The Variation in the Occurrence of Diatoms in the External Mucus of Florida Sharks

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Introduction

Elasmobranch skin has been extensively studied for its drag-reducing hydrodynamic structure and its implications for reduction in ship fuel cost[1]. Shark mucus and biofilm may also have antifouling properties of interest to ecologists and ship engineers. However, the external mucus and associated biofilm of sharks has not been widely studied. This study examines the mucus/biofilm of 7 shark species for the presence of diatoms, a universal precursor microfouler.

Bacteria and diatoms attach to all submerged surfaces and secrete Extracellular Polymeric Substance (EPS). EPS and associated microorganisms constitute a marine biofilm. All submerged surfaces develop biofilms[3,8,10], but environmental and substratum characteristics will determine which species of bacteria and diatoms will be present and dominate[2,4,5]. The properties of this initial biofilm can inhibit or promote macrofoulers from settling and further fouling the surface[6]. Natural antifouling compounds, such as those potentially present in shark biofilms, are of interest in anti-tumor and anti-fouling research, and a focus of some biochemists and pharmaceutical companies[7].

In this study, the mucus of seven species of Florida sharks was sampled and tested for diatoms. The presence (or absence) of diatoms in the external mucus of sharks could provide insight into the mechanisms underlying the absence of macrofouling on sharks.

Figure 1: Shark Capture Map

Methods

Shark Capture: A total of 27 sharks (7 species) were sampled and released in the Summer of 2014. Sampling occurred on the West coast of Florida in Pine Island Sound and Boca Grande Pass using a combination of handliing and gillnettting. Sharks captured and sampled were: *Carcharhinus acronotus* (Black Nose - 1), *Carcharhinus leucas* (Bull - 1), *Carcharhinus limbatus*(Blacktip - 6), *Rhizoprionodon terraenovae* (Atlantic Sharpnose - 1), *Sphyrna lewini* (Scalloped Hammerhead - 5), *Sphyrna mokarran* (Great Hammerhead - 1, and *Sphyrna tiburo* (Bonnethead - 5).

Mucus Sampling: A stainless steel scoopula was used to scrape the mucus off sharkskin in the direction of the dermal denticles. Standard area samples were collected one scoopula length posterior from the caudal pit and mucus was then preserved with formalin.

Laboratory Analysis: C. leucas, *C. limbatus*, *S. lewini*, and *S. mokarran* had heavy mucus obscuring mucus contents, making counting diatoms difficult. These samples were heated with 30% hydrogen peroxide to digest the organic matter while leaving silica frustules of the diatoms intact for counting and identification. The latter was accomplished using a compound microscope.

Results

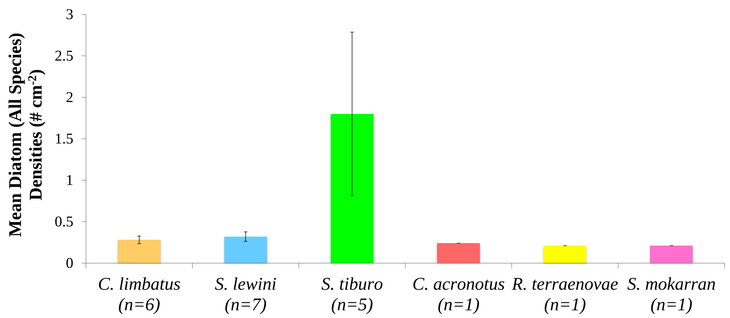

Figure 2: Mean densities for all diatom species ± 1 SE on the different shark species, with represented n values.

Only 3 shark species (*C. limbatus*, *S. lewini*, and *S. tiburo*) were caught and sampled in sufficient numbers for comparative statistics. Overall cell densities on sharks ranged from 0.3-1.8 cells cm^{-2}. While it seems that shark mucus consistently hosts some diatoms, it should be noted that the densities are 3 orders of magnitude less than typical diatom densities on submerged surfaces. For example, it is not uncommon for diatom densities in the biofilms of settlement panels or boat hulls to reach thousands per square centimeter (e.g., 1200 cells cm^{-2})[9]. In this study, the highest diatom density was found on *S. tiburo* (1.8 cells cm^{-2}) which is still low compared to normal submerged surfaces.

