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Staurosira patagonica sp. nov., a new diatom (Bacillariophyta) from southern Argentina, with a discussion on the genus *Staurosira* Ehrenberg

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With 47 figures and 3 tables

Abstract: We present a detailed morphological analysis by light and scanning electron microscopy of *Staurosira patagonica* sp. nov. from quaternary sediments of Maar Magallanes and recent sediments of the shallow lake Laguna Toro, both in Santa Cruz Province, Argentinian Patagonia. While the valve outline of this new taxon resembles *Staurosira incerta*, *S. construens* and *Pseudostaurosira pseudoconstruens,* it presents features (e.g., flat valve surface, bifurcate volae and radiate striae) that set it apart from them. *Staurosira patagonica* sp. nov. is smaller than other small fragilarioids species. We also discuss the main characteristics of *Staurosira*, we provide a list of species currently included in it, and we propose several new combinations accordingly with current concepts of araphid diatom genera.

Key words: Araphid diatoms, biodiversity, Fragilariaceae, freshwater, Patagonia, small fragilarioids, taxonomy

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Introduction

The Fragilariaceae Greville is a geographically widespread family with high species diversity. It has been registered in all continents (e.g., Hohn & Hellerman 1963, Patrick & Reimer 1966, Lowe 1974, Stoermer 2001, Manoylov et al. 2003, Morales & Edlund 2003, Morales 2006, Novelo et al. 2007 for North America, Rumrich et al. 2000, Metzeltin et al. 2005, Morales et al. 2014a, b for South America, Hustedt 1930, Krammer & Lange-Bertalot 1986, 1991, 2004, Schmidt et al. 2004 for Europe, Kilroy et al. 2003, Lowe et al. 2006 for Oceania; Joh et al. 2010, Hwang et al. 2011, Rioual et al. 2014, Suzuki et al. 2015 for Asia, Archibald 1983, Taylor et al. 2007 for Africa, Jones & Birks 2004 for the Arctic, Sabbe et al. 2003, Van de Vijver et al. 2014 for the Antarctic). After analyzing samples from North America and Europe, Morales (2001, 2006), Morales et al. (2010a, b) and Cejudo-Figueiras et al. (2011) concluded that the diversity of fragilarioids was even greater than that presented in the literature available at the time. In particular, in South America, the number of publications about diatoms is increasing but we have a large unknown flora yet to be described. Precisely because of this widespread distribution, high known diversity and the potentially higher number of taxa to be included in the family, studies on the Fragilariaceae to clarify taxonomic boundaries and biogeographic aspects are difficult. Patagonia has a unique geographical position as the only non-glaciated continental land mass

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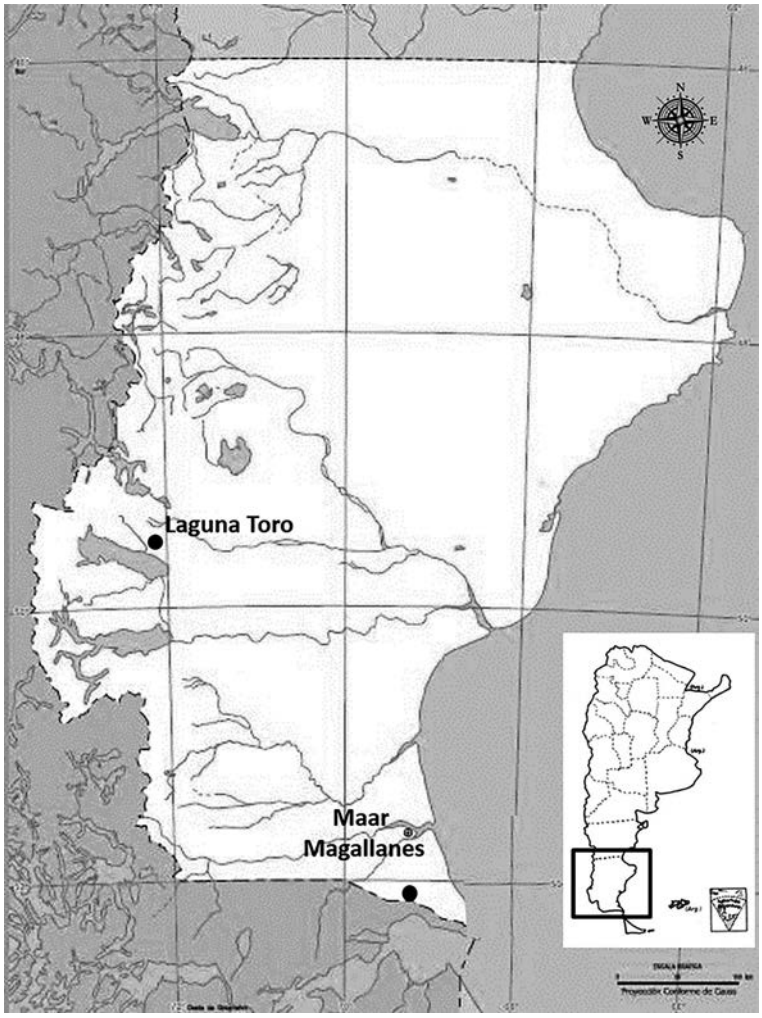


Fig. 1. Map of Argentina, showing Santa Cruz Province and the locations of the studied ecosystems.

south of 47,8°S, it is divided longitudinally by the Andes mountain chain that determines a marked discontinuity in the pluvial regime and in the influence of the western winds (Southern Westerlies core zone). Patagonia has a great diversity of wetlands, particularly, lakes, lagoons and peatlands, therefore, its flora and fauna constitute fragile ecosystems, vulnerable to human intervention. Diatoms are often used as bioproxies on studies to understand present and past environmental and climate changes, therefore is important to understand their taxonomy and ecology.

As more ecosystems in different geographical areas are studied, the greater the number of diatom species becomes (Metzeltin & Witkowski 1996, Moser et al. 1998). Although this is generally the case, it depends not only on the different studied areas, but also on the methods available for sample analysis. As Morales et al. (2013) stated, the process of identification of a

taxon is not always an easy task since it gets complicated by drift of particular species concepts over time. Therefore, the use of light (LM) and scanning electron microscopy (SEM) is essential to reexamine described taxa, preferably by their type material, and describe new taxa in order to better delimit taxonomic boundaries and approximate the actual diversity within different genera. SEM analysis has provided better descriptions of diatom taxa, in particular for small sized Fragilariaceae, whose reduced dimensions make accurate identification difficult (e.g., Williams & Round 1987, Morales et al. 2013). In addition to taxonomic concept drift, in South America, there has been extensive force-fitting into names used for northern hemisphere diatoms (Morales et al. 2014c). Therefore, there has been a misinterpretation of the taxonomy of southern hemisphere taxa resulting in entangled nomenclatural histories that require long time and effort to clarify (Morales et al. 2015).

In this contribution, we discuss the morphological features of the genus *Staurosira,* describe a new species, *Staurosira patagonica* sp. nov., found in fossil and recent sediment samples from Santa Cruz Province, Argentina and propose eight new combinations.

Materials and methods

Studied samples came from: a) sediment core M3 (32.68 to 32.80 m depth) recovered from Maar Magallanes (52°07´S 69°16´W) with a seismic-line driller (Maidana & Corbella 1997) and whose radiometric analysis (^{14}C), performed at the Beta Analytic Laboratories (Miami, USA) gave an age of 31.560 ± 480 years BP at 47 m depth; b) surface sediments from the shallow lake Laguna Toro (49°34'15,6''S 72°23'38,4''W) collected by dredging in April, 2013.

Diatom analyses were performed following standard methods described in Battarbee (1986). An aliquot of each sample was dried at 80° C. The sample was oxidized with H_2O_2 (30%, 100 Vol.) and heated in a microwave oven for 2 minutes, in order to eliminate organic material. Samples were then rinsed repeatedly until neutrality with distilled water. Permanent slides were mounted using Naphrax®. Light micrographs were captured using a Reichert-Jung Polivar binocular optical microscope equipped with a Plan Apo 100X, NA 1.32, immersion objective and DIC optics and a Canon EOS 600D digital camera.

