Type analysis of the South American diatom *Achnanthes haynaldii* (Bacillariophyta) and description of *Planothidium amphibium* sp. nov., from aerial and aquatic environments in Oregon (USA)

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Background and aims – *Planothidium haynaldii* (Schaarschm.) Lange-Bert. ($\equiv$ *Achnanthes haynaldii* Schaarschm.) is a widely reported species from temperate and cold zones of southern and northern hemispheres despite being originally described from a high altitude stratovolcano (Antisana, 4100 m a.s.l.) in Ecuador (tropical climatic zone). Although widely cited in the literature, studies concerning the original material were never carried out. The main objective of this paper is to clarify the identity of *Planothidium haynaldii* and two related species from North-western USA and Antarctic environments.

Methods – The original type slide of *Achnanthes haynaldii* Schaarschm. was observed. Additionally, selected samples containing populations currently identified either as *Planothidium haynaldii* or *Achnanthes lanceolata* var. *capitata* O.Müll. collected in Oregon (USA) and James Ross Island (Antarctica) were observed. The samples were analyzed using light (LM) and scanning electron microscopy (SEM).

Key results – A new species, commonly improperly identified as *Planothidium haynaldii*, is described as *Planothidium amphibium* C.E.Wetzel, Ector & L.Pfister sp. nov. from aerial and aquatic habitats of Oregon (USA). This species is widely distributed in the northern hemisphere according to illustrated literature records. *Achnanthes lanceolata* var. *capitata* is erected to species level and transferred to the genus *Planothidium*. *Planothidium capitatum* (O.Müll.) Van de Vijver, Kopalová, C.E.Wetzel & Ector comb. & stat. nov. seems to be an important component of the communities in the Antarctic region where large populations were found on James Ross Island and Livingston Island living in the epilithon and epipelon of large lakes. Finally, *Planothidium haynaldii* seems to be rarer than initially expected and its occurrence is confirmed only in the Andes mountain range in South America (recent freshwater sample from Ecuador and as fossil in Chile).

Key words – *Achnanthes*, *Planothidium*, *Planothidium haynaldii*, type material, biogeography, ecology, SEM.

INTRODUCTION

Achnanthes haynaldii Schaarschm. was described in 1881 by Julius Schaarschmidt from riverine aquatic plants collected on the stratovolcano Antisana (northern Andes, Ecuador) by Luigi Sodiro. Schaarschmidt (1881) described three varieties, namely: ‘*vulgaris*’, ‘ *β -elliptico-lanceolata*’ and ‘ *γ -oblongo-elliptica*’ without any illustration of the mentioned taxa. The first illustrations were provided by Cleve (1894: 99, plate 2, fig. 14a,b) who observed the original type

slide of Schaarschmidt and who considered the species as a variety of *Achnanthes lanceolata* (Bréb. ex Kütz.) Grunow in Cleve & Grunow.

Few years later Müller (1909) described a new variety *Achnanthes lanceolata* var. *capitata* O.Müll. from the temperate zone of South America (southern Patagonia), slightly different from the variety ‘*haynaldii*’ by its smaller dimensions (width and length) and lower striation density. Later, Frenguelli (1930) described a similar species, namely

Achnanthes looseri Freng., from samples collected in the Andes mountain range close to Antofagasta, Chile. The latter species remained forgotten for a long period until recently analysed and transferred to the genus *Planothidium* by Rivera & Cruces (2009).

In Europe and worldwide as well, the most influent publications about diatoms were those of Friedrich Hustedt in the late-mid 20th century. Hustedt (1933) considered *Achnanthes haynaldii* var. *vulgaris* Schaarschm. and *A. lanceolata* var. *haynaldii* Cleve as synonyms of *Achnanthes lanceolata* f. *capitata* (O.Müll.) Hust., while *Achnanthes haynaldii* var. *oblongo-elliptica* was considered by him as a synonym of *Achnanthes lanceolata* [= *Planothidium lanceolatum* (Bréb. ex Kütz.) Lange-Bert.] and as a consequence, the epithet ‘*haynaldii*’ remained unused for a long period despite the report of seven varieties of *Achnanthes haynaldii* proposed by Cleve-Euler in 1953 (fig. 528).

North American diatomists followed the species concept of Patrick & Reimer (1966, p. 271) concerning *Achnanthes lanceolata* var. *haynaldii* and considered O. Müller’s variety ‘*capitata*’ as a synonym of the mentioned taxon. The original drawings provided by the latter authors are shown in the figure 1.

