Comparative Morphometrics of *Syllomus* Carapace Bone Plates

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Introduction

Syllomus, a Miocene sea turtle found in the Atlantic Coastal Plain, has been briefly described in the literature, but its elements had not yet been morphometricaly analyzed. The carapace bone plates were ideal subjects of morphometric analysis and comparison to each other due to availability of multiple articulated elements. Although carapace bone plate configuration can vary among individual specimens, three conditions remain consistant for the genus, although each condition sometimes has a specific variation (Weems 1974):

Consistent Condition	Variation
8 costal plates present on each side	8th costal may split to form 9th
7 neural plates present	1st neural often splits
2 postneural plates present	3rd postneural is present if the 8th costal splits or has an extra rib head

The carapace bone plates of two *Syllomus* specimens at the VMNH were morphometrically analyzed to test that hypothesis that each bone plate occupies a set range of shape and/or size variables.

Procedures

1. Acquired scaled digital photographs of both *Syllomus* specimens as articulated specimens and of individual carapace plate bones.

2. Identified the location within the carapace of each individual plate bone.

3. Took the following morphometric measurements of each bone plate using TPSDig (Figure 3): width (cm), height (cm), and homologous Type I landmarks 1 through 4

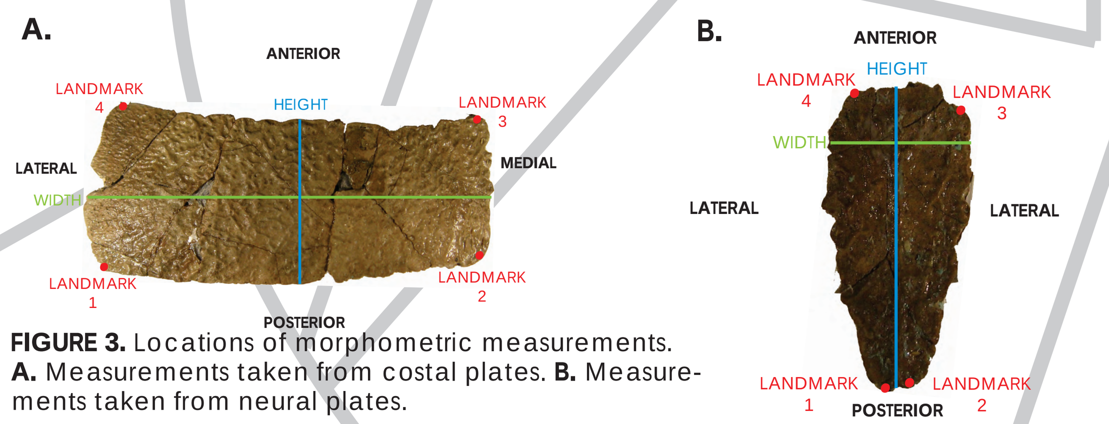

FIGURE 3. Locations of morphometric measurements. **A.** Measurements taken from costal plates. **B.** Measurements taken from neural plates.

4. Calculated the following derived variables from raw data:
   a. Bookstein coordinates of landmarks 1 through 4 (in PAST)
   b. Aspect ratio (width/height)

5. Performed Procrustes analysis for a general shape comparison across plate types in PAST.

6. Plotted Bookstein coordinates of landmarks 3 and 4 of costal plates grouped by right and left plates to look for differences in shape between plates from the two sides.

7. Performed Principal Component Analyses in PAST with the variables width, height, aspect ratio, and the X and Y Bookstein coordinates of landmarks 3 and 4 of all plates, costals only, and neurals only.

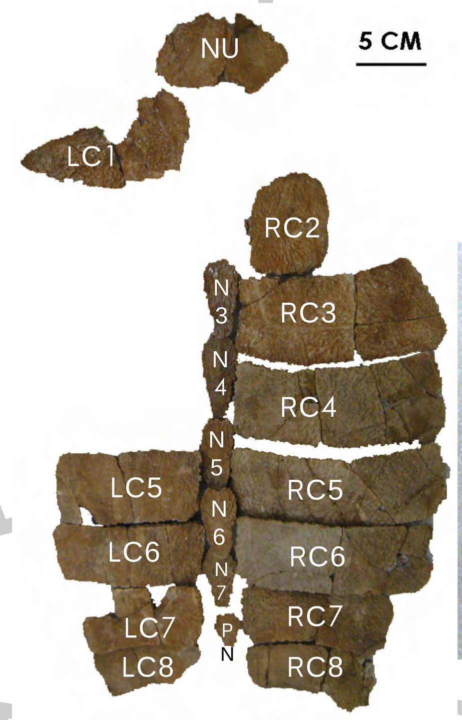

FIGURE 1. *Syllomus* specimen 1 carapace bone plates. NU: nuchal, N3-7: neurals, PN: post neural 1, RC2-8: right costals, LC1-8: left costals.

