Fine morphology of four *Licmophora* (*Bacillariophyta, Licmophorales*) species from Admiralty Bay and Elephant Island, Antarctic Peninsula

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RESUMO – **Morfologia fina de quatro espécies de *Licmophora* (*Bacillariophyta, Licmophorales*) da Baía do Almirantado e Ilha Elefante, Península Antártica.** Neste artigo, quatro espécies da diatomácea bentônica da Antártica, *L. antarctica* M. Peragallo, *L. belgicae* M. Peragallo, *L. gracilis* (Ehrenberg) Grunow e *L. luxuriosa* Heiden, são descritas em microscopia eletrônica, baseado em duas coleções de amostras obtidas durante diferentes expedições do Programa Antártico Brasileiro (verão de 1994, e 2003 a 2010). Amostragens do plâncton e bentos foram realizadas em diferentes locais da Ilha Rei George e Ilha Elefante, Península Antártica. Três espécies endêmicas, *L. antarctica*, *L. belgicae* e *L. luxuriosa*, são descritas, incluindo informação sobre estruturas como rimopórtula, poróides e multiscissura. *L. gracilis* também foi examinada para confirmar sua identidade. Comparações com espécies próximas também são providenciadas, bem como a distribuição na Península Antártica.

Palavras-chave: diatomáceas bentônicas, taxonomia, ultraestrutura.

ABSTRACT – In this paper, four Antarctic species of the diatom genus *Licmophora* namely *L. antarctica* M. Peragallo, *L. belgicae* M. Peragallo, *L. gracilis* (Ehrenberg) Grunow and *L. luxuriosa* Heiden are described using an electron microscope, based on two collections of samples collected during different expeditions under the Brazilian Antarctic program (Summer of 1994, and 2003 to 2010). Plankton and benthic samplings were carried out at different locations in King George and Elephant Islands, Antarctic Peninsula. The fine morphologies of three endemic species, *L. antarctica*, *L. belgicae* and *L. luxuriosa*, are described, including information on structures like rimoportula, poroids and multiscissura. *L. gracilis* was also examined for confirmation of its identity. Comparisons with allied species are also provided, as well as their geographic distribution around the Antarctic Peninsula.

Keywords: benthic diatoms, taxonomy, ultrastructure.

INTRODUCTION

Licmophora C. Agardh, 1827 is a benthic diatom genus widespread in coastal marine environments around the world (Honeywill 1998, Witkowski *et al.* 2000, Al-Handal & Wulff 2008a, 2008b, Lobban *et al.* 2011). Its species can thrive in different substrates like sediments, rocks, macroalgae, skin of vertebrates, and ice. The main features of *Licmophora* are heteropolar cells attached to the substrate by

mucilage tubes, frustules with 2-3 rimoportulae, and clavate or spathulate valves pierced by uniseriate striae, surrounding a narrow sternum. Usually, there are 1 or 2 rimoportulae per valve, having an internal labiate structure and it is externally flush, with a round or elongate opening. At the foot pole, a number of elongate slits constitute the multiscissura (*sensu* Honeywill 1998). Additionally, the valvocopula is septate in most of the species.

According to VanLandingham (1971), about 58 species have been described so far worldwide. After this review, four new species were added: *L. pinnulata* Ricard (1975), *L. unidenticulata* Takano (1983), *L. flucticulata* Lobban *et al.* (2011) and *L. comnavmaria* Lobban & Schefter (2013). *L. normaniana* (Greville) Wahrer was transferred from *Campylostylus normanianus* to the genus *Licmophora* (Wahrer *et al*. 1985). Comparatively, few investigations using electron microscope were developed to study frustule ornamentations in *Licmophora* (see literature in Gaul *et al.* 1993, Henderson & Reimer 2003). Modern investigations focused on the ultrastructure of a few species, already elucidating important diagnostic structures in *Licmophora*. (Montgomery 1978, Takano 1983, Wahrer *et al*. 1985, Sar & Ferrario 1990, Round *et al*. 1990, Honeywill 1998, Terasaka et al. 2005, Lobban *et al*. 2011, Lobban & Schefter 2013, Lobban 2013). Honeywill (1998) offers a comprehensive survey of the genus in Britain, describing 15 species of *Licmophora* in both scanning and transmission electron microscopes. Moreover, the author identified and illustrated different types of velum covering the areolae, as well as proposed the utilization of multiscissura as a valuable taxonomic character in the genus.

In Antarctica, about 11 valid species were recorded: *L. antarctica* Carlson, *L. belgicae* M. Peragallo, *L. charcotii* M. Peragallo, *L. gigantea* Mereschkowsky, *L. rouchii* M. Peragallo, *L. luxuriosa* Heiden, *L. plana* Heiden, *L. pseudohyalina* Frenguelli & Orlando, *L. gracilis* (Ehrenberg) Grunow, *L. abbreviata* Agardh, and *L. onassis* Hustedt (Agardh 1827, Van Heurck 1909, Peragallo 1921, Hustedt 1952, 1958, Frenguelli & Orlando 1958, Simonsen 1992). Simonsen analyzed the types of Heiden in Heiden & Kolbe (1928), giving illustrations of *L. belgicae* (as *L. decora*), *L. luxuriosa* and *L. plana*. All the species were collected from diverse benthic habitats, especially rocks and macroalgae. Recently, Al-Handal & Wulff (2008a, 2008b) recorded four species in Potter Cove, King George Island, describing their frustules in light microscope. To our knowledge, the only paper using electron microscopy for the description of species in Antarctica is Ahn *et al*. (1994) for *L. belgicae* (identified as *L. luxuriosa*).

In this paper four species of *Licmophora* found in King George and Elephant Islands, Antarctic Peninsula are described in electron microscopy, *L. antarctica* M. Peragallo, *L. belgicae*, *L. gracilis*, and *L. luxuriosa*. This contribution is part of a project investigating the taxonomy of benthic diatoms in Admiralty Bay and nearby, from which other papers were already published (Fernandes & Procopiak 2003, Procopiak & Fernandes 2003, Fernandes *et al*. 2007, Fernandes & Sar 2009).

MATERIAL AND METHODS

The material examined in this study came from two scientific collections, sampled during different periods and in different environments (Tab. 1). The first sampling was carried out during the XIII Expedition of the Brazilian Antarctic Program (PROANTAR XIII) in November and December of 1994 (Tab. 1), in different locations in Admiralty Bay, King George Island and in Elephant Island. Both islands are in the South Shetland Islands, Antarctic Peninsula. In Admiralty Bay (62°05'S, 58°35'W) five benthic samples were obtained in the intertidal and infralittoral zones by autonomous diving (SCUBA). The sampling points were located near the Brazilian Antarctic station. Cells were removed from small rocks by scrapping the surface with a fine tooth brush. The same methodology was used on Elephant Island (61°00'S, 65°30'W). In this site, sampling was carried out in the intertidal zone only; a total of eleven samples were collected.