The first light micrographs (LM) of a taxon bearing the epithet ‘*haynaldii*’ was a population from the USA (‘*Sippe aus den USA*’) provided by Lange-Bertalot & Krammer (1989: 88, plate 84, figs 20–25) as ‘(?) *Achnanthes lanceolata* var. *haynaldii*’. Lange-Bertalot explicitly used a question mark to his identification and indeed the illustrated valves seem to correspond to the drawings provided by Patrick & Reimer (1966). Later on, Krammer & Lange-Bertalot (1991, plate 41, figs 16–20) treated the same population (including the same images) as a subspecies variety: ‘*Achnanthes lanceolata* ssp. *lanceolata* var. (?) *haynaldii*’. Bukhtiyarova (1999) assigned this taxon to the genus *Planothidium* and kept it as a variety [*Planothidium lanceolatum* var. *haynaldii* (Schaarschm.) Bukht.], while in the same year Lange-Bertalot

(1999) transferred it also to *Planothidium* and proposed the new combination *Planothidium haynaldii* (Schaarschm.) Lange-Bert. All these transfers concerning supra and infra-specific combinations were made without a critical analysis of the type material.

An attempt on solving the identity of species around the ‘*lanceolata-haynaldii*’ complex was led by Lowe & Cody (2002) who discussed several *Planothidium* species from the USA and concluded that discrepancies concerning valve width between the description of the type material of *Achnanthes haynaldii* and the populations identified as *Planothidium haynaldii* from the USA were too high and that additional investigations of the original material should be carried out. Indeed Potapova (2011) pointed out that the original description of *Achnanthes haynaldii* did not include illustrations and that the type material had never been investigated. Meanwhile the concept followed by North American taxonomists (i.e. Spaulding et al. 2010, Potapova 2011) is the one presented in Patrick & Reimer (1966).

In this paper we clarify and specify the identity of *Achnanthes haynaldii*, illustrating for the first time the type material using light microscopy. Moreover, we describe a new similar species from the USA currently misidentified as *Planothidium haynaldii* and we illustrate a population of *Achnanthes lanceolata* var. *capitata* O.Müll. from the Antarctic region, usually regarded as a synonym of *Planothidium haynaldii*.

MATERIAL AND METHODS

The material used for description and illustration of *Achnanthes haynaldii* comes from the original slide (fig. 1A) MIC 3417 “Ecuador 59 Antisana ad 4100 meters (Sodiro)” borrowed from the Naturhistoriska Riksmuseet, Stockholm, Sweden. Since no raw material was available for scanning electron microscope analysis, only LM images are presented.

Figure 1 – A, original slide used by Schaarschmidt (1881) to describe *Achnanthes haynaldii* from Ecuador (Antisana volcano, 4100 m a.s.l., collected by Sodiro); B–C, drawing of ‘*Achnanthes lanceolata* var. *haynaldii*’ by Cleve (1894, plate 7, fig. 14a,b); D–E, ‘*Achnanthes (Microneis) looseri*’ by Frenguelli (1930: 198, fig. 1); F–G, ‘*Achnanthes lanceolata* forma *capitata* O. Müller’ by Hustedt (1933: 410, fig. 863g,h); H–I, ‘*Achnanthes lanceolata* var. *haynaldii* (Istv.-Schaarsch.) Cl.’ published by Patrick & Reimer (1966: 271, plate 18, figs 20–21). Scale bar represents 10 µm.

Table 1 – Chemical and physical parameters of water samples collected during a runoff event (drift samples) measured in the Oak Creek Watershed, Corvallis, Oregon, USA between 6 and 14 Mar. 2012.

	Unit	N	Min	Max	Mean	Stand. dev.	Median	Coeff. var. (%)
Conductivity	$\mu\text{S}\cdot\text{cm}^{-1}$	47	70.00	163.70	132.73	26.84	145.60	20.22
Silica	$\text{mg}\cdot\text{L}^{-1}$	47	10.20	22.10	17.50	2.46	18.50	14.05
Sodium	$\text{mg}\cdot\text{L}^{-1}$	47	2.65	7.68	5.16	1.16	5.56	22.57
Potassium	$\text{mg}\cdot\text{L}^{-1}$	47	0.18	0.55	0.32	0.10	0.30	30.62
Magnesium	$\text{mg}\cdot\text{L}^{-1}$	47	3.24	7.97	6.03	1.21	6.56	19.99
Calcium	$\text{mg}\cdot\text{L}^{-1}$	47	6.65	16.85	13.15	2.94	14.29	22.38
Chlorides	$\text{mg}\cdot\text{L}^{-1}$	47	0.87	4.31	2.35	0.79	2.62	33.46
Nitrates	$\text{mg}\cdot\text{L}^{-1}$	47	0.02	1.59	0.10	0.24	0.02	230.23
Sulphates	$\text{mg}\cdot\text{L}^{-1}$	47	0.14	3.87	1.81	0.70	1.93	38.34

Material used to describe a new similar species was collected at a catchment of 0.208 km², sub-basin of the 33 km² Oak Creek Watershed, located near Corvallis, Oregon, U.S.A (44°35'32.3"N 123°19'43.2"W). The climate in this region is relatively mild and often described as Mediterranean, with dry summers and wet winters. Average temperature in the watershed is 11.5°C and mean annual precipitation is approximately 111 cm·year⁻¹ (Oregon Climate Service, www.ocs.oregonstate.edu). The studied catchment is primarily agricultural (sheep and cattle grazing, growth of clover, wheat and fescue) with small inholdings of residential areas (Poor & McDonnell 2007).

