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First record of double aperture in a gastropod shell

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Abstract. The present study reports the occurrence of a *Cerithium atratum* (Born, 1778) shell with two apertures. The original aperture (measuring 5.8 by 5.0 mm), blocked by a small pebble fragment, could have prevented the head-foot part of the body to emerge. The gastropod (24.8 mm length) formed a new aperture similar to the original, measuring 5.9 by 4.6 mm and presenting a polished and circular outer lip, and partially formed anal and siphonal canal. This anomaly had not been registered yet in mollusks.

Keywords: *Cerithium atratum*, anomalous, double aperture, neoformation

Resumo. Primeiro registro de dupla abertura em concha de gastrópode. O presente estudo relata a ocorrência de um *Cerithium atratum* (Born, 1778) com dupla abertura na concha. A abertura original (5,8 mm x 5,0 mm), bloqueada por um pequeno fragmento de seixo, pode ter impedido a saída da região cefalopediosa. O gastrópode (24,8 mm de comprimento) formou uma nova abertura similar a original medindo 5,9 por 4,6 mm, presentando lábio externo circular e polido, além de um canal anal e sifonal parcialmente formados. Essa anomalia ainda não havia sido observada entre moluscos.

Palavras-chaves: *Cerithium atratum*, anomalia, dupla abertura, neoformação

Introduction

Mollusks follow, in general, a pattern of continued growth of the shell. However, predation attempts or mechanical damage can lead to regeneration mechanisms, causing deformities (Mondal & Harries 2015). In the event of survival after attempted predation, scars, resulting from regeneration, are sometimes easily perceived in the shells as fractured aperture, damaged outer lip, perforated body whorl or spire, and broken operculum. Usually, deformations are identified in such shell structures as unevenness in the body whorl of the shell or calluses on the damaged region (Peel 2015).

Another mechanism that can result in severe damage to the surface of marine gastropods shell is erosion. This mechanism may vary in intensity according to temperature, pH and salinity system (Berge *et al.* 2006). These factors acting together enable the dissolution of the calcium carbonate shell of these mollusks (Marshall *et al*. 2008).

Cerithium atratum (Born, 1778) is an anphiatlantic gastropod found in the intertidal zone. The adults of *Cerithium atratum* present lengths up to 38 mm, with 12-15 whorls, and are sculptured 9-20 axial ribs, present striations visible next the outer lip, protruding dark color nodules of regular size, and 2-3 rows of small beads. They have short siphonal and anal canals (Marcus & Marcus 1964), the aperture has an oval shape, with thick outer lip, polished inner lip without denticles.

This study was performed in order to describe a peculiar anomaly (double aperture) found in *Cerithium atratum*. Here we try to raise some

hypotheses of how this second opening may have formed during the life of the gastropod.

Material and methods

During the execution of a project about the biodiversity of two beaches in the Caucaia municipality, Ceará, Brazil, one *Cerithium atratum* shell with an anomaly was collected. The sampled individual presented a small pebble in its original aperture. This gastropod was found in May 2015 on Iparana Beach (3°41'20.4"S 38°36'37.2"W) in the middle littoral zone.

The collection was carried out in manual mode, wrapped tube and sent to the Laboratório de Invertebrados Marinhos do Ceará (LIMCE), Universidade Federal do Ceará (UFC), where it was observed in a stereoscope microscope and photographed. The small pebble in the original aperture was removed to see if the passage was obstructed or remained open. The measurements were performed with the support of the software ImageJ 1.49v.

The shell was submited to radiography in a X-Ray Spectro 70X Electronic equipment, where was exposed to radiation for 0.6 and 0.8 sec. The specimen described here was deposited in the Malacological Collection "Prof. Henry Ramos Matthews" - Series B under the number CMPHRM 4613B.

We consider the following body structures: inner lip (i); outer lip (o); siphonal canal (s); anal canal (ac); body whorl (bw) - the last compartment of the teleoconch previous to the spire; columella (co); secondary aperture or new aperture (na) - the high aperture located on the dorsum of the shell, parallel to the original aperture; neoformation (nf) - the tubular projection with an aperture located dorsally on the shell in body whorl region; new inner lip (ni); new outer lip (no); original aperture shell (oa) - the one where we find the pebble fragment, this opening follows the same pattern as the body whorl and termination of the columella. Other structures relating to neoformation: partial anal canal (pac); partial siphonal canal (psc); sidewall (sw) - the irregular wall located inside the original aperture.

