ANATOMICAL STUDY ON MYOFORCEPS ARISTATUS, AN INVASIVE BORING BIVALVE IN S.E. BRAZILIAN COAST (MYTILIDAE)

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ABSTRACT

The bivalve Myoforceps aristatus (Dillwyn, 1817), also known as Lithophaga aristata, have been recently collected in the coasts of Rio de Janeiro and Sao Paulo, Brazil; a species that bores shells of other mollusks. This occurrence has been interpreted as an invasion of this species, originally from the Caribbean. The distinguishing character of the species is the posterior extensions of the shell crossing with each other. Because specimens with this character have also been collected in the Pacific Ocean, they all have been considered a single species. However, it is possible that more than one species may be involved in such worldwide distribution. With the objective of providing full information based on Atlantic specimens, a complete anatomical description is provided, which can be used in comparative studies with specimens from other oceans. Additional distinctive features of M. aristatus are the complexity of the incurrent siphon, the kidney opening widely into the supra-branchial chamber (instead of via a nephropore), and the multi-lobed auricle.

KEYWORDS: Myoforceps aristatus, biological invasion, boring bivalve, Brazil, anatomy, systematics.

INTRODUCTION

Myoforceps aristatus (Dillwyn, 1817), previously known as Lithophaga aristata, is a small bivalve that bores into calcareous hard substrata, mainly shells of other mollusks. In the western Atlantic, the species is known from North Carolina to Florida, the Gulf of Mexico and the northern Caribbean Sea. The species is easily identified by pointed tips at the posterior ends of the valves, which cross like fingers (Abbott, 1974) and give the common name of the species as “scissor datemussel”.

Samples belonging to Myoforceps aristatus have been collected in the southeastern coast of Brazil in the last two years, far outside of the normal geographic range of the species. The samples were found in shells of larger size, including cultivated scallops (Pectinidae), and attracted attention as an invading bivalve causing possible damage to native species, because the datemussels perforate living shells, causing deformation of the host and even its death.

Only one species of the closely related genus Lithophaga Röding, 1798, is commonly found on the
S.E. Brazilian coast. Lithophaga bisulcata (Orbigny, 1842) is of larger size, normally inhabits soft rocks and corals, and it is not usually found boring into shells.

This paper reports the first occurrence of Myophorceps aristatus, another invasive species on the Brazilian coast, and provides new data on its morphology and anatomy. The geographic distribution of the M. aristatus includes the Pacific (e.g., Turner & Boss, 1962; Abbott, 1974), as samples of Myophorceps with crossing posterior ends of the shell have also been collected in that ocean. This paper provides anatomi-cal information that can be used in future comparative studies with samples from other oceans.

MATERIAL AND METHODS

The available specimens were preserved in 70% EtOH. They were dissected by standard techniques with the specimen immersed in alcohol. Examination and dissections were done with the aid of a stereomicroscope, and the drawings with the aid of a camera lucida.

The following abbreviations are used in the figures: af, anal fold; am, anterior adductor muscle; an, anus; au, auricle; bf, byssal furrow of foot; cv, ctenidial (efferent) vessel; dd, ducts to digestive diverticula; dg, digestive diverticula/gland; di, inner demibranch; do, outer demibranch; ef, excurrent siphon transverse fold; es, esophagus; ex, excurrent siphon; fg, gill food groove; fm, posterior foot retractor muscle; fr, ante-rior foot retractor muscle; ft, foot; gf, ventral gastric fold; gi, gill ciliary connection to mantle; go, gonad; gp, gill suspensory stalk; gs, gastric shield; gt, gastric transverse furrow; gv, gill ciliary connection to visceral sac; in, intestine; ip, inner hemipalp; ki, kidney; mb, mantle border; mg, pallial mucus gland; mi, inner fold of mantle edge; mm, middle fold of mantle edge; mo, mouth; mt, mantle; om, outer fold of mantle edge; op, outer hemipalp; pa, posterior adductor muscle; pc, pericardium; pf, pallial fold; pp, palp; sa, gastric sorting area; sh, shell; si, incumbent siphon; ss, style sac; st, stomach; uf, projection from fusion of mantle (separating siphons); um, fusion between left and right mantle lobes between siphons; ve, cerebro-visceral connective; ve, ventricle; vg, visceral ganglia.

