

INSULAR LIFE: NEW ENDEMIC SPECIES FROM SÃO PAULO OCEANIC ISLANDS, BRAZIL (PULMONATA, BULIMULIDAE), AS EXAMPLE OF ENDEMICITY

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Abstract Three new species of Bulimulidae (Gastropoda, Pulmonata) are described, each one endemic to a different island off the São Paulo coast, showing a high degree of endemism of these islands in terrestrial malacofauna. *Drymaeus castilhensis* occurs on Castilho Island, it is mainly characterised by the strong axial dark spots in the shell or in being totally pale beige, penis elongated, lacking any inner chambers or glands, and double ducts of albumen gland. *Drymaeus micropyrus* occurs on Queimada Pequena Island, it is mainly characterised by greenish-cream shell, with narrow axial spots, and single duct of albumen gland. *Bulimulus sula* is from Alcatrazes Island, its main features include a relatively cylindrical, featureless shell, bilobed penis and, mainly and remarkably, a genital appendix that looks like a small accessory penis. These three species are described and compared with similar species, and accounts on their biogeography.

Key words Taxonomy, new species, Pulmonata, endemism, isolation, land snails.

INTRODUCTION

The Brazilian oceanic islands have proven to bear high malacological diversity and to be a perfect laboratory for better understanding the evolutionary and environmental processes of speciation. The more remote islands have shown a relatively high degree of endemism in marine species, around 50% (Simone in prep.), while in the closer placed islands the marine endemism tends to zero. On the other hand, a very different scenario is found in the terrestrial malacofauna, in such the degree of endemism is practically 100%, even in the islands that are placed only a few kilometers off the coast. More precise data are currently unavailable as the large project on insular Brazilian malacofauna is still in progress, and has been developed by MZUSP researchers for over a decade.

The State of São Paulo has almost 400km of coastline along the Atlantic Ocean and several islands, some of which are far off the coast and for obvious reasons are the focus of faunistic surveys. The three islands herewith studied are shown in Fig. 1, and are as follows: **Alcatrazes** is an archipelago that is presently protected as an Ecological Station called Tupinambás (ESEC Tupinambás) and an Alcatrazes Refuge of 67,409 hectares of emerged and submerged areas; it is



Figure 1 Map of State of São Paulo divided in mesoregions, based on IBGE maps. Approximate localization of studied islands shown off the coast: 1, Castilho Island; 2, Queimada Pequena (Queimadinha) Island; 3, Alcatrazes Archipelago.

located ~45km off São Sebastião city. The main island, from which the samples were collected, has about 1.7 by 1km of extension of emerged area. **Queimada Pequena**, also known as “Queimadinha”, is part of an Area of Relevant Ecological Interest, jointed with the island Queimada Grande, includes a protected area of ~138 km²; it is located ~22km off Itanhaém city; its emerged area is ~900 m². **Castilho** is an island that belongs to the Ecological Station of Tupiniquins; it is located ~7km off Cananéia city; it has ~300m long, ~100m wide of emerged area.

All three islands have a vestige of Atlantic rainforest at the tip of large rocky blocks, surrounded by relatively shallow (~10–30m) waters, a strong rocky coast, and a narrow Restinga (saltmarsh) belt. All samples were collected in the rainforest area.

These three islands, in particular, have a relatively scanty terrestrial malacofauna, some minor-sized taxa of obscure taxonomy, such as subulinids and scolodontids, which are still being studied, and a “dominant” macro-sized bulimulid species. Castilho and Queimada Pequena have species belonging to the genus *Drymaeus* Albers, 1850, while that from Alcatrazes belongs to *Bulimulus* Leach, 1814. The conchological (Simone, 2006) and anatomical study revealed all as new species formally described herein. A discussion on the likely biogeographic processes that resulted in this endemism is also included.

MATERIAL AND METHODS

The specimens were collected in duly authorised projects as these regions are protected areas; a complete list of examined material follows each species’ description, with distinctions of “specimen” (a complete individual, shell and soft parts in alcohol) and “shell” (empty shell only). The samples were preserved unrelaxed in 75% EtOH. The dissections were performed by standard techniques, with the specimens immersed in alcohol, examined under dissecting stereomicroscopes. All drawings were done with the aid of a camera lucida and, when possible, each drawing was based on several specimens. Photos of all dissecting steps were made by digital camera coupled to the microscope. SEM examinations were performed in a Zeiss device of the Laboratory of Electronic Microscopy of the MZSP

Anatomical abbreviations: **aa**, anterior aorta; **ac**, albumen chamber; **ad**, albumen gland duct; **ag**, albumen gland; **an**, anus; **au**, auricle; **bc**, bursa copulatrix; **bd**, bursa copulatrix duct; **bg**, buccal ganglion; **bm**, buccal mass; **bv**, blood vessel; **cc**, cerebral commissure; **ce**, cerebral ganglion; **cd**, cerebral node; **cn**, cerebro-pedal and cerebro-pleural connectives; **co**, collar vessel; **cv**, pulmonary (efferent) vein; **da**, digestive gland anterior lobe; **dd**, duct to digestive gland; **df**, dorsal folds of buccal mass; **dg**, digestive gland posterior lobe; **di**, diaphragm or pallial floor; **ef**,

epiphallus inner longitudinal fold; **eh**, epiphallus; **eo**, spermoviduct; **es**, oesophagus; **fo**, free oviduct; **fp**, genital pore; **ga**, genital appendix; **gf**, genital fold; **gg**, genital gland; **go**, gonad; **hd**, hermaphrodite duct; **in**, intestine; **ki**, kidney; **kl** kidney lobe; **m1–m10**, extrinsic and intrinsic odontophore muscles; **mb**, mantle border; **mc**, circular muscle component of peribuccal muscles; **mf**, mantle fold; **mj**, jaw and peribuccal muscles; **mo**, mouth; **ne**, nephrostome; **oc**, odontophore cartilage; **od**, odontophore; **pc**, pericardium; **pe**, penis; **pi**, penis inner middle glandular portion; **pm**, penis muscle; **pn**, pneumostome; **pp**, pedal ganglion; **ps**, penis sheath; **pt**, prostate; **pu**, pulmonary cavity; **pv**, penis valve-like transverse fold; **pv**, pneumostome right flap; **ra**, radula; **rn**, radular nucleus; **rs**, radular sac; **rt**, rectum; **sa**, salivary gland aperture; **sd**, salivary gland duct; **sg**, salivary gland; **sp**, spermoviduct inner longitudinal fold; **sr**, seminal receptacle; **st**, stomach; **sy**, statocyst; **tg**, integument; **to**, tissue on radular ribbon preceding radular exposed region in buccal cavity; **ua**, ureter aperture; **ug**, urinary gutter; **un**, union of mantle border with nuchal surface; **up**, primary ureter; **ur**, secondary ureter; **ut**, uterus; **vd**, vas deferens; **ve**, ventricle; **vg**, vagina; **vi**, visceral ganglion; **vm**, visceral mass; **vp**, posterior pulmonary vessel.

Institutional acronyms: **MNRJ**, Museu Nacional da Universidade Federal do Rio de Janeiro, Brazil; **MZSP**, Museu de Zoologia da Universidade de São Paulo, Brazil; **USNM**, National Museum of Natural History, Smithsonian Institution, Washington DC, USA.

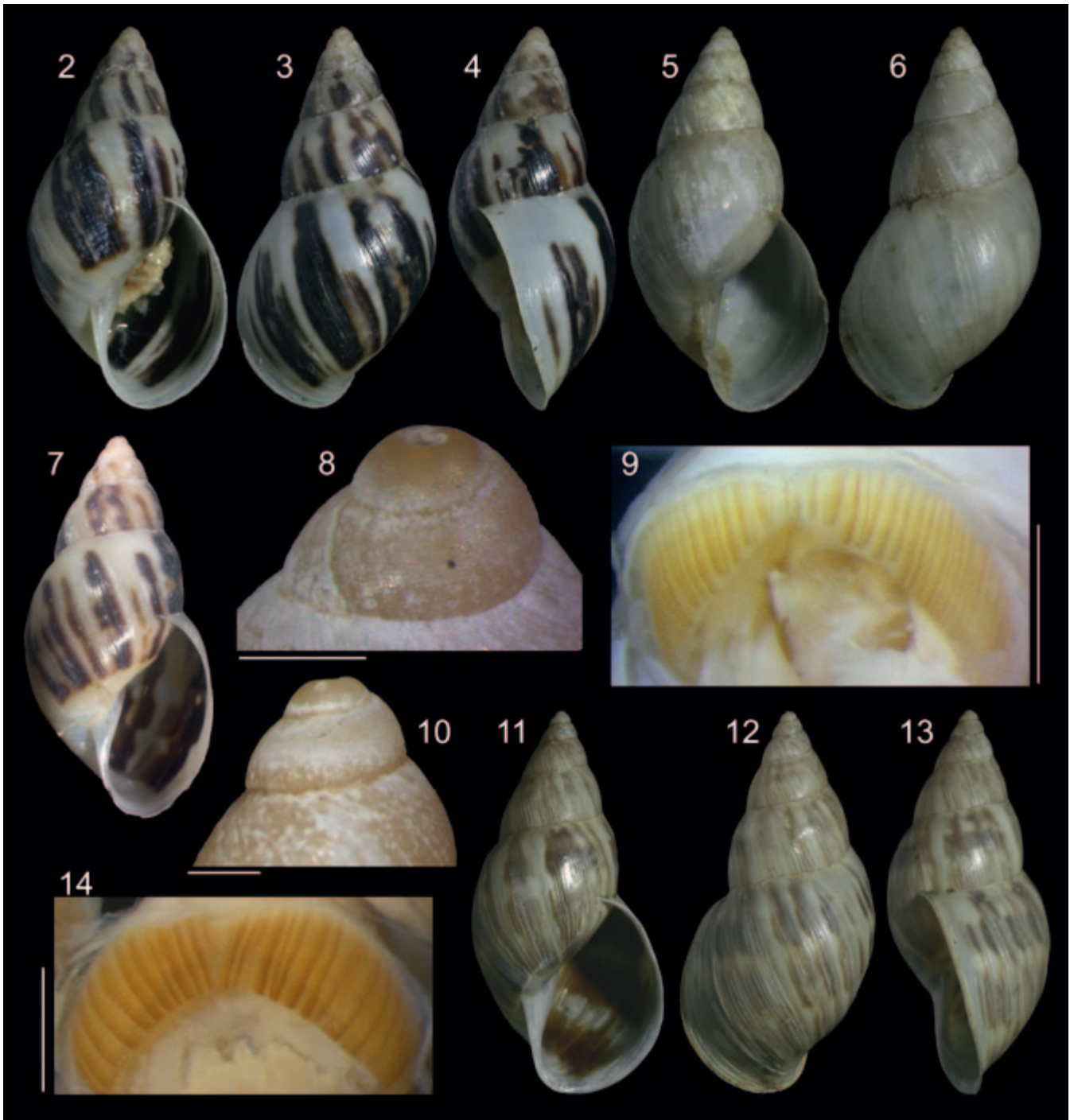
SYSTEMATICS

Drymaeus castilhensis sp. nov. (Figs 2–9, 21–24, 37–54)

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Types Holotype: MZSP 84277 (Figs 2–4). Paratypes: MZSP 49190 (3 specimens), 89627 (3 specimens), MZSP 44425 (1 specimen), MZSP 44459 (2 specimens), MZSP 137897 (6 specimens), MZSP 40326 (1 shell), MZSP 48329 (1 specimen); all from type locality.

Type locality **BRAZIL. São Paulo**; off Cananéia, Ilha de Castilho, 25°16'24.6"S 47°57'18.6"W (Amaral & Dornellas col., 7–8.i.2009).



