



## New records of *Leptogium* species in Brazil with identification key to insular species from São Paulo State

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Kitaura MJ, Oliveira B, Benatti NM 2017 – New records of *Leptogium* species in Brazil with identification key to insular species from São Paulo State. Current Research in Environmental & Applied Mycology (Journal of Fungal Biology) 7(2), 129–143, Doi 10.5943/cream/7/2/10

### Abstract

A survey of cyanolichen species occurring in Cananéia, Cardoso, Comprida and Ilhabela Islands of São Paulo State, Brazil, revealed the occurrence of sixteen species belonging to the genus *Leptogium*. The survey is based on literature review and on newly collected material. Two species (*L. milligranum* and *L. sulcatum*) are newly reported for Brazil and two others (*L. atlanticum* and *L. denticulatum*) for the studied islands, while *L. azureum*, *L. cyanescens*, *L. isidiosellum* and *L. moluccanum* were recollected by us. Descriptions for all insular species, along with an identification key are also presented.

**Key words** – Brazil – *Collembataceae* – cyanolichens – distribution – islands

### Introduction

The Brazilian Atlantic coastline is the 16<sup>th</sup> longest in the world, extending nearly 7.5 thousand kilometres. This coastline comprises many geographical features, including beaches, bays, reefs and islands (CIA 2017). The Atlantic Rainforest represents the major vegetation type found in many coastal areas, including the islands. Most of the coastal formations (that also includes Restinga woods, mangroves, and rocky shores) still remain poorly investigated from a lichenological point of view. A lichen survey of Cardoso Island (25°11'6"S, 47°59'43"W) and São Sebastião Island (23°45'40"S, 45°24' 44"W) in São Paulo State aimed to identify the foliose lichen species occurring at these sites.

*Leptogium* (Ach.) Gray is characterized by thin, homoimerous, more or less gelatinous, foliose thalli; varying coloration, such as bluish, greyish, brownish or blackish (Cyanobacteria photobionts *Nostoc*); smooth to wrinkled corticated upper surface; smooth to tomentose corticated lower surface; lecanorine apothecia with orange to brownish red discs; and hyaline, acicular or ellipsoid, transversely septate or muriform, ascospores. The genus is polyphyletic with worldwide distribution, and around 180 species are currently accepted (Kirk et al. 2008, Otálora et al. 2014).

### Materials & Methods

Specimens of *Leptogium* were collected at Ilhabela and Cardoso Islands during four field expeditions from 2012 to 2013. The collected specimens were identified by comparison of type

material and published descriptions of specimens from tropical and American locations, e.g., Vainio (1890), Malme (1924), Dodge (1933), Sierk (1964), Cunha (2007) and Kitaura (2012). The types of *L. azureum* (Sw.) Mont. (H-ACH! lectotype and BM! duplicate of lectotype), *L. cyanescens* (Rabenh.) Körb. (H-ACH 1913!), *L. denticulatum* Nyl. (H-NYL 41427!), *L. isidiosellum* (Riddle) Sierk (MICH! isotype) and *L. milligranum* Sierk (F!) were examined and descriptions were improved to refine circumscription of the species.

Other types were also requested on loan and used here in the identification key: *L. austroamericanum* (Malme) C.W. Dodge (S!), *L. marginellum* (Sw.) Gray (H-ACH 1917!), *L. phyllocarpum* (Pers.) Mont (S!), and *L. sessile* Vain. (TUR-V! holotype and isotypes). New descriptions were made, but not included herein, and characteristics are found in the identification key.

The specimens were described by following morphological and anatomical protocol (Kitaura et al. 2015), generating detailed descriptions. Complementary descriptions were made to *L. atlanticum* and *L. denticulatum*, completing the circumscriptions made in Kitaura et al. (2015). Histological sections were performed by razor blade of the thallus and apothecia, and histological slides were made with aqueous solution of glycerin 50%. We used a stereomicroscope (Olympus SZ61) and an Olympus CX22LED microscope equipped with a Canon REBEL T3 for imaging.

## Results

*Leptogium austroamericanum*, *L. azureum*, *L. cyanescens*, *L. diaphanum* (Sw.) Mont., *L. isidiosellum*, *L. kalbii* Marcelli & I.P.R. Cunha, *L. marginatum* M. Lindstr., *L. marginellum*, *L. moluccanum* (Pers.) Vain., *L. phyllocarpum*, *L. sessile*, and *L. ulvaceum* (Pers.) Vain. have already been mentioned to Cardoso, Comprida and Cananéia Islands (Marcelli 1987, 1992; Cunha 2007; Lindström 2007; Marcelli et al. 2007).

The species *Leptogium azureum*, *L. cyanescens*, *L. isidiosellum* and *L. moluccanum* were recollected in Ilhabela Island, but the others mentioned species were not personally revised. However, they were examined by colleagues from Lichenologist Study Group (GEL), as part of a continuous effort to investigate Brazilian coastal areas and, *L. marginatum*, by Lindström (2007).

Furthermore, the type material belong to tropical areas as *Leptogium austroamericanum* (Brazil), *L. diaphanum* (Jamaica), *L. kalbii* (Brazil), *L. marginatum* (Guiana), *L. marginellum* (Jamaica), *L. phyllocarpum* (Brazil), *L. sessile* (Dominica) and *L. ulvaceum* (Marians Islands) and they were already reported in others Brazilian regions (Spielmann 2006, Cunha 2007, Gumboski & Eliasaro 2011) and we considerate good species. We found the following species:

***Leptogium atlanticum*** Marcelli & Kitaura, The Bryologist 118(1): 12. 2015. Figs 1–2 Etymology –

This species is found in Brazilian coastal areas of the Atlantic Ocean. Description (see also Kitaura et al. 2015) – Thallus 4–10 cm broad, grey to bluish grey under stereomicroscopy, matt to bright, opaque, striate and with macules whitish. Lobes 0.4–1.2 cm wide, overlapping to agglomerated, usually adpressed, upper surface smooth to the naked eye, rugulose with longitudinal wrinkles under 20× magnification; apices of the lobes usually rotund, plane, smooth; lateral margin of the lobes ascending, sinuous, lobulated. Isidia absent. Lobules flattened, rotund apices, simple, laminal and marginal, concolorous with the thallus, 0.05–1.0 mm diam. Thallus attached by hapters.

