Dorsal and anal pterygiophore interdigitation patterns in four species of Morone (Teleostei, Percichthyidae) : an aid to larval identification

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Dorsal and anal pterygiophore interdigitation patterns in four species of 
Morone (Teleostei, Percichthyidae) -
An aid to larval identification$^{1,2}$

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ABSTRACT

The diagnostic potential of dorsal and anal pterygiophore interdigitation patterns was examined in larval stages of Morone saxatilis, M. chrysops, M. americana and M. mississippiensis. The number and position of pterygiophores relative to interneural spaces 1-6 and 10-13 and interhaemal spaces 12-15 as well as total number of dorsal and anal pterygiophores are characters useful in delimiting larvae of American Morone species. Interdigitation patterns useful in separating M. mississippiensis and M. americana larvae were not found, however these two species may not co-occur.
The genus *Morone* Mitchill comprises four American species (Robins et al. 1980; Setzler et al. 1980): *M. americana* (Gmelin), white perch; *M. saxatilis* (Walbaum), striped bass; *M. chrysops* (Rafinesque), white bass; and *M. mississippiensis* Jordan and Eigenmann, yellow bass. Representatives of the genus can be found in both freshwater and marine habitats where species pairs are sympatric throughout much of the range. *Morone mississippiensis* and *M. chrysops* naturally co-occur along the Mississippi River drainage, Texas and Oklahoma with *M. chrysops* also inhabiting the Great Lakes (Hubbs and Lagler 1964). *Morone americana* and *M. saxatilis* inhabit the Atlantic coastline (Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Scott and Crossman 1973; Lee et al. 1978) and *M. saxatilis* has been introduced along the Pacific coast (Setzler et al. 1980). Recent evidence indicates that *M. americana* and *M. chrysops* now are sympatric in the Great Lakes region (Scott and Christie 1963; Scott and Crossman 1973; Lee et al. 1978).

Difficulty in identifying larvae of the various *Morone* species has prompted extensive efforts to describe diagnostic external characters (Fish 1932; Yellayi and Kilambi 1969; Dorsa and Fritzche 1979; Schultz 1980; Mansueti 1958; Doroshev 1970; Hardy 1978; Drewry 1981; and others). However, genetic, environmental and preservative induced character variability may be responsible for continued identification error. Recently, Fritzche and Johnson (1980) described osteological characters useful in the identification of two of the four American *Morone* species. Based primarily on cultured material, Fritzche and Johnson (1980) relied on the morphology and
position of rostral and predorsal cartilages and anterior anal and
dorsal fin pterygiophores to separate larval white perch and striped
bass. Since the arrangement of pterygiophores, spines and rays has
been shown to be useful in delimiting various teleostean fishes
(Matsui 1967; Potthoff 1974, 1975, 1980; Houde and Potthoff 1976), we
have examined the position of pterygiophores in relation to vertebrae
in the larvae of M. saxatilis, M. chrysops, M. americana and M.
mississippiensis in a search for diagnostic patterns. Our purpose was
to confirm the observations of Fritzche and Johnson (1980) using wild
material, quantify the natural variability in this suite of characters
and expand the analysis to include all American Morone species.

METHODS

Specimens (N=185) utilized for this study were obtained from a
variety of sources. All specimens, with the exception of two larval
yellow bass (M. mississippiensis; 11, 18 mm SL) which were raised from
eggs under laboratory conditions, were collected by plankton net.
Institutional abbreviations used are: VIMS - Virginia Institute of
Marine Science; CBL - Chesapeake Biological Laboratory, Solomons,
Maryland; CLEAR - Center for Lake Erie Research; SAI - Steimle and
Associates, Inc. In the following list, we record species name,
number of larvae examined (N), institutional source, collection
locale, date of collection, and length range of specimens examined
(measured with an ocular micrometer and reported in mm SL): Morone
saxatilis, N = 20, VIMS, York R., Virginia, spring, 1980, 11.3 - 17.1;
Morone saxatilis, N = 20, CBL, Potomac R., Maryland, spring, 1980,

Larvae were cleared and stained following the methods of Dingerkus and Uhler (1977) and examined in 50% glycerin under a binocular microscope. Predorsal bone (or cartilage) and dorsal or anal pterygiophore interdigitation were determined following the methods of Potthoff (1975, 1980) and Houde and Potthoff (1976). The number and position of these elements relative to interneural or interhaemal spaces (Fig. 1) were recorded for each specimen and digit sequences were later analysed using computer pattern recognition. Occasionally, the proximal tip of an anal or dorsal pterygiophore would coincide closely with the distal tip of its associated neural or haemal spine. In these instances, the position of the fin element was difficult to determine but recorded in the anterior-most interneural or interhaemal space.