For SEM observations, aliquots of the cleaned material were dried on aluminum stubs at room temperature before being coated with gold and examined using a Carl Zeiss SUPRA 40 (15kV) at the Centro de Microscopías Avanzadas (CMA), FCEyN, Universidad de Buenos Aires, Argentina.

Images captured on both LM and SEM were measured using the Zeiss Axiovision 4.8.2 software, plates were edited using CorelDRAW X5®, and the graphics were made with the Past software (Hammer et al. 2001).

We performed a T-test in order to compare the populations from Maar Magallanes and Laguna Toro. Diatom relative abundances were calculated counting a minimum of 400 valves under LM, along random transects on each slide.

In order to identify the diatom assemblages on the studied samples, we used mostly South American literature (Metzeltin & Lange-Bertalot 1998, 2007, Rumrich et al. 2000, Metzeltin et al. 2005), and taxonomic articles by Morales (2001, 2006), Morales et al. (2010a, b, c, 2013, 2014a), among others. Additionally, non-South American references were also consulted, such as the general floras of Patrick & Reimer (1966) and Krammer & Lange-Bertalot (1986, 1991).

In the description of the genus and the new species, morphological terminology follows Anonymous (1975) and Ross et al. (1979) for striae, areolae and spines; Barber and Haworth (1981) for valve shape and striae pattern, and Williams and Round (1987) and Round et al. (1990) for areolar substructures, apical pore fields, and girdle bands features.

VanLandingham (1978) and online databases such as Algaterra (http://www.algaterra.org/), Algaebase (http://www.algaebase.org/search/species/), California Academy of Science (http://researcharchive.calacademy.org/research/diatoms/names/index.asp), The University and Jepson Herbaria (University of California, Berkeley) (http://ucjeps.berkeley.edu/INA.html), and

Diatoms of the United States (https://westerndiatoms.colorado.edu/) were consulted and filtered to make a list of the species presently included in the genus *Staurosira*.

Review of *Staurosira* Ehrenberg

In 1841, Ehrenberg mentioned the genus *Staurosira* for the first time, but without formal description. He merely listed *Staurosira construens* Ehrenberg and *S. pinnata* Ehrenberg from North and South American samples, but he did describe the features of *S. construens*, thus automatically making it the generitype. Two years later, Ehrenberg (1843a) described three North American representatives of the genus: *S. amphilepta* Ehrenberg (from Boston, Massachusetts), *S. construens* (from New Haven, Connecticut) and *S. pinnata* (also from New Haven), but still without a description of *Staurosira*. The formal, but brief, genus description was published in Ehrenberg (1843b), where he only included *S. construens* and a new species *S. trigongyla* Ehrenberg. Later, in 1854, Ehrenberg presented a first drawing of *S. construens*.

Though considering *Staurosira* as part of *Fragilaria* Lyngbye, Grunow (1862) distinguished its species mainly by their wider sternum at the center of the valve and he subdivided the taxa by their habitat into freshwater or marine taxa. Later, Petit (1877) kept *Fragilaria* and *Staurosira* as distinct genera, mainly because the different arrangement of plastids: in *Staurosira* they are adjacent to the girdle, while in *Fragilaria* they are appressed against the valve internal surface.

Williams & Round (1987) made a revision of several "fragilarioid" species, until then included in *Fragilaria*. Based on morphological, cytological, and ecological characteristics, they allocated species in six genera: *Fragilaria*, *Neofragilaria* D.M.Williams & Round (later, renamed as *Fragilariforma* D.M.Williams & Round (Williams & Round 1988)), *Pseudostaurosira* D.M.Williams & Round, *Punctastriata* D.M.Williams & Round, *Staurosira* Ehrenberg, and *Staurosirella* D.M.Williams & Round. These authors noted that, in general, it is not possible to distinguish small representatives of *Staurosira*, *Staurosirella*, *Pseudostaurosira* or *Punctastriata* only with LM. It is important to note that they did not only use the ability of species to form colonies and the structure of the spines as diagnostic characters, but also the striation pattern, apical pore fields, presence/absence of rimoportulae, cingulum structure and plastid morphology.

Currently, there is a large controversy on the concept of *Staurosira* as a genus. Lange-Bertalot (1989) used some *Staurosira* species as representative for the concept that he used for *Fragilaria sensu lato*. One year later, Round et al. (1990) differentiated *Staurosira* from *Fragilaria* by non-areolate and narrow copulae, wide valvocopulae and absence of rimoportulae. Mistakenly, they mention the genus as "*Staurosira* (Ehrenberg) D.M. Williams & F.E. Round", and the generitype as "*Staurosira construens* (Ehrenberg) Williams & Round = *Fragilaria construens*". Since both taxa were first described by Ehrenberg, the names of Williams and Round, and the brackets were not required. After that, in Krammer & Lange-Bertalot (1991) and Lange-Bertalot (1993), they proposed *Staurosira* as a subgenus of *Fragilaria*, remarking that the subgenus is meant to be a "recognition of the distinguished work of Williams & Round in their classification attempts", and stated that working at the subgenus level would be less troublesome to avoid name changes and confusion among diatomologists. Lange-Bertalot (1993) mentioned that *Staurosira* species have the "*Fragilaria*-like" features, but differ on the absence of rimoportulae, the apical pore fields are reduced compared to other groups (never of the ocellulimbus type), and the large cingulum with 6–8 open, ligulate copulae are often curved.

Rumrich et al. (2000) resurrected the original concept of *Staurosira,* recognizing it as a genus. They clearly stated that there were going to be nomenclatural issues with infrageneric taxa of *Fragilaria* and *Staurosira*, as part of a paradigm change in their classification. They added that the features used until that moment were not sufficient to describe *Staurosira*, consequently they added more, such as: absence of rimoportulae, copulae without areolae (features already considered by Round et al. (1990)), and valves generally short in length. They added that other characteristics (e.g., areolae and foramen shape, valvocopulae width and apical pore fields) are freely variable.

Table 1. Updated list of 26 taxa in the genus *Staurosira*.

