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Sturgeons and paddlefishes (Acipenseriformes)

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Abstract

The Order Acipenseriformes includes 25 living sturgeon species and two living paddlefish species, which are commonly considered “living fossils.” Phylogenetic analyses have supported two morphological divisions within acipenseriforms, Polyodontidae (paddlefishes) and Acipenseridae (sturgeons). Divergence times from molecular data range from 184 million years ago (Ma) to 114 Ma, although the oldest time is considered to be the most reliable and is in better agreement with the fossil record. The molecular estimates and fossil record suggest that the major lineages of Acipenseriformes diversified in the Jurassic and early Cretaceous (~180–100 Ma), probably associated with continental breakup.

The extant sturgeons (Acipenseridae, containing four genera—Acipenser, Huso, Pseudoscaphirhynchus, and Scaphirhynchus) and paddlefishes (Polyodontidae, containing two monospecific genera—Polyodon and Psephurus) with some extinct families form a monophyletic group of the ray-finned fishes, the Order Acipenseriformes. Sturgeons are diagnosed by presenting five rows of bony scutes or plates on their body, four barbels in front of mouth, and absence of teeth in adults. Paddlefishes are diagnosed by their paddle-like snout, absence of large scutes on their body, and minute barbels on their snout (1). Additionally, Polyodon is best known for its filtered-feeding habit based on numerous thin, elongate gill rakers unique to them among sturgeons and paddlefishes (2).

Acipenseriforms only inhabit the Northern Hemisphere, and the present biogeographic distribution of the extant species of this group reflects ancient relationships among fish faunas of Europe, Asia, and North America. Extant representatives are in two families with six genera and 27 species. Here, we review the relationships and divergence times of the major groups of acipenseriforms (Fig. 1).

Until recently, our knowledge of the phylogenetic relationships of sturgeons and paddlefishes was mainly based on anatomical studies (3, 4). Researchers usually agree that the diversification of the living acipenseriforms may go back to the Jurassic, where sturgeons and paddlefishes were already diversified (5).

The first comprehensive study (6) using molecular data, partial sequences of the mitochondrial genes cytochrome b (cyt b), 16S rRNA, and 12S rRNA, drew three major conclusions: the Pallid Sturgeon, Scaphirhynchus albus, was suggested as the closest species to all species of Acipenser and Huso; the two Huso species were embedded within Acipenser; and three major clades were proposed. Those clades were Acipenser sturio–Acipenser oxyrinchus, Acipenser schrenckii–Acipenser transmontanus, and all Ponto-Caspian species plus Acipenser dabryanus and Acipenser brevirostrum. However, these conclusions were tentative due to both limited taxon sampling as well as use of relatively short, partly nondiagnostic, gene fragments.

More recently, studies using combined DNA data sets (4012 bp) from five (7) mitochondrial genes (cyt b, 12S rRNA, cytochrome c oxidase subunit II, tRNAala, and tRNA Arg) and two (8) mitochondrial gene regions (16S rRNA and NADH5) and comprehensive taxonomic coverage resulted in five well-supported conclusions: (i) the two species of paddlefish form a monophyletic clade;

Fig. 1 A juvenile Shortnose Sturgeon from North America, Acipenser brevirostrum. Credit: M. H. Sabaj.

Acipenseriformes has existed at least since the early Jurassic (~200 Ma), and all fossil and recent taxa are from the Holarctic biogeographic region (2). Mé~?e Atlantic and Pacific Oceans seemingly began to open during the Jurassic and have continued opening during the Cretaceous. About 120 million years ago, the Tethys Sea shrank further, eventually becoming the Black, Caspian, and Aral Seas (12). These geological events appear to have played an important role in acipenseriform diversification and evolution (6, 10). In summary, the acipenseriform timetree shows Jurassic to mid-Cretaceous diversification of sturgeons and paddlefishes, which is indirectly supported by fossil evidence (3, 4, 13) and is consistent with continental movements and paleogeography.

Acknowledgment
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References
Table 1. Divergence time estimates (Ma) and their confidence/credibility intervals (CI) between sturgeons and paddlefishes (Acipenseriformes).

<table>
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<td></td>
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<tr>
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<td>184</td>
<td>184</td>
<td>200–150</td>
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Note: The estimates are from a Bayesian relaxed clock analysis of two data sets: (a) cytochrome b gene (b) complete mitochondrial genome data. The node time in the timetree uses estimate (a).