Results

The anomaly consists in the formation of a second aperture in the collected specimen (double aperture), which has occurred through the shell wall rupture, closing of the original aperture and reorientation of the shell growth. The specimen of this study consists of an empty shell with a pebble fixed at its original aperture.

The shell is 24.8 mm length with nine whorls and one perforation by erosion in the first whorl of the spire. It has worn periostracum, no protruding axial nodules, granular spiral lines or pronounced sutures, resulting in an eroded appearance (Fig. 1).

The original aperture is completely developed, measuring 5.8 x 5.0 mm. Outer and inner lips do not present cracking or fractures by predators. However, the siphonal and anal canals were apparently unobstructed. After removing the pebble, it was found that the aperture was closed, due to the formation of the secondary aperture sidewall (Figs. 2a-2e).

The neoformation measures 8.7 mm in length and it is located on the dorsal surface of the shell, inclined 74.7° to the axis of the siphonal canal, following the same orientation of the gastropod growth (Fig. 2b). A side suture between the wall of the new aperture and the body whorl was observed. We verified that the surface of the new whorl is consistent with the loss of periostracum in previous whorl (Figs. 2b-2c). The new aperture measures 5.9 x 4.6 mm, presented a polished outer lip, anal and siphonal canals partially formed. The new anal canal has a 32° inclination to the wall of the last whorl of shell (Figs. 2d-2f).

Through radiography, we observed that the *C. atratum* shell had normal internal structures, with no absorption or deformities in the columella. The columella presented six conserved compartments and a continuous columellar wall without fragmentation or deformity in previous growth whorls. It was also observed the occurrence of a transverse process on the original aperture, connecting the inner edge of the new aperture with the columella wall (Fig. 3e).

Discussion

The formation of the second shell aperture was a consequence of the obstruction of the original aperture by the pebble fragment. This fragment was fixed so that the gastropod failed to remove it. This event could certainly have caused the death of the animal, as it would not be able to feed themselves and move freely in the intertidal zone.

The question to be answered is how was the gastropod able to form the new aperture?. To answer this question we need to consider that the new formation did not exist in the gastropod. If the secondary aperture had accompanied the

Figure 1. Lateral and dorsal view of *Cerithium atratum* (Born, 1778) with double aperture. Scale bar: 5.0 mm.

development stages of the mollusk, the original aperture would be atrophied, and located in any of the previous whorls of the teleoconch, also it should present a smaller diameter than thar of the neoformation. The diameter of shell aperture varies in relation to the development of the gastropod, it is a disproportionate extent in all stages of development (Medeiros *et al.* 2015). We observed that the diameter of the original and the new apertures are relatively equal, in addition they are located in the same body around which suggests that *Cerithium atratum* managed to project out of the shell, formed a second outer lip, and finally a new inner lip soon. The definitive closure of the old aperture, which was found blocked, was conducted in conjunction with the formation of the new inner lip, as shown in Figures 2d-2e. The rupture of the shell wall may have occurred due to scraping of the inner wall by the *C. atratum* radula as it is adapted to this type of foraging (Meirelles & Matthews-Cascon 2003). However, with the outer, middle and inner layers of the shell in healthy conditions, it is unlikely that the specimen could cause any damage to the inner wall of the shell itself.

The surface of *Cerithium atratum* shell was not healthy, as shown by the erosion process found on the shell. Its periostracum had visible marks of degradation by natural erosion. The periostracum gastropod had visible marks of degradation by natural erosion. In marine environments, wear at the external surface are very noticeable, consequently this damage affects the composition of the inner layers of shells. Thus, depending on the gastropod, the density between these layers may vary considerably, resulting in rigid and brittle shells. (Taylor & Layman 1972, Barthelat *et al.* 2009), we find that this shell had already serious signs of weakness and lack of rigidity, which may have facilitated the rupture of the shell and escape of the mollusk. In life, the radula of the gastropod was essential to expand the space of the new aperture, allowing the soft parts of the mollusk could go out and reconstruct the entire outer lip.