The second collection was gathered during the expeditions sponsored by the Brazilian Antarctic Program spanning from 2003 to 2010 in December, February and March. Plankton samples were collected in seven oceanographic stations (Tab. 1) using a plankton net with 20 µm mesh size. All material was preserved in formalin at the final concentration of 2%. Samples of both collections are deposited in the UPCB Herbarium of the Federal University of Paraná State, Curitiba, Paraná, Brazil.

Table 1. Data of samples collected in different sites and algal communities (epilithon or phytoplankton) in Admiralty Bay (King George Island) and Elephant Island, Antarctic Peninsula. The occurrence of species in the samples is also showed, and indicated as follows: A (*Licmophora antarctica* M. Peragallo), B (*L. belgica*), G (L. *gracilis*) and L (L. *luxuriosa*).

Sampling sites, communities and codes of sampling stations	Sampling Date	Herbarium Number	Species Occurrence
Elephant Island (61°00'S, 65°30'W) - epilithon, intertidal (Station E1)	26/11/1994	UPCB-43995	B, G, L
Elephant Island - epilithon, intertidal (St. E2)	23/11/1994	UPCB-43996	B, G, L
Brazilian Antarctic station (EACF) (62°05'S, 58°35'W) - Martel Inlet, epilithon, intertidal (St. E3)	30/11/1994	UPCB-43997	B, G
Elephant Island - epilithon, intertidal (St. E4)	26/11/1994	UPCB-43998	B, G
Elephant Island - epilithon, intertidal (St. E5)	26/11/1994	UPCB-43999	B, G
Elephant Island - epilithon, intertidal (St. E6)	26/11/1994	UPCB-44000	A, B, G
Elephant Island - epilithon, intertidal (St. E7)	24/11/1994	UPCB-44001	B, G
Brazilian Antarctic station (EACF) - Martel Inlet, epilithon, intertidal (St. E8)	04/12/1994	UPCB-44002	B
Brazilian Antarctic station (EACF) - Martel Inlet, epilithon, 14 meter depth (St. E10)	30/11/1994	UPCB-44004	G
Elephant Island - epilithon, intertidal (St. E11)	26/11/1994	UPCB-44005	B, G
Elephant Island - epilithon, intertidal (St. E13)	26/11/1994	UPCB-44007	G
Elephant Island - epilithon, intertidal (St. E17)	26/11/1994	UPCB-44010	G
Arctowski Polish station, Admiralty Bay (62°09'S, 58°27'W), net phytoplankton	07/12/2009	UPCB-75128	B
Arctowski Polish station, Admiralty Bay, net phytoplankton	23/12/2009	UPCB-75131	A, B
Arctowski Polish station, Admiralty Bay, net phytoplankton	29/12/2009	UPCB-75132	A, B
Arctowski Polish station, Admiralty Bay, net phytoplankton	13/02/2010	UPCB-75133	A, B
Arctowski Polish station, Admiralty Bay, net phytoplankton	19/02/2010	UPCB-75134	A, B
Arctowski Polish station, Admiralty Bay, net phytopla nkton	25/02/2010	UPCB-75135	A, B
Arctowski Polish station, Admiralty Bay, net phytoplankton	21/01/2004	UPCB-75139	A, B
Arctowski Polish station, Admiralty Bay, net phytoplankton	03/02/2003	UPCB-75140	A, B
Arctowski Polish station, Admiralty Bay, net phy toplankton	21/01/2004	UPCB-75139	A, B, G
Thomas Point, Ezcurra Inlet (62°09'S, 58°29'W), net phytoplankton	07/12/2009	UPCB-75142	A, B
Thomas Point, Ezcurra Inlet, net phytoplankton	11/12/2009	UPCB-75143	B
Thomas Point, Ezcurra Inlet, net phytoplankton	23/12/2009	UPCB-75145	A, B
Thomas Point, Ezcurra Inlet, net phytoplankton	29/12/2009	UPCB-75146	A, B
Thomas Point, Ezcurra Inlet, net phytoplankton	13/02/2010	UPCB-75147	A, B
Thomas Point, Ezcurra Inlet, net phytoplankton	19/02/2010	UPCB-75148	A, B, G
Thomas Point, Ezcurra Inlet, net phytoplankton	25/02/2010	UPCB-75149	B
Macchu Picchu Point, Mackellar Inlet (62°05'S, 58°27'W), net phytoplankton	11/12/2009	UPCB-75150	A, B
Macchu Picchu Point, Mackellar Inlet, net phytoplankton	15/12/2009	UPCB-75151	B
Macchu Picchu Point, Mackellar Inlet, net phytoplankton	23/12/2009	UPCB-75152	B
Macchu Picchu Point, Mackellar Inlet, net phytoplankton	29/12/2009	UPCB-75153	A, B

Table 1. Continuation

Sampling sites, communities and codes of sampling stations	Sampling Date	Herbarium Number	Species Occurrence
Macchu Picchu Point, Mackellar Inlet, net phytoplankton	13/02/2009	UPCB-75154	A,B
Macchu Picchu Point, Mackellar Inlet, net phytoplankton	19/02/2010	UPCB-75155	A,B, G, L
Macchu Picchu Point, Mackellar Inlet, net phytoplankton	25/02/2010	UPCB-75156	A, B, G
Macchu Picchu Point, Mackellar Inlet, net phytoplankton	18/03/2004	UPCB-75157	G
Macchu Picchu Point, Mackellar Inlet, net phytoplankton	21/01/2004	UPCB-75158	A, B
Botany Point, Martel Inlet (62º05'S, 58º20'W), net phytoplankton	15/12/2009	UPCB-75160	B, G
Botany Point, Martel Inlet, net phytoplankton	23/12/2009	UPCB-75161	B
Botany Point, Martel Inlet, net phytoplankton	29/12/2009	UPCB-75162	A, B
Botany Point, Martel Inlet, net phytoplankton	13/02/2010	UPCB-75163	A, B
Botany Point, Martel Inlet, net phytoplankton	19/02/2010	UPCB-75164	A, B
Botany Point, Martel Inlet, net phytoplankton	25/02/2010	UPCB-75165	B
Brazilian Antarctic station (EACF) - Martel Inlet, net phytoplankton	11/12/2009	UPCB-75168	A
Brazilian Antarctic station (EACF) - Martel Inlet, net phytoplankton	15/12/2009	UPCB-75169	B
Brazilian Antarctic station (EACF) - Martel Inlet, net phytoplankton	23/12/2009	UPCB-75170	A, B
Brazilian Antarctic station (EACF) - Martel Inlet, net phytoplankton	29/12/2009	UPCB-75171	A, B
Brazilian Antarctic station (EACF) - Martel Inlet, net phytoplankton	13/02/2010	UPCB-75172	A, B
Brazilian Antarctic station (EACF) - Martel Inlet, net phytoplankton	19/02/2010	UPCB-75173	A, B
Brazilian Antarctic station (EACF) - Martel Inlet, net phytoplankton	25/02/2010	UPCB-75174	B, G
Brazilian Antarctic station (EACF) - Martel Inlet, net phytoplankton	21/01/2004	UPCB-75176	A, B
Brazilian Antarctic station (EACF) - Martel Inlet, net phytoplankton	14/12/2008	UPCB-75177	A
Lange Glacier, Admiralty Bay (62º06'S, 58º28'W), net phytoplankton	28/12/2009	UPCB-75179	B
Hennekin Point, Admiralty Bay, net phytoplankton	30/12/2007	UPCB-75180	A, B , L
Thomas Point, Ezcurra Inlet, net phytoplankton	27/12/2007	UPCB-75185	A, B, G
Thomas Point, Ezcurra Inlet, net phytoplankton	05/03/2008	UPCB-75186	A