Figures 2–14 Shell and jaws of types: 2–9, *Drymaeus castilhensis*; 2, holotype MZSP 84277 (L 33.7) apertural view; 3, same, dorsal view; 4, same, right view; 5, paratype MZSP 49190 (L 33.2) apertural view; 6, same, dorsal view; 7, paratype MZSP 89627 (L 28.5) apertural view; 8, same, detail of protoconch in profile; 9, jaw, anterior view; 10–14: *D. micropyrus* holotype MZSP 84939 (L 36.8); 10, protoconch in profile; 11, shell, apertural view; 12, same, dorsal view; 13, same, right view; 14, jaw, anterior view. Scales= 1mm.

Etymology The epithet is a reference to the local of occurrence, derived from Castilho Island.

Diagnosis Shell conical, aperture ample, weakly deflected. Colour white-cream, mostly with

strong dark brown axial spots; peri-umbilical area lacking spots; some species with uniform pale beige. Secondary ureter almost entirely closed, except for short portion preceding pneumostome. Anus external to pneumostome, opened

directly outside. Aperture of salivary glands lateral in middle level of buccal cavity. Intrinsic pair of odontophore muscles m7 originating in cartilages close to m6. Sigmoid intestinal loop very ample. Penis slender and long, lacking clear inner chambers. Inner spermoduct of spermoviduct protected by tall fold. Seminal receptacle small. Albumen gland duct double. Pleural ganglia inconspicuous.

Description

Shell (Figs 2–8) Adult shell around 35mm, conical-oval; apex acuminate; greatest width on last whorl; width $\sim 1/2$ shell length. Basal colour white to pale-cream; pattern of dark-brown spots arranged in irregular axial bands, slightly more concentrated in inferior half of whorls; peri-umbilical area flanked by area lacking spots (Figs 2–3, 7); dark spots absent in $\sim 20\%$ of specimens, being purely whitish-cream (Figs 5–6). Spire angle $\sim 50^\circ$. Protoconch of 2 whorls, $\sim 6\%$ of length, uniformly sculptured by delicate reticulate (Fig. 8), with ~ 25 spiral lines in last whorl; transition to teleoconch clear, slightly prosocline. Teleoconch smooth, except for growth lines, of ~ 4 whorls. Whorls profile slightly convex. Suture well-marked, slightly oblique (diagonal) to columellar axis. Aperture prosocline ($\sim 20^\circ$ from longitudinal general axis) (Fig. 4), oval; $\sim 50\%$ of shell length, $\sim 60\%$ of shell width. Peristome slightly reflected, especially on columellar region, partially covering umbilicus. Body whorl $\sim 1/2$ shell length. Umbilicus narrow.

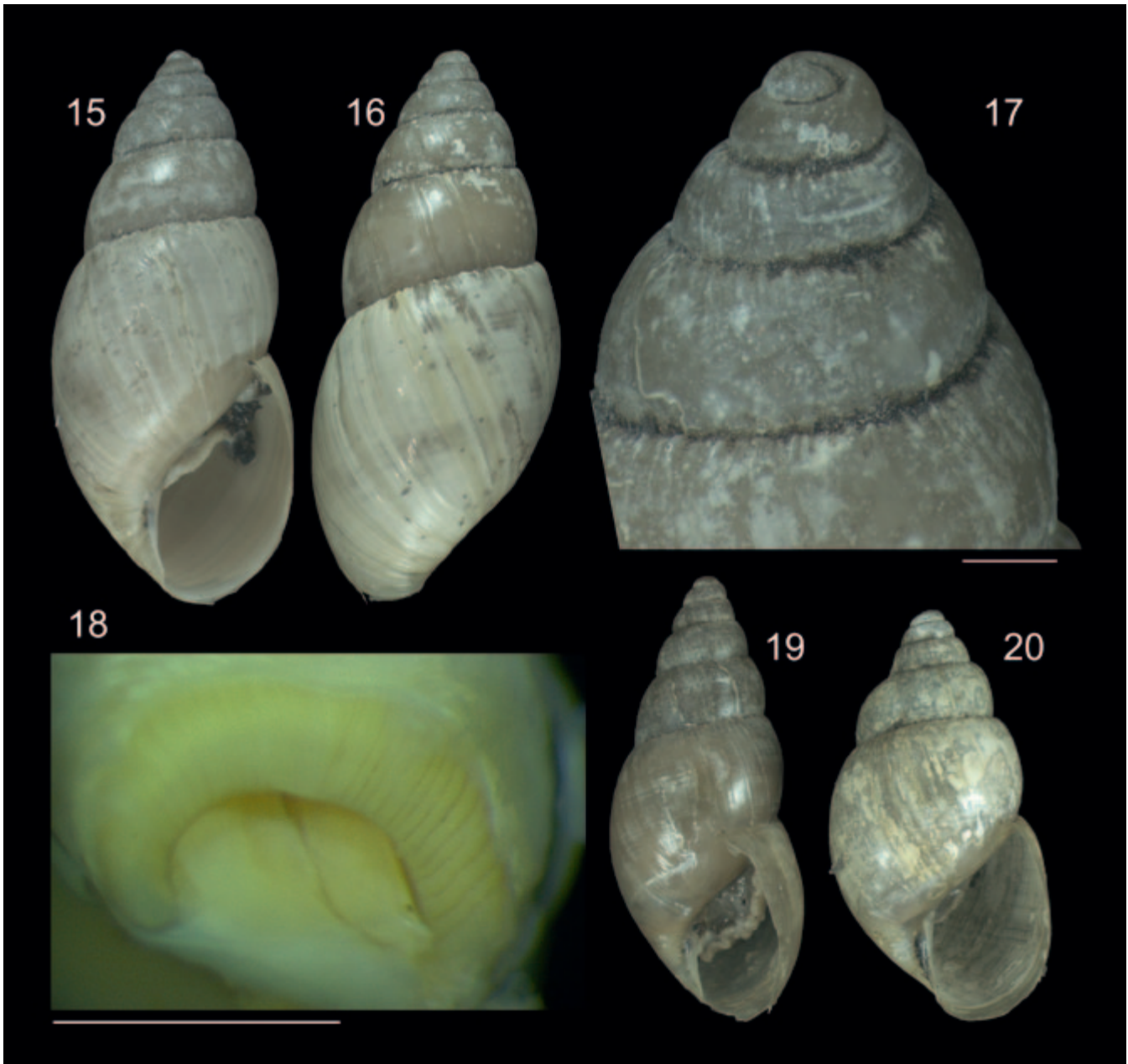
Head-foot Of typical shape. Colour uniformly clear. Columellar muscle thick, 1.5 whorls in length.

Mantle organs (Figs 37, 39) Mantle border thick, lacking pigments. Pneumostome (pn) protected by right ventral simple flap, with $\sim 1/5$ of aperture length. Dorsal fold not developed, immersed in mantle border. Pneumostome (pn) $\sim 1/10$ of aperture length, bearing exclusively air entrance and urinary gutter (Fig. 39: ua); aperture of ureter as longitudinal slit, starting $\sim 1/6$ whorl posterior to pneumostome. Anus as separated aperture located at right from pneumostome (Fig. 39: an). Lung of 1.5 whorls in length, wide and elongated. Pulmonary vessels conspicuous only in anterior fifth, with 4–6 stronger vessels (Fig. 39), remaining regions almost smooth, with

imbricated vessels of difficult visualization (Fig. 37: pu) being vessels draining to anterior collar vessel more calibrous. Pulmonary vein (cv) running longitudinally between middle and right thirds of pallial cavity roof, slightly oblique condition, gradually approaching from median line in posterior end. Reno-pericardial area beige, slightly triangular, located posteriorly at middle level of posterior end, occupying $\sim 30\%$ of cavity length and $\sim 60\%$ of its width (details below). Rectum (rt) and ureter (ur) narrow, running along right edge.

Visceral mass (Fig. 38) ~ 3 whorls in length. Both digestive gland lobes pale greenish beige in colour. Anterior lobe (da) flattened, occupying $\sim 1/5$ of visceral volume, located just posteriorly to pallial cavity, continuous to kidney. Posterior lobe (dg) with 2 spiral whorls, with $\sim 60\%$ of visceral volume. Stomach with $\sim 1/8$ of visceral volume, located between both digestive gland lobes, about one whorl posterior to pallial cavity (st). Digestive tubes (described below) surrounding anterior lobe of digestive gland. Gonad clearly multi-lobed, cream colour, encased between posterior lobe of digestive gland and columella, occupying $\sim 1/15$ of visceral volume.

Circulatory and excretory systems (Figs 37, 40) Pericardium (pc) ~ 3 times as long as wide, located longitudinally between middle and left thirds of posterior end of pallial roof; occupying $\sim 5\%$ of lung area. Auricle (au) located anteriorly, as continuation from pulmonary vein (cv), slightly smaller than ventricle (ve). Kidney (ki) simple, entirely solid, dorso-ventrally flattened; size reported above; somewhat triangular, width $\sim 2/3$ of length. Nephropore small, longitudinal slit in anterior-left corner, turned right (Fig. 40: ne). Primary and secondary ureter complete and closed (tubular); primary ureter (up) lying on right edge of kidney towards posterior and right, after forming strong curve, running afterwards anteriorly, as secondary ureter (ur) along entire left edge of rectum, except for longitudinal urinary aperture of $\sim 1/5$ of its length (ua). Right edge of urinary aperture running anteriorly, continuous to ventral edge of anus; left edge about twice longer, in its middle region abruptly turned left, flanking inner edge of pneumostome (Fig. 39: ua). No clear groove in front of urinary aperture after pneumostome.



Figures 15–20 *Bulimulus sula* shells and jaw of types: **15**, holotype MZSP 134475 (L 19.3) apertural view; **16**, same, dorsal view; **17** same, detail of shell apex, profile-slightly apical view; **18**, jaw of paratype MZSP 109568, anterior view; **19**, paratype MZSP 109568 (L 20.3); **20**, another paratype MZSP 109568 (L 18.7) with anomalous shape. Scales= 1mm.