The opening of the new aperture in the *C. atratum* shell could have been facilitated by the observed deterioration in periostracum (Fig. 1). The periostracum is the more external layer of the shell, formed by an organic matrix of proteins,

mucopolysaccharides and lipids. This layer protects the mollusk against external agents (Harper 1997), but when this layer is damaged it is optionally regenerated (Checa 2000; Araujo *et al.* 2014). With the loss of the periostracum, the ostracum and hypostracum begin to dissolve by the action of salinity, pH and water hardness (Douglas 1990). The formation of the inner layers are due to a microstructure arrangement secreted by the mantle, this material relates to biochemical aspects that favor the biomineralization (Ubukata 2001), with these layers damaged the shell loses its rigidity, earning a consistency malleable of easy drilling.

Therefore, it is possible that, after the shell had suffered the corrosive action of water, the gastropod could drill it from inside out, forming the

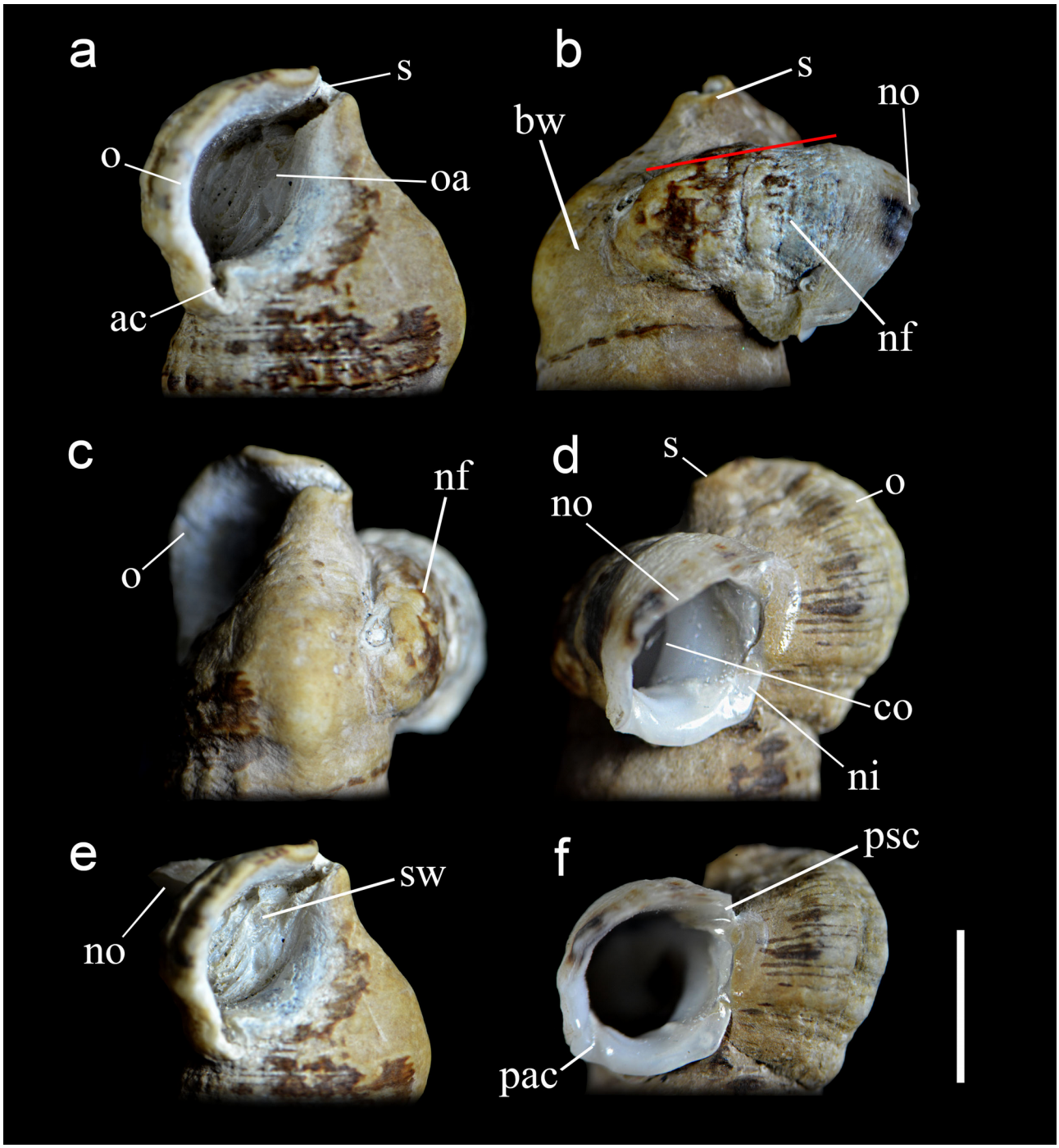

Figure 2. Detail of aperture: **a, e.** ventral view of the old aperture with the interior of the shell closed by regeneration. **b.** lateral view of the new aperture on the dorsal wall of the old body whorl. **c.** dorsal view of the new aperture. **d, f.** front view of the new aperture. The red line indicates the angle of deviation from the aperture of new growth. Scale bar: 5.0 mm.

