The genus *Stauroneis* (Bacillariophyta) from the South Shetland Islands and James Ross Island (Antarctica)

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Abstract: During a survey of the freshwater aquatic and limno–terrestrial diatom flora of the Maritime Antarctic Region, five taxa belonging to the genus *Stauroneis* that could not be identified were observed. Based on detailed LM and SEM observations, these five taxa have been described as new taxa: *Stauroneis australobtusa* sp. nov., *S. acidojarensis* sp. nov., *S. delicata* sp. nov., *S. jamesrossensis* sp. nov. and *S. reichardtiopsis* sp. nov. Comments are made on their taxonomic position and separation from other species in this genus. Brief notes on the ecology and distribution of the five taxa are added. A compiled list of all *Stauroneis* taxa present in the (sub–)Antarctic region is included in this paper and their biogeography based on the compiled data is discussed.

Key words: *Stauroneis,* Bacillariophyta, Antarctica, taxonomy, morphology, biogeography

Introduction

During the past decade the limno–terrestrial diatom flora of the (sub–)Antarctic region has been a subject of a thorough taxonomic revision. Detailed and more critical taxonomic analyses of the species in several diatom genera, such as *Navicula* Bory (Van de Vijver et al. 2011a), *Muelleria* (Frenguelli) Frenguelli (Van de Vijver et al. 2010, 2014), *Luticola* D.G. Mann (Van de Vijver & Mataloni 2008; Van de Vijver et al. 2011b; Kopalová et al. 2011; Zidarova et al. 2014), *Pinnularia* Ehrenberg (Van de Vijver & Zidarova 2011; Zidarova et al. 2012), *Hantzschia* Grunow (Zidarova et al. 2010) and *Surirella* Turpin (Van de Vijver et al. 2013) clearly showed that the diversity of the Antarctic diatoms has been largely underestimated in the past, as well as that the Antarctic diatom flora is highly specific with a large number of taxa presenting a restricted Antarctic distribution. Moreover, based on the diatom species diversity, a clear biogeographical separation could be determined between the different parts of the Antarctic Region as defined by Chown & Convey (2007): Sub–Antarctica (comprising the islands in the southern Indian Ocean and South Georgia), Maritime Antarctica and the Antarctic continent (i.e. Van de Vijver et al. 2010, 2011a, 2011b, 2013; Zidarova et al. 2010, 2012; Van de Vijver & Zidarova 2011; etc.).

In 2004 Van de Vijver et al. studied the genus *Stauroneis* in more than 850 samples taken from bryophytes, soils and lake sediments from various locations from both the (sub–) Antarctic and the Arctic Regions. This survey resulted in the observation of 25 different *Stauroneis* taxa, 17 of which were described as new to science. The genus *Stauroneis* was erected by Ehrenberg in 1843. Round et al. (1990) characterized the genus by the presence of a typical "stauros", extending from the raphe sternum to the valve margins and uniseriate striae composed of small rounded or transapically elongated poroids. Further analysis of the presence of these taxa in the (sub–)Antarctic Region, based on the same set of samples (Van de Vijver et al. 2005), suggested for first time that a clear biogeography can be produced between the different regions in (sub–) Antarctica based on diatom species occurrence.

However, most of the investigated samples in the 2004 study were collected on the islands in the southern Indian Ocean with only a handful of samples taken from the Maritime Antarctic region (King George Island). Since then, apart from several sparse *Stauroneis* records from the latter region (Zidarova et al. 2008; Kopalová et al. 2012) and the description of one new taxon (Zidarova et al. 2009), almost no new data for the genus *Stauroneis* in Maritime Antarctica were published, greatly limiting our knowledge on the diversity and biogeography of the genus in this region.

The present paper is a review on the species diversity in the genus *Stauroneis* in two localities in the Maritime Antarctic region: the South Shetland Islands and James Ross Island. During this survey, four taxa could not be identified using the currently available literature. These are described here as new for science and compared with morphologically similar species previously described from the Antarctic Region and elsewhere. Data about their ecology and biogeography are added. A list of all *Stauroneis* taxa present in the entire Antarctic Region is provided together with their actually known distribution and their biogeography is discussed.

Study area

1. South Shetland Islands

The South Shetland Islands (63°00'S, 60°00'W), located at about 130 km northwest of the Antarctica Peninsula (Fig. 1), belong to the Maritime Antarctic Province (Chown & Convey 2007). The archipelago comprises a series of 11 larger and many small islands, islets and rocks. Samples in the present study were obtained from several large islands: King George Island, Livingston Island, Nelson Island and Deception Island. The climate of the islands is typically maritime, with mean annual temperature around –5 °C, high precipitation levels and strong westerly winds (Toro et al. 2007). Most of the islands are covered by permanent ice and snow leaving only small parts, mainly on the coastal areas, ice–free in summer. The vegetation is limited to lichens and bryophytes with small patches of only two flowering plants: *Colobanthus quitensis* (Kunth) Bartl. and *Deschampsia antarctica* Desv.

2. James Ross Island

James Ross Island (64°10'S, 57°45'W) is located in the northern Weddell Sea, close to the northern tip of the Antarctic Peninsula (Fig. 1). The island is situated in the transitory zone between the Maritime Antarctic and Continental Antarctic regions (Øvstedal & Lewis–Smith 2001). The mean annual air temperature rarely exceeds –5 °C at sea level with the mean summer temperature slightly below 0 °C (Schwerdtfeger 1984). Compared to the South Shetland Islands, James Ross Island is more arid (Komárek & Elster 2008). The vegetation of the island is composed of a predominantly bryophyte and lichen tundra. Vascular plants are absent.

Materials and Methods

Samples from the study were obtained during several austral summers between 2003 and 2013. For light microscopy (LM) diatom samples were prepared following different methods. A small part of each sample was treated following the method of Van der Werff (1955): sub–samples were cleaned by adding 37% H_2O_2 and heated to 80 °C for about 1h followed by addition of $KMnO_4$. Following digestion and centrifugation (×3 for 10 min at 3700 g), the resulting clean material was diluted with distilled water to avoid excessive concentrations of diatom valves. Another set of the samples was prepared according to the method described in Hasle & Fryxell (1970): small sub–samples were cleaned using concentrated H_2SO_4 followed by the addition of $KMnO_4$. The samples were then faded with $H_2C_2O_4$ and washed with distilled water (×8). Cleaned diatom valves were mounted in Naphrax®.

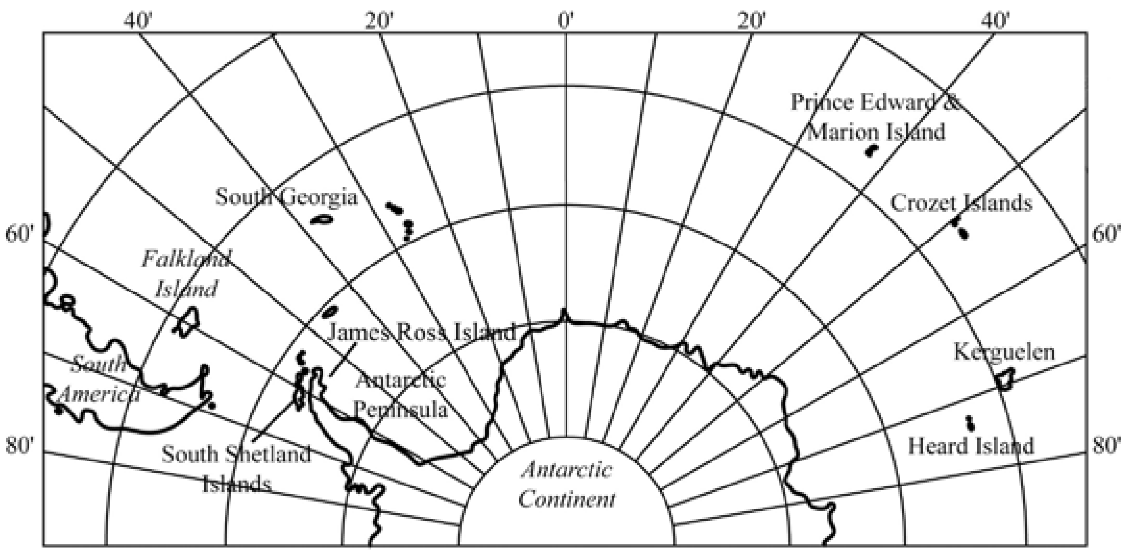


Fig. 1. Map of the region, showing the position of the South Shetland Islands and James Ross Island.

Light microscopy observations were done at the Botanic Garden Meise (Belgium) and University of Sofia (Bulgaria) in Olympus BX51 and Olympus BX53 microscopes equipped with Differential Interference Contrast (Nomarski) optics and digital imaging cameras.