Anatomy – Thallus ca. 150 µm thick, quadratic cells of the cortices, 5.0 × 7.5 µm diam., helicoidal columnar hyphae, 7–10 cells. Apothecia and pycnidia not observed.

Known distribution – Brazil, São Paulo State, Municipalities of Guarujá, Mongaguá, Praia Grande and Peruíbe, between 23°59'37"S, 46°15'23"W and 24°19'23"S, 47°00'08"W (Kitaura et al. 2015). This is the second citation of the species to date and now includes the Municipalities of Ilhabela and Cananéia, further extending the previously identified range.

Material examined – Brazil, São Paulo State, Ilhabela Municipality, southern part of the island, near the entrance of Parque Estadual de Ilhabela, 23°56'180" S, 45°25'631" W, alt. 104 m. vi. 2012. M. Benatti, L. Moro & M. Boro 3310 (SP 466568); Idem, M. Benatti, L. Moro & M. Boro

3318 (SP 466569); Idem, *M. Benatti, L. Moro & M. Boro* 3319 (SP 466570); Idem, 23°55' S, 45°24' W, alt. 98 m. 27. vi. 2012. *M. Benatti, L. Moro & M. Boro* 3320 (SP 466571); Idem, *M. Benatti, L. Moro & M. Boro* 3321 (SP 466572); Idem, southern part of the island, Parque Estadual de Ilhabela, 23°55'S, 45°24'W, alt. 275 m. 27. vi. 2012. *M. Benatti, L. Moro & M. Boro* 3325 (SP 466575); Idem, 23°51'S, 45°24'W, alt. 131 m. 27. vi. 2012. *M. Benatti, L. Moro & M. Boro* 3338 (SP 466576); Idem, southern part of the island, SABESP area, Bairro Bixiga, 23°47'S, 45°21'W, alt. 100 m. 06. xii. 2012. *M.N. Benatti, L. Moro & C. Mayumi* 3452 (SP 466586); Idem, eastern part of the island, around Praia de Castelhanos and beach vegetation with houses, on rock, on house near the restinga, 23°47'S, 45°21'W, alt. 2 m. 14. v. 2013. *M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi* 3502 (SP 466592); Idem, *M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi* 3520 (SP 466595 pr. max. p.); Idem, *M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi* 3563 (SP 466606); Idem, *M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi* 3564 (SP 466607); Idem, *M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi* 3567 (SP 466608); Idem, *M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi* 3568 (SP 466609).

Notes – *Leptogium atlanticum* is characterized by thallus with rugulose upper surface with scattered longitudinal wrinkles, covered by flattened, rotund and simple lobules grouped on lamina and margin.

The presence of helicoidal columnar hyphae was observed in these species, as well as in Kitaura et al. (2015), highlighting that columnar hyphae are, indeed, a good taxonomical characteristic for the group. The dehydration and hydration processes do not modify the columnar hyphae, number or arrangement of cells, and is closely related to the thallus surface. For example, straight to inclined columnar hyphae, 2–4 cells in length are present in smooth thallus, while helicoidal columnar hyphae, 7–10 cells in length are present in slightly wrinkled or ridged thallus, and, finally, thalli without columnar hyphae have a strongly wrinkled or ridged surface (Kitaura & Marcelli 2013).

*Leptogium atlanticum* was collected in restinga forest and can probably be found along the entire Brazilian coastline. It is a new record for Ilhabela Municipality, a location with the lowest currently known latitude.

*Leptogium atlanticum* is typically misidentified as *L. denticulatum* Nyl., but *L. atlanticum* has lobules on the lamina and margin of the thallus, and it is usually found in a sterile state, whereas in *L. denticulatum*, the ornaments are absent on the thallus and are usually collected with apothecia that have denticulate margin.

***Leptogium azureum* (Sw.) Mont., Hist. Nat. Iles Canar. 3: 129. 1840.**

Fig 3

Etymology – Epithet refers to the bluish colour of the thallus.

Description – Thallus 4–14 cm broad, bluish grey under fluorescent light, matt, opaque, light grey to bluish grey under stereomicroscopy, macules whitish, irregular scattered (absent in the type). Lobes up to 1.2 cm wide, overlapping to slightly agglomerated, usually adpressed, upper surface smooth to the naked eye, smooth to slightly wrinkled under 20× magnification; apices of the lobes usually rotund, ascending to revolute, smooth; lateral margin of the lobes plane to ascending, sinuous, smooth. Isidia and lobules absent. Thallus attached by hapters, evenly distributed, frequent; rhizines and hairs absent. Apothecia up to 2 mm diam., laminal to submarginal, usually pedicellate, disc plane to slightly cupuliform, reddish; margin of apothecia smooth, without ornaments; amphithecium yellowish, without ornaments; corona absent; pedicel up to 1.5 mm high, concolorous with the thallus, smooth and ridged in contact with apothecia.

Anatomy – Thallus 65–75 µm thick, quadratic cells of the cortices 5.0 µm diam., columnar hyphae inclined to sinuous, 4–6 cells. Cyanobacteria yellow to green, frequent, number of cells not determined, elliptic, usually 3.75 × 2.50 µm; gelatinous matrix frequent, uncoloured. Apothecia. hymenium ca. 125 µm high; subhymenium 40 µm thick, uncoloured; hypothecium 40–50 µm thick, prosoplectenchymatous; proper exciple (paraplectenchymatous subhymenium tissue) absent; parahymenial tissue continuous with hypothecium, coloplectenchymatous, 12 µm (3 cells) at the base, 25 µm (5–7 cells) at the apices; thalline exciple paraplectenchymatous, 75 µm (7–10 cells) at the apices, 125 µm (12–16 cells) at the lateral and base; basal paraplectenchymatous tissue absent.

Ascospores fusiform, 20–30 × 7–10 µm, 4–6 × 1–2(–3) cells, apices acute, submuriform to muriform. Pycnidia submarginal, ostiole brownish. Conidia not observed.