Staurosira ambigua E.Morales, Edlund & S.A.Spaulding 2010c, Phycol. Res. 58: 100, figs 1–12, 30–35.
Staurosira aventralis Lange-Bertalot & Rumrich in Rumrich et al. 2000, Iconogr. Diatomol. 9: 221, plate 11, figs 1–8.
Staurosira binodis (Ehrenberg) Lange-Bertalot in Hofmann et al. 2011, 260, plate 10, figs 7–12.
Staurosira circula Van de Vijver & Beyens 2002, Nova Hedwigia 75 (3–4): 325, figs 41–57.
Staurosira construens Ehrenberg 1843b, Abh. Königl. Akad. Wiss. Berlin 1843: 424.
Staurosira construens var. *capitata* (Héribaud) Bukhtiyarova 1995, Algologia 5 (4): 418.
Staurosira construens var. *exigua* (W.Smith) H.Kobayasi in Mayama et al. 2002, Diatom 18: 90.
Staurosira construens var. *minuta* (Tempère & Peragallo) N.A.Andresen, Stoermer & Kreis 2000, Diatom Res. 15 (2): 417.
Staurosira construens var. *triundulata* (Reichelt) Bukhtiyarova 1995, Algologia 5 (4): 418.
Staurosira contorta Flower 2005, Diatom Res. 20(1): 66, figs 10–11.
Staurosira dimorpha E.Morales, Edlund & S.A.Spaulding 2010c, Phycol. Res. 58: 103, figs 20–29, 42–53.
Staurosira fernandae García-Rodríguez, Lange-Bertalot & Metzeltin in Metzeltin & García-Rodríguez 2003, Las diatomeas Uruguayas, 34, plate 16, figs 1–2.
Staurosira incerta E.Morales in Ognjanova-Rumenova & Manoylov (eds.) 2006, Advances in Phycological Studies. Festschrift in Honour of Prof. Dobrina Temniskova-Topalova. Pensoft Publishers & University Publishing House, Sofia–Moscow, 137, figs 1–24.
Staurosira kjotsunarum E.Morales, Novais & Ector in Morales et al. 2012, Fottea 12 (1), 45, figs 27–38, 57–62.
Staurosira leptostaurum (Ehrenberg) Kulikovskiy & Genkal in Kulikovskiy et al. 2011, Algologia 21(3): 363, plate 2, figs 1-6, plata 8, fig 1.
Staurosira longirostris (Frenguelli) Metzeltin, Lange-Bertalot & García-Rodríguez in Metzeltinet al. 2005, Iconogr. Diatomol. 15, 270, plate 13, figs 4–13.
Staurosira longwanensis Rioual, E.Morales & Ector in Rioual et al. 2014, Fottea 14 (1): 92, figs 2–155.
Staurosira neoproducta (Lange-Bertalot) Chudaev & Gololobova 2012, Novosti Sist. Nizsh. Rast. 46: 74, plate 2, figs 2–7; plate 4, figs 1–3; plate 5, fig. 11.
Staurosira obtusa (Hustedt) M.Garcia 2006, Phycol. Res. 54: 88, figs 9–37.
Staurosira patagonica M.L.García, Maidana, Ector & E.Morales sp. nov. (this study)
Staurosira pottiezii Van de Vijver in Van de Vijver et al. 2014, Phytotaxa 167(3): 257, figs 1–25.
Staurosira stevensonii Manoylov, E.Morales & Stoermer 2003, Eur. J. Phycol. 38: 67, figs 1–12.
Staurosira sviridae Kulikovskiy, Genkal & Mikheyeva 2011, Algologia 21(3): 363, plate 2, figs 15–17, plate 8, fig. 8.
Staurosira tabellaria (W.Smith) Petit in Leuduger-Fortmorel & Petit 1878, J. Microgr. 2(4): 179.
Staurosira triangexigua Kulijovsjiy & Genkal in Kulikovskiy et al. 2011, Algologia 21(3): 363, plate 2, fig. 85.
Staurosira venter (Ehrenberg) Cleve & J.D.Möller 1879, Diatoms. Part V, No. 217–276. Upsala: Esatas Edquists Boktrykeri, No. 242.

There is another point of view about *Staurosira*: studies based on molecular analysis. Medlin et al. (2008) analyzed the genera recently separated from *Fragilaria* and *Synedra* using molecular techniques to establish their genetic monophyly. On their results, they recognize that the genera derived from *Fragilaria* are not monophyletic. However, they point out that these are well removed from *Fragilaria* sensu stricto (except for *Fragilariforma*). These genera deserve some taxonomic ranking because they all fall into a single well supported clade and all of these genera lack labiate processes. Medlin et al. emphasize that the morphological feature that would characterize these different clades is difficult to identify, even though, the type of covering over the areolae has been used to delimit many of these genera. It needs to be considered that, various types of areolae covering are scattered throughout the clades therefore it must be assumed that the ancestor of this clade was capable of making all these different types. Medlin et al. (2012) got new data based on additional genes analyses which it still supported their earlier analyses, thus they end up recommending that diatomologists continue to define taxa to the genus to which they would belong based on morphological data until the molecular analysis is fully resolved.

After the study of Williams & Round (1987), the use of SEM became essential to describe new species within the Fragilariaceae. Diatomologists started to analyze type material of already described species before publishing new ones, in order to compare their features or to complete their descriptions. Related to *Staurosira*, Hamilton (Canadian Museum of Nature) is currently working on the type material of *S. construens* (Ehrenberg 1843a, "Brenn-Torf aus Newhaven, Connecticut" Sample no. 1763; drawing no. 2235, fig. 23: a, b, c and d). In a personal communication, he commented that he found "two valve outlines that represent *S. construens* in the type population, one symmetrical and one asymmetrically cruciate. The symmetrical valves have in general straighter and narrower striae. The asymmetrical cruciate valves have wider separation of the straight to curved striae as the *S. construens sensu stricto*". Morales (2001, fig. 1 a, b and c) analyzed samples of *Staurosira construens* var. *construens* from Connecticut lakes and he observed a wide variety of frustule morphologies.

After an extensive literature search, trying to clarify the taxonomic concept and boundaries of the genus *Staurosira*, we provide an up to date list of 26 taxa included in this genus (Table 1), and we point out the main characters used to identify each species, following the concept stated in Williams & Round, 1987). Also, we have found 91 taxa (Table 2) that appeared in databases as *Staurosira*, but in some cases they were already transferred to other genera or in other cases there are no LM or SEM images to justify their inclusion in this genus.

All the *Staurosira* species have rectangular frustules in girdle view and they frequently tend to form ribbon-like colonies, with interlocking spines (Kociolek et al. 2015). The valve outline is elliptical or expanded in the middle area (cruciate). The valve surface has more or less pronounced costae, and the axial area is narrow in most of the species. Striae are narrow, uniseriate or biseriate, slightly spaced at the center in smaller specimens, the striae do not meet one another in the central sternum. Small oval to linear areolae are internally occluded by volae. Apical pores fields are present at each pole, usually very reduced, with variable number of poroids. Spines are hollow or solid, are located on the ribs in most species; the tips may be flattened, serrated or branched. Rimoportulae are absent. Barely visible plaques are sometimes present on the abvalvar edge of the mantle. The valvocopula is wide and has fimbriae. The copulae are open, ligulate, in general non-perforated, but the presence of one row of perforations in *S. longwanensis* Rioual et al. (Rioual et al. 2014) or two in *S. dimorpha* Morales et al. (Morales et al. 2010c) has been observed.

Consequently, in order to identify a *Staurosira* species, attention should be centered on its outline (elliptical or cruciform); in girdle view, the frustules are rectangular; striae are narrow and do not meet one another in the central sternum; the areolae are small, round and internally occluded by volae; reduced apical pores fields are present at each pole; rimoportulae are absent; the cingulum elements are open and ligulate. Based on these characters, we have found in the literature several taxa which need to be reassigned. It should be clear that authors such as

Table 2. List of taxa that are within *Staurosira*, but were transferred to other genera, or cannot be confirmed at present due to lack of LM or SEM images or both in order to provide details to make more accurate descriptions of the taxa.