Abbreviations of institutions: FMNH, Field Museum of Natural History, Chicago, USA; MZSP, Museu de Zoologia da Universidade de São Paulo, Brazil.

Systematics

Myophorceps aristatus (Dillwyn, 1817)
(Figs. 1-18)

For synonymy see Turner & Boss (1962:106). Complement:

Lithophaga (Myophorceps) aristata: Dall, 1898:800; Turner & Boss, 1962:105-108 (pls. 69-72); Abbott, 1974:434 (fig. 5083); Merlano & Hegedus, 1994:52 (fig. 52).

Lithophaga aristata: Morton, 1993:609-619 (figs. 1-6 + pls. 1-2); Redfern, 2001:202; Valentich-Scott & Dinesen, 2004:343-344 (figs. 9-11).

Types: See information by Turner & Boss (1962:106).

Description

Shell (Figs. 1-10): Description given by Turner & Boss (1962) adequate. Characterized by posterior extensions crossing, with left valve possessing an inferior projection (Figs. 2, 4, 6), and right valve a superior projection (Figs. 3, 5), like coring fingers (Figs. 1, 7, 8), however, some specimens are contrary (Figs. 9, 10). No clear pallial sinus detectable.

Main muscle system (Figs. 15, 16): Anterior adductor muscle dorso-ventrally flattened, antero-posteriorly elongated (length about 1/5 of total shell length); located in ventral-anterior corner of valves, close to valve edges. Posterior adductor muscle relatively small, about half of anterior adductor muscle size; somewhat rounded in cross-section; located far from valve edges, positioned between middle and posterior thirds of animal length, and between dorsal and middle thirds of animal height. Pair of anterior foot retractors thick, originating in middle level of anterior region of valves, in an area equivalent to 3/4 of that of anterior adductor muscle and relatively far and totally detached from this adductor muscle; extending toward posterior and ventral up to pedal base, approximately in middle region of ventral animal edge. Pair of posterior foot retractors thick, originating in middle level of anterior region of valves, in an area equivalent to 3/4 of that of posterior adductor muscle and relatively far and totally detached from this adductor muscle; extending toward posterior and ventral up to pedal base, approximately in middle region of ventral animal edge. Pair of posterior foot retractors almost symmetrical to anterior retractors; originating just dorsal to posterior adductor muscle in an area equivalent to 1/4 of that of this adductor muscle; extending toward anterior and ventral, inserting in pedal base just posterior to anterior foot retractor insertion.

Foot and byssus (Figs. 11, 15): Foot relatively small, of about 1/5 valve length, and approximately 4 times longer than wide. Foot base located about in middle
FIGURES 1-8. *Myoforceps aristatus* shells: 1-4) MZSP 48274 #1 (from Ubatuba, SP); 1) dorsal view; 2) left view; 3) right valve, inner view; 4) left valve, inner view; total length = 14.8 mm; 5-8) MZSP 48275 #1 (from Arraial do Cabo, RJ); 5) right view; 6) left view; 7) ventral view; 8) posterior view, showing characteristic crossed posterior projections; total length = 11.1 mm; 9-10) FMNH 311641 (from Florida), ventral and right views, specimen with contrary crossed posterior projections, total length = 24.1 mm.
region of ventral surface of visceral mass. Byssal furrow extending all along foot ventral surface, in median line, relatively deep (about half of foot thickness). Byssus not seen.