For scanning electron microscopy (SEM), part of the suspension was filtered through polycarbonate membrane filters (pore diameter 1 µm), pieces of which were fixed on aluminium stubs after air–drying. SEM studies were done in a ZEISS ULTRA SEM microscope at 3 kV (Natural History Museum London, UK) where the stubs were sputter–coated with a Gold–Palladium layer of 20 nm, except for Fig. 57, for which the observations were done at the Botanic Garden Meise (Belgium) after the stubs were sputter–coated with a 50 nm layer of Gold and examined in a JEOL–5800LV SEM at 20 kV.

Terminology follows Ross et al. (1979), Round et al. (1990) and Van de Vijver et al. (2004).

For comparisons of the new taxa with similar taxa the following literature was used: Lange–Bertalot & Metzeltin (1996), Rumrich et al. (2000), Lange–Bertalot et al. (2003), Van de Vijver et al. (2004), Werum & Lange–Bertalot (2004) and Metzeltin et al. (2009).

In addition, the type slides of the following *Stauroneis* taxa have been investigated:

- *S. acidoclinata* Lange–Bertalot & Werum (Praep. "Quellen" n° 3290 in Coll. Lange–Bertalot, Bot. Institut Universität Frankfurt am Main);
- *S. amplipora* Lange–Bertalot et al. (Praep. n° EU–I–107 in Coll. Lange–Bertalot, Bot. Institut Universität Frankfurt am Main);
- *S. jarensis* Lange–Bertalot et al. (Praep. n° EU–I–107 in Coll. Lange–Bertalot, Bot. Institut Universität Frankfurt am Main).
- *S. reichardtii* Lange–Bertalot et al. (Praep. n° EU–I–109A in Coll. Lange–Bertalot, Bot. Institut Universität Frankfurt am Main).

The biogeography of the species (Table 1) is based on Hustedt (1937), Lange–Bertalot et al. (2003), Werum & Lange–Bertalot (2004), Van de Vijver et al. (2004, 2005) and our own observations (incl. unpublished data).

Results and Observations

During the survey, a relatively high species diversity was recorded in the genus *Stauroneis* with a total of 11 taxa. A compiled list of all taxa, present in the (sub–) Antarctic Region with their geographic distribution range is given in Table 1. Six of the eleven recorded taxa have already been known from the Antarctic Region whereas one species has been found outside Antarctica (Table 1). For an eight taxon, previously reported from Maritime Antarctica as *Stauroneis* aff. *acidoclinata* Lange–Bertalot et Werum (Van de Vijver et al. 2004, 2005; Zidarova 2008), detailed observations on its populations from the South Shetland Islands and comparisons with the type of *S. acidoclinata* revealed that the Antarctic populations cannot be assigned to *S. acidoclinata* and therefore here the species is described as new: *S. acidojarensis* sp. nov. For another taxon, reported in Van de Vijver et al. (2004) as *S. subgracilior* "Peninsula" Lange–Bertalot et al., further investigations showed that the taxon has to be separated from *S. subgracilior sensu stricto* and is described here as *S. delicata* sp. nov. During the survey, three other taxa could not be assigned to any of the known *Stauroneis* species and they are described here as new: *S. australobtusa* sp. nov., *S. jamesrossensis* sp. nov. and *S. reichardtiopsis* sp. nov. Descriptions of the new species with comparisons with similar taxa and their so far known ecology and geographic distribution data are given below:

Stauroneis australobtusa sp. nov. (Figs 2–12)

Description

Light microscopy: In girdle view, frustules rectangular with a flat valve face (Fig. 8). Valves narrowly lanceolate with convex margins and weakly protracted, obtusely rounded apices (Figs 2–7). Pseudosepta distinct and always present at each valve pole (Fig. 3). Valve dimensions (n=17): length 34.1–58.0 µm, valve width 8.0–12.0 µm. Axial area relatively narrow, linear, not or occasionally only slightly widening toward the central area (Figs 6, 7). Central area expanded into a butterfly shaped stauros, moderately enlarging toward the margins. Raphe straight, filiform with with weakly curved, drop–like expanded proximal raphe endings (Figs 2, 4–7). Distal raphe fissures elongated, hooked. Transapical striae weakly to moderately radiate in the valve middle, becoming slightly more radiate toward the apices, 18–20 in 10 µm. Areolae coarse, visible in LM, ca. 18–23 in 10 µm.

Scanning electron microscopy: Externally (Fig. 9), striae continuing onto the mantle, composed of transpically elongated areolae. Some of the areolae of the most inner row clearly rounded. External proximal raphe endings distinctly laterally curved, terminating in drop–like pores (Fig. 9). Distal raphe fissures elongated, continuing onto the mantle, sickle–shaped to the same direction as the proximal raphe endings (Fig. 9). Internally, distinct, large pseudosepta present at each valve apex (Figs 10–12). Internal raphe branches straight with straight proximal raphe endings terminating onto a well developed stauros (Figs 10, 11). Internally areolae covered by hymenes (Fig. 11). Girdle bands clearly perforated (Fig. 12).

Holotype (designated here)**:** BR–4385 (Botanic Garden Meise, Belgium).

Isotypes (designated here)**:** PLP–270 (University of Antwerp, Belgium), BRM–ZU9/80 (Hustedt Collection, Bremerhaven, Germany).

Type locality: Byers Peninsula, Livingston Island, South Shetland Islands, sample BYM039 (Leg. B. Van de Vijver; coll. date 12/01/2009).

Etymology: The specific epithet refers to the similarity

Table 1. List of all *Stauroneis* species present in the (sub–)Antarctic region with their known distribution in Maritime Antarctica, the Antarctic Continent and Sub–Antarctica, and their presence outside Antarctica.

	Maritime Antarctic Region		**Antarctic Continent**	**Sub–Antarctica**		**outside Antarctica**
	South Shetland Islands	James Ross Island		Southern Indian Ocean	South Georgia	
Taxa observed in the present study						
S. acidojarensis sp. nov.	X					
S. australobtusa sp. nov.	X					
S. delicata sp. nov.	X				X	
S. huskvikensis Van de Vijver et Lange–Bertalot	X				X	
S. jamesrossensis sp. nov.	X	X				
S. latistauros Van de Vijver et Lange–Bertalot	X	X	X		X	
S. minutula Hustedt	X					X
S. nikolayi Zidarova	X					
S. pseudomuriella Van de Vijver et Lange–Bertalot	X	X		X		
S. pseudoschimanskii Van de Vijver et Lange–Bertalot	X	X			X	
S. reichardtiopsis sp. nov.	X					
Taxa observed in other recent studies						
S. acuta W.Smith					X	
S. bryocola Van de Vijver et Lange–Bertalot				X		
S. catharinae Van de Vijver et Lange–Bertalot				X		
S. catharinella Van de Vijver et Lange–Bertalot				X		
S. cf. *respectabilis* Lange–Bertalot et al.						X
S. fluminopsis Van de Vijver et Lange–Bertalot				X		
S. gracilis Ehrenberg				X	X	X

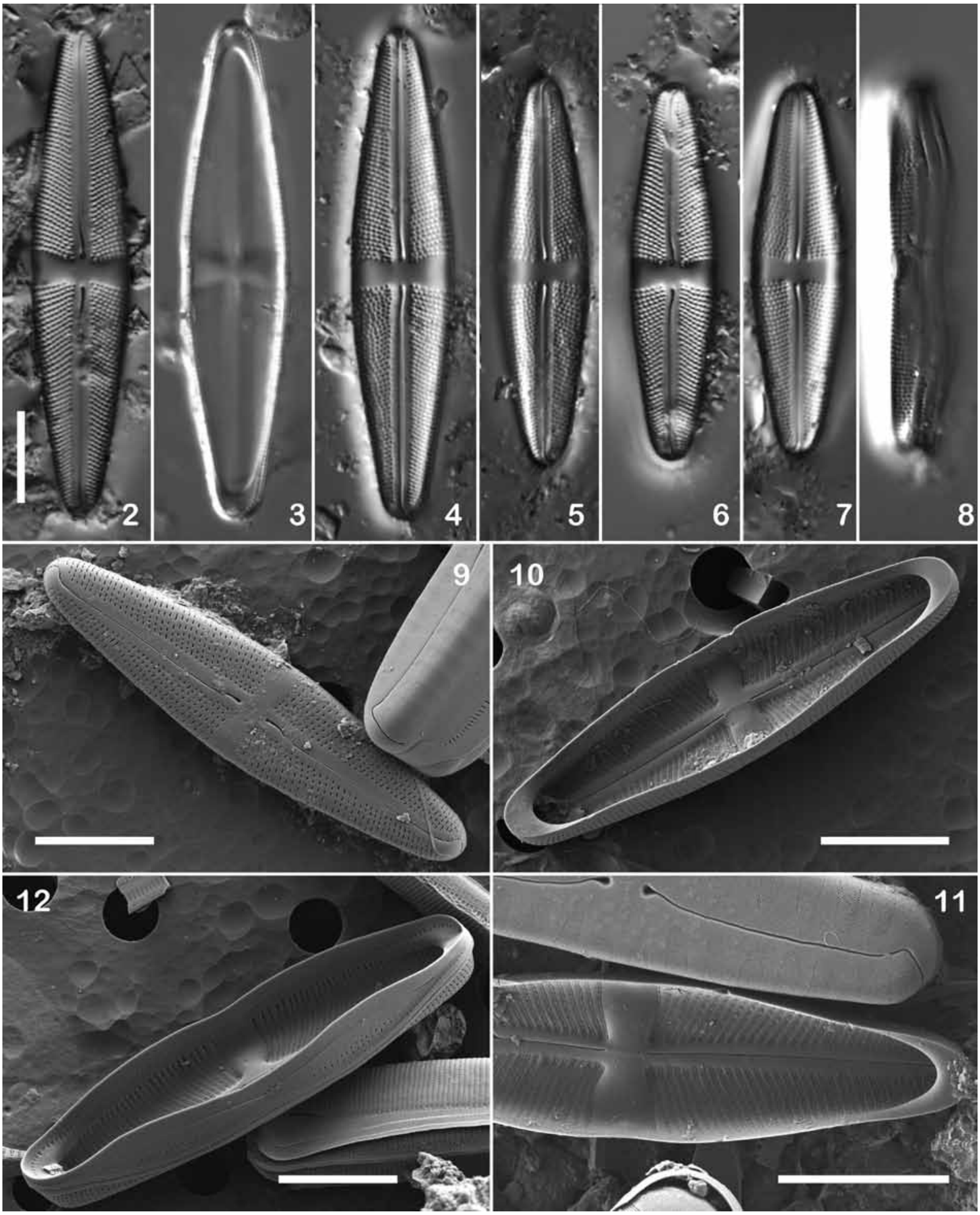
Table 1 Cont.