Taxa	**Current status**
Staurosira acuta Ehrenberg	Can not be confirmed
Staurosira acutirostrata (Metzeltin & Lange-Bertalot) Metzeltin & Lange-Bertalot in Metzeltin et al.	*Staurosirella acutirostrata* (Metzeltin & Lange-Bertalot) P.D.Almeida & C.E.Wetzel in Almeida et al.
Staurosira aequalis Grunow in Cleve & Möller	Can not be confirmed
Staurosira aequalis var. *producta* (Lagerstedt) Grunow in Van Heurck	*Staurosira neoproducta* (Lange-Bertalot) Chudaev & Gololobova
Staurosira alpestris (Krasske ex Hustedt) Van de Vijver	*Staurosirella alpestris* (Krasske ex Hustedt) Le Cohu
Staurosira altiplanensis Lange-Bertalot & Rumrich in Rumrich et al.	*Pseudostaurosira altiplanensis* (Lange-Bertalot & Rumrich in Rumrich et al.) E.Morales comb. nov. (see text)
Staurosira amphilepta Ehrenberg	Can not be confirmed
Staurosira anomala (W.Smith) Leuduger-Fortmorel & P.Petit	Can not be confirmed
Staurosira aventralis var. *asymmetrica* Flower	*Pseudostaurosira floweri* (Flower) E.Morales stat. nov. nom. nov. (see text)
Staurosira berolinensis (Lemmermann) Lange-Bertalot in Krammer & Lange-Bertalot	*Staurosirella berolinensis* (Lemmermann) Bukhtiyarova
Staurosira bidens (Heiberg) Grunow	*Fragilaria bidens* Heiberg
Staurosira bidens f. *major* Grunow in Van Heurck	Can not be confirmed
Staurosira bidens var. *patagonica* Cleve	Can not be confirmed
Staurosira borealis (Foged) Witkowski, Lange-Bertalot & Witon in Witon et al.	*Pseudostaurosira borealis* (Foged) M.L.García, E.Morales, Ector & Maidana stat. et comb. nov. (see text)
Staurosira brevistriata Grunow	*Pseudostaurosira brevistriata* (Grunow in Van Heurck) D.M.Williams & Round
Staurosira brevistriata var. *lapponica* (Grunow) Grunow	*Staurosirella lapponica* (Grunow) D.M.Williams & Round
Staurosira brevistriata var. *subacuta* Grunow	Can not be confirmed
Staurosira capucina (Desmazières) I.G.Borshchow	*Fragilaria capucina* Desmazières
Staurosira capucina var. *acuta* (Ehrenberg) Belloc	Can not be confirmed
Staurosira capucina var. *acuta* (Ehrenberg) Comère	Can not be confirmed
Staurosira capucina var. *contracta* (Schumann) Comère	Can not be confirmed.
Staurosira capucina var. *mesolepta* (Rabenhorst) Comère	*Fragilaria mesolepta* Rabenhorst
Staurosira capucina var. *tenuicollis* Cleve & Möller	? *Fragilaria capucina* var. *austriaca* (Grunow) Lange-Bertalot
Staurosira construens var. *pinnata* (Ehrenberg) Schumann	*Staurosira pinnata* Ehrenberg

Taxa	Current status
Staurosira construens var. *pumila* (Grunow in Van Heurck) J.C.Kingston	Can not be confirmed
Staurosira construens f. *subsalina* (Hustedt) Bukhtiyarova	*Pseudostaurosira salina* (Grunow in Van Heurck) Witkowski, Lange-Bertalot & Pliński in Pliński & Witkowski
Staurosira construens var. *subsalina* (Hustedt) N.A.Andresen, Stoermer & Kreis	*Pseudostaurosira salina* (Grunow in Van Heurck) Witkowski, Lange-Bertalot & Pliński in Pliński & Witkowski
Staurosira contracta (Schumann) P.Petit	Can not be confirmed
Staurosira crassa (Metzeltin & Lange-Bertalot) Metzeltin, Lange-Bertalot & García-Rodríguez	*Staurosirella crassa* (Metzeltin & Lange-Bertalot) F.C.P.Ribeiro & Torgan in Ribeiro et al.
Staurosira dubia Grunow in Cleve & Möller	*Staurosirella dubia* (Grunow in Cleve & Möller) E.Morales & Manoylov in Morales et al.
Staurosira elliptica (Schumann) Cleve & J.D.Möller	*Pseudostaurosira elliptica* (Schumann) Edlund, E.Morales & S.A.Spaulding
Staurosira elliptica (Schumann) D.M.Williams & Round	*Pseudostaurosira elliptica* (Schumann) Edlund, E.Morales & S.A.Spaulding
Staurosira epidendron Ehrenberg	*Melosira roeseana* var. *epidendron* (Ehrenberg) Grunow in Van Heurck
Staurosira gongyla Kryshtofowicz	Can not be confirmed
Staurosira grunowii Pantocsek	*Staurosirella grunowii* (Pantocsek) E.Morales, Buczkó & Ector in Morales et al.
Staurosira grunowii var. *biangulata* Héribaud	Can not be confirmed
Staurosira grunowii var. *major* Héribaud	Can not be confirmed
Staurosira grunowii var. minor Héribaud	Can not be confirmed
Staurosira grunowii var. *triangulata* Héribaud	Can not be confirmed
Staurosira harrisonii (W.Smith) Pfitzer	*Staurosirella harrisonii* (W.Smith) E.Morales & C.E.Wetzel in Morales et al.
Staurosira harrisonii var. *amphitetras* Grunow	*Staurosirella grunowii* (Pantocsek) E.Morales, Buczkó & Ector in Morales et al.
Staurosira harrisonii var. *dubia* (Grunow) Cleve in Cleve & Grunow	*Staurosirella leptostauron* var. *dubia* (Grunow) Edlund
Staurosira harrisonii var. *fossilis* Pantocsek	Can not be confirmed
Staurosira harrisonii var. *triangularis* Cleve in Cleve & Jentzsch	Can not be confirmed
Staurosira hyemalis f. *minima* (Kützing) P.Petit in Leuduger-Fortmorel & Petit	Can not be confirmed
Staurosira inflatissima (Hustedt) Metzeltin & Lange-Bertalot	*Fragilaria inflatissima* Hustedt
Staurosira intermedia (Grunow) Grunow	*Fragilaria vaucheriae* (Kützing) J.B.Petersen
Staurosira islandica (Grunow in Van Heurck) Peletan	*Fragilaria islandica* Grunow in Van Heurck
Staurosira jolinae Van de Vijver in Van de Vijver & Beyens	*Punctastriata jolinae* (Van de Vijver in Van de Vijver & Beyens) M.L.García, Maidana & Van de Vijver comb. nov. (see text)

Taxa	**Current status**
Staurosira kavnensis Pantocsek	*Fragilaria kavnensis* (Pantocsek) De Toni
Staurosira lancettula Schumann	*Punctastriata lancettula* (Schumann) P.B.Hamilton & Siver
Staurosira lapponica (Grunow in Van Heurck) Lange-Bertalot in Krammer & Lange-Bertalot	*Staurosirella lapponica* (Grunow in Van Heurck) D.M.Williams & Round
Staurosira laucensis Lange-Bertalot & Rumrich in Rumrich et al.	*Pseudostaurosira laucensis* (Lange-Bertalot & Rumrich in Rumrich et al.) E.Morales & M.L.Vis
Staurosira laucensis var. *vulpina* Lange-Bertalot & Rumrich in Rumrich et al.	*Pseudostaurosira laucensis* var. *vulpina* (Lange-Bertalot & Rumrich in Rumrich et al.) E.Morales in Morales et al.
Staurosira martyi (Héribaud) Lange-Bertalot in Krammer & Lange-Bertalot	*Staurosirella martyi* (Héribaud) E.Morales & Manoylov
Staurosira mercedes Lange-Bertalot & Rumrich in Rumrich et al.	Can not be confirmed
Staurosira (*variabilis* var.) *mesodon* (Kützing) Cleve & Grunow	*Diatoma mesodon* Kützing
Staurosira mesolepta (Rabenhorst) Cleve & J.D.Möller	*Fragilaria mesolepta* Rabenhorst
Staurosira mexicana Ehrenberg	*Fragilaria mexicana* (Ehrenberg) De Toni
Staurosira microstriata (Marciniak) Lange-Bertalot in Rumrich et al.	*Pseudostaurosira microstriata* (Marciniak) Flower
Staurosira (*brevistriata* var.) *mormonorum* (Grunow in Van Heurck) Grunow	*Fragilaria brevistriata* var. *mormorum* Grunow in Van Heurck
Staurosira (*brevistriata* var.) *mormonorum* (Grunow in Van Heurck) Pantocsek	*Fragilaria brevistriata* var. *mormorum* Grunow in Van Heurck
Staurosira mutabilis (W.Smith) E.Pfitzer	*Staurosirella mutabilis* (W.Smith) E.Morales & Van de Vijver in Morales et al.
Staurosira mutabilis var. *intercedens* (Grunow in Van Heurck) Grunow	*Staurosirella pinnata* var. *intercedens* (Grunow in Van Heurck) P.B.Hamilton in Hamilton et al.
Staurosira niagarae (Ehrenberg) Hollerbach & Krasavina	*Stephanodiscus niagarae* Ehrenberg
Staurosira oldenburgiana (Hustedt) Lange-Bertalot in Krammer & Lange-Bertalot	*Staurosirella oldenburgiana* (Hustedt) E.Morales
Staurosira oldenburgioides (Lange-Bertalot in Lange-Bertalot & Metzeltin) Kulikovskiy, Lange-Bertalot & Witkowski in Kulikovskiy et al.	*Staurosirella oldenburgioides* (Lange-Bertalot in Lange-Bertalot & Metzeltin) E.Morales, M.L.García & Maidana comb. nov. (see text)
Staurosira opacolineata (Lange-Bertalot in Lange-Bertalot & Metzeltin) Witon, Lange-Bertalot & Witkowski in Witon et al.	*Pseudostaurosira opacolineata* (Lange -Bertalot in Lange-Bertalot & Metzeltin) M.L.García & Maidana comb. nov. (see text)
Staurosira parasitica (W.Smith) P.Petit	*Pseudostaurosira parasitica* (W.Smith) E.Morales
Staurosira parasitica (W.Smith) Pelletan	*Pseudostaurosira parasitica* (W.Smith) E.Morales
Staurosira parasitoides Lange-Bertalot, Rol.Schmidt & Klee in Schmidt et al.	*Pseudostaurosira parasitoides* (Lange-Bertalot, Rol.Schmidt & Klee in Schmidt et al.) E.Morales, M.L.García & Maidana comb. nov. (see text)
Staurosira pinnata Ehrenberg	Can not be confirmed

