Characterization Of Gular Sac Tissue For The Brown Pelican

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Introduction:

Pelicans are famous predominantly for their lengthy beaks and extensible skin pouches. The mandibles draw interest for their bending optimization, intentional bowing cross-sections, and contradictory trend in bone density. While there have been multiple studies of whale VGB, a similar material, the pelican's pouch skin has not received the same level of attention. By focusing on the gular sac, we hope to better understand collagen's role and how this arrangement of it allows for such an expansive structure.

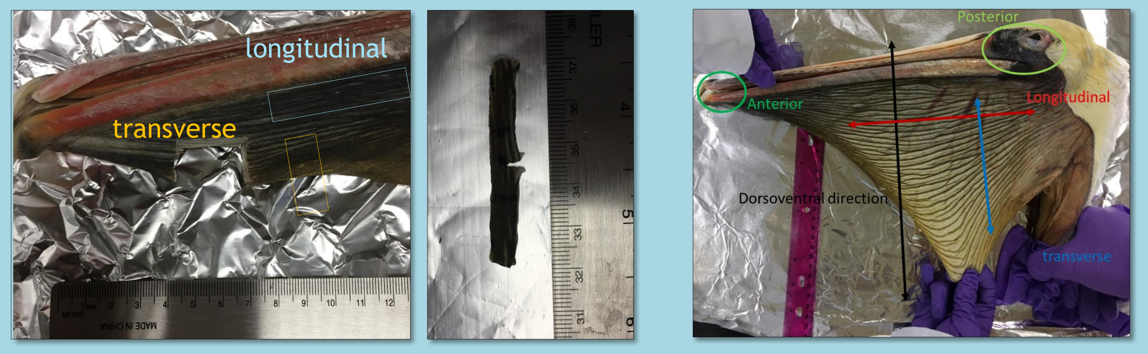


Figure 1: Visual of orientations pertaining to mechanical testing and anatomical directions pertaining to literature review.

Structure: Pelican Bills

Feeding mechanics define a bird's beak shape. Brown pelicans plunge as deep as 16 meters to feed, meaning mandibles must endure high bending stresses further elevated by rapid pouch inflation at these depths. Modelled as a cantilever beam with water as a uniform loading, the mandible should increase in flexural rigidity towards the cranial joint, in the posterior direction, mirroring the trend of dorsoventral stress [1]. Bending resistance is achieved by nearly elliptical cross-sections of the beak, with elongation in the dorsoventral direction. The elongated cross-section holds an additional role, directing bowing behaviour to the mediolateral plane [2]. The action of actively bowing outwards is referred to as streptognathism [3]. The sides of the mandible contain less material, allowing for the deflection of dorsoventral loading and a framework for rapid inflation of the pouch. Mandibles loaded dorsoventrally are eight times more resistant to bending than those tested in the mediolateral direction [4].

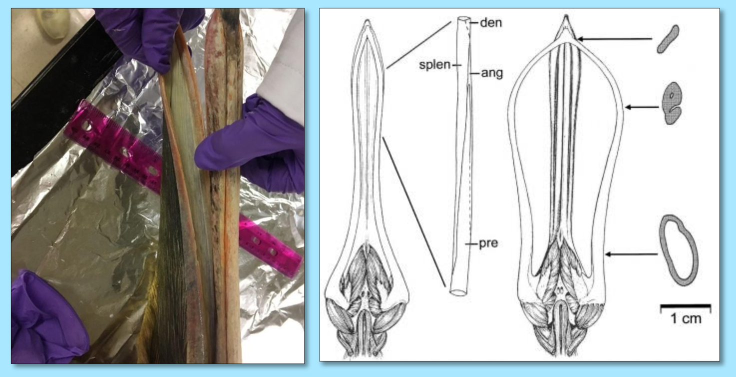


Figure 2: Mandible progression (left). Meyers, R. (2005) *Mandibular Bowing and Mineralization in Brown Pelicans* (right).

