

Brazilian species of *Gadila* (Mollusca: Scaphopoda: Gadilidae): rediscovery of *Gadila elongata* comb. nov. and shell morphometrics

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ABSTRACT. *Gadila elongata* **comb. nov.** was described in 1920 from the northern Gulf of Mexico. Until recently, it was only known from the type locality. Herein we present the first record of *G. elongata* from Brazil (Northeast coast, Ceará state, collected at 177 m) and a morphometrics analysis of the Brazilian species of *Gadila*. A multivariate Discriminant Function Analysis, based on nine shell morphometric variables (length, maximum diameter, length to maximum diameter ratio, distance of point of maximum diameter from anterior aperture, maximum curvature, anterior aperture height to anterior aperture width ratio, apical aperture height, apical aperture width and apical aperture height to apical aperture width ratio) enabled the distinction between all species studied. Comparisons of shell morphometrics show that length and length to maximum diameter ratio are the most important variables in the differentiation of *Gadila* species.

KEY WORDS. Conchology; marine molluscs; morphometry; taxonomy.

HENDERSON (1920) described *Cadulus elongatus* based on an empty shell collected from the mouth of the Mississippi River (29°N). Until the recent discovery of a specimen collected off the coast of Ceará (Northeast Brazil; 04°S), *C. elongatus* was only known from the type locality. Upon close examination of the morphology of the specimen collected in Brazil, we propose that *C. elongatus* should be transferred to *Gadila*.

Gadila is represented by at least 63 recent species (STEINER & KABAT 2004) that live on continental shelves and abyssal bottoms, with a worldwide distribution for the genus (SCARABINO 1995). The genus dates back to the Cretaceous (EMERSON 1962) and is characterized by smooth, small- to medium-length, curved shells that reach their maximum diameter at the anterior third. The apex of the shell can be simple or have flattened lobes which may vary in number (SCARABINO 1995).

Five species of *Gadila* have been previously recorded from Brazilian waters (SCARABINO 1994, CAETANO *et al.* 2006): *Gadila braziliensis* (Henderson, 1920); *G. dominguensis* (d'Orbigny, 1853); *G. pandionis* (Verrill & Smith in Verrill, 1880); *G. pocula* (Dall, 1889) and *G. simpsoni* (Henderson, 1920).

Here we present the first report of *G. elongata* **comb. nov.** from Brazilian waters, accompanied by a morphometric characterization of other congeneric species from Brazil.

MATERIAL AND METHODS

The material studied is derived from several oceanographic expeditions and was obtained from the following collections: (MORG) Museu Oceanográfico “Prof. Eliézer de Carvalho Rios”, Fundação Universidade do Rio Grande, Rio Grande, Brazil; (MZUSP) Museu de Zoologia, Universidade de São Paulo, São Paulo, Brazil; (IBUFRJ) Departamento de Zoologia, Instituto de Biologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil; (UERJ) Departamento de Zoologia, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil; (DOUFPE) Departamento de Oceanografia, Universidade Federal de Pernambuco, Pernambuco, Brazil; (CMPHRM) Coleção Malacológica “Prof. Henry Ramos Matthews”, Universidade Federal do Ceará, Ceará, Brazil; (CRPC) Colin Redfern Personal Collection, Abaco, Bahamas; (ANSP) Academy of Natural Sciences, Philadelphia, USA; and (USNM) United States National Museum, Washington, D.C., USA.

This research is based on empty shells. Identification of the specimens was based on comparisons of shell morphology with type material and/or original descriptions and illustrations. Damaged shells were excluded from the morphometric analysis to avoid noise or imprecision in the data. Shell measurements

were taken according to SHIMEK (1989), STEINER (1999), STEINER & LINSE (2000), ABSALÃO & DE PAULA (2004), including length (L), maximum diameter (Max), distance of point of maximum diameter from anterior aperture (Dmax), maximum curvature (Arc), distance of point of maximum curvature from the apex (Larc), anterior aperture height (Ha), anterior aperture width (Wa), apical aperture height (Hp), apical aperture width (Wp). The following ratios were calculated in order to assess the degree of shell slenderness and anterior and posterior aperture shape (L: Max; Ha: Wa; Hp: Wp, Larc: L). See ABSALÃO & DE PAULA (2004) for further discussion regarding the use of these ratios. To ensure independence among variables, we performed a preliminary correlation analysis among all variables, excluding those that showed strong correlation. A multivariate approach was carried out using Discriminant Function Analysis to integrate all morphometric data in a single analysis and a model was constructed with nine variables (L, Max, L: Max, Dmax, Arc, Ha: Wa, Hp, Wp and Hp: Wp). The variable Ha was excluded because it was highly correlated with other variables ($r > 0.8$). For the multivariate analysis, we standardized the morphometric data following ROMESBURG (1984). All statistical procedures were performed using STATISTICA for Windows'99 Edition (Statistica 5.5) by StatSoft, Inc, Tulsa, Oklahoma.

