A QUANTITATIVE APPROACH TO ASSESSING CORAL SEPTAL DENTITION

Sahale N. Casebolt and Ann F. Budd, Virginia Tech Department of Geosciences and University of Iowa Department of Geosciences

DEPARTMENT OF geosciences AT VIRGINIA TECH

THE UNIVERSITY OF IOWA

Abstract

Taxonomic classification in reef building corals (Scleractinia) can be challenging because many aspects of coral morphology, such as colony form, are highly plastic. Certain micro-scale features of the coral skeleton, like the shape of septal teeth, may be more reliable taxonomic indicators than the larger scale features. Although the taxonomic importance of septal tooth shape has long been acknowledged by coral systematists, tooth shape has always been discussed using qualitative descriptors, which can be ambiguous.

This analysis is an attempt to address two key questions related to coral micromorphology: (1) Can ambiguity in septal tooth shape descriptors be removed by addressing tooth shape using quantitative rather than qualitative descriptors?; and (2) does septal tooth shape (as determined quantitatively) vary more among species than it does within species? The results affirmatively answer both questions, which corroborates observations that micro-features are taxonomically meaningful, and demonstrates a novel approach to exploring coral morphology.

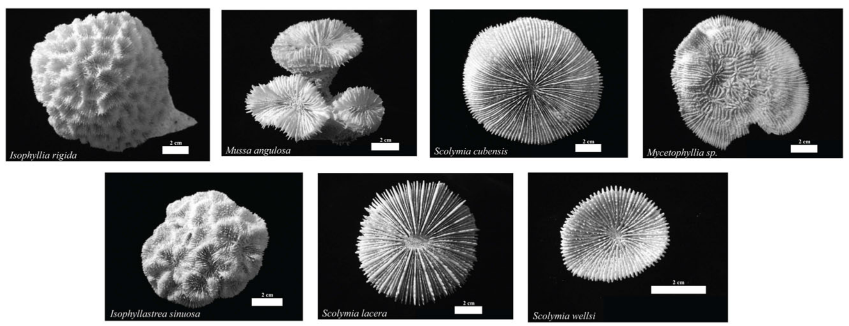

Figure 1: Colony photographs of the seven mussid species used in the analysis (note that these are not the specimens used for the analysis). Differences in macromorphology are clearly evident, although the taxonomic significance of these features is variable. Septal teeth are visible as small spikes on the colony surfaces.

Background

Increasing appreciation of the taxonomic significance of micro-features in corals has prompted coral workers to more closely examine the inter-specific variatation among these features (Budd and Stolarski 2009). Septal teeth form along the upper septal margin (the growing edge) of many scleractinian corals, and along with characteristics of the septa, septal walls, and septal granules, are an important component of coral micromophology (Budd and Stolarski, 2011).

The scleractinian family Mussidae includes the Caribbean genera *Isophyllastrea*, *Isophyllia*, *Mussa*, *Mycetophyllia* and *Scolymia*. The species within these genera are both solitary and colonial, and vary in their large-scale morphology (Figure 1), but have especially prominent and well-developed septal teeth. Species descriptions frequently us qualitative terms like "triangular" and "lobed" to describe septal dentition (Wells, 1956), however, these terms can be ambiguous. The aim of this project is to assess whether the teeth of seven mussid species are quantitatively different from one another.

Materials

Table 1: Specimens used in the analysis.

Genus	Species	Museum*	Catalog No.	Collector	Coll. Yr.	Locality
Isophyllastrea	*rigida*	SUI	102753	unknown		unkown
Isophyllia	*sinuosa*	SUI	CTS01#	unknown		unknown
Mussa	*angulosa*	SUI	102761	unknown	2002	Panama
Mycetophyllia	*lamarckiana*	SUI	CTS051	D. Carlon	2008?	Panama
Scolymia	*cubensis*	USNM	84939	T. Goreau		Jamaica
Scolymia	*lacera*	USNM	1090899	A. Antonius	1971	Colombia
Scolymia	*wellsi*	USNM	84926	R. Hubbard	1984	Trinidad and Tobago

* Museum abbreviations: SUI is University of Iowa Paleontological Repository and USNM is Smithsonian Institu-

Methods

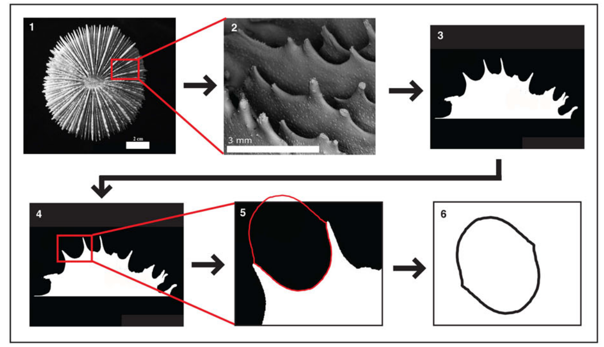

Figure 2: The steps for outline acquisition. Individual septa were isolated from the colony using various cutting and grinding implememnts, then photographed in profile view (steps 1-3). Profiles were then outlined in Adobe Illustrator, and the resulting curve was mirror imaged to make a shape appropriate for outline analysis (steps 4-6). Note that the outlines of the curve between tooth apexes (instead of outlines of the teeth themselves) were used for the analysis because the tooth apex represents the most homologous point along a septum to begin and end an outline.

Step 1: Chain codes are calculated for each outline (65 outlines total, species sample sizes range from 8 to 10). → Step 2: Convert chain codes to sine and cosine variables by elliptic Foureir analysis (20 harmonics calculated). → Step 3: Principal components analysis of the coefficients of the elliptic Fourier descriptors using covariance matrix. PCs visualized as boxplots. → Step 4: ANOVA for each of the first four pricipal components to determine if species means vary, followed by Tukey pariwise comparisons.