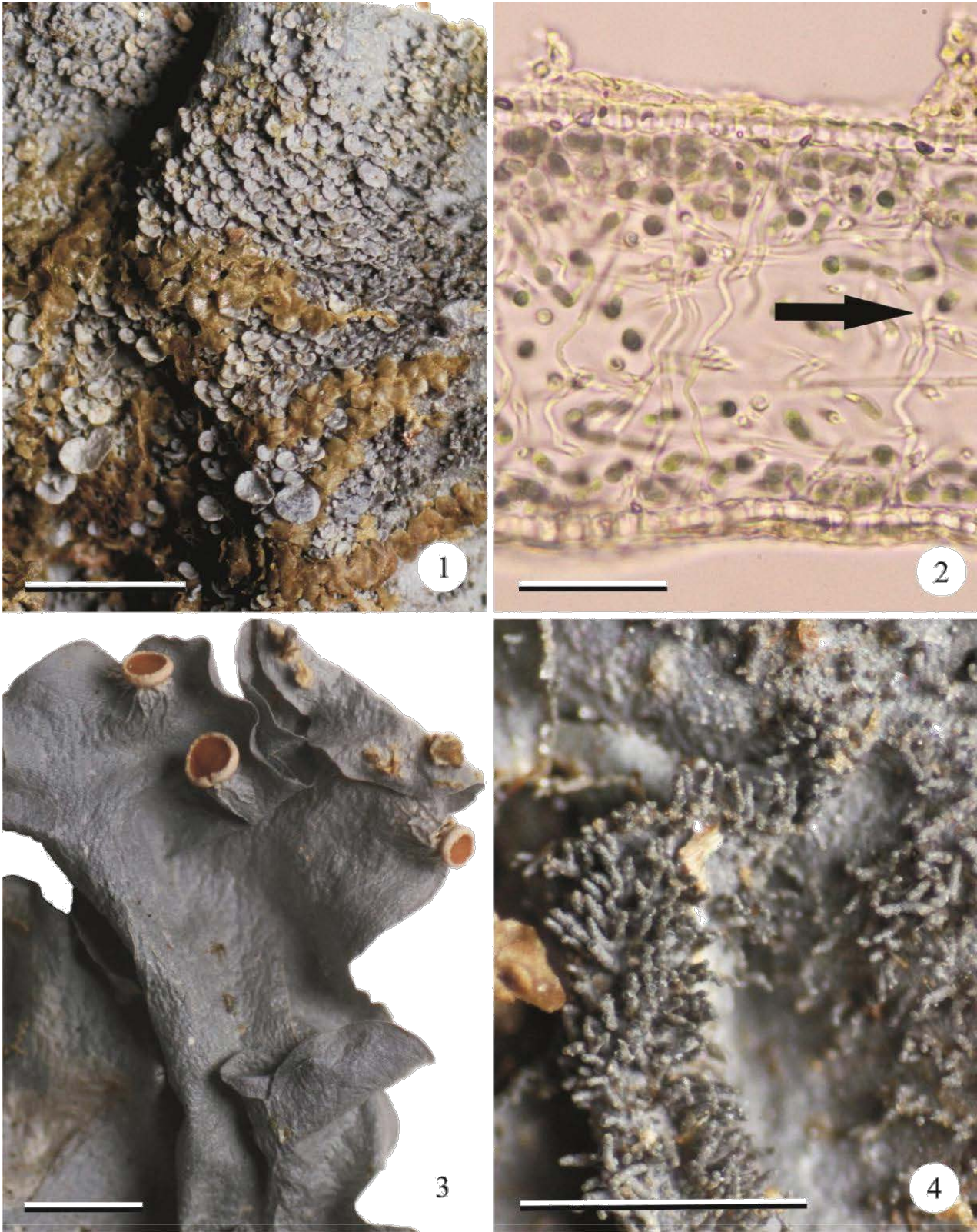
Known distribution – *Leptogium azureum* is widely scattered throughout the world, occurring usually in tropical and subtropical regions at different altitudes (Aragón et al. 2004). It was recorded to Asia in China, India, Indonesia, Malaysia, Papua, New Guinea, Sri Lanka, Thailand, and Vietnam (Wei 1991, Wolseley et al. 2002); to Oceania in Australia (Verdon 1992, Elix & McCarty 1998); to Africa in Ethiopia, Kenya, Tanzania, and Uganda (Swinscow & Krog 1988, Krog 2000); and to the Americas in the USA (Sierk 1964), Costa Rica (Dodge 1933, Breuss 2001), Guatemala (Boom et al. 2007), Argentina (Calvelo & Liberatone 2002), Venezuela (López-Figueiras 1986), Uruguay (Osorio 1972), and Brazil. The Brazilian states with records are Minas Gerais (Aptroot 2002), Rio Grande do Sul (Spielmann 2006) and São Paulo (Marcelli 1998, Cunha 2007), in the Municipalities of Bertioaga, Cananéia, Itanhaém, Mongaguá, Peruíbe, Praia Grande (Cunha 2007), and Ibiúna (Marcelli 1998).