Different types of samples (n = 38) were considered for diatom analysis and can be divided in two groups: one group (n = 8) composed of samples from different substrates outside the streambed (aerial environments), such as herbaceous vegetation, litter, bryophytes and soil samples from grasslands plots; a second group (n = 30) comprising water samples collected during a rainstorm event using an automatic water sampler (ISCO 6712 FS) installed a couple of meters upstream a weir to collect stream water samples at frequent intervals during storm runoff events (0.5–3 h). Sampler contained 24 bottles (1-L) and was linked to the recording stream gauge. Sampling was triggered by flow conditions. A total of 47 samples were collected for water analysis and a total of 30 drift samples for diatom analysis. Abiotic conditions were measured following standard procedures and are listed in table 1.

The samples concerning *Achnanthes lanceolata* var. *capitata* were collected from lakes during several field trips on Livingston Island (South Shetland Islands) in the southern Atlantic Ocean and James Ross Island in the northern Weddell Sea. Both localities belong to the Maritime Antarctic Region (Chown & Convey 2007). Details on sampling methods and physico-chemical analyses can be found in Kopalová & Van de Vijver (2013) and Kopalová et al. (2013).

Diatom samples for LM observation were prepared following the method described in van der Werff (1955). Subsamples of the original material were oxidized using 37% H₂O₂ and heating to 80°C for approximately 1h. The reaction was further completed by the addition of KMnO₄. Following digestion and centrifugation (three times 10 minutes at

3700 r.p.m.), the material free of organic matter was diluted with distilled water for sample mounting to avoid excessive concentrations of diatom valves and frustules on the slides. A subsample from the organic-free material was mounted in Naphrax® for diatom community studies. The slides were analysed using an Olympus® BX53 microscope, equipped with Differential Interference Contrast (Nomarski) and an Olympus® UC30 digital camera and with a Leica® DMRX with bright field equipped with a Leica® DC500 camera.

For scanning electron microscopy (SEM) of Antarctic material, parts of the oxidized suspensions were filtered through a 1- μm Isopore™ polycarbonate membrane filter (Merck Millipore). The stubs were sputter-coated with a gold-palladium layer of 20 nm and studied in a Zeiss Ultra SEM microscope at 3 kV (Natural History Museum London, UK). SEM images of the material collected in Oregon (USA) were taken with an ultra-high-resolution analytical field emission (FE) scanning electron microscope Hitachi SU-70 (Hitachi High-Technologies Corporation, Japan) operated at 5 kV and 10 mm distance (Public Research Centre - Gabriel Lippmann, Luxembourg). SEM images were taken using the lower (SE-L) detector signal.

Diatom terminology follows Ross et al. (1979) and Round et al. (1990). For comparison, the following publications were consulted: Schaarschmidt (1881), Cleve (1894), Müller (1909), Frenguelli (1923, 1930), Hustedt (1933), Cleve-Euler (1953), Patrick & Reimer (1966), Lange-Bertalot & Krammer (1989), Krammer & Lange-Bertalot (1991), Lange-Bertalot (1997), Lange-Bertalot & Genkal (1999), Potapova (2011).

Samples and slides are stored at the BR-collection (Botanic Garden Meise, Belgium).

RESULTS AND DISCUSSION

The identity of three species is here clarified (table 2). *Planothidium haynaldii* seems to be a rare species found in the Andes mountain range of South America (Ecuador, Chile), while *Planothidium capitatum* is mainly found in lakes in the Antarctic continent. *Planothidium amphibium* is the most common and widespread diatom among the three species here discussed and has been misidentified in the past

Table 2 – Morphological features of *Planothidium amphibium*, *P. haynaldii* and *P. capitatum*.

	<i>Planothidium amphibium</i>	<i>Planothidium haynaldii</i>	<i>Planothidium capitatum</i>
reference	this study	Schaarschmidt (1881)	Müller (1909)
central area	sinus	sinus	sinus
length (µm)	11–21	17–32	15–22
width (µm)	5–6	6.7–9.5	4.5–5
striae	13–16	14–16	14–15
valve shape	valves linear to linear-lanceolate; slightly to moderately swollen in the middle portion	valves linear to linear-lanceolate; markedly swollen in the middle portion	valves linear to linear-lanceolate; slightly expanded in the middle
apices	capitate to subcapitate, protracted apices	capitate (in larger cells) to subcapitate (smaller cells), protracted apices	capitate to subcapitate, protracted apices

as *Planothidium haynaldii*. Their identities are discussed as follows:

Planothidium haynaldii (Schaarschm.) Lange-Bert.
Fig. 2A–AJ

Basionym – *Achnanthes haynaldii* Schaarschm., Magyar Növénytani Lapok 5: 20. 1881 (Schaarschmidt 1881).

