

New records of rhodolith-forming species (Corallinales, Rhodophyta) from deep water in Espírito Santo State, Brazil

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Abstract Little is known about the diversity of non-geniculate coralline red algae (Rhodophyta, Corallinophycidae) from deep waters in Brazil. Most surveys undertaken in this country have been carried out in shallow waters. In 1994, however, the REVIZEE program surveyed the sustainable living resources potential of the Brazilian exclusive economic zone to depths of 500 m. In the present study, the rhodolith-forming coralline algae from the continental shelf of Espírito Santo State were identified. Samples were taken from 54 to 60 m depth by dredging during ship cruises in 1997. Three rhodolith-forming species were found: *Spongites yendoi* (Foslie) Chamberlain, *Lithothamnion muelleri* Lenormand ex Rosanoff and *Lithothamnion glaciale* Kjellman. These records extend the distribution ranges of these species into Brazilian waters and extend the depth distribution of non-geniculate coralline red algae into Brazilian water to 58 m.

Keywords Corallinales · Taxonomy · *Spongites* · *Lithothamnion* · Brazil

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Introduction

“Rhodolith” is the name given to free-living structures composed mostly (>50%) of non-geniculate coralline red algae (Rhodophyta, Corallinophycidae). The communities they denominate are called “rhodolith beds” (Foster 2001; Harvey and Woelkerling 2007). However, there is no consensus on use of the terms (Foster 2001). In this study, we follow Foster (2001) and Harvey and Woelkerling (2007).

The deepest known alga is a rhodolith-forming coralline red algal species discovered on an uncharted seamount at 268 m depth in the Bahamas (Littler et al. 1985). Little is known about the diversity of non-geniculate coralline red algae from Brazil deep water (Amado-Filho et al. 2007; Villas-Boas et al. 2009) in general and of rhodolith-forming species in particular. The Brazilian continental shelf contains extensive rhodolith beds from 20 to 100 m depth (Kempf et al. 1969; Kempf 1980; Amado-Filho et al. 2007) distributed from 3° to 22° S and is considered the largest area supporting rhodolith beds in the world (Foster 2001).

The continental shelf of Espírito Santo State is considered to be the region with highest marine algal species richness in Brazil (Amado-Filho et al. 2007) and is a transitional area from tropical to temperate floras (Guimarães 2003). Despite the urgent need to understand and preserve the marine biodiversity within rhodolith beds, which are a critical habitat for conservation, shallow rhodolith beds from Espírito Santo State have only recently been studied (Amado-Filho et al. 2007, 2010; Villas-Boas et al. 2009). Five rhodolith-forming genera (*Lithothamnion*, *Lithophyllum*, *Hydrolithon*, *Neogoniolithon* and *Sporolithon*) were reported from the region (Amado-Filho et al. 2007). Villas-Boas et al. (2009) report three rhodolith-forming species from the genus *Lithophyllum* [*L. corallinae* (Crouan and

Crouan) Heydrich, *L. johanseni* Woelkerling and Campbell, *L. stictaeforme* (Areschoung in J. Agardh) Hauck], already known to science, and one rhodolith-forming species (*L. depressum* Villas-Boas, Figueiredo et Riosmena-Rodriguez) new to science. Besides these, two other species were reported from the region (*Lithothamnion muelleri* Lenormand ex Rosanoff and *Mesophyllum engelhartii* (Foslie) Adey) (Amado-Filho et al. 2010).

A major survey evaluating the sustainable potential of living resources of the Brazilian Exclusive Economic Zone (REVIZEE program) was carried out in 1997. Its aim was to address potential fisheries resources and to identify the main benthic taxonomic groups on the outer shelf and continental slope from 50 to 500 m depth. Today, the REVIZEE program is the most widespread marine project carried out on the Brazilian coast generating biological, geological, physical and chemical data (Lavrado 2006). Rhodolith beds were recorded during fieldwork, but coralline algal species composition was not investigated. The material has been stored for later study (Yoneshigue-Valentin et al. 2006). Thus, Brazilian deep-water marine ecosystems still remain poorly described.

The current study aims to contribute to the knowledge of coralline red algae in Espírito Santo state, Brazil. The study reports previously unrecorded rhodolith-forming species in Brazilian deep water, discussing the implications of these new records for rhodolith diversity in Brazil.

Materials and methods

Field work

Rhodolith samples were collected during field trips conducted from October to November of 1997 by the REVIZEE program (Lavrado 2006). The material was collected offshore along the Espírito Santo State continental shelf at three studies sites: 34R (20°45'00"S–40°10'00"W); 28R (19°49'00"S–37°56'00"W); and 29R (19°48'01"S–37°46'22"W). Depths ranged from 55 to 58 m depth (see Yoneshigue-Valentin et al. 2006 for site descriptions). The region is influenced by the Brazilian current that runs along the South Atlantic Ocean and is characterized by sea surface temperatures ranging from 21 to 27°C (Lavrado 2006). At 50 m depth, the region is influenced by the South Atlantic Central Waters (SACW) and is characterized by temperatures from 6 to 20°C (Silveira et al. 2000).

Laboratory work

Since 1997, the samples had been preserved in 4% formalin seawater (Yoneshigue-Valentin et al. 2006). As a consequence of this long preservation time, specimens were

degraded, and it was difficult finding intact reproductive structures. The material was exhaustively sectioned, but in one case (Fig. 1d), we could not find a representative reproductive structure. Histological techniques for optical microscopy follow Moura et al. (1997). Microslides were prepared, and identification of material to species level followed descriptions of Chamberlain (1993), Chamberlain and Irvine (1994), and Wilks and Woelkerling (1995). Type specimens were not examined. Identified samples were incorporated in the herbarium collection of the Botanical Garden of Rio de Janeiro (RB). The herbarium code follows the *Index Herbariorum* (Holmgren and Holmgren 2011, continuously updated). Conceptacle measurements follow Adey and Adey (1973), thallus anatomical terminology follows Woelkerling (1988), growth form terminology follows Woelkerling et al. (1993) and typification data follow Woelkerling (1993).