Preparation and Observation of Samples

Preparation for analysis in light and electron microscopes followed the technique by Hasle & Fryxell (1970). Permanent slides were mounted with Naphrax resin (refractive index = 1.74, Northern Biological Supplies). Valves were measured and photographed using an Olympus BX-51 light microscope (LM) equipped with phase contrast. For scanning electron microscope (SEM), small drops of cleaned samples were placed on aluminum stubs and sputter-coated with gold (Balser DSC300) for observation with a Jeol-JSM 6360LV electron microscope at 15kV acceleration voltage and 8mm work distance. A few samples were mounted on a 150 mesh grid covered with formvar/carbon (Electron Microscope Supplies, USA) for examination in transmission electron microscopy (TEM) in a Jeol JM1200 EXII at 80 kV acceleration voltage.

Systematic treatment followed Round *et al*. (1990). Terminology was based on Ross *et al.* (1979), Cox & Ross (1980), Barber & Haworth (1981), and Honeywill (1998).

RESULTS

A total of four species of *Licmophora* were recorded, most occurring in all samples in both

Admiralty Bay and Elephant Island (Tab. 1). The species are described below.

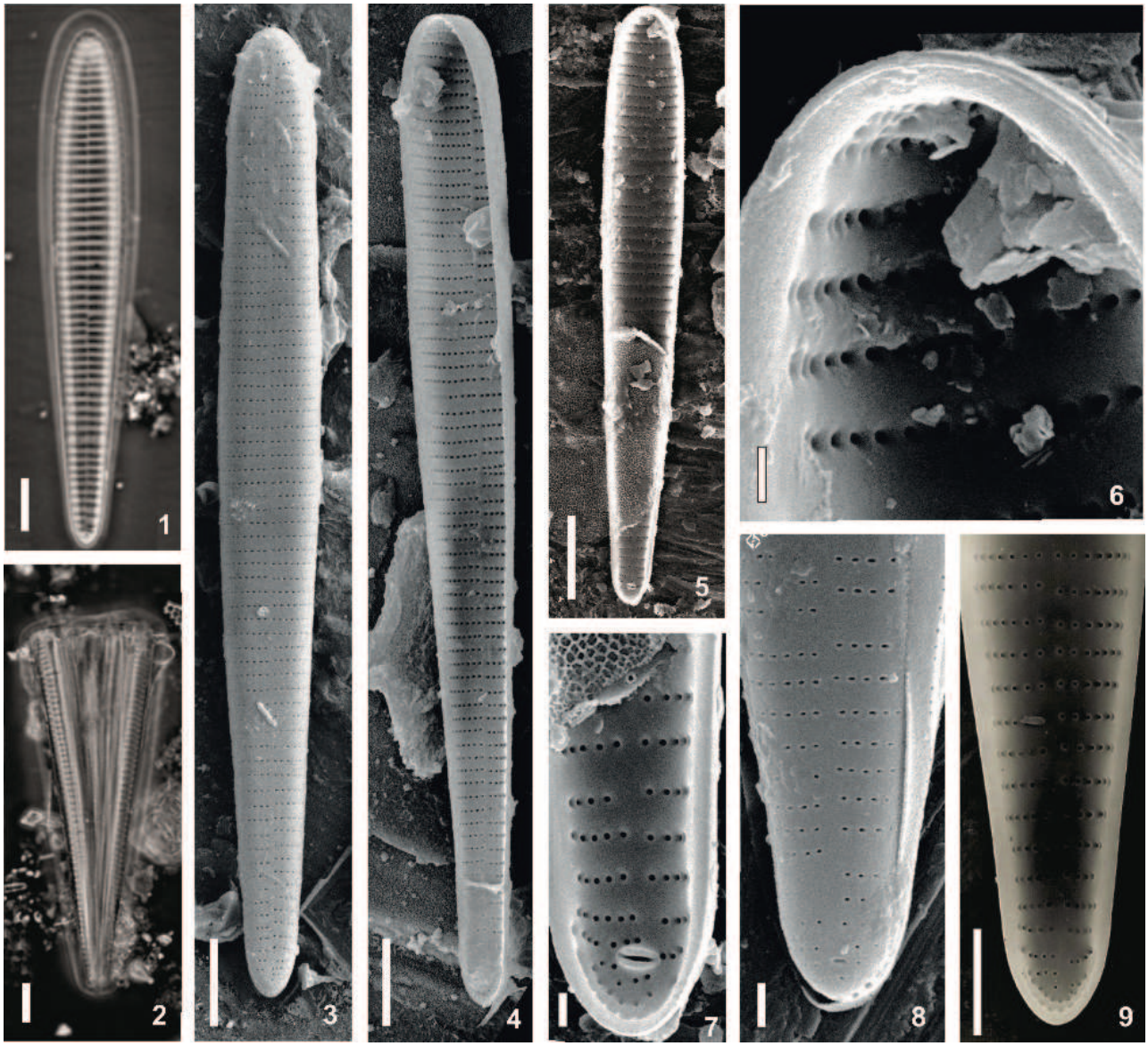
Licmophora antarctica M. Peragallo, Deuxième Expédition Antarctique Française, Botanique, p. 70, pl. 4, fig. 10, 1921.

(Figs. 1-9)

According to VanLandingham (1971), the name *L. antarctica* M. Peragallo (1921) is not valid, since there is a different species, *L. antarctica* Carlson (1913 in Süsswasser-Algen aus der Antarktis, Süd-Georgien und den Falkland Inseln, n.14, p.30, pl.3, figs 23, 24), described previously. Thus, this latter has the priority by the publication date. Taking into account that our material corresponds to the species described in Peragallo (1921). We provisionally use Peragallo's name until further nomenclatural investigations clarify its identity.