Taxa	Current status
Staurosira pinnata var. *trigona* (Krasske) Lange-Bertalot in Krammer & Lange-Bertalot	Can not be confirmed
Staurosira proboscoidea Lange-Bertalot & Rumrich in Rumrich et al.	Can not be confirmed
Staurosira producta (Lagerstedt) Cleve & J.D.Möller	*Fragilariforma virescens* (Ralfs) D.M.Williams & Round
Staurosira producta (Lagerstedt) Grunow	*Fragilariforma virescens* (Ralfs) D.M.Williams & Round
Staurosira pseudoconstruens (Marciniak) Lange-Bertalot in Krammer & Lange-Bertalot	*Pseudostaurosira pseudoconstruens* (Marciniak) D.M.Williams & Round
Staurosira punctiformis Witkowski, Metzeltin & Lange-Bertalot in Witkowski et al.	*Pseudostaurosiropsis punctiformis* (Witkowski, Metzeltin & Lange-Bertalot in Witkowski et al.) Witkowski, Seddon & Pliński in Pliński & Witkowski
Staurosira reimeri E.Morales, Manoylov & Bahls	*Stauroforma reimeri* (E.Morales, Manoylov & Bahls) E.Morales comb. nov. (see text)
Staurosira robusta (Fusey) Lange-Bertalot in Krammer & Lange-Bertalot	*Pseudostaurosira robusta* (Fusey) D.M.Williams & Round
Staurosira smithiana Grunow in Van Heurck	Can not be confirmed
Staurosira subsalina (Hustedt) Lange-Bertalot in Krammer & Lange-Bertalot	*Pseudostaurosira salina* (Grunow in Van Heurck) Witkowski, Lange-Bertalot & Pliński in Pliński & Witkowski
Staurosira tricarinata Ehrenberg	*Fragilaria tricarinata* (Ehrenberg) De Toni
Staurosira trigongyla Ehrenberg	*Fragilaria trigongyla* (Ehrenberg) De Toni
Staurosira ungeriana Grunow	*Ulnaria ungeriana* (Grunow) Compère
Staurosira ungeriana var. *abyssinica* (Grunow) according to Mills	*Fragilaria ungeriana* var. *abyssinica* Grunow
Staurosira vasta Pantocsek	*Fragilaria vasta* (Pantocsek) Mills

Kulikovskiy et al. (2011) are transferring taxa already located in other genera to *Staurosira* following a different concept from the one used herein. For example, we do not agree with the combination *Staurosira leptostauron* (Ehrenberg) Kulikovskiy & Genkal and *Staurosira berolinensis* (Lemmermann) Kulikovskiy & Genkal proposed in Kulikovskiy et al. (2011) (See Table 2).

We transfer eight *Staurosira* species to other genera (*Pseudostaurosira*, *Punctastriata*, *Staurosirella* and *Stauroforma*), we consider that there is sufficient published information that warrants their taxonomic transfer:

***Pseudostaurosira altiplanensis* (Lange-Bertalot & Rumrich in Rumrich et al.) E.Morales comb. nov.**

Basionym: *Staurosira altiplanensis* Lange-Bertalot & Rumrich in Rumrich et al. 2000, Iconogr. Diatomol. 9: 220, Plate 14, figs 1–8.

***Pseudostaurosira borealis* (Foged) M.L.García, E.Morales, Ector & Maidana stat. et comb. nov.**

Basionym: *Fragilaria construens* var. *binodis* f. *borealis* Foged 1974, Freshwater diatoms in Iceland, Biblioth. Phycol. 15: 56, Plate 3, fig. 6.

Synonym: *Staurosira borealis* (Foged) Witkowski, Lange-Bertalot & Witon in Witon et al. 2004, Diatom Res. 19(1), 123–134, figs 11–16.

***Pseudostaurosira floweri* (Flower) E.Morales stat. nov. nom. nov.**

Replaced Synonym: *Staurosira aventralis* var. *asymmetrica* Flower 2005, Diatom Res. 20(1): 66, fig. 15.

Etymology: Dedicated to our esteemed colleague R. Flower.

***Pseudostaurosira opacolineata* (Lange-Bertalot in Lange-Bertalot & Metzeltin) M.L.García & Maidana comb. nov.**

Basionym: *Fragilaria opacolineata* Lange-Bertalot in Lange-Bertalot & Metzeltin 1996, Iconogr. Diatomol. 2: 56, Plate 7, figs 36–41b, Plate 111, figs 2–3.

Synonym: *Staurosira opacolineata* (Lange-Bertalot) Witon, Lange-Bertalot & Witkowski in Witon et al. 2004, Diatom Res. 19(1), 123–134, figs 22–26.

***Pseudostaurosira parasitoides* (Lange-Bertalot, Rol.Schmidt & Klee in Schmidt et al.) E.Morales, M.L.García & Maidana comb. nov.**

Basionym: *Staurosira parasitoides* Lange-Bertalot, Rol.Schmidt & Klee in Schmidt et al. 2004, Algol. Stud. 114: 3, figs 1–5, 15–17.

***Punctastriata jolinae* (Van de Vijver in Van de Vijver & Beyens) M.L.García, Maidana & Van de Vijver comb. nov.**

Basionym: *Staurosira jolinae* Van de Vijver in Van de Vijver & Beyens 2002, Nova Hedwigia 75(3-4): 320, figs 1–40.