Results

Taxonomic accounts

Three species were identified: *Spongites yendoi* (Foslie) Chamberlain (Fig. 1); *Lithothamnion muelleri* Lenormand ex Rosanoff (Figs. 2, 3); and *Lithothamnion glaciale* Kjellman (Figs. 4, 5).

Spongites yendoi (Foslie) Chamberlain, 1993: 102 (Fig. 1)

Basionym: *Goniolothon yendoi* Foslie, 1900a: 25

Further references: Penrose (1996)

Synonyms: See Chamberlain (1993)

Lectotype: TRH (Yendo no. 66) Foslie (1904)

Type locality: Shimoda Harbour, Izul, Japan, K. Yendo, April 1899

Description: Plants non-geniculate, thallus-forming free-living rhodoliths with warty growth form (Fig. 1a) consisting of several layers of plants overgrowing one another. *Spongites yendoi* compose the most external layer. Cylindrical protuberances measuring 1–2 mm in height and 1 mm in diameter. Thallus pseudoparenchymatous with dorsiventral internal organization in encrusting portions and radial internal organization in protuberances. Monomerous thallus construction in encrusting portions (Fig. 1b) consisting of a single system of branched filaments that form a core running more or less parallel to the substratum and a more peripheral region in which portions of core filaments or their derivatives curve outwards toward the thallus surface terminating in one layer of flattened epithallial cells (Fig. 1c). The core region is plumose

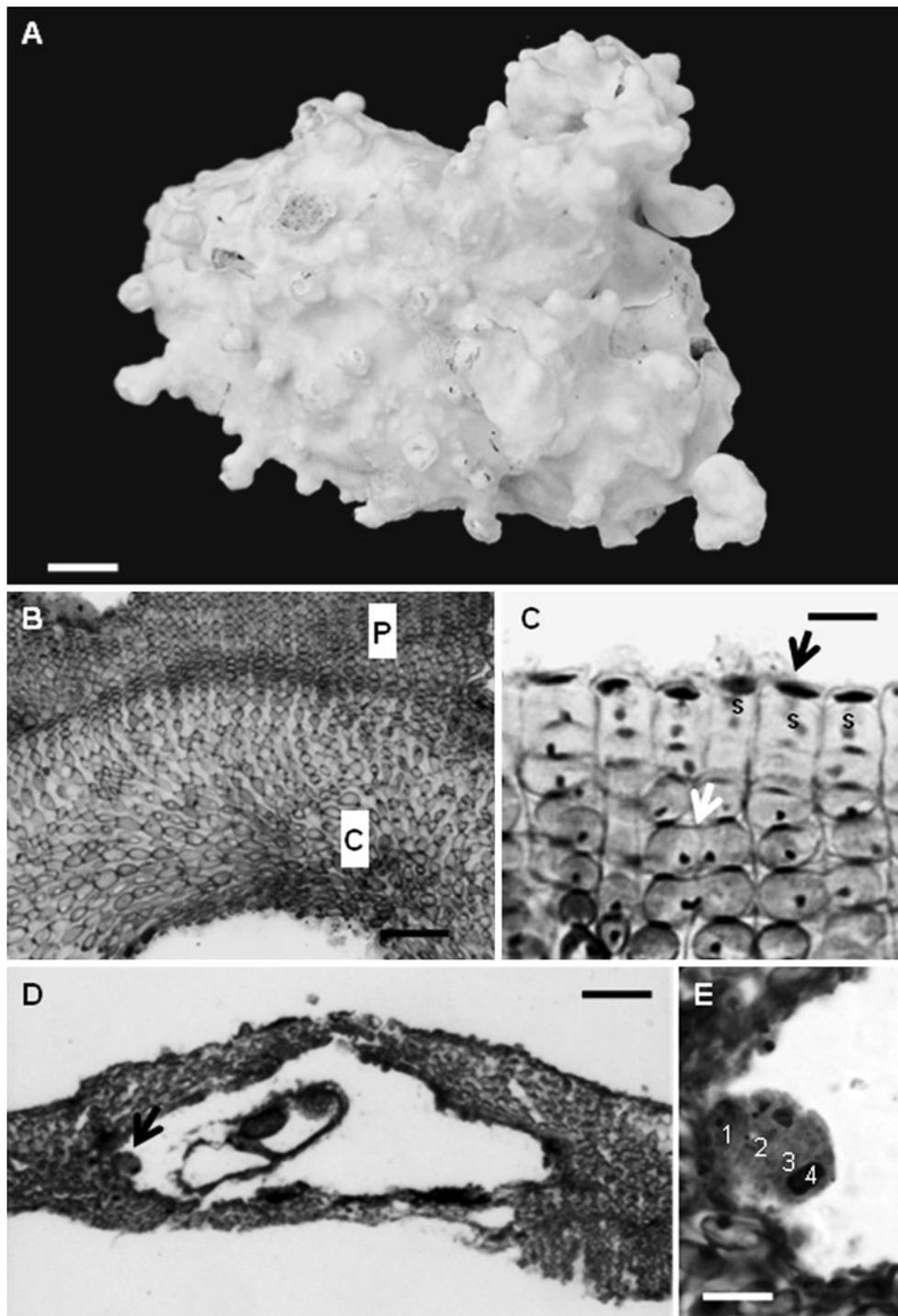


Fig. 1 *Spongites yendoi*. **a** Morphology of a rhodolith with warty growth form. *Scale bar* 2.5 mm. (RB 458711). **b** Longitudinal section showing the internal monomerous thallus construction. *P* peripheral region and *C* core region. *Scale bar* 52 μm . (RB 458711). **c** Longitudinal section of the outer perithallium showing the flattened, but rounded epithelial cells (*black arrow*) and cell fusions between cells of adjacent peripheral filaments (*white arrow*), *S* = subepithallial

initials cells. *Scale bar* 10.5 μm . (RB 458711). **d** Longitudinal section through a uniporate tetrasporangial conceptacle with roof protruding above the surrounding thallus surface. Note the tetrasporangium (*arrow*). *Scale bar* 45.7 μm . (RB 458711). **e** Longitudinal section showing a tetrasporangium in detail. Numbers 1–4 indicate the four spores in tetrasporangium. *Scale bar* 9 μm . (RB 458711)

