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A new color pattern for the ascidian-symbiontic *Lamellaria mopsicolor* (Mollusca: Caenogastropoda) in northeastern Brazil, with a discussion of its symbiotic lifestyle

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Abstract. *Lamellaria* is a marine gastropod genus of the family Velutinidae that lives on ascidian hosts, being commonly confused with sea slugs. Three species have been recorded in Brazilian waters to date: *Lamellaria patagonica*, *L. branca* and *L. mopsicolor*. The latter has been already recorded in the Brazilian Northeast but the works are poorly detailed. Thus, two new contributions the knowledge on *L. mopsicolor* are provided: (i) the first detailed record in northeastern Brazil and (ii) a new pattern of color variation, a white one, is reported. Additionally, the nature of the relationship between this gastropod and its tunicate hosts is discussed.

Keywords: Association, color variation, symbiosis, Velutinidae

Resumo. Um novo padrão de colocação para o simbionte de ascídias *Lamellaria mopsicolor* no Nordeste Brasileiro, com uma discussão sobre seu estilo de vida simbiontico. *Lamellaria* é um gênero de gastrópodes marinhos pertencentes à família Velutinidae que vivem sobre ascídias, sendo comumente confundidos com lesmas marinhas. Existem registros de três espécies na costa brasileira: *Lamellaria patagonica, L. branca* e *L. mopsicolor*. Esta última já foi registrada para o nordeste, mas os trabalhos fornecem poucos detalhes. Assim, duas novas contribuições em relação ao conhecimento da espécie *L. mopsicolor* são fornecidas: (i) o primeiro registro detalhado desta espécie para a Região Nordeste do Brasil e (ii) a adição de um novo padrão de cor (branco) para este gastrópode. Além disso, nós discutimos a natureza do relacionamento entre este lamelariídeo e seus hospedeiros tunicados.

Palavras-chave: Associação, simbiose, variação de cor, Velutinidae

Introduction

Ascidians are well-known for their extraordinary predation-deterring abilities. These benthic invertebrates are able to produce mechanical (*e.g.* tough tunics or spicules) and chemical defenses (*e.g.* low intracellular pH or high vanadium content) that discourage most generalist predators (Lambert & Lambert 1987, López-Legentil *et al.* 2006). Still, some groups have evolved in close association with ascidians, namely marine flatworms (Newman & Cannon 1996, Newman *et al.* 2000) and molluscan taxa such as Cypraeoidea Rafinesque, 1815 and Velutinidae Gray, 1840 (Fretter & Graham 1962, Millar 1971, Stoecker 1980, Cimino & Ghiselin 2001). *Lamellaria* snails (Velutinidea) are a group of sea slug-like mollusks very adapted to feeding on tunicates (Ghiselin 1964, Behrens 1980, Lambert 1980). They are characterized by a reduced internal shell that is either concealed or fully enveloped in a non-retractile mantle. The latter closely resembles the ascidians on which they live (Lambert 1980).

The genus *Lamellaria* Montagu, 1815 includes dioecious species lacking marginal teeth on the radula, and a male duct running freely in the

Lamellaria mopsicolor Marcus, 1958 (Marcus 1958, Simone 2004, Dias & Delboni 2008, Rios 2009). The first ranges strictly from southern Brazil to south Argentina and the Falkland Islands. *Lamellaria branca* occurs in southeastern Brazil (Off Ubatuba, São Paulo State) and on the Uruguayan coast at a 58 m depth. *Lamellaria mopsicolor* was described from shallow waters in the SE Brazilian coast (Marcus 1958), being subsequently recorded in the Lesser Antilles, Caribbean Sea (Marcus & Marcus 1963) and southern Brazil, specifically in the coast of Santa Catarina State (Wiggers & Magalhães 2003). In Northeast Brazil, *L. mopsicolor* was recorded in Pernambuco and Ceará States (Mello & Perrier, 1986; Miranda *et al*. 2013). Nonetheless, none of the aforementioned records were accompanied by either images or taxonomical information on the specimens. A satisfactory record of *Lamellaria* in Northeast Brazil is thus still lacking. In the present paper, we provide the first detailed record of *Lamellaria mopsicolor* Marcus, 1958 from NE Brazil, and describe a new variation in color pattern. Additionally, we discuss the symbiotic nature of the relationship between this gastropod and its ascidian host.

