

# Revision of the genus *Hantzschia* (Bacillariophyceae) on Livingston Island (South Shetland Islands, Southern Atlantic Ocean)

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**Background and aims** – The non-marine diatom flora of Livingston Island (South Shetland Islands, Maritime Antarctic Region) is currently under revision. One of the genera that still needed a revision is the genus *Hantzschia*, quite common in terrestrial habitats of the Antarctic Region.

**Methods** – Using both Light Microscopical and Scanning Electron Microscopical techniques, the morphology of all *Hantzschia* taxa, present in the samples from Livingston Island, has been analysed. Each taxon is compared with all other possible similar *Hantzschia* taxa, known worldwide.

**Key results** – Apart from the already known *Hantzschia abundans* and *H. amphioxys* f. *muelleri*, five new *Hantzschia* species are described: *Hantzschia acuticapitata* Zidarova & Van de Vijver sp. nov., *H. confusa* Van de Vijver & Zidarova sp. nov., *H. hyperaustralis* Van de Vijver & Zidarova sp. nov., *H. constricta* Van de Vijver & Zidarova sp. nov. and *H. incognita* Zidarova & Van de Vijver sp. nov.

**Conclusions** – The obtained results confirm the presence of a typical and highly specific non-marine diatom flora in the Antarctic Region and contradict the generally accepted idea about the cosmopolitanism of diatoms.

**Key words** – Antarctica, diatoms, *Hantzschia*, morphology, new species.

## INTRODUCTION

Diatoms (Bacillariophyta) are one of the most abundant groups of micro-algae present in the Antarctic Region, both in terms of number of species and of number of individuals (Jones 1996, Van de Vijver & Beyens 1999). The past ten years, the taxonomy of the Antarctic non-marine diatom flora has been thoroughly revised resulting in the description of a large number of new species (a.o. Van de Vijver et al. 2002, Van de Vijver & Mataloni 2008, Van de Vijver et al. 2010). An important part of these revisions focused on the typical terrestrial genera *Luticola*, *Muelleria* and *Diadesmis*. This is not surprising since one of the principal biomes in the Antarctic Region is formed by large, terrestrial ice-free areas, fellfields, wet soils, seepage areas and rocks. The soils of these areas form a suitable habitat for a large variety of terrestrial diatoms. Diatoms living in these habitats are well-adapted to survive the sometimes severe conditions such as a continuously changing soil humidity and freeze-thaw cycles. Apart from the above-mentioned (already revised) genera, two other terrestrial genera form large populations within the Antarctic Region: *Eunotia* and *Hantzschia*. The present paper revises the taxonomy of the genus *Hantzschia*, based on

observations made during a survey of the non-marine diatom flora of Livingston Island. Several unknown *Hantzschia* species were observed, that could not be assigned to any of the already described taxa. Five taxa will be described as new to science whereas three others are illustrated.

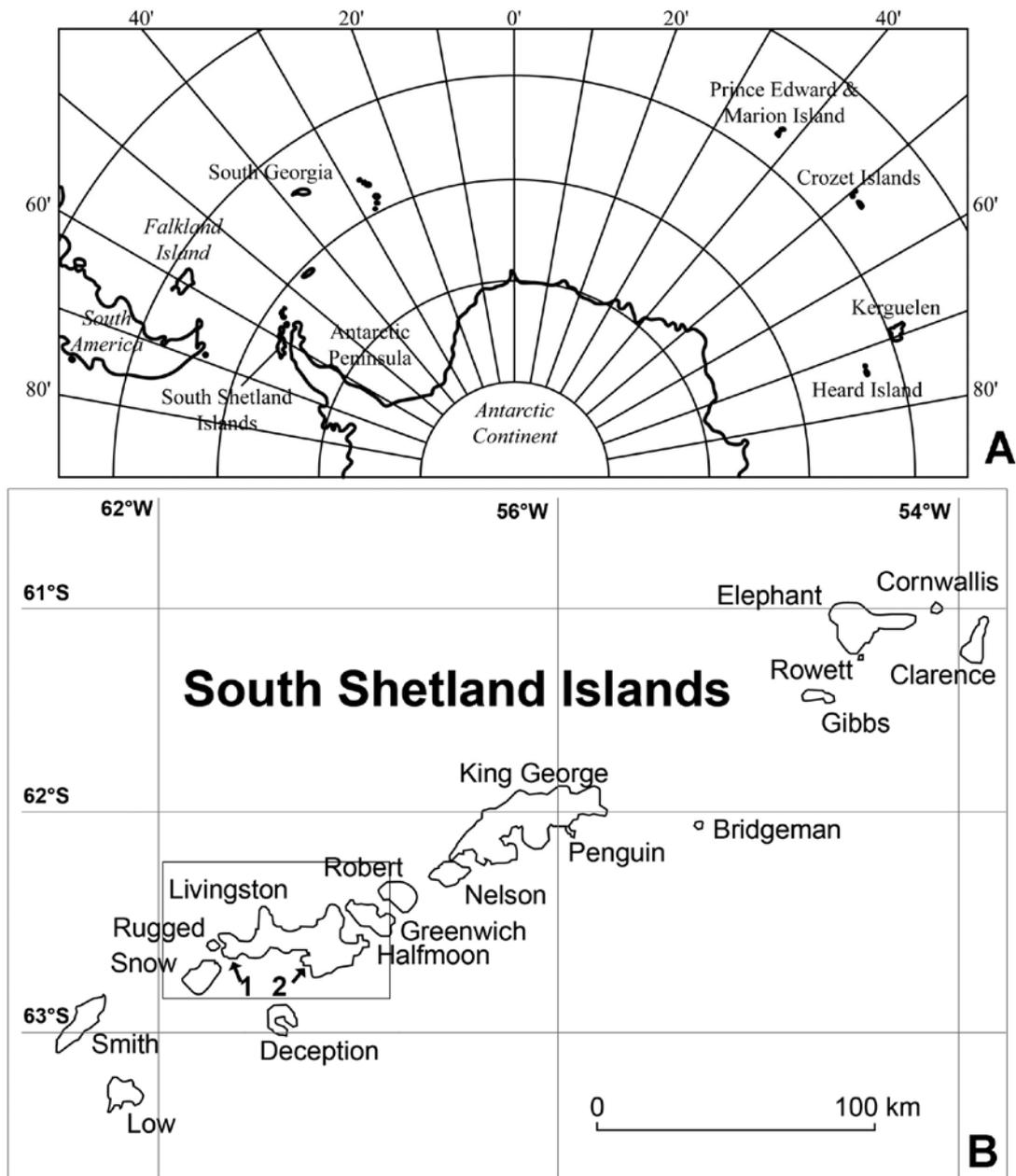
The genus *Hantzschia* is a relatively small genus with less than fifty species known worldwide, occurring in a wide variety of habitats ranging from freshwater to terrestrial and even intertidal and marine environments (Round et al. 1990). Described in 1877 by Grunow, the genus, belonging to the family Bacillariaceae, is characterized by a typical asymmetrical valve outline with usually a more convex dorsal side and a concave ventral side, the presence of uniseriate striae composed of small rounded areolae containing hymenes, a raphe that is subtended by fibulae and a complex girdle structure (Round et al. 1990). Species within the genus are separated based on number of striae and areolae per stria, the position and shape of the fibulae, the shape of the external and internal proximal raphe endings and the shape of the valve apices.

*Hantzschia amphioxys* (Ehrenb.) Grunow is considered to be the most common and well known species in this genus, living almost exclusively in (semi-wet) soils. The spe-

cies has been reported from all over the world although it is clear that due to force-fitting (Tyler 1996) and species drift, not all reported records actually represent *H. amphioxys* (Sabbe et al. 2003). In the past, a large number of varieties, formas and subspecies were described within this species (VanLandingham 1971). Following the adoption of a narrower species concept by certain authors, the number of described *Hantzschia* species increased considerably whereas others were assigned a different taxonomic rank, replacing in many cases former infraspecific taxa of *H. amphioxys* such as *Hantzschia hyperborea* (Grunow) Lange-Bert., formerly described under the name of *H. amphioxys* var. *hyperborea*

Grunow (Lange-Bertalot 1993, Lange-Bertalot et al. 2003, Metzeltin et al. 2005).

At present, in the Antarctic Region, only cosmopolitan *Hantzschia* taxa have been recorded (Kellogg & Kellogg 2002) such as *H. amphioxys* and *H. hyperborea*. In 2002, a new species was described from Ile de la Possession in the southern Indian Ocean (Van de Vijver et al. 2002), the only Antarctic endemic *Hantzschia* species described so far. The results obtained during the present study will allow a better understanding of the biogeography of the Antarctic terrestrial diatom flora.



**Figure 1** – A, the (sub-)Antarctic Region with the location of the South Shetland Islands; B, South Shetland Islands with the position of Livingston Island. The arrows indicate Byers Peninsula (1) and Hurd Peninsula (2).

## STUDY SITE

Livingston Island (974 km<sup>2</sup>) is the second largest island of the South Shetland Islands (62°34'35" – 62°10'35"S / 60°54'14" – 61°13'07"W), located in the Southern Ocean, at 110 km from the Antarctic Peninsula and 830 km from the tip of South America (Cape Horn) (fig. 1). The archipelago belongs to the so-called Maritime Antarctic Province (Stonehouse 1982). Glaciers and icecaps cover most of the island leaving only 10% ice-free during summer, mostly situated in the coastal areas. The largest of these ice-free zones is Byers Peninsula, the most western tip of the island (Toro et al. 2007). The climate on Livingston Island is maritime and less extreme than on the Antarctic Continent with a mean annual temperature of – 4°C and a maximum temperature in summer of + 7.5°C (Chipev & Veltchev 1996). Precipitation is much higher than on the Continent with mean annual values of 700–1000 mm (Bañón 2001). The vegetation on the island is sparse and composed of lichens, bryophytes and two native vascular plants (*Deschampsia antarctica* Desv. and *Colobanthis quitensis* (Kunth) Bartl.), in general restricted to the beaches and the lowlands.

