A proposed tooth-set of *Scapanorhynchus texanus*

Introduction

It's been many years now and I can no longer remember when I first heard about the fossil sharks of Big Brook; I think it was an article in the American Littoral Society's *Underwater Naturalist* from the late 80s. In any event, I found myself successfully sifting those then highly productive gravel bars; returning to the car, Gerry Case (I'd never heard of him at the time) approached me and proceeded to identify all my material. I thought at the time that 'goblin shark' (the Late Cretaceous *Scapanorhynchus texanus* at Big Brook) was an odd name, and became even more intrigued by how little was known about its living representative – *Mitsukurina owstoni*.

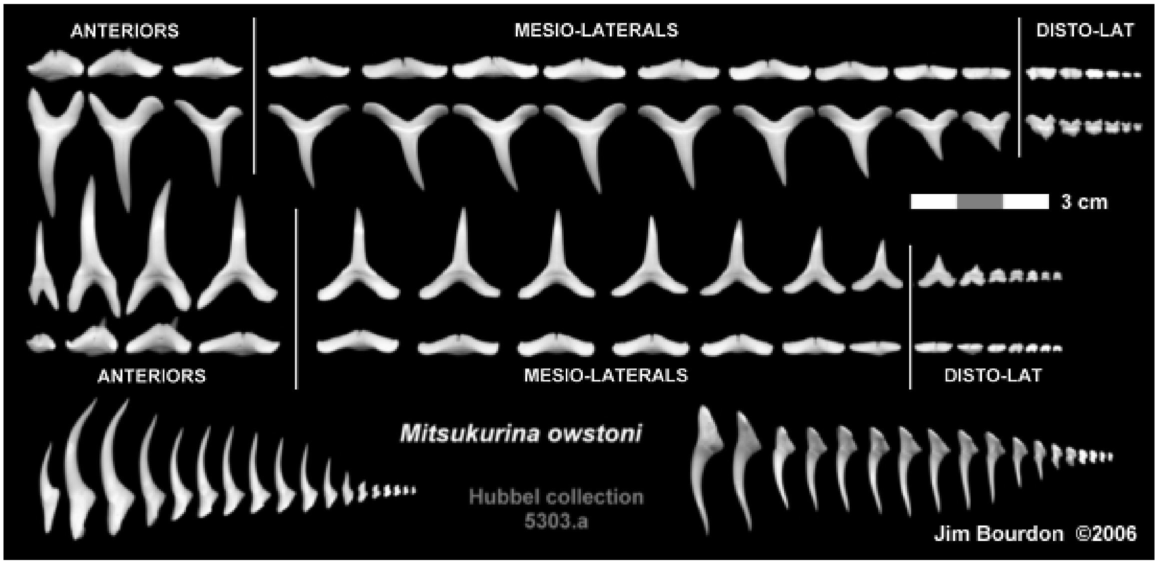
When first venturing into Eocene exposures (early 90s NJPS trip to Castle Hayne, NC), I was told that the strongly striated awl-like teeth found there were the Paleocene-Eocene sand tiger *Striatolamia*. Over the years I used the horizon as the primary determining factor for which of the two similar shark teeth was present. In 2007, Kim Greene, Howie Cohn and I began working a Castle Hayne Fm. (Eocene, Wayne Co., NC) exposure that was dominated (95%) by reworked Late Cretaceous shark teeth. As *Scapanorhynchus* (Cretaceous) and *Striatolamia* (Eocene) teeth dominate their respective faunas, I needed a better understanding of *Scapanorhynchus* (the *Striatolamia* dentition-design had been worked out by Cunningham 2000).

Using the Greene-Rouse collection of Elizabethtown (late Campanian, Bladen Co. NC – here called "E-town" material, a unique *Scapanorhynchus* tooth-design tooth characteristic was recognized – the 'neck' between the lingual crown and root was ridged (when teeth are in reasonably good condition) rather than smooth as seen in *Striatolamia*. So what did the full dentition look like? To supplement the teeth in the Greene-Rouse, Cohn and my personal collections, Tom Caggiano allowed me to study his large collection of E-town material. When attempting to reconstruct the tooth-set of a certain shark species based on isolated teeth, it is very important to make comparisons as widely as possible, but to construct the set only with teeth of a single time and place, in order to remove regional and/or chronologic variation.