Extensibility of the Pouch:

Despite the fame of the pouch, the gular sac tissue in pelicans has not received the attention it deserves. One group began characterization of the material through biaxial bubble inflation [2]. However, this was not motivated by vision of bioinspiration; their primary study was of convergent evolution pertaining to the rorqual whale family. See Figure 3 for depiction of the published tensile plots. Gular sac tissue is established as anisotropic—the material is nearly three times more extensible in the transverse or dorsoventral direction than in the longitudinal, or anterior-posterior direction.

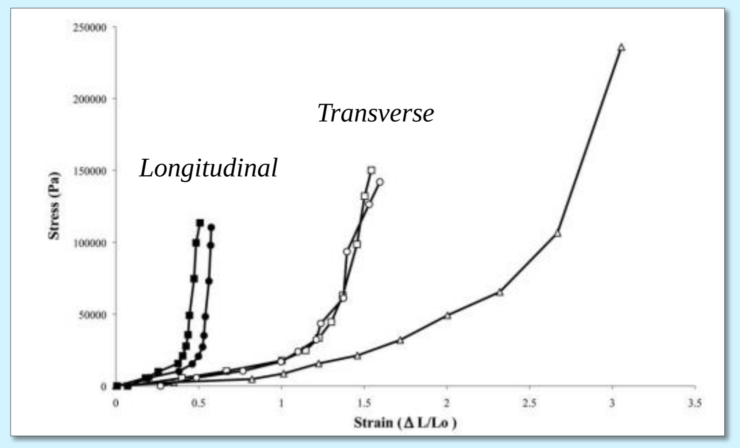


Figure 3: Field (2011) *Convergent Evolution Driven by Similar Feeding mechanics in Balaenopterid Whales and Pelicans*

Our own data, Figure 4 suggests a less prominent anisotropy; samples appear to stretch in the transverse direction, on average¹, about 1.68 to 1.90 times further than in the longitudinal.