References: Peragallo (1921, p. 70, pl. 4, fig. 10), Frenguelli & Orlando (1958, p. 111, pl. 5, figs.1-2), Peragallo (1921, p. 70, pl. 4, fig. 10), Al-Handal & Wulff (2008b, p. 57, fig. 8, but corresponding to *L. antarctica* Peragallo)

LM Description: Valves are heteropolar, spathulate with rounded apices (Fig. 1); 62-160 µm apical axis, 7-9 µm transapical axis. Striae are uniseriate, 6-10 in 10 µm, opposite to slightly alternate. Each stria



Figs. 1-9. *Licmophora antarctica*. LM and SEM images. **1**. valve surface (LM); **2**. Frustule in girdle view (LM); **3**. External view of whole valve; **4, 5.** Internal view of valves; **6**. Internal view of head pole with sessile rimoportula located in the intersection of valve surface and mantle; **7.** Internal view, detailing the foot pole with large rimoportula on valve surface; **8**. External view of foot pole. Note slit of rimoportula; **9.** Internal view of foot pole lacking rimoportula. Multiscissura is visible in the mantle edge. Bars: **1-5** = 10 µm; 7 = 2 µm; **6, 8** = 1 µm; **9** = 5 µm.

has 14-18 rounded areolae in 10 µm. Sternum is very narrow, running the entire valve surface (Fig. 1). Three rimoportulae per frustule are present; rimoportula of the head pole difficult to observe, smaller than the basal one. Cingulum has 2-3 bands per theca (Fig. 2)

SEM Description: The striae are composed of rounded to slightly elliptical areolae (Figs. 3-9). Internally, the virgae are thicker than vimine (Figs. 6-7). At the foot pole, small pores are located between the striae and the multiscissura (Figs. 7-8). The basal rimoportula, when present, is a large elongated labiate structure, transapically oriented, on the inner side of the valve surface (Figs. 5, 7), opening to the outside through a small slit (Fig. 8). The apical rimoportula opens internally through a very short stalked labiate structure elongated in apical direction, located at the intersection of the valve surface and the mantle (Fig. 6), and is externally slit-like. The multiscissura has 14-16 slits (Figs. 7, 9).

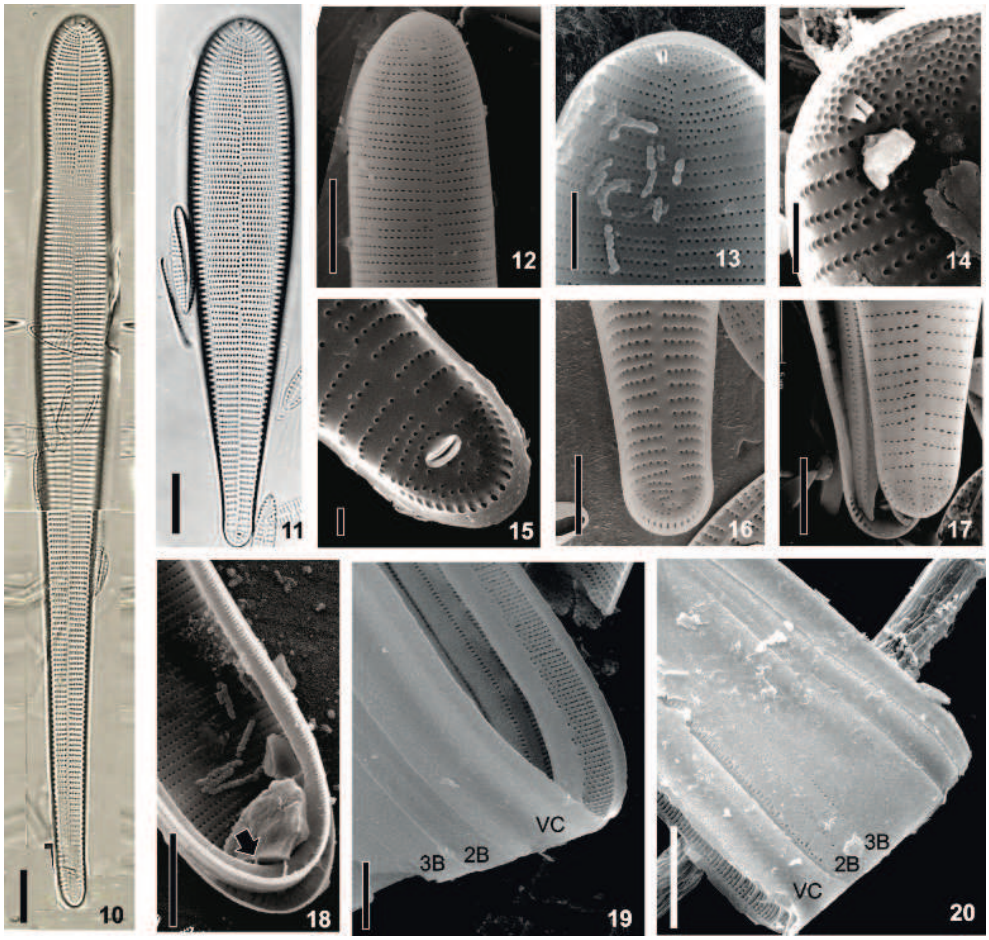
Ecology and distribution: epiphytic, accidental in the plankton; also recorded in bottom sediments (Al-Handal & Wulff 2008a). West of the Antarctic Peninsula: Margarita Bay, Kappa and Observatory Bay. North of the Antarctic Peninsula: King George Island (Frenguelli & Orlando 1958, Al-Handal & Wulff 2008b).

Licmophora belgicae M. Peragallo, Deuxième Expédition Antarctique Française, Botanique, p. 70, pl. 4, figs. 5-6, 1921.

(Figs. 10-20)

References: Peragallo (1921, p. 70, pl. 4, figs. 5-6), Frenguelli & Orlando (1958, p. 112, figs. 8-10), Hustedt (1958, p. 138), Simonsen (1992, p. 28, pl. 24, figs. 1-5 as *L. decora*), Cremer *et al*. (2003, p. 95, fig. 97, as *L. decora*).

LM Description: The valves are heteropolar, clavate with rounded apices (Figs. 10, 11) and a slight constriction at the foot pole; 78-131 µm apical axis, 11-18 µm transapical axis. Striae are uniseriate and transverse; 10-12 in 10 µm. Areolae are rounded, 16-20 in 10 µm. Sternum narrow. Virgae are irregular with different widths (Fig. 11). Three rimoportulae per frustule are present. The apical rimoportula is placed between the mantle and valvar surface. The rimoportula at the foot pole is larger than the one at



Figs. 10-20. *Licmophora belgicae*. LM and SEM images. **10, 11.** valves (LM); **11.** Note rimoportula in each pole of valve; **12.** External view of head pole showing slit of rimoportula; **13, 14.** Labiate structure of head pole rimoportula in internal view; **15, 16.** Internal views of foot pole, illustrating the presence **(15)** and the absence **(16)** of rimoportula, multiscissura is visible in the mantle; **17.** External view of foot pole lacking rimoportula, note bands of cingulum; **18-20**. Cingular bands; **18.** Valvocopula with shallow septum (arrow); **19, 20.** Striated valvocopula (VC) with septum (S) and hyaline strip (arrow), and longitudinally striated 2nd (2B) and 3rd (3B) bands. Bars: **10, 11** = 10 µm; **12-14, 16-20** = 5 µm; **15** = 1 µm.

the head pole, and is located on valve surface (Fig. 10).