The human presence on the island is limited to the permanent scientific bases of Juan Carlos I (Spain) and St. Kliment Ohridski (Bulgaria) that were established in 1988 at South Bay and the small Chilean Shirreff Base. On Byers Peninsula, temporary camps have been installed during the previous austral summers in the framework of the Limnopolar Project, as part of the International Polar Year.

## MATERIAL AND METHODS

During several austral summers (2004, 2006, 2008, 2009), material for diatom analysis has been sampled from various locations of Livingston Island, mainly from Hurd Peninsula and Byers Peninsula. In order to obtain a broad overview of the diversity and distribution of the diatom communities on the island, samples have been taken from different habitat types: freshwater lakes, seepage areas, wet rocks, rivers and mosses (ranging from aquatic to dry terrestrial). Samples were fixed in the field with 3% formaldehyde. Table 1 lists all samples used to describe new taxa from.

Diatom samples were prepared following two methods. The Byers Peninsula samples were treated using the method

of Van der Werff (1955). Small parts of the samples were cleaned by adding 37% H<sub>2</sub>O<sub>2</sub> and heating to 80°C for about 1 h whereafter the reaction was completed by addition of KMnO<sub>4</sub>. Following digestion and centrifugation (three times 10 minutes at 3700 × g), the resulting clean material was diluted with distilled water to avoid excessive concentrations of diatom valves that may hinder reliable observations. Samples obtained from Hurd Peninsula were prepared according to the method described in Hasle & Fryxell (1970). Small subsamples were cleaned using concentrated H<sub>2</sub>SO<sub>4</sub> followed by the addition of KMnO<sub>4</sub>. The samples were then faded with oxalic acid (H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>) and washed with distilled water eight times. Cleaned diatom valves were mounted in Naphrax<sup>®</sup>. Samples and slides are stored at the National Botanic Garden (Belgium) and the Central Laboratory of General Ecology (Bulgaria).

Light microscope (LM) observations were conducted using an Olympus BX51 microscope equipped with Differential Interference Contrast (Nomarski) optics. For scanning electron microscopy (SEM), part of the suspension was filtered through polycarbonate membrane filters with a pore diameter of 1 µm, pieces of which were fixed on aluminium stubs after air-drying. The stubs were sputter-coated with 50 nm of Au and studied in a JEOL-5800LV at 20 kV. Terminology follows Hendey (1964), Barber & Haworth (1981), Round et al. (1990) and Lange-Bertalot (1993).

## RESULTS

In most of the analysed terrestrial samples of Livingston Island used in the survey, specimens belonging to the genus *Hantzschia* are quite abundantly present. Based on LM and SEM observations, eight different taxa were recognized. Table 2 compares the morphological features of all species.

One of the taxa has been identified as *Hantzschia amphioxys* f. *muelleri* Ts.Kobay., and another has been assigned to *Hantzschia abundans*. Five of the taxa are described as new species: *Hantzschia confusa* Van de Vijver & Zidarova, *H. constricta* Van de Vijver & Zidarova, *H. hyperaustralis* Van de Vijver & Zidarova, *H. incognita* Zidarova & Van de Vijver and *H. acuticapitata* Zidarova & Van de Vijver. Finally, one up to now unidentified species is illustrated and discussed but due to the lack of sufficient observations, it is still unclear whether it also represents a new species.

Table 1 – List of all samples used to describe the new taxa.

Sample	Collection date	Locality	GPS coordinates	Short description
IIIa	31/01/2004	Hurd Peninsula, close to the "Juan Carlos I" Spanish Antarctic Base	62°39'46.9"S 060°22'41.2"W	wet soil under moss vegetation near a small stream
II7a	19/02/2004	Hurd Peninsula, close to the "St. Kliment Ohridski" Bulgarian Antarctic Base	62°38'52.5"S 060°22'14.0"W	wet soil under moss vegetation close to a small drying puddle
LIV-BY16A	16/12/2006	Byers Peninsula, close to the main plateau	(not determined)	biofilm in a flooded area between stones

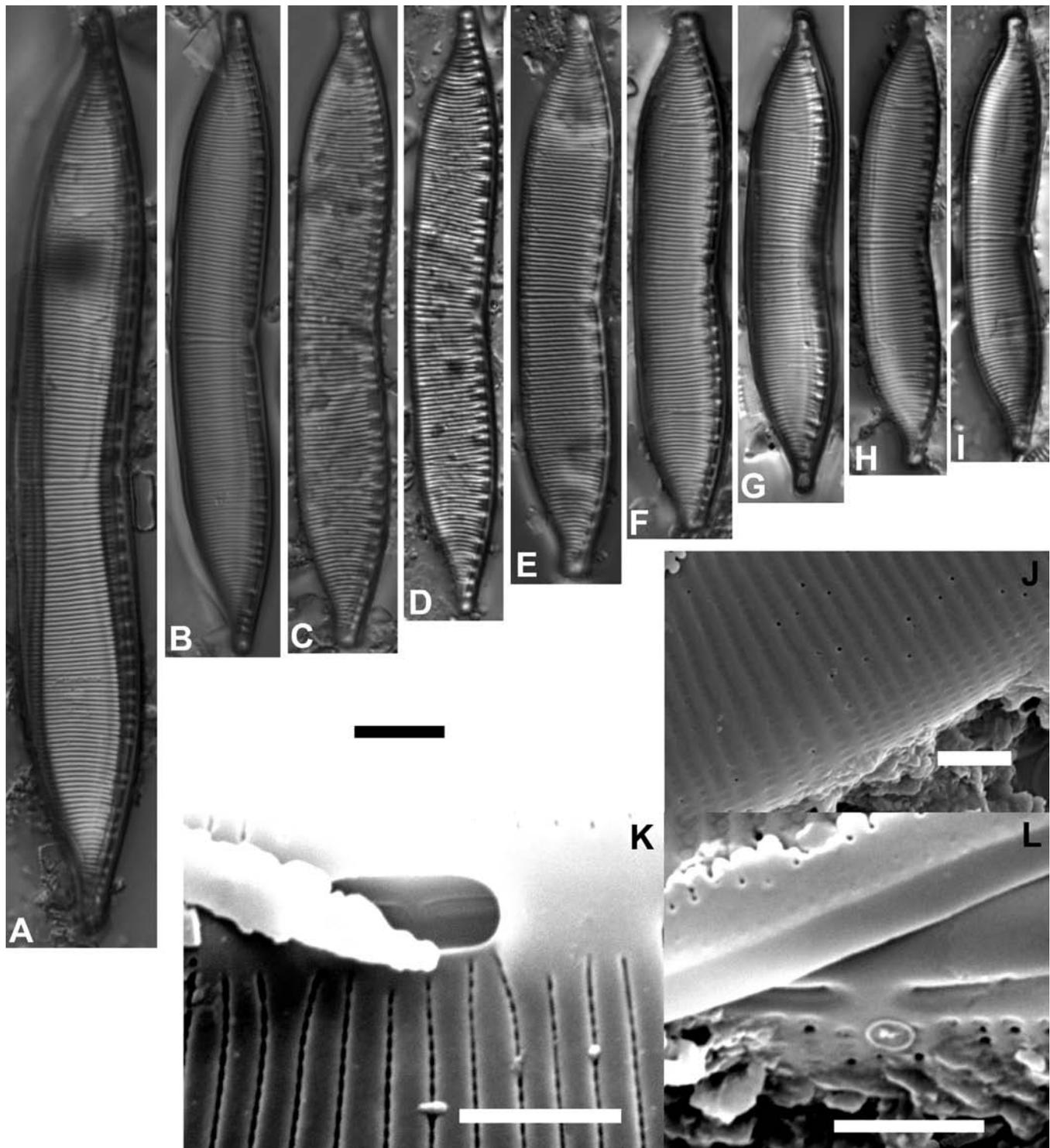
Table 2 – Comparison of all *Hantzschia* taxa found on Livingston Island.

	<i>H. amphioxys</i>	<i>H. amphioxys</i> <i>f. muelleri</i>	<i>Hantzschia</i> sp.	<i>H. incognita</i>	<i>H. confusa</i>	<i>H. acuticapitata</i>	<i>H. hyperaustralis</i>	<i>H. constricta</i>
length (µm)	15–50	40.7–55.7	50	48–67	55–56	57–67	70–120	95–112
width (µm)	5–7	5.0–5.8	9.5	7.4–8.1	8.4–10	7.8–9.1	11.6–14.7	10.5–12.7
dorsal margin	slightly convex to almost straight	slightly convex to almost straight	almost straight	moderately convex	convex	almost straight	straight to weakly convex	almost straight, constricted in the middle
ventral margin	moderately concave in the middle, slightly convex near the apices	moderately concave in the middle, slightly convex near the apices	slightly concave in the middle, slightly convex near the apices	concave in the middle, convex toward the apices	distinctly concave in the middle, convex near the ends	almost straight with small depression in the middle	slightly concave in the middle and convex to straight near the apices	almost straight, constricted in the middle
valve apices	shortly protracted rostrate-capitate	abruptly protracted, capitate	shortly protracted, subcapitate	rostrate	cuneate rostrate	obliquely and asymmetrically cuneate, protracted, rostrate to subcapitate	rostrate to cuneate-rostrate	elongated apiculate
striae	parallel to slightly radiate in the middle, parallel near the ends	parallel to slightly radiate in the middle, parallel near the ends	slightly radiate in the middle, parallel near the apices	parallel	parallel to slightly radiate in the middle, parallel near the ends	parallel	parallel	parallel
number of striae in 10 µm	20–29	(22–)24–26	19–20	18–20	18–20	22–23	20–22(–23)	20–22(–23)
number of areolae in 10 µm	40–50	c. 50	not observed	c. 45	c. 35–40	c. 50	50–60	50–60
number of fibulae in 10 µm	variable	6–9	5–6	5–8	(4–)5–6	6–9	5–7	(4–)5–7
middle fibulae	distant	more distant	more distant	not distant	more distant	slightly distant	slightly distant	slightly distant
raphe structure	not continuous, central raphe endings externally bent, internally bent to opposite directions	not continuous, central raphe endings unilaterally bent	not observed	straight, continuous, lacking central pores	unilaterally bent in the middle, continuous, lacking central pores	straight, continuous, lacking central pores	straight, continuous, lacking central pores	straight, continuous, lacking central pores