Digestive system (Figs 38, 41–44) Oral tube wide, muscular (Fig. 41: mj). Jaw simple, exposed portion horseshoe-shaped, notched at middle, bearing ~20 pairs of uniform, transverse folds (Fig. 9); becoming gradually longer and narrower from median line to lateral regions; colour yellow, translucent. Buccal mass spherical, with ~1/5 of haemocoel volume (Fig. 38: od). Dorsal surface of oral cavity with well-developed pair of dorsal folds (Fig. 42: df), width of each ~1/3 of

dorsal wall width; separated from each other by dorsal chamber as wide as folds. Odontophore with ~60% of buccal mass volume (Figs 41–42: od). Odontophore muscles (Figs 41–44): **mj**, jaw and peribuccal muscles originating in outer-ventral surface of odontophore cartilages (Fig. 44: mj), running towards dorsal, splaying in dorsal wall of oral tube (Fig. 41: mj); **m1**, jugal muscles covering entirely haemocoelic structures, more concentrated close to mouth; **m1v**,

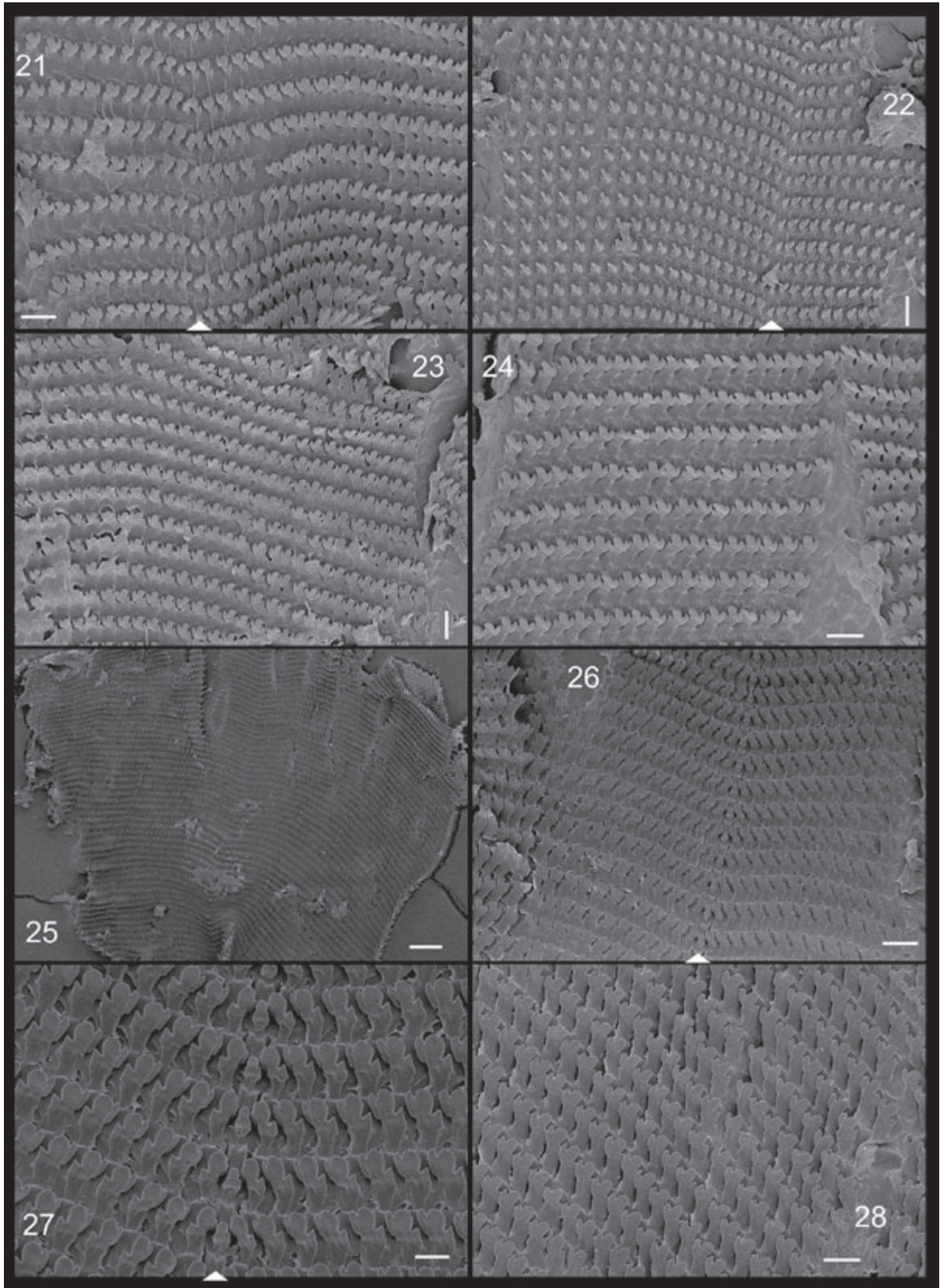
small pair of ventral protractors jugal muscles, originating in ventral surface of haemocoel close to mouth, running towards posterior, inserting in ventral-posterior region of odontophore close to m2 insertion (Fig. 38: m1v); **m2**, strong pair of retractor muscles of buccal mass, or radular muscles, originating as single bundle in columellar muscle, running anteriorly close to median line along ~50% of haemocoel length, inserting as two different bundles in ventro-posterior edge of odontophore, surrounding at some distance radular nucleus (Figs 38, 41, 43, 44: m2); **m4**, main pair of dorsal tensor muscles of radula, very thick, originating in postero-medial region of odontophore cartilages, in 2 oblique layers (Fig. 43: m4), surrounding outside and medially cartilages, inserting in subradular membrane in its region correspondent to buccal cavity; **m5**, pair of thick auxiliary dorsal tensor muscles of radula, originating in postero-ventral region of odontophore cartilages (Fig. 43: m5), along ~1/10 of their length, running towards median line covering m4, inserting in subradular membrane by side of m4 insertion; **m6**, horizontal muscle thin, located between both cartilages in region just posterior to their fusion, along ~2/5 cartilages length, keeping free ~1/5 of cartilages length posterior to it (Figs 43–44: m6); **m7**, small pair of muscles originating in middle-posterior level of cartilages central edge, just posterior to m6 (Fig. 43: m7), running medial-posteriorly inside radular sac, inserting splaying in dorso-postero inner surface of radular sac; **m10**, pair of strong ventral odontophore protractor muscles, originating in ventro-anterior region of haemocoel, just ventral to mouth, running towards posterior along buccal mass length (Figs 41: m10), inserting in latero-posterior surface of odontophore close to m2 insertions; **m11**, pair of narrow ventral tensor muscles of radula, originating in ventro-lateral surface of posterior region of cartilages, running close to cartilages towards anterior, inserting in ventral end of subradular membrane (br). Odontophore non-muscular structures (Figs 43–44): **oc**, odontophore cartilages flattened, elliptical, anterior region slightly projected anteriorly close to median line, ~twice longer than wide, fused with each other along ~3/5 in their anterior-medial edge (Figs 43, 44: oc), anterior end roughly rounded; **sc**, subradular cartilage, with expanding region in buccal cavity protecting subradular membrane. Radular sac short,

weakly extending beyond odontophore (Figs 38, 41: rs). Radular nucleus slightly expanded (Fig. 43: rn).

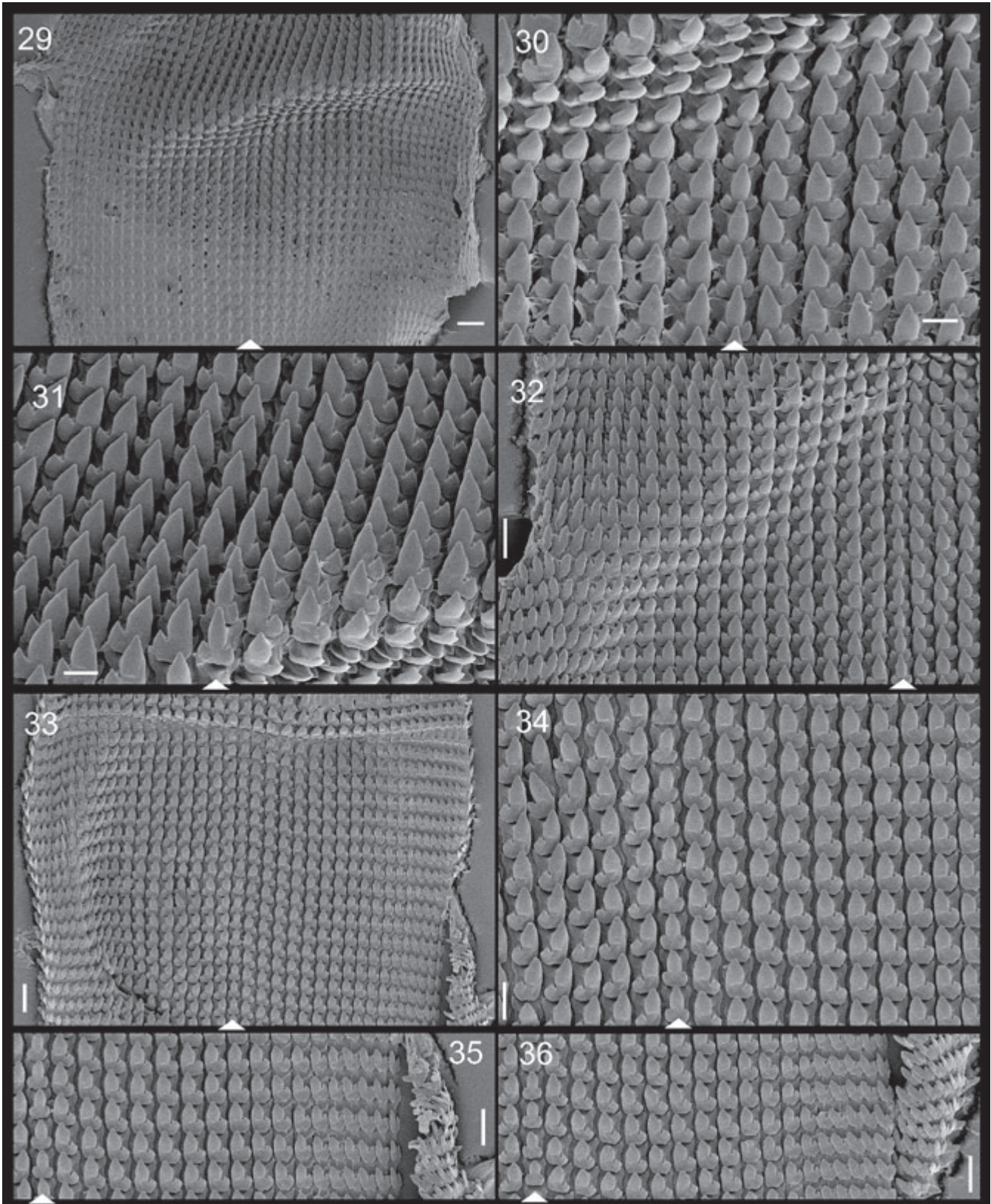
Radula (Figs 21–24) ~1.5 times longer than odontophore; with rachidian teeth, and ~25 pairs of lateral teeth; no clear distinction between lateral and marginal teeth (Fig. 23); all teeth with relative long and flattened base, keeping them separated from neighboring rows; central set of cusps rather small, located in anterior end of base (except for rachidian). **Rachidian** tooth (Figs 21–22: arrow) small, relatively reduced (~3 times smaller than neighboring teeth), ~1/70 of radular width; base ~3 times longer than wide, very flattened barely rectangular; central cusp with ~1/3 of base's width, in posterior end, slightly bended to right, tip blunt; pair of basal cusps slightly asymmetrical, with ~1/4 of central cusp's size. **Lateral teeth** similar to rachidian (Figs 23), except in being ~3 times larger, asymmetrical, arched towards lateral region, cutting edge ~4-times larger than that of rachidian; lateral teeth gradually decreasing towards lateral; set of cusps with ~1/3 of length of base; central cusp bluntly pointed; basal cusps strongly asymmetrical, inner basal cusp almost as large as central cusp in more central teeth, gradually becoming smaller and sometimes separated from central cusp (Fig. 24). **Marginal teeth** starting with no clear boundary with lateral teeth; shaped similarly to lateral teeth, except for being smaller and with set of cusps narrower and slightly more pointed (Fig. 22). Each radular row slightly arched disposed from both sides from rachidian (Figs 21–22).

Salivary glands covering oesophagus in its region preceding its anterior quarter (Fig. 38: sg), forming two elongated, white, thin masses. Each salivary duct differentiable in anterior side of glands, with ~1/12–1/20 oesophageal width (Fig. 38: sd). Salivary duct running in both sides of oesophageal origin (Figs 38, 41: sd), penetrating buccal mass wall in region close to buccal ganglia (Fig. 41: sd), running immersed in buccal dorsal wall along ~1/2 its length (Fig. 42: sd). Salivary ducts opening in middle level of dorsal folds, on their lateral side (Fig. 42: sa).