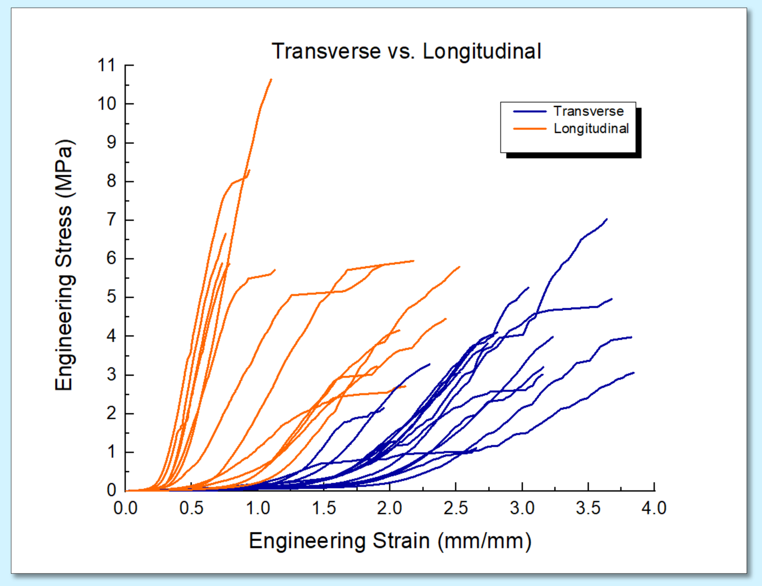


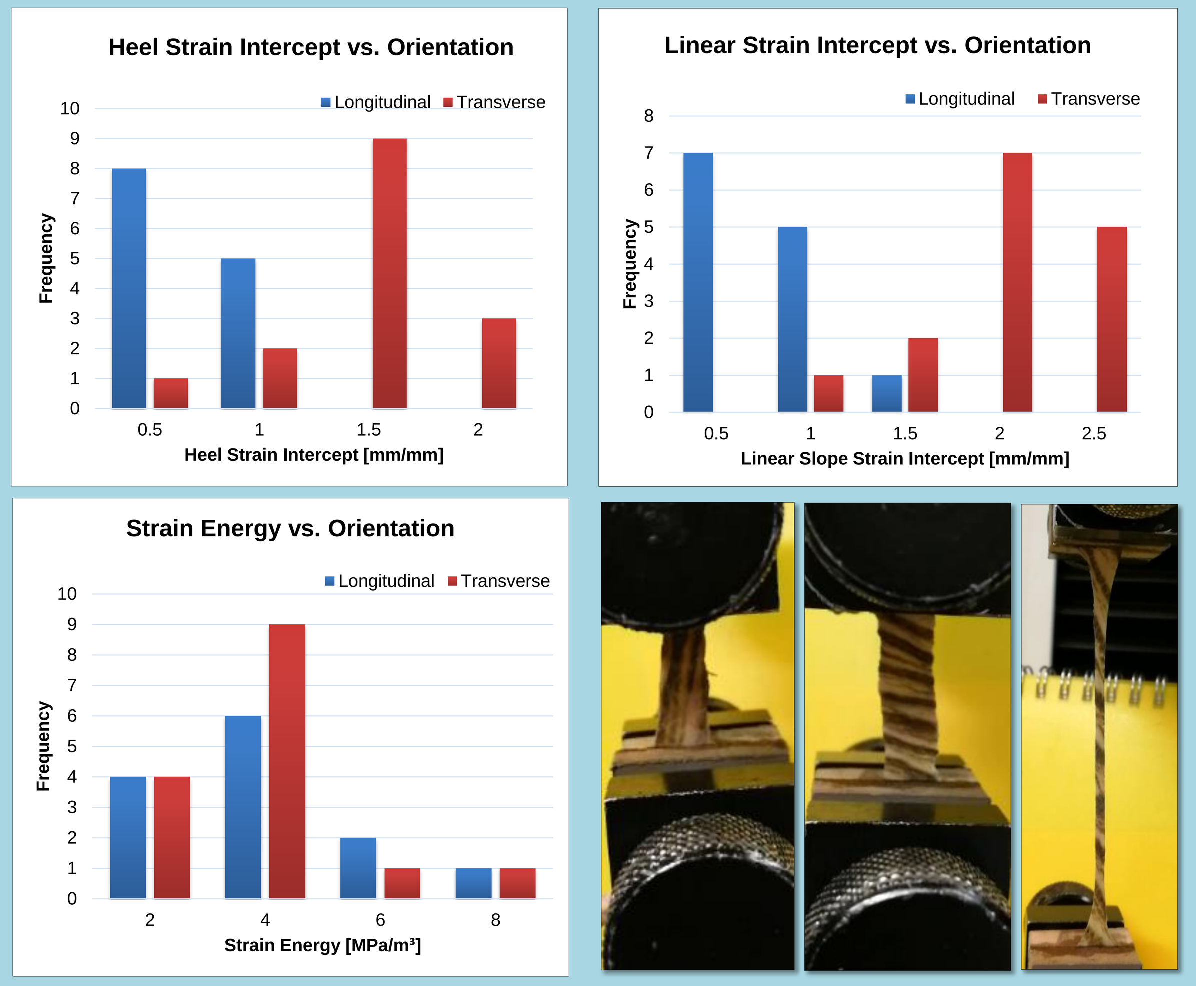
Figure 4: Anisotropy evident in 28 specimens undergoing mechanical loading.

Potvin reports the contents of the rorquals' ventral groove blubber (VGB) as consisting of an intermediate muscle layer sandwiched between collagen dermal layers [5]. This central muscle tier is thought to limit the rate of pouch expansion, providing some extent of control to water level in the pouch. Gular tissue is expected to be similar in structure where elastic properties exhibited are defined by the behaviour of collagen fibres. The pouch skin first stretches when applied low pressures, later stiffening as the collagen fibres straighten or align.