*Mantle* (Figs. 11, 13): Mantle edges of both lobes mostly free from one another. Three folds of mantle edge similarly sized, circular in section, well-separated from one another. Siphonal region restricted to posterior end, marked by gradual muscular enlargement of mantle thickness. Incurrent and excurrent siphons separated by thick transverse connection between mantle lobes, of about 1/6 animal length. This connection possessing a flap extending toward anterior (Fig. 13: uf), projecting inside infrabranchial pallial cavity, dorso-ventrally flattened, narrowing gradually to bluntly pointed tip, length equivalent to that of siphons. Inner mantle edge folding abruptly, becoming larger and wider from middle level to incurrent siphonal base (Fig. 13: pf); anterior end of this en-

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**FIGURES 11-15. Myophorceps aristatus anatomy:** 11) whole right view; right valve and mantle lobe removed (except for a short portion related to the siphons); 12) transverse section in middle region of gill, with some adjacent structures also shown; 13) posterior region, right view, with special emphasis on siphonal structures, with incurrent siphon sectioned longitudinally and most right structures removed, pallial flap covering siphons removed; 14) right palp, ventral view, both hemipalps deflected to show inner surfaces; 15) whole right view, with most right structures removed, and special emphasis on visceral structures and main muscles seen as in situ. Scales = 1 mm.
FIGURES 16-18. *Mysidopsis aristatus* anatomy: 16) whole right view, semi-diagrammatic representation of digestive tract and topology of main muscles, mucous gland (mg) and pericardium; 17) stomach right view, longitudinal section along gastric right wall; 18) ventral region of posterior adductor muscle (pa), with most integument and right gill removed, and topology of some adjacent structures shown. Scales = 1 mm.
Visceral mass (Figs. 11, 12, 15, 16): left and right gills. Above) (Fig. 13: uf) lying between posterior regions of tend ing from septum between siphons (described tion between lamellae of each demibranch. Flap ex- nected to pericardium (Fig. 12: pc). No clear connec- tremeities, except in region between demibranchs con- (Fig. 12). No clear vessels present in demibranch ex- connected to dorsal structures via tissue junctions demibranch and outer lamella of outer demibranch, about twice longer than inner lamella if inner demibranch and inner lamella of outer demibranch, to mantle via cilial junctions; outer lamella of inner demibranch and inner lamella of outer demibranch about twice longer than inner lamella if inner demibranch and outer lamella of outer demibranch, connected to dorsal structures via tissue junctions (Fig. 12). No clear vessels present in demibranch extremities, except in region between demibranchs con- nected to pericardium (Fig. 12: pc). No clear connection between lamellae of each demibranch. Flap ex- tending from septum between siphons (described above) (Fig. 13: uf) lying between posterior regions of left and right gills.

Visceral mass (Figs. 11, 12, 15, 16): General form somewhat triangular (foot positioned as ventral angle). Both pairs of foot retractor muscles forming ventral border of visceral sac (Fig. 15: fm, fr). Digestive diverticula (gland) greenish-beige in preserved specimens, occupying almost entire middle and anterior thirds of visceral sac. Gonad occupying dorsal region of middle and anterior thirds of visceral sac, extending throughout mantle lobes as described above. Reno-pericar- dial structures (described below) occupying posterior third of visceral sac. Visceral integument poorly mus- cular.

Circulatory and excretory systems (Figs. 15, 16): Heart occupying little more than half of entire reno-pericar- dial volume. Auricles connected directly to gills by pericardium in their middle-posterior quarter (Fig. 12: pc). Each auricle weakly triangular, its posterior surface with irregular, relatively large lobes (Fig. 15: au); anterior surface simple. Auricular connection to ventricle narrow and lateral to ventricle. Ventricle surrounding intestine, about as long as pericardium. Kidneys solid, whitish, located in lateral surfaces of reno-pericardial posterior region. Kidneys amply opened to supra-bran- chial chamber, by long fissure of somewhat same length as kidney; inner folds of renal glands exposed through renal aperture.

