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**Early Stages of Fishes
in the
Western North Atlantic Ocean**

**(Davis Strait, Southern Greenland
and Flemish Cap to Cape Hatteras)**

Volume Two

Scorpaeniformes through Tetraodontiformes

Michael P. Fahay

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Introduction to Volume Two

Justification for separation of taxa

Volume Two of the present monograph includes the larvae of fish species in four orders: Scorpaeniformes, Perciformes, Pleuronectiformes and Tetraodontiformes. This separation point is not only a convenient place to separate the two volumes based on total number of taxa, but it also occurs at a point that might be logical in a systematic sense. With two exceptions, the taxa included in Volume Two all belong to the group of percomorphs proposed to be remainders after isolation of two identifiable monophyletic sub-groups, Atherinomorpha and Smegmamorpha (*sensu* Johnson and Patterson, 1993) containing seven monophyletic orders covered in Volume One. The exceptions include the family Dactylopteridae, here included in the order Scorpaeniformes with a brief discussion detailing why Johnson and Patterson (1993) include it in an expanded (and independent) order Dactylopteriformes. The other exception pertains to the Mugilidae, here included as a family of the perciform suborder Mugiloidei, but elsewhere considered to be an order within the Smegmamorpha (Johnson and Patterson, 1993). Note also the inclusion of the gobiesocids in a perciform suborder Gobiesocoidei, rather than in the Batrachoidiformes as considered by some authors.

Relationships of Scorpaeniformes to Perciformes

Scorpaeniformes may be a specialized group of Perciformes, rather than a precursor to that polyphyletic group (e.g. Johnson and Patterson, 1993). Members of families within the Scorpaeniformes all have a suborbital stay (formed by the elongation of the 3rd and 4th infraorbital bones, usually connected to the preopercle) that is the basis for the term "mail-cheeked fishes". Larval scorpaeniforms are usually characterized by having very early forming, large pectoral fins and very spiny heads, often including well developed parietal ridges (see Washington *et al.*, 1984a). In other respects, however, these fishes can be classified as perciforms, whose larvae are also characterized by arrays of head spines. Until a consensus on this controversy is reached, the classification used in the present volume follows that in recent usage (e.g. Eschmeyer, 1990; Nelson, 1994).

Most ichthyologists agree that the classification of fishes is in a state of flux (e.g. Stiassny *et al.*, 2004). The classification of the nominal order Perciformes is particularly chaotic (as well as polyphyletic) and one of its nominal suborders, Percoidei, is nothing more than a wastebasket of species that do not obviously belong elsewhere. There are no described diagnostic characters that define this group. It is not the purpose of the present atlas to contribute to this chaos. Therefore, "perciform" suborders are presented alphabetically in order to avoid implying relationships. Moreover, families within several suborders (including Percoidei) are also presented alphabetically, since monophyly has not been established for many of these suborders.

Head spines and spinous scales

Many larvae of fishes in the orders Scorpaeniformes and Perciformes have an array of spines on their heads. These are variously developed in larvae of these two orders, ranging from none in a very few "percoids", cyclopterids and liparids, to a simple series of spines along the edge of the preopercle in many taxa, to a complex pattern of spines and spiny ridges ornamenting several major bones of the skull or upper pectoral girdle. Because of the importance of this skull ornamentation, terminologies of head spines (with names based on the bone on which the spines originate) are repeatedly portrayed throughout this monograph. Beginning with the Agonidae (Scorpaeniformes), and continuing through Perciformes, the presence or absence and nature of head spines are listed in a "Head Spine Checklist" in most species accounts. Spinous scales (or body spicules) are transitory characters in the larvae of some taxa that have not been adequately studied. In addition to their simple presence or absence (mentioned in several descriptions), the physical nature of these structures varies widely, as does the sequence in which they form on the larval body. Further attention to the development (and disappearance) and structure of these features would add another important data set in the effort to understand phylogenetic relationships, as it has in *Coryphaena* and *Rachycentron*, for example (G. D. Johnson, 1984).

Pleuronectiformes

Species in this large order are either dextral (meaning both eyes are situated on the right side of the head) or sinistral (where both eyes are situated on the left side of the head). Larvae undergo a remarkable and well-described transformation, during which one of the eyes migrates to the other side, either over the dorsal ridge, or through the head under the anterior dorsal fin. Coincident with this eye migration is a crossing of the optic nerves. Most non-pleuronectiform fishes have a dimorphic optic chiasma, where the nerve of the right or left eye is dorsal to the other with approximate equal frequency (Hensley and Ahlstrom, 1984). Most flatfishes, on the other hand, have monomorphic optic chiasmata. For example, in the 'left-eyed' Paralichthyidae, the right optic nerve is always dorsal to the left, whereas in the 'right-eyed' Pleuronectidae, the left optic nerve is always dorsal to

the right. Fishes in the Soleidae and Cynoglossidae, however, retain the truly dimorphic condition, where either condition might pertain. See Hensley and Ahlstrom (1984) for a complete discussion of exceptions to these rules and how interpretation of the optic chiasma condition contributes to studies of phylogenetic relationships. Pleuronectiformes is presumably monophyletic, although the question is currently open. A complete discussion of compositions of constituent groups, osteological characters in adults and an exposition of larval characters may be found in Ahlstrom *et al.* (1984a) and Hensley and Ahlstrom (1984).

Tetraodontiformes

Adults and larvae of fishes in this order exhibit extreme specializations. In many species, fin spines, fin rays, or entire fins and their supporting structures are reduced or lost. Vertebral numbers are typically low. Many have scales and/or teeth that are greatly modified. Several taxa exhibit extensive spination over their heads and bodies or have modified scales forming bony carapace plates surrounding the larval body. Members of two families are inflatable. Within the present study area, larvae of three species in Molidae may be collected. These taxa totally lack a caudal fin and ural bones. Instead, a "pseudocaudal" fin (also termed a "clavus") is formed by modified elements of the dorsal and anal fins (pterygiophores and fin rays) converging toward the caudal region during ontogeny (Tyler, 1980; Leis, 1984a; Johnson and Britz, 2005). The anterior dorsal spines in many taxa are equipped with a locking mechanism that serves to hold the first spine rigidly upright, and some have a "supra-neural element" (see glossary) that is positioned posterior to the fin spines, but anterior to the fin rays. See several chapters in the Tetraodontiformes section of Leis and Carson-Ewart (2004) for descriptions of many of these ontogenetic specializations summarized at the family level and for an exposition of ontogenetic characters, based on Indo-Pacific material, that is more comprehensive than the chapter in the present monograph.

Contribution of ontogeny

The purpose of this monograph is to demonstrate similarities and differences in larvae of given groups with the expectation that the perspective provided by the study of ontogenetic development will eventually contribute to the establishment of monophyly (or not) in these groups. The study and description of ontogeny not only illustrates similarities and differences in the morphology of early stages. The recent, increased use of clearing and differential staining techniques (for example Potthoff *et al.*, 1986) allows analysis of character transformation and homology, and often helps identify cases of homoplasy in phylogenetic studies. Taxa treated in Volume Two are particularly rich in their possession of transitory characters, and most of these characters are clearly highlighted, especially when they are shared by a number of taxa.

Species Accounts