RESULTS

Dorsal Fin Pterygiophores

The position of the first dorsal-spine bearing pterygiophore and the presence or absence of a pterygiophore in interneural space 10 or 11 (INS 10 or INS 11) are characters which delimit the larvae of Morone saxatilis, M. chrysops, M. americana, and M. mississippiensis
In larvae of *M. saxatilis*, the first dorsal pterygiophore is most frequently positioned in INS 4, posterior to the third neural spine (Fig. 1; Fritzsche and Johnson 1980). This element is anterior to the third neural spine in larvae of *M. americana*, *M. chrysops* and *M. mississippiensis*, and most frequently occupies INS 3 together with the third (or most posterior) predorsal bone (or cartilage). In our sample of 185 specimens, 12 patterns of predorsal and pterygiophore interdigitation were observed within interneural spaces 1-6 (Table 1). Of the four patterns observed in larvae of *M. saxatilis*, three were characteristic of striped bass only and occurred in 87.5% (35/40) of the sample. Only one pattern (of 9 observed) was common in larvae of *M. chrysops*, *M. americana* and *M. mississippiensis* (Table 1), occurring in percent frequencies of 78%, 84% and 77%, respectively.

The absence of a pterygiophore in INS 10 or INS 11 is a useful character identifying larval white perch and yellow bass (Fig. 1, Table 2). In our sample, eleven patterns of pterygiophore interdigitation were observed within interneural spaces 10-13 (Table 2). Patterns without blank interneural spaces characterized all larvae of *M. saxatilis* and *M. chrysops* and only 2.5% (2/80) of the combined sample of *M. americana* and *M. mississippiensis* larvae. The absence of a pterygiophore in INS 10 was the predominant pattern in larvae of white perch and yellow bass, occurring in 89% (71/80) of our combined sample (Table 2). Since pterygiophores of the soft dorsal fin first appear as cartilage (Fritzsche and Johnson 1980), the absence of a pterygiophore in INS 10 is diagnostic of *Morone* larvae in early stages of development (Fig. 2). Although incompletely
developed, _M. saxatilis_ flexion larvae 8.5 - 9.0 mm SL/NL are recognizable since the ventral tips of the proximal radial (Fig. 2, PR2) supporting the second soft ray lies anterior to the vertical plane extended from the tip of the eleventh neural spine (Fig. 2), NS11). In addition, the distance between the ventral tips of PR1 and PR2 is greater than the distance between the tips of NS10 and NS11 in _M. americana_ and less than that distance in _M. saxatilis_. Although not figured, these characters separate early larvae of _M. chrysops_ and _M. mississippiensis_ as well.

Excluding three predorsal elements, Morone larvae in our sample possessed 19-23 total dorsal pterygiophores (Table 3). As detailed by Fritzche and Johnson (1980), the anterior eight pterygiophores support 10 spines of varying lengths. The remaining elements support soft rays (Fig. 1). Although total counts overlapped among the four species, _M. chrysops_ larvae possessed modal counts which exceeded those of all other species (Table 3).

**Anal Fin Pterygiophores**

The number and position of pterygiophores within interhaemal spaces 12-15 separate larvae of _M. saxatilis_ and _M. chrysops_ from _M. americana_ and _M. mississippiensis_ (Table 4, Fig. 1). In our sample of 185 larvae, 17 patterns of interdigitation were observed (Table 4) and, with the exception of five specimens, pattern overlap between the above-named species pairs did not occur. Six patterns within interhaemal spaces 12-15 occurred in larval striped bass and white bass and were characterized by the absence of the anterior
spine-bearing pterygiophore in interhaemal space 12 (IHS 12). This element was most frequently positioned together with the first soft ray-bearing pterygiophore in IHS 13. In larval white perch (as well as yellow bass), the first anal pterygiophore is notably longer and more massive than in striped bass and this relative difference becomes exaggerated with growth (Fritzsche and Johnson 1980). As a result, greater variability in interdigitation patterns was observed in *M. americana* larvae (Table 4) since the proximal tip of this stout element often extended into IHS 12.

In our sample, specimens possessed 9-14 total anal pterygiophores. The first anal element supports three spines with succeeding pterygiophores supporting soft rays (Fig. 1). Larvae of *M. chrysops* were distinguishable from those of *M. americana* and *M. mississippiensis* by virtue of total counts (Table 3). In addition, total anal element counts of striped bass exceeded those of yellow bass.

**DISCUSSION**

The diagnostic potential of pterygiophore interdigitation patterns in the genus *Morone* was first recognized by Woolcott (1957) in an examination of adult osteology. Although unable to detect useful anal pterygiophore patterns, Woolcott (1957) demonstrated differences in total dorsal pterygiophore counts and the location of certain elements in relation to neural spines. It is not surprising, therefore, that our results and those of Fritzsche and Johnson (1980) illustrate the utility of this suite of characters in identifying
young stages of American Morone species. Indeed, the number and position of anal and dorsal pterygiophores in relation to vertebrae are characters which have been successfully used to delimit larval scombrids (Matsui 1967; Potthoff 1974, 1975), larval sparids (Houde and Potthoff 1976) and larval coryphaenids (Potthoff 1980). An important consideration in these studies, however, is the extent to which natural variability affects character utility. Previous investigations (Matsui 1967; Potthoff 1974, 1975; Houde and Potthoff 1976) have emphasized variability (expressed as percent occurrence) of a particular pterygiophore number in a single interhaemal or interneural space. Our data indicate that patterns of interdigitation (ie, sequence of pterygiophore numbers in more than one space), when judiciously chosen, exhibit less variability and are more useful as diagnostic characters.