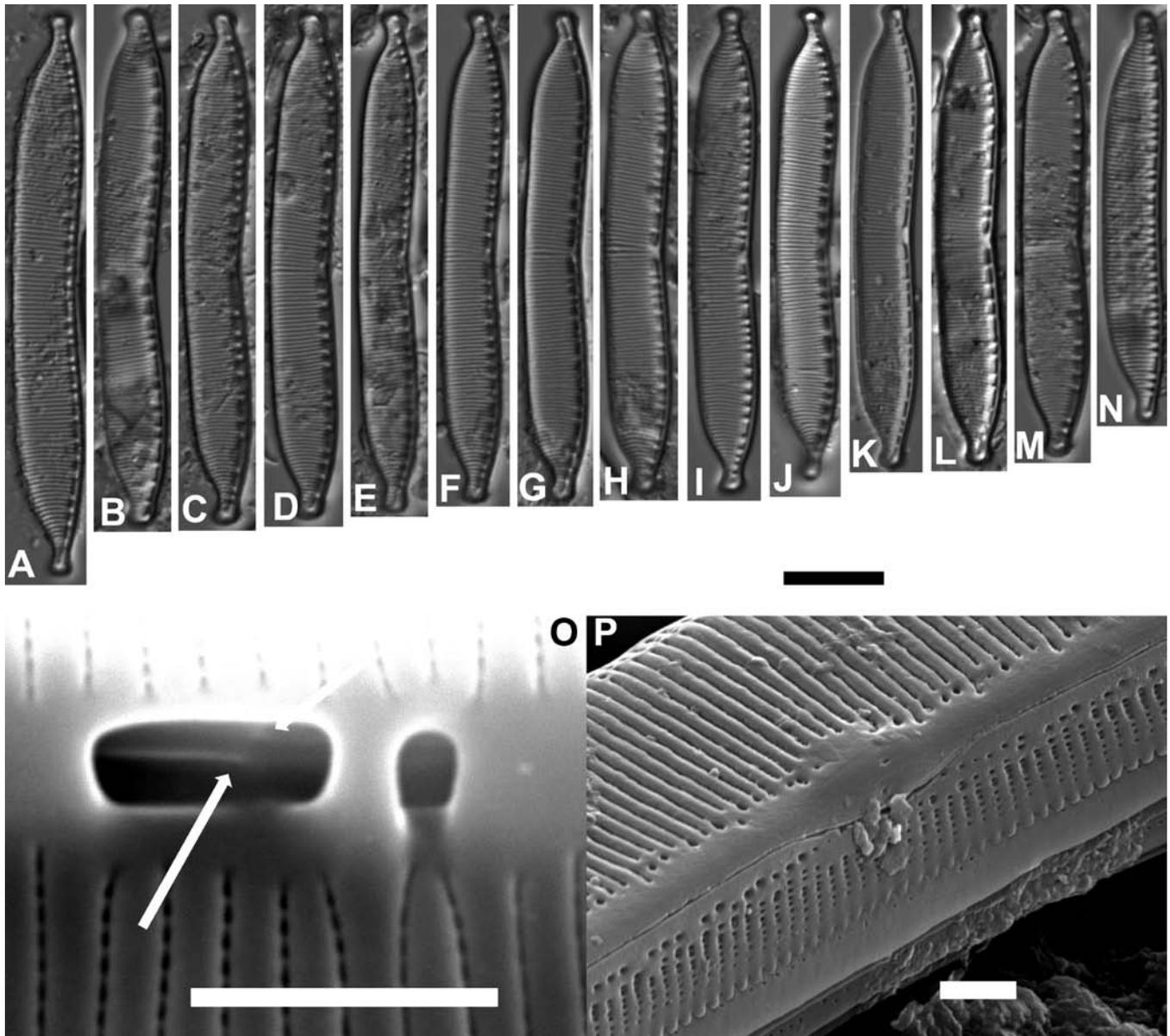
*Hantzschia abundans* Lange-Bert. (fig. 2A–L)

**Morphological observations** – The valves are clearly dorsi-ventral with a strongly convex dorsal side and a ventral side that is distinctly concave in the middle but convex towards

the ends (fig. 2B–I). The valve apices are elongated and cuneate, rostrate to subcapitate, and almost capitate in smaller valves. Valve length ranges from 48 to 71  $\mu\text{m}$  whereas the valve width is 7.3–9.0  $\mu\text{m}$ , although very rarely larger individuals have been observed, with a valve length up to 102



**Figure 2** – *Hantzschia abundans*: A–I, LM micrographs of the largest population on Byers Peninsula (sample LIV-BY16A); J, scanning electron micrograph, detail of the areolae; K, scanning electron micrograph, detail of the clearly bent internal central raphe endings; L, scanning electron micrograph, detail of the straight external central raphe endings. Scale bar represents 10  $\mu\text{m}$  except for J–L where scale bar = 2  $\mu\text{m}$ .



**Figure 3** – *Hantzschia amphioxys* f. *muelleri*: A–N, LM micrographs of the largest population on Byers Peninsula (sample LIV-BY16A); O, scanning electron micrograph, detail of the straight internal central raphe endings; P, scanning electron micrograph, detail of the clearly bent external central raphe endings. Scale bar represents 10  $\mu\text{m}$  except for O–P where scale bar = 2  $\mu\text{m}$ .

$\mu\text{m}$  and a valve width of 11  $\mu\text{m}$  (fig. 2A). The raphe is not continuous, possessing central raphe endings (fig. 2K & L). Externally, the central raphe endings are almost straight and moderately distant (fig. 2L). Internally the central raphe endings are close together and slightly unilaterally deflected (fig. 2K). The fibulae are densely spaced, 5–8 in 10  $\mu\text{m}$  with the median two clearly distant (e.g. fig. 2B, F & H). Each fibula is connected to 1–3 transapical costae. The striae are radiate and more spaced in the valve middle, parallel near the apices, 20–23 in 10  $\mu\text{m}$ . Puncta of the striae are not discernible in LM. In SEM, they appear as small rounded poroids, c. 45 in 10  $\mu\text{m}$  (fig. 2J).

**Remarks** – *Hantzschia abundans* was separated from *H. amphioxys* s. str. by Lange-Bertalot in 1993 based on its different valve dimensions, stria density and raphe structure:

*Hantzschia abundans* is slightly longer (up to 80 vs. up to 50  $\mu\text{m}$  in *H. amphioxys*), has a larger valve width (7–10 vs. 5–7  $\mu\text{m}$ ) and a lower stria density (15–20 vs. 20–29 in 10  $\mu\text{m}$  in *H. amphioxys*). The external central raphe endings in *H. abundans* are almost straight (Lange-Bertalot 1993: 345, fig. 2) whereas in *H. amphioxys* they are clearly unilaterally bent (Lange-Bertalot 1993: 339, figs 2 & 4). Internally, the central raphe endings in *H. abundans* are deflected to the same side (Lange-Bertalot 1993: 345, figs 5–6) while in *H. amphioxys*, they are going to opposite directions (Lange-Bertalot 1993: 341, figs 1–2).

The raphe structure of *Hantzschia abundans* from Livingston Island is identical to that of the European *H. abundans*. The Livingston Island specimens have a larger length range (up to 102  $\mu\text{m}$  in length and 11.6  $\mu\text{m}$  in breadth) and

a higher number of striae (20–23 vs. 15–20) in 10 µm with slightly more puncta (around 45 vs. 40 in 10 µm following Lange-Bertalot 1993).

*Hantzschia abundans* is quite similar to *H. confusa* (see below) by valve outline and dimensions and sometimes both species are present in the same sample. In SEM, they can be easily recognized by the valve ultrastructure, including a different raphe system. In *H. confusa* the raphe is continuous, lacking central pores (see below). A hyaline line enclosing the striae is present in *H. confusa* whereas in *Hantzschia abundans* such a line has never been observed. In LM, *H. confusa* can be recognized by the well visible, even countable areolae in LM, whereas in *Hantzschia abundans* the areolae are almost invisible in LM (fig. 2B–I). In *H. confusa* the valve ends are more cuneate and shortly protracted than in *Hantzschia abundans* and the number of the striae is lower (18–20 in 10 µm). The other *Hantzschia* taxa are sufficiently different, to avoid possible confusion with *H. abundans*.

**Ecology** – *Hantzschia abundans* is a common species, present in the majority of the investigated samples from Livingston Island taken from moist mosses around small pools and shallow streams as well as in soil under moss vegetation. The largest population was found in sample LIV-BY16A, taken from a biofilm in a flooded area between stones on Byers Peninsula close to the main plateau. The sample is dominated by various taxa of *Luticola*, *Hantzschia*, *Pinnularia* and *Dia-desmis*.

***Hantzschia amphioxys*** (Ehrenb.) Grunow f. *muelleri* Ts.Kobay. (fig. 3A–P)

**Morphological observations** – The valves are dorsiventral with a slightly convex to almost straight dorsal margin (fig. 3A–N). The ventral margin is moderately concave in the middle and slightly convex near the ends. The valve apices are abruptly protracted and clearly capitate, deflected towards the dorsal side (e.g. fig. 3A, C, F & J). Valve length ranges from 40.7 to 55.7 µm and the width is 5.0–5.8 µm. The fibulae appear unequally spaced with the median two clearly more distant, 6–9 in 10 µm, connected to 1–3 transapical costae (e.g. fig. 3K & L). The striae are parallel to slightly radiate in the middle, parallel near the ends, usually equidistant or occasionally, the striae in the middle are slightly more spaced than the others, 22–26 in 10 µm. Areolae are not visible in LM, in SEM countable, c. 50 in 10 µm. Externally, the raphe is not continuous, the central raphe endings are unilaterally bent (fig. 3P). Internally, the central raphe endings are deflected to opposite directions (fig. 3O, see arrows).