***Stauroforma reimeri* (E.Morales, Manoylov & Bahls) E.Morales comb. nov.**

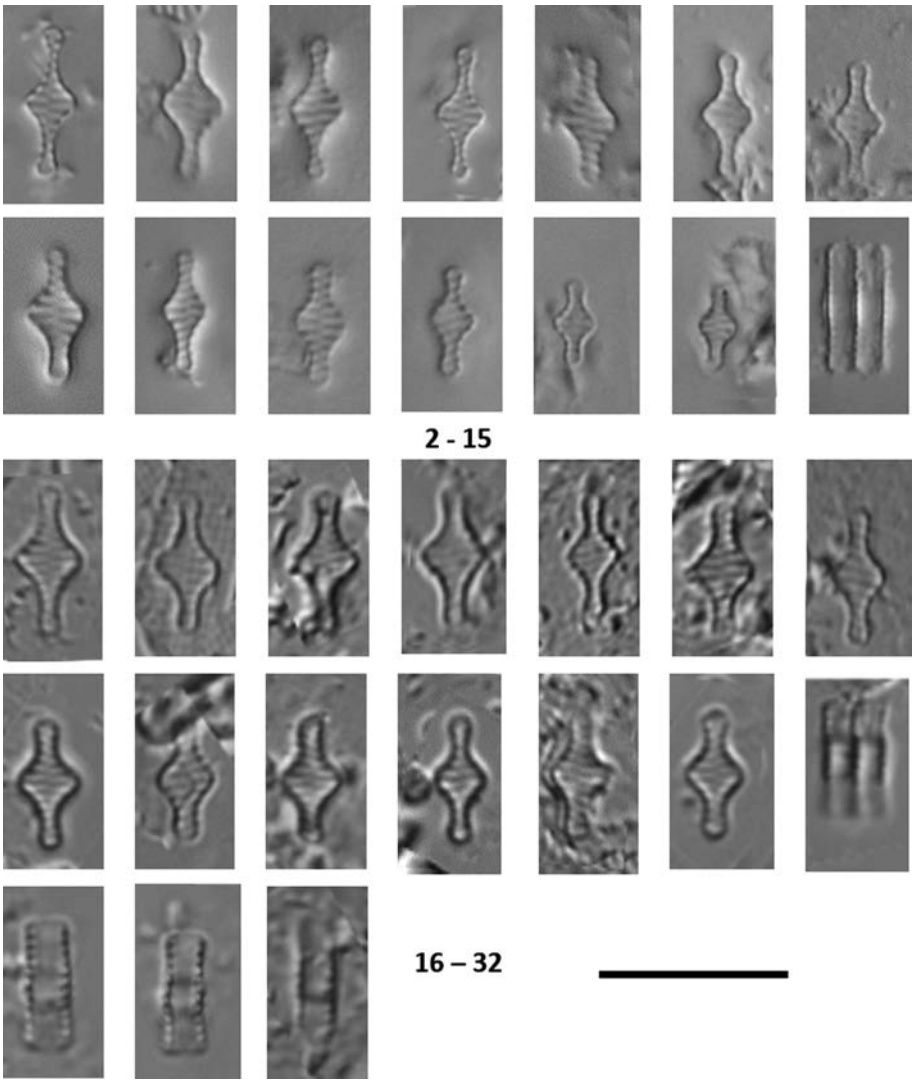
Basionym: *Staurosira reimeri* E.Morales, Manoylov & Bahls 2010a, Proc. Acad. Nat. Sci. Phil. 160: 31, figs 1–11, 33–38.

***Staurosirella oldenburgioides* (Lange-Bertalot in Lange-Bertalot & Metzeltin) E.Morales, M.L.García & Maidana comb. nov.**

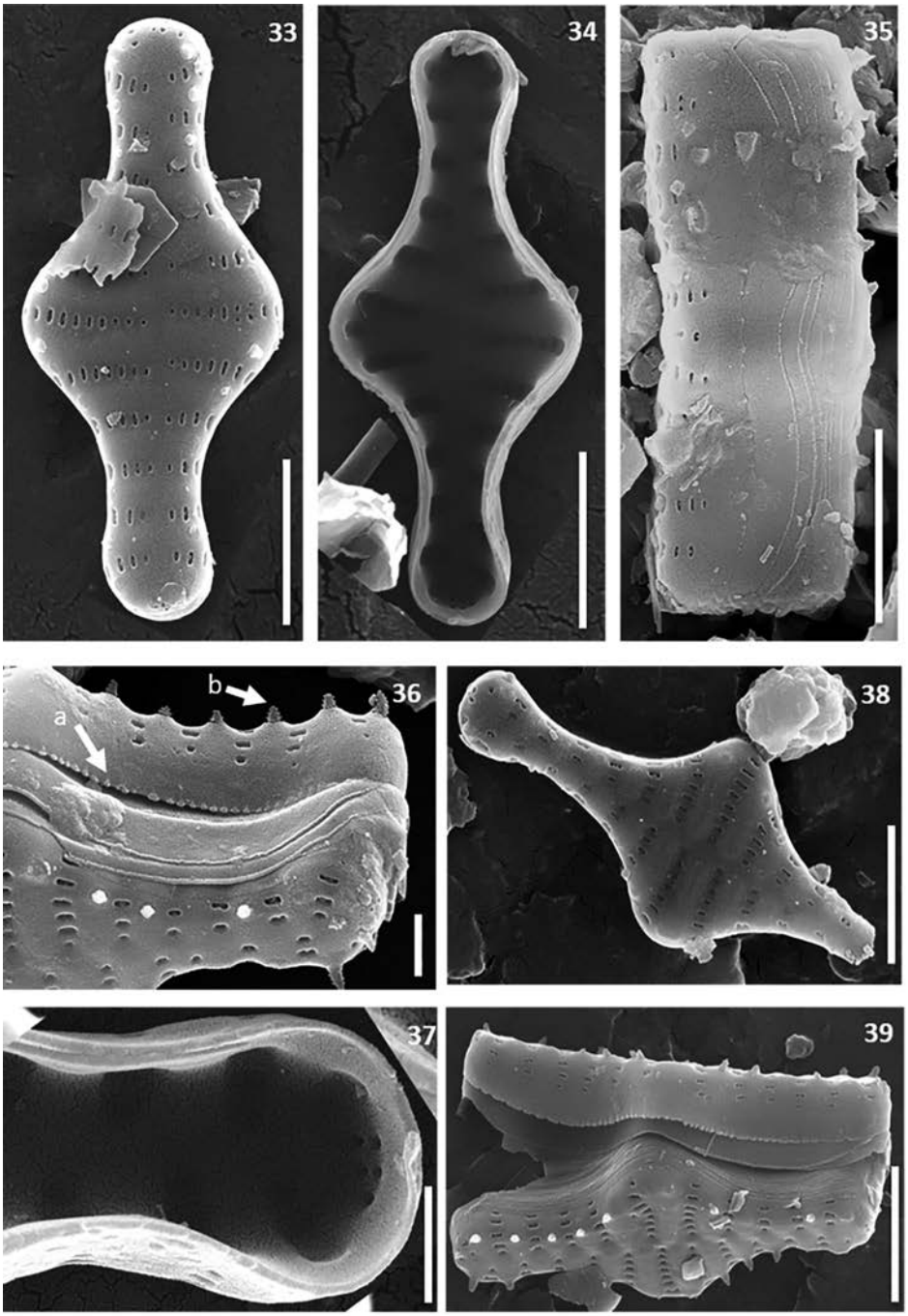
Basionym: *Fragilaria oldenburgioides* Lange-Bertalot in Lange-Bertalot & Metzeltin 1996, Iconogr. Diatomol. 2: 55–56, Plate 7, figs 42–47b, Plate 111, figs 8, 9.

***Staurosira patagonica* sp. nov.** Figs 2–32 (LM), 33–45 (SEM)

Frustules rectangular in girdle view, joined by their valve surface, forming ribbon-like colonies. Valves isopolar, with rostrate to capitate apices (in the longest specimens). Axial area linear, almost indistinguishable. Striae uniseriate, parallel, slightly radiate at the apices, alternate at both sides of the sternum. Striae continues on the mantle with 2 to 4 areolae. The areolae are apically-elongated, of variable length along the same stria; internally occluded by volae. Volae are bifurcate, projecting from the areolar sides, parallel to the apical axis. Interlocking spines conical, solid, located on the ribs; the spines seem to be serrated, depending on preservation in the material. Apical pore fields poorly developed, composed by 5–6 poroids, each surrounded by



Figs 2–15. LM images of *Staurosira patagonica* sp. nov., type material. Maar Magallanes, Santa Cruz, Argentina (type material, LPC 15216). **Figs 16–32.** Images of *Staurosira patagonica* sp. nov. population from Laguna Toro, Santa Cruz, Argentina. Figs 15, 29–32. Girdle view. Scale bar = 10 μm.