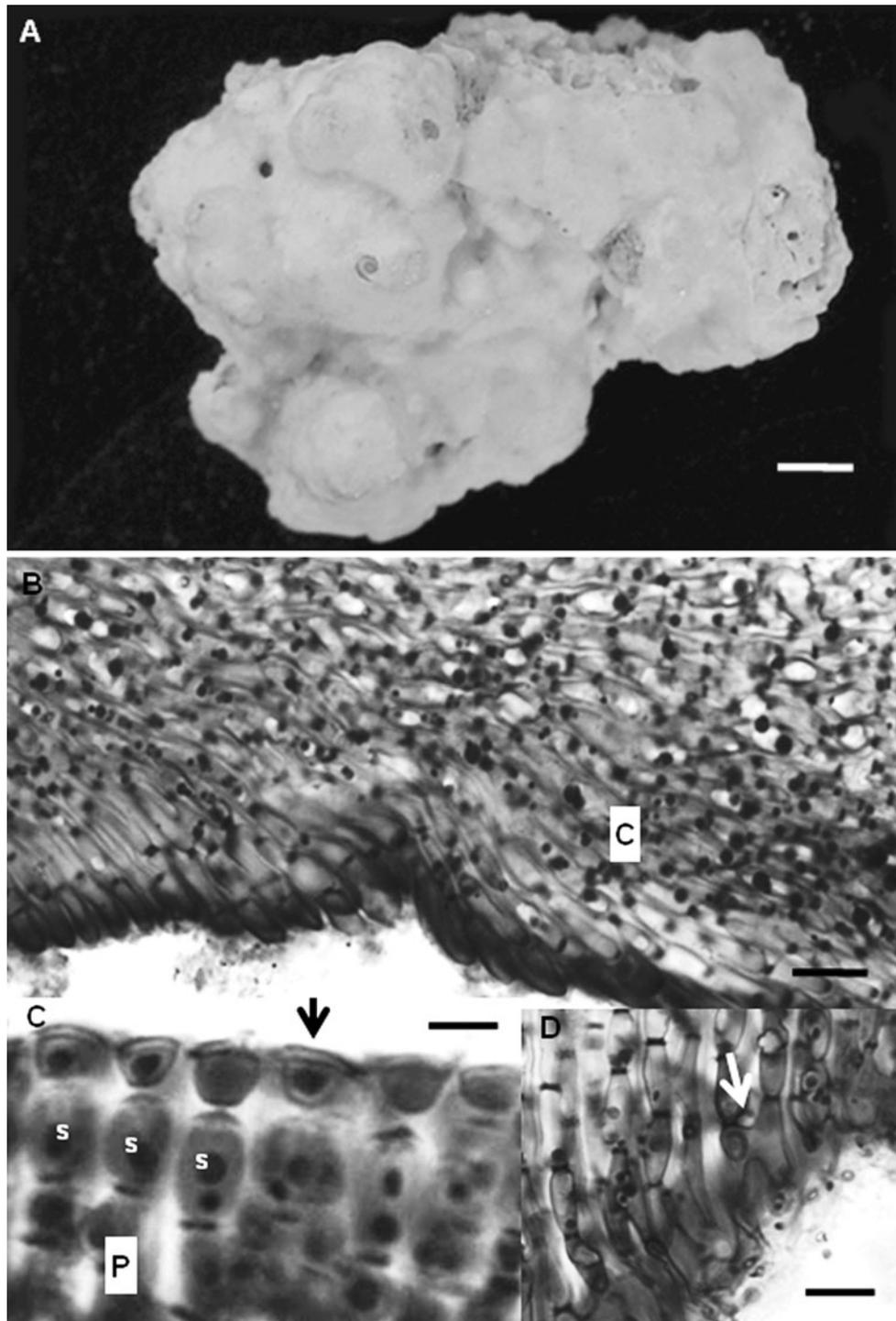


Fig. 2 *Lithothamnion muelleri*. **a** Morphology of a rhodolith with a warty growth form. Scale bar 4.5 mm (RB458708). **b** Longitudinal section showing the internal monomerous thallus construction. **c** Longitudinal section of the outer perithallium showing flared epithallial cells (arrow). Scale bar 16 µm (RB458708). **c** Longitudinal section of the outer perithallium showing flared epithallial cells (arrow). Scale bar 5 µm (RB458708).

d Longitudinal section showing perithallial filaments with cell fusions between cells of adjacent filaments (arrow). Scale bar 10 µm (RB458708). **P** peripheral region, **S** subepithallial initials cells, scale bar 5 µm (RB458708).

(non-coaxial), comprises most of the thallus thickness and is composed mainly of rectangular cells measuring 10–19 µm in length and 3–7 µm in diameter. Cells of the peripheral

region are squarish and measure 4–8 µm in length and 6–10 µm in diameter. Epithallial cells measure 2–3 µm in length and 6–8 µm in diameter, and subepithallial initials