Throughout our examination, we could not find interdigitation patterns which would delimit the larvae of white perch and yellow bass and total element overlap was great. Woolcott (1957) was unable to separate M. mississippiensis and M. americana adults using a variety of osteological characters but Whitehead and Wheeler (1966) delimit the species based on dorsal spine length and adult pigmentation. The extent to which these nominal species are sympatric is unknown, however current distributional data (Lee et al. 1978) do not indicate geographic overlap.

ACKNOWLEDGMENTS

During independent studies on development and ecology of larval Morone, we participated in a Morone identification workshop held in
Solomons, Maryland at The Sixth Annual Larval Fish Conference of The American Fisheries Society - Early Life History Section. We extend our appreciation to Dr. Douglas Martin (CBL) who organized these meetings, loaned larval material and encouraged the completion of this report. Special thanks to Robert W. Middleton (VIMS) for assistance with computer analysis.
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Mansueti, R. 1958. Eggs, larvae and young of the striped bass, Roccus saxatilis. Maryland Department of Research and Education, Chesapeake Biological Laboratory, Contribution No. 112.


FOOTNOTES

1 Contribution number 0000 of the Virginia Institute of Marine Science and number 000 of the Center for Lake Erie Research.

2 This research was supported in part by the National Marine Fisheries Service, Grant No. NA81FAD VA5B and by the U. S. Fish and Wildlife Service, Contract No. 14-16-0009-81-032.
Table 1. Patterns of predorsal and pterygiophore interdigitation within interneural spaces 1-6 in a sample of 185 *Morone* larvae. Abbreviations used are: P - predorsal bone (or cartilage), MS - *M. saxatilis*, MC - *M. chrysops*, MA - *M. americana*, MM - *M. mississippiensis*.

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| P P P P P P       | 2 | 2 | 1 | 15
| P P P P P P       | 1 | 2 | 2 | 1
| P P P P+1 P+1     | 1 | 2 | 1 | 5 51 42 23
| P P P P+1 P+1     | 2 | 1 | 1 | 5 4 4 4
| P P P P+2 P+2     | 1 | 2 | 1 | 5
| P P P P+2 P+2     | 2 | 1 | 1 | 2
| P P P+1 P+1      | 1 | 1 | 2 | 1
| P O PP+1 PP+1     | 1 | 2 | 1 | 1
| P PP PP PP P+1     | 1 | 1 | 2 | 1 | 3 2
| P PP PP PP P+1     | 1 | 2 | 1 | 1 | 1
| P PP PP P+1       | 3 | 1 | 1 | 1

TOTAL 40 65 50 30
Table 2. Patterns of pterygiophore interdigitation within interneural spaces 10-13 in a sample of 185 Morone larvae. Abbreviations used are MS - *M. saxatilis*, MC - *M. chrysops*, MA - *M. americana*, MM - *M. mississippiensis*.

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TOTAL 40 65 50 30
Table 3. Frequency of total dorsal and anal pterygiophores in a sample of 185 Morone larvae. Total dorsal element counts exclude predorsal bones.

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<th>DORSAL FIN</th>
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<td>M. chrysops</td>
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<td>3 45 15 2</td>
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<tr>
<td>M. americana</td>
<td>33 17</td>
<td>5 45</td>
</tr>
<tr>
<td>M. mississippiensis</td>
<td>3 27</td>
<td>69 11</td>
</tr>
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</table>
Table 4. Patterns of pterygiophore interdigitation within interhaemal spaces 12-15 in a sample of 185 Morone larvae. Abbreviations used are MS - _M. saxatilis_, MC - _M. chrysops_, MA - _M. americana_, MM - _M. mississippiensis_.

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**TOTAL** 40 65 50 30
FIGURE CAPTIONS

Figure 1. Diagramatic representation of the most frequently observed patterns of predorsal, dorsal and anal pterygiophore interdigitation in four species of *Morone*. Larger numerals indicate vertebral number. Smaller numerals indicate interneural or interhaemal space designation.

Figure 2. The arrangement of neural spines and dorsal pterygiophores in *Morone americana* (A-8.5 mm SL; B-11.2 mm SL) and *M. saxatilis* (C-8.5 mm SL; D-11.1 mm SL). Abbreviations used are NS9-neural spine of ninth vertebra; NS12 - neural spine of 12th vertebra; PR1 - proximal radial supporting the first soft ray of the second dorsal fin; PR2 - proximal radial supporting the second soft ray of the second dorsal fin; numerals indicate respective interneural space designations. Stippling indicates positive stain reactions (Alcian Blue or Alizarin Red).
saxatilis

chrysops

americana

mississippiensis

\( \square = \text{PREDORSAL BONE} \)

\( \text{/ = SPINE BEARING PTERYGIOPHORE} \)

\( \text{/ = RAY BEARING PTERYGIOPHORE} \)