**Remarks** – Based on valve width, stria density and raphe structure, this taxon is identical to *H. amphioxys* but can be separated from the nominate variety by its clearly capitate ends. Müller (1909) was the first to describe a taxon from Patagonia named *H. amphioxys* f. *capitata*, based on the presence of the capitate ends. Later, this taxon was renamed by Ko-Bayashi (1965) as *H. amphioxys* f. *muelleri* since, according to Ko-Bayashi (1965) it was “improper to use a name both for a variety and for a form” (e.g. *H. amphioxys* f. *capitata* Müller and *H. amphioxys* var. *capitata* Pantocsek). Apart of one record from East Ongul Island (Ko-Bayashi 1965), the only recently confirmed report of this taxon in Antarctica is

from the McMurdo Dry Valleys where Esposito et al. (2008) found large populations. In Kellogg & Kellogg (2002) the species is grouped under *H. amphioxys* f. *capitata* and it is possible that other records under this name represent in fact f. *muelleri*. The specimens observed on Livingston Island are identical to that found in the McMurdo Dry Valleys, although the valves from Livingston Island populations are longer, up to 55.7 µm, whereas in the McMurdo Dry Valleys a length of up to 44 µm is reported (Esposito et al. 2008). Both populations from the McMurdo Dry Valleys and Livingston Island differ slightly from the original description of Müller (1909) by having more striae, mostly 24–26 vs. 22 in 10 µm. Although no type material was available for further analysis, the Livingston population is identified as *H. amphioxys* f. *muelleri* based on the clearly abruptly protracted capitate ends that are not observed in the typical *H. amphioxys*. For comparisons with *H. amphioxys* s. str. and *H. abundans* see under *Hantzschia abundans* and Lange-Bertalot et al. (2003). *H. amphioxys* var. *capitata* Pantocsek has much larger valve dimensions (length 72 µm, width 8.1 µm) and a much lower number of striae (13 in 10 µm).

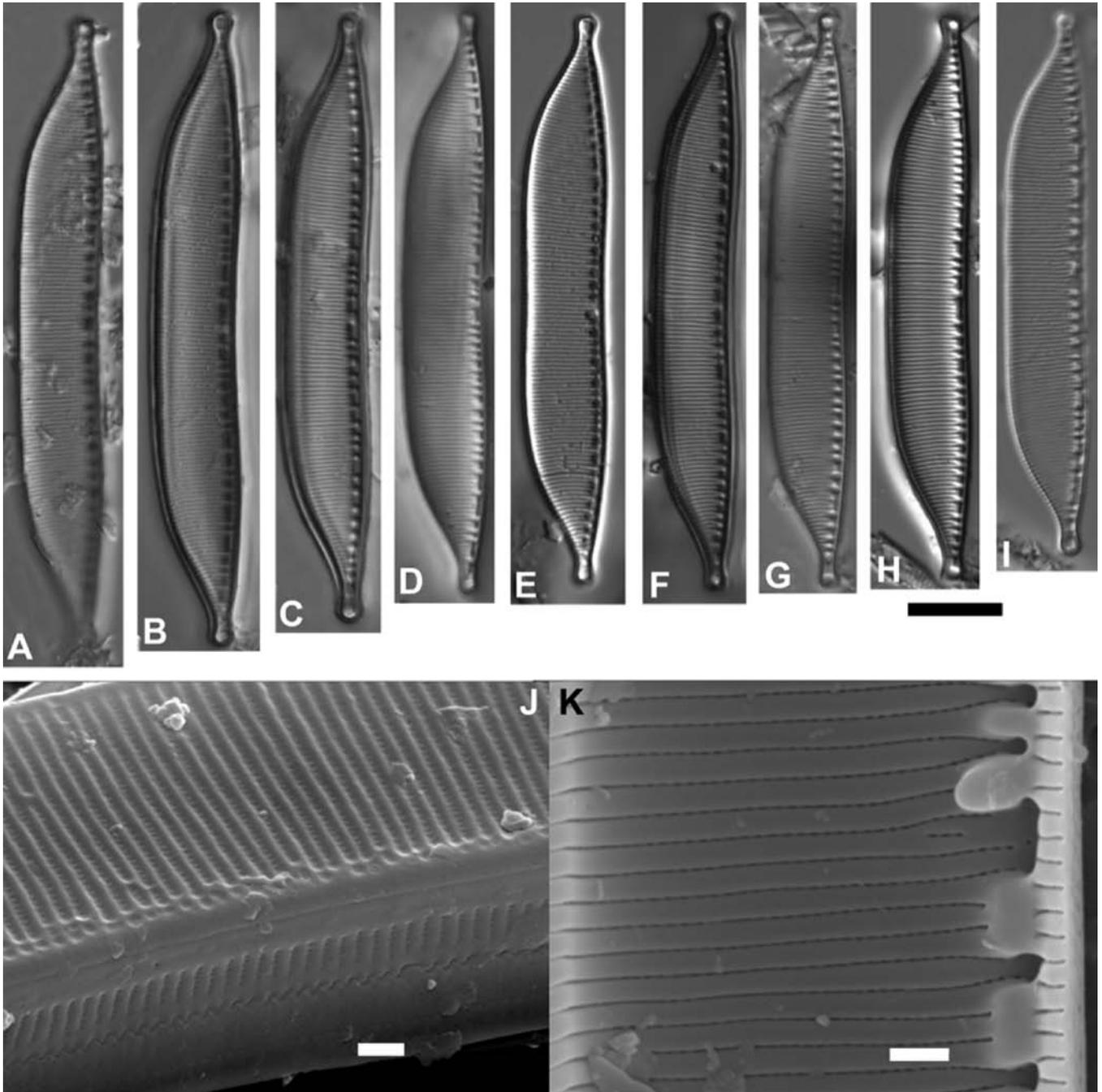
**Ecology** – *Hantzschia amphioxys* f. *muelleri* is the most common *Hantzschia* species in the samples from Livingston Island, found in a variety of terrestrial habitats, usually in association with other *Hantzschia* taxa.

***Hantzschia acuticapitata*** Zidarova & Van de Vijver, sp. nov. (fig. 4A–K)

**Diagnosis** – Valvae distincte dorsiventrales marginibus dorsilibus paene rectis omnino marginibusque ventralibus paene rectis sed in media, depressio exigua adest. Apices oblique asymmetricaeque cuneatae, denique protractae rostrataeque ad subcapitatae. Longitudo 57–67 µm, latitudo 7.8–9.1. Fibulae carinae raphis, 6–9 in 10 µm, fere aequidistantes, mediis duabus conspicue magis remotis inter se. Una fibula continens variabiliter cum 1–4 costis transapicalibus. Fines proximae interni externique ramorum raphis non interrupti. Striae transapicales parallelae omnino, 22–23 in 10 µm. Puncta striarum non aspectabilia microscopio photonoco, 50 in 10 µm. – Type: holo-: BR-4173 (National Botanic Garden of Belgium, Meise); iso-: PLP-140 (University of Antwerp, Belgium), BRM-ZU7/18 (Hustedt Collection, Bremerhaven, Germany). – Type locality: Livingston Island, Hurd Peninsula, sample Π1a/04 (coll. Zidarova, coll. date 31 Jan. 2004).

**Etymology** – Latin *acutus*, acute, pointed; *capitatus*, capitate; referring to the shape of the valve apices.

**Morphological observations** – The valves are clearly dorsiventral with almost straight dorsal margins throughout (fig. 4I). The ventral margins are also almost straight although in the middle, a slight depression can be noted (e.g. fig. 4B & F). The valve apices are obliquely and asymmetrically cuneate, finally protracted commonly rostrate to subcapitate. Valve length 57–67 µm, valve width 7.8–9.1 µm. The fibulae, 6–9 in 10 µm, are almost equidistant, only the median two slightly more distant than the others (e.g. fig. 4E & H), each of them connected to 1–4 transapical costae (fig. 4K). The external and internal raphe branches are straight and continuous showing no interruption near the valve middle, lacking central raphe endings (fig. 4J). The striae are parallel throughout,



**Figure 4** – *Hantzschia acuticapitata*: A–I, LM micrographs of the largest population on Hurd Peninsula (sample П11a/04); J, scanning electron micrograph, detail of the straight, uninterrupted external central raphe endings; K, scanning electron micrograph, detail internal areolae openings and the fibulae connected to 1–3 striae. Scale bar represents 10 µm except for J–K where scale bar = 1 µm.

showing no changes in density nor orientation, 22–23 in 10 µm. Puncta of the striae are not discernible in LM. In SEM, puncta appear as very small, rounded poroids, hardly countable, c. 50 in 10 µm (fig. 4J).

**Remarks** – *Hantzschia acuticapitata* can be confused with several other *Hantzschia* species showing a similar valve outline: *H. abruptirostrata* Lange-Bert. & Metzeltin, *H. bardii* Lange-Bert. et al., *H. delicatula* Metzeltin et al., *H. dorgaliensis* Lange-Bert. et al. and *H. herrmannii* Hust.. Unfortunately, since no SEM pictures exist of most of these species,

a comparison of the raphe system is not possible, reducing the differentiation of these species only on LM features and morphometrics. *Hantzschia abruptirostrata*, described from Uruguay (Metzeltin et al. 2005) has a typical concave ventral margin, is longer (length 75–103 vs. 57–67 µm) and has a lower number of striae (15.5–16.5 vs. 22–23 in 10 µm). Also from Uruguay is *H. delicatula* Metzeltin et al. that has smaller valves (length 43–50 vs. 57–67 µm) with less striae (18 vs. 22–23) and only shortly protracted ends. Two similar species were recently described from Sardinia (Lange-Bertalot

et al. 2003). *H. bardii* has comparable dimensions but has a strongly concave ventral side whereas in *H. acuticapitata*, the ventral side is almost straight. SEM observations of *H. bardii* show the presence of external central raphe endings (Lange-Bertalot et al. 2003: plate 101, fig. 13), a feature lacking in *H. acuticapitata*. *H. dorgaliensis* is much larger (75–85 vs. 57–67 µm) with a lower number of striae in 10 µm (18–19 vs. 22–23) and a different fibula-structure. Finally, *Hantzschia herrmannii*, found in Sumatra (Hustedt 1938), has more fibulae in 10 µm (10–12 vs. 6–9) and a higher stria density (24–28 vs. 22–23 in 10 µm).

