. Hydrobiol. 37:385-404.

Photographs of larvae and juveniles.

167. Vladykov, V.D. and V. Legendre. 1940. Determination on the number of eggs in ovaries of brook trout (Salvelinus fontinalis). Copeia: 218-220.

Counts of eggs in ovaries for specimens 125-379 mm. in length are tabulated.

168. Vladykov, V.D. 1956. Fecundity of wild speckled trout (Salvelinus fontinalis) in Quebec lakes. J. Fish. Res. Bd. Can. 13:799-841.

Notes on spawning and fecundity with good descriptions and illustrations of eggs in ovaries.

See also references 3, 4, 7, 22, 24, 103, 109, 110, 139.

Salvelinus namaycush

169. Garside, E.T. 1959. Some effects of oxygen in relation to temperature in the development of lake trout embryos. Canad. J. Zool. 37:686-698.

Short descriptions of the 18 stages of embryonic development and photos of normal and abnormal alevins are presented.

170. Garside, E.E. and F.E.J. Fry. 1959. A possible relationship between yolk size and differentiation in trout embryos. Canad. Journ. Zool. 37:383-386.

Myomere counts of reciprocal hybrids of lake and brook trout.

171. Hanson, J.A. and R.H. Wickwire. 1967. Fecundity and age at maturity of lake trout, Salvelinus namaycush Walbaum in Lake Tahoe. Calif. Fish Game. 53:154-164.

The spawning season of lake trout in Lake Tahoe is described and the average fecundity calculated from 44 females.

172. Royce, W.F. 1951. Breeding habits of lake trout in New York. Fish. Bull. 59:59-76.

Primarily an account of spawning behavior but some discussion of larval development included.

See also references 4, 7, 20, 22, 24.

Thymallus arcticus

173. Watling, H.J. and C.J.D. Brown. 1955. The embryological development of the American grayling (Thymallus signifer tricolor) from fertilization to hatching. Trans. Amer. Microscopical Soc. 74:85-93.

Not seen.

Osmeridae

Osmerus mordax

174. Cunningham, J.T. 1887. The eggs and larvae of Teleosteans. Trans. Roy. Soc. Edinb. 33:97-136.

Drawings and descriptions of eggs and larvae of Osmerus eperlanus as well as many marine forms. Good drawings. Spawning periods defined as well.

175. Hoover, E.E. 1936. Spawning activities of freshwater smelt, with special reference to the sex ratio. Copeia: 85-91.

Brief discussion of spawning activities in New Hampshire.

176. Kendall, W.C. 1927. The smelts. Bull, Bur. Fish. 42:217-375.

A great deal of life history information including spawning season and location, fecundity, egg description and development to postlarval stages. Also includes line drawings of stages from egg to 28 mm. taken from Ehrenbaum of Osmerus eperlanus.

177. Langlois, T.H. 1935. Notes on the spawning habits of the Atlantic smelt. Copeia: 141-142.

Describes spawning, estimates fecundity and gives egg diameter.

178. Lievense, S.J. 1954. Spawning of American smelt, Osmerus mordax, in Crystal Lake, Benzie County, Michigan. Copeia: 232-233.

Discussion of spawning activities in Michigan.

179. Van Oosten, J. 1940. The smelt Osmerus mordax (Mitchell). Great Lakes Fish. Investigation. 1-13 pp.

Discusses egg sizes, distribution of smelt in Great Lakes and timing of spawning runs in Great Lakes.

See also references 3, 4, 7, 19, 20, 24.

180. McKenzie, R.A. 1964. Smelt life history and fishery in the Miramichl River, New Brunswick. Fish. Res. Bd. Can. Bull. 144. 77 p.

Describes life history including spawning, fecundity and brief description of eggs.

Umbridae

Umbra limi

181. Ryder, J.A. 1886. The development of the mudminnow (Umbra limi). Amer. Naturalist. 20:823-824.

Description includes: egg, embryo and larval stages, but they are very brief.

See also references 4, 7, 12, 24.

Esocidae

Esox americanus

182. Crossman, E.J. 1962. The redfin pickerel, Esox a. americanus in North Carolina. Copeia: 114-123.

Describes spawning season and site. Also includes fecundity and brief egg descriptions.

Young 20-100 mm. are described and figured and characters distinguishing the redfin from the chain pickerel are highlighted.

183. Crossman, E.J. 1966. A taxonomic study of Esox americanus and its subspecies in eastern North America. Copeia: 1-20.

Information on fecundity plus drawings of E. a. americanus and E. a. vermiculatus of 50 and 100 mm. is presented.

184. Kleinert, S.J. and D. Mraz. 1966. Life history of the grass pickerel (Esox americanus vermiculatus) in S.E. Wisconsin. Wisc. Cons. Dept. Tech. Bull. No. 37. 1-40 pp.

Spawning information includes: discussion of nesting sites; descriptions include: photos of fry 12-83 mm.; discussion of identification of eggs, fry and fingerlings.

See also references 4, 7, 15, 16, 22, 24.

Esox lucius

185. Braum, E. 1964. Experimentelle Untersuchengen Zur ersten Nahrungasaufnahme und Biologie an Jungfischen von Blaufelchen (Coregonus wartmanni Bloch), Weissfelchen (C. fera Jurine) und Hechten (Esox lucius L.) (English Summary). Arch. Hydrobiol. Suppl. 28:183-244.

Primarily devoted to ecology of feeding, but contains line drawings of egg, 10 and 14 mm. Esox lucius as well as line drawings of Coregonus wartmanni and C. fera.

186. Brown, Frank B. 1907. On the early stages in the life histories of certain freshwater fishes. Trans. Norfolk Norwich Natural Soc. 8:478-488.

Descriptions and drawings of egg and larval stages of Esox lucius and Perca flavescens.

187. Carbine, W.F. 1941. Observations on the life history of the northern pike, Esox lucius L., in Houghton Lake, Mich. Trans. Amer. Fish. Soc. 71:149-164.

Growth rate of pike fry measured over first summer of life.

188. Carbine, W.F. 1944. Egg production of the northern pike, Esox lucius L. and the percentage survival of eggs and young on the spawning grounds. Pap. Mich. Acad. Sci. 49:123-137.

Data on fecundity and egg size is presented.

189. Clark, C.F. 1950. Observations on the spawning habits of the northern pike, Esox lucius in Northwestern Ohio. Copeia: 285-288.

Observations of spawning activities.

190. Franklin, Donald R. and L.L. Smith, Jr. 1960. Note on the development of scale patterns in the northern pike, Esox lucius L. Trans. Amer. Fish. Soc. 89:83.

Short note with three figures of pattern of scale development.

191. Franklin, D.R. and L.L. Smith, Jr. 1960. Notes on the early growth and allometry of the northern pike, Esox lucius L. Copeia: 143-144.

A brief description and line drawings of young from hatching to 40 mm. Tables with growth data are included.

192. Franklin, D.R. and L.L. Smith. 1963. Early life history of the northern pike, Esox lucius L., with special reference to the factors influencing the numerical strength of year classes. Trans. Amer. Fish. Soc. 92:91-110.

Spawning location, time and behavior along with information on fecundity are presented. Development of embryo is described briefly.

193. Frost, W.E. and C. Kipling. 1967. A study of reproduction, early life, weight-length relationship and growth of pike, Esox lucius L. in Windermere. J. Anim. Ecol. 36:651-693.

Fecundity and spawning time and location are discussed. Newly hatched larvae are described as well as 2, 3 and 10 day old individuals.

194. Gihr, M. 1957. Zur Entwicklung des Hechtes. Rev. suisse Zool. 64:355-474.

Includes drawings and measurements of larvae and drawings of egg stages.

195. Holcik, J. 1968. Life history of the pike - Esox lucius L. 1758 in the Klicava reservoir. Vest. csl. Spol. Zool. 32:166-180.

Spawning habitat discussed.

196. Kennedy, M. 1969. Irish pike investigations. 1. Spawning and early life history. Ir. Fish. Invest. (Ser. A). No. 5. 4-33 pp.

Includes description of egg and larval stages, showing habitats and some line drawings.

197. Kotlyarevskaya, N.V. 1969. The hatching process in the pike (Esox lucius L.) (In Russian). Vop. Ikhtiol. 9:116-128. Translated in Probl. Ichthyol. Vol. 9. 1969:85-94.

Descriptions include stages from fertilization to hatching; good drawings of 6.1-7.9 mm. larvae; plates of eye, muscle, and hatching glands in embryo.

198. Schwarz, D. 1889. Untersuchungen des Schwanzendes bei den Embryonder Wirbetiere Nach Beobachtungen an Selachien, Knockenfischen und Vogeln vergleichend dangestellt. Z. wiss. Zool. 48:191-223.

Includes figures and descriptions of Salmo salar and Esox lucius embryos.

199. Toner, E.D. 1966. Synopsis of biological data on the pike Esox lucius Linnaeus 1758. FAO Fisheries Synopsis No. 30. 35 p.

Very nice summary of life history information on northernpike with many references.

See also references 4, 7, 12, 18, 19, 22, 24, 26, 155.

Esox masquinongy

200. Bean, T.H. 1908. The muskalonge of the Ohio basin. Trans. Amer. Fish. Soc. 37:145-151.

Describes spawning season and locality, fecundity and eggs very briefly.

201. Galat, David L. 1973. Normal embryonic development of the muskellunge (Esox masquinongy). Trans. Amer. Fish. Soc. 102:384-391.

Descriptions and figures from cleavage to hatching.

See also references 4, 7, 12, 22, 24.

Esox niger

202. Armbruster, D.C. 1959. Observations on the natural history of the chain pickerel (Esox niger). Ohio J. Sci. 59:55-58.

Notes on spawning behavior and conditions of spawning are presented.

203. Underhill, A.H. 1949. Studies on the development, growth and maturity of the chain pickerel, Esox niger (Lesueur). J. Wildl. Mgt. 13:377-391.

Descriptions include: photo of newly hatched larva attached to vegetation.

See also references 4, 7, 9, 15, 16, 22, 24.

204. Wich, K. 1958. A compendium of the life history and ecology of the chain pickerel, Esox niger (LeSueur). Fishery Bull. 22. Mass. Div. of Fisheries and Game. 27 p.

Not seen.

Cyprinidae

205. Balinsky, B.I. 1948. On the development of specific characters in Cyprinid fishes. Proc. Zool. Soc. London. 118:335-344.

Development of European cyprinid larvae is discussed and illustrated with line drawings. A key is included. Great Lakes forms discussed included carp and the genus Phoxinus.

Campostoma anomalum

206. Kraatz, W.C. 1924. The intestine of the minnow, Campostoma anomalum (Rafinesque), with special reference to the development of its circling. Ohio J. Sci. 24:265-298.

Discusses anatomy, development and relation to adjacent structures of the intestine as well as variations in coiling. Many line drawings and photographs of intestine included.

207. Miller, R.J. 1962. Reproductive behavior of the stoneroller minnow, Campostoma anomalum pullum. Copeia: 407-417.

Spawning behavior and spawning sites of stonerollers discussed.

208. Reed, R.J. 1958. The early life history of two cyprinids, Notropis rubellus and Campostoma anomalum pullum. Copeia: 325-327.

Brief and sketchy.

See also references 4, 7, 12, 24.

Carassius auratus

209. Battle, H.I. 1940. The embryology and larval development of the goldfish (Carassius auratus L.) from Lake Erie. Ohio J. Sci. 40:82-93.

Descriptions and drawings from egg to 16 mm. stage.

210. Hamid Khan, M. 1929. Early stages in the development of goldfish, Carassius auratus. J. Bombay Nat. Hist. Soc. 33:614-617.

Egg and larval descriptions and drawings.