Digestive system (Figs. 16, 17): Palps described above (Fig. 16). Mouth elliptical, located at short distance from median end of palp folds; flanked by smooth surfaces, anterior and posterior tips relatively thick (Fig. 14: mo). Esophagus short and wide, of about 1/10 shell length, passing between anterior pedal re- tractor muscles, close to their anterior end; esophagus totally free from anterior adductor muscle. Esopha- geal inner surface smooth. Transition of esophagus and stomach marked by oblique, deep furrow (Fig. 17: gf), located in ventral and left surfaces; inner surface of this furrow with low, narrow, well-spaced folds parallel to furrow longitudinal axis. Stomach occupying about 1/3 of visceral sac volume and 1/4 of total animal length; located at anterior region of visceral sac, below umbos, just posterior and dorsal to esophagus (Fig. 16: st); general form elliptical. Inner surface (Fig. 17) mostly smooth; low, broad, arched fold located at left side (Fig. 17: gf), as continuation of posterior edge of furrow located between esopha- gus and stomach, anteriorly low, posteriorly weakly taller and rounded, close to left duct to digestive diverticula. Small sorting area in dorsal-right surface (Fig. 17: sa), opposed to previous described fold; com- posed by oblique, low, narrow folds close to each other. A pair of narrow ducts to digestive diverticula (Figs. 16, 17: dd), located at anterior region of gastric ventral surface, one on each side. Gastric shield of about 1/4 gastric surface (Fig. 17: gs); located at left, slightly dorsal and posterior to left duct to digestive diverticula. Intestine and style sac totally fused and nearly indistinguishable; both separated from gastric chamber by low, transverse fold (Fig. 17, preceding ss). Style sac extending directly toward posterior, nar- rowing gradually, reaching anterior surface of poste- rior adductor muscle; length slightly longer than that of stomach. Intestine continuing after style sac end, marked by abrupt 180° curve (Fig. 16); extending dor- sally, slightly at right along style sac surface; close to stomach posterior surface, performing wide loop to left, returning toward posterior, extending more dor- sal and away from preceding loop; passing through pericardium, and along dorsal surface of posterior adductor muscle. Anus a low, simple, small aperture located at anterior region of adductor muscle ventral sur- face (Figs. 13, 16, 18: an).

Genital system: Not seen in total detail. Gonad, as de- scribed above, covering dorsal region, reaching mantle...
lobes close to mantle edges (Figs. 11, 12, 15: go). Color cream or brown in preserved specimens. No genital apertures observed.

Central nervous system: Cerebral and pedal ganglia not seen in detail. Visceral ganglia (Fig. 18: vg) located just anterior to ventral surface of posterior adductor muscle; widely fused to one another in median line (Fig. 13); volume approximately 1/10 of posterior adductor muscle. Cerebro-visceral connectives relatively thick, extending through digestive diverticula.

Measurements (in mm): MZSP 48274 #1 (Figs. 1-4): 14.8 length by 5.1 height; MZSP 48275 #1 (Figs. 5-7): 11.1 by 4.2. FMNH 311641: 24.1 by 17.7 (Figs. 9, 10).

Distribution: North Atlantic: from Portugal to Senegal; from North Carolina to Venezuela, including the Gulf of Mexico. Now introduced to southeastern Brazilian coast. For occurrence in Pacific Ocean see Turner & Boss (1962).

Habitat: Boring calcareous substrata, mainly shells of other mollusks, from intertidal to 5 m depth.

Material examined. UNITES STATES OF AMERICA. Florida. Florida Keys, Monroe, Looe Key coral reef, 8 m depth, 24°32.8‘N 81°24.8‘W, 1 specimens, FMNH 311641 (Sta. FK-260; Bieler & Mikkelsen col., 19/iii/1999). BRAZIL. Rio de Janeiro; Búzios, Ossos Beach, MZSP 48275, 1 specimen (Simone et al. col., 19/iii/2005); Arraial do Cabo, Porcos Island, 22°57'35.5"S 41°59'47.7"W, MZSP 48276, 7 specimens [Simone et al. col., 19/iii/2005, in Thais haemastoma (Linné, 1767)]. São Paulo; Ubatuba, MZSP 48274, 10 specimens [Iris L.A. Álvares col.; iv/2005, in Nodipten nodosus (Linné, 1758)].