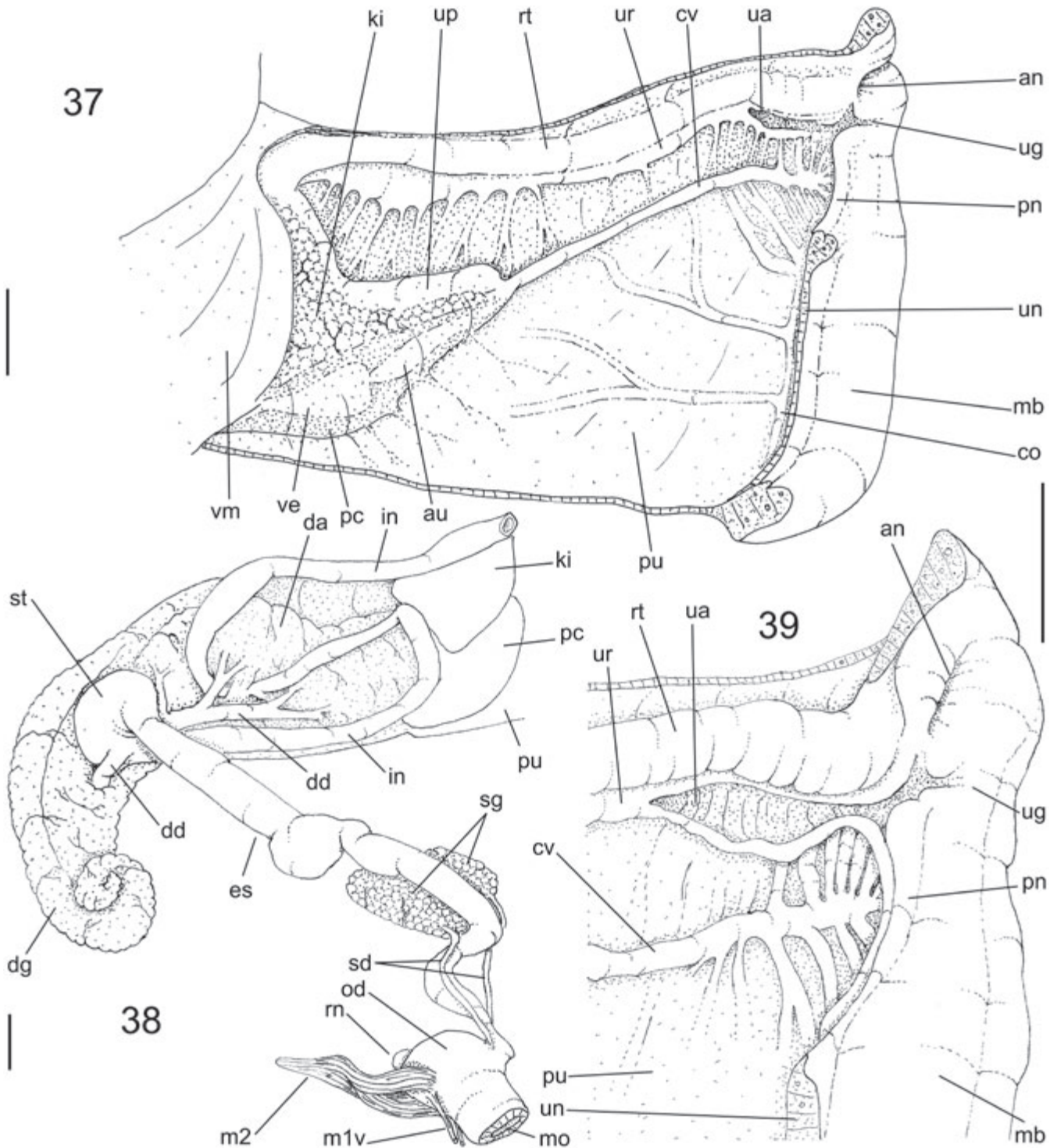
Oesophagus 1 whorl long, with thin, flaccid walls lacking clear subdivisions (Fig. 38: es); inner surface simple, with 5–10 simple longitudinal folds, clearer in contracted regions (generally along



Figures 21–28 radulae in SEM: 21–24, *Drymaeus castilhensis* (scales=40µm): 21, detail of central region. 22, same, slightly left view; 23, detail of right edge; 24, detail of more central region of right side; 25–28, *D. micropyrus*: 25, ample wide view, scale= 200µm; 26, detail of central region, scale= 50µm; 27, same, larger magnification, scale= 20µm; 28, detail of region close to right edge, scale= 40µm. White arrow indicates rachidian column.



Figures 29–36 radulae of *Bulimulus sula* in SEM: **29**, ample wide view, scale= 50 μ m; **30**, detail of central region, scale= 20 μ m; **31**, same, other radular level; **32**, ample view of left side, scale= 30 μ m; **33**, ample wide view of other specimen, scale= 50 μ m; **34**, detail of central-slightly right region, scale= 30 μ m; **35–36**, details of right edge region, scales= 40 μ m. White arrow indicates rachidian column.



Figures 37–39 *Drymaeus castilhensis* anatomy: 37, pulmonary (pallial) cavity, inner-ventral view, portion of visceral mass also shown, inner lip of pneumostome sectioned and deflected upwards; 38, digestive system as in situ, ventral view, topology of some adjacent strictures also shown, genital system and anterior rectum removed; 39, region of pneumostome as in Fig. 37. Scales= 2mm.

salivary glands); posterior half normally slightly bulging, of flaccid walls, crop-like. Stomach (Fig. 38: st) relatively narrow, curved, slightly bulging; position and size described above (visceral

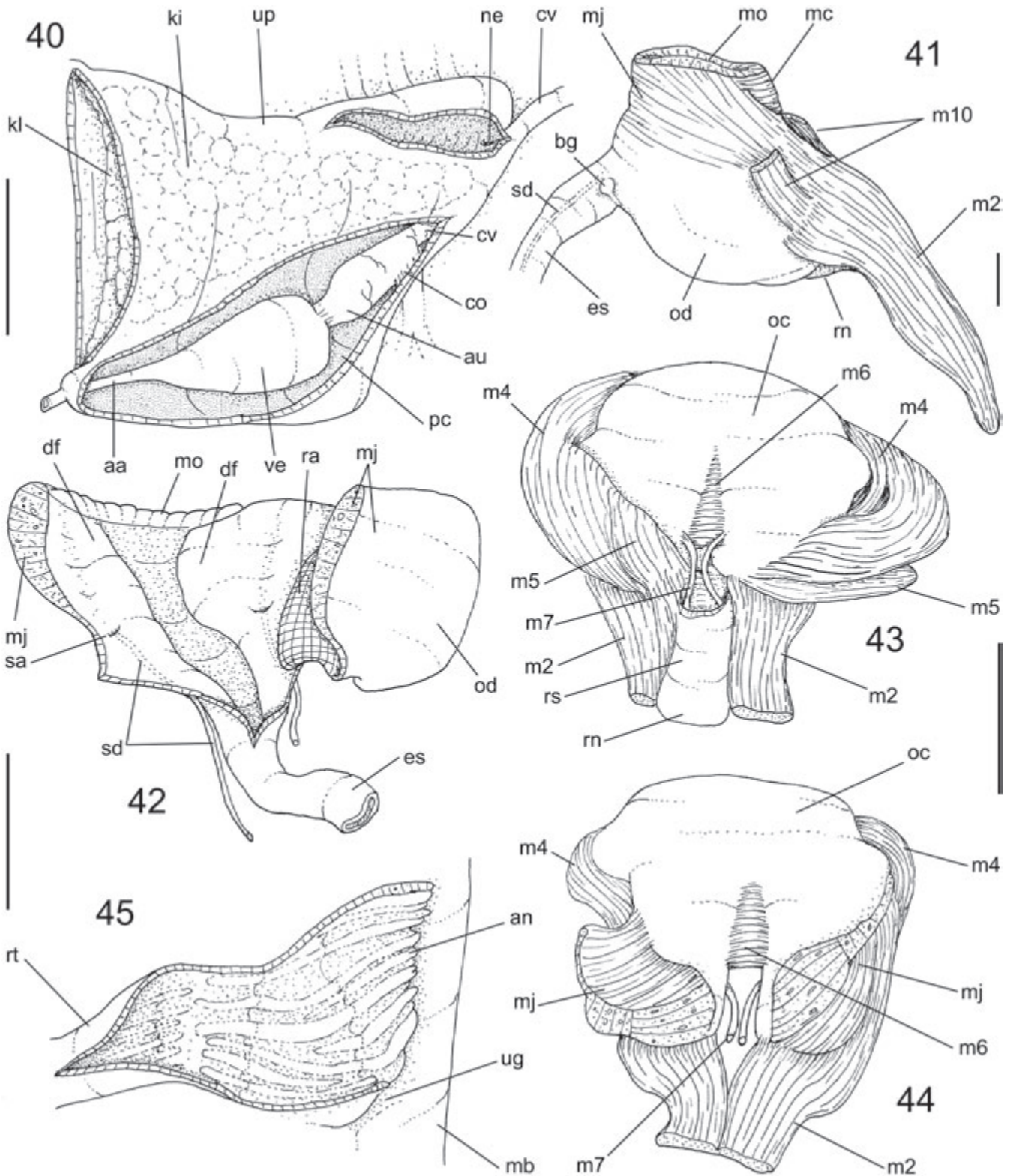
mass); gastric walls thin, flaccid; inner surface smooth, except for narrow longitudinal fold along smaller curvature, connecting oesophageal insertion with intestinal origin. Oesophageal

insertion on right side, intestinal origin on left side, both close to columella. Duct to anterior lobe of digestive gland encased between oesophagus and intestine (Fig. 38: dd-right). Duct to posterior lobe of digestive gland located a short distance from intestinal origin and posterior to the above-described duct, directed towards opposite side (Fig. 38: dd-left). Intestine initially as wide as oesophageal insertion, gradually narrowing up to ~half this width along its wide sigmoid loop in anterior lobe of digestive gland (Fig. 38: in). Rectum and anus position described above (pallial cavity) (Figs 37–39: rt, an). Anus sessile, as slit in right end of mantle edge directly turned outside; inner surface with 8–10 simple longitudinal, relatively tall folds, preceded by short smooth, transverse area separating them from simpler inner folds of rectum (Fig. 45).