≡ *Achnanthes lanceolata* var. *haynaldii* (Schaarschm.) Cleve, Le Diatomiste 2: 99. 1894 (Cleve 1894).

≡ *Achnanthidium lanceolatum* var. *haynaldii* (Schaarschm.) Comber, Catalogue of African Plants Collected by Dr. Friedrich Welwitsch 2: 389. 1901 (Comber 1901).

≡ *Achnanthidium lanceolatum* var. *haynaldii* (Schaarschm.) F.Meister, Die Kieselalgen der Schweiz. Beiträge zur Kryptogamenflora der Schweiz: 99. 1912 (Meister 1912).

≡ *Microneis lanceolata* var. *haynaldii* (Schaarschm.) Freng., Boletín de la Academia Nacional de Ciencias en Córdoba 27: 73. 1923 (Frenguelli 1923).

≡ *Achnanthidium haynaldii* (Schaarschm.) Morosov, Visnik Dnipropetrovskoi Hidrobiologichnoi Stantsii 1: 68. 1929 (Morosov 1929).

≡ *Achnantheiopsis haynaldii* (Schaarschm.) Lange-Bert., Archiv für Protistenkunde 148: 207. 1997 (Lange-Bertalot 1997).

≡ *Planothidium lanceolatum* var. *haynaldii* (Schaarchm.) Bukht., Diatoms of Ukraine inland waters: 44. 1999 (Bukhtiyarova 1999).

= *Achnanthes looseri* Freng., Revista Chilena de Historia Natural 34: 198, fig. 35–1. 1930 (Frenguelli 1930), **synon. nov.**

= *Planothidium looseri* (Freng.) P.Rivera & Cruces, Gayana Botanica 66: 96, figs 1–2. 2009 (Rivera & Cruces 2009), **synon. nov.**

Description – Valves linear to linear-lanceolate with convex margins and capitate (in larger cells) to subcapitate (smaller cells), protracted apices. Valve dimensions (n = 50):

length 17–32 µm, width 6.7–9.5 µm. Cells strongly bent in connective view (fig. 2I). Rapheless valve (fig. 2A–H & J–R): Axial area narrow and linear. Central area with a large horseshoe-shaped hyaline area on one side, showing a clear, hemicircular depression surrounded by a raised ridge (= sinus) (fig. 2A–R). On the other side, striae slightly shortened forming hence a small hemicircular central area on this side (fig. 2A). Fascia never observed. Striae weakly radiate almost throughout the entire valve, 14–16 in 10 µm. Raphe valve (fig. 2S–AJ): Axial area narrow, linear, almost not widening towards the central area. Central area asymmetrical, rectangular to bow-tie shaped bordered on one side by 2–5 irregularly shortened striae. Complete fascia never present. Raphe branches straight with simple proximal raphe endings. Distal raphe fissures unilaterally deflected, hard to observe in LM. Smaller valves can present slight ‘cymbelloid’ symmetry (fig. 2AC–AF). Striae radiate throughout the entire valve, becoming more distinctly radiate near the apices, 14–16 in 10 µm.

Ecology and distribution – *Planothidium haynaldii* was described as an epiphytic aquatic species from Ecuador. The species is dominant in the sample collected at the Antisana volcano. The varieties described by Schaarschmidt (1881) correspond actually to a size reduction series of the same species. There are hardly any other species found in the assemblage. The most common one is *Eunotia minor* (Kütz.) Grunow, whereas single valves of *Eolimna minima* (Grunow) Lange-Bert. and *Pinnularia borealis* Ehrenb. were also found. Despite being mentioned in several different regions of the world according to the published literature, we could not identify any image that could correspond to the type material here observed.

Frenguelli (1930) described *Achnanthes* (*Microneis*) *looseri* from a ‘trípoli’ (rotten stone, a fine powdered porous rock, usually weathered limestone mixed with diatomaceous, amorphous, or crystalline silica) from Calama, Antofagasta, Chile (2260 m a.s.l.). Recently Rivera & Cruces (2009) lectotyped the species and illustrated it with LM and SEM images. According to the authors *Planothidium looseri* has only been reported from Chilean localities. The species was

Figure 2 – *Planothidium haynaldii* LM: A–H, J–R, raphaeless valves; I, girdle view, S–AJ, raphe valves. Specimens from the original slide (Ecuador, Antisana volcano). Scale bar represents 10 µm.

also reported by Frenguelli (1934) in the tripoli of San Pedro de Atacama, Antofagasta, Chile. We consider here *P. looseri* as a synonym of *P. haynaldii* since all morphological characteristics (valve width, shape, stria density) are shared between both species. On the basis of our dataset, *Planothidium haynaldii* is only present in South America (Ecuadorian and Chilean localities at high altitude sites). Frenguelli (1935) also described a new variety *Achnanthes looseri* var. *lanceolata*, from Isla Cailín, Chiloé, Chile, which seems to be a rather distinct taxon but which needs more analysis before a clear conclusion can be drawn.