211. Kajishima, T. 1960. The normal developmental stages of the goldfish, Carassius auratus. Jap. J. Ichthy. 8:20-28.

Describes 28 developmental stages from unfertilized egg to development of dorsal and anal fin rays at 3 weeks. Also includes line drawings of each stage. Name of stages in English, paper in Japanese.

212. Matsushima, M. 1956. Spawning activity of wild gold-fish in Lake Sagami Reservoir, observed through the eggs deposited on "fish-nest" and the ovarian eggs. (English Summary). Bull. Freshw. Fish. Res. Lab. Tokyo. 6:1-20.

Discusses spawning behavior of goldfish.

See also references 4, 7, 15, 16, 24.

Clinostomus elongatus

See reference 12.

Couesius plumbeus

213. Nelson, J.S. 1973. Morphological differences between teleosts Couesius plumbeus (Lake chub) and Rhinichthys cataractae (Longnose dace) and their hybrids from Alberta. J. of Morphology. 139:227-238.

Good drawings of head of both species.

See also references 4, 7, 24.

Cyprinus carpio

214. Balon, E. 1958. Die Entwicklung des Donauwildkarpfens (Cyprinus carpio) L. im Laufe der praelarvelen Phase und der larvalen Periode. Biol. prace, Bratislava. 4:1-54.

Descriptions and drawings of larval and juvenile stages of carp.

215. Bragensky, R.Y. 1960. Early development of the carp. In C.G. Krevanoveski. Works on the early development of bony fishes. 129-149 pp. 9 Figures. (In Russian). Stud. A. N. Stenertsova Inst. Anim. Morphol. Soviet Acad. Sci. No. 28.

Not seen.

216. 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.

A general discussion of carp development including a table relating the appearance of certain structures to total length. Also includes 6 photographs of lateral view of carp from caudal peduncle to post opercular region showing pattern of scale development.

217. Okada, Y. 1959-60. Studies on the freshwater fishes of Japan. Prefectural University of Mie Tsu, Mie Prefecture, Japan. XIV and 860 pp. 133 Figures, 135 Tables.

Larval carp included.

218. Ramakrishna, K.V. and K.H. Alikunhi. 1967. Growth and propagation of common carp (Cyprinus carpio L.) in India - 4:Observations on the size of eggs, hatchlings, and fry of parents of various size. J. Bombay Nat. Hist. Soc. 64:238-250.

Describes egg and larval stages.

219. Smallwood, W.M. and M.L. Smallwood. 1931. The development of the carp , Cyprinus carpio. I. The larval life of the carp, with special reference to the development of the intestinal canal. J. Morphology. 52:217-231.

Brief discussion of spawning, hatching, larval periods, intestinal growth and digestive tract with line drawings of larval stages.

220. Swee, V.B. and H.R. McCrimmon. 1966. Reproductive biology of the carp, Cyprinus carpio L., in Lake St. Lawrence, Ontario. Trans. Amer. Fish. Soc. 95:372-380.

Includes fecundity, spawning time, location and behavior. No information on identifying eggs or larvae.

221. Verma, P. 1970. Normal stages in the development of Cyprinus carpio var. communis L. Acta. biol. hung. 21:207-219.

Describes 20 egg and 10 larval stages. Line drawings included.

See also references 4, 7, 12, 15, 16, 21, 24, 205.

Ericymba buccata

222. Hoyt, Robert D. 1971. The reproductive biology of the silverjaw minnow, Ericymba buccata Cope, in Kentucky. Trans. Amer. Fish. Soc. 100:510-519.

Spawning behavior and fecundity only.

223. Wallace, D.C. 1973. Reproduction of the silverjaw minnow, Ericymba buccata Cope. Trans. Amer. Fish. Soc. 102: 786-793.

Time of breeding and egg size only.

See also references 4, 7.

Exoglossum laurae

224. Raney, E.C. 1939. Observations on nesting sites of Parexoglossum laurae Hubbs and Trautman. Copeia: 1939:112-113.

Very brief description of spawning behavior, nesting and eggs.

See also references 4, 7.

Exoglossum maxillingua

225. VanDuzer, E.M. 1939. Observations on the breeding habits of the Cut-lips Minnow, Exoglossum maxillingua. Copeia: 65-75.

Includes spawning habitat, nesting mating activities, egg description, description of embryonic and larval forms.

See also references 4, 7, 24.

Hybognathus hankinsoni

Hybognathus nuchalis

226. Raney, Edward C. 1939. The breeding habits of the silvery minnow, Hybognathus regius Girard. Amer. Midl. Nat. 21:674-680.

Discusses migration, spawning, eggs and fecundity. Excellent drawings of newly hatched larva and larva of 12 mm. (std. length).

See also references 4, 7, 15, 16, 24.

Hybopsis amblops

Hybopsis storeriana

Hybopsis x-punctata

Nocomis biguttatus

Nocomis micropogon

227. Reighard, J.R. 1942. The breeding habits of the river chub, Nocomis micropogon (Cope). Pap. Mich. Acad. Sci. Arts and Lett. 28:397-423.

Includes nest location and construction and spawning behavior.

See also references 4, 7, 24.

Notemigonus crysoleucas

See references 4, 7, 12, 15, 16, 24.

Notropis analostanus

228. Stone, U.B. 1940. Studies on the biology of the satinfin minnows, Notropis analostanus and Notropis spilopterus. Ph.D. Thesis. Cornell University. 98 and vii pp. 14 plates.

Includes information on spawning season, habitat, behavior and fecundity along with a great deal of life history information. Description of development of Notropis analostanus is quite complete and includes egg, prolarva, postlarva and juvenile stages with numerous photographs. Description of N. spilopterus is less complete and includes 18.5 mm. and 23.7 mm. stages. Photographs of 17 mm., 18.5 and 23.7 mm. young N. spilopterus included. In addition, photographs of cleared and stained 15 mm. N. spilopterus and 11.2 mm. N. analostanus presented.

See also references 4, 7, 15, 16.

Notropis anogenus

Notropis atherinoides

229. Flittner, G.A. 1964. Morphometry and life history of the emerald shiner, Notropis atherinoides Rafinesque. Ph.D. Thesis. Univ. of Michigan, Ann Arbor. 239 p.

From abstract, thesis not seen.

Discusses spawning location and time. Brief description of eggs and prolarvae may be included.

See also references 11, 12, 20, 24.

Notropis bifrenatus

230. Harrington, R.W. 1951. (Notes) on spawning in an aquarium by the bridled shiner, Notropis bifrenatus with counts of the eggs deposited. Copeia: 85-86.

Notes on close observation of spawning act.

231. Harrington, R.W. 1948. The life cycle and fertility of the bridled shiner, Notropis bifrenatus Cope. Amer. Midl. Nat. 39:83-92.

Includes a brief description of eggs.

232. Harrington, R.W. 1957. Sexual photoperiodicity of the cyprinid fish, Notropis bifrenatus (Cope), in relation to the phases of its annual reproductive cycle. J. exp. Zool. 135:529-555.

Spawning behavior only.

233. Harrington, R.W., Jr. 1947a. The breeding behavior of the bridled shiner, Notropis bifrenatus. Copeia: 186-192.

Time and place of breeding and egg diameter.

234. Harrington, R.W., Jr. 1947b. The early life history of the bridled shiner, Notropis bifrenatus (Cope). Copeia: 97-102.

Eggs taken from known parents and fertilized in lab. Descriptions of embryological development and larval stages up to 2 weeks post hatching. Line drawings of egg development and one newly hatched prolarva.

See also references 4, 7, 24.

Notropis blennius

Notropis boops

Notropis chalybaeus

235. Marshall, Nelson. 1947. Studies on the life history and ecology of Notropis chalybaeus (Cope). Quart. J. Florida Acad. Sci. 9(3/4):163-188.

Includes discussion of egg and larval development, descriptions and drawings of larval stages and larval growth rate information.

See also reference 4, 7, 16.

Notropis chrysocephalus

See reference 12.

Notropis cornutus

236. Brancamp, Joseph H. 1938. The chronological order of scale formation of the common shiner, Notropis cornutus (Mitchell). M.S. Thesis. Ohio State University.

Not seen.

237. Fee, E. 1965. Life history of the northern common shiner, Notropis cornutus frontalis, in Boone County, Iowa. Proc. Iowa Acad. Sci. 72:272-281.

Fecundity only.

238. Raney, E.C. 1940. The breeding behavior of the common shiner, Notropis cornutus (Mitchell). Zoologica 24:1-14.

Includes: time and location of spawning; spawning behavior; and a very brief discussion of eggs and young.

See also references 4, 7, 19, 24.

Notropis dorsalis

Notropis emiliae

Notropis heterodon

Notropis heterolepis

Notropis hudsonius

239. Wells, Larue and R. House. 1974. Life history of the spottail shiner (Notropis hudsonius) in southeastern Lake Michigan, the Kalamazoo River and Western Lake Erie. Research Rept. 78. Bur. Sport Fish. and Wildl.

Brief determination of the spawning period. Fecundity information included.

See also references 4, 7, 15, 16, 20, 24.

Notropis lutrensis

240. Saksena, V.P. 1962. The post-hatching stages of the red shiner, Notropis lutrensis. Copeia: 539-544.

Descriptions and drawings from hatching to juvenile stages (5 mm.-16.4 mm.).

See also references 4, 7.

Notropis photogenis

Notropis procne

Notropis rubellus

241. Pfeiffer, Roman A. 1955. Studies on the life history of the rosyface shiner, Notropis rubellus. Copeia: 95-104.

Spawning time and location. Fecundity. Very general description of larvae collected in field.

See also references 4, 7, 24, 208.

Notropis spilopterus

242. Hankinson, T.L. 1930. Breeding behavior of the silverfin minnow, Notropis whipplii spilopterus (Cope). Copeia: 73-74.

Notes on spawning habitat and brief egg description.

Notropis stramineus

Notropis texanus

Notropis umbratilis

Notropis volucellus

Phenacobius mirabilis

Phoxinus eos

See reference 205.

Phoxinus erythrogaster

See reference 205.

Phoxinus neogaeus

See reference 205.

Pimephales notatus

See references 11, 12.

Pimephales promelas

243. Andrews, A.K. 1970. Squamation chronology of the fathead minnow, Pimephales promelas. Trans. Amer. Fish. Soc. 99:429-432.

Deals with development of scales from 13 mm. to 29 mm. young.

244. Burrage, B.R. 1961. Notes on some captive minnows Pimephales promelas Raf. Trans. Kansas Acad. Sci. 64:357-359.

Short notes on: dietary information; courtship behavior and spawning; behavior of young after hatching; behavior of parents after hatching.

245. Markus, H.C. 1934. Life history of Blackhead minnow (Pimephales promelas). Copeia: 116-122.

Discusses reproduction (nesting, spawning, incubation, male behavior) and development (brief descriptions of hatched postlarva).

246. Richardson, L.R. 1937. Observations on the mating and spawning of Pimephales promelas (Raf.). Canad. Field Nat. 51:1-4.

Includes spawning behavior and some discussion of eggs.

247. Wynne-Edwards, V.C. 1932. The breeding habits of the black-headed minnows (Pimephales promelas). Trans. Amer. Fish. Soc. 62:382-383.

Notes on spawning behavior. Includes a drawing of some eggs with brief description.

See also references 4, 7, 12, 24.

Pimephales vigilax

Rhinichthys atratulus

248. Bartnik, V.G. 1970. Reproductive isolation between two sympatric dace, Rhinichthys atratulus and R. cataractae in Manitoba. J. Fish. Res. Bd. Can. 27:2125-2141.

Describes time of spawning, nest location and spawning behavior. Also provides information on distinguishing young 9 mm. F.L. or larger based on chromatophores in lateral band and snout length.

249. Noble, R.L. 1965. Life history and ecology of western blacknose dace, Roone County, Iowa, 1963-1964. Proc. Iowa Acad. Sci. 72:282-293.

