

A new species of *Acar* (Bivalvia, Arcidae) from São Pedro e São Paulo Archipelago, Brazil

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ABSTRACT. *Acar transmar* is a new species endemic from São Pedro e São Paulo Archipelago, approximately located at middle Atlantic. The species is close related to *A. dominguensis* from the Caribbean to mainland Brazilian coast by shell characters and in having pallial eyes. The species differs mainly in being smaller and more trapezoid, in having umbos more anterior positioned, foot more elongated, triangular outer demibranch, amongst some other conchological and anatomical characters. The small size (about 5 mm) and the triangular outer demibranch are so far exclusive of the new species.

INTRODUCTION

Arquipélago de São Pedro e São Paulo, or Saint Peter and Saint Paul Archipelago, is the remotest Brazilian oceanic set of islands. It is the tip of a huge oceanic mountain, with a base of, approximately, 4 by 2 km large, 4 km depth, and an emerged tip of 13,000 m². The localization of the archipelago is about 1,010 km off Calcanhar Cape, Rio Grande do Norte State, and about 870 km off Fernando de Noronha, the largest Brazilian oceanic archipelago; somewhat located at middle way between Brazil and Africa, and close to Equator line (Souza, 2007); the coordinates are 00°55'00"N 29°20'42"W.

The Archipelago, abbreviated ASPSP, is a strategic point for the Brazilian economy, as ensures 238,000 km² of exclusive economic zone (Gonçalves, 2002). Since 1996, the Archipelago has continuously been occupied by 4-people researcher teams. Every person is allowed to work in that place only after a tough training, provided by the Brazilian Navy in its Rio Grande do Norte Base. Each team is allowed to work in 15-day expeditions.

Despite its importance in biological aspects, in being a so isolated place and important source for the understanding of evolutionary and biological colonization, the local malacofauna has not been the main goal of projects. Few published papers deal with mollusks from the ASPSP, they are restricted to species lists, with no deep taxonomical research (e.g., Edwards & Lubbock, 1983, which lists four molluscan species). Even the more classic revision considering the malacofauna of the Brazilian oceanic islands, Leal (1991), have not dealt with the ASPSP.

A project supported by the federal Brazilian council of research, CNPq, allows to collect and to study the ASPSP benthic invertebrate fauna. This paper deals with an uncommon arcid bivalve from those islands, occurring infratidally, in such conchological and anatomical analyses revealed a new species of the

genus *Acar* Gray, 1857 [type species *Arca gradata* Broderip & Sowerby, 1829, from California, USA] (Bartsch, 1931); considered by some authors subgenus of *Barbatia* Gray, 1842. The study has been facilitated by a previous anatomical and phylogenetic study on Western Atlantic arcid species (Simone & Chichvarkhin, 2004), mainly focusing the *Barbatia* group of species.

MATERIAL AND METHODS

The specimens were studied still alive, under a stereo-microscope, on board of seagoing tugboat "Almirante Guilhem", commander Captain Antonio Cesar Portela Marques, Brazilian Navy. Afterwards the specimens were fixed in 70% EtOH. The dissections were performed by standard techniques, with specimens immersed in fixative under a stereo-microscope. All drawings were done with the aid of a camera lucida. Most dissection steps were additionally digitally photographed. Some shells were additionally examined in SEM (scanning electronic microscope) in the Laboratório de Microscopia Eletrônica of the Museu de Zoologia da Universidade de São Paulo (MZSP); but these shells were not covered by gold.

