

Observations on the skeleton of the heterocercal tail of sharks (Chondrichthyes: Elasmobranchii)

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Abstract

This paper presents new illustrations and descriptions of the anatomy of the heterocercal tail of twelve species of sharks represented by multiple adult specimens. Nine species from the family Carcharhinidae were examined (bull shark, *Carcharhinus leucas*; blacktip shark, *C. limbatus*; dusky shark, *C. obscurus*; sandbar shark, *C. plumbeus*; tiger shark, *Galeocerdo cuvieri*; Atlantic sharpnose shark, *Rhizoprionodon terraenovae*; bonnethead, *Sphyrna tiburo*; great hammerhead, *S. mokarran*; and scalloped hammerhead, *S. lewini*). We also studied one species of Alopiidae (common thresher shark, *Alopias vulpinus*), as well as one species of Ginglymostomatidae (nurse shark, *Ginglymostoma cirratum*) and one species of Triakidae (smooth dogfish, *Mustelus canis*). Our most interesting observations concern anatomical relationships of the hemal arches and spines that support the ventral fin-web of the hypochordal lobe of the caudal fin and the modified neural arches and spines that support the epichordal portion of the caudal fin. Not surprisingly, the patterns of these skeletal elements differ in many details from the patterns described previously for the heterocercal caudal fin of actinopterygians such as paddlefishes, and these differences offer insight into general aspects of the anatomy of heterocercal caudal fins. Additionally, variation in caudal anatomy documented here suggests its potential as a source of phylogenetic characters at the species, generic, family and ordinal levels. This paper is a contribution to a symposium honoring Hans-Peter Schultze and his many contributions to the anatomy and systematics of fossil and living fishes.

Introduction

Several functional anatomical studies of heterocercal tails in sharks and sturgeons have been made (e.g., THOMSON 1976, FERRY & LAUDER 1996, LIAO & LAUDER 2000). However, very little detailed information is available concerning the anatomy of the endoskeletal supports of heterocercal tails (e.g., see BEMIS & GRANDE 1999 for polyodontids and HILTON, this volume for acipenserids). Historically important works on the skeleton of elasmobranchs such RYDER (1884), GARMAN (1913) and REMANE (1936) provide broad comparisons among taxa and treat aspects of skeletal development, but do not provide details concerning anatomical variation in the caudal skeleton necessary for rigorous phylogenetic comparisons among taxa. Although there is a long history of using vertebral calcification patterns in sharks for phylogenetic inference stemming from the work of HASSE (1879, 1882, 1885), most contemporary studies of the vertebrae of sharks concern age and growth determination rather than comparative anatomy (e.g., SIMPFENDORFER et al. 2002). One of the few works to document caudal skeletal elements of elasmobranchs is MIVART (1879); his interpretation of the caudal fin of *Mustelus antarcticus* is reproduced in Figure 1. Although we differ from Mivart about the interpretation of the homologies of some caudal elements, he described features of the caudal fin also observed by us. For instance, in his account of *M. antarcticus*, he noted that the hemal arches and spines (although he termed them differently) are not fused together near the base of the tail, but that they are fused into single elements more distally. SPRINGER & GARRICK (1964) undertook a broad survey of vertebral numbers among sharks, focusing on carcharhinids, and suggested that such counts could be used for systematic studies. We agree, and note

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