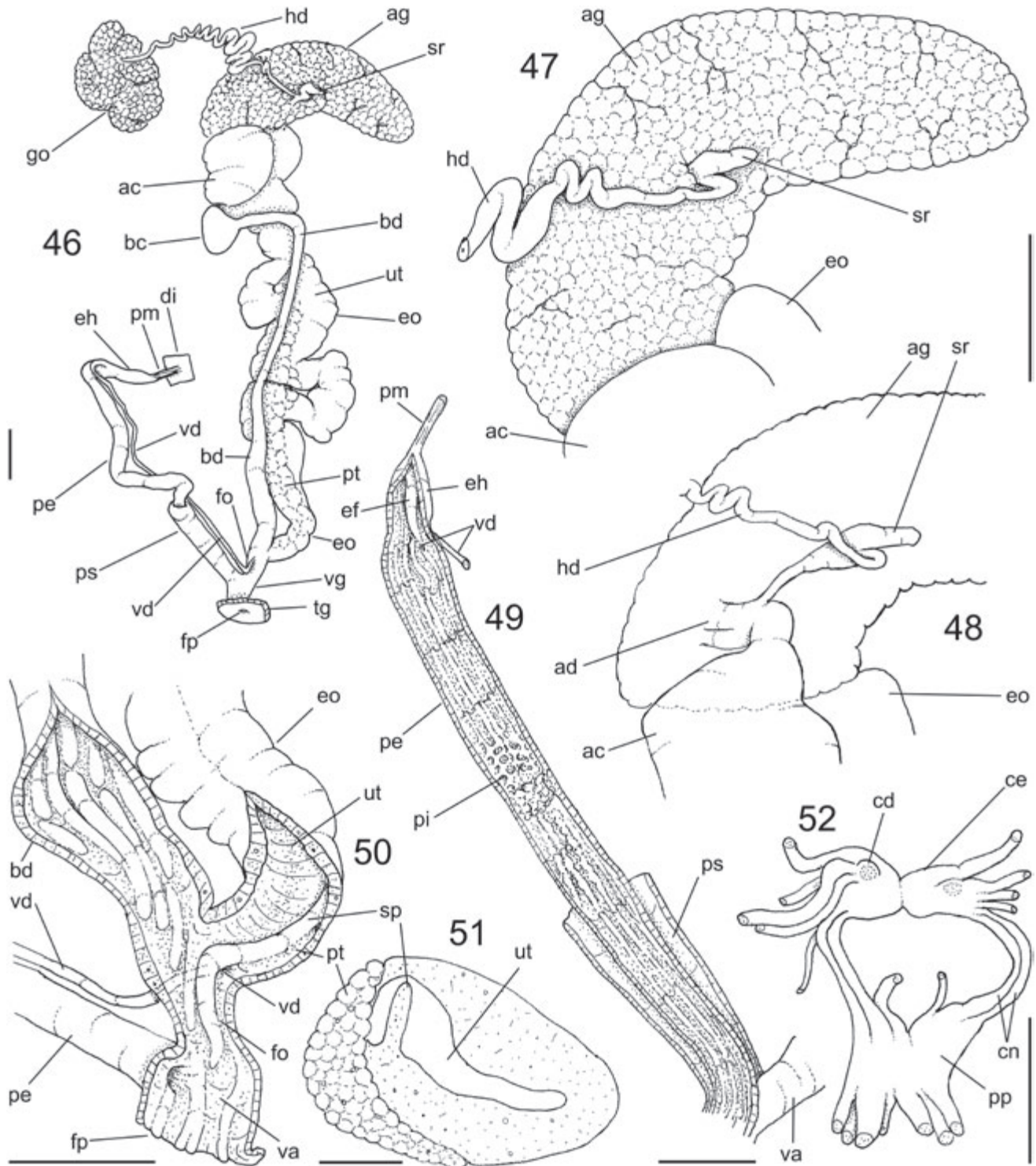
Genital system (Figs 46–51) Gonad position described above (visceral mass), composed of 8–10 lobes with minute digitiform acini (Fig. 46: go). Hermaphroditic duct (Figs 46–48: hd) narrow and weakly coiled in posterior third, gradually becoming wider (up to 3-times wider) and more intensely coiled in middle third; afterwards becoming narrow, almost uncoiled in anterior third; running for ~1/4 whorl close to columella; inserting in left side of receptacle's base (Figs 47, 48: hd). Seminal receptacle (Figs 47, 48: sr) relatively small, sac-like, ~twice longer than wide, ~twice wider than hermaphroditic duct. Fertilisation complex simple, located at narrow and elongated base of seminal receptacle (Fig. 48) as duct of seminal receptacle; ~as long as length of receptacle. Fertilisation complex totally immersed in albumen gland (Fig. 47), inserting in posterior end of spermo-viduct, in base albumen gland duct (Fig. 48: ad) relatively wide and divided into two ducts, ~5-times wider than receptacle's duct. Albumen gland (Figs 46–47: ag) solid, white, elliptical, slightly larger than gonad (~1/3 whorl). Albumen gland duct subterminal, connected to distal end of spermo-viduct (Fig. 48: ad), in lateral, large albumen chamber (Figs 46: ac); widely connected to distal end of spermo-viduct (Figs 46, 48: ac). Spermo-viduct of ~1.5 whorl in length, slightly narrower than albumen gland, ca. 20 times longer than wide; intensely coiled and difficult to rectify. Prostate gland occupying ~1/2 of spermo-viduct surface and ~1/4 its volume (Figs 46, 51: pt). Uterus occupying ~3/4

of spermo-viduct space, external walls thick-glandular (Figs 46, 51: ut), inner surface completely covered by ample transverse folds (Fig. 50: ut). Sperm groove simple in posterior 2/3 of spermo-viduct (Fig. 51: sp), protected ventrally by tall fold; gradually becoming tubular fold (Fig. 50: sp) becoming vas deferens shortly posterior to genital pore (~1/20 of remaining spermo-viduct length) (Fig. 50: vd), along anterior 1/20 of spermo-viduct, with ~1/10 of anterior spermo-viduct width, running outside of penis shield (Fig. 46). Vagina ~1/30 spermo-viduct length (Fig. 46: vg); inner surface simple, with 4–5 longitudinal, low, wide folds (Fig. 50: vg). Bursa copulatrix ~2/3 of spermo-viduct length; bursa duct as wide as adjacent spermo-viduct in its origin, gradually narrowing towards posterior end (Fig. 46: bd); bursa oval, ~1/5 of albumen gland size (Fig. 46: bc), located encased between pericardium and adjacent intestinal loop. Penis ~1/2 of spermo-viduct length, ~2/3 its anterior width (Fig. 46: pe); penis muscle inserting terminally, very short (Fig. 46: pm). Epiphallus ~1/7 penis' length, located as short terminal continuation of penis (Fig. 46: eh) inner surface with narrow longitudinal folds, located close to each other, one of them being larger, occupying ~1/2 inner space (Fig. 49: eh). Vas deferens inserted subterminally in penis tip (Figs 46, 49: vd). Internal penial surface lacking clear sub-chambers (Fig. 49: pe); except for short middle region with reticulated surface and transverse glandular fold (Fig. 49: pi); anterior and posterior halves with similar arrangement of 4–5 longitudinal folds, simple or sometimes slightly sinuous, separated from each other by space equivalent to their width (Fig. 49). Penis shield occupying basal ~1/3 of penis length (Figs 46, 49: ps). Genital pore round, simple.

Central nervous system (Fig. 52) Cerebral ganglia located dorsally in middle level of buccal mass, pedal ganglia located more posteriorly. Pair of cerebral ganglia (ce) widely fused with each other; cerebral commissure invisible; each ganglion about as wide as adjacent oesophageal section; several wide nerves originating in cerebral antero-lateral region. Cerebral node or gland located in antero-lateral quadrant, with ~1/10 each ganglion's size (cd). Four parallel connectives (cn) between cerebral ganglia and pedal ganglia. Pair of pedal ganglia (pp) forming single mass located opposite to cerebral ganglia,



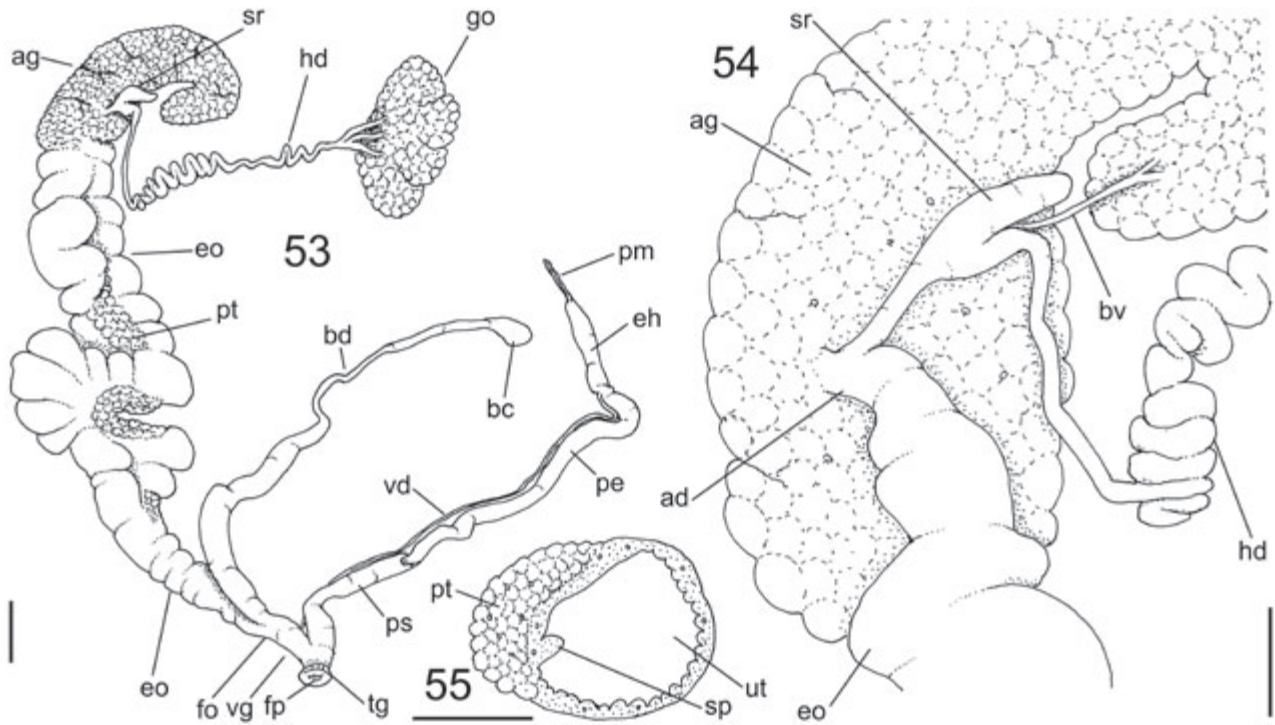
Figures 40–45 *Drymaeus castilhensis* anatomy: 40, reno-pericardial region, ventral view, longitudinal sections in ventral surface of pericardium and primary ureter done. 41, buccal mass, right view. 42, same, sectioned along right side, separating odontophore from oesophageal components, odontophore deflected, remaining buccal cavity in ventral view. 43, odontophore, dorsal view, radula, superficial layer of membranes and muscles removed, left muscles (right in Fig.) deflected, right muscles as in situ; 44, same, partial removal of m4, m5 and radular sac, right muscles (left in Fig.) deflected; 45, anal region, ventral view, anus sectioned longitudinally to show inner surface. Scales= 2mm.



Figures 46–52 *Drymaeus castilhensis* anatomy: 46, genital system extracted and uncoiled, mostly dorsal view; 47, same, detail of region of albumen gland, ventral view; 48, same, seen as transparent structure to show inner ducts; 49, penis, dorsal view, longitudinally sectioned to show inner surface; 50, genital system, detail of anterior region close to pore, some ducts sectioned longitudinally to show inner surface; 51, spermoviduct, transverse section in its middle level; 52, central nervous system (nerve ring), ventral view. Scales= 2mm.

slightly larger sized than cerebral ganglia. No differentiable individual pedal ganglion detectable except for medial weak constriction. At least

four pairs of pedal nerves originating from anterior side of these ganglia. Pair of statocysts not seen.



Figures 53–55 *Drymaeus micropyrus* anatomy: 53, genital system extracted and uncoiled, mostly dorsal view, scale= 2mm; 54, same, detail of region of albumen gland, ventral view, some structures seen as transparent, scale= 1mm; 55, spermoviduct, transverse section in its middle level, scale= 1mm.

Distribution Endemic from Castilho Island (Fig. 1).

Habitat Usually found on trees trunks or tall bushes, sometimes on naked rocks covered by green moss.

Measurements (length and width in mm)
 Holotype MZSP 84277 (Figs 2–4): 33.7 by 16.3;
 paratypes MZSP 89627 (Fig. 7): #1, 28.5 by 13.7;
 #2, 32.6 by 15.3; paratype MZSP 49190: 33.2 by 15.7; MZSP 44425: 32.6 by 15.3.

***Drymaeus micropyrus* sp. nov.**
 (Figs 10–14, 25–28, 53–55)

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Types Holotype: MZSP 84939 (Figs 11–13).

Type locality BRAZIL. São Paulo; off Peruíbe, Ilha Queimada Pequena (Queimadinha) 24°22'31"S 46°48'24"W (J Avelar col., 1.iii.2007).