DISCUSSION

The geographic distribution of Myoforceps aristatus is regarded by some authors as almost worldwide, including the Pacific coast of South America, Red Sea, Australia, Japan, etc. (e.g., Turner & Boss, 1962; Abbott, 1974). However, this species has not been reported in the western Atlantic areas southern than Venezuela (Merlano & Hegedus, 1994); this fact demonstrates the relevance of this report from the Brazilian coast. Turner & Boss (1962:108) advocated that the original distribution of the species was tropical to temperate from the eastern and western Atlantic and eastern Pacific, and that the remaining records are attributable to transport by ballast.

Related to the general geographic distribution of Myoforceps aristatus, no detailed study beyond analysis of the shell has been produced to verify whether specimens from all points of the world are really of a single species. It is possible that, actually, the species is restricted to the Atlantic, and the remaining records are merely of other cryptic species with similarly shaped shells. The following names were described to samples from the Pacific Ocean, and have been referred as synonym of M. aristatus: Lithophaga caudata Gray, 1827 (from Australia), L. gracilior Carpenter, 1856, L. tumidior Carpenter, 1856 (both Pacific coast of Mexico, described as subspecies of L. aristata), and L. carpenteri (Mörch, 1861) (Costa Rica). The species described for Atlantic samples, and also are considered as M. aristatus synonyms (Turner & Boss, 1962), are: Mytilus curvirostris (Schütt, 1787 (no loc.); Mytilus littoropus striatus Sowerby, 1807 (London); Mytilus aristatus Dillwyn, 1817 (Senegal); Modiolia candigera Lamarck, 1819 (Africa); Mytilus ropan Deshayes in Lamarck, 1836; Lithophagus salycalculus Carpenter, 1856; Lithodoma forficatus Ravenel, 1861 (South Carolina); Lithodoma bipennifera Guppy, 1877 (Trinidad).

Since the environmental problems brought by invasive species have increased in importance, mainly related to the extinction of native species and reduction of biodiversity (e.g., Sax & Brown, 2000; Clavero & García-Berthou, 2005), the fact that Myoforceps aristatus is another introduced species in the Brazilian coast gains weight. Compared to Western Pacific, for example (Mooney & Hobbs, 2000), the Brazilian coast has been relatively spared from invasive species of mollusks. There are tree currently detected species, one of them is the byssate bivalve Irgomonon bicolor (C.B. Adams, 1845). Like M. aristatus, I. bicolor is regarded to have originated from the Caribbean, being transported by counterbalance water of ships (Fernandes et al., 2004). Additionally, and different from I. bicolor, M. aristatus directly impacts native species; it causes damage to their shells, producing serious scars, deformations and even death. The infested specimens of the scallop Nodipten nodosus, studied herein, were cultivated in a marine farm in north São Paulo coast (Ubatuba), where M. aristatus is considered a problem (Álvares, personal communication). Beyond I. bicolor, other two marine species have been considered as invasive in Brazilian waters, the mytilid Perna perna (Linné, 1758) (Souza et al. 2004) and the dreissenid Mytilopsis
leucophaeta (Conrad, 1831) (Souza et al., 2005), both also possibly coming from the Caribbean.

The anatomical features of *Myoforceps aristatus* are similar to other members of Mytilidae (Coan et al. 2000). The main exclusive attributes of *M. aristatus* are the complexity of the incurrent and excurrent siphons; these structures are responsible for constructing the posterior projection of the shell (Morton, 1993), which is annexed to, but it is not part of, the shell. In addition, the folds and projections of the siphons can be used in species identification; they are reasonably uniform in the examined samples; something similar, but with another conformation, is found in the boring mytilid *Botula fusca* (Gmelin, 1791) (see Yonge, 1955; Wilson & Tait, 1984, fig. 3). The kidneys are widely communicated to the supra-branchial chamber by a long aperture, rather than a small aperture, the nephropore as in most bivalves. This wide renal communication is a long opening of each renal chamber, lying along the dorsal edge of the organ; the internal folds of the renal gland are easily visible through this aperture. This feature has not been previously reported to a bivalve. The lobed posterior surface of the auricles is another uncommon feature of this species; although, the significance those lobes is unknown. Lobed auricles appears to be a shared character with *Botula fusca* (Wilson & Tait, 1984).