Abbreviations

The following abbreviations are used in the figure captions: **aa**, anterior adductor muscle; **an**, anus; **ap**, pedal protractor muscle; **ar**, anterior retractor muscle of foot; **as**, accessory auricle; **au**, auricle; **by**, byssal furrow of foot; **cc**, cerebral commissure; **ce**, cerebral ganglion; **ci**, ciliary connection between gill and adjacent structures; **dd**, ducts to digestive diverticula; **dg**, digestive gland; **es**, esophagus; **ey**, eye of mantle edge; **ft**, foot; **gc**, gill connection in visceral sac; **gi**, gill; **go**, gonad; **gt** gill suspensory stalk; **id**, inner demibranch; **in**, intestine; **ki**, kidney; **mb**, mantle border; **ne**, nephropore; **od**, outer demibranch; **pa**,

posterior adductor muscle; **pc**, pericardium; **pg**, pedal ganglion; **pm**, pallial muscle; **pp**, palps; **pr**, posterior retractor muscle of foot; **rt**, rectum; **sh**, shell; **ss**, style sac and proximal portion of intestine; **st**, stomach; **tm**, connective between cerebral-pleural ganglia with visceral ganglion; **um**, umbo; **ve**, ventricle; **vg**, visceral ganglion.

Abbreviations of institutions: **MNRJ**, Museu Nacional da Universidade Federal do Rio de Janeiro, Brazil; **MZSP**: Museu de Zoologia da Universidade de São Paulo, Brazil.

SYSTEMATICS

Acar transmar sp. nov.

Figs 1-26

Type material. Holotype MZSP 87365. Paratypes: BRAZIL. **São Pedro e São Paulo Archipelago**, Belmonte Island, 00°55'00"N 29°20'42"W (Simone & Cunha col.); Enseada, MZSP 86530, 9 specimens, MNRJ, 2 specimens (28/x/2007), MZSP 86546, 6 specimens (31/x/2007), MZSP 86635, 3 valves (1/xi/2007), MZSP 86618, 1 specimen (4/xi/2007), MZSP 86577, 1 specimen (9/xi/2007).

Type locality. BRAZIL. **São Pedro e São Paulo Archipelago**; Belmonte Island, Enseada, 00°55'01"N 29°20'44"W (Simone & Cunha col., 31/x/2007).

Diagnosis. Species found in São Pedro e São Paulo Archipelago with up to 5.5 mm in length; outline somewhat trapezoid; umbos located between anterior and middle thirds; hinge bearing slightly uniformly sized teeth; mantle edge colorless, possessing eyes; foot with elongated, narrow tip; outer demibranch triangular and smaller than the inner demibranch; intestine with single, almost straight loop.

