Filtering is Rough: Quantifying Surface Roughness of Filtering Structures in the Megamouth Shark

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Introduction

- The megamouth shark is one of three extant filter-feeding sharks (whale shark (*Rhinocodon typus)*, basking shark (*Cetorhinus maximus*)) and one of fourteen extant species of filter-feeding chondrichthyans (3 sharks, 11 rays) (Fig. 1A)
- Filter-feeders have feeding structures used in the capture of suspended food particles in the water column (filter pad or gill rakers) (Fig. 1B)
- The megamouth has stratified gill rakers, resembling rakers in bony fishes, that protrude into the buccal cavity (Fig. 1B)
  - Imbricated denticles cover the surface of the rakers (Fig. 2)
  - Denticles on the gill rakers closely resemble the morphology of dermal denticles found on shark skin (Fig. 2B)

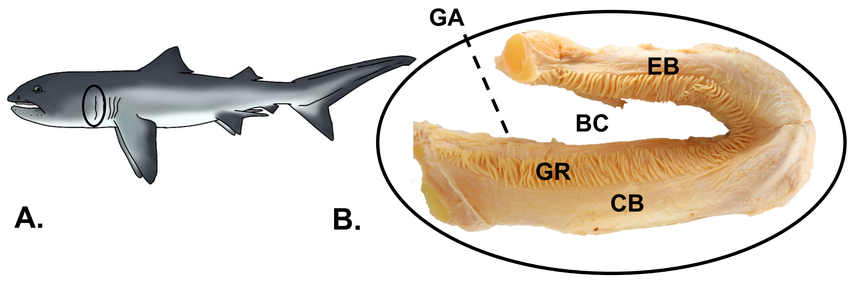

Figure 1: 1A - An illustration of a megamouth, *M. pelagios,* and one gill arch circled (lateral view). The gill arch is deep within the gill slit. 1B - Macrophotography image of one gill arch from the antero-lateral side of the arch (lateral view). Gill filaments not shown. GA – Gill Arch, GR – Gill Rakers, BC – Buccal Cavity, EB – Epibranchial Arch, CB – Ceratobranchial Arch

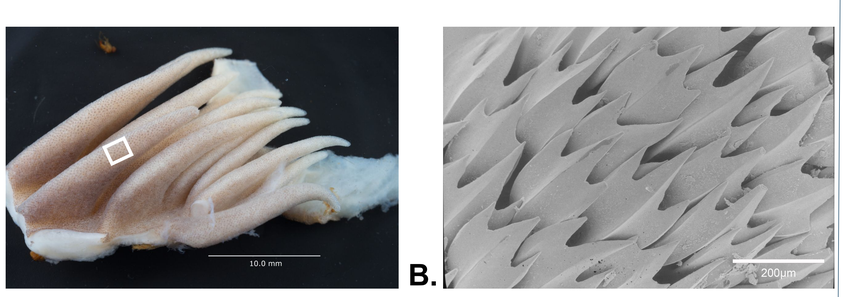

Figure 2: 2A – Macrophotography image of the gill rakers from the holotype. 2B – An SEM image of the denticles from megamouth gill rakers. The orientation of Figure 2B can be found in the white box in Figure 2A.

Research Aim

Aim: Explore the surface morphology of the filtering structures (gill rakers, gill arch, tongue) in the megamouth shark through gel-based profilometry

Materials & Methods

- I used gel-based profilometry to image multiple regions across the gill rakers, gill arch, and tongue
- I processed the images with GelSight software into 3D, topographic surfaces
- The 3D surfaces were processed using MountainMaps software, where I measured several metrology variables including root-mean-square surface roughness (Sq), skew (Ssk), and kurtosis (Sku)

Results

- Each filtering structure has a difference in denticle morphology varying from surface heights to denticle shape and number of riblets along the surface (Fig. 3)
- Denticles on the gill rakers overlap from base to base and create imbrication (Fig. 3A & 4E)
- The three surface riblets present on the epithelium of the gill arch (Fig. 3B & BF) are clearly visible compared to the gill rakers and tongue
- Denticles along the tongue are bristled and angled upright, rather than lying flat on the epithelium (Fig. 3C, 3D, 3G, 3H)