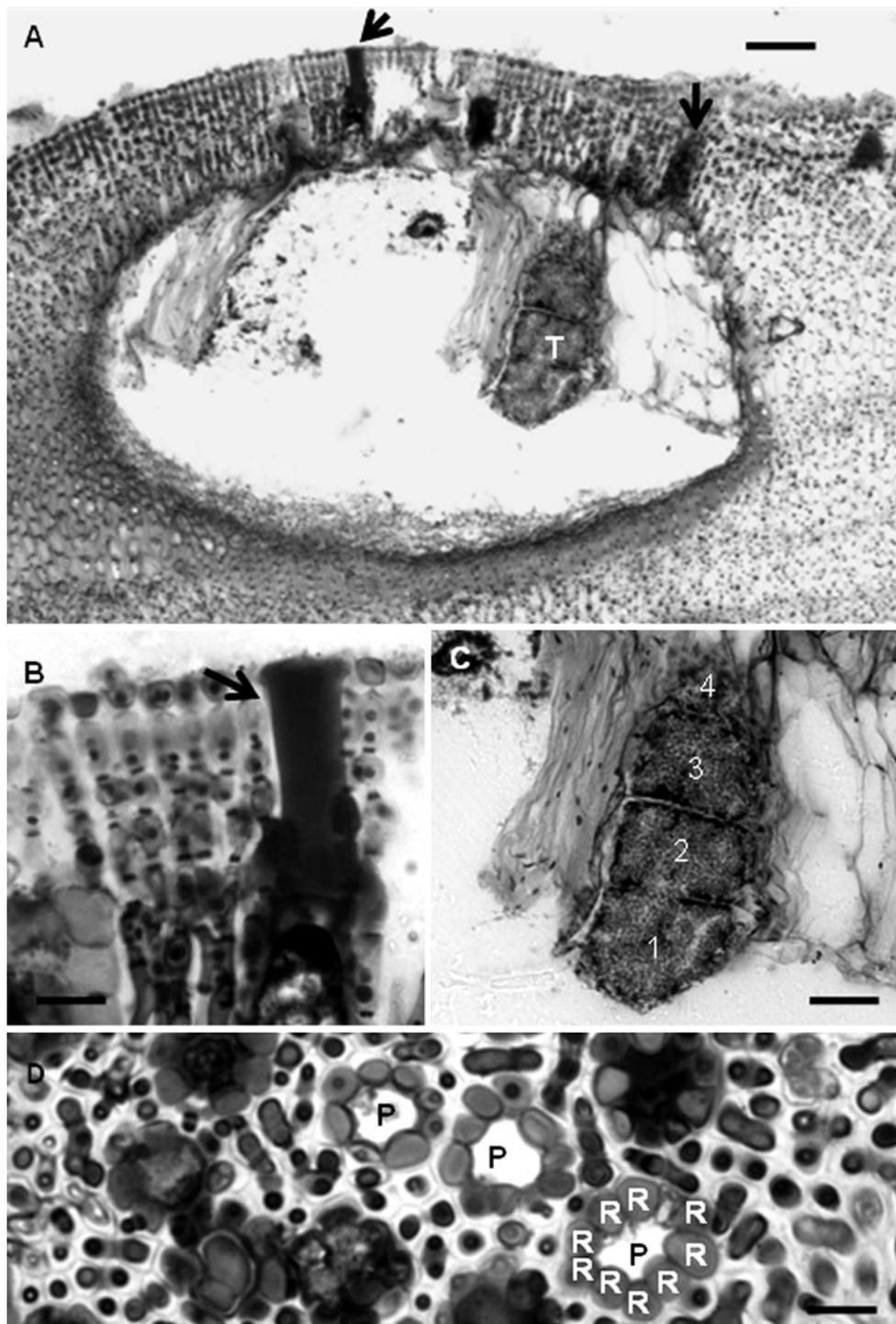


Fig. 3 Longitudinal section of *Lithothamnion muelleri*. **a** Multiporate tetrasporangial conceptacle. Note staining pore plugs (arrows), *T* Tetraspore. *Scale bar* 50 μm (RB458708). **b** Multiporate tetrasporangial conceptacle roof showing a densely staining pore plug (arrow). *Scale bar* 11 μm (RB458708). **c** Tetrasporangium in detail.

Numbers 1–4 indicate the four spores in tetrasporangium. *Scale bar* 28 μm (RB458708). **d** Surface view of the pore plate of a tetrasporangial conceptacle showing pores (P) surrounded by rosette cells (R). *Scale bar* 9.5 μm (RB458708)

cells measure 3–5 μm in length and 6–8 μm in diameter (Fig. 1c). Cells of adjacent filaments are linked by lateral cell fusions (Fig. 1c); trichocytes have not been observed.

Tetrasporangial conceptacles uniporate with the roof more or less raised above the surrounding thallus surface (Fig. 1d). Conceptacle roofs 3–8 cells thick including the