S. gremmenii Van de Vijver et Lange–Bertalot	X		
S. heinii Lange–Bertalot et Krammer	X	X	X
S. kriegeri Patrick	X	X	X
S. lardonii Van de Vijver	X		
S. lecohui Van de Vijver et Lange–Bertalot	X		
S. microproducta Van de Vijver et Lange–Bertalot	X		
S. pseudosmithii Van de Vijver et Lange–Bertalot	X		
S. respectabilis Lange–Bertalot et al.		X	
S. sofia Van de Vijver et Lange–Bertalot	X		
S. subaustralis Van de Vijver et Lange–Bertalot	X		
S. subgracilis Lange–Bertalot et Krammer	X?	X	X
S. supergracilis Van de Vijver et Lange–Bertalot	X		
S. sp. (Tonsberg)		X	

with the northern hemisphere species *S. obtusa* Lagerstedt. The latin '*australis*' means 'southern'.

Ecology and distribution: Due to possible confusion in the past with *Stauroneis obtusa,* the exact Antarctic distribution of *S. australobtusa* remains unclear. So far small populations of this species have been observed with certainty on two islands of the South Shetland Archipelago (Livingston Island and King George Island). The largest population was found on bryophytes in a small meltwater pool on Byers Peninsula, Livingston Island. The pool had a pH of 7.6, a conductivity value of only 49 µS.cm^{-1} and had a bottom that was entirely covered by a large microbial mat. A second important population was found in sample LIV–BY16A, taken from a biofilm in an area flooded by freshwater between stones on Byers Peninsula close to the main plateau. The sample is dominated by various taxa of *Luticola*, *Hantzschia*, *Pinnularia* and *Humidophila* Lowe et al.

Comparisons with similar taxa: Based on valve dimensions *Stauroneis australobtusa* has an intermediate position between *S. obtusa* and *S. microbtusa* Werum et Lange–Bertalot. As described by Lagerstedt (1873) *S. obtusa* is a large *Stauroneis* species with a valve length of more than 60 µm and a valve width of more than 10 µm, which makes the conspecifity with the smaller *S. australobtusa* unlikely. *Stauroneis microbtusa* Reichardt, described from Austria (Reichardt 2004), has slightly narrower valves with a valve width up to 10.5 µm and a slightly higher number of more coarsely punctate striae in 10 µm (up to 23 striae in 10 µm vs 18–20 in *S. australobtusa*; and 15–20 areolae vs 18–23 in 10 µm in *S. australobtusa*). The major difference between the two taxa are however the proximal raphe endings. In *S. australobtusa* they are clearly laterally curving with distinctly expanded pores, whereas in *S. microbtusa* the proximal raphe endings are only weakly curved. Another differen-ce is the size of the central area: in *S. microbtusa* the central area is larger and more expanded toward the margins compared to the central area of *S. australobtusa.* In the sub–Antarctic region, only *Stauroneis catharinella* Van de Vijver et Lange–Bertalot and *S. catharinae* Van de Vijver et Lange–Bertalot (Van de Vijver et al. 2004) have a similar valve outline to *S. australobtusa*. *Stauroneis catharinae* is much larger with a length of more than 65 µm and width of 11–13 µm and with a slightly denser striation (20–22 vs 18–20 striae in 10 µm in *S. australobtusa*). Moreover, the striae in *S. catharinae* are parallel at the apices and not radiate throughout the entire valve. *Stauroneis catharinella* has a comparable valve length but the valves are narrower (6–7.5 µm vs 8.0–12.0 µm) with a higher number of both striae and puncta (24 instead of 18–20 striae in 10 µm and 25–30 instead of 18–23 areolae in 10 µm). Another sub–Antarctic species, *Stauroneis lecohui*



Figs 2–12. *Stauroneis australobtusa* sp. nov., type population from Livingston Island, South Shetland Islands: (2–8) LM views, (3) shows the presence of pseudosepta, (8) a single valve in girdle view; (9–11) SEM view, (9) an entire valve (externally); (10–12) valves (internally). Scale bars 10 µm.

VAN DE VIJVER et LANGE–BERTALOT, described from the Crozet Archipelago (VAN DE VIJVER et al. 2004) has a different valve outline with more protracted acutely rounded apices and a higher number of striae (21–24 in 10 µm) that become less radiate and even parallel at the apices, compared to the 18–20 striae in 10 µm in *S. australobtusa* that are more radiate at the apices. *Stauroneis obtusa* f. *minor* KRASSKE (KRASSKE 1932) has much smaller valves with a length of 30–45 µm and a width of 5–7 µm, as well as a finer striation of 24–28 striae in 10 µm, compared to the larger valves of *S. astralobtusa* with a width of more than 8 µm and

18–20 striae in 10 µm. Finally, *Stauroneis correntina* Frenguelli has much larger valves (42–84 µm and width of 12–15 µm) with a coarser striation of 16 instead of 18–20 striae in 10 µm (Frenguelli 1933).

***Stauroneis acidojarensis* sp. nov. (Figs 13–29)**
Description

Light microscopy: Valves lanceolate to linear–lanceolate with moderately convex margins and weakly produced, narrowly rostrate to subrostrate apices (Figs 13–22). Pseudosepta absent. Valve dimensions (n=11): 26.4–48.0 µm, width 7.6–10 µm; however, in other populations larger lanceolate valves with a length of up to 61 µm and width of up to 11 µm were observed (Figs 23–26). Axial area very narrow, linear, only deltoidly widened close to the central area. Central area expanded into a relatively narrow, wedge–shaped stauros, moderately widening toward the margins, rarely almost rectangular (Figs 15, 22). Central area occasionally bordered by several irregularly shortened striae (Figs 13, 16, 22). Raphe undulating, with proximal raphe endings terminating almost straight (i.e. Figs 13, 20, 22) or weakly unilaterally deflected (i.e. Figs 15, 17–19) and finally expanded. Distal fissures hooked, visibly sickle–shaped in larger and medium–sized valves (Figs 13, 16, 18, 19 and Figs 23–26). Transapical striae finely punctate, weakly or moderately radiate in the middle and radiate throughout, 20–23 in 10 µm. Areolae discernible in LM, ca. 24–27 in 10 µm.

Scanning electron microscopy: As only a few specimens were found in the SEM, the SEM observations were made on two different populations from Livingston Island: the type population (Fig. 27) from a small pool on Byers Peninsula and another population from a sediment core taken from Limnopolar lake on Byers Peninsula (Figs 28, 29). Externally (Figs 27, 28), striae continuing onto the mantle, composed of narrow, dash–like transapically elongated areolae. External raphe branches straight with proximal raphe endings terminating almost straight and distinctly drop–like enlarged. Distal fissures elongated, continuing onto the mantle, sickle–shaped. Internally (Fig. 29), proximal raphe endings finishing straight onto a thickened stauros. Distal raphe endings terminating onto small helictoglossae (Fig. 29). Areolae covered by hymenes, forming a continuous strip over the striae (Fig. 29).

Holotype (designated here)**:** BR–4386 (Botanic Garden Meise, Belgium).