TAXONOMY

Gadila Gray, 1847

Type species: *Dentalium gadus* Montagu, 1803, by original designation.

Gadila elongata (Henderson, 1920) **comb. nov.**

Figs 1-3

Cadulus (Platyschides) elongatus Henderson, 1920: 122, pl. 19, fig. 15.

Polyschides elongatus: Steiner & Kabat, 2004: 587.

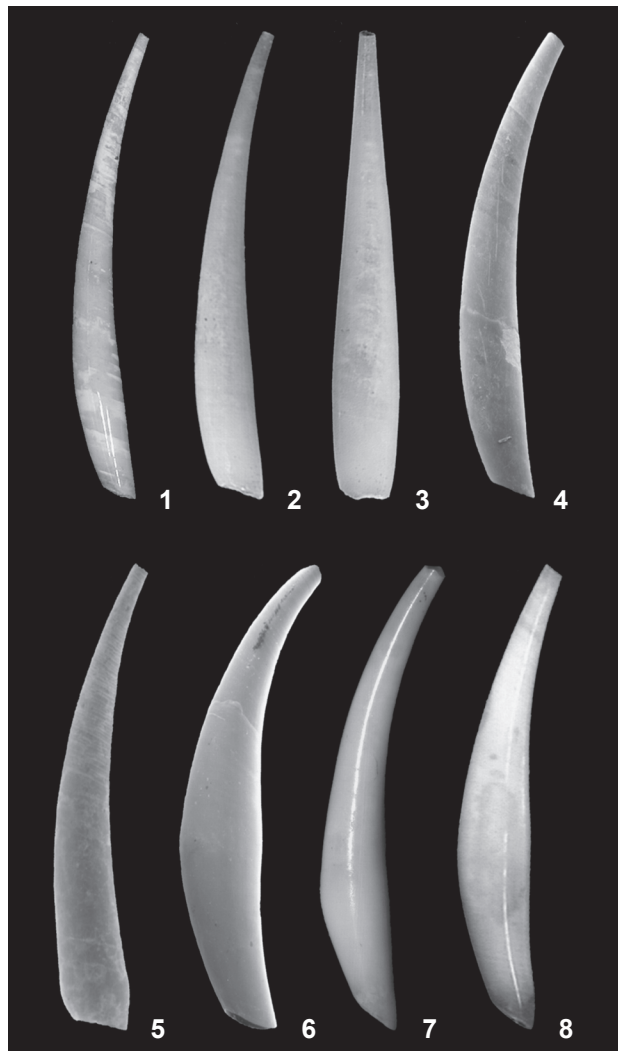
Diagnosis. Shell medium (*ca.* 14 mm of length), exceedingly slender and evenly curved. Translucent bands alternating with white bands in fresh specimens, or all bands white. Shell diameter slightly increasing towards the maximum diameter. Maximum diameter at anterior fifth of shell. No evident swelling. Apex circular, slightly flat. Aperture oblique.

Taxonomic summary. Holotype USNM 323596. Type-locality: "off the mouth of Mississippi River, USBF, stn 2378, 29°14.30'N, 88°09.30'W, 68 fms [124 m]".

Additional material examined. Brazil, Ceará: (04°14'S, 37°12'W, 177 m), 1 empty shell, 12.XI.2001, MNRJ 10482.

Distribution. USA: mouth of Mississippi River (HENDERSON 1920); Brazil: Ceará. Empty shells collected between 124 and 177 m (HENDERSON 1920).