In agreement with typical morphological characters of Mytilidae (Coan et al., 2000), *M. aristatus* has the visceral sac greatly compacted dorsally, with the internal organs, mainly the digestive tubes, compressed upwards. Another mytilid exclusivity, and possibly related to the preceding character, is the invasion of the gonad into the mantle lobes. The more typical bivalve gonad is inside the visceral sac, however, in mytilids, the gonads are only partially placed inside it, being mostly located along the mantle lobes, reaching, when fully mature, the regions close to the mantle edge (being bordered by the mantle muscles originating from the shell pallial line). The palps are also characteristically long and narrow, having transverse folds. Finally, the foot is relatively small, and operates only as a stalk for the byssus.

The anterior boring gland or pallial glands, present in some boring mytilids as, e.g., *Gregariella coralliophaga* (Gmelin, 1791) (Morton, 1982), *Botula fusca* (Wilson & Tait, 1984), and *Lithophaga lithophaga* (Linné, 1758) (Jaccarini et al., 1968), were also observed in *Myoforceps aristatus*. Those structures are responsible for the coral or rock boring, secreting, normally, a neural mucoprotein with calcium binding ability (Jaccarini et al., 1968).

CONCLUSIONS

1. *Myoforceps aristatus* has been only recently found on the southwest Brazilian coast and is considered introduced, originally from the Caribbean.

2. There is the possibility that the worldwide distribution of *M. aristatus* is uncertain. Its distribution is possibly restricted to the Atlantic, and its occurrence in other seas can be interpreted as cryptic species with similarly shaped shells.

3. The anatomical study revealed characters common to mytilid bivalves plus possible unique features that can be used for comparison with samples from other regions.

RESUMO

O bivalve *Myoforceps aristatus* (Dillwyn, 1817), também conhecido como *Lithophaga aristata*, tem sido recentemente coletado nas costas do Rio de Janeiro e São Paulo, Brasil; uma espécie que perfura conchas de outros moluscos. Esta ocorrência está sendo interpretada como uma invasão de uma espécie originada do Caribe. O caráter distintivo da espécie é a região posterior da concha, com extensões que se cruzam. Como espécimes com esta característica também têm sido coletados no oceano Pacífico, eles tem sido considerados como pertencentes à mesma espécie. Entretanto, é possível que mais de uma espécie possam estar envolvidas nesta suposta distribuição mundial. Com o objetivo de fornecer informação completa baseada em material do Atlântico, uma descrição anatômica completa é dada, a qual pode ser usada em estudos comparativos com espécimes de outros oceanos. As características distintivas adicionais de *M. aristatus* são a complexidade do sifão inalante, o rim com uma abertura ampla para a câmera supra-branquial (ao invés de ser via nefróporo) e aurícula multi-lobada.

PALAVRAS-CHAVE: *Myoforceps aristatus*, invasão biológica, bivalve perfurador, Brasil, anatomia, sistemática.

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REFERENCES

Abbott, R.T. 1974. American Seashells. Second edition. Van Nostrand Reinhold Company, New York, 663 p. + 240 pls.

Carpenter, P.P. 1856. Catalogue of the Reigen Collection of Mazatlan Mollusca in the British Museum. Oberlin Press, Warrington, 552 p.

Clavero, M & García-Berthou, E. 2005. Invasive species are a leading cause of animal extinctions. Trends in Ecology and Evolution, 20(3):110.

Coan, E.V.; Scott, P.V. & Bernard, F.R. 2000. Bivalve seashells of western North America. Santa Barbara Museum of Natural History Monographs, Santa Barbara, 764 p.

Dall, W.H. 1898. Contribution to the Tertiary Fauna of Florida. With special reference to the Silex beds of Tampa… Transactions of the Wagner Free Institute of Science of Philadelphia, 3:571-947.

Dillwyn, L.M. 1817. A descriptive catalogue of recent shells, arranged according to the Linnean method. London, 2 vols. i-xii + 1092 p.