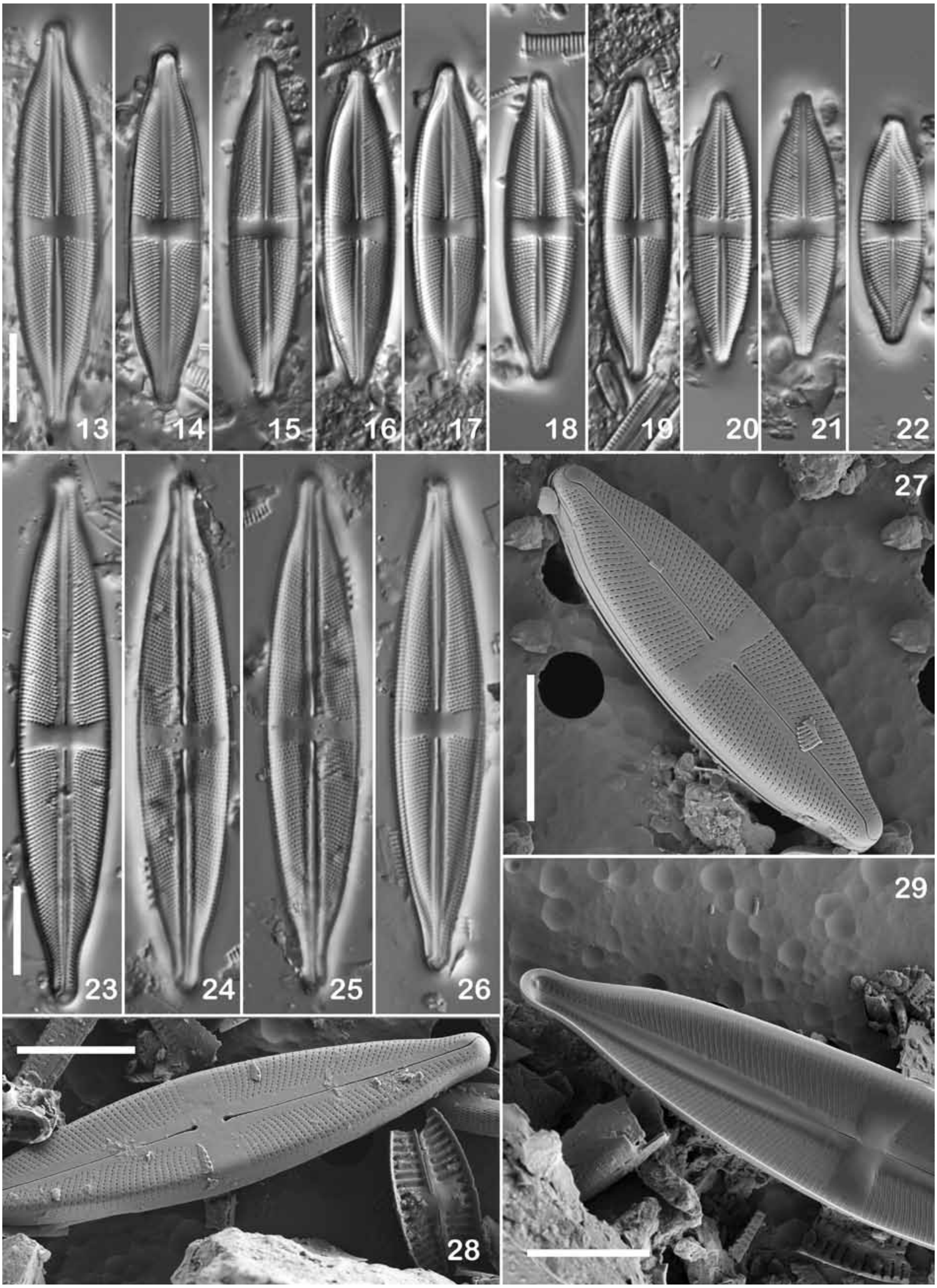
Isotypes (designated here)**:** PLP–271 (University of Antwerp, Belgium), BRM–ZU9/81 (Hustedt Collection, Bremerhaven, Germany).

Type locality: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY067 (Leg. B. Van de Vijver; coll. date 18/01/2009).

Etymology: The specific epithet refers to the resemblance of the new species to both *Stauroneis acidoclinata* and *S. jarensis.*

Ecology and Distribution: *Stauroneis acidoja-rensis* is a common species on the islands of the South Shetland Archipelago (Livingston Island, King George Island and Nelson Island). The largest population was observed in a small pool on the southern beaches of Byers Peninsula (Livingston Island) with a pH of 7.3 and a conductivity level of 87 µS.cm^{-1}. The pool was entirely surrounded by a continuous vegetation of bryophytes hanging from the shore in the lake water. The bottom of the pool was covered by algal mats and fine sediment. A second large population was found on Hurd Peninsula (Livingston Island) in a small brook flowing out from a shallow lake with a low specific conductance (58 µS.cm^{-1}) value and pH of 6.3. On King George Island, the new taxon was reported from the sediment of a small, muddy pool with a high pH (8.8) and a moderately high conductivity (250 µS.cm^{-1}). On Nelson Island, *Stauroneis acidojarensis* was rarely observed in low abundance among cyanobacterial mats on the bottom of a shallow, drying pool.

Comparisons with similar taxa: *Stauroneis acidojarensis* shares similar features with three European *Stauroneis* taxa: *S. acidoclinata, S. jarensis* and, to some extent to *S. amplipora.* The past decade, *S. acidojarensis* has been reported from Antarctica as *Stauroneis* aff. *acidoclinata* (Van de Vijver et al. 2004; Zidarova 2008; etc.). Van de Vijver et al. (2004) mentioned as only difference between the European (type) and the Antarctic populations, identified as *S.* aff. *acidoclinata,* the lower number of areolae in the latter. Further investigation of the type of *S. acidoclinata* (Figs 30–37) and comparisons with the populations of *S. acidojarensis* showed that similarity between these two taxa can be found in valve outline and striation pattern of the larger valves of *S. acidojarensis* (Figs 13, 23–26). Apart of having a different number of areolae, as observed by Van de Vijver et al. (2004), the two taxa can be separated by the shape of the central and axial areas. In *S. acidoclinata* the central area is narrower and usually rectangular and the axial area is broader, compared to *S. acidojarensis* (see Figs 30–37 and Figs 13–26, correspondingly). Moreover, the medium–sized and smaller valves in the populations of *S. acidojarensis* have a different, more lanceolate outline with much narrower apices compared to the more linear–lanceolate valves with rostrate apices of *S. acidoclinata.* Therefore we conclude that conspecifity between the two taxa should be excluded. Another recently described *Stauroneis* species is *S. jarensis,* described from Sardinia (Lange–Bertalot et al. 2003). *Stauroneis acidoclinata* and *S. jarensis* share a similar valve outline, valve dimensions and striation pattern. However, when describing *Stauroneis acidoclinata,* Werum & Lange–Bertalot (2004) did not make any comparison between these two taxa.



Figs 13–29. *Stauroneis acidojarensis* sp. nov.: (13–22) LM view of valves from the type population from Livingston Island, South Shetland Islands; (23–26) LM view of valves from another population from Livingston Island, South Shetland Islands; (27–29) SEM views, (27) an entire valve (externally) from the type population on Livingston Island, South Shetland Islands, (28) valve (externally) from a population on Livingston Island, South Shetland Islands, (29) valve (internally) from a population on Livingston Island, South Shetland Islands. Scale bars 10 µm.

Based on their original descriptions (Lange–Bertalot et al. 2003; Werum & Lange–Bertalot 2004) and our own observations they can be separated by the valve outline, axial and central area (Figs 30–37 and Figs 38–40, respectively) and the number of areolae, being lower in *S. jarensis*. A comparison was made between the populations of *S. acidojarensis* and the type of *S. jarensis.* Based on valve outline, dimensions and striation pattern, similarity between the two taxa exists when medium sized valves of *S. acidojarensis* (Figs 13–22) are compared to *S. jarensis* (Figs 38–40). The two species can still be differentiated by the broader rostrate apices present in *S. jarensis* (Figs 38–40). Another difference is the (regular) presence of shortened striae, bordering the central area in *S. acidojarensis,* a feature never mentioned by Lange–Bertalot et al. (2003) in the original description of *S. jarensis*, nor observed by us during the study of its type population (Figs 38–40). Conspecifity between *S. jarensis* and *S. acidojarensis* still cannot be entirely excluded, but until more populations of the European *S. jarensis* are investigated, we propose to keep the Antarctic populations as a separate taxon. Additionally, in valve outline, the smaller valves of *Stauroneis acidojarensis* are much more similar to *S. amplipora* than to *S. jarensis*. However, *Stauroneis amplipora* has a narrower central area (Figs 41–46), a higher number of areolae and completely different proximal raphe endings, being straight with enlarged pores, turned clearly to the primary side (Lange–Bertalot et al. 2003; pl. 41, figs 13,14; pl. 42, figs 1–5; pl. 43, figs 1–4) to avoid confusion with *S. acidojarensis.* Finally, larger valves of *Stauroneis acidojarensis* in valve outline, central area and raphe endings resemble *S. elisa* Lange–Bertalot et al., but the latter species differs in having larger valve dimensions with a length of more than 60 µm and width of more than 12 µm (vs length of up to 61 and width of up to 11 µm in *S. acidojarensis*), as well as a much coarser striation of 16–18 striae in 10 µm (Lange–Bertalot et al. 2003), compared to the 20–23 striae in 10 µm in *S. acidojarensis.*