Figs 33–39. SEM images of *Staurosira patagonica* sp. nov., recovered from Maar Magallanes, Santa Cruz, Argentina (type material, LPC 15216). Fig. 33. External valvar view. Fig. 34. Internal valvar view. Fig. 36. Detail of the apical pore field, mantle plaques (a), serrated spines (b) and areolae. Fig. 37. Internal view of the apical pore field. Fig. 38. External valvar view of a capitated specimen. Fig. 39. Opened frustule, showing the valvocopula and open girdle elements. Scale bars in figs 33–35, 38, 39 = 2 µm; scale bars in figs 36, 37 = 500 nm.

a rim. Cingulum composed of up to six open girdle bands without areolae. Mantle plaques small and numerous, located on the advalvar edge of the mantle. Dimensions (n = 123): length 4.7–8.3 µm (6.7 ± 0.8), width 2.3–4.1 µm (3.1 ± 0.4), striae 15–20 in 10 µm, and areolae 58–70 in 10 µm.

Holotype: Figs 2–15 (LM) and Figs 33–39 (SEM) presented herein were made from the holotype population on slide LPC 15216, deposited (dry material available) in Colección de la División de Ficología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Argentina. Samples were collected by Dr. Hugo Corbella in April, 1993.

Isotype: Figs 16–32 (LM) and Figs 40–45 (SEM) presented herein were made from isotype population on slide BA 49157, deposited in Herbario Nacional de Plantas Celulares, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Buenos Aires, Argentina.

Synonyms: *Fragilaria construens* (Ehrenberg) Grunow *sensu* Maidana & Corbella (1997), *Staurosira construens* var. *construens* sensu Echazú (2012).

Type locality: Maar Magallanes (52°07´S 69°16´W), Santa Cruz province, Argentina.

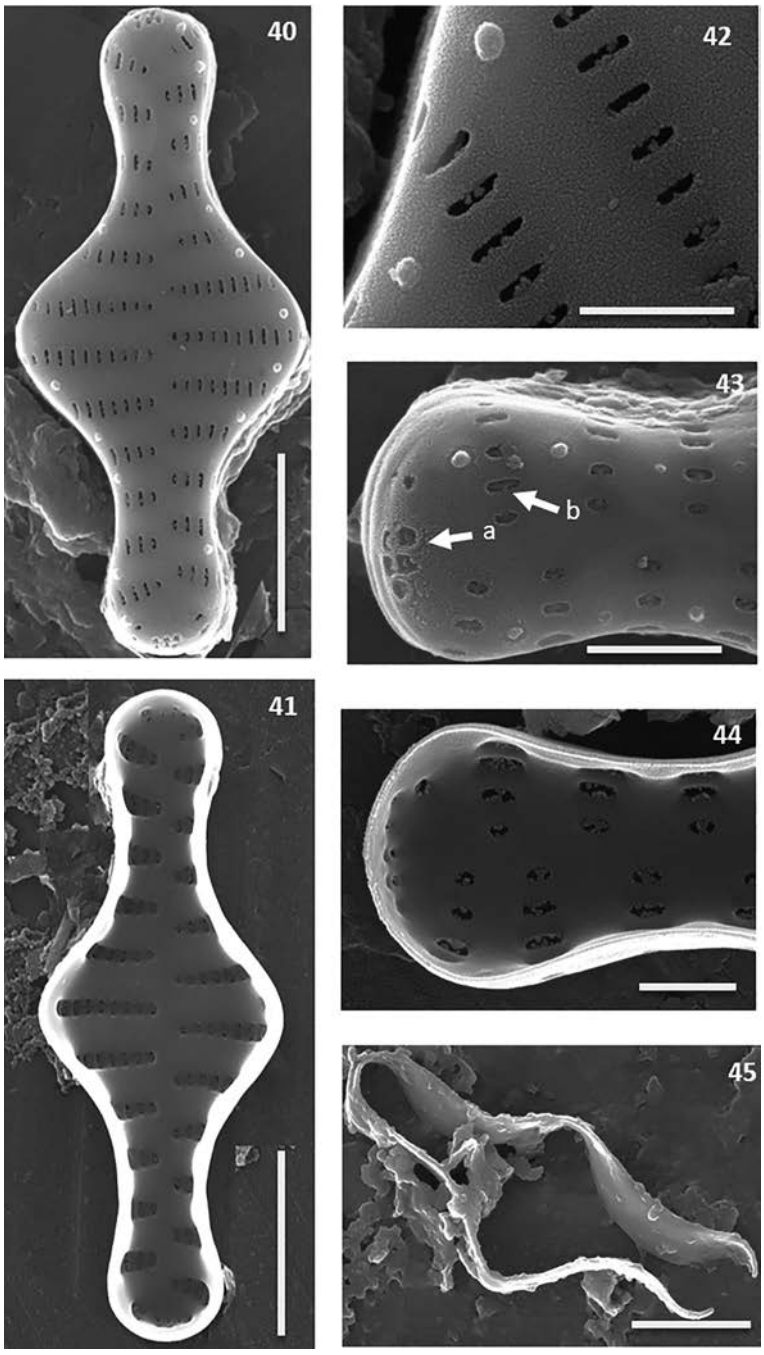
Etymology: The specific epithet refers to the area where Maar Magallanes and Laguna Toro are located, the southern Argentinian Patagonia.

Comments: Under LM, *S. patagonica* resembles the valve drawings of *S. construens* showed in Ehrenberg (1854, fig. 23 a and b), but SEMs of *S. construens* shown in Williams & Round (1987), reveal differences between the two species, including the much smaller size of *S. patagonica*. The valve outline in *S. patagonica*, although cruciate, is less rhombic, less slender, than *S. construens*; the latter is markedly cruciate, sometimes asymmetric, as stated by Hamilton (pers. comm.). In *S. patagonica*, the valve surface is flat, while *S. construens* has ribs somewhat raised *sensu* Williams & Round (1987, figs 15–17), giving its valve face a wavy or irregular appearance. Mantle plaques are absent in *S. construens* while in *S. patagonica* they are small and numerous.

The spines of *S. construens* are smooth, hollow, conical at their base and flattened at the tips (Williams & Round 1987, figs 15–17), while in *S. patagonica* the spines are conical from the base to the top, serrated, solid and with acute tips. However, some of the specimens seem to have spines not as developed as in other *Staurosira* taxa; the valves from Maar Magallanes (fossil material) have serrated spines, while the spines appear to be reduced in the recent material from Laguna Toro, but this could be attributed to erosion of the material since we could observe that the population from Maar Magallanes was better preserved than the one from Laguna Toro. Morales (2001) observed morphotypes of *S. venter* (Ehrenberg) Cleve & J.D.Möller with both, well developed and small spines. *Staurosira patagonica* was found forming chains of at least 2 cells, thus reduced spines of this species would not be preventing the formation of colonies. Morales et al. (2010c) reported two variants within a population of *S. dimorpha,* with and without spines; both types formed colonies. It is possible that the connection between the frustules in the spineless population of *S. dimorpha* and *S. patagonica* is also accompanied by the secretion of mucilage or due to mineralization occurring on the outer layer of the frustule.

The areolae of *S. patagonica* seem to be wider than the ones observed in *S. construens*. Also, in *S. patagonica* areolae are more spread than in *S. construens.* Although there is a decrease in size from the valve margins to the center in some specimens, in general, *S. patagonica*, shows an irregular areolar size along the same stria in comparison to what is observed on SEM images provided by Williams & Round (1987) for *S. construens*. However, variability in areolar size along a stria has also been reported for other populations of *S. construens* and *S. construens* var. *venter* by Morales (2001) and Morales et al. (2002).

Comparing the populations from Maar Magallanes and Laguna Toro, we found a wider range of valve sizes in Maar Magallanes, where we also found specimens with more capitate ends (Figs 2–4, 22, 26 and 38). It has to be considered that we have observed many more specimens in the population from Maar Magallanes than in Laguna Toro; in the latter only about 60 individuals were observed. Nonetheless, the morphometric data of both populations overlap (Fig. 46). The



Figs 40–45. SEM images of *Staurosira patagonica* sp. nov., recovered from the shallow lake Laguna Toro, Santa Cruz, Argentina. Fig. 40. External valvar view. Fig. 41. Internal valvar view. Fig. 42. Areolae detail with remains of the internal volae and reduced spines. Fig. 43. Close up of an external view, detail of the apical pore field with each pore surrounded by a rim (a) and the areolae close up with bifurcate volae (b). Fig. 44. Close up of internal view and detail of the apical pore field. Fig. 45. Opened girdle band. Scale bars in figs 40, 41 = 2 µm; scale bars in figs 42–45 = 500 nm.