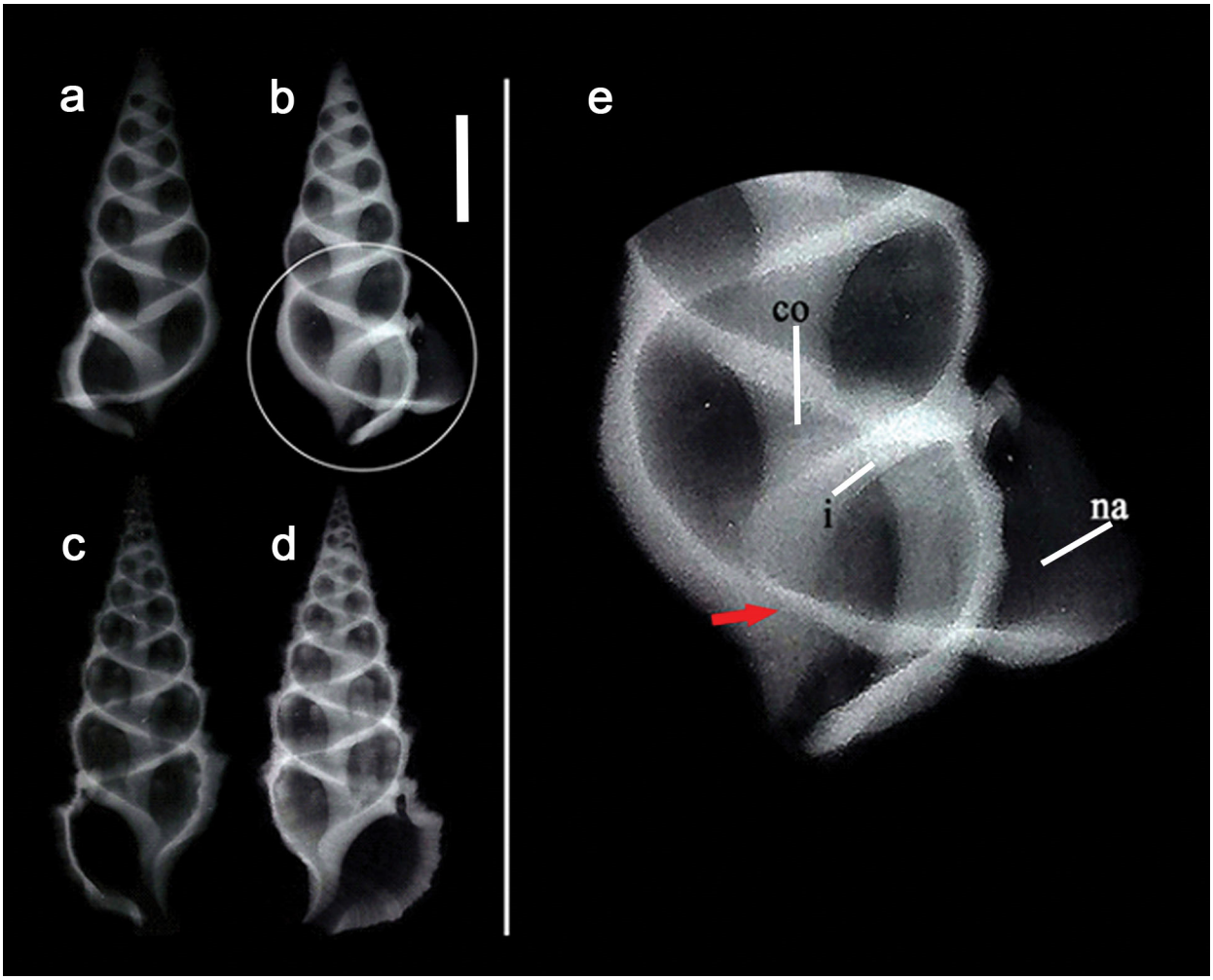

Figure 3. X-ray of the shell: **a.** dorsal view. **b.** ventral view. **c**, **d.** respectively, dorsal and ventral view of a normal shell of the same species. **e.** Detail of **b.** The arrow indicates a transverse process. **a, c** exposure 0.8 sec., **b, d** exposure 0.6 sec.. Scale bar: 5.0 mm.