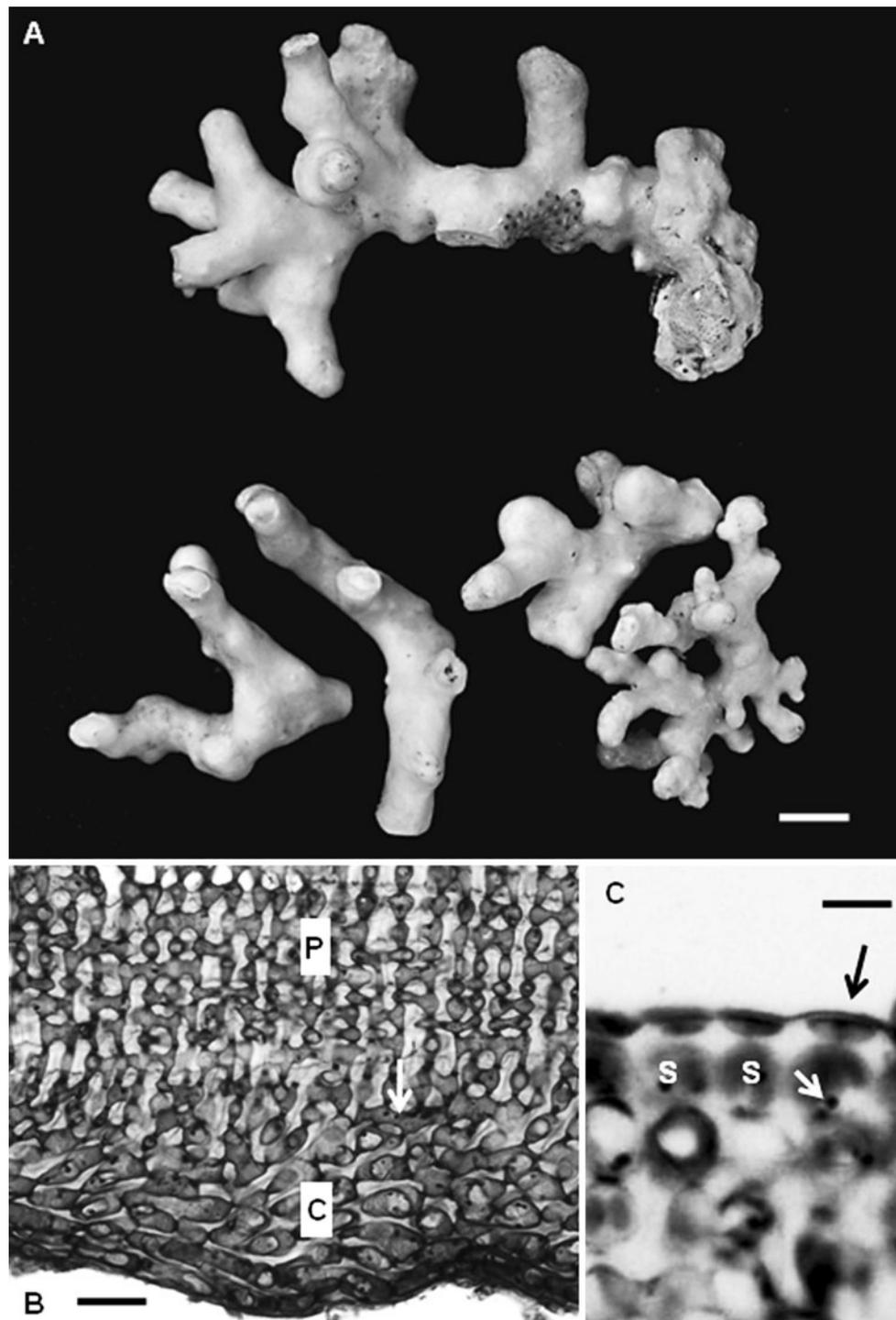


Fig. 4 *Lithothamnion glaciale*. **a** Morphology of a rhodolith with terete fructicose growth form. Scale bar 5.5 mm (RB 458706). **b** Longitudinal section showing the monomerous internal thallus construction and cell fusions. *P* peripheral region and *C* core region.

Scale bar 23 μ m (RB 458706). **c** Longitudinal section of the outer perithallium showing flared epithallial cells (black arrow) and small bodies near the primary pit connections (white arrow), *S* subepithallial initials cells. Scale bar 8.5 μ m (RB 458706)

epithallial cells, pore without an apical plug. Conceptacle chambers 280–290 μ m in diameter and 105–110 μ m in height, usually without a central columella and with

chamber floors, located 13–15 cell layers below the thallus surface. Tetrasporangia (Fig. 1e) measure 13–15 μ m in diameter and 17–20 μ m in length.

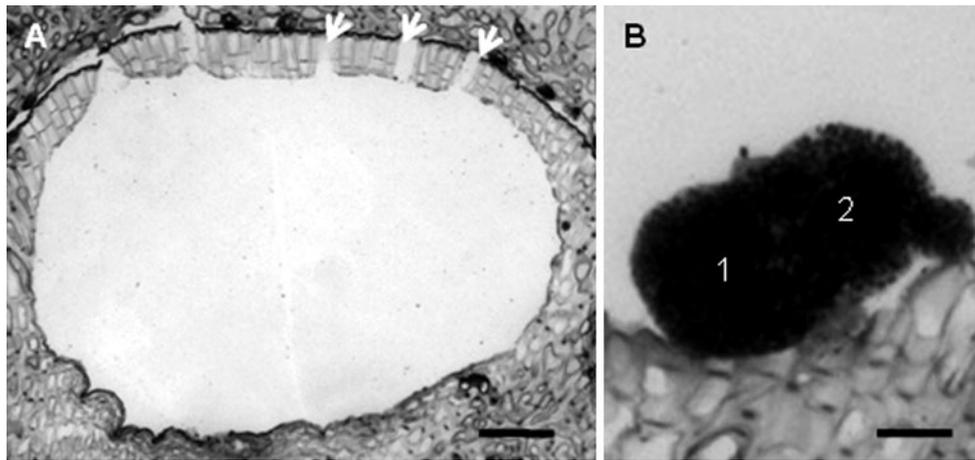


Fig. 5 Longitudinal section of *Lithothamnion glaciale*. **a** Bisporangial multiporate conceptacle. Note the pore plate (arrows). Scale bar 57 μ m (RB 458706). **b** Bisporangium in detail. Numbers 1 and 2 indicate the two spores in bisporangium. Scale bar 12 μ m (RB 458706)

Material examined: Ibiracu, Espírito Santo, Brazil, 19°49'00"S, 37°56'00"W (54 m depth, 31.x.1997, RB 458711); Alegre, Espírito Santo, Brazil, 20°45'00"S, 40°10'00"W (55 m depth, 03.xi.1997, RB 458712).

Comments: Most characters (Table 1) observed in the examined specimens agree with descriptions of *S. yendoi* from southern Australia (Penrose 1996) and South Africa (Chamberlain 1993). *Spongites yendoi* is a cosmopolitan species, occurring in tropical, temperate and polar regions (Chamberlain 1993; Penrose 1996). It has been reported for shallow areas of southern Namibia, South Africa, southern Mozambique (Chamberlain 1993; Maneveldt et al. 2008), Indonesia, Japan (Chamberlain 1993), eastern Australia (Lund et al. 2000), southern Australia (Penrose 1996), New Zealand (Harvey et al. 2005; Farr et al. 2009), Mexican tropical Pacific (Fragoso and Rodríguez 2002), Mexican tropical Atlantic and the Caribbean (Mateo-Cid et al. 2007). The current record extends both the species geographic distribution along the southwestern Atlantic and its vertical distribution down to 55 m depth.

Lithothamnion muelleri Lenormand ex Rosanoff, 1866: 101, pl. 6 figs 8–11 (Figs. 2, 3)

Further references: Wilks and Woelkerling (1995); Woelkerling (1996)

Synonyms: See Wilks and Woelkerling (1995)

Lectotype: CN (herb. Lenormand); from Western Port Bay, Victoria; collected by W. H. Harvey, 1851, communicated by F. Mueller; lectotype designated by Woelkerling (1983: 193) and Wilks and Woelkerling (1995, fig. 1A).