Planothidium amphibium C.E.Wetzel, Ector & L.Pfister, sp. nov.
Figs 3A–AS & 4A–J

Type: holo-: BR-4384 (Botanic Garden Meise, Belgium) (here designated as the specimen illustrated in figures 3M and 3Y); iso-: PLP-269 (University of Antwerp, Belgium). – Type locality: Population collected in submerged green algae at the Oak Creek Watershed, Sheepfarm near Corvallis, Oregon, USA, 44°35'32.3"N 123°19'43.2"W, sample CRP-1295 (leg. Laurent Pfister, coll. date 6 Mar. 2012).

Etymology – ‘*amphibius*’, living in water and on land; ‘*amphi-*’ from Greek: around, double, on both sides, of two kinds.

LM: description – Valves linear to linear-lanceolate with convex margins and capitate to subcapitate, protracted apices. Specimens at the small end of the size range are nearly elliptical. Valve dimensions (n = 60): length 11.0–21.0 µm

Figure 3 – *Planothidium amphibium* LM: A–W, rapheless valves; X–AR, raphe valves; AS, girdle view. Specimens from the type slide BR-4384 (Botanic Garden Meise). Holotype specimen indicated (white arrows). Population collected in submerged green algae at the Oak Creek Watershed, located near Corvallis, Oregon, USA. Scale bar represents 10 µm.

Figure 4 – *Planothidium amphibium* SEM: A–F, rapheless valve; A, external view; B, internal view; C, detail of apical striae and areolae; D, apical striae and raised virgae; E, detail of sinus depression; F, internal detail of areolae; G–J, raphe valve; G, external view; H, internal view; I, tilted view of a complete frustule with unperforated open girdle bands; J, internal view. Population from Oak Creek Watershed, Oregon, USA. Scale bars: A–B, G–J = 5 μ m, C–E = 2 μ m, F = 1 μ m.

(max 27.9 μm), width 5.0–6.0 μm . **Rapheless valve** (fig. 3A–W): Axial area narrow, linear, weakly but gradually widening towards the central area. Central area with a large horseshoe-shaped hyaline area on one side, showing a clear, hemicircular depression surrounded by a raised ridge. On the other side, striae shortened forming hence a small hemicircular central area on this side. Fascia never observed. Striae weakly radiate almost throughout the entire valve, becoming distinctly radiate near the apices, 13–16 in 10 μm . **Raphe valve** (fig. 3X–AS): Axial area very narrow, linear, not widening towards the central area. Central area asymmetrical, rectangular to bordered by 2–3 clearly shortened striae but never entirely lacking. Complete fascia never present. Raphe branches straight with simple proximal raphe endings. Distal raphe fissures unilaterally deflected, hard to observe in LM. Striae radiate throughout the entire valve, becoming more distinctly radiate near the apices, 14–16 in 10 μm .

SEM: description, external and internal view – Striae of the rapheless valve composed of three rows of small rounded areolae (fig. 4A–F), occasionally with a fourth row of very small areolae interposed between larger areolae (fig. 4C). Near the central area, striae often with the middle row having smaller areolae (fig. 4A). Striae continuing shortly on the valve mantle (fig. 4C). Areolae covered by individual perforated hymenes (fig. 4D–F). Horseshoe-shaped sinus clearly present on the rapheless valve, forming a deep circular depression on one side of the central area, surrounded by a thickened silica ridge (fig. 4B, 4E). Cavum never present. Raphe valve shows striae slightly broader than the virgae, composed of three to four rows of rounded areolae (fig. 4G, 4I), the central two rows composed of smaller areolae than the outer rows. Near the central area, usually three or two rows of shorter striae (fig. 4G). Raphe branches straight to weakly undulating (fig. 4G). Proximal raphe endings unilaterally weakly deflected terminating in simple pores, surrounded by a shallow spatulate depression (fig. 4G–4J). Distal raphe fissures clearly bent, continuing shortly onto the valve mantle (fig. 4G), opposite to the proximal endings. Internally, striae clearly sunken between raised virgae (fig. 4H, 4J). Central nodule only weakly raised (fig. 4H). Proximal raphe endings terminating inconspicuously deflected to opposite sides (fig. 4H). Distal raphe endings terminating on small helictoglossae (fig. 4J).

Taxonomical remarks – *Planothidium amphibium* is closely related to *Planothidium haynaldii* by general valve outline, but differs from it mainly by having smaller cells. The main difference concerns the valve width. On the basis of the pictures and descriptions, the identification as *Planothidium haynaldii* in many floristic and taxonomic papers (see discussion) should be considered as belonging to *Planothidium amphibium*.