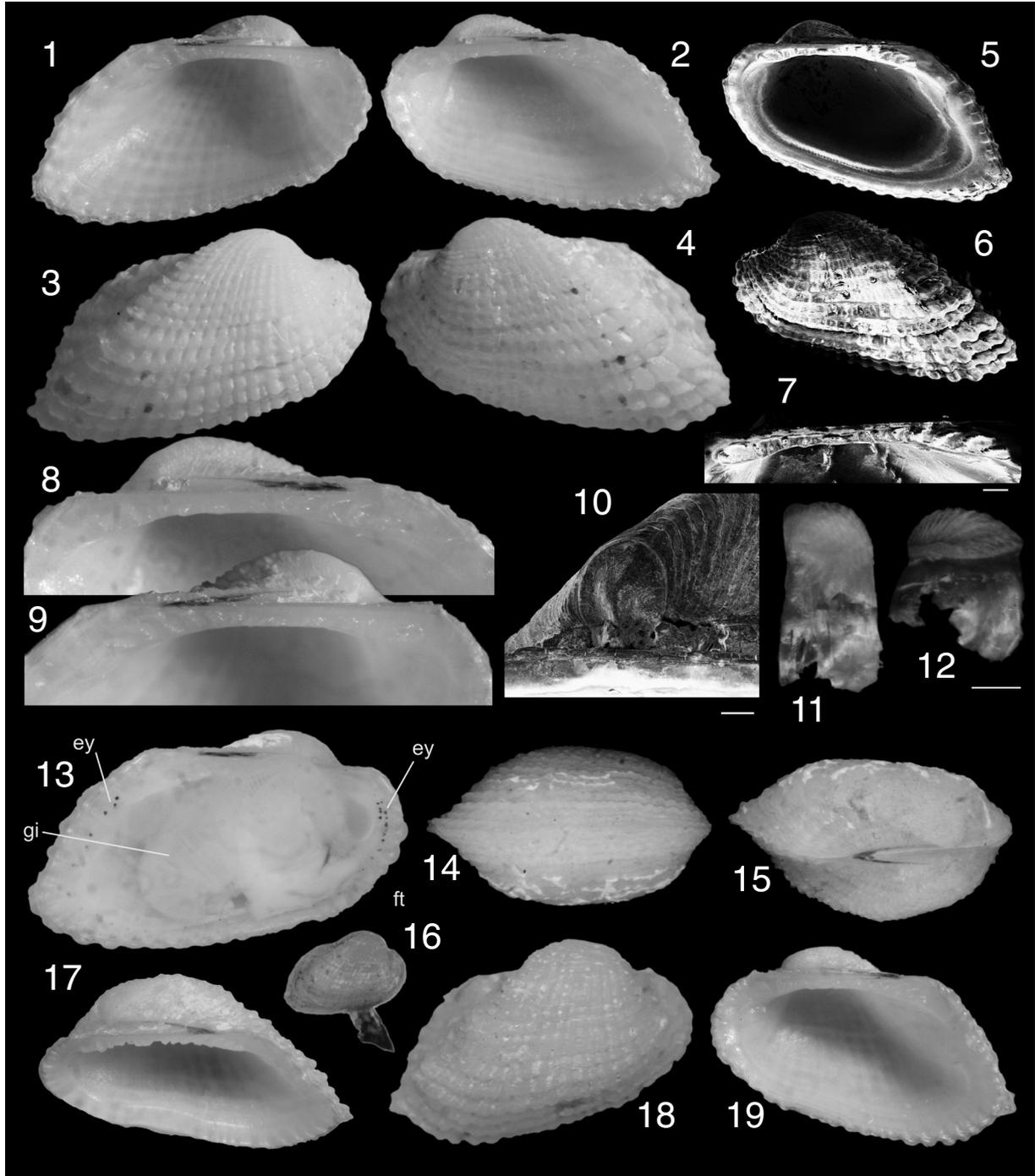
Description

Shell (Figs 1-10, 13-19). Up to 5 mm in length, outline trapezoidal, color pure white. Periostracum very thin, transparent, beige. Anterior region about 2/3 of posterior region; antero-posterior length about 1.8

times longer than dorso-ventral height; inflation equivalent to shell height (Figs 14, 15). Prodissoconch (Fig. 10) rounded, flattened; umbo pointed, central in dorsal edge; sculptured by about 20 narrow and low radial lines somewhat uniformly disposed, interval between two successive lines equivalent to double width of each line; outer boundary clear; antero-posterior length = 165 µm, dorso-ventral height = 200 µm. Lunule narrow, about 1/6 of broader region of shell in its wider, middle level, about half shell in length (Figs 15, 17); ligament restrict to its outer edge and in posterior half; outer surface plane, possessing lines parallel to hinge edge. Umbos blunt, located on middle of hinge and between middle and anterior thirds of shell; protruded about 1/5 of dorso-ventral shell height beyond hinge. Sculpture about 25 radial cords, uniformly sized, interval between cords equivalent to ¼ each cord width, each cord about three times wider than tall, extending weakly beyond shell margin; commarginal cords with approximately same characters than radial cords, except in being more spaced and narrower; commarginal and radial cords forming an uniform reticulate; sculpture of posterior slope with radial cords more spaced and commarginal cords weakly taller, almost forming scales (Figs 3, 4, 6, 18). Hinge relatively thick, constituted by about 12 teeth in each valve, being central teeth about 1/3 of anterior and posterior teeth; 3-4 anterior teeth obliquely positioned; 3-4 posterior teeth forming chevrons (Figs 1, 2, 5, 8, 9, 17, 19). Inner surface glossy, white; muscle scars shallow (Fig. 5); scar of anterior adductor muscle oval, located about 1/10 of shell length posterior from anterior edge, occupying about 1.5% of inner surface; scar of posterior adductor muscle elliptical, about 1.5 times larger than anterior scar, located about 1/5 of shell length posterior to posterior edge; both adductor scar located in same dorsal level, approximately 1/5 of shell height ventral to hinge; pallial line broad, simple; scar of posterior pair of retractor muscles of foot located just anterior to scar of posterior adductor muscle, somewhat triangular, anterior end weakly narrower than posterior end, length equivalent to that of posterior adductor scar, wider (posterior) region about half that of posterior adductor scar.