Fernandes, F.C.; Rapagnã, L.C. & Bueno, G.B.D. 2004. Estudo da população do bivalve exótico Isognomon bicolor (C.B. Adams, 1845) (Bivalvia, Isonomonidae) na Ponta da Fortaleza em Arraial do Cabo – RJ. In: Silva, J.S.V & Souza, R.C.C.L. (Orgs.). Água de Lastro e Bioinvasão. Interciência, Rio de Janeiro, p. 133-141.

Guppy, R.J.L. 1877. First sketch of a marine invertebrate fauna of the Gulf of Paria and its neighborhood. Proceedings of the Scientific Association of Trinidad, 2:134-157.

Jaccarini, V; Bannister, W.H. & Micallef, H. 1968. The pallial glands and rock boring in Lithophaga lithophaga (Lamellibranchia, Mytilidae). Journal of Zoology, 154(4):397-401.

Lamarck, J.B.P.A.M. 1819. Histoire naturelle des animaux sans vertèbres, présentant les caractères généraux et particuliers… J.B. Bailliere, Paris, v.6, 232 p.

Lamarck, J.B.P.A.M. 1836. Histoire naturelle des animaux sans vertèbres, présentant les caractères généraux et particuliers… Second edition rev. J.B. Bailliere, Paris, v.7, 736 p.

Merlano, J.M.D. & Hegedu, M.P. 1994. Molluscos del Caribe colombiano. Colciencias, Fundacion Natura Colômbia, Bogota, 291 p + 74 pls.

Mooney, H.A. & Hobbs, R.J. 2000. Invasive species in a changing world. Island Press, Washington, 447 p.

Mörch, O.A.L. 1861. Beiträge zur Molluskenfauna Central-Amerika’s. Malakozoologische Blätter, 7:170-213.

Morton, B. 1982. The mode of life and functional morphology of Gregariella coralliophaga (Gmelin, 1791) (Bivalvia: Mytilacea) with a discussion on the evolution of the boring Lithophaginea and adaptive radiation in the Mytilidae. Proceedings of the International Marine Biological Workshop, 1(2):875-895.

Morton, B. 1993. How the “forceps” of Lithophaga aristata (Bivalvia: Mytiloidea) are formed. Journal of Zoology, 229(4):609-621.

Ravenel, E. 1861. Description of new Recent shells from the coast of South Carolina. Proceedings of the Academy of Natural Sciences of Philadelphia, 1861:41-44.

Redfern, C. 2001. Bahamian seashells: a thousand species from Abaco, Bahamas. Boca Raton, Florida, 280 p + 124 pls.

Sax, D.F. & Brown, J.H. 2000. The paradox of invasion. Global Ecology & Biogeography, 9(5):363-371.

Schröter, J.S. 1787. Eiseitung in die Conchylien Kenntniss nach Linnei. Halle, v.4.

Souza, R.C.C.L.; Fernandes, F.C & Silva, E.P. 2004. Distribuição atual do mexilhão Perna perna no mundo: um caso recente de bioinvasão. In: Silva, J.S.V & Souza, R.C.C.L. (Orgs.). Água de lastro e bioinvasão, Interciência, Rio de Janeiro, p. 157-172 (Capítulo 12).

Turner, R.D. & Boss, K.J. 1962. The genus Lithophaga in the western Atlantic. Johnsonia, 4(41):81-116.

Valentich-Scott, P. & Dinesen, G.E. 2004. Rock and coral boring Bivalvia (Mollusca) of the middle Florida Keys, U.S.A. Malacologia, 46(2):339-354.

Wilson, B.R. & Tait, R. 1984. Systematics, anatomy and boring mechanisms of the rock-boring mytilid bivalve Botula. Proceedings of the Royal Society of Victoria, 96(3-4):113-125.

Yonge, C.M. 1955. Adaptation to rock boring in Botula and Lithophaga (Lamellibranchia, Mytilidae) with a discussion on the evolution of the habit. Quarterly Journal of Microscopical Science, 96(3):383-410.