Etymology The epithet is a reference to the name of the local of occurrence, derived from Queimadinha or Queimada Pequena (Fig. 1),

meaning “small burned” island; the epithet comes from Greek *mikros*, meaning small, little, and from Greek *pyro*, meaning fire.

Diagnosis Shell conical, aperture ample, weakly deflected. Colour greenish-cream, with brown narrow axial spots, joint forming larger axial spots; peri-umbilical area with same pigmentation. Secondary ureter almost entirely closed, except for short portion preceding pneumostome. Anus outside pneumostome, open directly outside. Aperture of salivary glands lateral in middle level of buccal cavity. Intrinsic pair of odontophore muscles m7 originating in cartilages close to m6. Sigmoid intestinal loop very ample. Penis very slender and long, with thick, muscular walls, lacking clear inner chambers. Inner spermoduct of spermoviduct protected by low fold. Seminal receptacle small. Albumen gland duct simple, lacking albumen chamber. Pleural ganglia inconspicuous.

Distinctive description

Shell (Figs 10–13) Adult shell around 35mm, conical-oval; apex acuminate; greatest width on

last whorl; width ~48% shell length. Basal colour white to greenish-cream; pattern of clear-brown spots arranged in axial lines, sometimes in conjunct forming three equidistant bundles of spiral wide band, slightly more concentrated in superior third of whorls (Figs 12–13); peri-umbilical area possessing same spot patterns of remaining areas (Fig. 11). Spire angle ~43°. Protoconch of 2 whorls, ~4% of length, uniformly sculptured by delicate reticulate (Fig. 10), with ~25 spiral lines in last whorl; transition to teleoconch weak, slightly prosocline. Teleoconch smooth, except for growth lines, slightly more than 4 whorls. Whorls profile slightly convex. Suture well-marked, slightly oblique (diagonal) to columellar axis. Aperture prosocline (~20° from longitudinal general axis) (Fig. 13), oval; ~50% of shell length, ~58% of shell width. Peristome slightly reflected, especially on columellar region, partially covering umbilicus (Fig. 11). Body whorl ~1/2 shell length. Umbilicus narrow.

Head-foot Similar to preceding species, except for columellar muscle clearly divided into 2 bundles.

Mantle organs Similar characters as *D. castilhensis*. Except for greater concentration and development of anterior vessels close to pneumostome. Anus and ureter aperture similar.

Visceral mass Same features as preceding species.

Circulatory and excretory systems Characters like those of *D. castilhensis*; except for reno-pericardial area ~20% larger in pallial cavity.

Digestive system General features similar to those of *D. castilhensis*. Distinctions following: jaw (Fig 14), similar-shaped, but lacking notch in median region, possessing uniform width along its length; slightly thicker and darker coloured. Odontophore pair of m10 (ventral protractor muscles) about twice thicker, with 3–4 clear layers of muscles. Radula (Figs 25–28) also similar constituted, but with much more teeth – ~65 teeth per row in each side of rachidian (Fig 25); teeth rows located closer to each other in having proportionally shorter base of teeth; rachidian (Figs 26, 27) ~twice larger (~half of neighboring teeth) and symmetrical; lateral and marginal teeth with set of cusps occupying more than half

of base, central cusp occupying more than half of cutting edge, rounded, inner basal cusp normally more anteriorly positioned, outer basal cusp located in base, both basal cusps similarly shaped to each other, triangular, blunt, with ~1/3 of central cusp's size; marginal teeth gradually becoming narrow towards lateral, with 3 cusps similarly sized (Fig. 28).

Genital system (Figs 53–55) Most structures similar to those of preceding species, including characters of hermaphrodite duct (Fig. 53: hd), with more intense coiled portion in middle, and almost straight distal portion; intense coiled spermoviduct (eo), shortness of seminal receptacle (Fig. 54: rs), of free oviduct (Fig. 53: fo) and vagina (vg). Distinctions following: duct of albumen gland single (Fig. 54: ad) lacking any detectable albumen chamber; fold flanking spermoviduct along spermoviduct very shorter (Fig. 55: sp); prostate gland (pt) much wider in posterior region, gradually becoming narrower anteriorly; anterior structures preceding genital pore (fp) of thicker muscular walls; penis (pe) slightly more elongated, with thicker muscular walls.

Central nervous system Similar features as *D. castilhensis*.

Distribution Endemic from Queimada Pequena (Queimadonha) Island (Fig. 1).

Habitat On plants and shrubs.

Measurements (in mm) **Holotype:** 6 whorls, 36.8 by 18.0 (Figs 11–13).

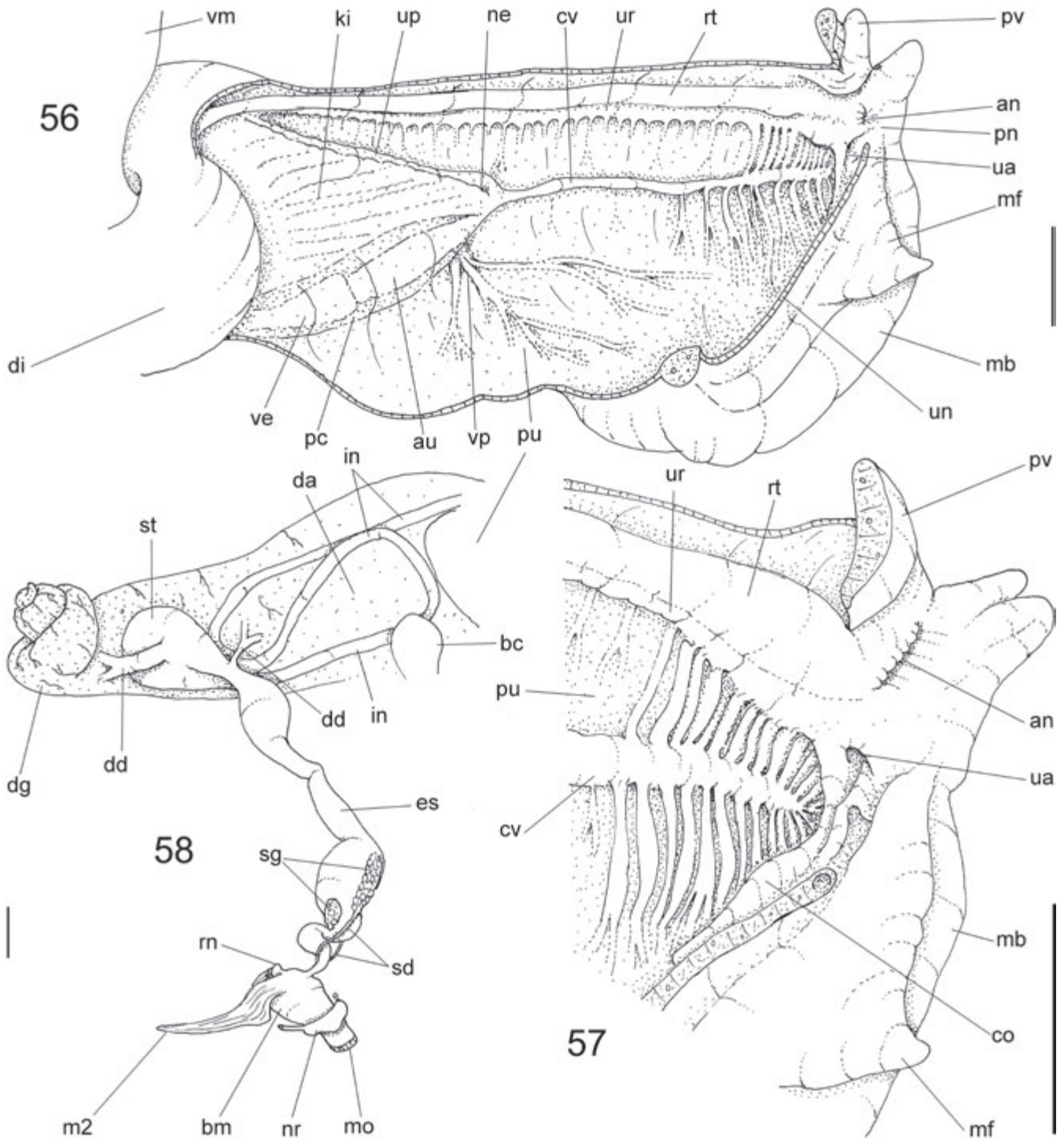
***Bulimulus sula* sp. nov.**
(Figs 15–20, 29–36, 56–71)

urn: lsid: zoobank.org:act:3431D816-0AA9-4411-95B9-D66E8CD54615

Types Holotype: MZSP 134475 (Figs 15–17). Paratypes: MZSP 109568 (7 specimens), 28343 (3 specimens), 101923 (47 specimens), MNRJ (2 shells), USNM (2 shells); all from type locality.

Additional samples 102399 (6 shells), 109567 (35 shells), 101924 (48 shells), 134473 (~100 shells); all from type locality.

Type locality **BRAZIL. São Paulo;** off São Sebastião, Ilha de Alcatrazes, near Porto dos



Figures 56–58 *Bulimulus sula* anatomy: **56**, pulmonary (pallial) cavity, inner-ventral view, portion of visceral mass also shown, inner lip of pneumostome sectioned and deflected upwards; **57**, same, detail of pneumostome region; **58**, digestive system and uncoiled visceral mass, ventral view, midgut as in situ, topology of some adjacent structures also shown. Scales= 2mm.

Faroleiros, 24°06'03.07"S 45°41'43.90"W (Simone col., viii.2011) (Fig. 1).

Etymology The epithet is a reference the species of seabird that gives the name to that

island – alcatraz or atobá in Portuguese – the common name for *Sula leucogaster* (Boddaert, 1783), the commonest species in that region. The epithet is in apposition in relation to the bird's genus name.

Diagnosis Shell relatively cylindrical, aperture antero-posteriorly elongated, not deflected. Colour uniform pale brown. Secondary ureter entirely closed. Intrinsic pair of odontophore muscles with posterior, transverse pair m9 and well-developed m11. Aperture of salivary glands lateral in middle level of buccal cavity. Anus external to pneumostome, opened directly outside. Penis slightly bilobed, with transverse inner fold separating both lobes; no flagellum or epiphallus. Seminal receptacle reduced. Free oviduct with solid globose annexed gland. Presence of genital appendix.

Distinctive description

Shell (Figs 15–17, 19–20) Adult shell around 20mm, fusiform, relatively cylindrical; apex blunt; greatest width on penultimate whorl; width $\sim 1/2$ shell length. Colour uniform pale brown; surface relatively glossy, with narrow axial undulations and growth lines. Periostracum slightly thickened. Spire angle $\sim 50^\circ$, being almost cylindrical in penultimate and last whorls. Protoconch of 2 whorls, $\sim 8\%$ of length, practically smooth, except for some weak spiral lines (Fig. 17). Whorls profile slightly convex. Suture well-marked, slightly oblique (diagonal) to columellar axis. Aperture prosocline ($\sim 20^\circ$ from longitudinal general axis) (Fig. 19), oval; $\sim 44\%$ of shell length, $\sim 53\%$ of shell width. Peristome practically not reflected, except small region partially covering umbilicus. Body whorl $\sim 74\%$ shell length. Umbilicus closed.

Head-foot Similar to preceding species. Colour uniformly clear. Columellar muscle relatively thin in distal half, 1.5 whorls in length. Median separated bundle, with $\sim 1/4$ width of remaining columellar muscle, running along middle-dorsal region of columellar muscle. Pedal gland yellow, relatively large, $\sim 1/2$ of foot length; invading haemocoel, protruding $\sim 1/3$ of its length inside haemocoel.