Figures 1-19, *Acar transmar* shell and other structures.

1-10, Holotype, length = 5.2 mm; **1**, left valve, inner view; **2**, right valve, inner view; **3**, right valve, outer view; **4**, left valve, outer view; **5**, right valve in SEM, inner view; **6**, same, outer view; **7**, same, detail of hinge, inner-slightly ventral view, scale = 100 µm; **8**, right valve, inner view, detail of hinge area; **9**, same for left valve; **10**, detail of prodissoconch area, SEM, scale = 50 µm; **11**, byssus, right view; **12**, same, dorsal view (base somewhat bended), scale = 500 µm; **13**, holotype, whole right view, right valve extracted; **14**, paratype MZSP 86546#3, ventral view, length = 4.4 mm; **15**, same, dorsal view; **16**, paratype MZSP 86530, alive, right view, length = 4.6 mm; **17**, paratype MZSP 86546#2, right valve, dorsal-slightly left view, length = 4.8 mm; **18**, same, outer view; **19**, same, inner view.



Main muscle system (Figs 13, 20-22, 26). Anterior adductor muscle oval in transversal section, located about 1/10 of shell length posterior from anterior edge, occupying about 1.5% outer surface in each side. Posterior adductor muscle elliptical in transversal section (axis parallel to adjacent shell border), about 1.5 times larger than anterior adductor muscle, located about 1/5 of shell length posterior to posterior edge. Both adductor scar located in same dorsal level, approximately 1/5 of shell height ventral to hinge. Pallial muscles well-developed, being particularly larger in posterior region (Fig. 20: pm). Pair of pedal anterior retractor muscles originated just dorsal to anterior adductor muscle, in area equivalent to 1/20 of that of adductor; running ventral and posteriorly, in both sides of esophagus; inserting along anterior region of foot base (Fig. 26: ar). Pair of pedal posterior retractor muscles originating just anterior to and slightly more medial than posterior adductor muscle (size see shell scar) (Figs 20, 21); about 15 times broader and thicker than anterior pair of pedal retractor muscles; running ventrally and slightly anteriorly, inserting along posterior 2/3 of foot base (Fig. 26: pr). Pair of pedal protractor muscles about as large as pedal anterior retractor muscles, originating narrowly, covering ventral edge of anterior adductor muscle (Fig. 26: ap), running ventral and posteriorly gradually changing from flattened to cylindrical, inserting along lateral region of anterior foot base. Pallial muscles well-developed, mainly in posterior, incurrent region (Figs 13, 20: pm).

Foot and byssus (Figs 16, 22, 26). Foot thick posteriorly, with long anterior projection, tapering gradually along about half shell length; anterior end sharply pointed. Byssal furrow extending along entire ventral foot side, narrow; anteriorly shallow, gradually becoming deeper towards posterior. Foot base marked by narrow waist, with approximately 1/4 of shell length; dorsal to this, visceral sac gradually expanding. Byssus (Figs 11, 12, 16) normally laterally flattened, about 1/6 of shell length antero-posteriorly long, about half shell length in dorso-ventral height; color iridescent yellow to beige; about half projecting outside. Byssal dorsal region expanded, encased inside posterior half of pedal byssal furrow; dorsal surface (Fig. 12) with 2 series of oblique, tall folds encased in pedal musculature.