Materials and Methods

Samplings were carried out in February 2014 and February 2015, in two metropolitan beaches: Barra (13°00'35" S, 38°31'46" W) and Porto da Barra (13°00'13" S, 38° 31'58" W), Salvador, Bahia State, Brazil. Six specimens (three males and three females) were collected under rocks, living next to or on Dideminidae ascidians. Two brown specimens (found under rocks) were only photographed. Identification was based on external characters, shell, and radula. The material analyzed was deposited in the Gastropoda Collection of the Museu de Zoologia da Universidade Federal da Bahia (UFBA 065; UFBA 066; UFBA 067; UFBA 068).

Results

Altogether, the eight snails reported here showed five different color patterns: one black (4 mm length, male), three grayish (4 mm length, male; 5mm length, male and 10 mm length, female), one yellowish (7 mm length, female), two brown (6 and 5 mm, only photographic record) and one individual with a new color pattern for this species, a white one (5 mm length, female) (Figure 1A-G). All lamellariids found on hosts were associated with Didemnidae ascidians (Figure 1H-J) and showed a spotted dorsal surface (Figure 1A) very similar to the oral aperture pattern of the tunicate. The external characters, shell, and radula (Figure 2A-C) compare fittingly with the original description by Marcus (1958) and subsequent works on this species (Simone 2004, Dias & Delboni 2008).

Discussion

The genus *Lamellaria* currently comprises 19 species (Gofas & Bouchet 2015), three of which were recorded in Brazil: *Lamellaria patagonica, L. branca* and *L. mopsicolor*. The most notable environmental difference between these three species is of bathymetrical nature. The first two are found in deeper waters, from 16 to 75 m depths and 75 to 134 m depths, respectively (Simone 2004) and the last one inhabits shallower regions (intertidal and subtidal zones) (Simone 2004). *Lamelaria mopsicolor* has been recorded in the Lesser Antilles (Marcus & Marcus 1963), Northeast (Mello & Perrier 1986, Miranda *et al.* 2013) and south-southeastern Brazil (Marcus 1958, Marcus & Marcus 1963, Wiggers & Magalhães 2003). Nevertheless, the work of Simone (2004) limits *L. mopsicolor*'s distribution to "SE coast of Brazil", not discussing either the Caribbean or southern and northeastern Brazilian records. Faunal studies on Northeast Brazil's *Lamellaria* did not provide taxonomical data, and apparently no specimens were deposited in institutional collections (Mello & Perrier 1986, Miranda *et al.* 2013), which hinders future analyses. In addition to filling a gap in the distribution of *L. mopsicolor*, our data provide the first detailed study dealing with northeastern Brazilian specimens. Nonetheless, it highlights the lack of knowledge on the genus *Lamellaria* in the region, as is the case in other gastropods (Sales *et al.* 2011, 2013, Queiroz *et al.* 2011, 2013, Padula *et al*. 2012, Galvão Filho *et al.* 2015).