***Stauroneis jamesrossensis* sp. nov. (Figs 47–57)**
Description

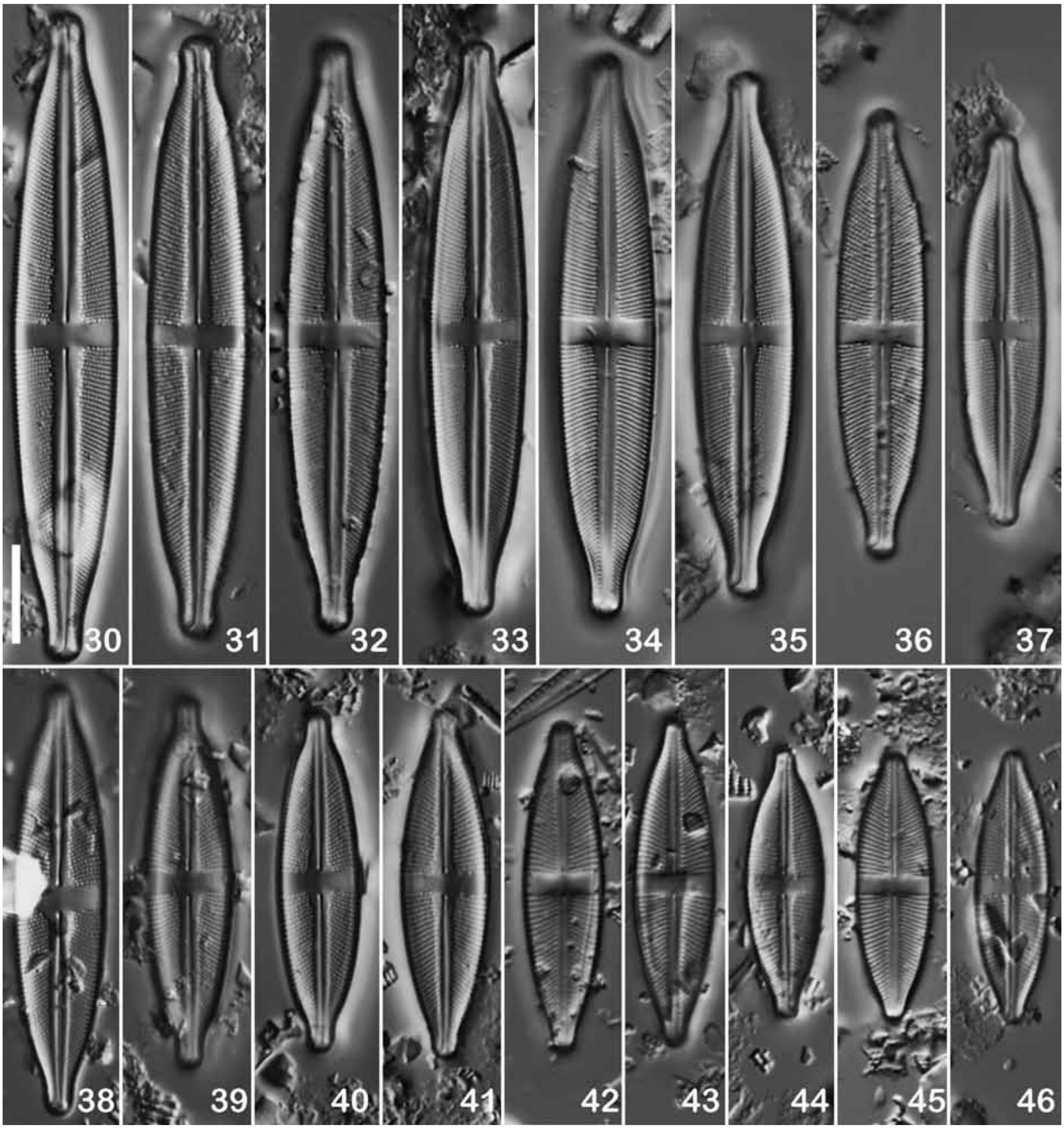
Light microscopy: Valves linear–lanceolate with moderately to weakly convex margins, sometimes almost parallel margins (Fig. 52) and subcapitate (larger valves) to rostrate–subcapitate (smaller valves) apices (Figs 47–55). Pseudosepta absent. Valve dimensions (n=23): length 30.8–44.5 µm, width 8–9.3 µm. Axial area narrow, linear, very narrow near the apices and slightly deltoidly widening towards the central area. Central area forming a rectangular (Figs 47, 50–53) or wedge–shaped stauros (Figs 48, 49, 54, 55), only weakly or moderately expanding toward the margins. Raphe straight to weakly undulating with straight proximal raphe endings terminating in small, weakly expanded pores. Distal fissures clearly visible in larger valves, hooked, sickle–shaped (Figs 48, 49). Transapical striae finely punctate, weakly to moderately radiate in the middle, becoming more radiate toward the apices, 21–23 in 10 µm. Areolae discernible in LM, ca. 25–30 in 10 µm.

Scanning electron microscopy: Externally (Fig. 56), striae continuing onto the mantle, composed of transapically elongated areolae. Rarely some of the areolae of the innermost row rounded. External raphe branches almost straight with weakly unilaterally deflected proximal raphe endings, terminating in small, drop–like pores. Distal fissures are elongated, continuing onto the mantle and hooked sickle–shaped. Internally (Fig. 57), raphe branches straight with straight proximal raphe endings, terminating on a thickened stauros. Distal raphe endings finish onto small helictoglossae. Areolae internally covered by hymenes.

Holotype (designated here)**:** BR–4387 (Botanic Garden Meise, Belgium).
Isotypes (designated here)**:** PLP–272 (University of Antwerp, Belgium), BRM–ZU9/83 (Hustedt Collection, Bremerhaven, Germany).
Type locality: Komarék slope below Berry Hill, James Ross Island, sample S1E (Leg. J. Komarék; coll. date 22/02/2007).
Etymology: The specific epithet refers to the island from where the new species is described: James Ross Island.

Ecology and distribution: *Stauroneis jamesro-ssensis* has been only recorded on James Ross Island and Nelson Island. The largest population was observed on James Ross Island in a sample taken from a seepage area at low altitude. The sample was dominated by *Hantzschia, Humidophila* and several *Stauroneis* species including *S. latistauros* Van de Vijver et Lange–Bertalot and *S. pseudoschimanskii* Van de Vijver et Lange–Bertalot.

Comparisons with similar taxa: *Stauroneis jamesrossensis* was earlier reported from James Ross Island as *S. jarensis* (Kopalová et al. 2012; p. 196, fig. 4: V, W). In some samples, valves with larger and smaller valve dimensions were found although in the type population, these larger and smaller valves were never found. It is likely that the true size range for this new taxon should be in reality: length = 23.3–46.5 µm, width = 7.3–9.3µm. Based on the dimensions and striation pattern almost no differences can be found between the *Stauroneis jamesrossensis* and *S. jarensis*. However, analysis of the type material of *Stauroneis jarensis* revealed that the latter species has a different valve outline with more convex margins and clearly rostrate or subrostrate apices (Figs 38–40), compared to the more linear valves with subcapitate or rostrate–



Figs 30–46. LM views of valves from the type populations of *Stauroneis acidoclinata, S. jarensis* and *S. amplipora*: (30–37) *Stauroneis acidoclinata* (type, Praep. "Quellen" n° 3290 in Coll. LANGE–BERTALOT, Bot. Institut Universität Frankfurt am Main); (38–40) *Stauroneis jarensis* (type, Praep. n° EU–I–107 in Coll. LANGE–BERTALOT, Bot. Institut Universität Frankfurt am Main); (41–46) *Stauroneis amplipora* (type, Praep. n° EU–I–107 in Coll. LANGE–BERTALOT, Bot. Institut Universität Frankfurt am Main). Scale bar 10 µm.

subcapitate apices of *S. jamesrossensis* (Figs 47–55). Other differences include the number of areolae in *S. jamesrossensis* that is higher (25–30 vs 21–26 in 10 µm in *S. jarensis*) and the proximal raphe endings that are much more expanded in *S. jarensis* (LANGE–BERTALOT et al. 2003; pl. 39, figs 4–8, pl. 40, figs 3–6). *Stauroneis jamesrossensis* also resembles *S. reichardtii* LANGE–BERTALOT et al. The latter species can be separated based on the distinctly protracted capitate to subcapitate apices (and not subcapitate to rostrate–subcapitate as in *S. jamesrossensis*) and the lower number of areolae (22–25 vs 25–30 in 10 µm in *S. jamesrossensis*). From the Antarctic *Stauroneis acidojarensis, S. jamesrossensis* can be separated based on its valve outline with subcapitate or rostrate–subcapitate apices that are never observed in *S. acidojarensis* and the narrower central area. *Stauroneis acidojarensis* has weakly protracted, narrowly rostrate to subrostrate apices, as well as a central area that is more expanded toward the margins, often bordered by several short striae (Figs 13–26). Other similar *Stauroneis* taxa are at present not known.