**Ecology** – *H. acuticapitata* has been found in several samples. The largest population was recorded in sample Π1a/04, taken from wet soil near a stream, close to the Spanish Juan Carlos I base. The sample was dominated by other *Hantzschia* species such as *H. hyperaustralis* Van de Vijver & Zidarova and *H. incognita* Zidarova & Van de Vijver (see below), *Nitzschia hamburghensis* Lange-Bert., *N. aff. perminuta* (Grunow) Perag., *Planothidium lanceolatum* (Bréb.) Lange-Bert. and *Pinnularia* sp. 1.

***Hantzschia confusa*** Van de Vijver & Zidarova, **sp. nov.** (fig. 5A–G, 5I–K)

**Diagnosis** – Valvae distincte dorsiventrals marginibus dorsalibus fortius convexis marginibus ventralibus minus convexis in partibus distalibus sed concavis in media parte, valva ita aliquid geniculata apparet. Apices cuneatim rostrati, flexi ad latus dorsale. Longitudo 55–56 µm, latitudo 8.4–10.0. Fibulae carinae raphis, (4–)5–6 in 10 µm, fere aequidistantes, mediis duabus conspicue magis remotis inter se. Una fibula continens variabiliter cum 1–3 costis transapicalibus. Fines proximi externi ramorum raphis non interrupti, flexi unilateralter. Striae transapicales parallelae ad leviter radiatae in media parte valvae, 18–20 in 10 µm. Striae in media parte valvae conspicue magis remotae inter se, absentes ad apices. Puncta striarum non aspectabilia microscopio photonico, 35–40 in 10 µm. In SEM, zona hyalina, angustior in latere ventrali, latior in latere dorsali omnino ambiens strias. – Type: holo-: BR-4174 (National Botanic Garden of Belgium, Meise); iso-: PLP-141 (University of Antwerp, Belgium), BRM-ZU7/19 (Hustedt Collection, Bremerhaven, Germany). – Type locality: Livingston Island, sample LIV-BY16A (coll. Toro, coll. date 16 Dec. 2006).

**Etymology** – Latin *confusus*, confused; referring to the confusion that may exist when comparing the species with *H. abundans* and *H. amphioxys*.

**Morphological observations** – The valves are clearly dorsiventral. The ventral side is distinctly concave in the middle and more convex towards the apices (fig. 5A–F). The dorsal side is convex. The valve apices are cuneate-rostrate, bent towards the dorsal side to almost straight. Valve length 55–56 µm, valve width 8.4–10.0 µm. Fibulae 4–6 in 10 µm with the median two distinctly more spaced than the others. Each fibula is connected to 1–3 transapical costae. The raphe, externally, is unilaterally bent in the middle but continuous and lacking central pores (fig. 5I). The striae, 18–20 in 10 µm, are parallel to slightly radiate in the middle, where they are more spaced than in the rest of the valve. In SEM, a well-delimited hyaline zone, narrower at the dorsal side and wider at the

ventral side, stretches continuously over the whole valve circumference and encloses an area of striae on the valve face (fig. 5K). No striae are present at the valve ends. Puncta of the striae are well discernible in LM, c. 35–40 in 10 µm (fig. 5G & J).

**Remarks** – *Hantzschia confusa* is quite similar to *H. abundans* sharing the same valve outline and dimensions. In SEM, they can be easily recognized by the valve ultrastructure, including a different raphe system. *H. confusa* has a continuous raphe, lacking central pores. A rather broad hyaline line encloses the striae in *H. confusa* whereas in *Hantzschia abundans* such a line has never been observed. *H. confusa* can be recognized by the well visible, even countable areolae in LM (fig. 5G), whereas in *Hantzschia abundans* the areolae are almost invisible in LM (fig. 5H). In *H. confusa* the valve ends are more cuneate and shortly protracted than in *Hantzschia abundans* and the number of the striae is lower (18–20 in 10 µm). Other *Hantzschia* species with the same combination of valve features are so far unknown.

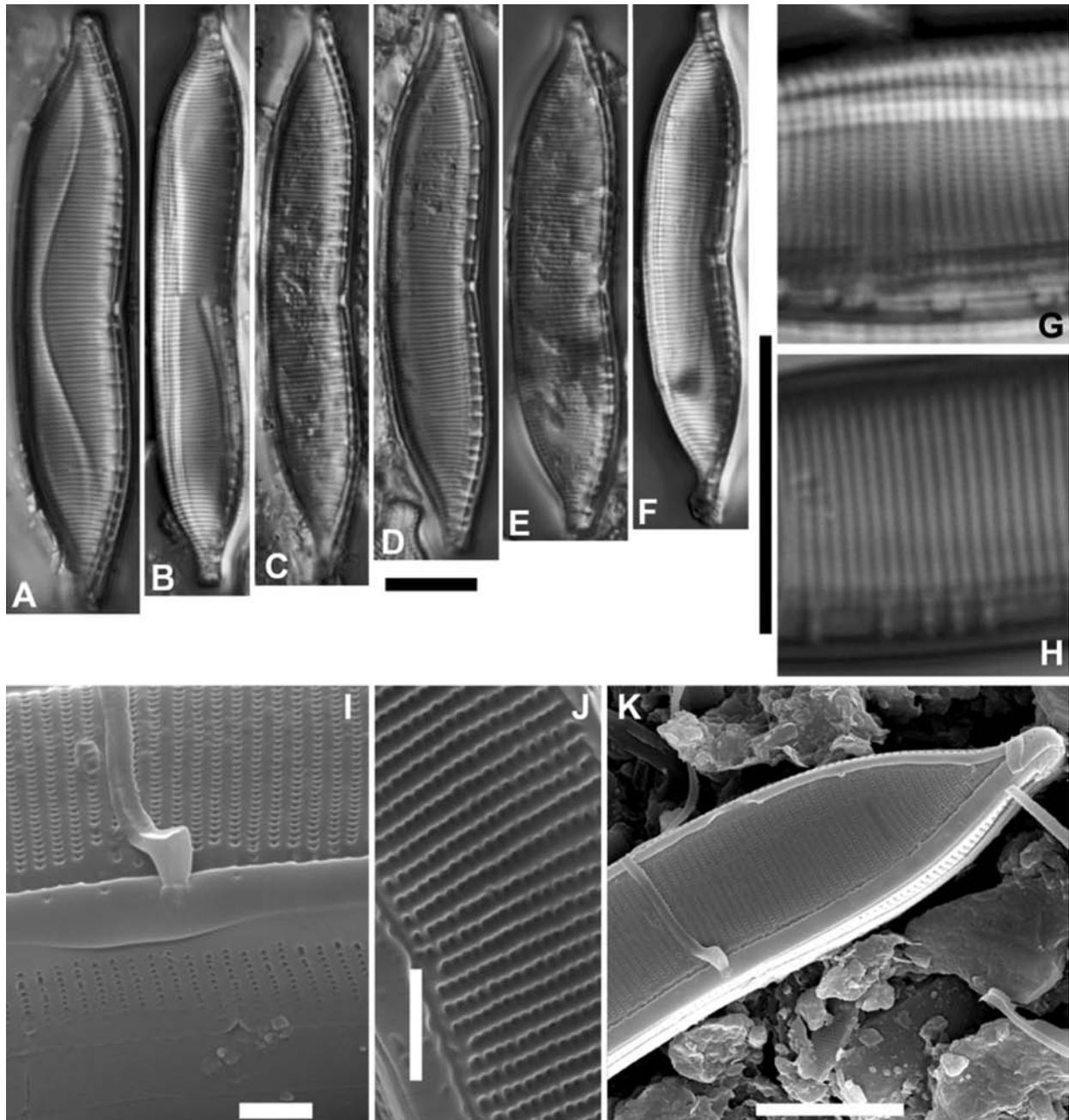
**Ecology** – *Hantzschia confusa* is a common species in soil and on mosses on Livingston Island. One of the largest populations was found in sample LIV-BY16A, taken from a biofilm in an area flooded by freshwater between stones on Byers Peninsula close to the main plateau. The sample is dominated by various taxa of *Luticola*, *Hantzschia*, *Pinnularia* and *Diadesmis*.

***Hantzschia hyperaustralis*** Van de Vijver & Zidarova, **sp. nov.** (fig. 6A–I)

**Diagnosis** – Valvae distincte dorsiventrals marginibus dorsalibus rectis ad leviter convexis marginibus ventralibus minus convexis in partibus distalibus sed concavis in media parte, valva ita aliquid geniculata apparet. Apices typice rostrati ad cuneatim rostrati. Longitudo 70–120 µm, latitudo 11.6–14.7. Fibulae carinae raphis, 5–7 in 10 µm, comparate parvae, fere aequidistantes, mediis duabus leviter magis remotis inter se. Una fibula continens variabiliter cum 1–4 costis transapicalibus. Fines proximi externi internique ramorum raphis non interrupti. Striae transapicales parallelae omnino, 20–22(–23) in 10 µm. Puncta striarum non aspectabilia microscopio photonico, 50–60 in 10 µm. – Type: holo-: BR-4175 (National Botanic Garden of Belgium, Meise); iso-: PLP-142 (University of Antwerp, Belgium), BRM-ZU7/21 (Hustedt Collection, Bremerhaven, Germany). – Type locality: Livingston Island, Byers Peninsula, sample LIV-BY16A (coll. Toro, coll. date 16 Dec. 2006).

**Etymology** – The specific epithet refers to *H. hyperborea*, a large *Hantzschia* species, widespread in nordic environments, that bears some similarities with the new species.