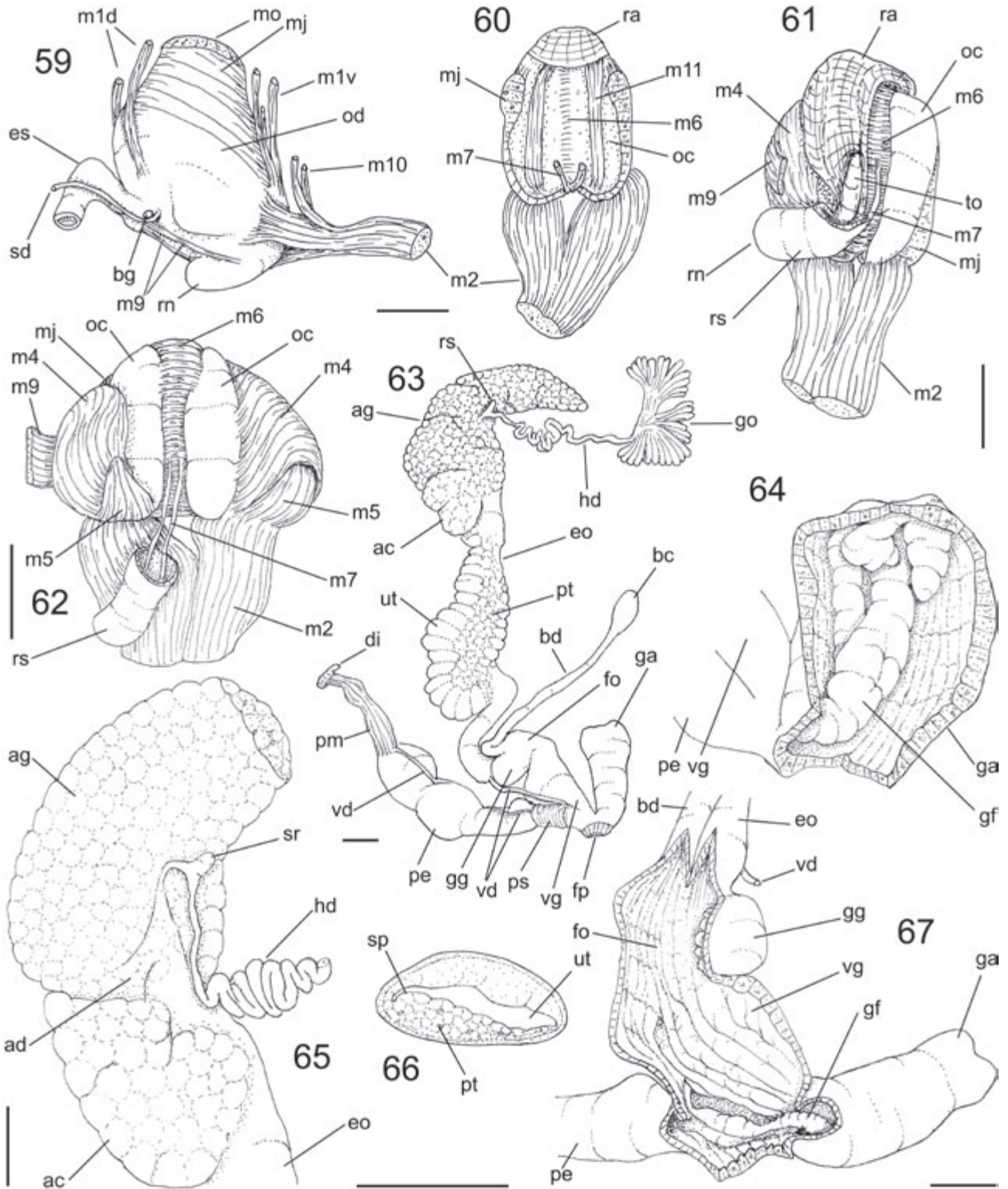
Mantle organs (Figs 56, 57) Main characters similar to those of preceding species, distinctions and interesting features following. Dorsal fold (mf) slightly triangular, with $\sim 1/3$ of aperture length. Pneumostome (pn) $\sim 1/12$ of aperture length, bearing air entrance and urinary gutter (Fig. 57: ua) and anus only partially; aperture of ureter (ua) simple pore, slightly turned to left, located at right end of dorsal fold, protected

posteriorly and left by long transverse fold (co) ($\sim 1/2$ outer lip length). Anus as separated aperture located at right from pneumostome (Fig. 57: an), but with its left edge slightly turned inside pneumostome (an). Pulmonary vessels conspicuous, mainly in anterior half at left and anterior third at right from pulmonary vein (cv), with 10–12 strong vessels (Fig. 57), remaining regions almost smooth, with imbricated vessels difficult to see properly (pu), except for 3 large vessels converging to pericardium right end (vp). Renopericardial area widely triangular.

Visceral mass (Fig. 58) ~ 4 whorls in length. Main features similar to those of preceding species. Anterior lobe slightly longer and flattened.

Circulatory and excretory systems (Figs 56) Characters similar to those of preceding species. Kidney (ki) slightly larger, possessing internally strong lobe, U-shaped in section (opened to left), longitudinally folded, with most folds converging anteriorly towards nephropore.

Digestive system (Figs 58–62) General features similar to those of preceding species. Distinctions and worthy characters following. Jaw thin, pale yellow; exposed portion with ~ 17 pairs of uniform, transverse-slightly oblique folds; middle region not notched, with 4–5 V-shaped folds (Fig. 18). Buccal mass with $\sim 1/6$ of haemocoel volume. Odontophore muscles (Figs 59–62): **mj**, jaw and peribuccal muscles originating very thick (mainly anteriorly) and laterally (Figs 60, 61: mj); **m1v**, similar, but slightly broader and in two pairs (Fig. 59: m1v); **m1d**, pair of small dorsal protractor muscles of buccal mass, originating in inner dorsal region of mouth, running separated from each other straight towards posterior along entire buccal mass length, inserting just anterior to oesophageal origin (Fig. 59: m1d); **m2**, also strong, but with narrower and more lateral insertion in odontophore (Figs 59–62: m2); **m4**, also very strong, but being a single solid bundle (Fig. 62: m4); **m5**, similar, slightly shorter (Fig. 62: m5); **m6**, much longer, inserting along entire cartilages length, being slightly thicker in anterior end, width $\sim 3/4$ that of cartilages (Figs 60, 62: m6); **m7**, originating between middle and posterior thirds of m6 (Fig. 62: m7) (instead of cartilages); **m9**; narrow pair (absent in preceding species) on posterior surface of odontophore, originating in dorsal oesophageal origin, just by side of buccal



Figures 59–67 *Bulimulus sula* anatomy. 59, buccal mass, right view; 60, odontophore, ventral view, ventral superficial layer of membrane and muscles removed; 61, same, right-slightly dorsal view, radula and radular sac partially deflected, some right muscles removed to show cartilage (oc); 62, same, dorsal view, radular sac partially shown and deflected downwards, both cartilages slightly deflected, left intrinsic muscles as in situ, right muscles deflected outside; 63, genital system extracted and uncoiled, mostly dorsal view; 64, genital appendix opened longitudinally, dorsal view; 65, detail of albumen gland region, dorsal-slightly left view; 66, spermoviduct, transverse section in its middle level, 67, anterior-proximal region of genital system, dorsal view, female portion opened longitudinally. Scales= 1mm.

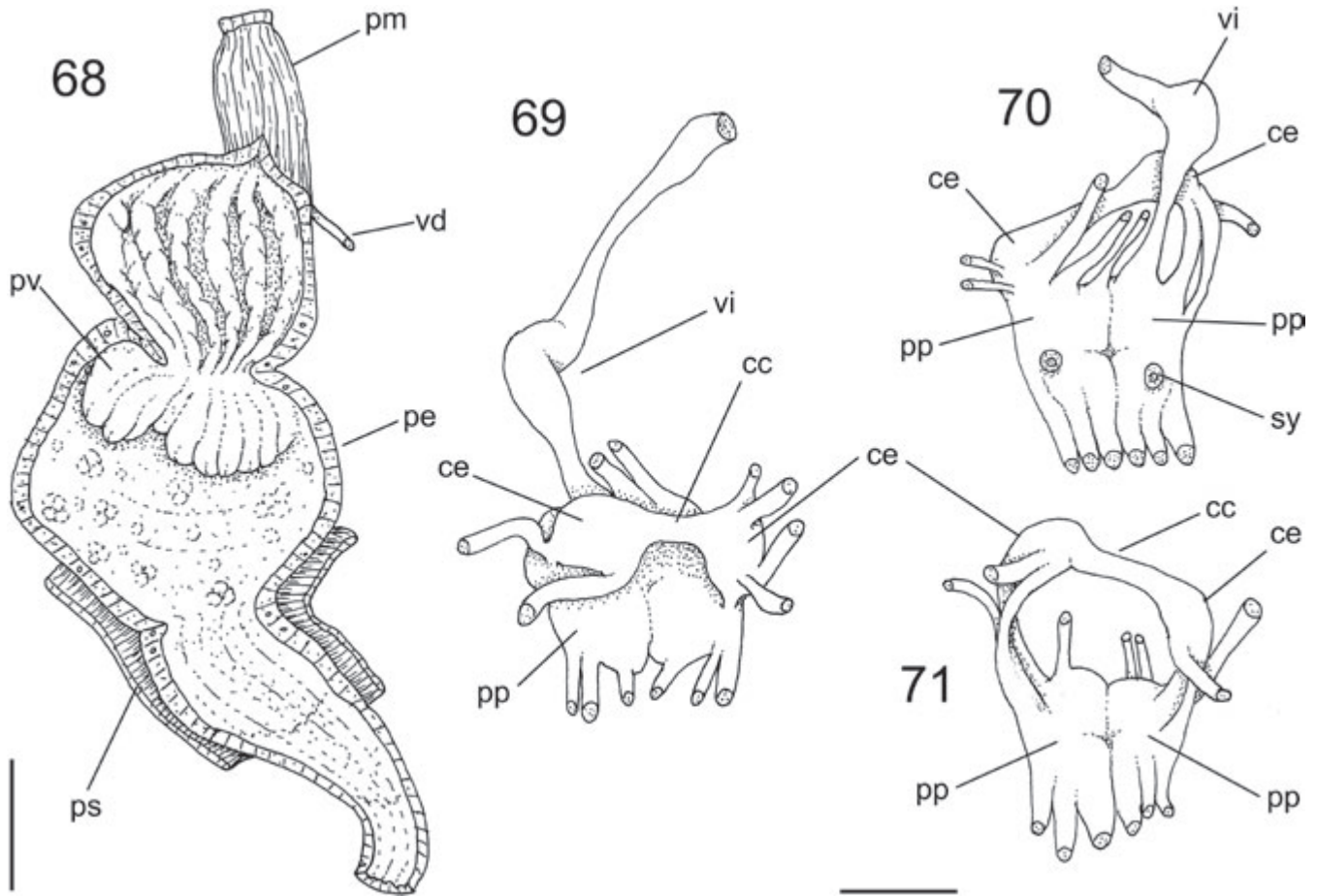
ganglia, running dorsally separated from each other, inserting splaying in base of radular sac (Fig. 59: m9); **m10**, much narrower, inserting in m2 base (Figs 59: m10), instead of odontophore; **m11**, pair of ventral tensor muscles of radula, of similar constitution but slightly broader (Fig. 60: m11). Odontophore non-muscular structures (Figs 61–62): **oc**, pair of odontophore cartilages separated from each other; each cartilage flattened, elliptical (~3 times longer than wide); anterior and bluntly pointed, slightly turned medially; posterior end rounded; ~twice longer than wide (Fig. 62: oc); remaining of similar features. Radular sac slightly longer (Fig. 59: rs). Radular nucleus not expanded (Figs 61–62: rs).