Stauroneis reichardtiopsis **sp. nov. (Figs 58–64, 68–76)**

Description

Light microscopy: Valves linear–elliptic or lanceolate–elliptic with weakly to moderately convex margins and distinctly protracted, capitate apices (Figs 58–64). Pseudosepta absent. Valve dimensions (n=22): 45.5–51 µm, width 9.8–11.5 µm, although smaller valves with a length of less than 40 µm and breadth of 9.3 (Fig. 68) µm have been also observed in other populations (Figs 68–72). Axial area linear, not narrow, nor broad, only weakly widening toward the central area. Central area forming relatively broad butterfly–shaped stauros, sometimes asymmetrical (Fig. 61), moderately expanded toward the margins. Raphe lateral, with proximal raphe endings expanded and weakly unilaterally deflected. Distal fissures hooked. Transapical striae moderately radiate in the middle, geniculate, becoming more radiate toward the apices, 21–24 in 10 µm. Areolae discernible in LM, 24–30 in 10 µm, most often ca. 27 in 10 µm.

Scanning electron microscopy: Striae continue onto the mantle and composed of transapically elongated areolae (Figs 73–75); rarely areolae are rounded, mostly at the apices (Fig. 74). Externally, raphe with distinctly expanded drop–like proximal raphe endings, weakly deflected to one side (Figs 73, 75). Terminal fissures elongated, continuing onto the mantle, hooked (Figs 73, 74). Internally (Fig. 76), proximal raphe endings straight and finish onto a thickened stauros. Distal raphe endings terminate onto small helictoglossae. Areolae internally covered by hymenes, forming a continuous strip over the striae. Single areolae sometimes border the central area at one side (Fig. 76).

Holotype (designated here)**:** BR–4388 (Botanic Garden Meise, Belgium).

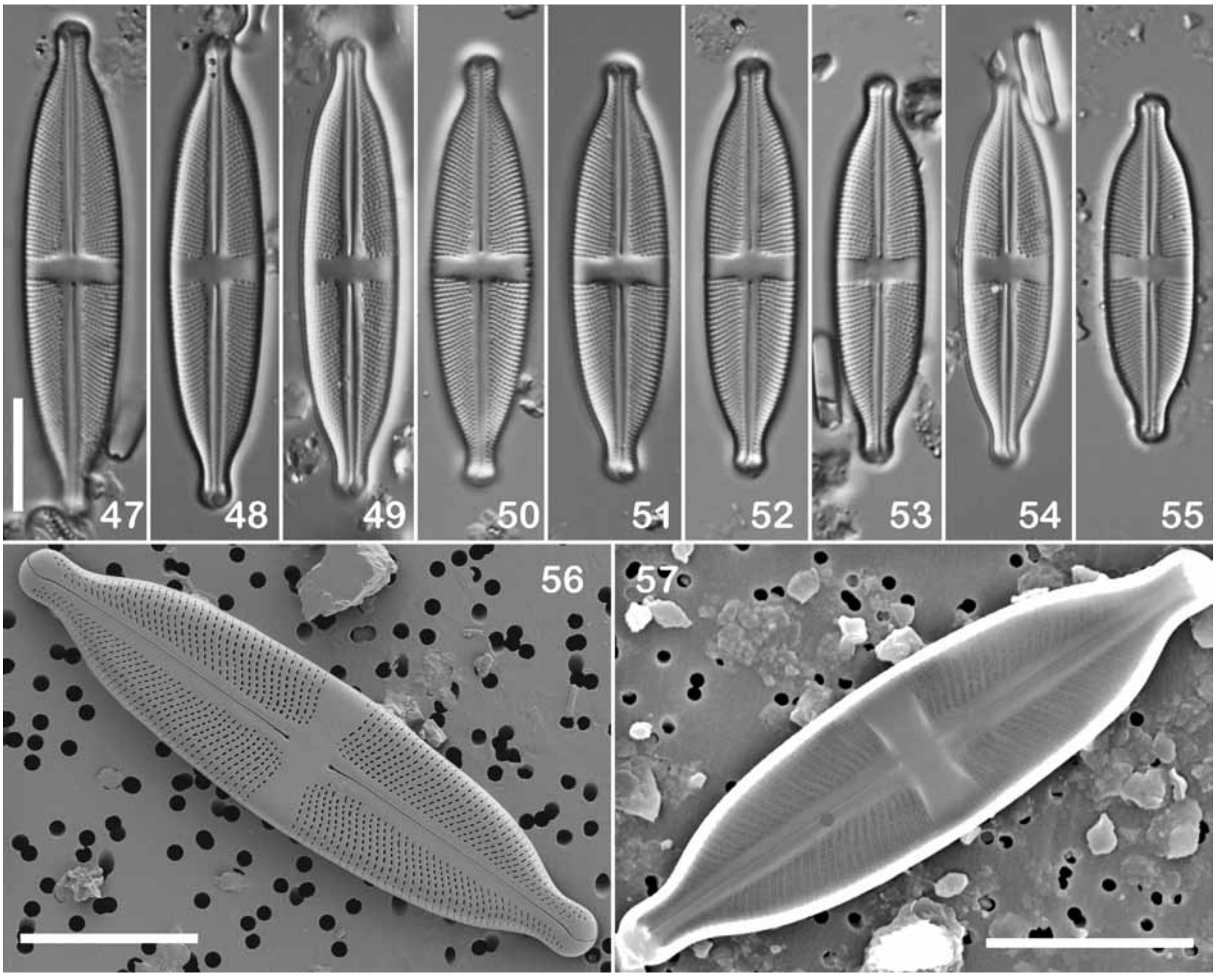
Isotypes (designated here): PLP–273 (University of Antwerp, Belgium), BRM–ZU9/84 (Hustedt Collection, Bremerhaven, Germany).

Type locality: Byers Peninsula, Livingston Island, South Shetland Islands, sample BYS013 (Leg. B. Van de Vijver; coll. date 14/01/2009).

Etymology: The specific epithet refers to the resemblance of the new species to *Stauroneis reichardtii*.

Ecology and distribution: *Stauroneis reichardtiopsis* was observed on several islands of the South Shetland Archipelago (Livingston Island and King George Island). The largest population was found in a seepage area sample on Byers Peninsula (Livingston Island). Small populations were also recorded among cyanobacterial mats on the bottom of small pools, among very wet bryophytes and in wet soils.

Comparisons with similar taxa: *Stauroneis reichardtiopsis* has been reported once as *Stauroneis reichardtii* by Zidarova (2008) from Livingston Island. *Stauroneis reichardtii* was described by Lange–Bertalot et al. (2003) from Sardinia. Based on valve outline, dimensions and striation pattern in its original description, *S. reichradtiopsis* is not easy to separate from *S. reichardtii*. According to the original description of *Stauroneis reichardtii* in Lange–Bertalot et al. (2003) this species has linear–elliptic, linear–lanceolate or elliptic–lanceolate valves with a length of 22–48 µm and a width of 6.2–11.5 µm. During the analysis of the slide, containing the type of *S. reichardtii* (Praep. n° EU–I–109A in Coll. Lange–Bertalot) we could only find a few valves of *S. reichardtii* (Figs 65–67) and none of these valves had a valve width larger than 9.7 µm. Further measurements of all valves of *S. reichardtii* pictured in Lange–Bertalot et al. (2003; pl. 36, figs 1–4; pl. 37, figs 1–14), showed that the width of all shown valves varies between 6.2–9.7 µm and never exceeded 9.7 µm, whereas the valve length entirely matched the length range, given in the original description of the species in Lange–Bertalot et al. (2003). Compared to *S. reichardtii,* the Antarctic *S. reichardtiopsis* has more linear–elliptic, larger and, especially, wider valves, with a width of usually more than 9.8 µm (and not 6.2–9.7 µm, as observed by us for the type of *S. reichardtii*). The two species also differ in their central areas. The central area of *S. reichardtii* (Figs 65–67) is comparably narrower and smaller than the central area of *S. reichardtiopsis* (Figs 58–64, 68–72). Another difference is the number of areolae in the striae. The number of areolae in *S. reichardtiopsis* is higher (24–30 vs 22–25 in 10 µm in *S. reichardtii*). Moreover, the analysis of all observed populations of *Stauroneis reichardtiopsis* could not prove that the two taxa are conspecific since no valves were found that can form a clear continuum between the type of *S. reichardtii* and the Antarctic *S. reichardtiopsis.* Although some of the smallest valves in the populations of *S. reichardtiopsis* have similar valve width to *S. reichardtii* (i.e. Fig. 68 and Fig. 67, correspondingly), they still could be differentiated by the larger and more expanded central area, the higher number of areolae in the striae and the more linear valve outline. Additionally, apart of single records of valves with a width of 9.3 µm (Fig. 68) in the populations of *Stauroneis reichardtiopsis*, valves with a smaller width (i.e. less than 9.3 µm) were never observed. Considering the differences in the valve outline, valve width, central area and number of areolae in the two taxa, we propose that the Antarctic populations are kept as an independent taxon. Based on valve dimensions and central area, *S. reichardtiopsis* is very similar to the Mongolian *Stauroneis suranii* Metzeltin et al., described in Metzeltin et al. (2009). *Stauroneis suranii*, however, has a lower number of striae (18–21 vs 21–24 in 10 µm) composed of a lower number of areolae (22–24