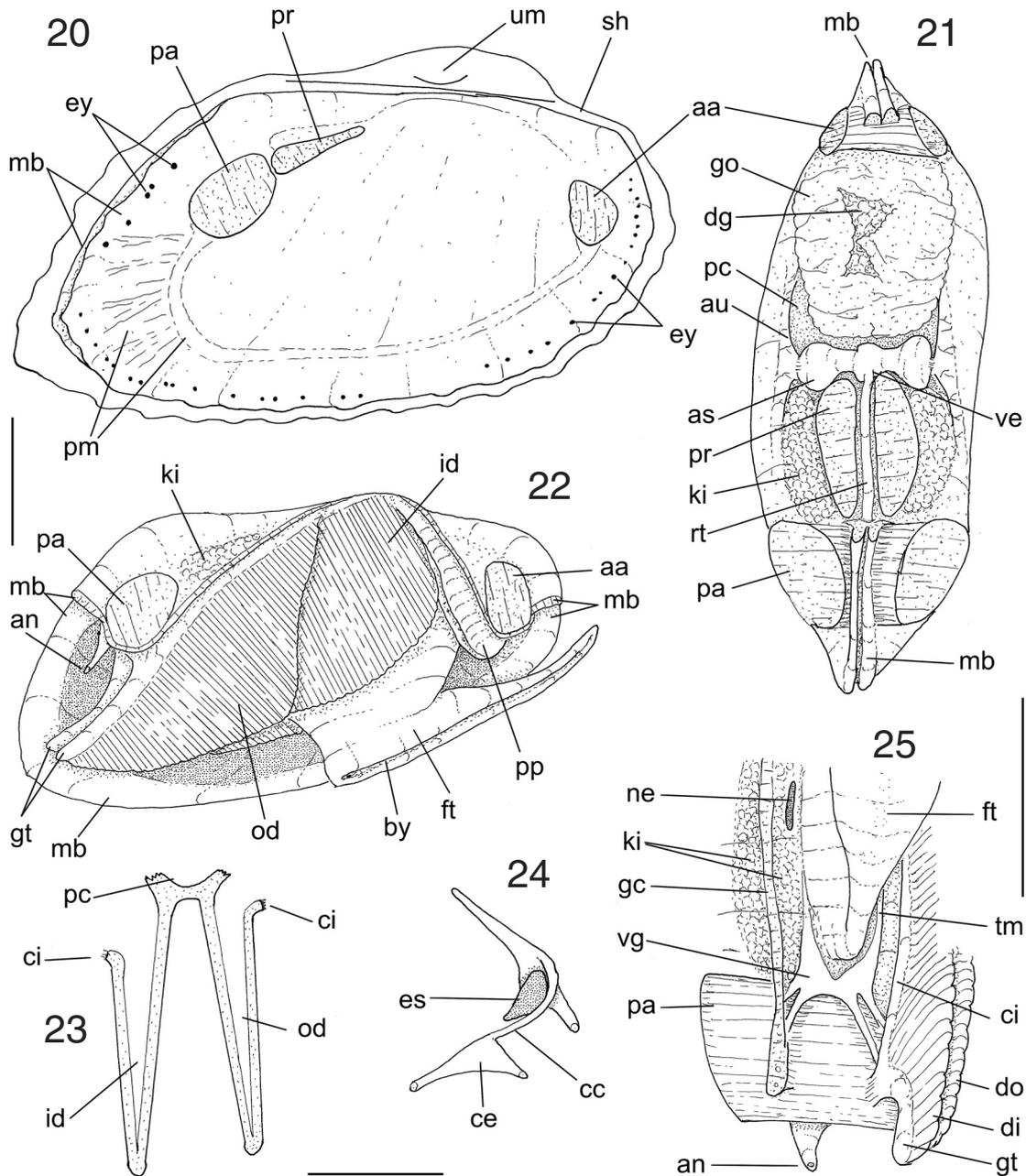
Mantle (Figs 13, 20). Mantle lobes totally free from each other. No pigments. Mantle edge trifolded, each fold similar sized; height of each fold equivalent to shell thickness. Inner fold possessing a series of small eyes; each eye rounded, dark; those in dorsal sides of anterior and posterior edges larger (size equivalent to double fold thickness; gradually eyes becoming smaller towards ventral, in both sides, with area lacking eyes in region of mantle edge equivalent to 1/5 of shell length, located in anterior end of ventral side (Fig. 20); eyes in both mantle lobes disposed