Radula (Figs 29–36) slightly longer than odontophore; with rachidian teeth, and ~20 pairs of lateral teeth; no clear distinction between lateral and marginal teeth (Figs 29, 32, 33). **Rachidian** tooth (Figs 30, 31, 35, 36: arrow) small, ~1/40 of radular width and ~ twice times longer than wide; base wider, barely triangular, cutting edge as blunt main cusp, as long as base, ~80% of base width; pair of basal cusps, each one bluntly pointed (Fig. 31) to rounded (Figs 30, 34), ~1/3 of main cusp's size. **Lateral teeth** similar to rachidian (Figs 31, 34), except in being slightly asymmetrical, weakly arched towards median region, and with main cusp ~50% larger than that of rachidian, median basal cusp absent, lateral basal cusps slightly larger than that of rachidian, located slightly separated from main cusp's base (Figs 30, 34); lateral teeth gradually narrowing towards lateral, maintaining similar shape. **Marginal teeth** starting with no clear boundary with lateral teeth; shaped similarly to lateral teeth, except for being narrower (Figs 33, 35, 36). Each radular row relatively straight in same level (Figs 29, 33).

Salivary glands relatively small (Fig. 58: sg), covering small portions of anterior third of oesophagus; strongly asymmetrical, left gland being clearly smaller (~half) than right gland; forming two thin, separated masses. Stomach (Fig. 58: st) relatively widely bulging. Oesophageal insertion on ventral side, intestinal origin on dorsal side. Duct to anterior lobe of digestive gland very narrow, originated in oesophagus in region preceding its insertion in stomach (Fig. 58: dd-right). Duct to posterior lobe of digestive gland located in middle surface of gastric ventral wall (Fig. 58: dd-left), ~twice broader than anterior duct.

Intestine very narrow, with relatively ample loops (Fig. 58: in). Anus also located in mantle edge directly turned outside (Figs 56, 57: an).

Genital system (Figs 63–68) General conformation as described for the first species, noteworthy and distinctive features follow. Gonad with 3–4 lobes, minute elongated digitiform acini (Fig. 63: go). Hermaphroditic duct (Figs 63, 65: hd) uniformly narrow along its length, weakly coiled only in middle third; inserting on left side of receptacle's base (Fig. 65: hd). Seminal receptacle (Fig. 65: sr) minute, sac-like, slightly longer than wide, ca. 3-times hermaphroditic duct width. Albumen chamber bilobed, ~half of albumen gland size (Fig. 63: ac); its duct simple, turned posteriorly (Figs 65: ad). Spermooviduct with prostate gland occupying slightly less than ~1/2 of spermooviduct surface and ~1/4 its volume (Figs 63, 66: pt). Uterus intensely transversally folded (Fig. 63: ut). Sperm groove not protected by fold (Fig. 66: sp); becoming vas deferens before free oviduct (fo) (Fig. 67: vd). Large solid gland located just anterior to vas deferens origin, with ~1/5 of vaginal chamber (Figs 63, 67: gg). Bursa copulatrix slightly longer than ~1/2 of spermooviduct length; bursa duct with ~1/2 width of adjacent spermooviduct along its length (Fig. 63: bd). Penis ~1/3 of spermooviduct length, slightly claviform, anterior half clearly narrower than distal, slightly bilobed half (Fig. 63: pe). Epiphallus absent. Vas deferens inserted terminally (Figs 63, 68: vd), close to penis muscle's base (pm). Internal penial surface with three sub-chambers (Fig. 68: pe); anterior half with narrow conic outline, weak longitudinal, wide folds; posterior half with two chambers: anterior chamber slightly globose, inner surface smoothly glandular, with tall transverse fold in transition with posterior chamber, valve-like, projected to base (Fig. 68: pv); posterior half also slightly globose, inner surface with 6–7 tall, longitudinal folds, with deep furrow separating them, one of them originated from vas deferens aperture. Penis shield occupying basal ~1/5 of penis length (Figs 63, 68: ps). Genital appendix, or hemi-penis (Figs 63, 64, 67: ga) with almost half of penis' size, its same width; base as wide as vaginal base, gradually widening up to blunt and flat tip; inner surface with strong folds in dorsal side, tall, surface slightly irregular, a central wider fold along entire appendix length, other three smaller folds



Figures 68–71 *Bulimulus sula* anatomy: 68, penis, dorsal view, opened longitudinally; 69, central nervous system, dorsal view; 70, same, ventral view; 71, same, anterior view. Scales= 1mm.

in distal half (Fig. 64: gf); central fold continuing with one of the vaginal folds (Figs 67: gf).

Central nervous system (Figs 69–71) Located in anterior region of buccal mass (Fig. 58: nr). Similar to that of preceding species except in being more concentrated, with connective ~half shorter. Pair of cerebral ganglia (ce) separated from each other by narrow commissure slightly as long as each ganglion (cc). Pair of pedal ganglia (pp) forming single mass located opposite to cerebral ganglia, ~twice larger sized than cerebral ganglia. No differentiable individual pedal ganglion detectable except for medial weak constriction. Pair of statocysts very small, located in ventral region of pedal ganglia anterior end (Fig. 70: sy). Visceral ganglion (vi) located relatively close to nerve ring, slightly smaller than each cerebral ganglion.

Distribution Endemic to Alcatrazes Island (Fig. 1).

Habitat Empty shells located in ground mixed with local vegetation. Alive specimens found buried 5–10cm on soil, normally protected by roots of local grasses occurring between small trees.

Measurements (length and width in mm) Holotype MZSP 134475 (Figs 15–17): 19.3 by 8.7; paratypes MZSP 109568 (Figs 19–20): #1, 20.3 by 9.1; #2, 18.7 by 8.1.

DISCUSSION

There are no species in Brazilian territory with which *Drymaeus castilhensis* and *D. micropyrus* can be confused (Simone, 2006). The colour pattern of *D. castilhensis* is similar to that of *D. magus* (Wagner, 1827), a species that also occurs in SE Brazil, it differs in being more elongated, in having a more pointed and taller spire, and by a wider and longer peristome. The colour pattern of *D. micropyrus* is somewhat similar to that of

D. expansus (Pfeiffer, 1848) and *D. vanattai* Pilsbry, 1898, both Amazonian species, but it differs by a more acuminate spire, much less expanded peristome, and in lacking purple pigment at its aperture. Its colour pattern also resembles that of *D. papyraceus* (Mawe, 1823) and of *D. papyrifactus* Pilsbry, 1898, both from south Brazil and neighborhood; but it differs from the former in having a wider shell, and much more expanded and shorter body whorl and peristome; and differs from the latter in having more elongated shell, more pointed spire, and the peristome is more expanded and elliptical.

Drymaeus castilhensis differs from *D. micropyrus* by the features pointed out in their diagnoses, but the main distinction is mainly in the pigmentation; *D. castilhensis* has a pattern of brown spots somewhat axially disposed (Figs 2–4, 7), and more rarely (~20%) a uniform cream colour (Figs 5–6) (the base's colour or the spotted specimens); on the other hand, *D. micropyrus* has a mosaic of narrow, rather uniform, pale brown spots, with axial lines and three sets of thickenings somewhat spirally disposed (Figs 11–13). Additionally, the shell of *D. castilhensis* has the spire and its whorls slightly more inflated than that of *D. micropyrus*, which is more pointed (Figs 11–13). *D. castilhensis* always has a pale periumbilical band (Figs 2, 7), which is absent in *D. micropyrus* (Figs 11, 13). Anatomically both species are surprisingly similar, sharing most features, except for those explored in the distinctive description of the latter species. The main anatomical distinction is in the genital structures, *D. micropyrus* has a single albumen gland duct (Fig. 54: ad), with a smaller developed albumen chamber, while *D. castilhensis* has the double duct (Fig. 48: ad) and a larger, bilobed chamber (Fig. 46: ac). The inner longitudinal fold of the spermoviduct that separates the masculine from feminine portion of the spermoviduct, is relatively tall and well-developed in *D. castilhensis* (Figs 50, 51: sp), while that of *D. micropyrus* is low and relatively wide (Fig. 55: sp). The penis epiphallus of *D. castilhensis* is proportionally shorter (Fig. 46: eh), than that of *D. micropyrus* (Fig. 53: eh).

Bulimulus sula has clear conchological affinity with *B. tenuissimus* (d'Orbigny, 1835), the most common species of the genus in Brazil, which has been adapted even to urban regions (Simone, 2006: 120). The shell of *B. sula* differs from that of *B. tenuissimus* in having a more elongated last

whorl, producing a more cylindrical or fusiform profile, while the last whorl of *B. tenuissimus* is more uniform with the spire's growth, having a triangular profile. *B. tenuissimus*' anatomy was described by Resende & Lanzieri (1964) and Araujo *et al.* (1969). *B. sula* differs from *B. tenuissimus* anatomically mainly in having a more poorly vascularised lung (Fig. 56: pu); a more uniformly folded jaw (Fig. 18); the penis muscle inserting terminally (and not subterminally) (Fig. 63), lacking the penis glandular arrangement; having the genital appendix (Fig. 67: ga) and a lateral gland in the free oviduct (Fig. 67: gg); by the shorter seminal receptacle (Fig. 65: sr); and in having only two albumen chambers (Fig. 63: ac). On the other hand, *B. sula* has a well-developed transverse valve-like fold in middle region of the penis (Fig. 68: pv) that has also been found in *B. tenuissimus* and in *B. corumbaensis* Pilsbry, 1897 (Resende & Lanzieri, 1964: figs 1, 80), and which may be a generic feature. Other possibly generic features, which justify the genus attribution of *B. sula* are the dotted sculptured protoconch (Fig. 17), the relatively simple shell (lacking colour or sculpture), lack of deflected peristome, and the penis shield (Figs 63, 68: ps)

Additionally, *Bulimulus sula* differs further from *B. corumbaensis* and *B. angustus* Weyrauch, 1966 in lacking a developed axial sculpture and bands. The more elongated last whorl and smoother shell surface differentiates *B. sula* from *B. dukenfieldi* Melvill, 1900; *B. ephippium* Ancey, 1904; *B. felipponei* Marshall, 1930; *B. marcidus* (Pfeiffer, 1853); *B. sporadicus* (d'Orbigny, 1835); and *B. transparens* (Reeve, 1849) (Simone, 2006). The remaining congener species cannot be confused with *B. sula*.

The presence of the genital appendix in *Bulimulus sula* (Fig. 63: ga) is intriguing. It appears to be absent in any known bulimulid. Something similar has been described as "Pfeiffer gland" in two species of *Euconulus* Reinhardt, 1883 (Simroth, 1912: 555), a Gastrodontoidea euconulid, not close related to bulimulids. Another similar structure, also tentatively called "Pfeiffer gland", has been described for the Achatinoidea subulinid *Synapterpes hanleyi* (Pfeiffer, 1846) (Salgado & Coelho, 1999), another group not related to bulimulids. Certainly further studies are necessary to clarify the analogy, function and taxonomical implications of such genital appendices.

During the Holocene the sea level was ~120m lower than the today's level as reported by Vieira (1981). Today the depth of water between São Paulo coast and the main oceanic islands is shallower than 100m so it is assumed that these islands were continuous with the coast around 8,000 years ago. The fauna should be comparable on the islands and the mainland today. However, the very common presence of endemic species in these Paulistan islands indicates that they had some kind of previous isolation, possibly caused by a valley or river, etc. (now submerged), in such the invertebrate fauna could speciate. The endemism of the insular fauna is not restricted to the land molluscs; a species of snake, *Bothrops insularis* (Amaral, 1921), and spider *Mesabolivar cuarassu* Huber, Brescovit & Rheims, 2005, are endemic of Queimada Grande island.

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