SEM Description: Valves have transverse striae composed of rounded to slightly elongate areolae (Figs. 12-17). Virgae are thicker than vimine (Figs. 14, 15). The foot pole has small rounded pores between the larger striae and the multiscissura (Figs. 15, 16). A group of radiate striae is present at the margin of the head pole (Figs. 12-14). A basal rimoportula, when present, is located at the end of the sternum; internally, the labiate structure is shortly stalked, transapically oriented, located near the first striae (Fig. 15). The apical rimoportula is located between the mantle and valvar face; it opens externally by a slightly elongated slit (Fig. 12), coarser than the areolae and has an internal labiate structure, sessile and elongate in the apical direction (Fig. 14). The multiscissura has 18-24 slits (Figs. 15-16). The cingular bands are open; areolate (Figs. 17-20). The valvocopula is ligulate and has a rudimentary septum (Figs. 18-19) with 30-34 transverse striae in 10µm (Fig. 19). The remaining two bands have two rows of poroids running in apical direction (Figs. 19, 20).

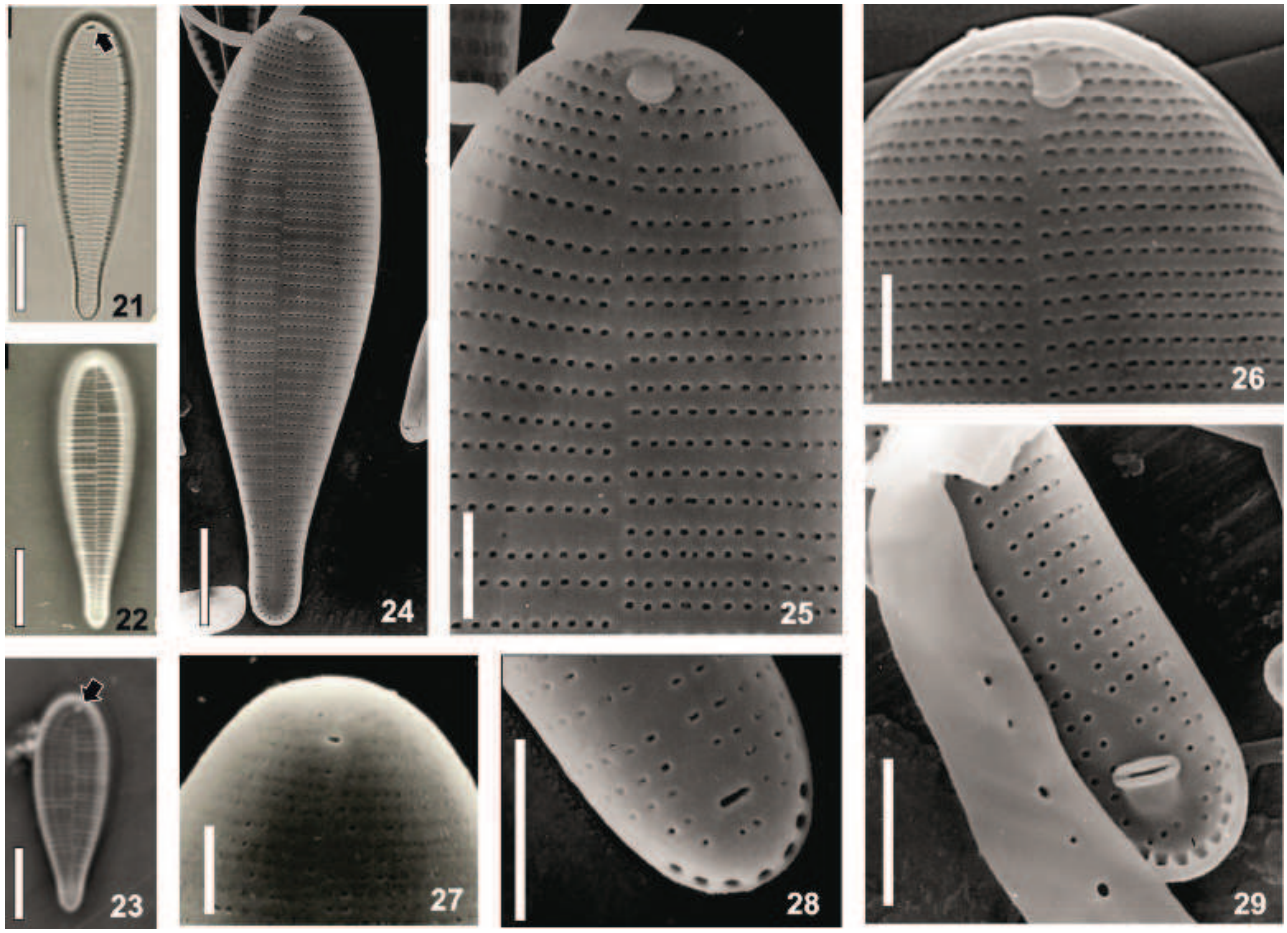
Ecology and distribution: epiphytic, accidental in the plankton. Recorded North of the Antarctic Peninsula: King George Island; West of the Antarctic Peninsula: Pettermann Island (Peragallo 1921, Hustedt 1958, Frenguelli & Orlando 1958, Krebs 1983, Ahn *et al*. 1994 (as *L. luxuriosa*), Cremer *et al*. 2003).

Licmophora gracilis (Ehrenberg) Grunow, Botanischer Theil, Algen, p. 34, pl. 17, fig. 6, 1867.

(Figs. 21-34)

References: Grunow (1867, p. 34, pl. 17, fig. 6), Frenguelli & Orlando (1958, p. 112, pl. 4, figs. 38-42), Honeywill (1998, p. 239, figs 9a-h), Witkowski *et al*. (2000, p. 65, pl. 18, figs. 12-15, pl. 19, figs. 7-15), Cremer *et al*. (2003, p. 95, figs. 98-99), Al-Handal & Wulff (2008a, p. 58, figs. 29-30).

LM Description: The valves are heteropolar, spathulate (Figs. 21-23), or clavate (Figs. 30, 31) with rounded apices; 21-69 µm apical axis, 5-10 µm



Figs. 21-29. *Licmophora gracilis*. Spathulate valves in LM and SEM. **21-23.** small specimens (LM). Note rimoportula in **21** and **23** (arrows); **24.** Whole valve in internal view; **25, 26.** Head poles in internal view; rimoportula is short stalked; **27.** Head pole in external view with a rimoportula slit; **28.** Detail of foot pole in external view showing rimoportula slit and multiscissura; **29.** Labiate structure of inclined rimoportula at the foot pole in internal view. Bars: **21-23** = 10 µm; **24** = 5 µm; **25-29** = 2 µm.

transapical axis. The foot pole is somewhat rostrate. Striae are delicate and uniseriate, 16-26 in 10 µm. The virgae are arranged irregularly over the valve surface. The sternum is very narrow (Fig. 22). Two rimoportulae per frustule are present; one in the foot pole of one valve and the other in the head pole of the other valve (Figs. 21, 23, 30, arrows).