new aperture. After the rupture of the body whorl dorsal wall, the regeneration and growth mechanisms may have been activated, with the mantle epithelial cells, specialized in the deposition of calcium, begining to form a fragile outer lip, and then forming the new whorl of the shell. The next step would be closing the old aperture, even when it was blocked with the pebble fragment. With the old siphonal and anal canals sealed, it would, finally, occurred the formation of the inner lip. However, the *C. atratum* was not successful in completing the formation of the new siphonal and anal canals.

Another hypothesis is that *Cerithium atratum* had already a perforated shell when the pebble set. The rupture may have been caused by the impact of dynamics in intertidal zone (Helmuth & Denny 2003) or predation attempts by crabs. These events could have created a small fracture allowing the projection of the gastropod and finally started the formation of the outer lip (Fig. 4). It would be unlikely that the shell was broken, the aperture clear and *Cerithium atratum* chose to form a new aperture instead of just regenerating the fractured shell.

The survival of the *C. atratum* with the original shell aperture blocked would be possible by the feeding on debris particles that would penetrate through the siphonal canal, or which were already housed inside before the obstruction. The relative survival period for marine gastropods to starvation may be between 12 to 40 days. However, that can depend on factors related to the physiology of the gastropod, body size, age, and gender (Zhang & Goshima 2013).

This study aimed to describe the anomalous shell collected and formulate hypotheses on the formation of the secondary aperture during the life of the gastropod. More complex experiments must be conducted in order to improve the view of the

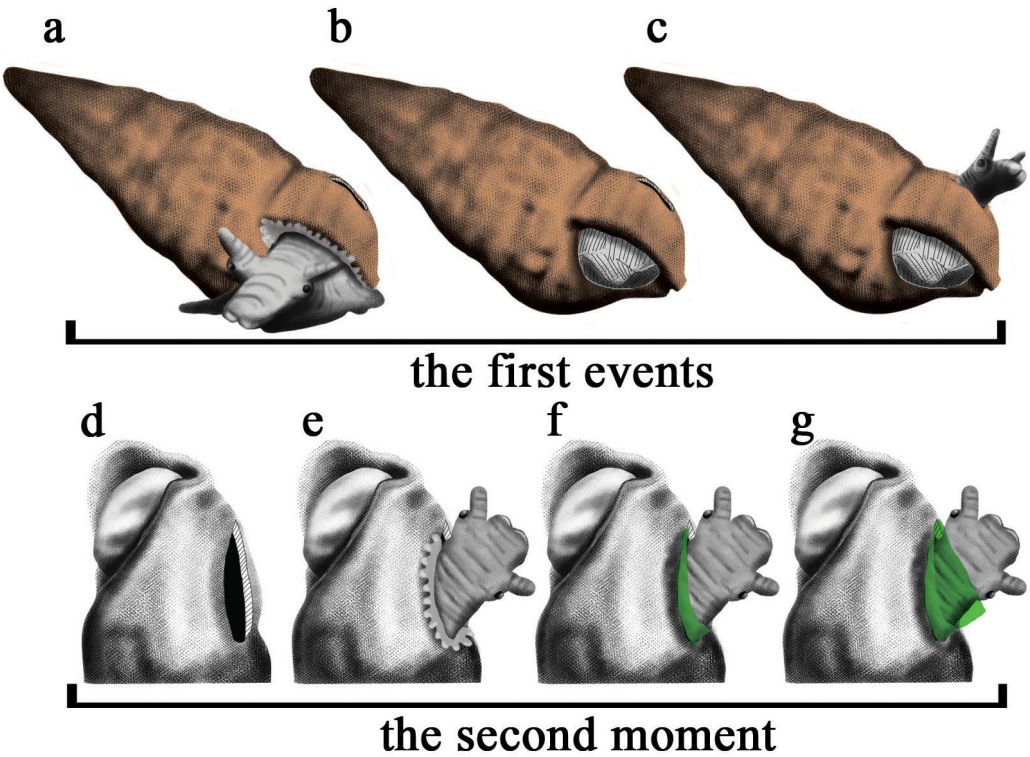

Figure 4. Hypothesis of the new aperture formation. **a.** *Cerithium atratum* as a perforation in its shell. **b.** event of the aperture blocked by pebble fragment. **c-e.** the Cerithium atratum was not able remove the fragment of its aperture out through for perforation lateral the shell. **f, g.** beginning of the formation of the outer lip.