Isolectotypes: MEL 588439; L 941.149–249 (communicated by Lenormand)

Description: Plants non-geniculate, thallus-forming free-living rhodoliths with warty growth form (Fig. 2a). Protuberances cylindrical, 1–3 mm in length and 1–3 mm in diameter. Thallus pseudoparenchymatous with dorsiventral internal organization. Monomerous thallus construction (Fig. 2b) consisting of a single system of branched filaments that forms a core running more or less parallel to the substratum and a more peripheral region in which portions of core filaments or their derivatives curve outwards toward the thallus surface. The developing filamentous core is plumose (non-coaxial) with cells of adjacent filaments not arranged in arching tiers. Cells of core filaments are rectangular measuring 7–18 μ m in length and 3–9 μ m in diameter. 16–22 layers of peripheral filaments in which cells are also rectangular measuring 12–17 μ m in length and 5–7 μ m in diameter and terminate in a single layer of flared epithallial cells (Fig. 2c) that measure 4–6 μ m in length and 5–7 μ m in diameter. Subepithallial initials cells measure 7–11 μ m in length and 4–7 μ m. Bead-like groups of fused cells (Fig. 2d). Core fusions are localized; trichocytes have not been observed.

Tetrasporangial conceptacles multiporate with roofs slightly raised above the surrounding thallus surface, 7–9 cells thick including the epithallial cell (Fig. 3a); apical pore channels with plugs (Fig. 3b). Conceptacle chambers 375–755 μ m in diameter and 200–320 μ m in height, usually without a central columella; tetrasporangia scattered across the chamber floor. Mature tetrasporangia long, measuring 145–147 μ m in length and 57–59 μ m in diameter, containing four zonately arranged tetraspores (Fig. 3c). Pore channels surrounded by 8–10 rosette cells in surface view (Fig. 3d).

Material examined: Itaguaçu, Espírito Santo, Brazil, 19°48'01"S, 37°46'22"W (58 m depth, 16.xi.1997, RB

Table 1 Comparison of characters of *Spongites yendoi* from Espírito Santo state (Brazil) and other regions of the world

	Brazil ^a	Mexico/Caribbean ^b	South Africa ^{c,d}	Australia ^e
Growth form	Encrusting to warty	Encrusting	Encrusting to warty	Encrusting to lumpy
Thallus construction	Monomerous	Monomerous	Monomerous	Monomerous/dimerous
Arrangement of trichocytes	Not present	Mostly solitary	Solitary	ND
Cell number in tetrasporangial conceptacle chamber roof	3–8	ND	4–7 ^f	3–5
Tetrasporangial conceptacle chamber height	105–110 µm	80–150 µm	62–117 µm ^a 109–185 µm ^b	109–185 µm
Tetrasporangial conceptacle chamber diameter	280–290 µm	180–295 µm	147–207 µm ^a 164–232 µm ^b	164–232 µm

ND no data

^a Present study

^b Mateo-Cid et al. (2007)

^c Chamberlain (1993)

^d Penrose (1991)

^e Penrose (1996)

^f data taken from Chamberlain (1993), figure 6

458708); Ibiracu, Espírito Santo, Brazil, 19°49'00"S, 37°56'00"W (54 m depth, 31.x.1997, RB 458709); Alegre, Espírito Santo, Brazil 20°45'00"S, 40°10'00"W (55 m depth, 03.xi.1997, RB 458710).

Comments: Most characters (Table 2) observed in the examined specimens agree with descriptions of the same species from southern Australia (Wilks and Woelkerling 1995; Woelkerling 1996). According to Wilks and Woelkerling (1995), *Lithothamnion muelleri* occurs from Albany, (Western Australia) eastwards to Corner Inlet (Victoria) and in Bruny Island (Tasmania, southern Australia). The records from Tierra del Fuego require confirmation based on modern collections (Wilks and Woelkerling 1995). According to Yabur-Pacheco and Riosmena-Rodríguez (2006), there are also records in the southwestern Gulf of California, Mexico and other areas of the eastern Pacific (Riosmena-Rodríguez, unpublished data), but there is no description for the species for these areas yet. There are also records of this species in Chile (Ramírez and Santelices 1991) and in the French Antarctic, near South America (Joubin 1913). In Australia, it is abundant in shallow (Wilks and Woelkerling 1995; Woelkerling 1996) and deep waters down to 85 m (Woelkerling 1996). In the Gulf of California, it was found between 2 and 20 m with greater abundance in shallow waters (Yabur-Pacheco and Riosmena-Rodríguez 2006). The present record extends the species vertical distribution in Brazilian waters down to 58 m depth and confirms its affinity with cold waters.

Lithothamnion glaciale Kjellman, 1883: 123 pl. 2, 3. (Figs. 4, 5).

Further references: Adey (1970a); Adey and Adey (1973); Chamberlain and Irvine (1994)

Synonyms: See Chamberlain and Irvine (1994)

Lectotype: UPS, Kjellman specimen 241 (Chamberlain and Irvine 1994: 183). The provisional typification of Adey (1970a: 228) is not in accord with the ICBN Art. 7.11 and thus cannot be accepted. The designation by Chamberlain and Irvine (1994: 183) is, however, in accord with Art. 7.11, even though reference is made to the provisional typification of Adey (1970a). Chamberlain and Irvine (1994: 183) explicitly stated though that they had not seen and thus examined the lectotype (Woelkerling et al. 2005).

Description: Plants non-geniculate, thallus-forming free-living rhodoliths with fruticose growth form (Fig. 4a). Protuberances are generally terete and measure 4–10 mm in length and 2–4 mm in diameter. Thallus pseudoparenchymatous with dorsiventral internal organization in encrusting portions and radial internal organization in protuberances. Monomerous thallus construction in encrusting portions (Fig. 4b) consisting of a single system of branched filaments that form a core running more or less parallel to the substratum and a more peripheral region in which portions of core filaments or their derivatives curve outwards toward the thallus surface. The developing filamentous core is plumose (non-coaxial) with cells of adjacent filaments not arranged in arching tiers. Cells of adjacent filaments linked by lateral cell fusions (Fig. 4b), generally presenting small bodies near the primary pit connections as described in Adey (1970a) (Fig. 4c). Peripheral filaments terminating in a single layer

Table 2 Comparison of characters of *Lithothamnion muelleri* and *L. glaciale* from Espírito Santo state (Brazil) and with the same and related species from other areas