Good tooth condition is critical for proper evaluation of tooth positions; the four collections yielded 75 teeth that provided sufficient root, cusp and cusplet detail to permit consideration. The multiple tooth hollows of the jaws of macrophagous (not filter-feeders: Siverson, 1999; Shimada, 2002) lamniforms result in recognizable positional variations of their teeth; these characteristics were used for sorting and arranging teeth. My positional hypotheses were then compared and contrasted with published fossil tooth identifications and three modern goblin shark tooth-sets from the Hubbell collection.

Previous Works and Terminology

Although many papers report *Scapanorhynchus,* most include only a few tooth positions and no opinion on the entire tooth-set. Arambourg (1952) included multiple positions for *S. rapax* (Maastrichtian of Morocco) but appears to have recognized three upper and three lower (including a 'parasymphyseal'-type as the first) anterior teeth. Cappetta & Case (1975) provided a good set of images of *S. texanus* (upper Campanian, Monmouth Co., NJ); their captions (and text) made no positional assignments beyond anterior vs. lateral. Herman (1977) also depicted multiple tooth-positions of *S. raphiodon* (Turonian of Belgium), but generally grouped them as anteriors (2 positions), anterolaterals or laterals. Cappetta (1980) was most specific with Davis' *S. lewisii* (type species of *Scapanorhynchus*) from the Late Santonian of Lebanon --Uppers: 3 anteriors, 1-2 intermediates, 9-10 laterals and 8-11 posteriors; Lowers: symphyseal, parasymphyseal, 2 anteriors, 8-10 laterals and 5 posteriors. Shimada (2002) includes a detailed description of the *Mitsukurina owstoni* dentition. In this paper he interpreted the formula as – upper: symphyseal, 2 anteriors, 1 intermediate, 10 laterals and multiple posteriors; lower: symphyseal, 2 anteriors, 1 intermediate, 9 laterals and multiple posteriors.



Despite the conflicting text tooth-formulae, the figured teeth can, in most cases, be correlated with those in other papers; this suggests only a difference in terminology. For this report, I will follow Siverson (1999) and simply refer to the teeth emanating from the anterior hollow as anteriors and those from the lateral hollow as laterals (mesio- or disto-). Using tooth-sets of the modern goblin shark as a guide, the upper anterior hollow includes three teeth; the lateral hollow includes nine larger positions (mesio-laterals) followed by 4-7 reduced 'posterior' files (disto-laterals). The lower anterior hollow includes four teeth, the first of which is significantly smaller than the others; these are generally referred to as parasymphyseals but are referred to within as the A0 position, because of its inclusion in the same hollow as the other lower anteriors. Seven or eight files might be deemed mesio-laterals and another 4–6 as disto-laterals. Examining these modern teeth, certain lateral tooth positions (files 3-5) have very subtle differences which cannot be properly quantified and would require rather subjective determinations if found isolated. True intermediate teeth (*sensu* Applegate 1965 or Siverson 1999, not Shimada 2002) are uncommon in Recent goblin sharks and will not be addressed herein. Based on the E-town material, anteriors can be distinguished from laterals and uppers from lowers; absolute lateral positioning has proved to be more subjective and required the usage of tooth-metrics. Because metrics requires similar positioning, the labial perspective was employed to best achieve this result.

Scapanorhynchus texanus (ROEMER 1849) tooth-design

The salient striations of the anterior teeth are often thought of as a distinguishing characteristic of this species; however, they are usually much weaker or even absent in lateral teeth. More reliable are the ridges on the neck (present when condition permits) which are not present in other taxa.