**Morphological observations** – The valves are clearly dorsiventral with a straight to weakly convex dorsal margin (fig. 6A–G). The ventral margin is slightly concave in the middle and more convex to straight near the valve apices. The valve apices are typically rostrate to cuneate-rostrate (fig. 6A–G). Valve length ranges from 70 to 120 µm, valve width from 11.6 to 14.7 µm. The fibulae, 5–7 in 10 µm, are relatively small and connected to 1–4 transapical costae. The fibulae are irregularly scattered along the valve margin, showing a quite variable thickness. The external and internal raphe is

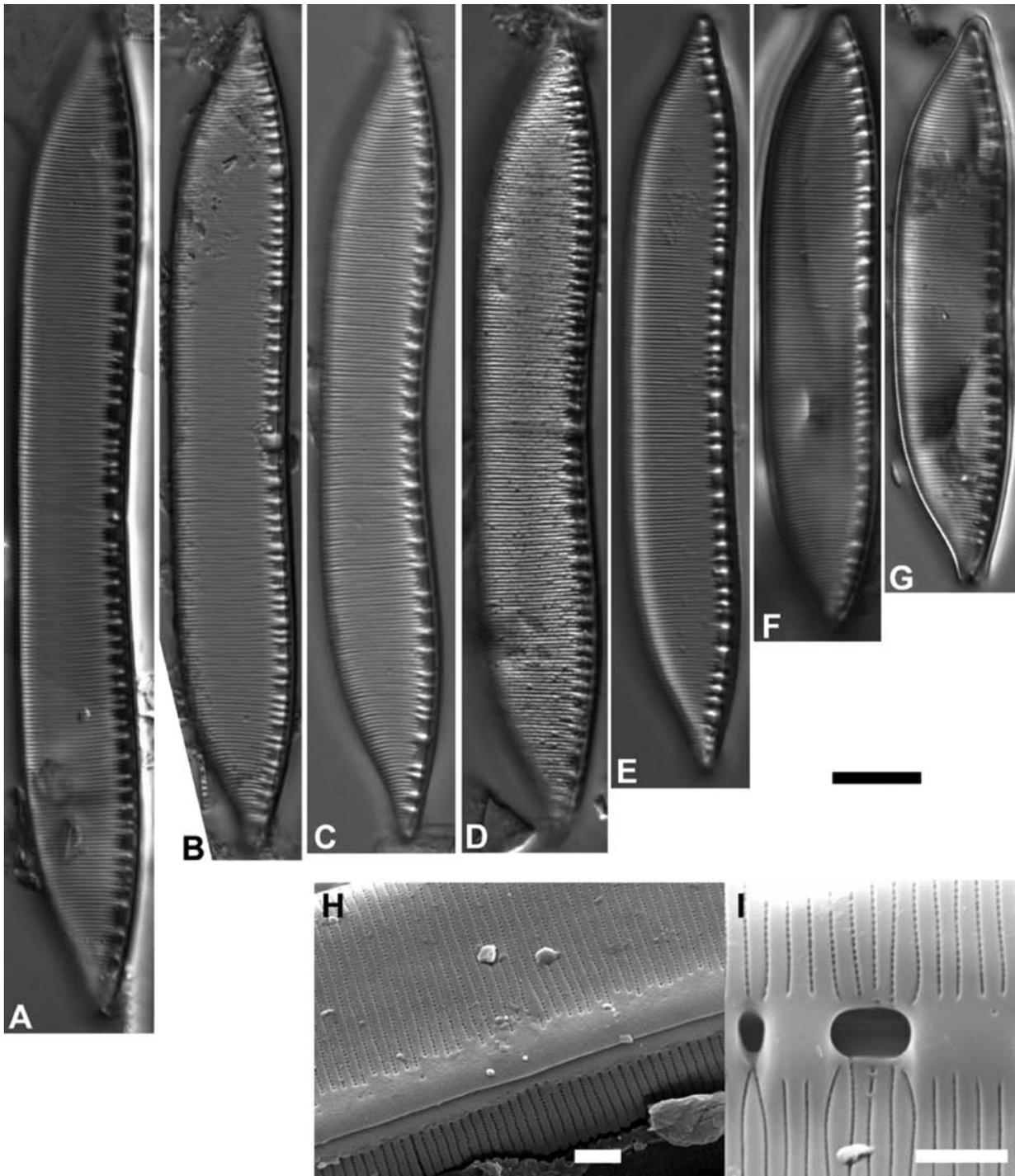


**Figure 5** – *Hantzschia confusa*: A–F, LM micrographs of the largest population on Byers Peninsula (sample LIV-BY16A); G, light microscope detail of the areolae of *H. confusa*; H, light microscope detail of the areolae of *H. abundans*; I, scanning electron micrograph, detail of the clearly bent external, uninterrupted central raphe endings; J, scanning electron micrograph, detail of the striae and the areolae; K, scanning electron micrograph, half a valve with focus on the hyaline zone bordering the striae. Scale bar represents 10  $\mu\text{m}$  except for I–J where scale bar = 2  $\mu\text{m}$ .

straight and continuous, lacking central pores (fig. 6H & I). The striae are parallel and equidistant throughout the entire valve, 20–22(–23) in 10  $\mu\text{m}$ . The areolae are not discernible in LM. In SEM, the areolae appear to be very small, rounded poroids, countable: 50–60 in 10  $\mu\text{m}$  (fig. 6H).

**Remarks** – Based on its valve dimensions, *Hantzschia hyperaustralis* can be confused with other large *Hantzschia* species such as *H. borgei* O.Müll., *H. hyperborea* (Grunow) Lange-Bert. and *H. considerata* Lange-Bert. et al. *Hantzschia*

*borgei* and its variety *rostellata* were described from Patagonia in 1909 by Müller. These are the only records of this species so far and in later floristic accounts of southern South America the species has never been reported again (Rumrich et al. 2000, Metzeltin et al. 2005). According to the original description in Müller (1909), *Hantzschia borgei* has comparable dimensions and stria density but the striae do not reach the dorsal valve margin as they do in *H. hyperaustralis*. Analysis of the type material (Sample 376, Stockholm registration number A4473, no type slide available) did unfortunately

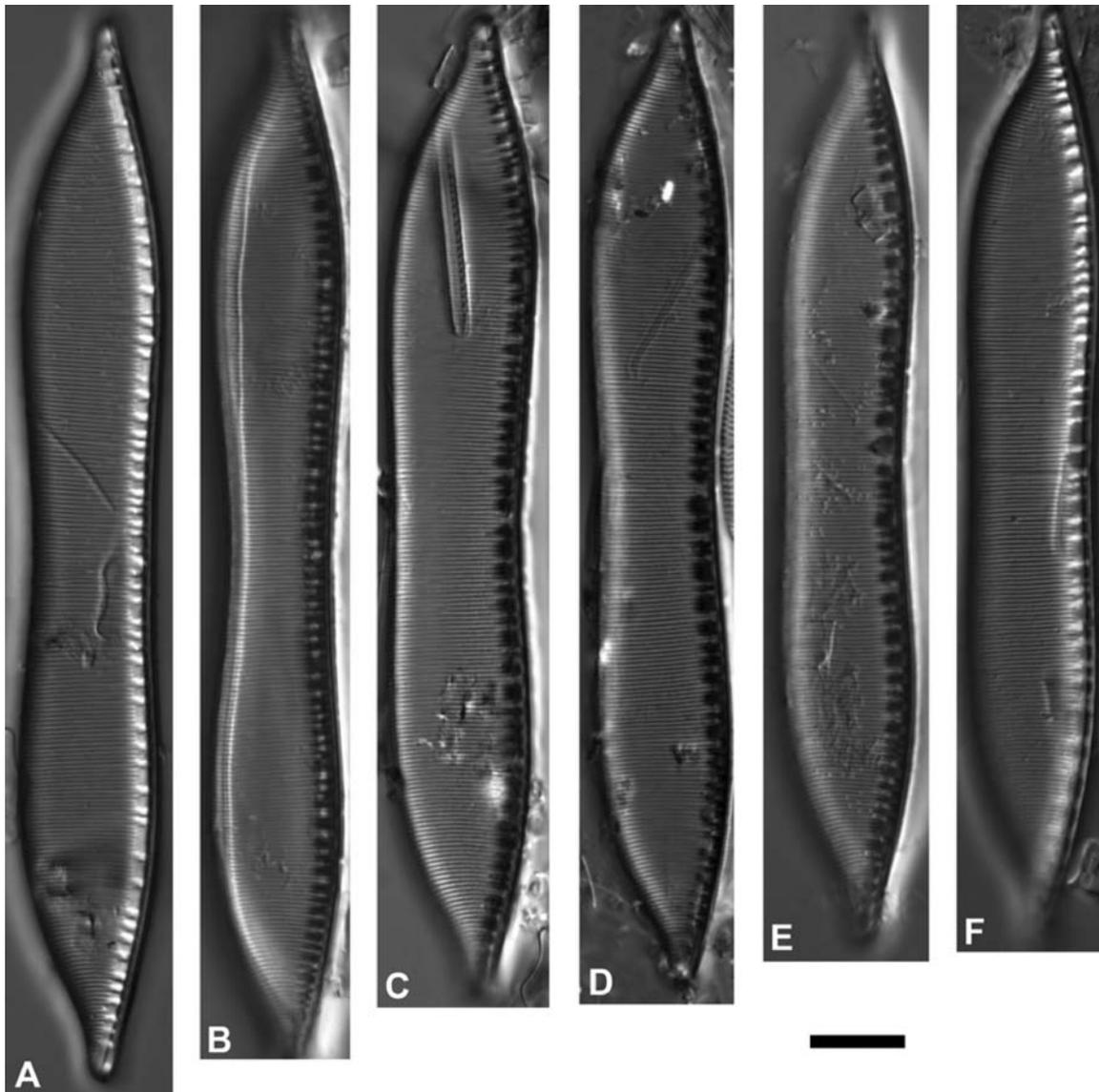


**Figure 6** – *Hantzschia hyperaustralis*: A–G, LM micrographs of the largest population on Byers Peninsula (sample LIV-BY16A); H, scanning electron micrograph, detail of the straight external, uninterrupted central raphe endings; I, scanning electron micrograph, detail of the straight internal, uninterrupted central raphe endings. Scale bar represents 10  $\mu\text{m}$  except for H–I where scale bar = 2  $\mu\text{m}$ .

not reveal any specimens but based on the drawing in Müller (1909), it is clear that *H. borgei* has a very typical central part where some striae start at the ventral side but never reach over to the dorsal side.