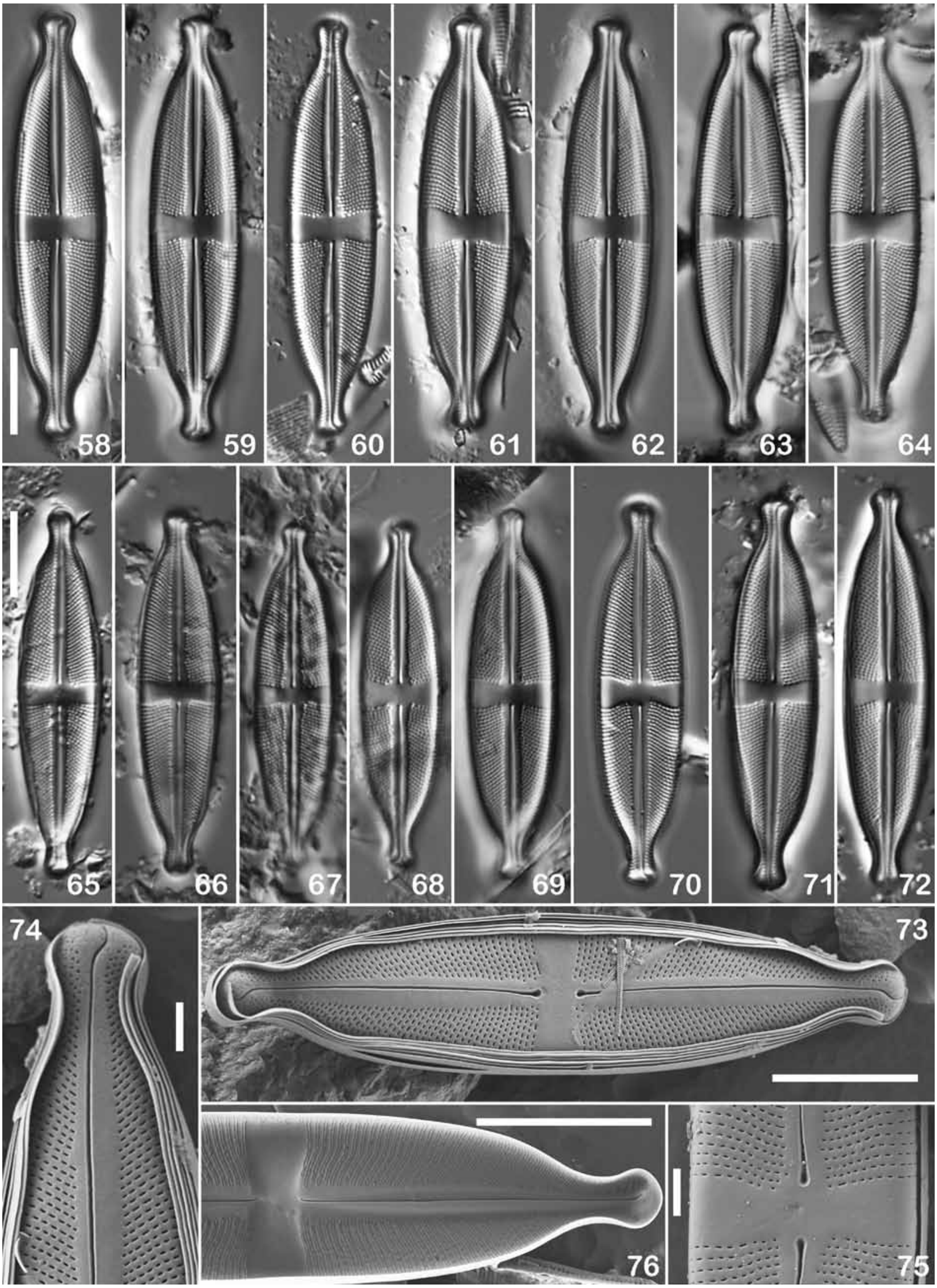


Figs 47–57. *Stauroneis jamesrossensis* sp. nov., type population from James Ross Island: (47–55) LM view; (56–57) SEM views, (56) an entire valve (externally), (57) an entire valve (internally). Scale bars 10 µm.

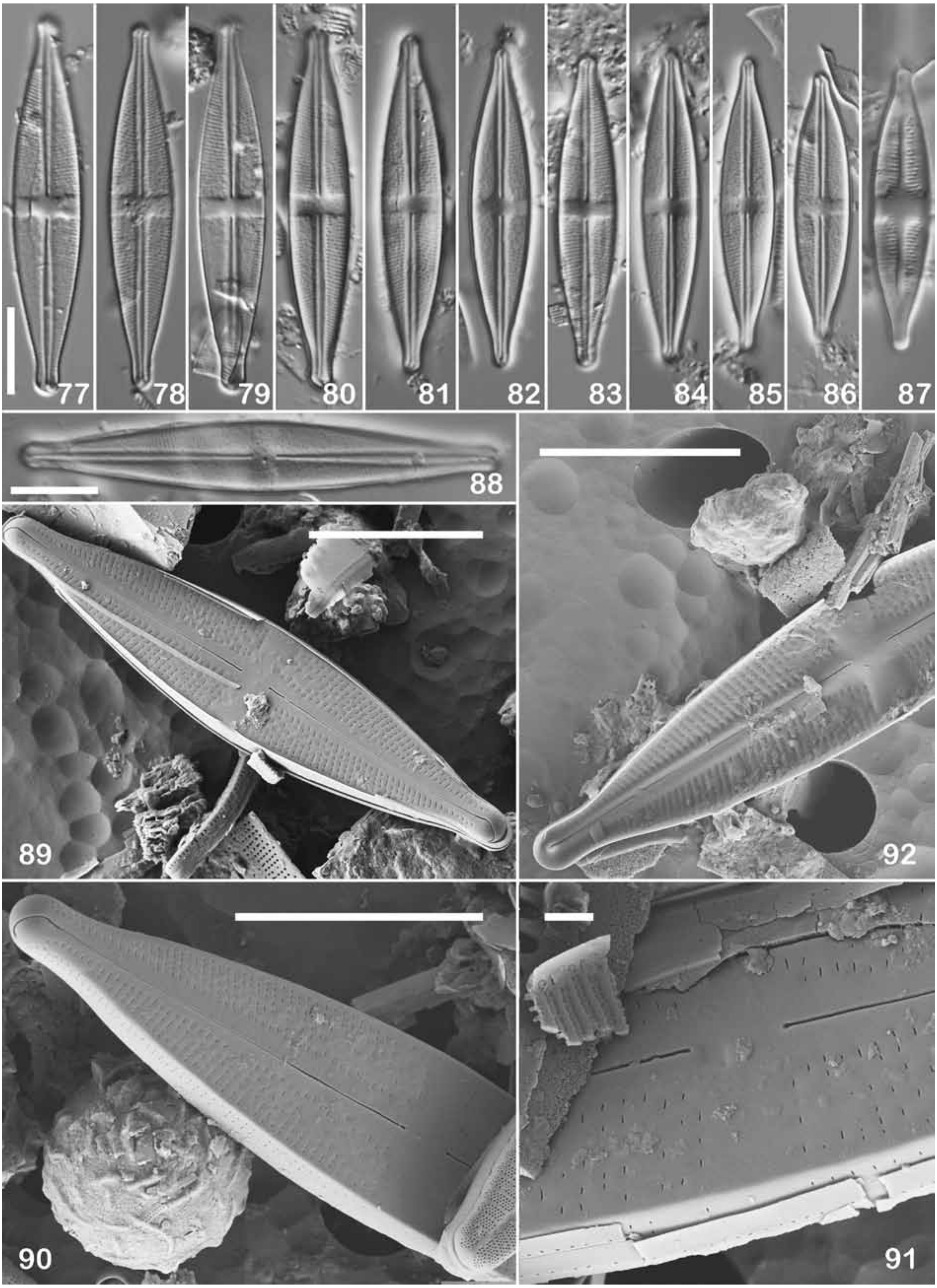
vs 24–30 in 10 µm) that in SEM appear elongated dash–like (METZELTIN et al. 2009; p. 112, pl. 88, fig. 12). *Stauroneis amphicephala* KÜTZING sensu VAN DE VIJVER et al. (2004) is a much larger species with a length of ca. 60 µm and a width of 12–14 µm (KÜTZING 1844) compared to *S. reichardtiopsis.* The Antarctic *Stauroneis jamesrossensis* is easily separated from *S. reichardtiopsis* by its narrower valves (width of 8–9.3 µm vs (9.3) 9.8–11.5 µm) with subcapitate or rostrate–subcapitate apices (and not protracted capitate as in *S. reichardtiopsis*), as well as by the narrower central area compared to *S. reichardtiopsis.*