The anteriors are the awl-like teeth with long, narrow splayed root lobes and strong lingual protuberance most readily associated with *Scapanorhynchus*. The anterior tooth positions are best distinguished by the angle of the root lobes to each other; when viewed labially, teeth from the first position (A1) have lobes that are most acutely and the third (A3) most obtusely splayed. Uppers and lowers can be best distinguished by lateral profile – the cusp of the lowers tends to be more lingually directed than its upper counterpart which usually has a stronger labial re-curvature of the cusp's tip. A small 'parasymphyseal'-type tooth was not represented in the E-town material; however, a more anterior-like tooth-design with a reduced crown was present and deemed the A0 (symphyseal-most position of the lower anterior hollow). Variations of the A1 design are present however, these would more likely represent sexual dimorphism. The first and second anteriors (A1 & A2) usually lack lateral cusplets, while the third usually has them.

Lateral teeth are quite different from the anteriors – broader, more labio-lingually compressed and bearing cusplets (usually a large primary and reduced secondary) on each shoulder. Lower teeth have relatively more erect cusps whereas the uppers are more distally inclined and broader. Disto-laterals are significantly smaller and relatively thicker than the mesio-laterals. The root lobes tend to be higher, broader, more labio-lingually compressed and much more splayed than the anteriors.

The *Scapanorhynchus texanus* Tooth-Set

The combined E-town collections provide only 75 teeth in sufficiently good condition to image, capture metrics and study. These were first separated as anteriors (n=35) or laterals (40), then grouped by tooth-design and/or metrics (crown height-width ratio and cusp inclination).

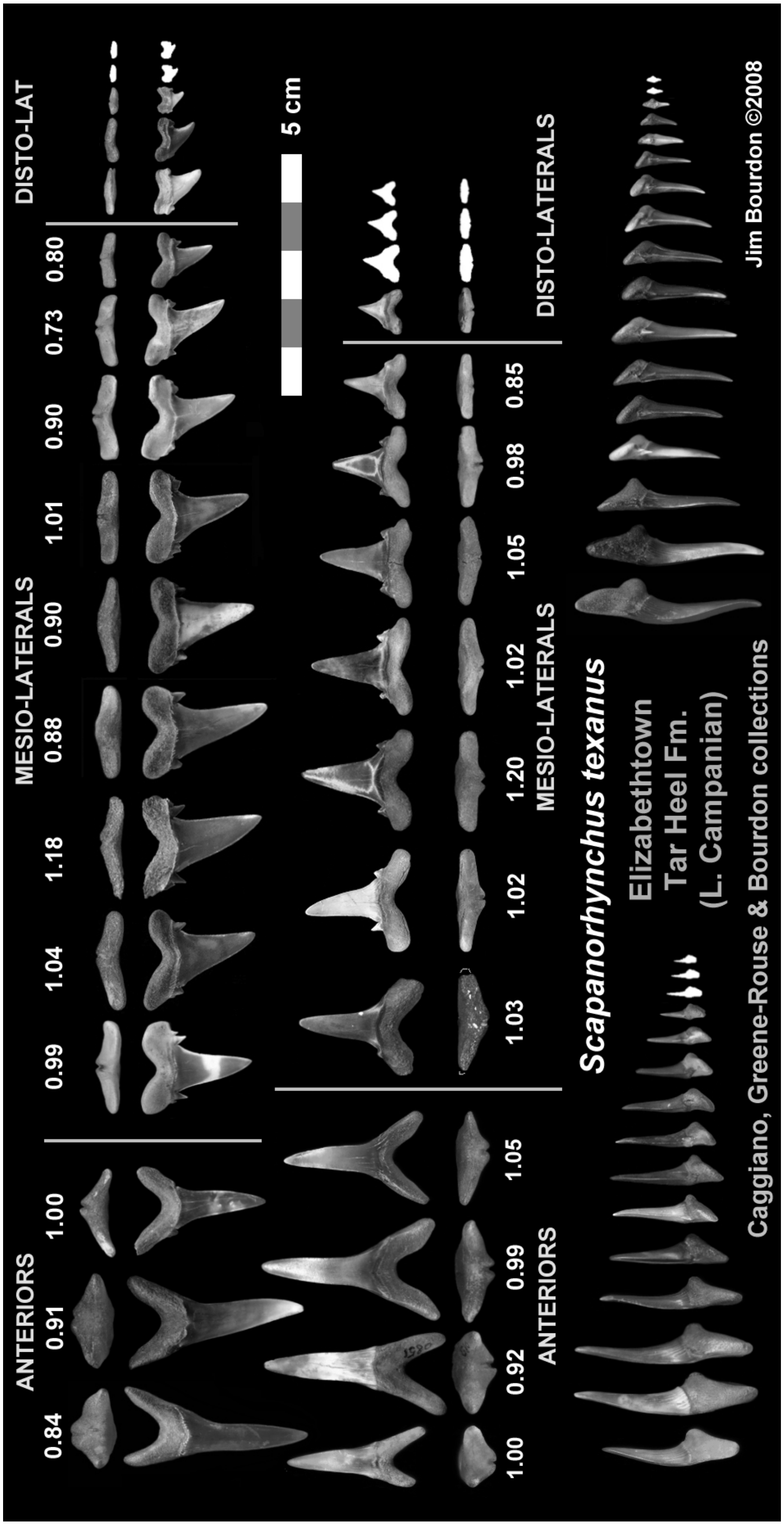
The anteriors were grouped by root-design (= interpreted hollow-position) then attributed to jaw (upper vs lower) on the basis of lateral profile. The specimen count for each of the six positions (UA1-A3 & LA1-L3) was relatively equivalent but four of the specimens were sufficiently different from the others in their group to be excluded (due to pathology, extreme variation or possibly being of a different species). The remaining specimens provided the basis for the various anterior tooth-positions identified here.