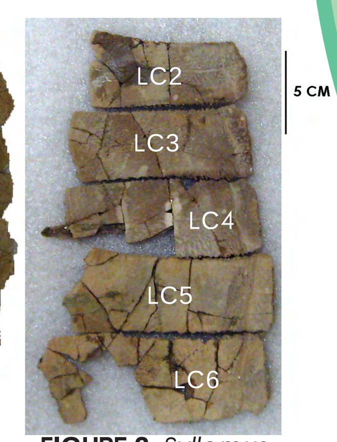

FIGURE 2. *Syllomus* specimen 2 carapace bone plates. LC2-6: left costals.

Abstract

Several specimens of the cheloniid *Syllomus* have been found within Miocene deposits of the Atlantic Coastal Plain, and although some had been described in 1974 by Weems, no specimens had ever undergone morphometric analysis. This project tested the hypothesis that each individual bone plate of the carapace would occupy a set range of morphometric values congruent to its position within the overall carapace. Bone plates from two incomplete Syllomus specimens from bed 14 of the Calvert Formation in Westmoreland County, Virginia, were digitally photographed for morphometric analysis. The plate height (cm), width (cm), and coordinates of four landmarks (one at each corner of the plate) were measured from photographs of fourteen costal plates, five neural plates, one nuchal plate, and one postneural plate. The aspect ratios of the plates and the Bookstein coordinates of their landmarks were then calculated, compared across plate types and locations, and used in Principal Component Analyses in PAST. As expected, significant differences in size and shape were found between the groups of neural, costal, nuchal, and postneural plates, and no significant differences were found between homologous left and right costal plates. Outliers in the Bookstein plots include the first and eighth left costal plates (due to lateral and medial tapering respectively), the third right costal plate, and the third neural plate. A moderate correlation of height to width exists within the neurals, and a weak correlation is seen between the height and width of costal plates, with the nuchal plate plotting more closely to the costals. All performed PCAs were largely inconclusive, as PC1 of all three analyses represented only 65% or less of variation. PC1 of each analysis did not represent an isolated variable, nor did it singly represent size or shape. Thus, morphometrics cannot reliably identify the positions within the carapace of individual bone plates.

Results

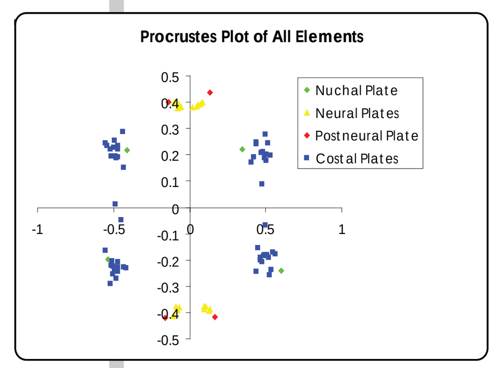

FIGURE 4. Procrustes plot comparing all studied bone plates.

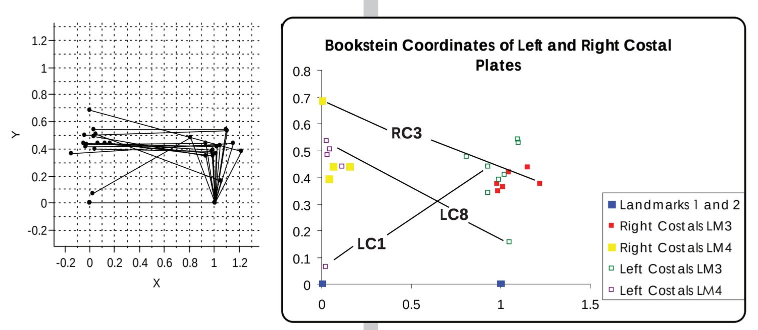

FIGURE 5. Bookstein coordinates of left and right costal plates, with linked coordinates plot.