Material examined – Brazil, São Paulo State, Ilhabela Municipality, southern part of the island, Parque Estadual de Ilhabela, 23°55'S, 45°24'W, alt. 275 m. 27. vi. 2012. *M. Benatti, L. Moro & M. Boro* 3323 (SP 466573); Idem, *M. Benatti, L. Moro & M. Boro* 3324 (SP 466574); Idem, near the SABESP Water Station, Castelhanos Road, 23°47'S, 45°21'W, alt. 100 m. 04. ix. 2012. *M.N. Benatti, L. Moro, C. Mayumi & M. Boro* 3352 (SP 466578); Idem, trees and rocks near home park guard, on trunk, 23°47'S, 45°21'W, alt. 100 m. 04. ix. 2012. *M.N. Benatti, L. Moro, C. Mayumi & M. Boro* 3380 (SP 466579), Idem, *M.N. Benatti, L. Moro, C. Mayumi & M. Boro* 3381 (SP 466580); Idem, old Fazenda da Toca, on trunk, 23°47'S, 45°21'W, alt. 100 m. 06. xii. 2012. *M.N. Benatti, L. Moro & C. Mayumi* 3407 (SP 466581); Idem, *M.N. Benatti, L. Moro & C. Mayumi* 3409 (SP 466582); Idem, *M.N. Benatti, L. Moro & C. Mayumi* 3414 (SP 466583); Idem, *M.N. Benatti, L. Moro & C. Mayumi* 3416 (SP 466584); Idem, Pousada das Maritacas, urban perimeter, 23°47'S, 45°21'W, alt. 100 m. 06. xii. 2012. *M.N. Benatti, L. Moro & C. Mayumi* 3466 (SP 466587 - pr. max. p.); Idem, eastern part of the island, around Praia de Castelhanos and beach vegetation with houses, on rock, in house near restinga, 23°47'S, 45°21'W, alt. 2 m. 14. v. 2013. *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3503 (SP 466593); Idem, on trunk, *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3517 (SP 466594 - pr. max. p.); Idem, *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3520 (SP 466595, pr. min. p., specimen with apothecia); Idem, *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3521 (SP 466596 pr. max. p.); Idem, on branch, *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3522 (SP 466597); Idem, in trip, on trunk, *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3524 (SP 466598); Idem, in the trip to the beach, on trunk, 23°47'S, 45°21'W, alt. 2 m. 14. v. 2013. *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3527 (SP 466599); Idem, in the trip to Praia Mansa, on trunk, 23°47'S, 45°21'W, alt. 2 m. 14. v. 2013. *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3528 (SP 466600); Idem, *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3529 (SP 466601); Idem, *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3536 (SP 466602); Idem, *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3537 (SP 466603); Idem, Cocaia trip, entrance to Costabela, on trunk, 23°47'S, 45°21'W, alt. 2 m. 15. v. 2013. *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3554 (SP 466604); Idem, bairro tesouro da Colina, on rock in “poço da nega”, 23°47'S, 45°21'W, alt. 2 m. 15. v. 2013. *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3562 (SP 466605); Idem, *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3567 (SP 466608); Idem, *M. Benatti, I.H.S. Crusius, L. Moro & C. Mayumi* 3568 (SP 466609).

Notes – *Leptogium azureum* is characterized by the bluish colour of the thallus, usually smooth upper surface, and pedicellate apothecia by the thallus. The thallus forms the smooth pedicel that rise the apothecia.

The apothecia of *Leptogium azureum* are not ornamented and differ from *L. denticulatum* apothecia that have denticulate margin. The amphithecium is yellowish and composed of several layers of paraplectenchymatous cells (12–16 cells). *Leptogium azureum* has a widely scattered distribution, but few records were made in Brazil (Aragón et al. 2004), and cyanolichens are probably undersampled in many Brazilian regions.





**Figs 1–4** – *Leptogium* species. 1, 2 *L. atlanticum* (SP 466568). 1 Details of lobules on the upper surface. 2 Transversal section of the thallus with helicoidal columnar hyphae (arrow). 3 *L. azureum* and details of pedicellate apothecia. 4 *L. cyanescens* with details of cylindrical isidia. – Bars: 1, 3 = 2 mm; 2 = 50  $\mu$ m; 4 = 1 mm.

*Leptogium cyanescens* (Rabenh.) K rk., Syst. Lich.: 420. 1855.

Etymology – Epithet refers to pale bluish colour of the thallus.

Fig 4

*Description* – Thallus 3.5–8.0 cm broad, bluish grey to blackish under fluorescent light, matt, opaque, grey to bluish grey under stereomicroscopy, macules absent. Lobes up to 1.5 cm wide, usually overlapping to agglomerated, adpressed, attached in points, upper surface smooth to the naked eye, smooth to rugulose under 20× magnification; apices of the lobes usually rotund, plane, slightly ascending, without ornamentation; lateral margin of the lobes ascending, sinuous, isidiate to lobulate. Lower side smooth under the naked eye, rugulose under 20× magnification. Isidia usually cylindrical, 0.15–0.25 × 0.05–0.10 mm, simple to irregularly branched, firm, erect, concolorous with the thallus. Lobules rotund to irregular, apices rotund to crenulated, 0.25–0.30 × 0.25 mm, simple to irregularly branched, firm, erect, concolorous with the thallus, usually marginal, grouped, frequent. Thallus attached by hapters, frequent, homogeneous; rhizines and hairs absent. Apothecia not observed.

*Anatomy* – Thallus 25–40 µm thick, quadratic cells of the cortices 5 µm diam.; columnar hyphae 2.5 µm thick, slightly inclined, 2 cells. Cyanobacteria blue, dense, number of cells of filament not determined, spherical, 3.75 µm diam.; gelatinous matrix scarce, uncoloured. Pycnidia absent.

*Known distribution* – *Leptogium cyanescens* is considered a temperate species with tropical distribution (Sierk 1964). In Asia, it was recorded in India, Indonesia, Malaysia, Papua, New Guinea, Sri Lanka Taiwan, and Thailand (Wolseley et al. 2002); in Africa, to Ethiopia, Kenya, Tanzania, and Uganda (Swinscow & Krog 1988, Krog 2000); in Oceania, to Australia (Verdon 1992) and Papua, New Guinea (Streimann 1986, Elix & McCarty 1998); in Europe, to England (Seaward 1994), Finland (Vitikainen et al. 1997) Portugal, Spain and the Balearic Islands (Llimona & Hladun 2001), and Germany (Wirth 1994); and in the Americas, to the USA (Sierk 1964), Guatemala (Boom et al. 2007), Costa Rica (Feuerer 2013), Argentina (Calvelo & Liberatone 2002, Feuerer 2013), Venezuela (Vareschi 1973, López-Figueiras 1986, Feuerer & Sipman 2005), Uruguay (Osorio 1972, 1992, 1998), and Brazil (Marcelli 2002). Records are found in Minas Gerais (Aptroot 2002), Paraná (Osorio 1977), Rio Grande do Sul (Spielmann 2006, Käffer et al. 2009) and São Paulo in the Municipalities of Bertioiga, Cananéia, Iguape, Itanhaém, Mongaguá, Peruíbe and Praia Grande (Cunha 2007).

*Material examined* – Brazil, São Paulo State, Ilhabela Municipality, São Sebastião Island, near the SABESP Water Station, Castelhanos Road, 23°47'S, 45°21'W, alt. 100 m. 04. ix. 2012. *M.N. Benatti, L. Moro, C. Mayumi & M. Boro 3351 (SP 466577)*.