data presented herein. Others tips anomalies have already been registered. Anomalous shells are commonly found with deformities in their siphonal canal, deviation from the axis of the spire, albinism, or "tumors" (Matthews *et al.* 1979).

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References

Araujo, R., Delvene, G. & Munt, M. 2014. Presence of organic layers in shells of fossil and Recent Unionoida (Bivalvia) and their implications. **Journal of Molluscan Studies**, 80: 74–83.

Barthelat, F., Rim, J. & Espinosa, H. 2009. A review on the structure and mechanical properties of mollusk shells–perspectives on synthetic biomimetic materials. **Springer - Applied Scanning Probe Methods XIII**, 17–44.

Berge, J. A., Bjerkeng, B., Pettersen, O., Schaanning, M. T. & Øxnevad, S. 2006. Effects of increased sea water concentrations of CO2 on growth of the bivalve Mytilus edulis L. **Chemosphere**, 62: 681–687.

Checa, A. 2000. A new model for periostracum and shell formation in Unionidae (Bivalvia, Mollusca). **Tissue & cell**, 32: 405–416.

Douglas Hunter, R. 1990. Shell dissolution rate in freshwater pulmonate snails : influence of Periostracum and water chemistry. **The Nautilus**, 104: 87–91.

Harper, E. M. 1997. The molluscan periostracum: an important constraint in bivalve evolution. **Palaeontology**, 40: 71–97.

Helmuth, B. & Denny, M. W. 2003. Predicting wave exposure in the rocky intertidal zone: Do bigger waves always lead to larger forces? **Limnology and Oceanography**, 48: 1338–1345.

Marcus, E. & Marcus, E. 1964. On Cerithium atratum (Born, 1778) (Gastropoda: Prosobranchia). **Bulletin of Marine Science of the Gulf and Caribbean**, 14: 494–509.

Marshall, D. J., Santos, J. H., Leung, K. M. Y. & Chak, W. H. 2008. Correlations between gastropod shell dissolution and water

chemical properties in a tropical estuary. **Marine Environmental Research**, 66: 422–429.

Matthews, H. R., Matthews-Cascon, H. & Pinheiro, P. R. 1979. Casos anômalos em conchas de moluscos gastrópodos do Brasil. **Arquivos de Ciência do Mar**. 19: 69–80.

Medeiros, C., Caldeira, R. L., Mendonça, C. L. F., Carvalho, O. D. S. & D'ávila, S. 2015. Ontogeny and morphological variability of shell in populations of Leptinaria unilamellata (d'Orbigny, 1835) (Mollusca, Pulmonata, Subulinidae). **SpringerPlus**, 4: 191.

Meirelles, C. A. O. & Matthews-Cascon, H. 2003. Relations between shell size and radula size in marine prosobranchs (mollusca: gastropoda). **Thalassas**, 19: 45–53.

Mondal, S. & Harries, P. J. 2015. Temporal patterns in successful and unsuccessful shell-breaking predatory attack strategies on Varicorbula in the Plio-Pleistocene of Florida. **Palaeogeography, Palaeoclimatology, Palaeoecology**, 428: 31–38.

Peel, J. S. 2015. Operculum regeneration following failed predation in the Silurian gastropod Oriostoma. **Palaeontology**, 58: 229–237.

Taylor, J. D. & Layman, M. 1972. The mechanical properties of bivalve (Mollusca) shell structure. **Palaeontology**, 15: 73–87.

Ubukata, T. 2001. Nucleation and Growth of Crystals and Formation of Cellular Pattern of Prismatic Shell Microstructure in Bivalve Molluscs. **Forma**, 16: 141–154.

Zhang, Y. & Goshima, S. 2013. Effects of crushed conspecifics and starvation periods on the foraging behavior of the marine gastropod sea snail Nassarius fraterculus. **Journal of Marine Animals and Their Ecology**, 6: 20–27.

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