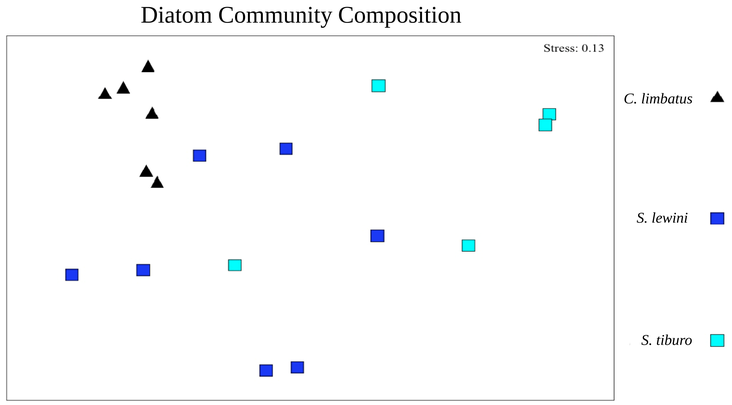

Figure 3: Non-Metric Multidimensional Scaling Plot showing diatom community composition between shark samples, stress value = 0.13. Diatom community composition is somewhat distinct when comparing between these three species of sharks, and especially for *C. limbatus*.

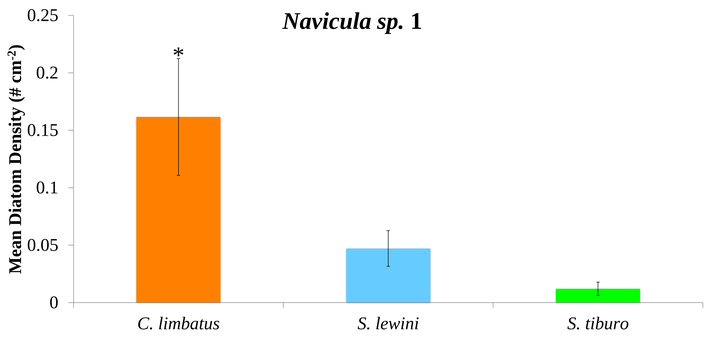

Figure 4: Graph of mean density of diatom *Navicula sp.* 1 ± 1 SE on the different shark species

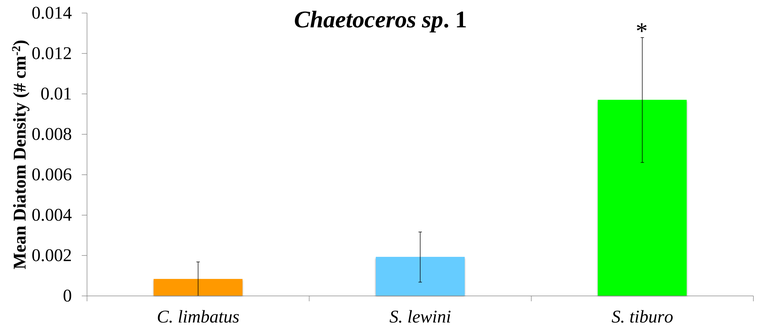

Figure 5: Graph of mean density of diatom *Chaetoceros sp.* 1 ± 1 SE on the different shark species

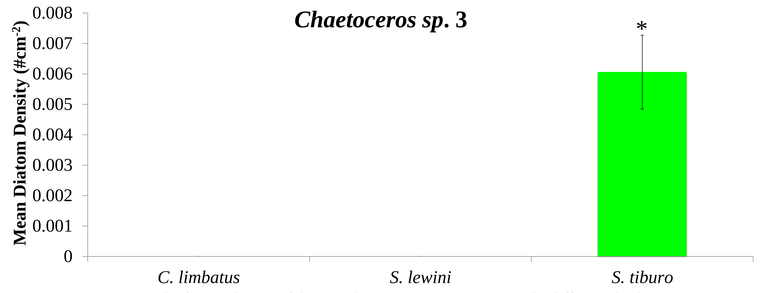

Figure 6: Graph of mean density of diatom *Chaetoceros sp.* 3 ± 1 SE on the different shark species

Over thirty-five different diatom species were found on the seven shark species, but only three diatom species (*Navicula sp.* 1 and *Chaetoceros sp.* 1&3) were determined to have significant differences in their association with particular shark species. While these densities are significantly lower than typical submerged surfaces, they still reflect previously unobserved species relationships between sharks and diatoms; diatom communities on sharks appear to have some degree of distinction.

Discussion

Diatom densities in the external mucus of Florida sharks were orders of magnitude less than normal marine surfaces. The low wettability and microstructure of the dermal denticles are thought to prevent microfouling, but the presence of diatoms in this mucus proves that shark mucus is not completely free of microfoulers. It is unknown whether this microfouling is occurring due to, or in spite of, the external mucus.

Conclusion

The external mucus of sharks contains diatoms, although densities were orders of magnitude less than common submerged surfaces. To my knowledge, this is the first record of diatom microfouling on the externa of sharks. Some antifouling property of sharks, whether it is the structure of their dermal denticles and/or chemical composition of the mucus, restricts the settling of diatoms on sharks. That being said, diatom densities were sufficient to discern significant relationships between sharks and diatoms. Although sharks have antifouling properties, diatoms are still able to settle on them and some diatom species are more adept at settling on particular species of sharks.

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