*Notes* – *Leptogium cyanescens* is characterized by the bluish colour of the thallus and a smooth and isidiate upper surface. The isidia are usually cylindrical (the largest have a withered appearance), but granular types are also found when young and flattened types with age on the lamina and on the margin of the lobes.

Sierk (1964) mentioned that *L. cyanescens* can be a temperate species because fertile specimens were commonly found in the USA. However, the North American species of *Leptogium cyanescens* can be different from the South American species that are usually found to be sterile. The circumscription of the species of *L. cyanescens* must be re-established, and further studies are necessary.

***Leptogium denticulatum*** Nyl., Annales des Sciences Naturalles, Botanique et Biologie Végétale 7: 302. 1867 Figs 5–6

*Etymology* – Epithet refers to denticulate margin of the apothecia (Nylander 1867).

*Description* – (see also Kitaura et al. 2015) – Thallus 4 cm broad, bluish, matt, opaque to bluish grey under stereomicroscopy. Lobes up to 0.8 cm wide, agglomerated, adpressed, attached in points, upper surface slightly rugulose to the naked eye, wrinkled under 20× magnification; apices of the lobes rotund, plane to revolute, smooth; lateral margin of the lobes plane, sinuous, smooth. Isidia and lobules absent. Thallus attached by hapters, frequent and homogeneous. Apothecia up to 2 mm diam. laminal, subpedicellate, disc usually concave, reddish; margin of apothecia with denticle or lobuloid structure (without constricted base), amphithecium yellowish, smooth; pedicel very short.

Anatomy – Thallus 45–65 µm thick, quadratic cells of the cortices 5.0 µm diam., inclined to sinuous columnar hyphae, ca. 4 cells. Apothecia: hymenium ca. 125 µm high; subhymenium 25 µm thick, uncoloured; hypothecium 12.5 µm thick, prosoplectenchymatous; proper exciple absent; thalline exciple paraplectenchymatous, 12 µm (3 cells) at the apices, 25 µm (5 cells) at the lateral, 75 µm (9 cells) at the base. Ascospores fusiform, 20–25 × 5.0–7.5 µm, 3–4 × 1–3 cells, submuriform, apices acute. Pycnidia not observed.

Known distribution – *Leptogium denticulatum* is recorded in Asia, to Japan (Hue 1898), China, India, Malaysia, Thailand (Wolseley et al. 2002, Rout et al. 2010), Taiwan (Aptroot 2002), and South Korea (Jayalal et al. 2014); in the Americas, to Costa Rica (Dodge 1933), USA (Sierk 1964), Uruguay (Osorio 2000), Hawaii (Benner & Vitousek 2012); and in Brazil, to Paraná (Cunha 2007), Minas Gerais (Kitaura et al. 2015), and São Paulo States. The Municipalities of Guarujá, Mongaguá, Peruíbe, Praia Grande (Cunha 2007), São Paulo (Benatti et al. 2013), and Ibiúna (Kitaura et al. 2015) were cited to São Paulo.

Material examined – Brazil, São Paulo State, Cananéia Municipality, Ilha do Cardoso, trees near little river, 25°01' S, 47° 56' W, alt. 8 m. 19. vi. 2012. M. Benatti, I.H.S. Crusius & L. Moro 3270. (SP 466566).

Notes – *Leptogium denticulatum* is characterized by the absence of ornaments on the thallus, but with a crown of denticules on the apothecium margins. Many specimens of *L. denticulatum* were described with ornaments on the thallus, but this could be an erroneous identification. Neither the type material from Colombia (H-NYL 41427!) nor the specimens of *L. denticulatum* analysed by Kitaura et al. (2015) showed lobules on the thallus, emphasising that the ornaments are indeed restricted on the margin of apothecia. Therefore, the known distribution of *L. denticulatum* could be more restricted than previously thought and the specimens not collected in America Continent should be revised India (Rout et al. 2010) and South Korea (Jayalal et al. 2014).

The analysed specimen has the thallus more wrinkled than the examined material by Kitaura et al. (2015) and is constituted by inclined to sinuous columnar hyphae with ca. 4 cells high, differing from the type material with straight columnar hyphae of 2 cells. Furthermore, the apothecia of Benatti 3270 is bigger than the type and other studied specimens from Brazil (Kitaura et al. 2015), but we are keeping this insular specimen in *L. denticulatum* pending further studies.

***Leptogium isidiosellum*** (Riddle) Sierk, The Bryologist 67(3): 282. 1964.

Fig 7

Etymology – Epithet refers to the presence of abundant isidia over the thallus.

Description – Thallus ca. 6 cm broad, bluish grey to blackish under fluorescent light, matt, opaque, grey under stereomicroscopy. Lobes up to 6 mm wide, overlapping to agglomerated, adpressed to ascending, attached in points, upper surface ridged to the naked eye, irregular to longitudinal ridges under 20× magnification; apices of the lobes rotund to irregular, ascending to revolute, smooth; lateral margin of the lobes ascending, crenulate, smooth to isidiate. Isidia flattened to cylindrical, apices rotund, simple to irregular branched, laminal and marginal, grouped, abundant, whitish to concolorous with the thallus, 0.05–0.25 × 0.025–0.05 mm. Lobules absent. Thallus attached by hapters.

Anatomy – Thallus ca. 175–225 µm thick, quadratic cells of the cortices, 5.0 × 5.0 µm, columnar hyphae absent. Apothecia and pycnidia not observed.

Known distribution – *Leptogium isidiosellum* was recorded in the USA and Caribbean (Riddle 1918, Sierk 1964), Uruguay (Osorio & Geymonat 2006), and Brazil. The Brazilian Municipalities have records in Santa Catarina (Marcelli 1992, Osorio 1997), Bahia (Marcelli 1992), and São Paulo. The São Paulo Municipalities with records are Cananéia, Itanhaém and Bertioga (Marcelli 1992).