Planothidium amphibium is also closely related to *Planothidium lanceolatum* (Bréb. ex Kütz.) Lange-Bert. (Straub 1985, Van de Vijver et al. 2013) but differs by having always a wide protracted subcapitate to capitate end. *Planothidium biporum* (M.H.Hohn & Hellerman) Lange-Bert., *P. incuriatum* C.E.Wetzel, Van de Vijver & Ector and *P. bagualense* C.E.Wetzel & Ector are similar species concerning general dimensions and valve shape, but differ from *P. amphibium*

by having a cavum instead of a sinus as recently described by Wetzel et al. (2013) and Wetzel & Ector (2014).

Achnanthes semifasciata (Østrup) M.Møller in Foged is a similar species but the type slide illustrated by Foged (1974, plate 36, fig. 12a,b) from Iceland presents a larger specimen more similar to *P. haynaldii*. The species was originally described as *Navicula semifasciata* Østrup (Østrup 1918: 28, plate 3, fig. 41) and presents larger dimensions and thus a synonymization with *P. amphibium* should be discarded. Florin (1944: 425, fig. 3a–c) illustrated a new form *A. haynaldii* f. *semiaperta* Florin having a unilateral expansion on the raphe valve, which is not observed in *P. amphibium*.

Ecology and distribution – *Planothidium amphibium* was registered as a dominant species in several samples collected in Oregon (USA). Indeed the species reached between 10 to 28% of relative abundance in moist terrestrial habitats, such as soil samples collected in grassland prairies of the riparian zone (including bryophytes and herbaceous vegetation). In drift (water) samples the relative abundance of *P. amphibium* increased with discharge and the amount of rainfall observed in the catchment (fig. 5). During the rainfall storm event the species reached 43% of the diatom assemblage (min. = 6.7%, mean = 22.3%, $\pm$ 8.3, $n=27$). The relative abundance during the rainfall event fluctuated between 30–43% (fig. 5). Common species found associated with *P. amphibium* were *Fragilariforma nitzschoides* (Grunow) Lange-Bert., *Diplooneis* cf. *separanda* Lange-Bert., *Gomphonema micropus* Kütz., *Nitzschia* cf. *hantzschiana* Rabenh., *Planothidium lanceolatum*, *Eolimna tantula* (Hust.) Lange-Bert., *Gomphonema duplipunctatum* Lange-Bert. & E.Reichardt and *Meridion constrictum* Ralfs.

Figure 5 – Precipitation and discharge data from Oak Creek Watershed, Oregon, USA for the 9 to 14 Mar. 2012 period. Grey dots correspond to relative abundance of *Planothidium amphibium*.

Indeed Otte & Bellis (1985) have also observed the ability of “*A. haynaldii*” (most probably *P. amphibium*) to live in a soil marsh system in North Carolina associated with other edaphic diatoms. According to the categories of van Dam et al. (1994), *P. amphibium* should be considered a subaerial alkaliphilous species (mainly occurring at pH > 7). The water from the Oak Creek could be classified as moderately soft with calcium hardness ranging between 16.7 and 42.2 mg.L⁻¹ CaCO₃. The species seems to be rarer and even occasional (e.g. Blanco et al. 2008, Barinova & Tavassi 2009, Falasco & Bona 2011, Novais et al. 2014) compared to *P. lanceolatum*; it can reach higher abundances in Russia (Kulikovskiy et al. 2010, Hoff et al. 2014) and North America (i.e. Lowe & Cody 2002). According to Lowe & Cody (2002) individuals often occur regularly in samples that are collected from cooler, clear water of the northern USA and when present, they usually co-occur with *Planothidium lanceolatum*.

However, ecological information gathered from the literature is quite sparse and precise details about the ecological requirements of the species are still poorly known.

As previously mentioned *Planothidium amphibium* is the most common diatom amongst the species here discussed and has been misidentified in the past as *Planothidium haynaldii* (= *Achnanthes haynaldii*, = *Achnanthes lanceolata* var. *haynaldii*, = *Planothidium lanceolatum* var. *haynaldii*) from a wide range of ecozones (fig. 6) including:

- Palearctic (i.e. Terry 1908, Meister 1912, Kaiser 1916, Steinecke 1916, Héribaude 1920, Cholnoky 1922, Rich 1925, Budde 1929, Szemes 1931, 1960, Bastow 1949, Topachevsky & Oksiyuk 1960, Robinson 1982, Hartley 1986, Lange-Bertalot & Krammer 1989, Wendker