Includes a discussion of reproduction, fecundity, brief egg description, and pattern of scale formation.

250. Schwartz, F.J. 1958. The breeding behavior of the southern blacknose dace, Rhinichthys atratulus obtusus Agassiz. Copeia: 141-143.

Notes on spawning behavior and site selection.

See also references 4, 7, 24.

Rhinichthys cataractae

251. Gee, J.H. and Northcote, T.G. 1963. Comparative ecology of two sympatric species of dace (Rhinichthys) in the Fraser River System, B.C. J. Fish. Res. Bd. Can. 20:105-118.

Reproduction, age, growth and food habits of Rhinichthys falcutas and Rhinichthys cataractae.

Semotilus atromaculatus

252. Reighard, J.R. 1910. Methods of studying the habits of fishes, with an account of the breeding habits of the horned dace. Bull. U.S. Bur. Fish. 28:1111-1136.

Spawning behavior only.

See also references 4, 7, 24.

Semotilus corporalis

253. Reed, Roger J. 1971. Biology of the fallfish, Semotilus corporalis (Pisces, Cyprinidae). Trans. Amer. Fish. Soc. 100:717-725.

Spawning behavior, fecundity, description of egg, larval and prejuvenile stages with poor figures of 6.8, 10.0 and 18.0 mm. fry.

See also references 4, 7, 24.

Semotilus margarita

254. Langlois, T.H. 1929. Breeding habits of the Northern dace. Ecology. 10:161-163.

Notes on spawning location, nesting, breeding behavior, egg description and fecundity data.

See also references 4, 7, 24.

Catostomidae

Carpiodes carpio

255. Behmer, D.J. 1967. Spawning periodicity of the river carpsuckers, Carpiodes carpio. Proc. Iowa Acad. Sci. 72:252-262.

Time of spawning only.

256. Buchholz, M. 1957. Age and growth of River Carpsucker in Des Moines River, Iowa. Proc. Iowa Acad. Sci. 64:589-600.

Spawning information includes location and fecundity. Physical description of egg also included.

See also references 4, 7.

Carpiodes cyprinus

257. Gerlack, Jim. 1973. Early development of the quillback carpsucker, Carpiodes cyprinus. M.S. Thesis. Millersville State College, Millersville, Penna.

Not seen.

See also references 4, 7, 12, 15, 16, 24.

Carpiodes velifer

Catostomus catostomus

258. Bailey, M.M. 1969. Age, growth and maturity of the longnose sucker, Catostomus catostomus, of Western Lake Superior. J. Fish. Res. Bd. Canada. 26:1289-1299.

Fecundity and egg diameter only.

259. Harris, R.H.D. 1962. Growth and reproduction of the longnose sucker, Catostomus catostomus (Forster), in Great Slave Lake. J. Fish. Res. Bd. Can. 19:113-126.

Descriptions include egg and fingerling stages.

See also references 4, 7, 24.

Catostomus commersoni

260. Crawford, D.R. 1923. The significance of food supply in the larval development of fishes. Ecology. 4:147-153.

Descriptions include five line drawings of newly hatched larvae with a brief discussion of development for Catostomus commersoni.

261. Culbertson, G. 1903. A note on the breeding habits of the Common or White Sucker. P. Indiana Acad. 65-66 pp.

A short note on the spawning activities of white suckers.

262. Raney, E.C. 1943. Unusual spawning habitat for the common white sucker, Catostomus c. commersonnii. Copeia: 256.

Spawning location and behavior only.

263. Reighard, J. 1920. Breeding behavior of the suckers and minnows. I. The suckers. Biol. Bull. 38:1-32.

Paper covers spawning site, season and behavior of Catostomus commersoni, Moxostoma macrolepidotum and Hypentelium nigricans.

264. Stewart, N.H. 1926. Development, growth and food habits of the white sucker, Catostomus commersonii Le Sueur. Bull. U.S. Bur. Fish. 42:147-184.

A very complete study with descriptions and drawings from egg to adult. Spawning information includes breeding habits, spawning conditions and fecundity. Descriptions include egg to 50 mm. stages with excellent line drawings of embryo and larval stages (12 figures of developying embryo and figures of 9, 12, 14, 15.5, 18, 25, 30, 50 mm. larvae). Also a discussion of development of head, mouth and intestine is included.

See also references 4, 7, 11, 12, 15, 16, 22, 24.

Erimyzon oblongus

265. Carnes, W.C., Jr. 1958. Contributions to the biology of the eastern creek chubsucker, Erimyzon oblongus oblongus (Mitchill). M.S. Thesis. North Carolina College. viii and 69 pp. 9 Plates.

Life history study including fecundity, and time of spawning run. Description of egg and larval stages through 586 hours with line drawings also included.

266. Wagner, C.C. and E.L. Cooper. 1963. Population density, growth and fecundity of the creek chubsucker, Erimyzon oblongus. Copeia:350-357.

Spawning information includes fecundity. Descriptions include egg stage only.

See also references 4, 7, 15, 16.

Erimyzon sucetta

Hypentelium nigricans

Ictiobus bubalus

267. Wrenn, W.B. and B.G. Grinstead. 1968. Larval development of the smallmouth buffalo, Ictiobus bubalus. J. Tenn. Acad. Sci. XLVI:117-120.

Description of egg, prolarvae, postlarvae and juvenile with line drawings of the latter three stages.

See also references 4, 7.

Ictiobus cyprinellus

268. Johnson, R.P. 1963. Studies on the life history and ecology of the bigmouth buffalo, Ictiobus cyprinellus (Valenciennes). J. Fish. Res. Bd. Canada. 20:1397-1429.

Spawning information includes general behavior, fecundity and egg size. Descriptions include photo of 18 mm. fork length larva.

See also references 4, 7, 24.

Ictiobus niger

Lagochila lacera

Minytrema melanops

Moxostoma anisurum

269. Meyer, W.H. 1961. Life history of three species of redhorse (Moxostoma) in the Des Moines River, Iowa. M.S. Thesis. Iowa State Univ.

Not seen.

See also references 4, 7, 24.

Moxostoma carinatum

Moxostoma duquesnei

270. Bowman, M.L. 1959. Life history of the black redhorse, Moxostoma duquesnei (Le Sueur), in Missouri. Ph.D. Thesis. University of Missouri, Columbia. 144 pp.

Not seen.

271. Bowman, M.L. 1970. Life history of the Black Redhorse Moxostoma duquesnei (Le Sueur), in Missouri. Trans. Amer. Fish. Soc. 99:546-559.

Spawning and fecundity information only.

Moxostoma erythrurum

See reference 269.

Moxostoma hubbsi

Moxostoma macrolepidotum

See references 12, 269.

Moxostoma valenciennesi

Cobitidae

Misgurnus anguillicaudatus

Ictaluridae

Ictalurus catus

272. Ryder, J.A. 1883. Preliminary notice of the development and breeding habits of the Potomac catfish, *Ameiurus albidus* (Le Sueur) Gill. Bull. U.S. Fish Comm. 3:225-230.

Prose description of fry up to 15th day after birth. No drawings.

Ictalurus melas

273. Forney, J.L. 1955. Life history of the black bullhead, *Ameiurus melas* R. of Clear Lake, Iowa. Iowa State Coll. J. Sci. 30:145-162.

Spawning information includes fecundity. Descriptions include size distribution of young of the year.

See also references 4, 7.

Ictalurus natalis

See reference 12.

Ictalurus nebulosus

274. Armstrong, P.B. 1962. Stages in the development of *Ictalurus nebulosus*. Syracuse Univ. Press, Syracuse, N.Y. 8 pp.

Descriptions include excellent drawings of egg to postlarval stage (17 days), and limited verbal descriptions.

275. Breder, C.M., Jr. 1935. The reproductive habits of the common catfish, *Ameiurus nebulosus* (Le Sueur), with a discussion of their significance in ontogeny and phylogeny. Zoologica. 19:143-185.

Spawning information includes behavior and nests. Descriptions include eggs and early larval stages.

276. Breder, C.M. 1932. The breeding of bullheads in the aquarium. Bull. New York Zool. Soc. 35:129-131.

Spawning behavior and description of eggs of Ictalurus nebulosus.

See also references 4, 7, 12, 15, 16, 24.

Ictalurus punctatus

277. Marzolf, R.C. 1957. Reproduction of channel catfish in Missouri ponds. J. Wildl. Man. 21:22-28.

Spawning information includes nesting patterns, time and success.

278. Saksena, V.P., K. Yamamoto and C.D. Riggs. 1961. Early development of the channel catfish. Progr. Fish Cult. 23:156-61.

Descriptions include morphology of embryo to the development of pectoral fin-buds, two photos of 19 stages of embryo with descriptions.

See also references 4, 7, 12, 15, 16, 24.

Noturus exilis

279. Sumner, Francis B. 1899. On the early development of the catfish (Noturus). Science. 9:313-314.

Notes on cleavage and segmentation only.

See also references 4, 7.

Noturus flavus

280. Bowman, H.B. 1936. Further notes on the margined madtom, Rabida insignis (Richardson) and notes on a kindred species, Noturus flavus (Rafinesque). Ph.D. Thesis. Cornell Univ. 99 pp.

Not seen.

See also references 4, 7, 12, 24.

Noturus furiosus

Noturus gyrinus

Noturus insignis

281. Bowman, H.B. 1932. A description and ecologic study of the margined mad tom, Rabida insignis (Richardson). M.S. Thesis. Cornell Univ. 41 pp. 9 Figures.

Not seen.

Noturus miurus

Pylodictis olivaris

Aphredoderidae

Aphredoderus sayanus

282. Mansueti, A.J. 1963. Some changes in morphology during ontogeny in the pirateperch, Aphredoderus s. sayanus. Copeia:546-557.

Line drawings of pirate perch from 9.5 mm. to 31 mm. Table of anal rays and spines by size from 5 mm. to adult. Line drawings of skeleton of 17 and 45 mm. individuals. Description of migration of vent.

See also references 4, 7.

Percopsidae

Percopsis omiscomaycus

283. Magnuson, J.J. and L.L. Smith, Jr. 1963. Some phases of the life history of the trout-perch. Ecology. 44:83-95.

Includes discussion of time and location of spawning and fecundity.

See also references 4, 7, 11, 12, 24.

Gadidae

Lota lota

284. Bailey, M.M. 1972. Age, growth, reproduction and food of the burbot, Lota lota (Linnaeus), in southwestern Lake Superior. Trans. Amer. Fish. Soc. 101:667-674.

Spawning information includes time and fecundity.

285. Chen, Lo-chai. 1969. The biology and taxonomy of the burbot, Lota lota leptura, in interior Alaska. Biol. Papers of the Univ. of Alaska. No. 11. 1-51 pp.

Brief account of spawning time with review of other accounts. Some information on fecundity and egg size.

286. Evropeizeva, N.W. 1947. On the larval period of Lota lota L. (Teleostei, Gadidae). Trav. Soc. Nat. St. Petersb. (Leningr.). 69:70-87.

Not seen.

287. Kanansky, W.J. 1928. Zur Morphologie der Brut von Lota lota L. Zool Anz. Leipzig. 79:143-148.

Descriptions include 5 figures of early stages.

288. Prince, E.E. and A. Halkett. 1906. The eggs of the freshwater ling. Ottawa Naturalist. 19:219-224.

Not seen.

289. Volodin, V.M. Embryonic development of Lota lota. Trudy. Inst. Biol. Vnutrennich Vodochr. No. 3(6):227-230.

Not seen.

See also references 4, 7, 11, 12, 21, 24.

Cyprinodontidae

290. Foster, N.R. 1967. Comparative studies on the biology of killifishes (Pisces, Cyprinodontidae). Ph.D. Dissertation. Cornell Univ. 369 pp.

