

# FUNCTIONAL MORPHOLOGY OF DORSAL FINS IN TWO SHARK SPECIES

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## INTRODUCTION

Contrary to most teleost fishes, sharks lack a gas bladder and despite high lipid content in the liver are negatively buoyant [1]. Shark fins also lack the fine motor control of teleost fins [2]. Shark dorsal fins are composed of basals, radials and ceratotrichia [3, 4]. We investigate the functional morphology of shark dorsal fins in white spotted bamboo sharks, *Chiloscyllium plagiosum*, and spiny dogfish, *Squalus acanthias*, two unrelated species that inhabit different habitats and have strikingly different dorsal fin morphology. We hypothesize that the benthic bamboo shark is going to use the dorsal fins to augment thrust during steady swimming and will have fine control of the fins during maneuvering. The spiny dogfish with spines in front of each fin will use these fins as stabilizers in steady swimming and as a pivot in turning.

## METHODS

We swam four sharks of each species in a flow tank at  $0.5BL.s^{-1}$  and  $0.75BL.s^{-1}$  while recording dorsal and lateral views using high speed video with electromyographic data. Later, we induced turning in a circular tank with objects to simulate a complex environment and induce spontaneous turning, while gathering the same type of data. Electrodes were bilaterally implanted into three regions along the dorsal fin muscle on the first and second dorsal fins and unilaterally in the left red epaxial musculature just below each fin for reference. We also investigated fin skeletal and muscular anatomy.

## RESULTS AND DISCUSSION

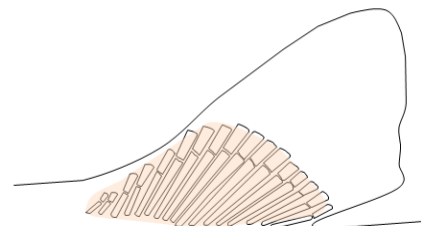
The dorsal fin anatomy of benthic white-spotted bamboo sharks and benthopelagic spiny dogfish reflects swimming habit. Differences are apparent in external and internal anatomy. Bamboo sharks have a larger second dorsal fin area and proportionally more muscle extending into both dorsal fins than spiny dogfish. Skeletal elements

are composed of a variable number of basals and radials that are almost indistinguishable and lack a clear arrangement in spiny dogfish (Fig 1 top). In contrast, bamboo sharks have a single row of multiple plate-like elongated basals followed by a row of shorter radials that fans out into the fin web (Fig.1 bottom). Between each basal and radial is a cartilaginous pad, indicating a movable joint. Bamboo fin muscle bundles are discrete and correspond with the radials. Spiny dogfish fin muscles have a more compact structure and lack discrete bundles. Dorsal fin complexity in spiny dogfish is increased by the presence of an anterior spine. The spines are wrapped in thick collagen fibers pointing posteriorly, which insert into the skin near the middle portion of the fin base. Similar bundles of collagen fibers run in the opposite orientation from the middle to the end of the fin base. The collagen fibers appear to make the fin more rigid but also create bending planes in the middle of the fin.

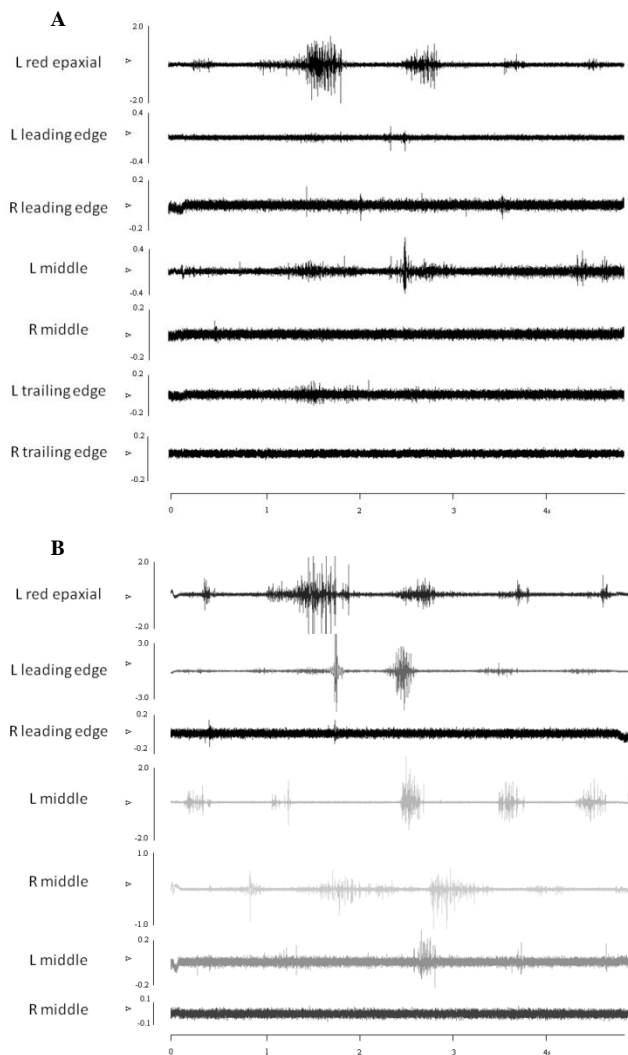
Spiny dogfish



Bamboo shark



**Figure 1:** Schematic representation of the skeletal and muscular anatomy of bamboo shark first dorsal fin. Shaded area represents the area occupied by the dorsal fin muscle.



**Figure 2:** Representative traces of muscle activity along the first (A) and second (B) dorsal fins of a bamboo shark during a left turn.

During steady swimming, the spiny dogfish first dorsal fin moves independently of the body with higher amplitude at lower speeds, indicating a stabilizing function to counter increased instability. The first dorsal fin has a three dimensional conformation at maximum displacement. The second dorsal fin appears to move passively with the caudal portion of the body, although it cannot be ruled out at this point that the dorsal fin may augment thrust. This will be later tested using particle image velocimetry. Bamboo shark dorsal fins move in synchrony with the trunk, showing relatively higher amplitude of movement compared to dogfish at both speeds. First and second dorsal fins show a similar kinematic pattern with comparable displacements when corrected for axial displacement and appear independent of speed. This indicates a different function of the dorsal fins during steady swimming in the two species. The

first dorsal fin in spiny dogfish likely contributes to stability while the second dorsal fin, as well as both dorsal fins in bamboo sharks, appears to contribute to added thrust. Preliminary electromyography data corroborates these conclusions.

During turning maneuvers, the first and second dorsal fins were active in both species, with contralateral and ipsilateral musculature showing bursts throughout the turn. There appears to be independent control of the different muscle bundles along the fin, since onset, offset and duration varied among the three implanted regions for both species. Muscle fin activity suggests that there is a thrust component to bamboo dorsal fins during maneuvers (Figure 2). Spiny dogfish dorsal fins revealed variable muscle activation patterns and might be more versatile than first thought.

## CONCLUSIONS

Dorsal fin bending in dogfish may play a role in stabilizing forces, while the complex structure of bamboo shark fins imparts greater mobility to redirect thrust forces, as corroborated by anatomical, kinematic and electromyography analyses.

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## ACKNOWLEDGEMENTS

The authors would like to acknowledge Jason Ramsay, Shannon Gerry, Jocelyne Dolce, Matt Lotti, Stacey Sakai, Andrea Scott and Ashley Stoher for help with experiments and animal care, and the undergraduates that participated in this project Bonnie Witte, Ashley Heinze, Britt McGee and Kim Arbonies. The experiments were approved under the IACUC protocol # AN05-07-001. A. Maia is funded by MCTES/FCT/SFRH/BD/36852/2007