1990, Pastor 1991, Medvedeva 1994, 1995, 1999, 2001, Müllner 1995, Laugaste & Pork 1996, Temniskova-Topalova & Ognjanova-Rumenova 1997, Bukhtiyarova 1999, 2007, 2008, Lange-Bertalot & Genkal 1999, Balbi 2000, Nikulina 2001, 2003, 2005, 2006, 2008, 2010a, 2010b, 2011, 2014, Pierre 2001, Kawecka 2003, 2012, Karayeva & Dzhanfarova 2004, Medvedeva & Barinova 2004, Barinova et al. 2005, 2010, Korol 2005, Novoveska 2005, Reiter & Burchardt 2005, Savateev & Medvedeva 2005, Shevchenko 2007, Blanco et al. 2008, 2010, Barinova & Tavassi 2009, Tsarenko et al. 2009, Kulikovskiy et al. 2010, Falasco & Bona 2011, Hoff et al. 2011, 2014, Medvedeva & Miski 2011, Nikulina & Kociolek 2011, Soltanpour-Gargari et al. 2011, Turskaya 2011, Genkal et al. 2012, Gorokhova et al. 2012, Lai et al. 2014, Novais et al. 2014);

- Nearctic (i.e. Tempère & Peragallo 1915, McIntire 1968, Moore 1972, 1981, Bacon & Taylor 1976, Duthie & Socha 1976, Otte & Bellis 1985, Mattson et al. 1995, Andrieu & Kingston 1998, Stoermer et al. 1999, Camburn & Charles 2000, Kellogg & Kellogg 2002, Kociolek 2005, Eberle 2008, Bogan et al. 2012);
- Antarctic (i.e., Schmidt et al. 1990, Oppenheim 1994, Unrein & Vinocur 1999, Unrein 2000, Vinocur & Pizarro 2000, Vinocur & Unrein 2000, Unrein et al. 2005, Van de Vijver et al. 2010, Kopalová & Van de Vijver 2013, Rochera et al. 2013, Kopalová et al. 2014);
- Indomalayan (i.e. Hustedt 1927, Amossé 1969, Asai 1995, Lee et al. 1995, Shiono & Jordan 1995, Peerapornpisal et al. 2000);
- Afrotropic (i.e. Comber 1901, Müller 1910, Woodhead &

Figure 6 – Distribution records of *Planothidium haynaldii* (= *Achnanthes haynaldii*, = *Achnanthes lanceolata* var. *haynaldii*, = *Planothidium lanceolatum* var. *haynaldii*) with illustration (grey dots) and without (white dots) according to the literature; most of these records probably belong to the new species *Planothidium amphibium*. Type localities of *P. amphibium* (grey star), Oak Creek Watershed, Oregon, USA, *P. haynaldii* (grey inverted triangle), Antisana volcano, Ecuador; *Planothidium looseri* (grey triangle), Calama, Antofagasta, Chile and *Planothidium capitatum* (= *Achnanthes lanceolata* var. *capitata*) (grey square), South Patagonia, Argentina, are indicated as well.

- Tweed 1958);
- Neotropic (i.e. Maidana et al. 2005, Morales et al. 2009);
 - Australasian (Foged 1978, Schowe 2012, Schowe & Harding 2014).

Although extensive, the majority of records do not provide images to confirm the distribution of the species. Illustrated and confirmed records of *Planothidium amphibium* (as *P. haynaldii* or *A. haynaldii*) (fig. 6, grey dots) are those from Australia (Foged 1978, plate 15, fig. 8, as *Achnanthes lanceolata* (Bréb.) Grun. f. *capitata* O.Müll.), Canada (Reavie & Smol 1998, plate 12, fig. 9, as *Achnanthes lanceolata* var. *rostrata* (Østrup) Hust.), Siberia (Lange-Bertalot & Genkal 1999, plate 9, fig. 11), USA (Lowe & Cody 2002, figs 30–37), Spain (Blanco et al. 2010, plate 45, figs 1–6, as *Planothidium* aff. *lanceolatum*), northern Mongolia (Kulikovsky et al. 2010, plate 41, figs 10–13), New Zealand (Schowe 2012: 19, fig. 2.4) and Kamchatka (Hoff et al. 2014: 28, figs 3–22). Morales et al. (2009) observed *P. haynaldii* as the second most important species in terms of relative abundance in several rivers and streams of cloud forest and alpine streams in Bolivia; our personal observations confirm the presence of *P. amphibium* also in this country of South America. Records from the African continent lack illustrations and for several other citations, further confirmation is needed.

Planothidium capitatum (O.Müll.) Van de Vijver, Kopalová, C.E. Wetzel & Ector, **comb. & stat. nov.**
Fig. 7A–Z

Basionym – *Achnanthes lanceolata* var. *capitata* O.Müll., Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie 43 (Heft 4, Beiblatt Nr. 100): 8. 1909 (Müller 1909). – Type: South Patagonia (South America).