Material examined – Brazil, São Paulo State, Cananéia Municipality, Ilha do Cardoso, trees near little river, 25°01' S, 47° 56' W, alt. 8 m. 19. vi. 2012. M. Benatti, I.H.S. Crusius & L. Moro 3275 (SP 466567); Idem, Ilhabela Municipality, Ilha de São Sebastião, Parque Estadual de Ilhabela, Municipality green house “Cachoeira da Água Branca”, 23°47'S, 45°21'W, alt. 100 m. 06. xii. 2012. M.N. Benatti, L. Moro & C. Mayumi 3443 (SP 466585); Idem, Pousada das Maritacas, urban

perimeter, 23°47'S, 45°21'W, alt. 100 m. 06. xii. 2012. M.N. Benatti, L. Moro & C. Mayumi 3466 (SP 466587 - pr. min. p.); Idem, eastern part of the island, around Praia de Castelhanos and beach vegetation with houses, on trunk (chapéu-de-sol), 23°47'S, 45°21'W, alt. 2 m. 14. v. 2013. M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi 3487 (SP 466590); Idem, on trunk, 23°47'S, 45°21'W, alt. 2 m. 14. v. 2013. M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi 3517 (SP 466594 - pr. min. p.).

Notes – *Leptogium isidiosellum* is characterized by the presence of a ridged thallus and upper surface covered by simple to irregularly branched isidia. The isidia are flattened and whitish when young, turning cylindrical and becoming concolorous to the thallus with maturation, originating on the apices of wrinkles.

*Leptogium isidiosellum* can be confused with *L. coralloideum*, but they are differentiated by the tissues of apothecia. *Leptogium coralloideum* is the isidiate species-pair of *L. phyllocarpum*, and the apothecia are composed of thick paraplectenchymatous proper exciple and a one-celled layer of thalline exciple. *Leptogium isidiosellum* has a thick paraplectenchymatous thalline exciple. Apothecia were not found in the material examined here, but the specimens have flattened and cylindrical isidia, similar to the type material and other Brazilian specimens with apothecia.

***Leptogium milligranum*** Sierk, *The Bryologist* 67(3): 290. 1964.

Figs 8–9

Etymology – Epithet refers to the presence of granular isidia over the thallus.

Description – Thallus up to 9 cm broad, grey to blackish under fluorescent light, matt, opaque yellowish, brownish to blackish under stereomicroscopy, macules absent. Lobes up to 5 mm wide, overlapping to agglomerated, adpressed, upper surface ridged to the naked eye, with irregular to longitudinal ridges under 20× magnification; apices of the lobes rotund, ascending, smooth; lateral margin of the lobes ascending, crisped, smooth to isidiate. Isidia granular, rotund, simple to branched, laminal and marginal, concolorous with the thallus to blackish, abundant, simple, pilled to coralloid, 0.1 mm diam. Lobules absent. Thallus attached by hapters.

Anatomy – Thallus 60–120 µm thick, quadratic cells of the cortices 5.0 µm diam., columnar hyphae absent; gelatinous matrix scarce, uncoloured. Apothecia and pycnidia not observed.

Known distribution – *Leptogium milligranum* is recorded in the USA (Sierk 1964), Venezuela (López-Figueiras 1986), and Canada (McMullin 2012).

Material examined – Brazil, São Paulo State, Ilhabela Municipality, Ilha de São Sebastião, Parque Estadual de Ilhabela, Pousada das Maritacas, 23°47'S, 45°21'W, alt. 100 m. 06. xii. 2012. M. Benatti, L. Moro & C. Mayumi 3467 (SP 466588); Idem, Parque Estadual de Ilhabela, eastern part of the island, around Praia de Castelhanos and beach vegetation with houses, on trunk (chapéu-de-sol), 23°47'S, 45°21'W, alt. 2 m. 14. v. 2013, M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi 3493 (SP 466591); Idem, M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi 3474 (SP 466589).

Notes – *Leptogium milligranum* is characterized by having a ridged upper cortex, covered by abundant granular isidia. The isidia are usually blackish, and vary from simple to coralloid, often darkening the thallus surface.

*Leptogium milligranum* differs from *L. isidiosellum* by the isidia, which are granular and blackish in *L. milligranum*, but cylindrical and concolorous with the thallus in *L. isidiosellum*. In specimens that are fertile, the apothecia of *L. milligranum* are composed of a thick paraplectenchymatous proper exciple, while those of *L. isidiosellum* have a thick paraplectenchymatous thalline exciple.

Granular isidia are also found in *L. kalbii* Marcelli & Cunha, but *L. milligranum* has ridged surfaces, and *L. kalbii* has rugose and striate (not plicate) surface that is commonly weakly bullate in distal portions (Marcelli et al. 2007).

***Leptogium moluccanum*** (Pers.) Vain., *Étud. Class. Lich. Brésil* 1: 223. 1890.

Fig 10

Etymology – Epithet refers to locality, Moluccas Island, where the species was originally collected.



Description – Thallus ca. 2.5–3.0 cm broad, bluish grey under fluorescent light, matt, opaque bluish under stereomicroscope, macules absent. Lobes up to 1.2 cm wide, overlapping to agglomerated, attached in points, upper surface smooth to the naked eye, rugulose under 20× magnification; apices of the lobes rotund, ascending, smooth; lateral margin of the lobes ascending, crisped, smooth. Isidia and lobules absent. Thallus attached by hapters. These are frequent with homogeneous distribution; hairs and rhizines absent. Apothecia up to 2 mm diam., laminal, subpedicellate, disc concave to plane, reddish; margin of apothecia smooth, without ornaments; amphithecium bluish near to the margin and yellow at the base, corona absent, pedicel very short.

Anatomy – Thallus ca. 75 µm thick, quadratic cells of the cortices, 5.0 µm diam.; columnar hyphae straight to inclined, 4–6 cells. Apothecia. Hymenium 100 µm high; subhymenium 40 µm thick, uncoloured; hypothecium 50 µm thick, uncoloured, prosoplectenchymatous, proper exciple absent, thalline exciple paraplectenchymatous, 5 µm (1 cell) thick at the apices and lateral, 40 µm (3–4 cells) thick at the base. Ascospores fusiform, 15.0–25.0 × 7.5–10.0 µm, 3–4 × 1–2 cells, acute apices, submuriform. Pycnidia not observed.

Known distribution – *Leptogium moluccanum* is recorded to Oceania (Gaudichaud 1826), Venezuela (López-Figueiras 1986), the USA (Sierk 1964), Canada (McMullin 2012), and Brazil in Minas Gerais (Vainio 1890) and São Paulo (Marcelli 1991, Benatti et al. 2013).