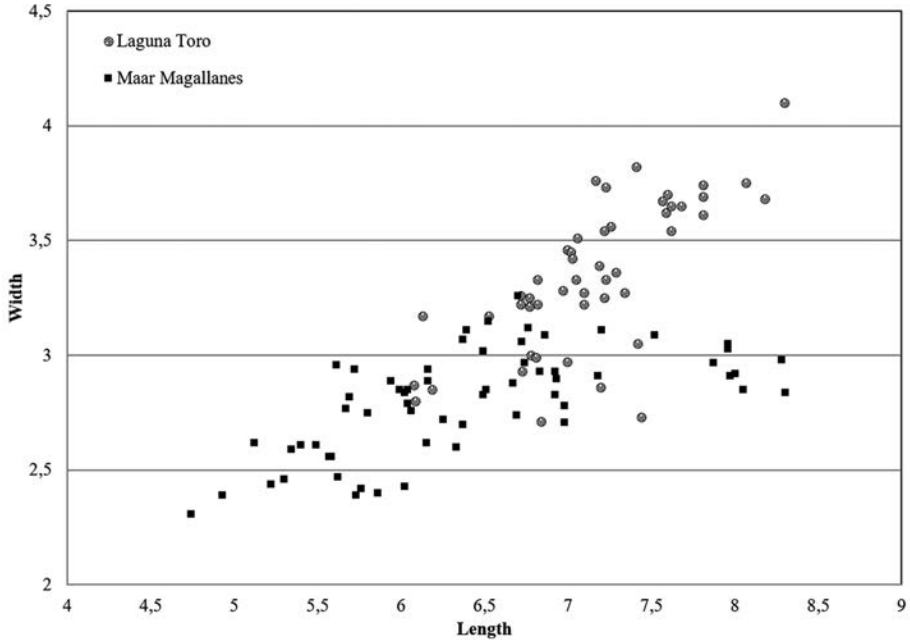


Fig. 46. Comparison of length vs. width of the populations from Laguna Toro and Maar Magallanes.

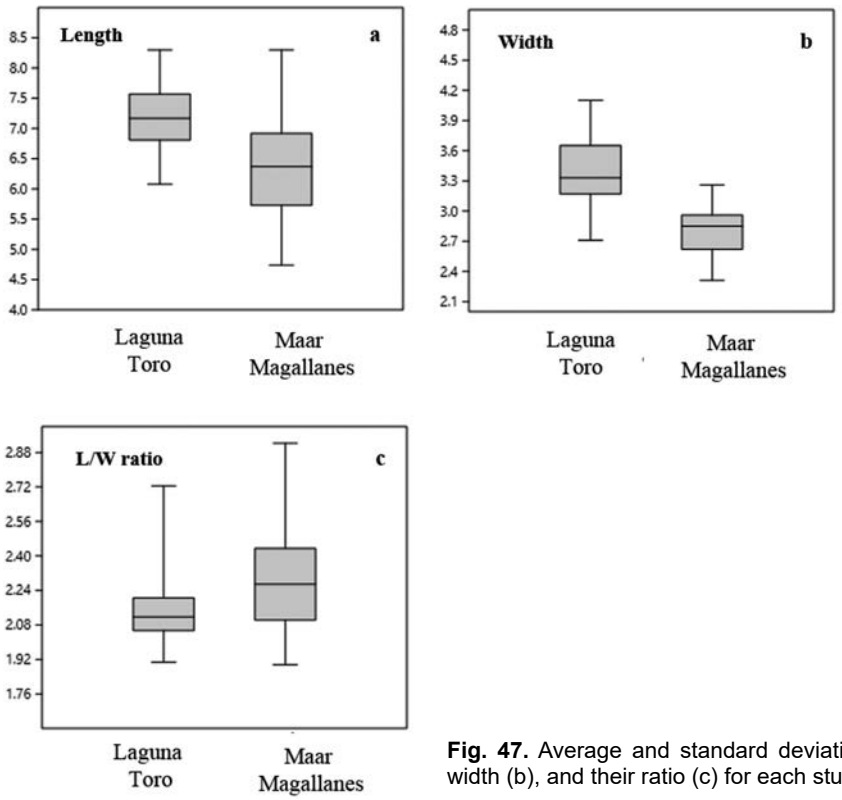


Fig. 47. Average and standard deviation of length (a), width (b), and their ratio (c) for each studied population.

Table 3. Comparison of valve features of small cruciform fragilarioid species.

Species	*Staurosira patagonica*	*Staurosira construens*		*Staurosira incerta*	*Pseudostaurosira pseudoconstruens*
References	this study	Williams & Round (1987)	Hamilton (pers. comm.)	Morales (2006)	Marciniak (1982)
Length (µm)	4.74–8.3 (7.11 ± 1.07)	7–25	8–12	8–17	4–22
Width (µm)	2.31–4.1 (3.32 ± 0.56)	5–12	4–6	4–6	3–7
Striae (in 10 µm)	15–20 uniseriate	14–18 uniseriate	14–16 uniseriate	13–16 uniseriate	15–18 uniseriate
Areolae	elongate	elliptical to linear	linear-elliptical to elliptical	slit-like	rounded to elliptical
Spines	solid, serrate, on the costae, curved	hollow, on the costae, curved	conical and solid	hollow, spathulate and located on the costae	located on the striae
Axial area	narrow, linear	narrow, lanceolate	n. d.	narrow, lanceolate	narrow, lanceolate
Girdle elements	open	open, ligulate	n. d.	closed, not perforated	open, plates on the mantle

valves from Maar Magallanes cover the whole length range calculated for this new taxon, the longest being the ones with more capitate ends. On the other hand, the longest valves from Laguna Toro seem to be wider than those from Maar Magallanes.

The populations from Maar Magallanes and Laguna Toro cannot be differentiated from one another based on their morphological and morphometrical features because there are no significant differences ($p < 0.05$) between them based on their length, width and length/width ratio (Fig. 47 a, b and c). Despite the mean values of the apical axis length are different (Fig. 47 a), the range of variation in valve length from Laguna Toro is contained within that of the population from Maar Magallanes, which shows more dispersion in its values. Regarding valve width (Fig. 47 b), the population from Laguna Toro seems to be wider than the one from Maar Magallanes.

Ecology: *Staurosira patagonica* was extremely abundant only in a section of the sediment core M3 from Maar Magallanes (32.68 to 32.80 m depth, 88 and 96% relative abundance, respectively). We found this species in an assemblage along with *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck, *Thalassiosira patagonica* Maidana and *Discostella stelligera* (Cleve & Grunow) Houk & Klee.

In surface sediments from Laguna Toro, *S. patagonica* represented 14.9% of the total diatom abundance. Species that co-dominated in this ecosystem were *Staurosira construens* var. *venter* (16.6%) and *Nitzschia* aff. *vermicularis* (13.9%).

Although Maidana & Corbella (1997) related the appearance of *S. patagonica* with cold conditions, we do not know the exact chemical and physical characteristics of the type locality for this new taxon (Maar Magallanes). However, several chemical and physical characteristics of Laguna Toro were measured (pH 8.5, water temperature 4.1 °C, and electric conductivity 313 $\mu S.cm^{-1}$) which give a rough idea of the ecological requirements for this taxon.

Echazú (2012, plate 30: figs 21, 22; plate 45: fig. 5) shows a valve with the characteristics of *S. patagonica* but reported as *S. construens.* In her study Echazú includes other lakes from Southern Patagonia, this prompts a re-examination of the diatoms reported as *S. construens* for the region.

Acknowledgements

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