Includes spawning behavior, spawning substrate, and descriptions of egg and larval stages of Fundulus notti (very brief), F. notatus and F. diaphanus as well as many other non-Great Lakes cyprinodonts. Many of the descriptions are literature derived.

291. Rosen, D.E. 1964. The relationship and taxonomic position of the halfbeaks, killifishes, silversides and their relatives. Bull. Amer. Mus. Nat. Hist. 127:217-268.

Not seen.

Fundulus diaphanus

292. Newman, H.H. 1907. Spawning behavior and sexual dimorphism in Fundulus heteroclitus and allied fish. Biol. Bull. 12:314-348.

Discusses spawning behavior of 3 species of Fundulus: F. heteroclitus, F. diaphanus, F. majalis.

See also references 4, 7, 11, 12, 15, 24, 290.

Fundulus notatus

293. Carranza, J. and H.E. Winn. 1954. Reproductive behavior of the black-stripe topminnow Fundulus notatus. Copeia: 273-278.

Spawning information includes: location; season; courtship behavior/spawning act; and fecundity.

See also references 4, 7, 290.

Fundulus notti

Poeciliidae

Gambusia affinis

294. Gopinath, K. 1943. Observations on the breeding and development of Gambusia affinis (Baird and Girard) in Indian waters (Abstract). Proc. Indian Sci. Congr. 30:61-62.

Not seen.

295. Krumholz, L.A. 1948. Reproduction in the western mosquito fish, Gambusia affinis affinis (Baird and Girard) and its use in mosquito control. Ecol. Monogr. 18:1-43.

Spawning information includes fecundity. Descriptions include figures of embryo and description of young.

296. Kuntz, A. 1913. Notes on the habits, morphology of the reproductive organs, and embryology of the viviparous fish, Gambusia affinis. Bull. U.S. Fish. Comm. 33:177-199.

Descriptions include figures and descriptions of embryos and larvae.

297. Ryder, J.A. 1886. On the development of viviparous osseous fishes. Proc. U.S. Nat. Mus. 8:128-155.

General gametogenesis with notes on genus Gambusia.

See also references 4, 7, 15, 91.

Atherinidae

Labidesthes sicculus

298. Nelson, J.S. 1968. Life history of the brook silverside, Labidesthes sicculus, in Crooked Lake, Indiana. Trans. Am. Fish. Soc. 97:293-296.

Spawning information includes behavior and location. Description includes egg size.

See also references 4, 7, 12, 24.

Gasterosteidae

Culaea inconstans

See reference 12.

Gasterosteus aculeatus

299. Craig-Bennet, A. 1931. The reproductive cycle of the three spined stickleback, Gasterosteus aculeatus L. Philos. Trans. London B. 219(466):197-279.

Spawning information includes season, behavior and suitable conditions.

300. Grumback, J. and P.E. Nelson. 1959. Life history of the threespine stickleback Gasterosteus aculeatus (Linneaus) in Karluk Lake and Bare Lake, Kodiak Island, Alaska. Fish. Bull. 59:537-559.

Spawning season indicated.

301. Horsfall, J.H. 1864. Observations on the three-spined stickleback, its ova and fry (Gasterosteus aculeatus) Linn. and G. spinulosus (Yarrell). Intell. Observ. 5:4-7.

Not seen.

302. Jacobs, D.L. 1948. Nesting of the brook stickleback (Abstract). Proc. Minn. Acad. Sci. 16:33-34.

Deals with Gasterosteus aculeatus. Spawning information includes site and nest description. Description of egg included.

303. Jepps, Margaret W. 1938. Notes on the breeding of sticklebacks. Proc. Zool. Soc. London. Vol. A108:253-255.

Breeding behavior of Gasterosteus discussed.

304. Kuntz, A. and L. Radcliffe. 1918. Notes on the embryology and larval development of twelve Teleostean fishes. Bull. Bur. Fish. 35:87-134.

Good descriptions of spawning, egg and larval stages with figures. Key to eggs given.

305. Pelkwijk, J.J. ter und N. Tinbergen. 1937. Eine reizbiologische Analyse einiger Verhaltensweisen von Gasterosteus aculeatus L. Z. Tierpsychol. 1:193-200.

Spawning habits are described.

306. Swarup, H. 1958. Stages in the development of the stickleback, Gasterosteus aculeatus (L.). J. Embryol. exp. Morphol. 6:373-383.

Descriptions and drawings from egg to 11 mm. larva.

307. Thomopoulos, A. 1953. Sur l'oeuf de lepinoche Gasterosteus aculeatus L. Bull. Soc. Zool. Fr. 78:142-149.

Drawings of early egg development stages.

308. Vrat, F. 1949. Reproductive behavior and development of eggs of the three-spined stickleback (Gasterosteus aculeatus) of California. Copeia:252-260.

Descriptions include figures and extensive discussions of egg, embryo and newly hatched larva.

See also references 4, 7, 12, 15, 24.

Pungitius pungitius

See reference 3, 24.

Percichthyidae

Morone americana

309. Mansueti, R.J. 1964. Eggs, larvae and young of the white perch, Roccus americanus, with comments on its ecology in the estuary. Chesapeake Sci. 5:3-45.

Very complete descriptions and line drawings of egg and larval stages.

310. Morgan, R.P., II. 1975. Distinguishing larval white perch and striped bass by electrophoresis. Ches. Sci. 16:68-70.

Describes method of distinguishing M. americana from M. saxatilis by electrophoresis of muscle proteins.

See also references 4, 15, 24.

Morone chrysops

311. Riggs, C.D. 1955. Reproduction of the white bass, Morone chrysops. Invest. Ind. Lakes and Streams. 4:87-110.

Includes fecundity, spawning time, location and behavior.

See also references 4, 12, 24.

Morone mississippiensis

Centrarchidae

312. Breder, C.M., Jr. 1936. The reproductive habits of the North American sunfishes (family Centrarchidae). Zoologica. 21:1-48.

Notes on the reproductive season, nesting, courtship, spawning act, with an annotated specific list of spawning habits for Micropterus dolomieui, M. salmoides, Lepomis auritus, Ambloplites rupestris and Pomoxis annularis.

313. Carbine, W.F. 1939. Observations on the spawning habits of centrarchid fishes in Deep Lake, Oakland County, Michigan. Trans. 4th N. Amer. Wildl. Conf. 275-287 pp.

Reproduction in Deep Lake centrarchids.

314. Childers, W.F. 1967. Hybridization of four species of sunfishes (Centrarchidae). Bull. Ill. Nat. Hist. Surv. Vol. 29. Art. 3. 214 p.

Discusses spawning time and location and summarizes adult characters for Lepomis macrochirus, L. cyanellus, L. microlophus and L. gulosus. Also contains photographs of prolarval bluegill and redear sunfish.

315. Meyer, F.A. 1970. Development of some larval centrarchids. Prog. Fish. Cult. 32:130-136.

Species included: Micropterus dolomieui, M. salmoides, Lepomis macrochirus, L. cyanellus, and L. microlophus. Description includes: egg diameter, length at start of caudal ray information, time and length to free swimming stage, and length when all rays are formed. Good line drawings of several stages of each species included.

316. Snyder, D.E. 1970. Preliminary key to larval centrarchids of the Conawingo Reservoir, Lower Susquehanna River. Conawingo and Muddy Run Fish Studies. Unpublished manuscript.

Key to families in reservoir and to Ambloplites, Lepomis cyanellus, Micropterus salmoides, M. dolomieui, Pomoxis annularis, and P. nigromaculatus. Separate keys to prolarvae, early postlarvae and late postlarvae.

Ambloplites rupestris

See references 4, 12, 24, 312, 316.

Lepomis cyanellus

317. Duwe, A.E. 1955. The development of the gas bladder in the green sunfish, Lepomis cyanellus. Copeia:92-95.

Describes development of gas bladder from 47-292 hours past fertilization. Points out differences between green sunfish and bluegill in gas bladder development.

318. Duwe, A.E. 1959. The differentiation of the heart of the green sunfish, Lepomis cyanellus. Turtox news. 37:290-291.

Not seen.

319. Hunter, J.R. 1963. The reproductive behavior of the green sunfish, Lepomis cyanellus. Zoologica, 48:13-24.

Spawning information includes sexual dimorphism, nest construction, and behavior.

See also references 4, 24, 314, 315, 316.

Lepomis gibbosus

320. Balon, E.K. 1959. Die Entwicklung des akklimatisienten Lepomis gibbosus (Linne 1758) wahrend der embroyalen Periode in den Donausertenwassern. Z. Fisch. N.F. 8:1-27.

Drawings of egg and larval stages and some notes on spawning habits.

See also references 4, 12, 15, 326.

Lepomis gulosus

321. Carr, A.F. 1939. Notes on the breeding habits of the warmouth bass. Proc. Florida Acad. Sci. 4:108-112.

Spawning behavior and a brief description of eggs and larvae.

322. Larimore, R. Weldon. 1957. Ecological life history of the warmouth (Centrarchidae). Bull. Ill. Nat. Hist. Surv. 27:1-83.

Six photos of larvae from 3.4-12 mm. with detailed descriptions. Spawning and fecundity information as well.

Lepomis humilis

323. Barney, R.L. and B.J. Anson. 1923. Life history and ecology of the orange-spotted sunfish, Lepomis humilis. Rep. U.S. Com. Fish. Appendix XV. 16 pp.

Spawning season and nesting described.

Lepomis macrochirus

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Describes formation of gas bladder in young from 1 day old to 14 mm. postlarva.

325. Morgan, G.D. 1951. A comparative study of the spawning periods of the bluegill, Lepomis macrochirus, the black crappie Pomoxis nigromaculatus (Le Sueur) and the white crappie, Pomoxis annularis Raf. of Buckeye Lake, Ohio. J. Sci. Labs, Denison Univ. 42:112-118.

Discusses time of spawning.

326. Werner, R.G. 1966. Ecology and movements of bluegill sunfish fry in a small northern Indiana lake. Ph.D. Thesis. Indiana Univ. 74 pp.

Photographs, measurements and counts of Lepomis macrochirus, L. gibbosus, and L. microlophus fry from 15 mm. to 38 mm. Information on growth, feeding and movements included as well.

See also references 4, 15, 24, 314, 315, 317.

Lepomis megalotis

327. Witt, A. and R.C. Marzolf. 1954. Spawning and behavior of the longear sunfish, Lepomis m. megalotis. Copeia: 188-190.

Spawning information includes nest and nest site, and spawning behavior.

See also references 4, 24.

Lepomis microlophus

See references 4, 314, 315, 326.

Micropterus dolomieui

328. Doan, K.H. 1939. Growth of bass fry. Copeia:81-87.

Data on smallmouth from 9.2-16.5 mm. S.L. with measurements of eye diameter, head length, pectoral length, snout to dorsal origin, dorsal length, snouth to anal origin, and length of anal fin.

329. Harrison, A.C. 1953. The acclimatization of smallmouth bass. Piscator. 7:89-96.

Breeding habits of smallmouth bass in rivers.

330. Kramer, R.H. and L.L. Smith, Jr. 1962. Formation of year classes in largemouth bass. Trans. Amer. Fish. Soc. 91:29-41.

Discusses spawning behavior, nesting sites and growth of young. No descriptions.

331. Pflieger, W.L. 1966. Reproduction of the small mouth bass (Micropterus dolomieui) in a small Ozark stream. Am. Midl. Nat. 76:410-418.

Reproductive behavior including sections on nesting chronology, nest description, and nest behavior. Brief discussion of egg and fry development with egg and fry counts.

332. Tester, A.L. 1930. Spawning habits of the small-mouthed black bass in Ontario waters. Trans. Amer. Fish. Soc. 60:53-59.