*Hantzschia hyperborea*, typical for the Arctic Region, although the species was also reported from southern Chile (Rumrich et al. 2000), shows some similar features such as

valve dimensions, number of areolae and stria density, but can nevertheless be easily separated. The species has a more concave ventral side and more rostrate-capitate to capitate ends compared to the rostrate to cuneate-rostrate ends in *H. hyperaustralis*. The fibulae in *H. hyperborea* are clearly more spaced in the middle. As a result of this, the striae are also slightly more spaced in the middle, contrary to *H. hyperaustralis* where no difference in striation density can be noted



**Figure 7** – *Hantzschia constricta*: A–F, LM micrographs of the largest population on Hurd Peninsula (sample Π7a/04). Scale bar represents 10 μm.

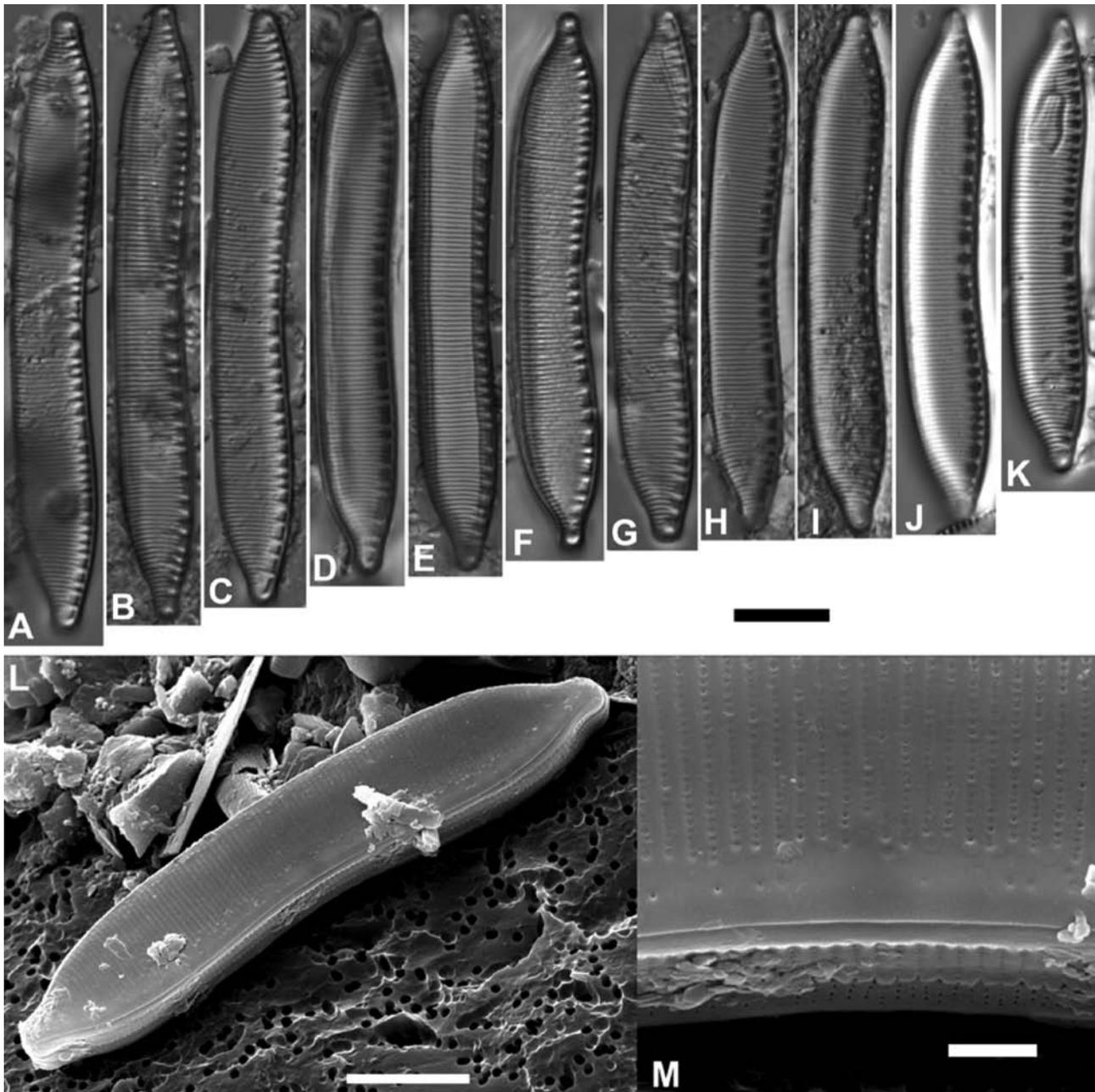
throughout the entire valve. In SEM, the separation of the two taxa is even clearer since *H. hyperborea* shows deflected central raphe endings whereas *H. hyperaustralis* has a continuous raphe. *Hantzschia considerata*, described from Sardinia (Lange-Bertalot et al. 2003), has similar dimensions but can be much larger with less striae in 10 μm (13–15 vs. 20–22 in 10 μm). The species has a coarser striation pattern (27–30 areolae in 10 μm vs. 50–60 in *H. hyperaustralis*). Since no SEM pictures were provided with the original description and the type material was not investigated, the details of the raphe endings cannot be compared. Recently, Metzeltin et al. (2009) described *Hantzschia mongolica*, another large *Hantzschia* species that is closely related to *H. hyperborea*. *H. mongolica* can however be separated from *H. hyperaustralis* by a much lower stria density (11–14 vs. 20–22 in 10 μm) and wider spaced middle fibulae.

**Ecology** – The species is often recorded in terrestrial habitats on Livingston Island, found among mosses near small pools and streams, together with other *Hantzschia* species.

***Hantzschia constricta*** Van de Vijver & Zidarova, **sp nov.** (fig. 7A–F)

**Diagnosis** – A *Hantzschia hyperaustralis* differt valves constrictis in media parte valvae. Longitudo 95–112 μm, latitudo 10.5–12.7 μm. Fibulae carinae raphis 4–7 in 10 μm. Striae transapicales 20–23 in 10 μm. Puncta 50–60 in 10 μm. – Type: holo-: BR-4176 (National Botanic Garden of Belgium, Meise); iso-: PLP-143 (University of Antwerp, Belgium), BRM-ZU7/20 (Hustedt Collection, Bremerhaven, Germany). – Type locality: Livingston Island, Hurd Peninsula, sample Π7a/04 (coll. Zidarova, coll. date 19 Feb. 2004).

**Etymology** – Latin *constrictus*, constricted; referring to the constriction near the valve middle.



**Figure 8** – *Hantzschia incognita*: A–K, LM micrographs of the largest population on Hurd Peninsula (sample II1a/04); L, scanning electron micrograph, entire valve with straight external, uninterrupted central raphe endings; M, scanning electron micrograph, detail of the straight external, uninterrupted central raphe endings. Scale bar represents 10  $\mu\text{m}$  except for M where scale bar = 2  $\mu\text{m}$ .

**Morphological observations** – The valves have an almost straight, less dorsiventral valve outline with constricted ventral and dorsal margins and elongated, apiculate apices (fig. 7A–F). Valve dimensions and valve features including the raphe structure and striation pattern are similar to *H. hyperaustralis*. Valve length 95–112  $\mu\text{m}$ , valve width 10.5–12.7  $\mu\text{m}$ . Fibulae (4–)5–7 in 10  $\mu\text{m}$ . Striae 20–22(–23) in 10  $\mu\text{m}$ , areolae 50–60 in 10  $\mu\text{m}$ .

**Remarks** – The only feature separating *Hantzschia constricta* from *H. hyperaustralis* is the valve outline, as valve dimensions, raphe structure and striation pattern are similar.

Contrary to *H. hyperaustralis*, the valves in *H. constricta* are more or less straight lacking the typical *Hantzschia* flexion in the middle, with longer valve apices and the clear constriction in the valve middle. Since there are no other *Hantzschia* species that present constricted valves, the species rank is justified for this unknown taxon.

**Ecology** – *H. constricta* is so far only found in a sample from a wet soil near a small puddle above the Todorina Bouza lake. The sample is dominated by *Psammothidium incognitum* (Krasske) Van de Vijver and several, until now unidentified *Gomphonema* species.

***Hantzschia incognita*** Zidarova & Van de Vijver, **sp. nov.** (fig. 8A–M)

**Diagnosis** – Valvae distincte dorsiventrales marginibus dorsalibus moderate convexis sed numquam rectis marginibus ventralibusque minus convexis in partibus distalibus sed concavis in media parte, valva ita aliquid geniculata apparet. Apices rostrati, sed numquam protractis capitatis ad subcapitatis. Longitudo 48–67  $\mu\text{m}$ , latitudo 7.4–8.1. Fibulae carinae raphis, 5–8 in 10  $\mu\text{m}$ , aequidistantes omnino, mediis duabus numquam remotis inter se. Una fibula continens variabiliter cum 1–3 costis transapicalibus. Fines proximi externi internique ramorum raphis non interrupti. Striae transapicales parallelae aequidistantes omnino, 18–20 in 10  $\mu\text{m}$ . Puncta striarum non aspectabilia microscopio photonico, 45 in 10  $\mu\text{m}$ . – Type: holo-: BR-4177 (National Botanic Garden of Belgium, Meise); iso-: PLP-144 (University of Antwerp, Belgium), BRM-ZU7/22 (Hustedt Collection, Bremerhaven, Germany). – Type locality: Livingston Island, Hurd Peninsula, sample П1а/04 (coll. Zidarova, coll. date 31 Jan. 2004).

**Etymology** – Latin *incognitus*, unknown; referring to the combination of morphological features never observed in any *Hantzschia* species.