Lateral teeth were then separated into upper and lowers. The uppers included 25 teeth separated into nine mesio-lateral and three disto-lateral groupings, and the 13 lowers into seven mesio- and one disto-lateral file group (3 teeth were excluded for similar reason as the anteriors). Disto-laterals are very uncommon, particularly the lowers, so low specimen counts are to be expected.

These preliminary conclusions were then compared with modern tooth-sets and Cappetta's (1980) *S. lewisii* description. Both of these sources suggest that my original upper lateral groupings (probably my original third through fifth files, which were over-represented) actually represent five rather than three tooth-positions, making my preliminary upper mesio-lateral count too low. Except for the under-represented disto-laterals, the E-town lower tooth-groupings compared well with the extant tooth-set and Cappetta (1980). As noted, the proposed tooth-set represents the splitting of the original set in order to accommodate the 'missing' positions.

The resulting arrangement shows upper mesio-laterals (UmL) which become progressively more distally inclined; the cusp inclination of the UmL1 is nearly upright (88-89-degrees) while the UmL7 is close to 70-degrees. In addition, the crown's height-to-width ratio appears to peak in the UmL4 position (1.25:1), and generally stabilizes in position UmL5 to remain in the 0.9-1.0:1 range for the remaining mesio-laterals. In the modern tooth-sets, the lower laterals become progressively shorter distally and vary little in inclination; however, between individuals, the cusps may or may not be mesially recurved or inclined (there is an example in the LmL2 position). In addition, neither the height-to-width ratios nor the relative cusp-widths (probably sexual dimorphism) appear to be consistent between individuals. The available fossil material does not permit a completely harmonious series of teeth and intermixes cusp inclination and other features. These differences are most obvious in the first few lower mesio-lateral positions of the proposed tooth-set.