SEM Description: The valves have transverse striae composed of 16-20 areolae in 10 µm (Figs. 24, 32). Areolae are rounded (Figs. 25, 33) to slightly elongated (Fig. 26) in the transapical direction. The rimoportula of the head pole is labiate and stalked, transapically oriented (Figs. 25-26) in inner view; opened through an elongated slit on the valvar surface, externally (Fig. 27). At the foot pole, the rimoportula is located on the valve surface, internally it is labiate and short stalked, transapically oriented (Figs. 29, 33, 34), being larger than the one at the head pole. Its external aperture is an elongated slit (Fig. 28). The multiscissura is composed of 7-9 slits (Figs. 28, 29, 34). The valvocopula has a rudimentary septum.

Ecology and distribution: epiphytic and growing on sediments, accidental in the plankton (Al-Handal & Wulff., 2008a). The species was recorded west of the Antarctic Peninsula: Port Melchior, Kappa and Observatory Bay and north of the Antarctic Peninsula: King George Island (Frenguelli & Orlando 1958, Al-Handal & Wulff 2008a). It is a common species in Europe and Arctic coasts (Witkowski 2000).

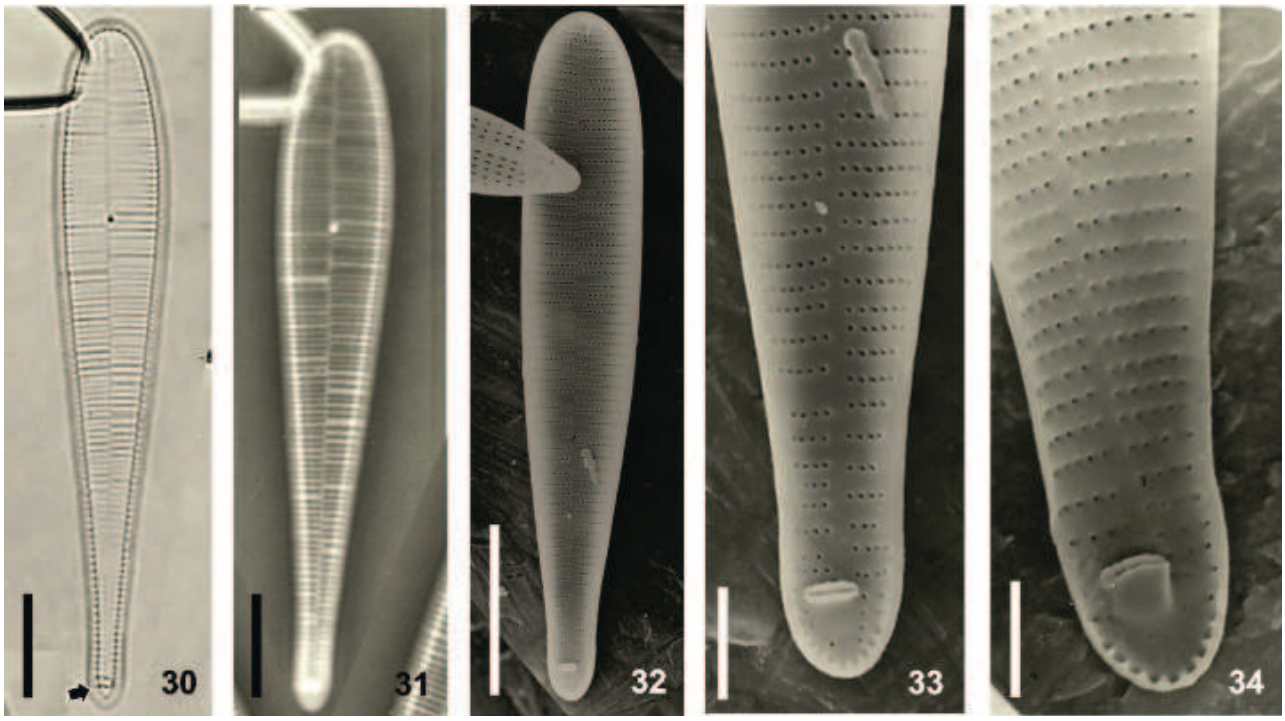
Licmophora luxuriosa Heiden *in* Heiden & Kolbe, Botanik, v. 8, n.5, p. 572; pl. 6, figs. 140, 141, 1928.

(Figs. 35-44)

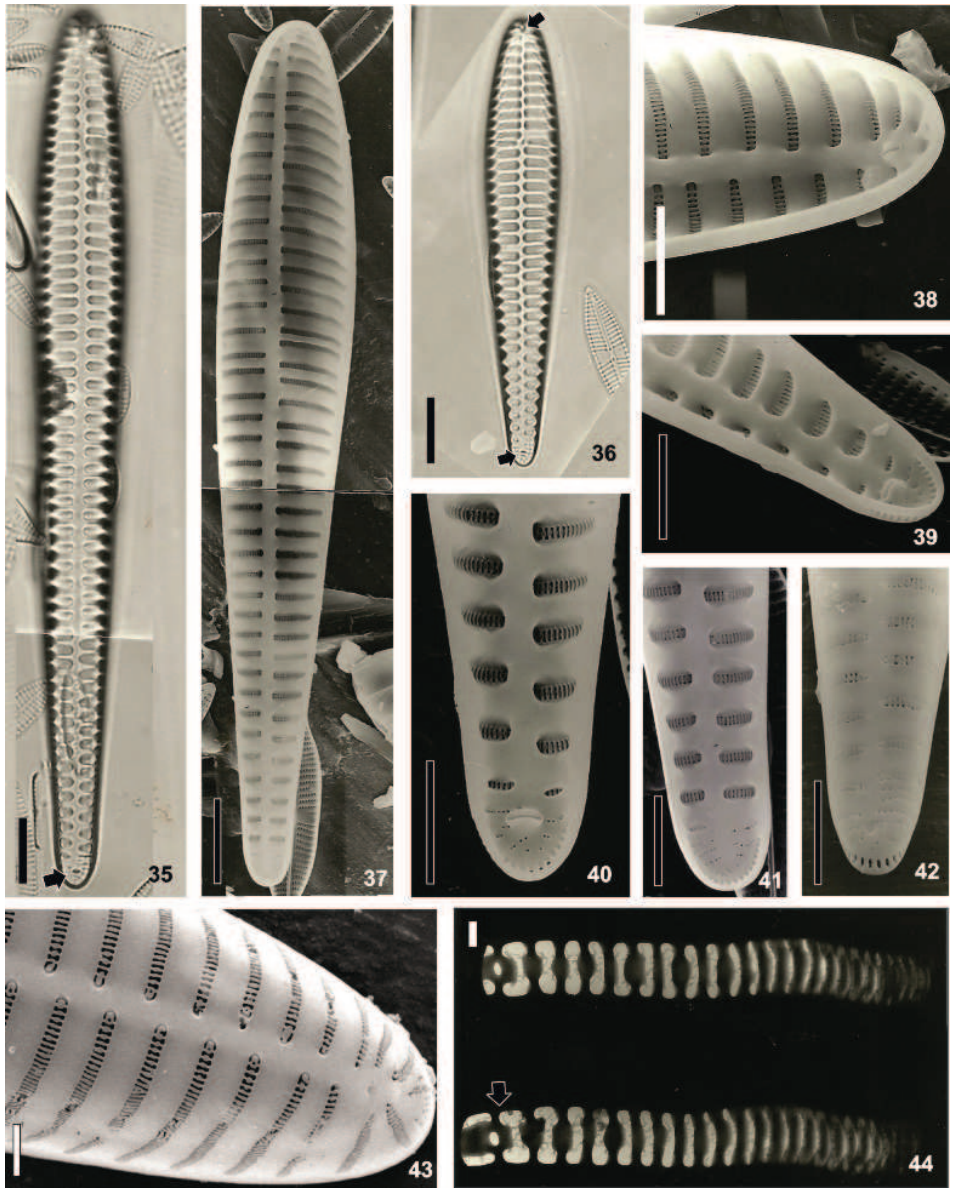
References: Heiden & Kolbe (1928, p. 572, pl. 6, figs. 140-141), Hendey (1937, p. 337), Simonsen (1992, p. 28, pl. 25, figs. 1-7, pl. 26, figs. 1-3), Al-Handal & Wulff (2008b, p. 429, figs. 9-15).