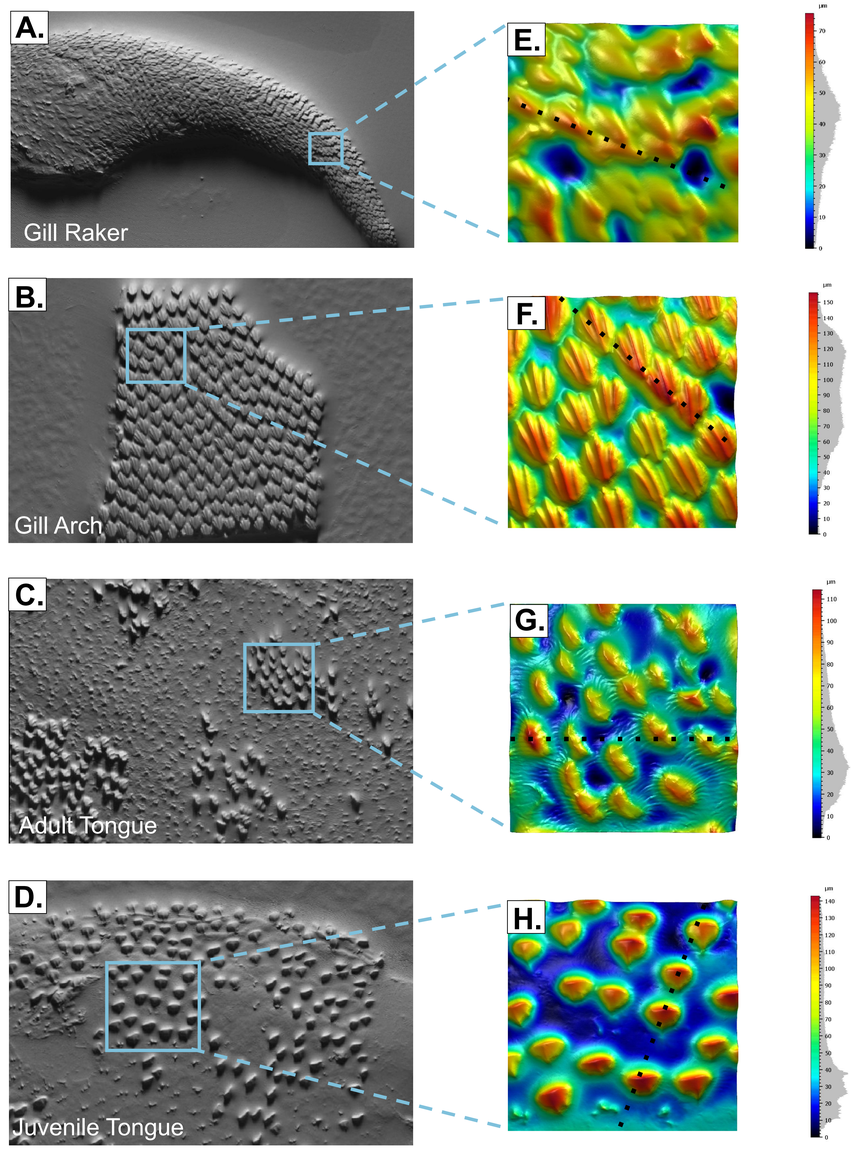

Figure 3: Grayscale plan-view images of the filtering structures (left) and 3D reconstructions of the surface topography from each given area in blue (indicating anatomical region of study), as colored elevation maps with z-height scale bars (right). Color shows height of the surface, with red representing the max height and blue the minimum height. 3A & 3E – Gill raker. 3B & 3F- Epithelium from the gill arch. 3C & 3G – Adult tongue. 3D & 3H – Juvenile tongue. Height profiles indicated by black dotted line (Fig. 4)

Results cont.

- The profiles of each filtering structure is highly variable with a rough surface due to multiple peaks and valleys within an area (Fig. 4)
- Small depressions between denticles and riblets are responsible for the negative skew (Ssk) values for the gill raker and gill arch (Table 1)
- Kurtosis values for the gill raker and tongue reflect a leptokurtic distribution of peaks and valleys, similar to that of shark skin (Table 1)

Table 1: Table of surface metrology parameters for megamouth filtering structures and shark skin comparison (Ankhelyi *et al.* 2018). Table is organized in order of increasing surface roughness. Sq – Roughness, Ssk – Skew, Sku – Kurtosis

Species	Body Region/Structure	Sq (um)	Ssk	Sku
Megamouth Shark	Gill Raker	8.60	-0.32	3.55
White Shark	Mid Body	9.80	0.18	3.10
Megamouth Shark	Adult Tongue	23.25	0.86	4.00
Megamouth Shark	Juvenile Tongue	26.33	1.17	4.16
Leopard Shark	Mid Body	28.70	-1.35	6.20
Megamouth Shark	Gill Arch	31.03	-0.11	2.24
Gulper Shark	Mid Body	72.7	-0.159	2.12

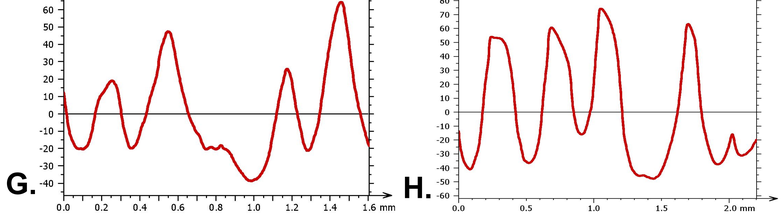

Figure 4: Surface profiles across the region of studies on the filtering structures in Figure 3 (E-H) with profile indicated by black dotted line. 4E- Height profile for denticles on the gill raker. 4F- Height profile for denticles on the epithelium of the gill arch. 4G- Height profile for the denticles on an adult megamouth tongue. 4H - Height profile for the denticles on a juvenile megamouth tongue.

Discussion

- The surface roughness and 3D morphology of the denticles along the filtering structures may indicate a variable flow environment within the buccal cavity and will affect how prey is captured and retained

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