somewhat intercalated; about 12 anterior and about 20 posterior eyes.

Pallial cavity (Figs 13, 22, 25). Occupying about 70% of shell inner volume; dorsal end bluntly pointed, located inside umbonal cavity. Pair of palps dorso-ventrally elongated, edging anterior border of cavity; dorso-ventral height about 6 times antero-posteriorly length; dorsal region narrow; ventral region broader, surrounding integument recovering protractor pedal muscles, partially attached to ventro-posterior edge of anterior adductor muscle. Palps inner surface smooth in dorsal quarter, remaining with about 10 perpendicular, wide folds; interval between folds very narrow; another smooth area surrounding mouth. Each gill occupying about 80% of cavity area; dorsal length about 85% of shell length. Each inner demibranch about double as outer demibranch. Outer demibranch triangular; ventral angle blunt, rounded (Fig. 22: od); dorsal edge with about 75% of total gill length, keeping free gill anterior region. Each inner demibranch claviform, anterior third approximately with same height along its length; anterior edge encased inside palps; antero-ventral corner rounded (Fig. 22: id). Both hemipalps with similar fashion (Fig. 23) in gills middle region; lateral and medial connections via cilia. Pair of gill suspensory stalk relatively broad (Figs 22, 25: gt), with about 1/3 of gill length, inserted in ventral surface of posterior adductor muscle; no detectable food groove. Suprabranchial chamber narrow, region dorsal to gills about 1/20 from total pallial cavity.

Visceral mass (Figs 13, 21, 26). Occupying entire region between both adductor muscles, and about 1/3 of shell inner volume, excluding pair of posterior pedal retractor muscles. Stomach occupying about 1/3 of visceral volume, running along central region. Digestive diverticula restrict to antero-dorsal region, surrounding stomach, color greenish beige. Reno-pericardial structures occupying about 1/5 of visceral volume, positioned in anterior region of posterior adductor muscle, part surrounding base of pair of pedal posterior retractor muscles.

Circulatory and excretory systems (Figs 21, 25). Pericardium located just anterior to origin of pair of pedal posterior retractor muscles, restrict to dorsal, postero-umbonal region. Auricles triangular, ventral side connected directly to middle region of gills along about 1/3 their length; walls thin, translucent. In short dorso-ventral distance, both auricles connecting to lateral expansions of ventricle looking accessory auricles (Fig. 21: as), occupying about 3/4 of pericardial width; ventricle central region surrounding intestine generally slightly smaller than these accessory auricles. Kidneys solid, dark green; each one located between pericardium and posterior surface of posterior adductor muscle, surrounding origin of



esc=9; num=24; set=4; let=14

Figures 20-25, *Acar transmar* anatomy.

20, whole right view, right valve removed; **21**, specimen totally removed from shell, dorsal view, dorsal region of mantle partially removed to expose pericardial and adjacent structures; **22**, whole right view, right valve and infra-branchial part of right pallial lobe removed; **23**, gill, transversal section in its middle region; **24**, cerebral ganglia as in situ, right-slightly anterior and dorsal view, topology of esophagus also shown; **25**, posterior region of visceral sac, ventral view, some structures seen if integument was transparent, right gill (left in figure) removed. Scales = 1 mm.

both posterior pedal retractor muscles (Figs 21, 22: ki). Nephropores longitudinal slits located between anterior and middle thirds of membrane between kidneys and suprabranchial chamber (Fig. 25: ne), dislocated medially, on inner demibranch.