Taxonomical characters of the studied specimens are consistent with the original description of *L. mopsicolor* (Marcus 1958: Figures 1 and 2). Marcus (1958) described *L. mopsicolor* as having a brown color pattern. Posteriorly, Dias and Delboni (2008) reported the color polymorphism adding to three patterns: yellow, gray and black. Our specimens show all the preceding patterns and a previously unreported white coloration (Figure 1E and I). Some authors have pointed that color variation seems to be a common fact among lamelariids (Behrens 1980, Behrens 1984). Dias and Delboni (2008) raised the hypothesis that ascidian pigment could be incorporated during feeding

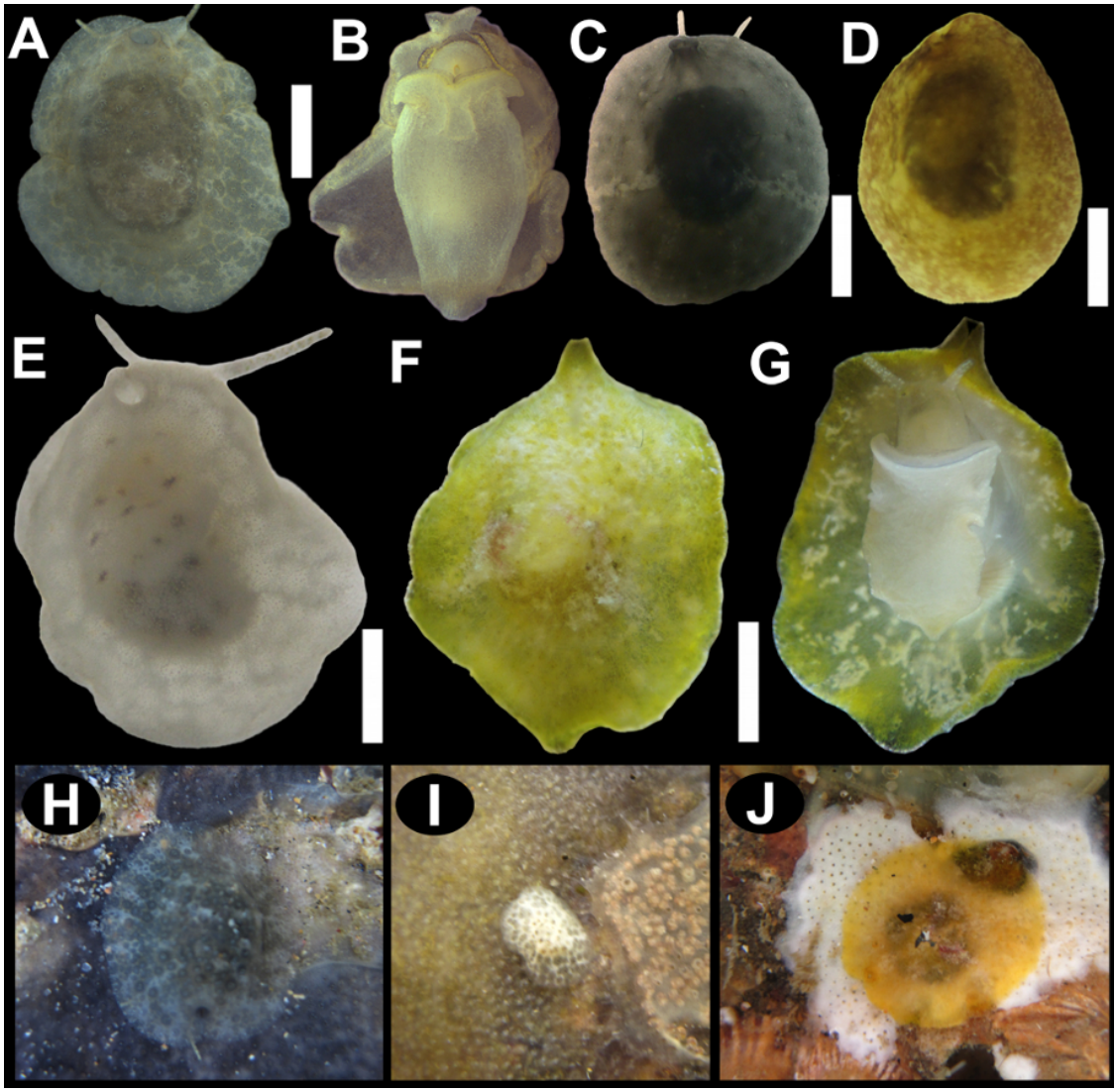

Figure 1 – Color polymorphism of *Lamellaria mopsicolor* (A-G) and its association with Didemnidae ascidians (H-I). (A and C-F) Dorsal view, (B and G) Ventral view. (A, B and H) Grey color; (C) Black color; (D) Brown color; (E and I) White color; (F, G and J) Yellow color. Scale: A-C = 3 mm; D, F and G = 2 mm; E = 1.5 mm.