Remarks. The larger size and slender profile of the shell suggest that this species belongs to *Gadila*, not *Polyschides* (STEINER & KABAT 2004). Additionally, the absence of an apex divided into four lobes, characteristic of the holotype (Fig. 1) and the Brazil-



Figures 1-8. (1-3) *Gadila elongata*: (1) holotype USNM 323596, 14.1 mm; (2-3) MNRJ 10482, 13 mm; (4) *G. braziliensis*, IBUFRJ 3110, 10 mm; (5) *G. dominguensis*, IBUFRJ 9513, 8 mm; (6) *G. pandionis*, IBUFRJ 14314, 13 mm; (7) *G. pocula*, IBUFRJ 14312, 10 mm; (8) *G. simpsoni*, IBUFRJ 14317, 5 mm.

ian specimen (Figs 2 and 3), reinforces the idea that its placement in *Gadila* is more appropriate. In the original description, HENDERSON (1920: 123) stated: "Apical characters are not clearly shown, but a slight flare of the rim with certain irregularities indicates a probable *Platyschides* affiliation". Since *Platyschides* was synonymized with *Gadila* by SCARABINO (1995), we conclude that our classification is consistent with Henderson's statement.

Gadila braziliensis is characterized by a slender shell with a low expansion rate and a simple apex (Fig. 4). These characters are shared with *G. dominguensis* (Fig. 5) and *G. elongata* (Figs 1-3). *G. braziliensis* has a smooth external shell surface.

By contrast, the shell surface of *G. dominguensis* is sculptured by transversal rings close to the apex. *G. dominguensis* also has a notable swelling in the shell, close to the anterior aperture. This feature is lacking in both *G. braziliensis* and *G. elongata*. *Gadila elongata* is also distinguished by having a longer (ca. 14 mm shell length) and markedly more slender shell. The other congeneric species treated in this paper, *G. pandionis* (Fig. 6), *G. pocula* (Fig. 7) and *G. simpsoni* (Fig. 8), have a more inflated shell with a notched apex.

The morphometric results obtained for the *Gadila* species are given in table I. Two species, *G. elongata* and *G. pocula*, are not included in these statistical comparisons because of the insufficient number of shells (only one specimen for each species).

The multivariate Discriminant Function Analysis distinguished between the four species: *G. braziliensis*, *G. dominguensis*, *G. pandionis* and *G. simpsoni* (Wilks' Lambda = 0.01; $F_{27,362} = 69.87$; $p < 0.0000$). This analysis correctly classifies nearly 97% of the specimens (Fig. 9), with only two out of 136 being incorrectly classified. The Discriminant Functions (FD) based on the raw coefficients of canonical variables are shown below:

$$\text{FD1} = 0.81L + 1.72\text{Max} + 1.48L: \text{Max} - 2.86\text{Dmax} - 0.47\text{Arc} - 0.47\text{Ha}: \text{Wa} + 0.80\text{Hp} - 1.62\text{Wp} - 0.43\text{Hp}: \text{Wp}$$

$$\text{FD2} = 1.08L - 0.92\text{Max} - 0.62L: \text{Max} - 0.60\text{Dmax} - 1.01\text{Arc} + 1.35\text{Ha}: \text{Wa} - 1.31\text{Hp} + 1.06\text{Wp} + 0.69\text{Hp}: \text{Wp}$$

$$\text{FD3} = -0.20L - 1.58\text{Max} - 0.55L: \text{Max} + 0.58\text{Dmax} + 0.24\text{Arc} - 0.71\text{Ha}: \text{Wa} + 3.11\text{Hp} - 3.07\text{Wp} - 1.38\text{Hp}: \text{Wp}$$

The proportion of explicability was 0.74 for the FD 1 (= Discriminant Function 1), 0.19 for the FD 2 and 0.07 for the FD 3. Figure 9 plots only FD 1 vs. FD 2, giving a robust distinction