Digestive system (Fig. 26). Palps described above (pallial cavity). Esophagus about 1.5 times longer than anterior adductor muscle, initially running touching posterior side of this muscle; esophageal width about 1/3 that of anterior adductor muscle; esophageal inner surface smooth. Stomach main chamber spherical, located in dorsal side of middle visceral cavity; two pairs of ducts to digestive diverticula located each one in middle of gastric antero-lateral walls. Gastric inner surface mostly smooth; gastric shield occupying about 1/4 of inner surface, located in postero-left region; a transversal fold separating gastric main chamber from

style sac, running ventrally along anterior-right side, separating style sac from intestinal regions. Style sac about as long as gastric main chamber, and with approximately 1/4 of its width. Intestine separating from style sac in its terminal, ventrally. Intestine narrow (about 1/3 of style sac width), simple and short, performing a single loop along anterior side of posterior pedal retractor muscles; crossing pericardium, both origins of these muscles, and along medial region of posterior adductor muscle dorsal and posterior sides. Anus very narrow, preceded by detached region with about 1/4 of posterior adductor muscle length (Figs 22, 25: an).

Genital system. Gonad above described (visceral mass). No gonoduct or special aperture to kidney found.

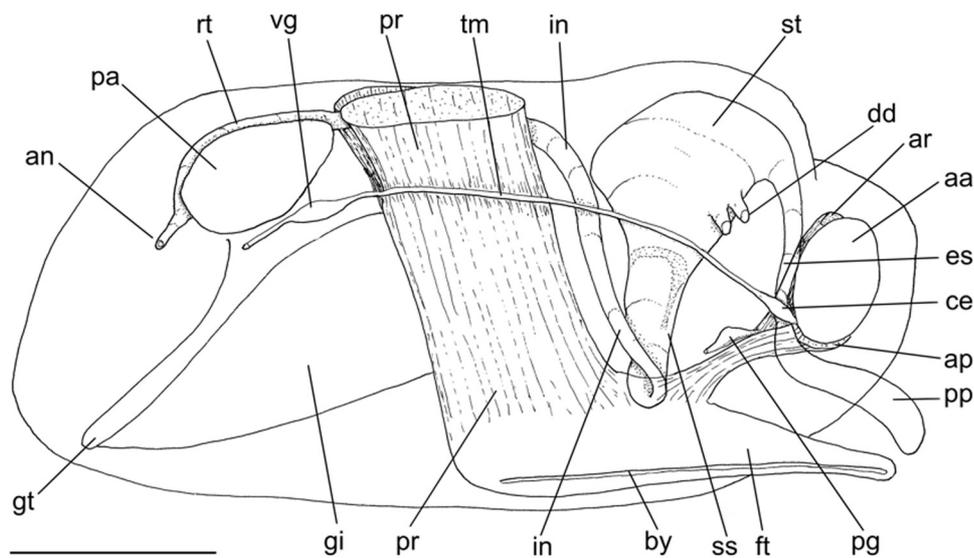


Figure 26. *Acar transmar*, semi-diagrammatic representation, whole right view, mainly concern to digestive tubes, main muscles and central nervous system as in situ, palps represented part removed and deflected. Scale = 1 mm.

Central nervous system (Figs 24-26). Pair of cerebral ganglia located in postero-ventral region of anterior adductor muscle; each one elliptical, with about half size of esophageal transversal section. Cerebral commissure (Fig. 24) with about 1.5 times each ganglion length, running close to adjacent region of esophagus. Pair of pedal ganglia equivalent in size to cerebral pair, located at relative short distance from cerebral ganglia (distance equivalent to a ganglia

length); each pedal ganglion elliptical, located very close from each other (pedal commissure very short), touching base of pair of anterior pedal retractor muscles (Fig. 26: pg). Pair of visceral ganglia (Fig. 25, 26: vg) located in antero-ventral region of posterior adductor muscle; each ganglion oval, about 50% larger than cerebral ganglion; located close from each other (visceral commissure very short), with a pair of large nerves running postero-laterally. Cerebro-

visceral connectives relatively thick, passing through gonad and kidney, connected terminally to visceral ganglia.