***Stauroneis delicata* sp. nov. (Figs 77–92)**
Description
Light microscopy: Valves lanceolate with moderately convex margins and gradually narrowing, protracted, rostrate–subcapitate (larger valves) to narrowly rostrate (smaller valves) apices (Figs 77–88). Pseudosepta absent (Fig. 79). Valve dimensions (n=25): length 30.7–44.0 (55.3) µm, width 6.2–8.1 (8.5) µm. Axial area very narrow and linear, only weakly widening towards the central area. Central area forming a relatively small, rectangular to weakly wedge–shaped stauros, almost not or only slightly expanding toward the margins. Raphe lateral with straight proximal raphe ending, finishing almost inconspicuously enlarged. Distal raphe fissures barely visible in smaller valves; in larger valves distal fissures hooked (Figs 77, 80–82). Occasionally, heavily silicified valves lacking a raphe observed (Fig. 87). Transapical striae faint, punctate, weakly radiate in the middle, becoming slightly more radiate toward the apices and finally at the apices almost parallel, 24–27 in 10 µm. Areolae not always well discernible in LM.

Scanning electron: Valve face flat, abruptly turning into the valve mantle (Figs 89, 71). At the junction of the valve face and mantle, a narrow hyaline area present, interrupting the striae, continuing afterwards onto the mantle (Figs 90, 91). Striae composed of narrow, dash–like, transapically elongated areolae, often irregularly spaced (Figs 89–91) and therefore variable in number in 10 µm, ca. 20–30 in 10 µm; areolae of the striae at the apices sometimes fusing together to form a one–areola stria (Fig. 89). External



Figs 58–76. *Stauroneis reichardtiopsis* sp. nov. and *Stauroneis reichardtii*: (58–64) *Stauroneis reichardtiopsis,* LM views of valves from the type population from Byers Peninsula, Livingston Island, South Shetland Islands; (65–67) *Stauroneis reichardtii*, LM views (type, Praep. n° EU–I–109A in Coll. Lange–Bertalot, Bot. Institut Universität Frankfurt am Main); (68–72) *Stauroneis reichardtiopsis* sp. nov., valves from Hurd Peninsula, Livingston Island. South Shetland Island; (73–76) *Stauroneis reichardtiopsis* sp. nov., SEM views of valves from the type population from Byers Peninsula, Livingston Islands, South Shetland Islands, (73) entire valve (externally), (74) a detail showing the terminal raphe fissures and areolae (externally), (75) central area and proximal raphe endings (externally), (76) valve view (internally). Scale bars 10 µm, except for (74) and (75) where 2 µm.



Figs 77–92. *Stauroneis delicata* sp. nov., type population from Livingston Island, south Shetland Islands: (77–88) LM views, (87) a heavily silicified valve without a raphe; (89–92) SEM views, (89) an entire valve (externally), (90) part of the valve showing striation and raphe endings, (91) a detail of the central area showing the proximal raphe endings, (92) part of a valve (internally). Scale bars 10 µm, except for (91) where 1 µm.

raphe straight with straight or slightly curved proximal raphe endings terminating with small pores (Fig. 91). Distal fissures elongated, continuing onto the mantle, hooked, sickle–shaped (Figs 89, 90). Internally (Fig. 92), proximal raphe endings straight, terminating on a thickened stauros. Distal fissures finish onto small helictoglossae. Areolae are covered by hymenes.

Holotype (designated here)**:** BR–4389 (Botanic Garden Meise, Belgium).
Isotypes (designated here)**:** PLP–274 (University of Antwerp, Belgium), BRM–ZU9/82 (Hustedt Collection, Bremerhaven, Germany).
Type locality: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY028 (Leg. B. Van de Vijver; coll. date 11/01/2009).
Etymology: The specific epithet refers to the delicate nature of the striae.

Ecology and distribution: *Stauroneis delicata* has been found on several localities within the Maritime Antarctic Region. The largest populations were found on Livingston Island but smaller populations were noted on Paulet Island (Van de Vijver et al. 2004), Signy Island (South Orkney Islands, Sterken, pers. comm.) and South Georgia (Van de Vijver, unpubl. res.). The type population was found in a sample from a sediment core, making it impossible to identify the exact environmental preferences of this species. Therefore, the ecological preferences are deduced from the associated diatom flora that is composed of only freshwater diatom species such as *Hippodonta hungarica* (Grunow) Lange–Bertalot et al., *Nitzschia perminuta* (Grunow) Peragallo, several *Stauroneis* and *Muelleria* species (such as *S. latistauros*, *M. variolata* Spaulding et Kociolek) and *Plantothidium frequentissimum* (Lange–Bertalot) Lange–Bertalot, reflecting clearly lake water conditions since typical aerophilic genera such as *Humidophila* or *Luticola* are only present in very low numbers or completely absent.

Comparisons with similar taxa: Van de Vijver et al. (2004) reported *Stauroneis delicata* under the name *S. subgracilior* "Peninsula", suggesting they doubted that the Antarcic populations truly belonged to *S. subgracilior sensu stricto* Lange–Bertalot et al. The latter species, described in Lange–Bertalot et al. (2003), can be separated based on its valve outline with more lanceolate valves and more elongated, protracted rostrate to rostrate–capitate apices and the higher number of striae (28–31 vs 24–27 in 10 µm in *S. delicata*). The proximal raphe endings in *S. subgracilior* are weakly deflected to one side whereas in *S. delicata* they are almost straight. Another similar taxon to *Stauroneis delicata* is probably the Chilean *S. punensis* Lange–Bertalot et Rumrich, described from Río Lauca (Rumrich et al. 2000). *Stauroneis punensis* has comparable valve dimensions and a similar valve outline but less protracted apices. The striation of *S. punensis* is finer, with 27–31 striae in 10 µm, whereas in *S. delicata* the number of the striae is lower, 24–27 in 10 µm. Other differences include the larger central area in *S. punensis* that is more expanded toward the margins. Hustedt described *S. schroederi* Hustedt (in A. Schmidt 1913; pl. 299, fig. 31), later documented by Simonsen (1987). Based on the illustrations, the latter species has a different valve outline, with more rhombic–lanceolate valves, distinctly convex margins and protracted, narrowly rounded apices, compared to the lanceolate valves with moderately convex margins and rostrate–subcapitate apices of *S. delicata.* Another similar taxon, *Stauroneis neohyalina* Lange–Bertalot et Krammer has distinctly more protracted capitate–subcapitate apices and a larger central area that is more expanded toward the margins (Lange–Bertalot & Metzeltin 1996; t. 35, figs 1–9). *Stauroneis gracilior* Reichardt is larger with a valve length of 47–53 µm giving the species a more elongate, slender outlook (Reichardt 1995).

Biogeographical discussion
Based on Table 1, the total diversity of *Stauroneis* taxa in the entire (sub–)Antarctic Region counts up to 28 species, making it one of the most diverse diatom genera in these latitudes after *Pinnularia, Luticola* and *Muelleria.* The highest species richness is observed on the sub–Antarctic islands (24 taxa), whereas in the Maritime Antarctic region the species richness is only half (11 taxa) and on the Antarctic Continent only one *Stauroneis* species (i.e. *S. latistauros*) is recorded (Table 1). Furthermore, in the Maritime Antarctic region, all eleven taxa are observed on the South Shetland Islands whereas only four taxa are present on the more southerly located James Ross Island (Table 1). These results are not surprising since it is well known that the diatom species diversity decreases when moving southwards (i.e. Jones 1996; Van de Vijver & Beyens 1999; Van de Vijver et al. 2011b).

As can be seen in Table 1, a clear separation exists based on species diversity and presence in the different parts of the Antarctic Region: only one species, *Stauroneis pseudomuriella* Van de Vijver et Lange–Bertalot has a wide Antarctic distribution, ranging from the islands of the southern Indian Ocean to the islands of the southern Atlantic ocean and James Ross Island. Only one taxon, *S. latistauros,* has been known from both the islands of the southern Atlantic Ocean and the Antarctic Continent (Table 1). Six of the eleven taxa found during the present study, have not been found outside Maritime Antarctica and 12 other *Stauroneis* taxa are only present on the islands of the Southern Indian Ocean (Table 1). Moreover, only 6 *Stauroneis* taxa have a confirmed distribution outside the Antarctic Region (Table 1). These results, as already observed in other genera, such as *Luticola* (Van de Vijver et al. 2011b) and *Pinnularia* (Zidarova et al. 2012), prove once again that the Antarctic diatom flora is highly specific, composed predominantly of endemic species as well as that a clear separation exists between the islands of the Southern Indian Ocean, the Southern Atlantic Ocean and the Antarctic Continent.

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