Material examined – Brazil, São Paulo State, Ilhabela Municipality, Ilha de São Sebastião, Parque Estadual de Ilhabela, eastern part of the island, around Praia de Castelhanos and beach vegetation with houses, on trunk, 23°47'S, 45°21'W, alt. 2 m. 14. v. 2013. M. Benatti, I.H.S. Crusius. L. Moro & C. Mayumi 3521 (SP 466596 - pr. min. p.).

Notes – *Leptogium moluccanum* is characterized by the bluish thallus, usually smooth upper surface, without isidia or lobules, and by the subpedicellate apothecia.

*Leptogium moluccanum* apothecia are composed of a thick paraplectenchymatous thalline exciple like the apothecia of *L. azureum*. However, *L. moluccanum* apothecia are subpedicellate, whereas *L. azureum* apothecia are pedicellate. The vegetative structure of ornamentation is lacking on both species.

***Leptogium sulcatum*** M. Lindstr., Bibliotheca Lichenologica 95: 418. 2007. Figs 11–12 Etymology – Epithet refers to the distinctly furrowed upper surface.

Description (see also Lindström 2007) – Thallus ca. 7 cm broad, grey under fluorescent light, matt, opaque, grey under stereomicroscopy; macules in surface depression, yellowish. Lobes 4–6 cm wide, overlapping, adpressed, upper surface ridged to the naked eye, foveolate with irregular furrows under 20× magnification; apices of the lobes usually rotund, plane, smooth; lateral margin of the lobes ascending to revolute, undulate, smooth to lobulated. Foveolate cavities irregular, 0.5–1.8 mm diam., with irregular furrows. Isidia absent. Lobules flattened, apices rotund to slightly elongated, simple, on the furrows and margin of the lobes, concolorous with the thallus, ca. 0.25 mm diam. Thallus attached by hapters.

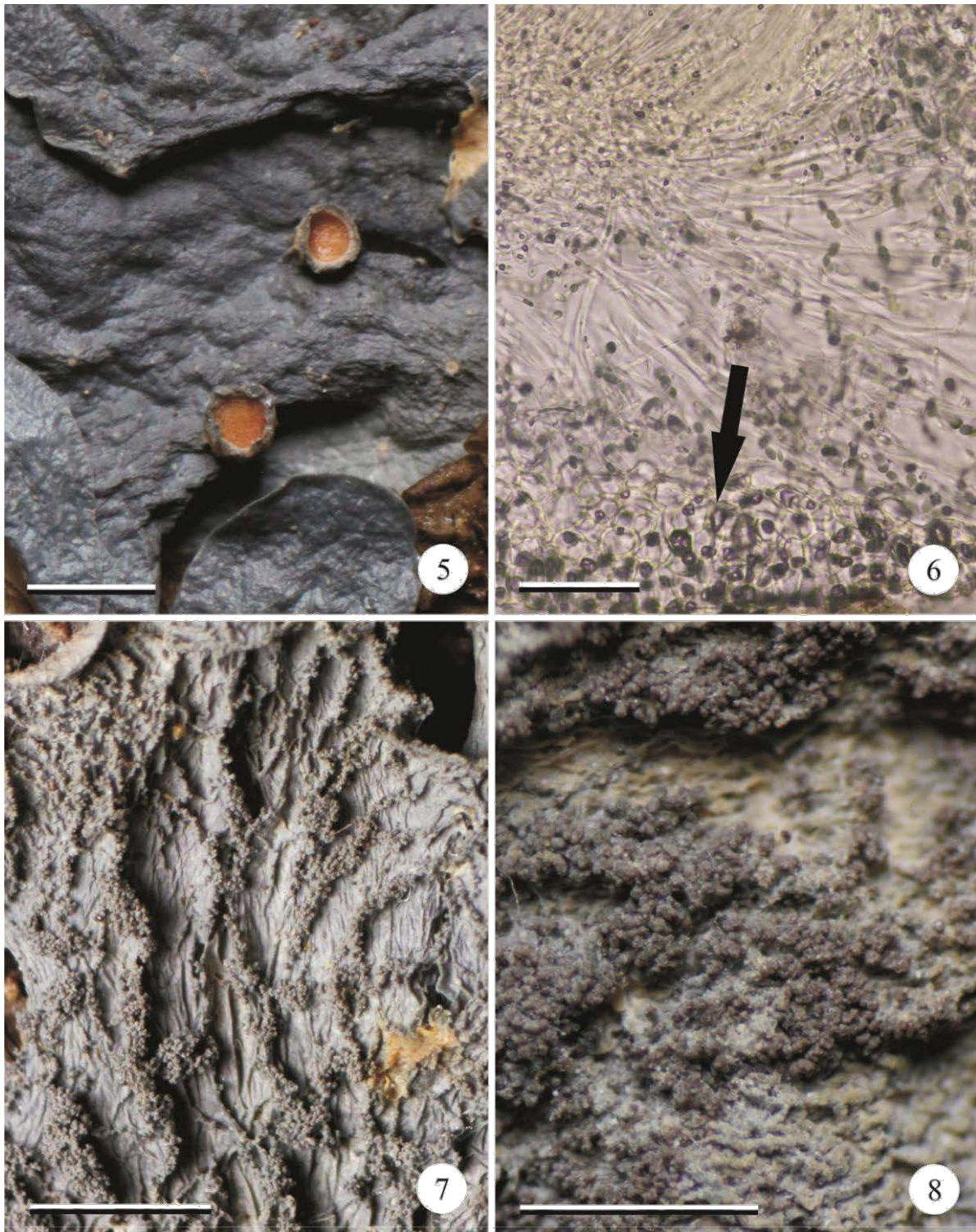
Anatomy – Thallus 85–100 µm thick, quadratic cells of the cortices 5.0 µm diam., columnar hyphae straight, 4–5 cells. Apothecia and pycnidia not observed.

Known distribution – *Leptogium sulcatum* is recorded in Mexico, Belize, Costa Rica, Panama, Jamaica, Venezuela, Guyana, Suriname, French Guiana, Ecuador and Peru (Lindström 2007). This is the first record for Brazil.