LM Description: Valves are heteropolar, clavate with rounded apices (Figs. 35, 36); 41-109 µm apical axis, 11.5-19 µm transapical axis. Transverse striae are uniseriate and robust; 5-7 in 10 µm, composed of delicate areolae. The sternum is straighter and wider (Fig. 35) than other species. Three elongated rimoportulae are present in the frustule. In the case of a valve presenting one rimoportula, this structure occurs in the head pole. In valves having two rimoportulae, the one located in the foot pole is larger than the one at the head pole (Figs. 35, 36, arrows).

SEM and TEM Descriptions: Valves have transverse striae (Fig. 37) composed of 44-55 areolae in 10 µm. Striae in the head pole become strongly radiate (Figs. 38, 43). Virgae are large, coarsely silicified internally (Figs. 38-40). The areolae are elongated in



Figs 30-34. *Licmophora gracilis*. **30, 31.** (LM) and **32-34** (SEM); **30.** Valve in bright field with a large rimoportula at foot pole (arrow); **31.** Same valve in face contrast; **32.** Whole valve in internal view; **33, 34.** Internal views of foot pole detailing slightly different rimoportulae, and multiscissura. Bars: **30-32** = 10 µm; **33-34** = 2µm.



Figs 35-44. *Licmophora luxuriosa.* **35, 36.** Valves with rimoportulae (arrows) (LM); **37-43.** SEM; **37.** Whole valve in internal view; **38.** Head pole with sessile rimoportula in internal view; **39-41.** Internal views of foot poles with (**39, 40**) or without (**41**) rimoportula. Multiscissura and striae with small poroids are also visible; **42.** Multiscissura at the end of foot pole in external view; **43.** External view of valvar surface composed of striae and large virgae; **44.** TEM detailing occlusion of areolae. Rota-like structures (arrow) are present at every vimine next to the sternum. Bars: **35-37** = 10 µm; **38-42** = 5 µm; **43** = 2 µm; **44** = 30nm.

the apical direction, juxtaposed (Figs. 38-44). The velum is sustained by irregular pegs (Fig. 44). The areolae next to the sternum have a C-shaped morphology (Fig. 43) due to an expansion of the vimine, also forming a central circle (Figs. 43, 44, arrow). In the foot pole there are small rounded pores arranged in radiate rows, between the last two large striae and the multiscissura (Figs. 40, 41). The rimoportula at the foot pole, located on the valve surface has a circular external opening (Fig. 42) and an internal short stalked large labiate structure, transapically oriented (Figs. 39, 40). On the head pole, the rimoportula has an outer circular aperture (Fig. 43), opening inside through a labiate sessile structure, apically oriented, and located between the valve surface and the mantle (Fig. 38). The multiscissura has 18-20 slits (Figs. 40-42).

Ecology and distribution: Epiphytic (Al-Handal & Wulff 2008b). The species has been recorded north of the Antarctic Peninsula: King George Island and Bransfield Strait (Hendey 1937, Ahn *et al*. 1994, Al-Handal & Wulff 2008b).

DISCUSSION

In this study, the four species of *Licmophora* were found in almost all sampling points, and during different years of sampling, especially the collection from Admiralty Bay. *Licmophora antarctica* M. Peragallo, *L. belgicae*, and *L. gracilis* were particularly frequent in that area. These results indicate the widespread distribution of *Licmophora* in the studied region. In other neritic areas of the Antarctic Peninsula, the genus has been frequently reported in shallow waters like in Potter Cove (Klöser 1998, Al-Handal & Wulff 2008a, 2008b), Maxwell Bay (Ahn *et al.* 1997), Peterson Islands and Lockroy (Peragallo 1921), Anvers Islands, Margarita Bay, and Deception Islands (Frenguelli & Orlando 1958). To date, the most abundant species in these previously investigated areas were *L. antarctica* M. Peragallo, *L. belgicae*, and *L. gracilis*. Furthermore, ecological studies carried out in similar regions have revealed the significant contribution of *Licmophora* and other benthic diatoms for both the plankton and the benthic communities in shallow waters in different zones of Antarctica (Krebs 1983, Everitt & Thomas 1986, Ahn *et al*. 1994, Lange *et al.* 2007). Although no quantitative analyses have been performed in our work, Lange *et al*. (2007) investigated the phytoplankton ecology in Admiralty Bay during the summers of 2003 and 2004, simultaneously to our sampling stations. The authors found that the contribution of *Licmophora* (and other benthic pennates) to the phytoplankton biomass was almost as large as 'typical' planktonic species.

Licmophora antarctica M. Peragallo is an easily recognizable species due to its elongated valve, large and rounded areolae, and coarser striation (6-10 in 10µm) on the valve surface, also having large virgae between the striae (Peragallo 1921, Frenguelli & Orlando 1958, Al-Handal & Wulff 2008b). The dimensions of *L. antarctica* M. Peragallo found in the present study overlap and even expand the data found in the original description, which reported valves 140-150 µm long and with 7 striae in 10 µm (Peragallo 1921). Al-Handal & Wulff (2008b) recorded specimens with a slightly higher number of striae (10-12 in 10µm) and a wider transapical axis (7-11 µm) (Tab. 2). *Licmophora antarctica* M. Peragallo is similar to *L. belgicae*, though the latter is more densely striated (6-10 in 10 µm in the former, usually 10-12 in 10 µm, rarely lower; 9-10 in 10 µm in the latter) (Peragallo 1921, Frenguelli & Orlando 1958, Hustedt 1958, Simonsen 1992, Al-Handal & Wulff 2008a). *Licmophora antarctica* M. Peragallo has 14-16 slits composing the multiscissura, while in *L. belgicae* there is a larger number (18-24). Moreover, the valve shape is different between the two species, spathulate in *L. antarctica* M. Peragallo and clavate in *L. belgicae*.

Regarding *L. belgicae*, our specimens showed similar dimensions of apical and transapical axes and overall shape compared to the material investigated by previous authors (Heiden & Kolbe 1928 as

Table 2.Comparative morphological data of selected species of *Licmophora*, and of the material investigated from the Antarctic Peninsula.