Includes size of eggs and growth rate of fry.

333. Turner, G.E. and H.R. McCrimmon. 1970. Reproduction and growth of smallmouth bass, Micropterus dolomieui, in a Precambrian lake. J. Fish. Res. Bd. Can. 27:395-400.

Spawning information includes conditions suitable for spawning and spawning activity. Behavior of postlarval bass discussed as well.

See also references 4, 11, 12, 15, 18, 19, 22, 24, 312, 315, 316.

Micropterus salmoides

334. Applegate, R.L. Pyloric caeca counts as a method for separating the advanced fry and fingerlings of largemouth and spotted bass. Trans. Am. Fish. Soc. 95:226.

Presents pyloric caeca counts for largemouth and spotted bass.

335. Carr, Marjorie H. 1942. The breeding habits, embryology and larval development of the largemouthed black bass in Florida. Proc. New England Zool. Club. 20:43-77.

Drawings and tables discussing the development of bass from egg to yolk sac absorption are presented.

336. Chew, Robert L. 1974. Early life history of the Florida largemouth bass. Florida Game and Fresh Water Fish Comm. Fishing Bull. No. 7. 76 pp.

Spawning information includes season, behavior and fecundity. Descriptions include photographs and verbal descriptions of egg to 168 hour larva.

337. Kelley, J.W. 1962. Sexual maturity and fecundity of the largemouth bass, Micropterus salmoides (Lacepede), in Maine. Trans. Amer. Fish. Soc. 91:23-28.

Fecundity information presented as well as 5 stages of ovum development with good descriptions of the eggs.

See also references 4, 15, 18, 19, 24, 312, 315, 316.

Pomoxis annularis

338. Hansen, D.F. 1943. On the nesting of the white crappie, Pomoxis annularis. Copeia:259-260.

Description of spawning sites and a brief egg description.

339. Morgan, George D. 1954. The life history of the white crappie, (Pomoxis annularis), of Buckeye Lake, Ohio. J. Sci. Labs. Denison Univ. 43:113-144.

Description of larvae up to yolk sac absorption.

340. Siefert, R.E. 1965. Early scale development in the white crappie. Trans. Amer. Fish. Soc. 94:182.

Scale development discussed.

341. Siefert, R.E. 1968. Reproductive behavior, incubation and mortality of eggs and postlarval food selection in the white crappie. Trans. Amer. Fish. Soc. 97:252-259.

Includes spawning site and behavior plus photo of egg.

342. Siefert, R.E. 1969. Characteristics for separation of white and black crappie larvae. Trans. Amer. Fish. Soc. 98:326-328.

Primarily tables of myomere counts. No identifying figures.

343. Vasey, F.W. 1971. The early life history of white crappie in Table Rock Reservoir. State of Missouri, Project No. F-1-R-20, Study I-7, Job. No. 1. 1-11 pp.

Not seen.

See also references 4, 15, 24, 312, 316, 325.

Pomoxis nigromaculatus

Percidae

344. Winn, H.E. 1958. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae). Ecol. Monographs. 28:155-191.

Describes reproductive behavior, spawning location and season, fecundity and eggs for Percina caprodes, Hadropterus maculatus, Etheostoma caeruleum, E. spectabile, E. saxatile, E. exile, E. blennioides, E. microperca, E. nigrum, E. maculatum, E. flabellare and Hadropterus copelandi.

Ammocrypta pellucida

Etheostoma blennioides

345. Winn, H.E. 1957. Egg site selection by 3 species of darters (Pisces: Percidae). Brit. J. Anim. Behavior. 5:25-28.

Discusses factors determining choice of spawning site.

346. Fahy, W.E. 1954. The life history of the northern greenside darter, Etheostoma blennioides blennioides Rafinesque. J. Elisha Mitchell Sci. Soc. 70:139-205.

Description of reproductive behavior, location of spawning sites, fecundity, egg, embryonic development, prolarvae, and postlarvae included. Drawings also.

See also references 4, 24, 344.

Etheostoma caeruleum

347. Reeves, Cora D. 1907. The breeding habits of the rainbow darter (Etheostoma caeruleum Storer); a study in sexual selection. Biol. Bull. 14:35-39.

Description of spawning behavior, nesting, coloration patterns and line drawing of spawning act.

See also references 4, 24, 344.

Etheostoma chlorosomum

Etheostoma exile

See reference 12.

Etheostoma flabellare

348. Lake, Charles. 1936. The life history of the fan-tailed darter Catonatus flabellaris flabellaris (Rafinesque). Amer. Midl. Nat. 17:816-830.

Includes: nest location, spawning behavior, fecundity, and drawings of egg, prolarval, and postlarval stages (1 for each).

See also references 4, 12, 24, 344.

Etheostoma microperca

See reference 344.

Etheostoma nigrum

349. Speare, E.P. 1965. Fecundity and egg survival of the central johnny darter in southern Michigan. Copeia: 308-314.

Includes fecundity and hatching time information.

See also references 4, 11, 12, 24, 344.

Etheostoma olmstedi

350. Atz, J.W. 1940. Reproductive behavior in the eastern johnny darter, Boleosoma nigrum olmstedi (Storer). Copeia: 100-106.

Spawning behavior only.

351. Tsai, Chu-Fa. 1972. Life history of the eastern johnny darter, Etheostoma olmstedi Storer, in cold tailwater and sewage-polluted water. Trans. Amer. Fish. Soc. 101:80-88.

Fecundity information only.

See also references 4, 15.

Etheostoma spectabile

352. Linder, A.D. 1958. Behavior and hybridization of two species of Etheostoma (Percidae). Trans. Kansas Acad. Sci. 61:195-212.

Spawning information, brief egg description, and drawings of several larval stages included for Etheostoma spectabile and E. radiosum.

Etheostoma zonale

Perca flavescens

353. Mansueti, Alice J. 1964. Early development of the yellow perch, Perca flavescens. Chesapeake Sci. 5:46-66.

Very complete descriptions and line drawings taken from material of known parentage of egg to juvenile stage (44 mm.).

354. Norden, Carroll R. 1961. The identification of larval yellow perch, Perca flavescens and walleye, Stizostedion vitreum. Copeia:282-288.

Description of prolarva, postlarva. Excellent drawings of Perca flavescens: prolarva, 5.8 mm.; postlarva, 13.0 mm. (Lake Erie) and postlarva, 13.0 mm. (Lake Michigan). Also of Stizostedion vitreum: prolarvae, 8.0 mm. (Lake Erie) and postlarva, 14.8 mm. (Lake Michigan).

355. Pycha, R.L. and L.L. Smith, Jr. 1954. Early life history of the yellow perch, Perca flavescens (Mitchell) in the Red Lakes, Minnesota. Trans. Amer. Fish. Soc. 84:249-260.

Deals primarily with juvenile perch during first summer. Line drawings of pattern of scale formation from 20-35 mm.

See also references 4, 15, 24, 186.

Percina caprodes

356. Cooper, J.E. 1976. Early development of the logperch, Percina caprodes (Rafinesque). Unpublished manuscript.

Descriptions and illustrations of stages from fertilization to 22.5 mm.

See also references 4, 12, 24, 344.

Percina copelandi

See reference 344.

Percina evides

Percina maculata

357. Petravicz, W.P. 1938. The breeding habits of the black-sided darter, Hadropterus maculatus Girard. Copeia: 40-44.

Includes spawning behavior, description of egg and larval stages with figures.

358. Raney, E.C. and E.A. Lachner. 1939. Observations of the life history of the spotted darter, Poecilichthys maculatus (Kirtland). Copeia:157-165.

Spawning time and location. Description of eggs. Line drawing of newly hatched larva, 5 mm. long.

See also references 4, 24, 344.

Percina phoxocephala

Percina shumardi

Stizostedion canadense

359. Nelson, W.R. 1968a. Embryo and larval characteristics of sauger, walleye and their reciprocal hybrids. Trans. Amer. Fish. Soc. 97:167-174.

Descriptions with measurements and counts and excellent figures. Summarizes characters used in distinguishing walleye from sauger fry.

360. Nelson, W.R. 1968b. Reproduction and early life history of sauger, Stizostedion canadense, in Lewis and Clark Lake. Trans. Am. Fish. Soc. 97:159-166.

Time and location of spawning, duration of incubation period and length of yolk sac stage all described. No descriptions of egg or larval stages.

361. Priegel, G.R. 1967. Identification of young walleyes and saugers in Lake Winnebago, Wisconsin. Prog. Fish Cult. 108-109 pp.

Gives method for distinguishing young sauger and walleye by external color spot technique.

See also references 4, 11, 12, 24.

Stizostedion vitreum

362. Carpenter, C.E. 1939. Embryology of the walleyed pike (Stizostedion vitreum). M.S. Thesis. Ohio State Univ.

Not seen.

363. Ellis, D.V. and M.A. Giles. 1965. The spawning behavior of the walleye, Stizostedion vitreum (Mitchell). Trans. Amer. Fish. Soc. 94:358-362.

Discusses spawning behavior only.

364. Olson, D.E. 1966. Physical characteristics of fertilized and unfertilized walleye eggs during early stages of development. Minnesota Fish. Invest. 4:31-38.

Drawings and description of early egg stages.

365. Priegel, G.R. 1969. Food and growth of young walleyes in Lake Winnebago, Wisc. Trans. Am. Fish. Soc. 98:121-124.

Food and growth of walleyes during first summer (10-175 mm.). No descriptions or drawings.

366. Priegel, G.R. 1970. Reproduction and early life history of the walleye in the Lake Winnebago region. Techn. Bull. Dep. Nat. Resources. Wisc. No. 45:1-105.

Spawning information: locality, season, behavior migration. Egg description and fecundity. Hatching and fry movements. Food of young.

See also references 4, 12, 24, 359, 361.

Sciaenidae

Aplodinotus grunniens

367. Daiber, F.C. 1953. Notes on the spawning population of the freshwater drum (Aplodinotus grunniens Rafinesque) in Western Lake Erie. Am. Midl. Nat. 50:159-171.

Includes fecundity and some discussion of time and location of spawning.

368. Davis, C.C. 1959. A planktonic fish egg from fresh water. Limnology and Oceanography. 4:352-355.

Contains a description with good line drawings of egg of Aplodinotus grunniens. Briefly describes newly hatched fry as well.

369. Edsall, T.A. 1967. Biology of the freshwater drum in western Lake Erie. Ohio J. Sci. 67:321-340.

Mostly age and growth information, but does discuss the time of spawning in western Lake Erie.

370. Priegel, G.R. 1966. Early scale development in the freshwater drum, Aplodinotus grunniens Rafinesque. Trans. Amer. Fish. Soc. 95:434-436.

Scale development discussed.

371. Swedberg, D.V. and C.H. Walburg. 1970. Spawning and early life history of the freshwater drum in Lewis and Clark Lake, Missouri River. Trans. Amer. Fish. Soc. 99:560-570.

Includes time and location of spawning, fecundity and descriptions of fertilized egg, 10 hr., 20 hr., hatching, 3.2 mm., 4.4 mm., 4.5 mm. and 4.7 mm. stages of development.

See also references 4, 12, 24.

Cottidae

372. Khan, N. 1971. Comparative morphology and ecology of the pelagic larvae of nine Cottidae (Pisces) of the northwest Atlantic and St. Lawrence drainage. Ph.D. Thesis. Univ. of Ottawa, Ottawa. 234 p.

Not seen.

Cottus bairdi

373. Koster, W.J. 1936. The life-history and ecology of the sculpins (Cottidae) of central New York. Ph.D. Thesis. Cornell Univ. 87 pp. 10 plates.