Material examined – Brazil, São Paulo State, Cananéia Municipality, Ilha do Cardoso, trees near little river, 25°01' S, 47° 56' W, alt. 8 m. 19. vi. 2012. M. Benatti, I.H.S. Crusius & L. Moro 3263 (SP 466563); Idem, M. Benatti, I.H.S. Crusius & L. Moro 3264 (SP 466564); Idem, M. Benatti, I.H.S. Crusius & L. Moro 3266 (SP 466565).

Notes – *Leptogium sulcatum* is characterized by presence of irregular furrows from which lobules originate on the peak and mainly restricted to the old thallus parts. The upper surface of *Leptogium sulcatum* is similar to that of *L. reticulatum* Mont. and *L. foveolatum* Nyl., but they differ by the size of cavities. *Leptogium reticulatum* has a scrobiculous upper surface, whereas *L. foveolatum*, as the name implies, has a foveolate surface. *Leptogium sulcatum* has cavities up to 1.8

with irregular furrows, that differ of *L. reticulatum* up to 1,0 mm diam. without furrows (Cunha 2007) and *L. foveolatum* ca. 2.0 mm diam. and smooth upper surface (Kitaura 2012), and it is the only species with lobules on the furrows and margin of lobes.



**Figs 5–8** – *Leptogium* species. 5, 6 *L. denticulatum* (SP 466566). 5 Details of ornamented apothecia. 6 Transversal section of the apothecia with thick thalline exciple (arrow). 7 Isidiate surface of *L. isidiosellum* (SP 466585). 8 Upper surface of *L. milligranum* (SP 466588). – Bars: 5, 8 = 1 mm; 6 = 50  $\mu$ m; 7 = 2 mm.

Furthermore, *Leptogium reticulatum* has transversally septate ascospores, while *L. foveolatum* has muriform ascospores similar to *L. sulcatum*, but the thallus does not develop any vegetative

structures. *Leptogium sulcatum* has already been collected in several South American countries, and it is registered here as a new citation to Brazil, São Paulo State, Cananéia Municipality.

### Key to Insular Species of *Leptogium*

1. Vegetative ornaments present .....2
2. Isidioid ornaments, with or without constricted base, on the thallus and apothecia .....3
3. Usually granular isidia .....4
4. Ridged upper surface; granular isidia, usually 0.1 mm diam., concolorous with the thallus to blackish .....*L. milligranum*
- 4'. Rugose to striate (not plicate) upper surface, granular to lobuloid isidia, 0.1–0.25 mm diam., concolorous with the thallus ..... *L. kalbii*
- 3'. Usually cylindrical isidia .....5
5. Upper surface smooth to slightly ridged or wrinkled at 20× magnification, thallus with columnar hyphae straight to inclined ..... *L. cyanescens*
- 5'. Upper cortex ridged to wrinkled at 20× magnification, thallus with columnar hyphae sinuous, helicoidal or absent .....6
6. Upper surface with wrinkles (not plicate, ridged) .....*L. austroamericanum*
- 6'. Upper surface irregular to longitudinal ridges ..... *L. isidiosellum*
- 2'. Lobuloid or denticule ornaments, with or without constricted base, on the thallus and apothecia  
7
7. Ornaments only on the margin of apothecia and amphithecia .....8
8. Thallus slightly wrinkled to the naked eye, columnar hyphae straight to inclined 2-4 hyphae, denticular or lobuloid structure without constricted base only on apothecia margin  
.....*L. denticulatum*
- 8'. Thallus ridged to the naked eye, columnar hyphae absent, lobules or lobuloid structure on apothecia margin .....9
9. Only marginal apothecia, up to 0.5 mm diam., lobules with restricted base ..... *L. marginellum*
- 9'. Submarginal to laminal apothecia, more than 0.5 mm diam., lobules usually without restricted Base .....*L. phyllocarpum*
- 7'. Ornaments usually on the thallus, apothecia with or without ornaments .....10
10. Thallus with foveolate upper surface, with irregular furrows ..... *L. sulcatum*
- 10'. Thallus with other types of upper surface, without furrows ..... 11
11. Laminal and marginal lobules, rotund ..... *L. atlanticum*
- 11'. Usually marginal lobules, rotund to elongated, delicate ..... *L. diaphanum*
- 1'. Vegetative ornaments absent ..... 12
12. Marginal apothecia on the thallus ..... *L. marginatum*
- 12'. Submarginal to laminal apothecia on the thallus ..... 13
13. Smooth upper surface, straight to inclined columnar hyphae, proper exciple absent and thick thalline exciple ..... 14
14. Apothecia pedicellate ..... *L. azureum*
- 14'. Apothecia subpedicellate to adnate ..... *L. moluccanum*
- 13'. Ridged upper surface, sinuous columnar hyphae or absent, thick proper exciple and thin thalline exciple ..... 15
15. Sessile apothecia with circular wrinkles on the margin ..... *L. sessile*
- 15'. Subpedicellate to adnate apothecia, smooth margin ..... *L. ulvaceum*

### Discussion

The number of *Leptogium* species has now increased from 12 to 16 for the islands of São Paulo State: *Leptogium atlanticum* Marcelli & Kitaura, *L. denticulatum* Nyl., *L. milligranum* Sierk, and *L. sulcatum* M. Lindstr being newly recorded. Studies of *Leptogium* species are still scarce in São Paulo State and Brazil. This is complicated by the lack of basic literature, identification keys,



precise descriptions, and difficulty of recognizing species. We have yet not examine all types related to the studied species and their synonyms, and concordant names were used to identify found species. Therefore, we are aware that several names can change with a more throughout revision of the genus.



**Figs 9–12** – *Leptogium* species. 9 Details of granular isidia of *L. milligranum*. 10 Subpedicellate apothecia of *L. moluccanum* (SP 466596). 11, 12 *L. sulcatum* (SP 466563). 11 Details of surface. 12 Lobules on the furrow. – Bars: 9, 12 = 0.5 mm; 10, 11 = 2 mm

## Acknowledgements

The authors thank the curators of BM, F, H, MICH, S and TUR for their effective and timely support, as well as the reviewers. The first and second authors also acknowledge the grants from CAPES (PNPD) and UFMS (bolsa permanência).

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