¹*Anisotropic disparity averages described as 1.68 to 1.90 by weighted average and average, respectively*.

Experimental:

This dataset of 28 tensile specimens aims to isolate mechanical properties or testing parameters indicative of a transverse or longitudinal orientation. It seeks to examine possible impacts of sample hydration, loading strain rates, and regional differences across the pouch—both dorsoventrally and proximally. Figure 5 depicts a strain energy distribution independent of orientation; however, the strain intercepts of the heel and linear regions are dependent. Notice the transverse sample's fibre alignment in the direction of loading.



:**Figure 5:** Heel region intercept strain (top right). Linear region intercept strain (top left). Strain energy (bottom left). Experimental set-up of samples in different orientations: long, transverse, and transverse prior to fracture (bottom right).

Application:

With high-resolution images of the gular sac tissue taken at different orientations and fracture surfaces, we can better understand its complex structure.

With control of the pouch reliant on the blood vessels and smooth muscle layer, avian surgeons must avoid constricting these with sutures. The anisotropic properties of the material also pose a problem. This study hopes to see just how important the collagen or microstructure is to its extensibility. Suturing a torn area shut may not leave the structure oriented correctly; this would affect the inflation of the pouch.

Mechanical testing for the properties of the sac tissue will further define the material. If it is found that these natural properties are significant and applicable to artificial or man-made materials, this study will help us understand what features or structures are advantageous. This includes the interest in the connection of lower mandible to the gular tissue.

In the Works:

- TEM and SEM analysis of fracture surfaces and microstructure orientation.
- Reduction of skin slippage inside tensile grips.

Planned:

- Examination of mandible-gular tissue interface.

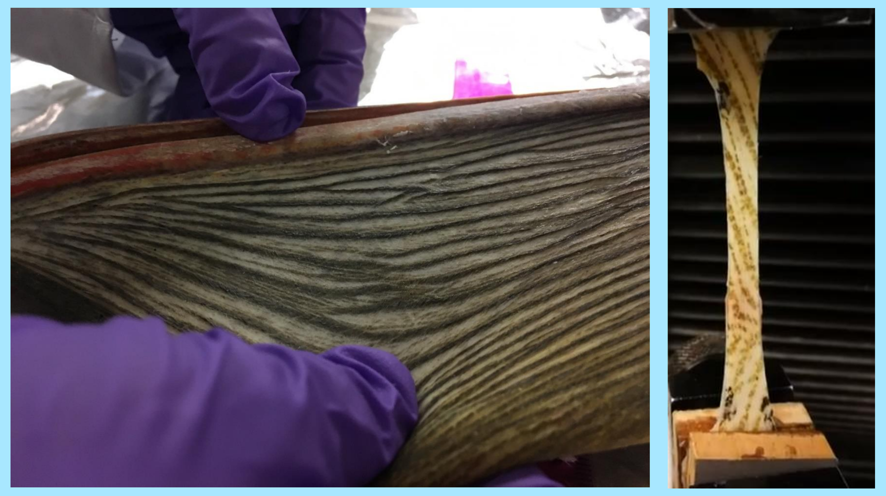


Figure 6: Region of mandible-gular interface (left). Slippage occurring via marked jawline (right).

Gular tissue specimens are difficult to grip firmly for the duration of a tensile test—slippage and tearing occur at the jaws of the material tester quite frequently, ending tests prematurely. This could explain the discrepancy in failure stresses recorded between this dataset and initial material characterization [4]. Although several styles of grip textures have been utilized—cheese graters, conventional studded, and knurled, for example—the pouch skin consistently fails at locations initiated by either jaw. See Figure 6 for depiction of slippage. Before receiving another pelican, we will be using chicken skin to refine our testing process. We also intend to optically determine the extension of the material through markings and the capturing of the stretch of the individual points.

References:

[1] Bock WJ, Kummer B. 1968. The avian mandible as a structural girder. J Biomech 1:89–96.

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