Figure 3: The steps for analysis of septal tooth profiles. Elliptic Fourier analysis of the outlines and PCA of the resulting Fourier descriptors were done using the program SHAPE version 1.3 (Iwata and Ukai, 2002) and ANOVA and Tukey comparisons were done using SAS version 9.2.

Results

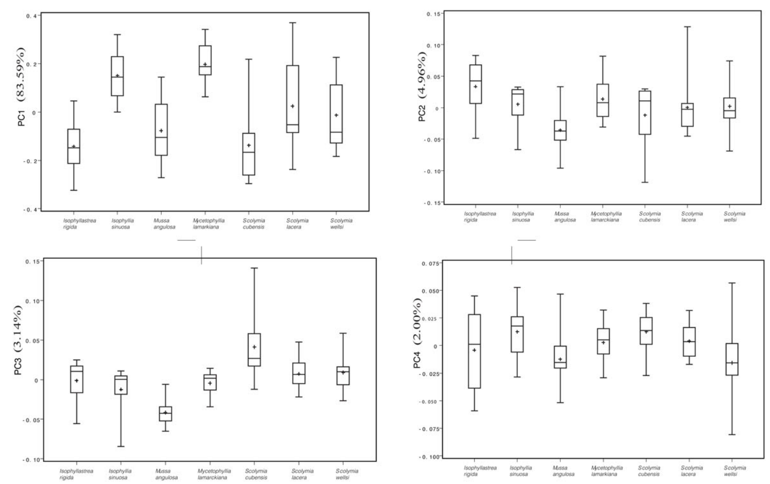

Figure 4: Boxplots of the first four PCs visually display variation among the seven species within each PC. Boxplots show means (+), medians (horizontal lies), interquartile ranges, and max/min points. Species names are listed on the horizontal axes. Vertical axes show standard deviation of the PC. Percentages of vairance accounted for by each PC are written next to vertical axes.

Table 2: ANOVA results indicate that the means are significantly different ($p < 0.05$) in the first 3 PCs:

PC1	$F = 8.13$, $p < 0.0001$
PC2	$F = 2.35$, $p = 0.02$
PC3	$F = 8.05$, $p < 0.0001$
PC4	$F = 1.49$, $p = 0.20$

Table 3: Tukeys for PCs 1 and 2. Values are mean differences. Significant values ($p < 0.05$) are bold:

PC2 \ PC1	ISIN	IRIG	MANG	MLAM	SCUB	SLAC	SWEL
ISIN		**0.29**	**0.23**	0.04	**0.29**	0.12	0.16
IRIG	0.02		0.07	**0.34**	0.00	0.16	0.13
MANG	0.04	**0.07**		**0.27**	0.06	0.01	0.06
MLAM	0.00	0.02	0.05		**0.33**	0.17	**0.21**
SCUB	0.02	**0.04**	0.02	0.03		0.16	0.12
SLAC	0.00	0.03	0.03	0.01	0.01		0.03
SWEL	0.00	0.03	0.03	0.01	0.01	0.00	

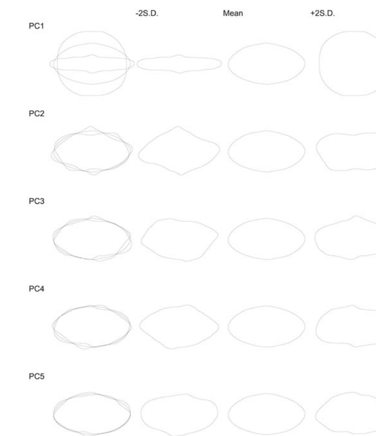

Figure 5: The shape changes described by PCs 1-5. Left column is the summary of outlines, third column is the mean outline shape for that PC, and second and fourth columns are two standard deviations away from the mean.

PC1 describes the overall width of the inter-tooth scoop. This corresponds to the distances between septal teeth relative to septal tooth height.

PC2 describes the straightness of the sides of the inter-tooth curve. This corresponds to the level of tooth triangularity. Corals with more "boxy" outlines have more triangular shaped teeth.

PC3-PC5 describe small irregularities in tooth outlines. Such irregularities are generally due to the presence or absence of small granules on the growing margin of a septum.

Discussion

The results indicate that an elliptic Fourier analysis of septal teeth is capable of successfully distinguishing some of the seven closely related mussid species from one another. Importantly, this is not meant to be a diagnostic technique, but rather an affirmation that septal tooth shape varies among species.

In future analyses of septal tooth shape, several methodological issues will be addressed. First, the effects of threshhold adjustments on the outlines need to be determined. The reliability of this method would be undermined if changes in threshold adjustments significantly alter the results. Second, the effects of size on the elliptic Fourier descriptors must be more accurately assessed. Size is an important variable in septal tooth variation among species, and removal of size information from the analysis would be inappropriate. However, size may be impacting some of the shape information in unexpected ways. For example, in very small outlines, pixilation along the outline might incorrectly appear homologous to real irregularities along the outlines in larger specimens.

The primary motivation behind this project was to create a method that would be applicable to fossilized corals. Although none of the specimens used in the analysis were fossils, many fossil scleractinians show exceptional preservation, including the preservation of undamaged septal teeth. Inclusion of fossil species in this analysis might provide some insight into how the morphology those specimens compares to modern species, and in a modified form may be useful as a character in phylogenetic analyses with fossil corals.

References

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