LM: description – **Valves** linear to linear-lanceolate with convex margins and capitate to subcapitate, protracted apices. **Valve dimensions** ($n = 30$): length 15.0–22.0 μm , width 4.5–5.0 μm . **Rapheless valve** (fig. 7C–L): Axial area narrow, 1/10 of the total valve width, linear, weakly but gradually widening towards the central area. Central area with a large horseshoe-shaped hyaline area on one side, showing a clear, hemicircular depression surrounded by a raised ridge. On the other side, striae shortened forming hence a small hemicircular central area on this side. Fascia never observed. Striae weakly radiate almost throughout the entire valve, becoming distinctly radiate near the apices, 14–15 in 10 μm . **Raphe valve** (fig. 7M–U): Axial area narrow, less than 1/10 of total valve width, linear, almost not widening towards the central area. Central area asymmetrical, rectangular to bow-tie shaped bordered on one side by 2–3 clearly shortened striae, while striae on the other side usually entirely lacking. Complete fascia never present. Raphe branches straight with simple proximal raphe endings. Distal raphe fissures unilaterally deflected, hard to observe in LM. Striae radiate throughout the entire valve, becoming more distinctly radiate near the apices, 14–15 in 10 μm .

SEM: description, external and internal view – Striae of the rapheless valve composed of three rows of small rounded areolae (fig. 7W), occasionally with a fourth row of very small areolae interposed between larger areolae. Near the

central area, striae often with the middle row having smaller areolae (fig. 7W). Striae continuing shortly on the valve mantle (fig. 7W). Striae of the raphe valve broader than the virgae, composed of four rows of rounded areolae (fig. 7X), the central two rows composed of smaller areolae than the outer rows. Near the central area only three, occasionally even two rows of areolae. Raphe branches straight to weakly undulating (fig. 7X). Proximal raphe endings unilaterally weakly deflected terminating in simple pores, surrounded by a shallow spatulate depression (fig. 7X). Distal raphe fissures clearly bent, continuing shortly onto the valve mantle (fig. 7X), opposite to the proximal endings. Internally, striae clearly sunken between raised virgae (fig. 7Y–Z). Areolae covered by individual perforated hymenes. Horseshoe-shaped sinus clearly present on the rapheless valve, forming a deep circular depression on one side of the central area, surrounded by a thickened silica ridge (fig. 7Y). Cavum never present. Central nodule only weakly raised (fig. 7Z). Proximal raphe endings terminating inconspicuously deflected to opposite sides (fig. 7Z). Distal raphe endings terminating on small helictoglossae. Shallow depressions present in the central area (fig. 7Z).

Taxonomical remarks – Originally described in the genus *Achnanthes*, the taxon should be transferred to *Planothidium* because it presents solitary, heterovalvar cells, with a slightly concave raphe valve and a convex rapheless valve. The valves present multiserial striae and a horseshoe-shaped structure located in the central area (a shallow rimmed depression) called a sinus, absent in the genus *Achnanthes* sensu stricto. First described as a variety of *Achnanthes lanceolata* by Müller, the taxon should be considered as a separate species mainly due the unilateral lack of striae in the central area never observed in the type material of *P. lanceolatum* or any related species (see Van de Vijver et al. 2013). *Planothidium capitatum* is very closely related to *Planothidium haynaldii* and *P. amphibium*, but differs from both by showing slender valves and the unilateral lack of striae in the raphe valve.

Ecology and distribution – So far *P. capitatum* has been found in several localities in the Maritime Antarctic Region. Its presence is confirmed from the South Shetland Islands (Livingston Island, Deception Island, King George Island) and James Ross Island from our own observations. Müller (1909) also reports this taxon from Patagonia. Large populations were found on James Ross Island and Livingston Island, usually reported under the name of *P. cf. haynaldii* or *P. haynaldii* (Van de Vijver et al. 2010, Kopalová & Van de Vijver 2013, Kopalová et al. 2014). The largest populations on Ulu Peninsula (James Ross Island) were found living in the epilithon and epipelon of larger lakes with a slightly to clearly alkaline pH (7.7–8.9) and low to moderate specific conductance levels (75–250 $\mu\text{S cm}^{-1}$). The species has so far not been reported from the sub-Antarctic Region and the Antarctic Continent (Kellogg & Kellogg 2002, Van de Vijver et al. 2002). Unrein & Vinocur (1999) highlighted that *Achnanthes lanceolata* var. *haynaldii* was a dominant species throughout summer in the Tres Hermanos Lake, Potter Peninsula, King George Island (Antarctica) and that it was responsible for the density peaks recorded in early summer conditions in phytoplankton assemblages. However, the identity of this taxon

Figure 7 – *Planothidium capitatum* LM and SEM: A–B, original drawings of *Achnanthes lanceolata* var. *capitata* by Müller (1909: 8, plate 1, figs 6–7); LM: C–L, rapheless valves; M–U, raphe valves; V, girdle view. SEM: W, rapheless valve external view; X, external view of raphe valve; Y, internal view of rapheless valve; Z, internal view of raphe valve. C–Z: Population from Green Lake 2, Ulu Peninsula, James Ross Island. Scale bars represent 10 µm.

is uncertain and should most probably be attributed to *Planothidium capitatum*.

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