The small number of isolated E-town teeth available for this study not only precludes certainty in the proposed tooth-set, but requires intermixing some ontogenetic and gender variations. Digital rescaling has been employed and the rescaling factor noted with the anteriors and mesio-laterals. Despite its limitations, the proposed reconstruction is likely close to the actual arrangement and should serve as a reasonable guide to those with their own collection(s) of these teeth. Shimada & Seigel (2005) proposed a method of determining *Mitsukurina* body length (TL) based on tooth size and suggested it might be applicable to fossil goblin sharks as well. Using this formula, the included reconstruction would represent a 4.2 meter individual. Additional details on the


ANTERIORS
MESIO-LATERALS
DISTO-LAT
0.84
0.91
1.00
0.99
1.04
1.18
0.88
0.90
1.01
0.90
0.73
0.80
5 cm
1.00
0.92
0.99
1.05
ANTERIORS
1.03
1.02
1.20
1.02
1.05
0.98
0.85
MESIO-LATERALS
DISTO-LATERALS
Scapanorhynchus texanus
Elizabethtown
Tar Heel Fm.
(L. Campanian)
Caggiano, Greene-Rouse & Bourdon collections
Jim Bourdon ©2008

species are available at http://www.elasmo.com/genera/cretaceous/Scapanorhynchus.html.

[Upon completing this tooth-set in mid-February, I began reconstruction of a similarly-aged but much larger collection from Mississippi. Not yet complete, the developing arrangement is beginning to look very close to the above proposal.]

I'd like to acknowledge Tom Caggiano, Kim Greene, Ellie Rouse and Howie Cohn for providing specimens for this project. Mikael Siverson (Western Australian Museum) was invaluable for his comments and suggestions on tooth scaling and positioning. Earl Manning (Metairie, Louisiana) was not only kind enough to arrange the Mississippi loan, but his detailed review greatly improved this paper. Kenshu Shimada (DePaul University) took the time to review this article for the *Paleontograph* and provided very useful feedback and suggestions.

References

Applegate, S., 1965. Tooth terminology and variation in sharks, with special reference to the sand shark, *Carcharias taurus* Rafinesque. 86: Los Angeles County Museum Contributions in Science 86:1-18.
Arambourg. C., 1952. Les Vértebrés Fossiles des Gisements de Phoshates (Maroc-Algérie-Tunisie). [Vertebrate fossils of the phosphate beds (Morocco-Algeria-Tunisia)] Notes et Mémoires du Division of Mines and Geology, French Morocco 92, 1-372.
Cappetta, H., 1980. Les sélaciens du Crétacé supérieur du Liban. 1: Requins. [The Late Cretaceous selachians of Lebanon. 1: Sharks.] Palaeontographica Abteilung A 168(1-4):69-148.
Cappetta, H. & Case, G., 1975. Contribution à l'étude des sélaciens du groupe Monmouth (Campanien - Maestrichtian) du New Jersey. [A contribution to the study of the selachians of the Monmouth Group (Campanian-Maestrichtian) of New Jersey.] Palaeontographica Abteilung A 151(1-3):1-46.
Cunningham, S., 2000. A comparison of isolated teeth of early Eocene *Striatolamia macrota* (Chondrichthyes, Lamniformes), with those of a Recent sand shark, *Carcharias taurus*. Tertiary Research 20(1-4):17-31.
Herman, J., 1977. Les sélaciens des terrains néocrétacés et paléocènes de Belgique et des contrées limitrophes. Eléments d'une biostratigraphie intercontinentale. [The selachians of the Late Cretaceous and Paleocene formations of Belgium and adjacent countries.] Mémoires pour servir à l'explication des Cartes géologiques et minières de la Belgique, 1975 (published 1977), 15:1-401.
Shimada, K., 2002. Dental homologies in lamniform sharks (Chondrichthyes: Elasmobranchii). Journal of Morphology 251:38-72.
Shimada, K. and Seigel, J., 2005. The relationship between the tooth size and total body length in the goblin shark, Mitsukurina owstoni (Lamniformes : Mitsukurinidae). *Journal of Fossil Research*, vol 23(1), 49-56.
Siverson, M., 1999. A new large lamniform shark from the uppermost Gearle Siltstone (Cenomanian, Late Cretaceous) of Western Australia. Transactions of the Royal Society of Edinburgh: Earth Sciences 90:49-65.