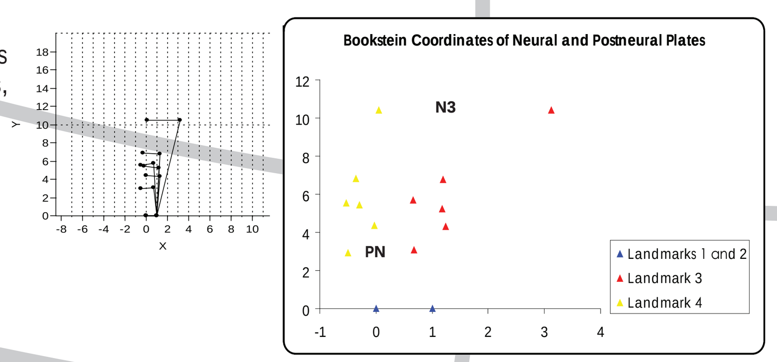

FIGURE 6. Bookstein coordinates of neural and postneural plates, with linked coordinates plot.

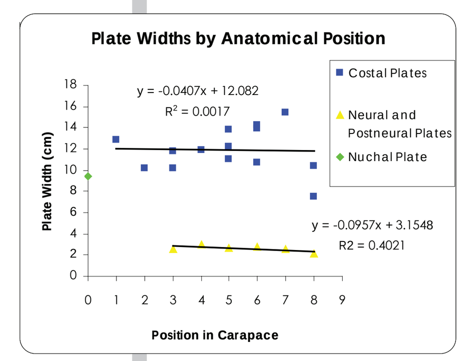

FIGURE 7. Plate widths compared to their anatomical position (see Figures 1 and 2).

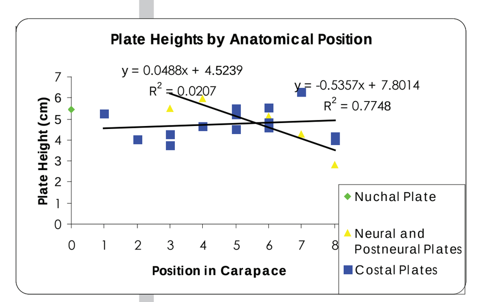

FIGURE 8. Plate heights compared to their anatomical position.

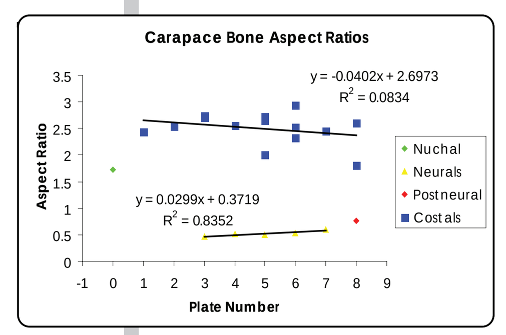

FIGURE 9. The aspect ratio of individual plates compared to their anatomical placement.

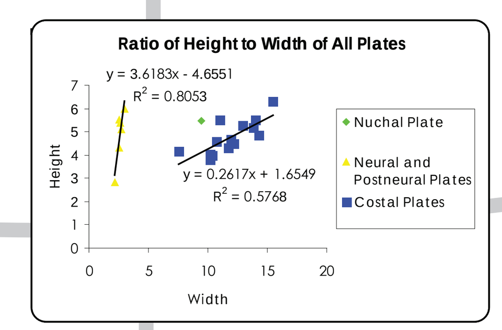

FIGURE 10. The height compared to width of all plates.

PCA: All Plate Types

PC	Eigenvalue	% Variance
1	4.26968	60.995
2	1.52193	21.742
3	0.891101	12.73

TABLE 1. Eigenvalues of and percent variance represented by the principal components above the Joliffe cut-off of all carapace bone plates combined.

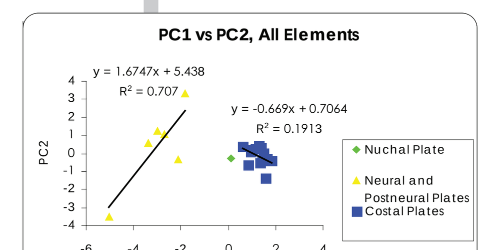

FIGURE 11. Principal component 1 vs. principal component 2 for all plates.

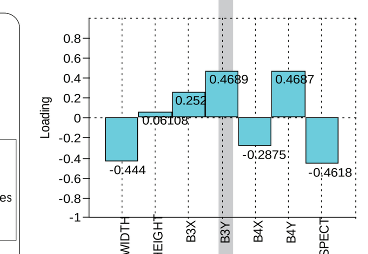

FIGURE 12. Loading coefficients of the 7 variables used in the PCA for principal component 1.

PCA: Costal Plates

PC	Eigenvalue	% Variance
1	2.61344	37.335
2	1.65945	23.706
3	1.14235	16.319
4	0.872678	12.467

TABLE 2. Eigenvalues of and percent variance represented by the principal components above the Joliffe cut-off of costal plates.