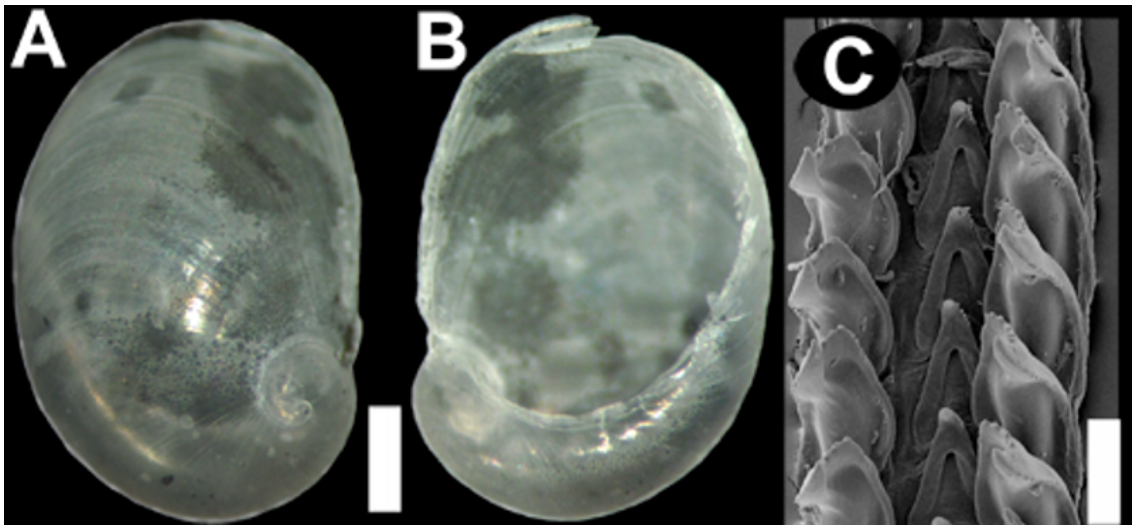

Figure 2 – Shell and radula of *Lamellaria mopsicolor*. (A) Shell - Dorsal view, (B) Shell - Ventral view; (C) Radula; Scale: A-B = 1.5 mm; C = 100 µm.

by *L. mopsicolor*, resulting in color polymorphism. This assertion seems quite appropriate, as we found associated specimens whose color patterns were similar to their hosts in the field (Figure 1H and I). The only associated specimen that did not present such a pattern was the yellow *L. mopsicolor* collected on a white ascidian (Figure 1J). Even so, despite its contrasting color, it did present white spots (Figure 1F and G). If color polymorphism of this species is indeed associated with the host's pigmentation, it is possible that this individual had recently changed its ascidian host.