**Morphological observations** – The valves are clearly dorsiventral with a moderately convex but never straight dorsal side (fig. 8A–K). The ventral side is concave in the middle part and convex towards the margins. The valve apices are rostrate, but never protracted subcapitate to capitate. Valve length 48–67  $\mu\text{m}$ , with a valve width of 7.4–8.1  $\mu\text{m}$ . The number of fibulae ranges from 5 to 8 in 10  $\mu\text{m}$ , equally spaced throughout the entire ventral margin with the median fibulae not more distant than others, composed of 1–3 transapical costae. External and internal raphe branches are straight and continuous showing no interruption near the valve middle, lacking central raphe endings (fig. 8L–M). The striae are parallel and equidistant throughout the entire valve, 18–20 in 10  $\mu\text{m}$ . Puncta are not resolved in LM, c. 45 in 10  $\mu\text{m}$  in SEM (fig. 8M).

**Remarks** – *Hantzschia incognita* can be confused with several other *Hantzschia* species such as *H. abundans* Lange-Bert., *H. subrupestris* Lange-Bert., *H. calcifuga* E.Reichardt & Lange-Bert. and *H. possessionensis* Van de Vijver & Beyens. *H. abundans* and *H. subrupestris* seem to be the most similar species but can be separated based on a different raphe structure, since these species have central raphe endings, and the central fibulae are always more distant from each other than the other fibulae (Lange-Bertalot 1993), which is not the case in *H. incognita*. The dorsal side in *H. abundans* is usually more convex, compared to *H. incognita*. *Hantzschia subrupestris* has similar valve outline and dimensions but a lower number of striae (14–16 vs. 18–20 in 10  $\mu\text{m}$ ) and a considerably lower number of areolae (24 vs. 45 in 10  $\mu\text{m}$ ). Moreover, the species has bent central raphe endings (Lange-Bertalot 1993), whereas in *H. incognita* the raphe is straight and central raphe endings are absent. *Hantzschia possessionensis*, described from the subantarctic Crozet archipelago (Van de Vijver et al. 2002), has larger valve dimensions (75–90 vs. 48–67  $\mu\text{m}$ ), less striae (15–16 vs. 18–20 in 10  $\mu\text{m}$ ) and more spaced fibulae in the middle. The central raphe endings are unilaterally bent. Finally, *H. calcifuga*, found in Germany

and Austria (Werum & Lange-Bertalot 2004), has a larger length/width ratio giving the latter a more slender outlook, unilaterally bent central raphe endings and fibulae that are more distant in the middle.

**Ecology** – *H. incognita* is a common species in soil and on mosses on Livingston Island. One of the largest populations was found in sample П1а/04, taken from wet soil near a stream, close to the Spanish Juan Carlos I base. The sample was dominated by other *Hantzschia* species such as *H. hyperaustralis* and *H. acuticapitata*, *Nitzschia hamburgiensis*, *N. aff. perminuta*, *Planothidium lanceolatum* and *Pinnularia* sp.1.

***Hantzschia* sp.** (fig. 9A–B)

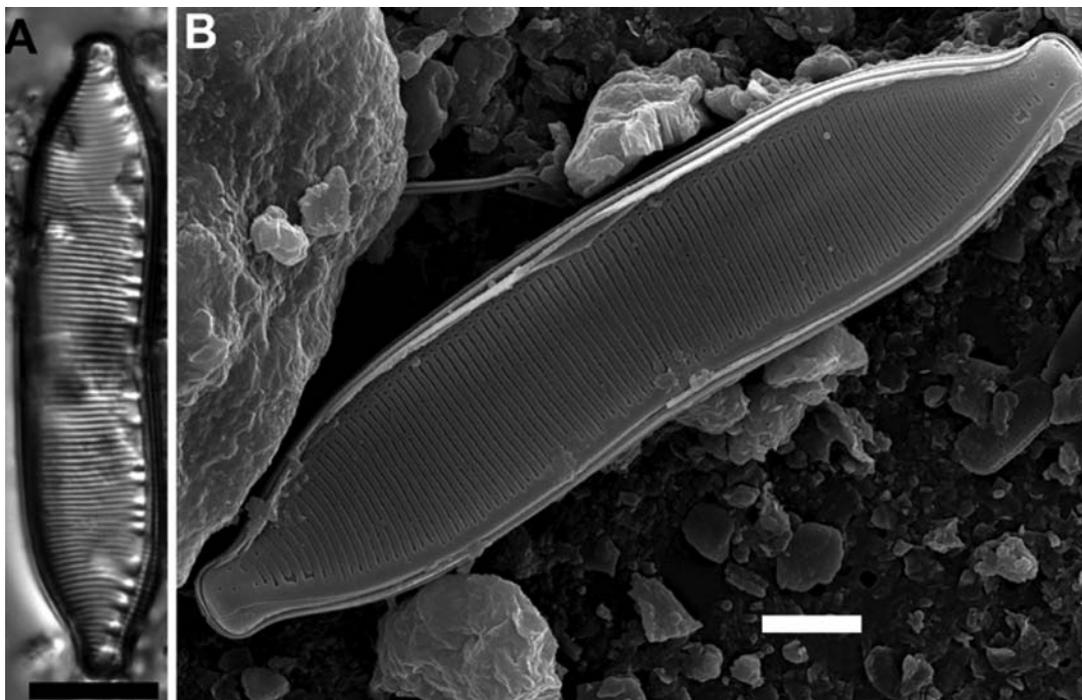
**Morphological observations** – The valves are dorsiventral with an almost straight dorsal margin (fig. 9A). The ventral margin is slightly concave in the middle and slightly convex near the apices. The apices are shortly protracted, subcapitate. Valve length is 50  $\mu\text{m}$ , valve width around 9.5  $\mu\text{m}$ . The fibulae are unequally spaced, 5–6 in 10  $\mu\text{m}$ , the two fibulae in the middle are more distant than the others. Each fibula is connected to 2–3 transapical costae. The striae are slightly radiate in the middle, parallel near the apices, 19–20 in 10  $\mu\text{m}$ . Areolae are not visible in LM. In SEM, the areolae seem to be connected by long transapical grooves. The raphe structure could not be observed on the single specimen found in the SEM due to the presence of the girdle bands (fig. 9B).

**Remarks** – So far, only two specimens of this species have been observed, one in LM and one in SEM. Based on the valve outline and dimensions, the most similar species is *H. paracompecta* Lange-Bert. although the latter has much broader valves (12–13  $\mu\text{m}$  vs. 9.5  $\mu\text{m}$ ). Since this species was extremely rare, we were not able to make observations on the raphe structure in SEM. Further studies are necessary in order to clarify whether it represents a new species or not.

**Ecology** – The species was found in sample LIV-BY16A, taken from a biofilm in a flooded area between stones on Byers Peninsula close to the main plateau. The sample is dominated by various taxa of *Luticola*, *Hantzschia*, *Pinnularia* and *Diadesmis*.

## DISCUSSION

For quite a long time, the taxonomy of the genus *Hantzschia* has not been studied in detail in the Antarctic Region. Ko-Bayashi (1965) investigated some forms related to *H. amphioxys* and Van de Vijver et al. (2002) described *H. possessionensis* from the Crozet Archipelago but apart from these two studies, only European species and varieties were found in the Antarctic material (Kellogg & Kellogg 2002), leading to the false conclusion that only cosmopolitan species prevailed in the Antarctic Region. The results of the present study indicate that the past ideas about the distribution of (mainly European) *Hantzschia* species in Antarctica proved to be incorrect. The observed diversity of *Hantzschia* species on Livingston Island is confirmed once more that force-fitting (Tyler 1996) in the past has led to the incorrect conclusion that mostly cosmopolitan diatom species are found in Antarctica. Previous studies on other genera, such as *Stauroneis* (Van de Vijver



**Figure 9** – *Hantzschia* sp.: A, LM picture of one specimen from Byers Peninsula (sample LIV-BY16A); B, scanning electron micrograph, entire valve with straight external, uninterrupted central raphe endings. A, scale bar represents 10  $\mu\text{m}$ ; B, scale bar represents 5  $\mu\text{m}$ .

et al. 2004), *Muelleria* (Spaulding et al. 1999, Van de Vijver et al. 2010), *Luticola* (Esposito et al. 2008; Van de Vijver & Mataloni 2008) have already shown a greater diversity in these genera and the presence of typical Antarctic taxa that had been previously assigned to well-known, mainly European, species in the past. Taking into account that several difficult genera, such as *Eunotia*, *Pinnularia*, *Gomphonema* and *Nitzschia* still need a thorough revision, we expect that the number of Antarctic taxa will even more increase in future.

The biogeography of all new *Hantzschia* taxa found on Livingston Island is completely unknown. A comparison with neighbouring islands and regions is so far not possible since it will require a thorough verification of all reported occurrences. Most papers dealing with the Antarctic diatom flora published up to now, usually do not illustrate *Hantzschia* species since in most cases, the only reported one is the ‘presumably’ cosmopolitan *H. amphioxys* (see Kellogg & Kellogg 2002), too ‘well-known’ to be of interest to show. However, *Hantzschia amphioxys* has been considered in the past as being extremely variable in morphology and dimensions thus, obscuring the true taxonomy of this group. Most of the species found on Livingston Island, e.g. *Hantzschia abundans*, *H. confusa*, *H. incognita* and even *H. hyperaustralis*, have probably been included in older reports within the range of *Hantzschia amphioxys* and its varieties. Sabbe et al. (2003) stated that the Antarctic specimens of *H. amphioxys* do not correspond to the generally accepted concept of this species. In order to establish the correct distribution of each species, samples from other localities will have to be reanalysed and/or new studies will have to be done.

A very intriguing observation, however, is the fact that all newly described species from Livingston Island present a continuous raphe lacking typical central raphe pores. Al-

though it is not uncommon in the genus *Hantzschia* to lack central pores (Round et al. 1990), most species described from the northern hemisphere such as *Hantzschia amphioxys* or *H. abundans* possess central raphe endings well separated from each other (Lange-Bertalot 1993). It is unclear whether all species described from the southern hemisphere lack central pores as in many species descriptions, this feature is never mentioned (Metzeltin et al. 2005). The lack of central raphe endings might point to a common ancestor. However, this can only be proven by using molecular techniques.

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