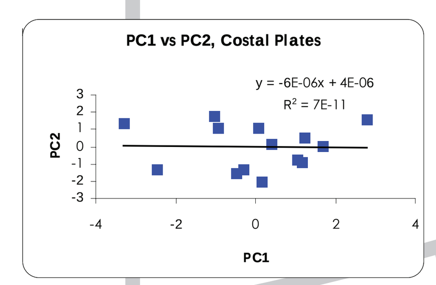

FIGURE 13. Principal component 1 vs. principal component 2 for costal plates.

PCA: Neural & Postneural Plates

PC	Eigenvalue	% Variance
1	4.57489	65.356
2	1.81182	25.883

TABLE 3. Eigenvalues of and percent variance represented by the principal components above the Joliffe cut-off of neural and postneural plates.

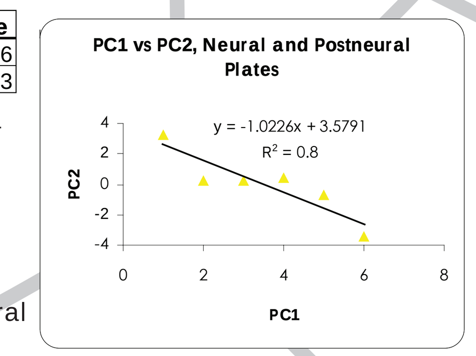

FIGURE 14. Principal component 1 vs. principal component 2 for neural and postneural plates.

Discussion

The procrustes plot of all plates together (Figure 4) showed the neural plate and costal plate landmarks grouping withinin observably differing morphospaces, with the nuchal plate landmarks clustering with those of the costals, and the postneural plate landmarks clustering with those of the neurals. The plot of the Bookstein landmarks in Figure 5 demonstrated that there is no significant difference between right and left homolgous costal plates. Plates that had outlying Bookstein landmarks (Figures 5 and 6) were left costal plate 1, right costal plate 3, left costal plate 8, and neural plate 3. Right costal plate 8 and left costal plate 3 do not share the same outlying Bookstein landmark positions as their homologous counterparts, possibly because the LC3 and RC8 plates are larger than these counterparts, and thus there are greater distances between the original landmarks of LC3 and RC8, making their transformation into Bookstein coordinates less sensitive to shape.

When comparing plate widths, heights, and aspect ratios to anatomical positions within the carapace (Figures 7, 8, and 9), the measurements of the neural and postneural plates had much stronger trends than did those of the costal plates, which had no trends. The neural plates also demonstrated a stonger trend in the comparison of plate height to width (R^2=0.81) than did the costal plates (R^2=0.57), as shown in Figure 10.

All three principal component analyses were largely inconclusive, as PC1 did not represent an overwhelming amount of variance (85% or higher), and the PCA of all plates and the PCA of the costal plates had 3 and 4 PCs above the jolliffe cut-offs respectively. Furthermore, none of the PCs were generally represented by a single variable, nor did the PCs represent solely size or shape, as all of the loading charts resembled that shown in Figure 12.

In conclusion, of the analyzed plate types, only the third neural plate and the first, third, and eighth costal plates have any chance of being identified by morphometric standards due to their differences in shape from the other carapace bones. However, as left costal plates 3 and right costal plate 8 demonstrate, above a certain size, the Bookstein landmarks of these plates more closely cluster with those of other plates. Although the neural plates show size and aspect ratio trends across their anatomical sequence whereas the costal plates do not, these trends are weak to moderate. Thus, when finding one or more *Syllomus* carapace bone plates of unknown articulation, the best that morphometrics can do is weakly support a hypothesis of plate placement within the shell, which should be determined by qualitative observation and comparison and contrast between plates.

Possible Future Works

-Make carapace sample size more robust by integrating additional *Syllomus* specimens from USNM and AMNH into analyses

-Perform similar analysis on *Syllomus's* sister staxon, *Natator* (Hirayama 1994)

Works Cited

Hirayama, Ren. 1994. Phylogenetic systematics of chelenioid sea turtles. The Island Arc, 3: 270-284.

Weems, Robert E. 1974. Middle Miocene Sea Turtles (*Syllomus*, *Procolpochelys*, *Psephophorus*) from the Calvert Formation. Journal of Paleontology, 48(2): 278-303.

Acknowledgements

The author wishes to thank A. Dooley of the Virginia Museum of Natural History for assistance with the project and access to the *Syllomus* specimens, and M. Kowalewski of Virginia Tech for assistance with the quantitative methods.