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Submission of Manuscripts: Manuscripts should be sent to the Editor-in-Chief (H. Zaher, Museu de Zoologia da USP, Caixa Postal 42-494, CEP 01248-970, São Paulo, SP, Brazil). Manuscripts are considered on the understanding that they have not been published or will not appear elsewhere in substantially the same or abridged form. The criteria for acceptance of articles are: quality and relevance of research, clarity of text, and compliance with the guidelines for manuscript preparation.

Manuscripts should be written preferentially in English, but texts in Portuguese or Spanish will also be considered. Studies with a broad coverage are encouraged to be submitted in English. All manuscripts should include an abstract in Portuguese and English regardless of the original language.

Authors are requested to pay attention to the instructions concerning the preparation of the manuscripts. Close adherence to the guidelines will expedite processing of the manuscript, whereas manuscripts deviating from the required form will be returned for revision prior to review.

Manuscript Form: Manuscripts should not exceed 100 pages of double-spaced typescript on 21 by 29.7 cm (A4 format) or 21.5 by 28 cm (letter format) paper, with wide margins. The pages of the manuscript should be numbered consecutively.

The text of articles should be arranged in the following order: Title Page, Abstracts, Body of Text, Literature Cited, Tables, Appendices, and Figure Captions. Each of these sections should begin on a new page. All typescript pages must be double-spaced.

(1) **Title Page:** This should include the title, author(s) name(s), institutions, and keywords in English as well as in the language of the manuscript, and a short running title in the language of the manuscript. The title should be concise and, where appropriate, should include mention of families and/or higher taxa. Names of new taxa should not be included in titles.

(2) **Abstract:** All papers should have an abstract in English and another in Portuguese, regardless of the original language. The abstract is of great importance as it may be reproduced elsewhere. It should be in a form intelligible if published alone and should summarize the main facts, ideas and conclusions of the article. Telegraphic abstracts are strongly discouraged. Include all new taxonomic names for referencing purposes. Abbreviations should be avoided. It should not include references. Abstracts should not exceed 350 words.

(3) **Body of Text:** The main body of the text should include the following sections: Introduction, Materials and Methods, Results, Discussion, and Acknowledgments. The first page of the manuscript should be numbered 000. The title page should be followed by the heading of each section. Subsections should be numbered using Arabic numerals. Italics and bold type should be used only in the case of foreign words, chemical symbols, and plant or animal names.

(a) **Introduction:** Should be self-contained with a clear statement of the main problem to be addressed. The scope and objectives of the study should be presented. The significance of the study should be discussed in the context of the existing literature. The introduction should include a statement of the hypothesis or questions to be addressed in the study.

(b) **Materials and Methods:** Should provide sufficient information for the reader to replicate the study. The methods should be described in enough detail to allow others to understand and verify the results. The experimental design, materials, and procedures used should be described in detail. The methods section should include the following subheadings: Materials, Methods, and Procedures. All chemicals and reagents should be identified by their common and/or systematic names. The methods section should be clear and concise, avoiding the repetition of technical terms. The methods section should be structured to clearly differentiate between the different stages of the study.

(c) **Results:** Should present the data collected during the study. The results should be presented in a logical and organized manner, with supporting data presented in a table or figure. The results should be presented in a way that allows the reader to understand the key findings of the study.

(d) **Discussion:** Should interpret the results in the context of the existing literature. The discussion should address the implications of the findings and their relevance to the field. The discussion should not repeat the results, but should rather focus on the interpretation of the findings and their significance. The discussion should also address the limitations of the study and suggest areas for further research.

(e) **Conclusion:** Should summarize the main findings of the study and their implications. The conclusion should also address the limitations of the study and suggest areas for future research.

(f) **References:** Should be a list of all the sources cited in the manuscript. The references should be listed alphabetically by author name. Each reference should include the name of the author(s), the title of the work, the publication date, the volume number, the page numbers, and the names of the publishers. The references should be formatted according to the style guide of the journal.

For other details of manuscript preparation of format, consult the CBE: Style Manual, available from the Council of Science Editors (http://www.councilscienceeditors.org/publications/style.cfm).

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