General life history of Cottus bairdii and C. cognatus including spawning season, site, behavior and fecundity. Also includes description of egg and prolarva for both species. Also included are photographs of 7.5, 9 and 10.5 mm. Cottus bairdii; 7, 8 and 9 mm. Cottus bairdii kumlieni; and 7, 9.5 and 10 mm. Cottus cognatus.

374. Ludwig, G.M. and C.R. Norden. 1969. Age, growth and reproduction of the northern mottled sculpin (Cottus bairdi bairdi) in Mt. Vernon Creek, Wisconsin. Milwaukee Public Museum, Occasional Papers. No. 2. 67 p.

Describes spawning time and site, fecundity, eggs and briefly discusses larval size at time of hatching and absorbing yolk sac.

375. Savage, T. 1963. Reproductive behavior of the mottled sculpin, Cottus bairdi Girard. Copeia:317-325.

Primarily behavioral. Gives some information on time and temperature during spawning in Maryland streams.

See also references 4, 12, 24.

Cottus cognatus

See reference 373.

Cottus ricei

See reference 12.

Myoxocephalus quadricornis

376. Khan, N.Y. and D.J. Faber. 1974. A comparison of larvae of the deepwater and fourhorn sculpin, Myoxocephalus quadricornis L. from North America. 1. Morphological development. 703-712 pp. In J.H.S. Blaxter. The early life history of fish. Springer-Verlag, New York. 765 pp. 299 Figures.

Descriptions include: line drawings of 9-17 mm. larvae of deepwater sculpin and line drawings of 12.8-17 mm. larvae of fourhorn sculpin.

377. Zvjangina, D.A. 1963. On spawning and development of the fishes of the Laptev Sea Myoxocephalus quadricornis, Osmerus eperlanus. Tr. Inst. Okeanol. 62:3-12.

Not seen.

See also references 4, 24.

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APPENDIX II

FISH SPECIES LISTS

OF THE

U. S. WATERS OF THE GREAT LAKES

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Table 1.--Fishes of Lake Superior (U.S.), classified according to their abundance and importance as commercial, sport, or forage fish.

Species	Abundance*	Importance**	Species	Abundance	Importance
Petromyzontidae			Catostomidae		
Sea lamprey	1	-	Silver redhorse	3	-
Silver lamprey	3	-	Longnose sucker	1	C-S-F
			White sucker	1	S-F
Acipenseridae					
Lake sturgeon	2	-	Ictaluridae		
			Black bullhead	3	-
Anguillidae			Tadpole madtom	3	-
American eel	3	-	Stonecat	3	-
Clupeidae			Percopsidae		
Alewife	1	F	Trout-perch	1	F
Salmonidae			Gadidae		
Bloater	1	C-F	Burbot	1	C
Kiyi	1	C-F			
Lake herring	1	C-F	Gasterosteidae		
Shortjaw cisco	1	C-F	Brook stickleback	3	-
Alantic salmon	1	S	Ninespine stickleback	1	F
Chinook salmon	1	S			
Coho salmon	1	S	Centrarchidae		
Pink salmon	1	S	Rock bass	3	-
Brook trout	1	S	Smallmouth bass	3	-
Brown trout	1	S			
Lake trout	1	C-S	Percidae		
Rainbow trout	1	S	Johnny darter	1	F
Splake (hybrid)	1	S	Logperch	1	F
Lake whitefish	1	C-F	Sauger	3	-
Pygmy whitefish	1	F	Walleye	1	S
Round whitefish	1	C-F	Yellow perch	3	-
Osmeridae			Cottidae		
Rainbow smelt	1	C-S-F	Fourhorn sculpin	1	F
			Mottled sculpin	1	F
Esocidae			Slimy sculpin	1	F
Muskellunge	3	-	Spoonhead sculpin	1	F
Northern pike	1	S			
Cyprinidae					
Carp	3	-			
Lake chub	3	-			
Longnose dace	3	-			
Brassy minnow	3	-			
Emerald shiner	1	F			
Golden shiner	3	-			
Sand shiner	3	-			
Spottail shiner	1	F			

* 1-Common; 2-Uncommon, although formerly common; 3-Uncommon, present or past.

** C-Commercial species; S-Sport species; F-Forage species.

Table 2.--Fishes of Lake Michigan, classified according to their abundance and importance as commercial, sport, or forage fish.

Species	Abundance*	Importance**
Petromyzontidae		
Chestnut lamprey	3	-
Sea lamprey	1	-
Acipenseridae		
Lake sturgeon	2	-
Lepisosteidae		
Longnose gar	1	-
Amiidae		
Bowfin	1	-
Anguillidae		
American eel	3	-
Clupeidae		
Alewife	1	C-F
Gizzard shad	3	-
Hiodontidae		
Mooneye	3	-
Salmonidae		
Bloater	1	C-F
Kiyi	2	-
Lake herring	1	C-F
Shortnose cisco	2	-
Atlantic salmon	3	-
Chinook salmon	1	S
Coho salmon	1	S
Pink salmon	3	-
Brook trout	1	S
Brown trout	1	S
Lake trout	1	C-S
Rainbow trout	1	S
Splake (hybrid)	3	-
Tiger trout	3	-
Lake whitefish	1	C-F
Round whitefish	1	C-F
Osmeridae		
Rainbow smelt	1	C-S-F
Umbridae		
Central mudminnow	3	-
Esocidae		
Grass pickerel	3	-
Northern pike	1	C-S
Cyprinidae		
Carp	1	C-S-F
Creek chub	3	-
Lake chub	3	-
River chub	3	-
Blacknose dace	3	-
Longnose dace	3	-
Pearl dace	3	-
Goldfish	3	-
Bluntnose minnow	3	-
Fathead minnow	3	-
Bigmouth shiner	3	-
Blacknose shiner	3	-
Common shiner	3	-
Emerald shiner	2	F
Golden shiner	3	-
Mimic shiner	3	-
Sand shiner	3	-
Spotfin shiner	3	-
Spottail shiner	1	F
Stoneroller	3	-
Catostomidae		
Black (?) buffalo	3	-
Quillback	3	-
Golden redhorse	3	-
Shorthead redhorse	3	-
Silver redhorse	3	-
Longnose sucker	1	C-S-F
Northern hog sucker	3	-
Spotted sucker	3	-
White sucker	1	C-S-F
Ictaluridae		
Black bullhead	1	C-F
Brown bullhead	3	-
Yellow bullhead	3	-
Flathead catfish	3	-
Channel catfish	1	S-F
Tadpole madtom	3	-
Aphredoderidae		
Pirate perch	3	-
Percopsidae		
Trout-perch	1	F
Gadidae		
Burbot	1	C
Atherinidae		
Brook silverside	3	-
Gasterosteidae		
Brook stickleback	3	-
Ninespine stickleback	1	F
Percichthyidae		
White bass	3	-
Centrarchidae		
Largemouth bass	3	-
Rock bass	3	-
Smallmouth bass	1	S
Black crappie	3	-
White crappie	3	-
Bluegill	3	-
Green sunfish	3	-
Longear sunfish	3	-
Pumpkinseed	3	-
Warmouth	3	-
Percidae		
Iowa darter	3	-
Johnny darter	1	F
Logperch	2	F
Walleye	2	C-S
Yellow perch	1	C-S-F
Sciaenidae		
Freshwater drum	1	F
Cottidae		
Fourhorn sculpin	1	F
Mottled sculpin	3	-
Slimy sculpin	1	F
Spoonhead sculpin	2	-

* 1-Common; 2-Uncommon, although formerly common; 3-Uncommon, present or past.

** C-Commercial species; S-Sport species; F-Forage species.

Table 3.--Fishes of Lake Huron (U.S.), classified according to their abundance and importance as commercial, sport, or forage fish.

Species	Abundance*	Importance**
Petromyzontidae		
Sea lamprey	1	-
Silver lamprey	1	-
Acipenseridae		
Lake sturgeon	2	-
Lepisosteidae		
Longnose gar	1	-
Spotted gar	3	-
Amiidae		
Bowfin	3	-
Anguillidae		
American eel	3	-
Clupeidae		
Alewife	1	F
Gizzard shad	1	F
Hiodontidae		
Mooneye	3	-
Salmonidae		
Bloater	2	-
Kiyi	2	-
Lake herring	2	-
Shortnose cisco	2	-
Atlantic salmon	3	-
Chinook salmon	1	S
Coho salmon	1	S
Pink salmon	3	-
Brown trout	1	S
Lake trout	1	S
Rainbow trout	1	S
Splake (hybrid)	1	S
Lake whitefish	1	C-F
Round whitefish	1	F
Osmeridae		
Rainbow smelt	1	S-F
Umbridae		
Central mudminnow	3	-
Esocidae		
Muskellunge	3	-
Northern pike	1	S
Cyprinidae		
Carp	1	C-S-F
Goldfish	3	-
Bluntnose minnow	3	-
Pugnose minnow	3	-
Emerald shiner	2	F
Golden shiner	3	-
Spottail shiner	1	F
Catostomidae		
Black (?) buffalo	1	C
Golden redhorse	3	-
Quillback	1	C-F
Longnose sucker	1	F
White sucker	1	C-S-F
Shorthead redhorse	3	-
Ictaluridae		
Black bullhead	1	C-S-F
Brown bullhead	3	-
Yellow bullhead	3	-
Channel catfish	1	C-S-F
Tadpole madtom	3	-
Stonecat	3	-
Percopsidae		
Trout-perch	1	F
Gadidae		
Burbot	2	-
Atherinidae		
Brook silverside	3	-
Gasterosteidae		
Brook stickleback	3	-
Ninespine stickleback	1	F
Percichthyidae		
White bass	3	-
Centrarchidae		
Largemouth bass	3	-
Rock bass	3	-
Smallmouth bass	1	S
Black crappie	1	C-S
White crappie	3	-
Bluegill	3	-
Green sunfish	3	-
Pumpkinseed	3	-
Warmouth	3	-
Percidae		
Johnny darter	1	F
Logperch	3	-
Walleye	2	-
Yellow perch	1	C-S-F
Scianidae		
Freshwater drum	1	C-S-F
Cottidae		
Fourhorn sculpin	1	F
Slimy sculpin	1	F

* 1-Common; 2-Uncommon, although formerly common; 3-Uncommon, present or past.
** C-Commercial species; S-Sport species; F-Forage species.

Table 4.--Fishes of Lake Erie (U.S.), classified according to their abundance and importance as commercial, sport, or forage fish.