Species of *Lamellaria* Montagu, 1815 have been historically treated as predators of ascidian species (Herdman 1893, Fretter & Graham 1962, Ghiselin 1964, Lambert 1980). However, it is possible that this relationship could be, in reality, a kind of symbiosis *sensu lato* (Paracer & Ahmadjian 2000, Schmidt & Roberts 2009, Martin & Schawb 2013). Here, we consider the term symbiosis as originally intended by its creator, Anton de Bary (1879), and also adopted by Paracer and Ahmadjian (2000), *i.e*., simply "different organisms living together". If lamelariids are to be understood as symbiotic (*sensu lato*) snails, two main points must be considered: cryptic coloration and host-dependent development. Symbiotic organisms tend to develop complex cryptic coloration, mimicking the host's color pattern and/or texture and this has been recorded in many invertebrates such as annelids (Santa-Isabel *et al.* 1996, Britayev & Fauchald 2005), crustaceans (Marin *et al.* 2005, Ayyagari & Kondamudi 2014) and mollusks (Yamamoto 1973, Goud & Hoeksema 2001). This characteristic was also observed in *Marsenina stearnsii* (Dall, 1871) and *L. diegoensis* Dall, 1885 (Ghiselin 1964, Lambert 1980, Behrens 1984). Individuals of *L. mopsicolor* seem to follow the same pattern, with color and texture matching those of their hosts (Figure 1H and I).

Regarding developmental aspects, Harris (1971) pointed out that one of the characteristics of a symbiotic organism is that its settlement depends on the presence of a host, as is the case in some nudibranchs (Thompson 1958, 1962, Tardy 1962). Although knowledge on *L. mopsicolor* development is restricted to the initial phase (*e.g.*, egg capsules and intracapsular development - Dias & Delboni 2008), it seems that *Lamellaria* species need a host at least to lay their eggs (Fioroni & Meister 1976, Dias & Delboni 2008). This fact seems to be widespread in the family, as it has already been observed in other genera/species such as *Velutina velutina* (O. F. Müller, 1776) and *M. stearnsii* (Diehl 1956, Page 2002). Even though there is no information on the settlement *of L. mopsicolor*, the necessity of a host to settle was recorded in a close species, *M. stearnsii* (Page 2002).

Albeit Dias and Delboni (2008) pointed out *L. mopsicolor* as parasitic snail, we discourage the utilization of the term "parasite" for the time being for the reasons mentioned below. Even considering a less complex definition of parasitism (*i.e.* a kind of symbiosis in which one of the involved benefits at the expense of the other) (Paracer & Ahmadjian 2000, Rohde 2005), there are no experimental works evaluating possible negative impacts of *L. mopsicolor* on ascidians hosts. Furthermore, professedly parasite gastropods tend to lose their radula throughout their evolutionary history (Fretter & Grahan 1949, Kantor 1995, Simone & Martins 1995). They generally tend to have a well-developed proboscis and a greatly simplified digestive system, as is the case in the families Coralliophilidae, Eulimidae and Pyramidelidae (Fretter & Grahan 1949, Kantor 1995, Simone & Martins 1995). In contrast, *L. mopsicolor* has a somewhat complex radula for an allegedly parasitic snail (Figure 2C), as well as a short proboscis and an intricate digestive system (Marcus 1958, Simone 2004). Consequently, in cases such as this, where there are many evidences favoring the idea of a symbiotic (*sensu lato*) lifestyle and experimental studies on the real nature of the interaction are non-existent, we suggest the usage of the term symbiosis, as originally proposed by Anton de Bary (1879), meaning a broad category including some associations (*e.g.* Commensalism, Mutualism and Parasitism) (Paracer & Ahmadjian 2000, Rohde 2005). With the lack of studies addressing negative impacts on the hosts of *L. mopsicolor*, confirming it as a parasitic gastropod seems implausible. Until further information on the real nature of the association comes to light, we encourage usage of the term symbiosis (*sensu lato*).

According to what was previously exposed, we report the first thorough record of *L. mopsicolor* from northeastern Brazilian waters, specifically from Bahia State, providing detailed taxonomical information and filling a gap in its distribution. Furthermore, new information on color variation is presented. Additionally, until experimental data becomes available, we recognize this gastropod as symbiotic (*sensu lato*) to ascidians rather than a parasite. As it was intended by Anton de Bary and also suggested by Martin and Schawb (2013), we believe that the use of this term, meaning a broader

category, should be encouraged in such situations.

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