Development. One specimen (MZSP 86530#1) possesses a young individual attached by byssus to resilium of right valve, just anterior to umbo. Size of this young specimen: length= 0.7; height= 0.8; inflation= 0.2mm.

Measurements (respectively antero-posterior length, dorso-ventral height and maximum inflation, in mm). Holotype: 5.3 by 3.1 by 2.5; Paratype MZSP 86546#2: 5.0 by 3.4 by 3.0; #3: 4.6 by 3.1 by 2.7.

Distribution. São Pedro e São Paulo Archipelago.

Habitat. Infratidal rocks, in their occult surface, from 2 to 8 m depth.

Material examined. Types.

Etymology. The specific epithet refers both, to the name of the boats that transport the researchers to the Archipelago, Transmar; and by the fact that the species crossed the almost half ocean to its place, a contraction "trans", from transport, and "mar", sea in Portuguese.

DISCUSSION

Acar transmar is one of the smallest representatives of the genus, with larger specimens reaching about 5 mm. The single species occurring in the South Atlantic that can be confused is *A. dominguensis* (Lamarck, 1819) (Abbott, 1974; Rios, 1994; Simone & Chichvarkhin, 2004: 363-365, Figs 12-15, 60-65; Ardovini & Cossignani, 2004). Conchologically, both species share the strong reticulated shell sculpture, the inflation of the shell equivalent to its height, and the lunule with thin ligament. On the anatomy, both species are similar in having the pallial eyes, the colorless mantle border, the simplicity of the intestinal loop, and the siphonate, pointed anus. These characters demonstrate that *A. transmar* may be a sister-taxon of *A. dominguensis*, and this is the result if the characters of *A. transmar* are inserted in the analysis done in that paper (Simone & Chichvarkhin, 2004: fig. 74, table 1).

On the other hand, *Acar transmar* differs from *A. dominguensis* in having a smaller size (about 5 mm instead of about 20 mm of the other species); the outline is trapezoid in *A. transmar*, while it is more rectangular in *A. dominguensis*; the umbos are more anterior in *A. transmar*, than those of *A. dominguensis*, which are almost central; the hinge of *A. transmar* has more uniform teeth, whereas *A. dominguensis* has the anterior set of teeth clearly separated and differently sized in relation to middle and posterior teeth (see Simone & Chichvarkhin, 2004: fig. 20). Anatomically,

A. transmar has totally unpigmented soft parts, while those of *A. dominguensis* are stained with purple, mainly in the exposed regions and in the gill stalks; the foot of *A. transmar* always have a long and projected anterior tip, this does not happen in *A. dominguensis*, which possesses the normal fashioned anterior region; the byssus of *A. transmar* is thinner and its dorsal wider tip (encased inside pedal byssal furrow) is shorter and more rounded; the palps are narrower and with fewer internal folds in *A. transmar* than those of *A. dominguensis*; the outer demibranch of *A. transmar* is always triangular and smaller than the inner demibranch, this is not found in *A. dominguensis*, whereas has both similar sized; and the intestinal loop runs much closer to the style sac in *A. transmar* than that of *A. dominguensis*, which is wider.

No other Atlantic species of *Acar*, as well as of *Barbatia*, can be confused with *A. transmar*. Its similarity with *A. dominguensis*, and its conchological characters, suggest that *A. transmar* belongs to the genus *Acar*, like, e.g., the cancellate sculpture. Another interesting character of both species is the simple, thin periostracum, clearly found in *A. transmar*; normally the genera related to *Barbatia*, as well as most arcids, have the periostracum with well-developed hair or even scales.

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