Species	Abundance*	Importance**
Petromyzontidae		
Sea lamprey	1	-
Silver lamprey	3	-
Acipenseridae		
Lake sturgeon	2	-
Lepisosteidae		
Longnose gar	1	-
Spotted gar	3	-
Amiidae		
Bowfin	1	-
Anguillidae		
American eel	3	-
Clupeidae		
Alewife	1	F
Gizzard shad	1	C-F
Hiodontidae		
Mooneye	3	-
Salmonidae		
Lake herring	2	-
Chinook salmon	1	S
Coho salmon	1	S
Brown trout	3	-
Lake trout	2	-
Rainbow trout	3	-
Lake whitefish	2	-
Osmeridae		
Rainbow smelt	1	C-S-F
Umbridae		
Central mudminnow	3	-
Esocidae		
Grass pickerel	3	-
Muskellunge	3	-
Northern pike	2	-
Cyprinidae		
Carp	1	C-S-F
Creek chub	3	-
River chub	3	-
Silver chub	2	F
Blacknose dace	3	-
Goldfish	1	C-F
Bluntnose minnow	1	F
Fathead minnow	3	-
Silverjaw minnow	3	-
Blackchin shiner	2	-
Blacknose shiner	2	-
Common shiner	3	-
Emerald shiner	1	F
Golden shiner	1	F
Mimic shiner	1	F
Rosyface shiner	3	-
Spotfin shiner	1	F
Spottail shiner	1	F
Striped shiner	3	-
Stoneroller	3	-
Catostomidae		
Bigmouth buffalo	1	C-F
River carpsucker	3	-
Lake chubsucker	3	-
Quillback	1	C-F
Black redhorse	3	-
Catostomidae (cont.)		
Golden redhorse	3	-
Shorthead redhorse	1	F
Silver redhorse	3	-
Longnose sucker	2	-
Northern hog sucker	3	-
Spotted sucker	3	-
White sucker	1	C-S-F
Ictaluridae		
Black bullhead	1	C-S-F
Brown bullhead	3	-
Yellow bullhead	3	-
Channel catfish	1	C-S-F
Flathead catfish	3	-
Brindled madtom	3	-
Tadpole madtom	3	-
Stonecat	1	F
Percopsidae		
Trout-perch	1	F
Gadidae		
Burbot	2	-
Cyprinodontidae		
Banded killifish	3	-
Atherinidae		
Brook silverside	1	F
Gasterosteidae		
Brook stickleback	1	F
Percichthyidae		
White bass	1	C-S-F
White perch	3	-
Centrarchidae		
Largemouth bass	1	S
Rock bass	1	S
Smallmouth bass	1	S
Black crappie	1	S
White crappie	1	S
Bluegill	1	S
Green sunfish	3	-
Longear sunfish	3	-
Orangespotted sunfish	3	-
Pumpkinseed	1	S
Redear sunfish	3	-
Percidae		
Blackside darter	3	-
Fantail darter	2	-
Greenside darter	2	-
Iowa darter	3	-
Johnny darter	1	F
River darter	3	-
Logperch	2	-
Sauger	2	-
Walleye	1	C-S
Yellow perch	1	C-S-F
Sciaenidae		
Freshwater drum	1	C-S-F
Cottidae		
Mottled sculpin	1	F
Slimy sculpin	2	F

* 1-Common; 2-Uncommon, although formerly common; 3-Uncommon, present or past.

** C-Commercial species; S-Sport species; F-Forage species.

Table 5.--Fishes of Lake Ontario (U.S.), classified according to their abundance and importance as commercial, sport, or forage fish.

Species	Abundance *	Importance **
Petromyzonidae		
Sea lamprey	1	-
Lepisosteidae		
Longnose gar	1	-
Amiidae		
Bowfin	1	-
Anguillidae		
American eel	1	C
Clupeidae		
Alewife	1	F
Gizzard shad	1	F
Hiodontidae		
Mooneye	3	-
Salmonidae		
Bloater	2	-
Lake herring	2	-
Chinook salmon	1	S
Coho salmon	1	S
Brown trout	3	-
Lake trout	2	-
Rainbow trout	3	-
Round whitefish	2	-
Lake whitefish	2	-
Splake	3	-
Osmeridae		
Rainbow smelt	1	C-S-F
Umbridae		
Central mudminnow	3	-
Esocidae		
Chain pickerel	3	-
Grass pickerel	3	-
Muskellunge	3	-
Northern pike	1	S
Cyprinidae		
Fallfish	3	-
Carp	1	C-S-F
Creek chub	3	-
Lake chub	3	-
Blacknose dace	3	-
Longnose dace	3	-
Goldfish	1	F
Bluntnose minnow	1	F
Fathead minnow	3	-
Silvery minnow	3	-
Blackchin shiner	3	-
Common shiner	1	F
Emerald shiner	1	F
Golden shiner	1	F
Rosyface shiner	3	-
Spotfin shiner	3	-
Spottail shiner	1	F
Striped shiner	3	-
Catostomidae		
Silver redhorse	3	-
Shorthead redhorse	1	F
Quillback	1	F
Northern hog sucker	3	-
Longnose sucker	3	-
White sucker	1	C-S-F
Ictaluridae		
Black bullhead	3	-
Brown bullhead	1	C-S-F
Yellow bullhead	3	-
Channel catfish	1	S-F
Tadpole madtom	3	-
Stonecat	1	F
Percopsidae		
Trout-perch	1	F
Gadidae		
Burbot	2	-
Cyprinodontidae		
Banded killifish	1	F
Atherinidae		
Brook silverside	1	F
Gasterosteidae		
Threespine stickleback	1	F
Brook stickleback	3	-
Percichthyidae		
White bass	1	F
White perch	1	C-S-F
Centrarchidae		
Largemouth bass	3	-
Rock bass	1	C-S-F
Smallmouth bass	1	S
Black crappie	1	C-S-F
White crappie	3	-
Bluegill	3	-
Pumpkinseed	1	C-S-F
Percidae		
Fantail darter	3	-
Johnny darter	1	F
Logperch	1	F
Walleye	2	-
Yellow perch	1	C-S-F
Sciaenidae		
Freshwater drum	1	S-F
Cottidae		
Fourhorn sculpin	2	-
Mottled sculpin	1	F
Slimy sculpin	1	F

* 1-Common; 2-Uncommon, although formerly common; 3-Uncommon, present or past.
** C-Commercial species; S-Sport species; F-Forage species.

APPENDIX III

DISTINGUISHING FAMILY CHARACTERISTICS AMONG GREAT LAKES FISH LARVAE

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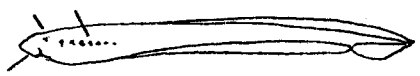
Distinguishing Family Characteristics Among Great Lakes Fish Larvae

Alice J. Lippson

Yolk-Sac Larvae Larvae

Petromyzontidae - lampreys

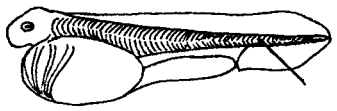
Worm-like, opaque larvae (amnocoete), broad hood-shaped upper lip, external gill openings, rudamentary eyes.



Acipenseridae - sturgeons

Yolk-sac larvae - dense, opaque, darkly pigmented; no adhesive organ; very high myomere count.

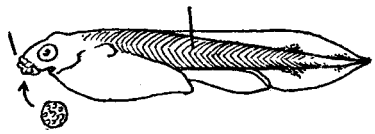
Larvae - ventral suctorial mouth; strongly heterocercal tail; dorsal, anal, and pelvic fins posterior, anal fin origin posterior to dorsal fin origin, pelvic fin well past mid-body.

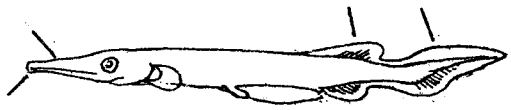


Lepisosteidae - gars

Yolk-sac larvae - large, dense, opaque with mound-like adhesive organ on snout; high myomere count.

Larvae - elongate with well extended snout, remnants of adhesive organ on tip of snout; tail strongly heterocercal moderating with growth; dorsal and anal fins posterior, anal fin origin anterior to dorsal fin origin, pelvic fin ca. at mid-body.

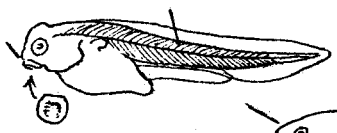


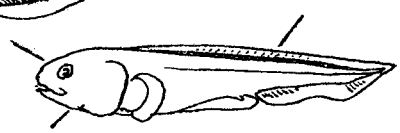


Amiidae - bowfins

Yolk-sac larvae - dense, opaque, with ring-like adhesive organ on snout; high myomere count.

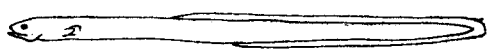
Larvae - head robust, rounded; gular plate develops at throat; tail moderately heterocercal; dorsal fin long, its origin above pectoral fins.





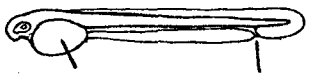
Anguillidae - freshwater eels

Larval stages absent from Great Lakes, elvers with adult characteristics.



Clupeidae - herrings

Yolk-sac larvae - long, slender, highly transparent; yolk small, anterior, oil globules (if present) in posterior of yolk; vent posterior ca. 3/4 or more back on body; origin of dorsal finfold anterior, at nape or slightly behind.

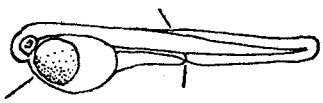


Larvae - elongate; vent more anterior, ca. 2/3 back on body; gas bladder distinct; single dorsal fin, anal fin origin posterior to dorsal fin base.

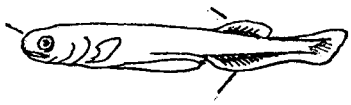


Hiodontidae - mooneyes

Yolk-sac larvae - large, robust, opaque; yolk large ca. 1/2 distance to vent, single, large oil globule in anterior of yolk; vent posterior to midbody ca. 3/5 back on body; origin of dorsal finfold posterior, ca. mid



Larvae - robust; snout bulbous and bluntly squared, protruding; mouth inferior; single dorsal fin posterior, its base over long anal fin; pigmentation sparse, mid-dorsal line beginning at dorsal fin continuing around caudal and vertically to vent.



Salmonidae - trouts

Salmons and trouts

Yolk-sac larvae - large, robust; yolk large, initially pendulous; fin development well advanced before yolk absorbed; vent ca. 2/3 back on body; dorsal finfold with marked identation behind developing dorsal fin.

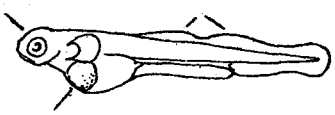


Larvae (alevin) - robust, head rounded; adipose fin; pelvic fin origin below dorsal fin; anal fin origin well posterior to dorsal fin base.



Whitings

Yolk-sac larvae - large, less robust than salmons and trouts; head large; yolk absorbed before fin development; vent ca. 2/3 back on body; dorsal finfold with two indentations.



Larvae - as with salmons and trouts.

Osmeridae - smelts

Yolk-sac larvae - long, slender "herring-like"; head small; yolk in unique position well posterior to pectoral fins with single large anterior oil globule, ventral half peppered with melanophores; vent posterior ca. 3/4 back on body.



Yolk-sac Larvae Larvae

Larvae - elongate, slender; head small; vent position remains posterior; adipose fin develops; anal fin origin posterior to dorsal fin base; gas bladder usually distinct.



Umbridae - mudminnows

Yolk-sac larvae - vent slightly posterior to mid-body; yolk large with many small oil globules; tip of tail extends to margin of caudal finfold.

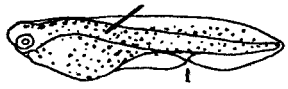


Larvae - body robust; thick, darkened urostyle extends to posterior margin of caudal fin which becomes rounded with growth; pectoral fins low; single dorsal fin and short anal fin posterior on last third of body, body heavily peppered with melanophores.

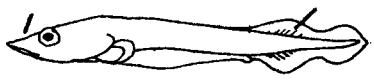


Esocidae - pikes

Yolk-sac larvae - robust, densely pigmented; vent ca. 2/3 back on body.



Larvae - elongate; snout extended, depressed; posterior dorsal and anal fins.



Cyprinidae - minnows and carps

Yolk-sac larvae - yolk long, anteriorly spherical, posteriorly cylindrical; vent usually beyond mid-body.



Larvae - single dorsal fin, gas bladder obvious becoming 2-chambered with growth and usually pigmented dorsally. Pigmentation often in rows; dorso-laterally, mid-laterally, along ventral margin of myomeres and mid-ventrally on abdomen. Anal fin origin below or only slightly behind dorsal fin base, pelvic fin origin below or slightly in advance of origin of dorsal fin.



Catostomidae - suckers

Yolk-sac larvae - recently hatched with long cylindrical yolk, more bulbous anteriorly; vent posterior, 2/3-3/4 back on body.



Larvae - single dorsal fin but with more rays than cyprinids; three rows of pigment (variable); inferior mouth (later stages); gas bladder 2-chambered with growth; anal fin more posterior than in cyprinids.