	<i>Lithothamnion muelleri</i>		<i>Lithothamnion corallitoides</i>		<i>Lithothamnion glaciale</i>		
	Brazil ^a	Southern Australia ^b	British Isles ^c	Ria de Vigo ^d	Ría de Arousa ^e	British Isles ^f	Brazil ^a
Branch diameter	1–3 mm	1–4 mm	Mainly <1 mm	ND	<1.5–1.7 mm	>1 mm	2–4 mm
Core cells (l) × (d) μm	(7–18) × (3–9)	(2–30) × (2–15)	Fusiform (5–35) × (5–10)	ND	Fusiform (5–10) × (5–10)	ND	Elliptical (10–20) × (7–11)
Core fusions	Localized	ND	Very extensive	Very extensive	Very extensive	ND	Localized
Groups of fused cells	Bead-like	ND	Star-like	ND	ND	ND	Bead-like
Peripheral cells (l) × (d) μm	(12–17) × (5–7)	ND	(10–30) × (5–12)	ND	ND	(7.5–26) × (15–50)	(12–21) × (7–13)
Tetra/bisporangia conceptacle shape	Slightly raised above	Protruding above or flush	Without rim, pore plate convex	Protruding above	ND	Slightly raised	Buried, non-raised rim, pore plate level
Diam. of tetra/bisporangial conceptacle chamber (μm)	375–755	280–780	234–380	200–400	ND	150–360	300–430
Height of tetra/bisporangial conceptacle chamber	200–320	150–200	83–117	108	ND	110–180	160–280
Roof thickness (no. of cells/length) (μm)	7–9/66–80	5–9	ND/29–39	ND/27–31	ND	ND/5–40	3–4/25–35
No. of layers surrounding conceptacles below thallus surface	7–9	5–9	10 ^g	9–11 ^h	ND	ND	13–14
Tetra/bisporangial shape	Long	Long	Long and thin	ND	Long	ND	Elliptical

ND no data

^a Present study

^b Woelkerling (1996)

^c Chamberlain and Irvine (1994)

^d Adey and McKibbin (1970)

^e Peña and Bárbara (2004)

^f Adey and Adey (1973)

^g Data taken from Chamberlain and Irvine (1994), figure 85A

^h Data taken from Adey and McKibbin (1970), figure 5

ⁱ Data taken from Chamberlain and Irvine (1994), figure 87B

of flared epithallial cells (Fig. 4c) that measure 4–7 μm in length and 9–12 μm in diameter. Subepithallial cells rounded measuring 21–22 μm in length and 10–12 μm in diameter. Core cells are elliptical in shape measuring 10–20 μm in length and 7–11 μm in diameter. Bead-like cell fusions between core filaments are restricted to certain random areas of the thallus. Cells of the peripheral filaments are generally rectangular measuring 12–21 μm in length and 7–13 μm in diameter. Trichocytes have not been observed.

Bisporangial conceptacles multiporate buried within the thallus with non-raised rim and pore plate level (Fig. 5a) with conceptacle roofs 3–4 cells including the epithallial cell (Fig. 5b). Conceptacle chambers 300–430 μm in diameter and 160–280 μm in height with the chamber floor located 13–14 cell layers below the surrounding thallus surface. Bispores elliptical measuring 30–32 μm in diameter and 49–51 μm in height and (Fig. 5c).

Material examined: Ibiracu, Espírito Santo, Brazil, 19°49'00"S, 37°56'00" (54 m depth, 31.x.1997, RB 458706); Alegre, Espírito Santo, Brazil, 20°45'00"S, 40°10'00"W (55 m depth, 03.xi.1997, RB 458707).

Comments: Most characters (Table 2) observed in the examined specimens agree with descriptions of the same species from the British Isles (Adey and Adey 1973; Chamberlain and Irvine 1994) and the Arctic seas (Kjellman 1883). *Lithothamnion glaciale* has previously been recorded only from temperate waters of the North Atlantic Ocean. There are deep-water records down to 34 m depth (Chamberlain and Irvine 1994) and 40 m (Adey and Adey 1973) throughout the northern British Isles, south to northern Devon (Lundy) and Yorkshire, in Ireland, Arctic Russia to British Isles, Iceland, Faroes, western Baltic Arctic Canada to USA, Greenland, Japan and China (Chamberlain and Irvine 1994). Adey (1966, as *Lithothamnium* "a") showed that it formed 38.4% of total coralline cover from low tide level down to 17 m in the Gulf of Maine, and Adey et al. (1976) recorded this species as one of the principal deep-water crustose Corallines of Japan occurring over 60 m. The species has also been found in Quebec, Canada by dredging in a non-specific depth (Cardinal et al. 1979) and in up to 15 m depth at the northeastern coast of the United States (Adey 1970a). It is also recorded from the Arctic Sea (Kjellman 1883) except in the Siberian and Kara Sea. The current study is the first reporting of the species for the southern Atlantic Ocean. Records from Hamel and Lemoine (1953) from France are unconfirmed (Chamberlain and Irvine 1994).

Discussion

Spongites yendoi has a variable external morphology; especially, the degree of wartiness and whether adjacent

thallus margins are flush with or overgrown by each other may vary considerably. Herbivore grazing commonly affects the physiognomy of *S. yendoi* (Maneveltdt and Keats 2008). The shape of tetra/bisporangial conceptacles is raised, flush with, or sunken below the thallus surface. The character that is regarded as being noticeably consistent is the peripheral structure, which comprises most of the thallus thickness and is composed mainly of small, squarish cells. The core region is considered to be relatively thin and composed of elongate cells (Chamberlain 1993). Variations, particularly in external morphology, are directly attributed to habitat influences (Maneveltdt and Keats 2008). A wide range of variation in conceptacle size and degree of prominence is seen (Chamberlain 1993; Maneveltdt and Keats 2008). Normally, *S. yendoi* produces a lumpy or protuberant crust, but plants may also become smooth when they are grazed. Populations of *S. yendoi* in the north of Richards Bay (South Africa), the northern limit of the geographic extent of *S. cochlear* along the East Coast, are sparse, patchy, thick and protuberant. Because grazing reduces the number of protuberances, there is in general less surface area for conceptacle production. Furthermore, grazing even alter the size, shape and internal dimensions of the conceptacles in this place (Maneveltdt and Keats 2008). In Brazil, the external morphology is warty with individual thalli overgrowing each other. Tetra/bisporangial conceptacles are generally conical with a larger chamber diameter than those generally reported from Australia (Penrose 1996) and South Africa (Penrose 1991; Chamberlain 1993), but similar conceptacle diameters are reported from Mexican and the Caribbean (Mateo-Cid et al. 2007).