	Length (µm)	Maximum Width (µm)	Transapical striae in 10 µm	Areolae in 10µm	Multiscissura slits	Septum	Basal Rimoportula	Head Rimoportula
L. abbreviata [1, 2]	30-80	7-13	13-16	60	11-12	moderately deep	short stalk	short stalk
L. antarctica [3, 4, 5]	35-150	6-12	7-12	13-16	11-12	ND	ND	ND
L. belgicae [3, 4, 5, 6, 7, 8]	40-223	11-22	8.5-14	30	ND	ND	ND	ND
L. ehrenbergii [1]	53-78	9-16	11	55	14	moderately deep	short stalk, inclined	no stalk
L. gracilis [1, 2, 6]	18-45	4-8	18-26	26	14	rudimentary	stalked, upright	short stalk
L. luxuriosa [3, 4, 7]	58-172	8-21	5-8	ND	ND	moderately deep	ND	ND
L. antarctica (this study)	62-160	7-9	6-10	14-18	14-16	not found	short stalk, upright	short stalk
L. belgicae (this study)	78-130	11-18	10-12	16-20	18-24	rudimentary	short stalk, upright	short stalk
L. gracilis (this study)	21-69	5-10	16-26	16-20	7-9	rudimentary	stalked, inclined	stalked, inclened
L. luxuriosa (this study)	41-109	11.5-19	5-7	44-55	18-20	not found	short stalk, inclined	sessile

[1] Honeywill (1998), [2] Wahrer et al. (1985), [3] Al-Handal et al. (2008a), [4] Al-Handal et al. (2008b), [5] Peragallo (1921), [6] Frenguelli & Orlando (1958), [7] Heiden & Kolbe (1928) [8] Hustedt (1958). ND = no data.

L. decora, Frenguelli & Orlando 1958, Hustedt 1958, Al-Handal & Wulff 2008a as *L. decora*), and summarized in Tab. 2. On the other hand, the number of striae (10-12 in 10 µm, in our material) was more discrepant in relation to recorded literature elsewhere. Van Heurck (1909, as *L. reichardtii* var. ?) found coarser striated valves, 8.5-10 striae in 10 µm. Al-Handal & Wulff (2008a) recorded more finely striated specimens, ranging from 12 to 14 in 10 µm. Only Frenguelli & Orlando (1958) provide a similar range of striae - 9.5 - 10 in 10 µm - to that found in the present material.

With respect to the nomenclature of *L. belgicae*, Heiden & Kolbe (1928) described *L. decora* Heiden based on the unnamed variety *Licmophora reichardtii* var. *?* of Van Heurck (1909, pl. 3, fig. 1). Later, Hustedt (1958:138) considered *L. decora* a synonym of *L. belgicae* M. Peragallo. To corroborate this nomenclatural change, we examined Heiden´s microscope slide (n. 283/43) deposited at the Friedrich Hustedt Diatom Study Centre, and the illustrations in Simonsen (1992:28, Pl. 24, Figs. 1-5). We found valves very similar to *L. belgicae*, as well as identical dimensions to the description of Peragallo (1921), particularly the number of striae, 8.5 - 10.0 in 10 µm. We concluded the species is the same in both the references; therefore, *L. belgicae* has precedence over *L. decora*, as proposed by Hustedt (1958).

Licmophora luxuriosa is a large and heavily silicified species with a distinctly clavate shape, besides specific valve features (Tab. 2). The only closely related species is *L. ehrenbergii* (Kützing) Grunow, though this latter has spathulate valves (Honeywill 1998). *Licmophora luxuriosa* has 5-7 robust striae in 10 µm, while *L. ehrenbergii* is more densely striated, 10-11 striae in 10µm. The fine morphology of the valve reveals discrete differences; the most important is related to the velum covering of areolae. Both the species show the vimines close to the C-shaped sternum and they are modified to form rota-like structures. However, in *L. luxuriosa* the velum is supported by irregular pegs which are also more spread out when compared to *L. ehrenbergii*. The velum in this species has a higher number of pegs and arranged more regularly one to another (Honeywill 1998: 235, Fig. 3i). In both the species there is a large rimoportula possessing a short stalk at the foot pole, but sessile in the head pole. Another species bearing some resemblance with *L. luxuriosa* is *Licmophora abbreviata* Agardh, since both have the same overall shape and coarser striae than the other species (Tab. 2), except for *L. ehrenbergii* (see above). However, *L. abbreviata* is more finely striated (15-17 striae in 10 µm), showing a higher number of areolae per striae (60 in 10 µm) and the multiscissura is composed of 9-13 slits (Honeywill 1998), against 18-20 slits in *L. luxuriosa*. Finally, the structure of areolae in *L. abbreviata* is characteristic, each poroid having rounded sides, and the one associated with the sternum is D-shaped, lacking the rota-like vimines as in *L. ehrenbergii* (Honeywill 1998) or *L. luxuriosa* (this paper). Our material of *L. luxuriosa* presented general dimensions very close to the valves reported in the original description (Heiden & Kolbe 1928, Simonsen 1992) and in the other few publications from different locations of Antarctica (Al-Handal & Wulff 2008b). Hendey (1937) reported valves as wide as 18 - 26 µm. To confirm the measurements taken by Heiden & Kolbe (1928), the lectotype (slide 283/44) and isolectotype (slide 283/43) designated by Simonsen (1992) and deposited at the Friedrich Hustedt Diatom Study Centre were accessed. The valves examined included all the specimens photographed by Simonsen (1992, Plates 25 and 26), presenting the following dimensions: 96.7 - 121.0 µm length, 10.7 - 13.3 µm width and 6-8 striae in 10 µm. Therefore, the apical axis and the number of striae of our material fit well in the original data of Heiden & Kolbe (1928), while the range of valve width was somewhat smaller than the range furnished in the original description (13-21 µm). The cingulum was observed in the original material, the valvocopula being septate and finely striate, about 29-30 striae in 10 µm (see Plate 26, Fig. 3 in Simonsen 1992).

From the four species investigated in this work, *L. gracilis* is the only one that has been studied by electron microscopy previously; hence allowing a more detailed comparison of the valve morphology (Tab. 2). The number of striae of the present material showed a large range, 16 to 26 striae in 10 µm. It is important to remark that, since we found valves with such a range of striae occurring in the same sample, we did not separate the species in its varieties, namely the nominal and var. *anglica*. To date, the differentiation between them resides in the striae density, that is, coarse (20-23 in 10 µm) in the nominal variety and finer (24-26 in 10 µm) in *L. gracilis* var. *anglica* (Peragallo 1897-1905, Hustedt 1931-1959, Witkowski *et al*. 2000). Our specimens also presented a complete transition of valve shape; from small spathulate valves (Figs. 21-24) to larger and clavate forms (Figs. 30-32). The fine morphology of *L. gracilis* in our material agrees with

that described in Honeywill (1998), regarding poroid structure and rimoportulae features (Tab. 2). Only the multiscissura had 7-9 elongated slits in our material, compared to the nine recorded in Honeywill (1998).

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