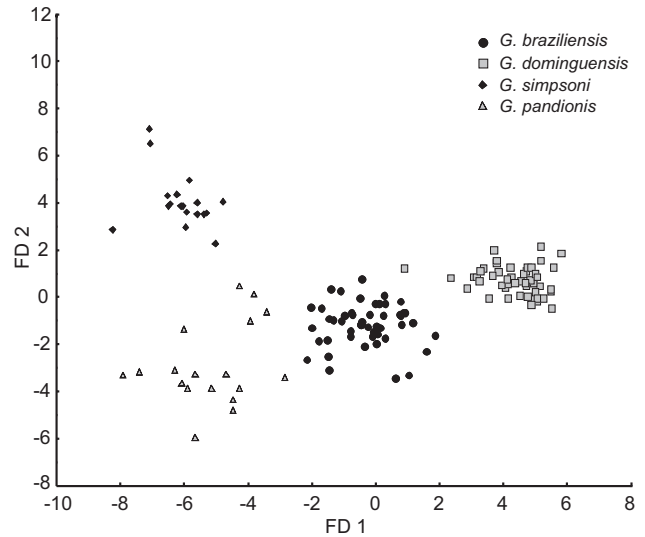


Figure 9. Results from Discriminant Analysis for the species of *Gadila*.

between the four species studied. The axis defined by FD 1 split the species into three groups. *Gadila braziliensis* presents intermediate values, distributed around positive and negative low values (between -2 and 2); *G. dominguensis* presents strongly positive values (between 2 and 6); while *G. pandionis* and *G. simpsoni* are characterized by strongly negative values (between -2 and -8). On the other hand, the axis formed by FD 2 was able to separate *G. simpsoni* from the other three species, with the former being characterized by exclusively positive values.

Table I. Values of shell morphometric parameters for species of *Gadila* from Brasil. (L) Length, (Max) maximum diameter, (Dmax) distance of point of maximum diameter from anterior aperture, (Arc) maximum curvature, (Larc) distance of point of maximum curvature from the apex, (Ha) anterior aperture height, (Wa) anterior aperture width, (Hp) apical aperture height, (Wp) apical aperture width. All measurements are in millimeters. * Type dimensions obtained from HENDERSON (1920).

Parameters	<i>G. braziliensis</i> (n = 50)	<i>G. dominguensis</i> (n = 50)	<i>G. elongata</i>	<i>G. pandionis</i> (n = 16)	<i>G. pocula</i>	<i>G. simpsoni</i> (n = 18)
	Mean (\pm SD)	Mean (\pm SD)	Type*	Mean (\pm SD)	Type*	Mean (\pm SD)
L	7.7 (0.7)	8.4 (0.9)	14.1	10.8 (2.2)	12.0	5.2 (0.6)
Max	1.0 (0.1)	1.0 (0.1)	1.5	1.6 (0.4)	1.9	0.8 (0.1)
L: Max	7.7 (0.5)	8.3 (0.7)		6.6 (0.5)		6.3 (0.6)
Dmax	1.9 (0.3)	0.8 (0.2)		3.7 (0.8)		2.1 (0.3)
Arc	0.5 (0.1)	0.4 (0.1)		0.9 (0.2)		0.2 (0.0)
Larc	3.1 (0.4)	3.2 (0.5)		4.3 (1.0)		1.8 (0.1)
Ha	0.6 (0.0)	0.7 (0.1)	1.4	1.0 (0.2)	1.4	0.5 (0.0)
Wa	0.7 (0.1)	0.8 (0.1)	1.0	1.2 (0.3)	1.2	0.4 (0.0)
Ha: Wa	0.8 (0.1)	0.9 (0.0)		0.9 (0.1)		1.3 (0.1)
Hp	0.3 (0.0)	0.2 (0.1)	0.4	0.4 (0.1)	0.6	0.2 (0.0)
Wp	0.3 (0.0)	0.2 (0.0)	0.4	0.5 (0.1)	0.6	0.3 (0.0)
Hp: Wp	0.9 (0.0)	0.8 (0.2)		0.7 (0.0)		0.7 (0.1)

In the FD 1, shell length to maximum diameter ratio (L: Max) seems to be the most important variable to distinguish species along this axis. There is a gradient of shell slenderness, with *G. dominguensis* being the most slender and *G. pandionis* and *G. simpsoni*, representing the more inflated shells. *Gadila braziliensis* occupies an intermediate position between these two extremes. The axis defined by FD 2, reflects the shell length and clearly separates *G. simpsoni* from the others species by its lower shell length.

Although the morphometric approach in Scaphopoda studies is relatively recent and rarely used, it has been useful in distinguishing among congeneric species (CAETANO & ABSALÃO 2005, SCARABINO & CAETANO 2008). In groups such as Scaphopoda, with a limited number of conchiliological characters, the morphometric approach constitutes a valuable tool for making taxonomic decisions and its inclusion in subsequent works should be considered.

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