Spongites yendoi is similar to both *Spongites decipiens* (Foslie) Chamberlain and *Spongites tunicatus* Penrose. The species differs from *S. decipiens* in having a monomerous thallus construction and not a strictly dimerous one. Moreover, cells of the basal filaments in *S. decipiens* are notably larger in diameter than cells of the core filaments in *S. yendoi* (Chamberlain 1993). The species differs from *S. tunicatus* in lacking a corona of filaments in the pore canals of tetra/bisporangial conceptacles (Penrose 1996).

The character that delimits *Lithothamnion muelleri* from other species of *Lithothamnion* is that the cells of filaments bordering the pore canals in tetra/bisporangia conceptacles do not differ in size and shape from other cells of the roof (Wilks and Woelkerling 1995). The Brazilian specimens of *Lithothamnion* reported here possess this same feature. Tetra/bisporangia conceptacle chamber heights in the Brazilian material are, however, slightly larger than those reported from Australia (Woelkerling 1996).

Lithothamnion glaciale is similar to three other species of *Lithothamnion* namely *Lithothamnion tophiforme* (Esper) Unger (Adey et al. 2005), *Lithothamnion lemoineae* Adey

(Adey 1970a) and *Lithothamnion corallioides* (Crouan and Crouan) Crouan and Crouan (Chamberlain and Irvine 1994). *L. glaciale* differs from *L. lemoineae* by possessing tetra/bisporangial conceptacles that are usually taller and from *L. tophiforme* by possessing fewer cells in the tetra/bisporangial conceptacle roof. The occurrence of large “staining bodies” (phosphotungstic hematoxylin) in some species of crustose corallines has been previously described (Adey 1966). Possibly these structures are storage proteins (Adey and Mckibbin 1970). *L. glaciale* has small bodies near the primary pit connections (“pit bodies”), and *L. tophiforme* has abundant, large “staining bodies”. In *L. lemoineae*, large “pit bodies” have been reported in the upper perithallium especially in the tetra/bisporangial conceptacle roofs (Adey 1970a). In *L. corallioides*, these bodies if present are extremely small, although thin staining plates are usually seen at the end of cells (Adey and Mckibbin 1970). *L. glaciale* and *L. corallioides* differ in the protuberance diameter, which is greater in *L. glaciale*. Furthermore, the tetra/bisporangial conceptacle pore plate is flush with the surrounding thallus surface in *L. glaciale* and raised in *L. corallioides*, and the chamber diameter and height of the multiporate conceptacles are larger in *L. glaciale*. Moreover, the most reliable character in distinguishing *L. glaciale* from *L. corallioides* is the difference in thallus core structure. In *L. glaciale*, the core cells are elliptical in shape (bead-like), and cell fusions between core filaments are restricted to certain random areas of the thallus. In *L. corallioides*, core cells are fusiform (star-like) in shape, and their cell fusions are very extensive (Chamberlain and Irvine 1994). The Brazilian rhodoliths identified as *L. glaciale* possess large terete protuberances, bear conceptacles with flush pore plates and possess cell fusions within the core region of the thallus that are restricted to certain random areas of the thallus, all features consistent with that reported for *L. glaciale* elsewhere. *L. glaciale* differs from the previously described *L. muelleri* by (1) possessing a thinner roof and fewer cells in their tetra/bisporangial conceptacle roofs and (2) by the shape of the cells in the tetra/bisporangial conceptacle roof that differ in size and shape from other cells of the roof. In *L. muelleri*, the cells of filaments bordering the pore canals in tetra/bisporangia conceptacles do not differ in size and shape from other cells of the roof.

Lithothamnion glaciale is a polar to cold-temperate species (Adey and Adey 1973). As such, its growth rate is reported to be limited by temperatures above 15°C (Adey 1970b). At 50–64 m depth off the continental shelf at Espírito Santo State where it was encountered here for the first time, water temperatures are similarly low also enabling the existence of other temperate seaweeds such as the deep-water kelp *Laminaria abyssalis* Joly and Oliveira (Yonshigue-Valentin et al. 1995), which may survive temperatures of 24°C but has its growth optimum at

15–20°C (Tom Dieck and de Oliveira 1993). At 50 m depth, this region is influenced by the South Atlantic Central Waters (SACW) characterized by temperatures of 6–20°C (Silveira et al. 2000). This may explain survival of *L. glaciale* in Brazilian tropical deep waters.

Based on the published literature, until now, 28 species of non-geniculate coralline red algae from Brazilian waters have been reported (Taylor 1960; Figueiredo and Steneck 2002; Tâmega and Figueiredo 2005, 2007; Villas-Boas and Figueiredo 2005; Rocha et al. 2006; Nunes et al. 2008; Villas-Boas et al. 2009; Farias et al. 2010; Amado-Filho et al. 2010; Bahia et al. 2011). This study presents two new records for Brazil, increasing the number to 30 species. The genus *Spongites* was previously recorded for Brazil at 2–4 m depth along southeastern shores (Tâmega and Figueiredo 2005), but the species remained unidentified. Therefore, this is the first record of *S. yendoi* for Brazil. *Lithothamnion occidentale* (Foslie) Foslie and *L. sejunctum* Foslie were previously reported from shallow Brazilian coral reefs (Figueiredo and Steneck 2002) but without a full species description. The first species of *Lithothamnion* described from Brazilian waters was *L. superpositum* Foslie from Bahia, Rio Grande do Norte and Santa Catarina states (Farias et al. 2010) and *L. muelleri* from shallow waters in Espírito Santo state (Amado-Filho et al. 2010). This study is the first report and description of polar to cold-temperate *L. glaciale* from Brazilian waters and extends the depth range of non-geniculate coralline red algae down to 58 m in Brazilian waters.

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