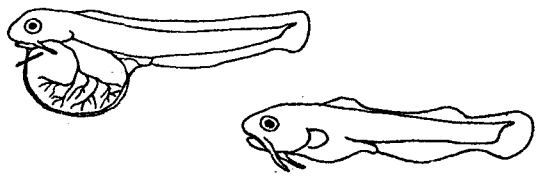


Yolk-sac Larvae Larvae

Ictaluridae - freshwater catfishes

Yolk-sac larvae - barbels evident at hatching large bulbous yolk; vitelline vessels often evident over yolk.

Larvae - adult-like in appearance.



Aphredoderidae - pirate perches

Yolk-sac larvae - small, stubby; vent in normal pre-anal fin position.

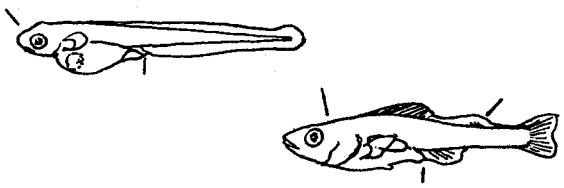
Larvae - stubby, head and body robust; vent migrates to jugular position; single dorsal fin.



Percopsidae - trout perches

Yolk-sac larvae - head large, vent slightly anterior; yolk large with single large oil globule, snout prolonged, mouth inferior; scattered melanophores over ventral half of yolk.

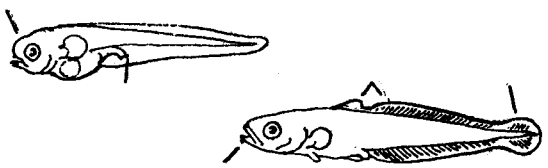
Larvae - head large, snout long; single dorsal; adipose fin; gas bladder distinct.



Gadidae - cods

Yolk-sac larvae - small, slender, transparent; large rounded head; gut short; vent anterior ca. 2/5 back on body opening laterally on finfold.

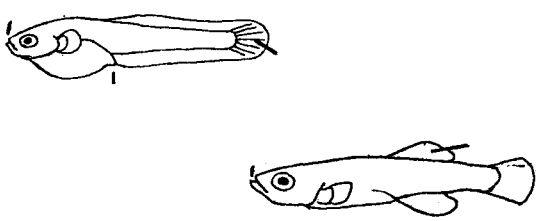
Larvae - elongate; head and snout extended; caudal peduncle tapers to isocercal tail; 2 dorsal fins, 2nd dorsal fin and anal fin long (60 + rays); pelvic fins under pectoral fins; single barbel develops on lower jaw.



Cyprinodontidae - killifishes

Yolk-sac larvae - stubby, robust; vent anterior ca. 2/5 back on body, immediately posterior to yolk; caudal fin with rays at hatching; mouth small, superior.

Larvae - robust; head large; single dorsal fin; caudal peduncle stocky with rounded caudal fin.



Yolk-sac Larvae Larvae

Poeciliidae - livebearers

Yolk-sac larvae - within female.

Larvae - stubby; head large; scales and fins fully developed at birth, mouth small, superior; short single dorsal fin (7-8 rays vs 10 or more in cyprinodonts).

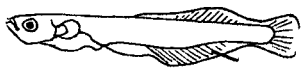


Atherinidae - silversides

Yolk-sac larvae - elongate, slender; vent well anterior ca. 1/4 back on body; pre-anal finfold absent or vestigial; mouth small, terminal.

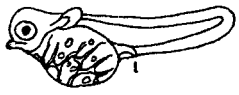


Larvae - elongate, slender; 2 dorsal fins, 1st dorsal small, both dorsal fins over long anal fin.

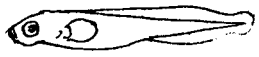


Gasterosteidae - sticklebacks

Yolk-sac larvae - short, stubby; vent at mid-body or slightly posterior; vitilline vessels over yolk; few small oil globules.

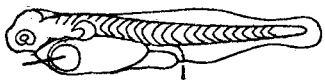


Larvae - well pigmented, snout rounded initially becoming pointed with growth; head sloping, mouth small, superior; older larvae with narrow caudal peduncle and fusiform body.



Percichthyidae - temperate basses

Yolk-sac larvae - vent slightly posterior to mid-body; single large oil globule in anterior of yolk; myomere count moderate (23-26).

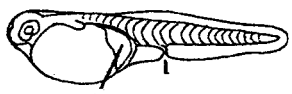


Larvae - mouth well developed, teeth develop early; single-chambered gas bladder distinct; uncoiled gut "S" shaped; 1st spinous dorsal fin develops secondarily, separate from 2nd soft-rayed dorsal fin.



Centrarchidae - sunfishes

Yolk-sac larvae - yolk large, bulbous; one or more oil globules, often single large globule in posterior of yolk; vent anterior to mid-body, ca. 2/5 or less back on body.



Larvae - robust, gas bladder distinct; usually gut short, coils with growth; head large, mouth moderate; spinous and soft dorsal fins continuous.



Yolk-sac Larvae Larvae

Percidae - perches

Yolk-sac larvae - vent at mid-body; single large oil globule in anterior of yolk; pectorals well developed at hatching; myomere count higher than in percichthyids or centrarchids (30-42 or more).

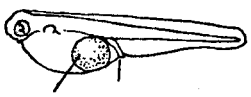


Larvae - spinous dorsal fin separate from soft-rayed 2nd dorsal fin; pectoral fins usually large.



Sciaenidae - drums

Yolk-sac larvae - small, 3-5 mm; gut short; large single oil globule, myomere count moderate (ca. 25); vent anterior to mid-body.



Larvae - heavy truncated body; large, deep head, throat broad and oblique; gas bladder distinct; preopercular spines develop; 1st spinous and 2nd soft-rayed dorsal fins continuous, 2nd dorsal long (24 + rays).



Cottidae - sculpins

Yolk-sac larvae - large, robust; head very large, body stocky with large rounded yolk; gut short, immediately adjacent to posterior of yolk; vent anterior ca. 2/5 back on body.



Larvae - yolk retained until after fin rays well formed; size approximately same as yolk-sac stage until full fin development; head large; snout extended sloping; preopercular spines develop; pectoral fins very large; 2 dorsal fins, second dorsal fin and anal fin long; caudal fin spatulate.



This pictorial key has been developed for use at the Great Lakes Ichthyoplankton Workshop, sponsored by the United States Fish and Wildlife Service and held at Ann Arbor, Michigan, April 19-21, 1976. It is a preliminary attempt at a methodology for the separation of ichthyoplankton specimens at least to the family level. It is presented with the expectation that further refinement will be possible as a result of the workshop experience.

Typical body form representative of the family is used except where only one species of the family is distributed in the Great Lakes. In this case, the illustration is species-specific if larval stages have been described. Otherwise, family characteristics of species from other regions are used.

References used for the key are those which appear under each family in "Manual for Identification of Early Developmental Stages of Fishes of the Potomac River Estuary" (PPSP-MP-13 by Lippson and Moran, Environmental Technology Center, Martin Marietta Corporation). Additional references for those families not included in the Potomac River manual are as follows:

Petromyzontidae:

Vladykov, V.D. 1960. Description of young amnocoetes belonging to two species of lampreys: Petromyzon marinus and Entosphenus lamottenii. J. Fish. Res. Bd. Can. 17(2): 267-289.

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Knight, A.E. 1963. The embryonic and larval development of the rainbow trout. Trans. Amer. Fish. Soc. J. 92(4):344-355.

Wales, J.H. 1941. Development of steelhead trout eggs. Calif. Fish and Game, 27(4):250-260.

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Mazuranich, J.J. and W.E. Nielson. 1959. Whitespot disease of salmon fry. Progressive Fish Culturist 21(4):172-176.

Dumas, R.F. 1966. Observations on yolk sac constriction in landlocked Atlantic salmon fry. Progressive Fish Culturist 28(2):73-75.

Palmer, D.D. et al., 1951. The effects of retardation of the initial feeding on the growth and survival of salmon fingerlings. Progressive Fish Culturist 13(2):55-62.

Osmeridae:

Kendall, W.C. 1927. The smelts. Bull. U.S. Bur. Fish. 42 (doc. 1015):217-375.

Bigelow, H.B. and W.C. Schroeder. 1963. Family Osmeridae, pp. 553-572. In Fishes of the Western North Atlantic. Part Three. Sears Foundation for Marine Research, Yale Univ., 630 pp.

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildlife Service, Fish. Bull 74: viii and 577 pp.

Aphredoderidae:

Mansueti, A.J. 1963. Some changes in morphology during ontogeny in the pirateperch, Aphredoderus s. sayanus. Copeia 1963(3):546-557.

Percopsidae:

Fish, M.P. 1932, op. cit.

Gadidae:

Fish, M.P. 1932. op. cit.

Sciaenidae:

Fish, M.P. 1932. op. cit.

Taber, C.A. 1969. Distribution and identification of larval fishes in the Buncombe Creek Arm of Lake Texana with observations on spawning habits and relative abundance. Univ. of Oklahoma. Ph.D. dissertation under direction of Oklahoma Fish and Game Council, 106 pp.

Cottidae:

Fish, M.P. 1932. op. cit.

Bigelow, H.B. and W.E. Schroeder 1953. op. cit.

APPENDIX IV

LIST OF WORKSHOP ATTENDEES

Name	Affiliation
Charles Anjard	Ichthyological Associates, Inc.
R. M. Bailey	University of Michigan
Ralph Barr	NUS Corporation
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Paul Bradfield	Bay DeNoc Community College
Bruce Bushweiler	CDM/Limnetics
Richard Cole	Michigan State University
Cynthia J. Cook	NUS Corporation
John E. Cooper	Aquatic Ecology Associates
C. Lawrence Cooper	Ohio State University
John Dorr III	University of Michigan
George Drewry	University of Maryland
J. R. Edmunds	Ecological Analysts, Inc.
Lee Emery	U. S. Fish and Wildlife Service
Dan Faber	National Museum of Natural Science, Canada
Carlos Fetterolf	Great Lakes Fishery Commission
Ronald L. Fobes	Consumers Power Company
Eugene Fritz	U. S. Fish and Wildlife Service
Ronald A. Fritzsche	University of Maryland
Lee Fuiman	Cornell University
Joseph L. Geiss	Minnesota DNR
Mary Gessner	Ohio State University
C. P. Goodyear	U. S. Fish and Wildlife Service
Jerry D. Hardy, Jr.	University of Maryland

Name	Affiliation
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Roy J. Irwin	U. S. Fish and Wildlife Service
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David J. Jude	University of Michigan
John Kennedy	Swanson Environmental, Inc.
Ron Kernehan	Ichthyological Associates, Inc.
Leslie Knapp	Smithsonian Institute
Alice J. Lippson	Martin Marietta Laboratories
Jules J. Loos	Academy of Natural Sciences
Lawrence Lubbers	University of Maryland
Bruce Manny	U. S. Fish and Wildlife Service
F. Douglas Martin	University of Maryland
Timothy J. Miller	University of Michigan
H. W. Mohr, Jr.	Ichthyological Associates, Inc.
R. Lynn Moran	Martin Marietta Laboratories
Kenneth N. Mueller	Northern States Power Company
Donald Nelson	Michigan DNR
Stephen Nepzy	Ontario Ministry of Natural Resources
Joel E. Schaeffer	Michigan
Eilen M. Setzler	University of Michigan
John Shauver	Michigan DNR
Richard Seifert	EPA
Darrell E. Snyder	Colorado State University
Frank J. Tesar	University of Michigan

Name	Affiliation
Nancy J. Thurber	University of Michigan
Waldo W. Wakefield	Academy of Natural Sciences
Johnson C. L. Wang	Ecological Analysts, Inc.
Ronald Waybrandt	Michigan DNR
Robert Welford	U. S. Fish and Wildlife Service
Robert Werner	State University of New York
Kathryn V. Wood	University of Maryland

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