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MORPHOLOGY OF NEW TAXA IN THE *CYMBELLA ASPERA* AND *CYMBELLA NEOCISTULA* GROUPS, *CYMBELLA YAKII* SP. NOV., AND *CYMBELLA* CF. *HANTZSCHIANA* FROM EVEREST NATIONAL PARK, NEPAL*

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Abstract. Three new species and one new variety of the genus *Cymbella* are described from the Gokyo and Dudh Koshi Valleys in Everest National Park, Nepal. *Cymbella himalaspera* Jüttner & Van de Vijver and *C. subhimalaspera* Jüttner & Van de Vijver are related to species in the group around *C. aspera* (Ehrenberg) H. Peragallo but differ from similar taxa with respect to the shape of the areolae, the proximal raphe endings and the stigmata. *Cymbella neocistula* var. *nepalensis* Jüttner & Van de Vijver differs from the nominate form in valve shape. *Cymbella yakii* is similar to species around *C. parva* (W. Smith) Kirchner in Cohn and *C. excisa* Kützing but differs in valve shape and the number of stigmata. A taxon similar to *C. hantzschiana* Krammer is described in detail.

Keywords: algae, Bacillariophyceae, new species, Himalaya, Gokyo

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INTRODUCTION

High altitude freshwaters are an important natural resource and provide refuges for aquatic organisms that are confined to oligotrophic habitats. Although in the Himalayas many are still considered pristine, there is increasing concern about the effects of climate change on the hydrology and ecology of aquatic ecosystems (IPCC 2007). A possible decline in water availability and increasing impacts of tourism in some areas could also lead to water quality deterioration and to loss of biodiversity (Ren *et al*. 2004). To date there is only limited knowledge of freshwaters in the Himalayas, particularly at higher altitudes, although recently a number of studies on the hydrology and limnology of lakes and rivers have been conducted (e.g., Aizaki *et al*. 1987; Johnson *et al*. 1998; Lami & Giussani 1998; Lacoul & Freedman 2006; Stubauer *et al*. 2008). In 2008 a project was begun in the Gokyo Valley, Everest (Sagarmatha) National Park, Nepal, aiming to assess the environmental conditions and the biodiversity of aquatic habitats, and to provide data against which future changes due to climate warming and the effects of tourism can be compared (Sharma *et al*. 2009). One of its principal components is analysis of the diatom flora of the lakes, streams and associated wetland habitats, since diatoms are particularly suitable as indicators of environmental change related to

* Dedicated to Dr. Kurt Krammer on the occasion of his 85th birthday

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changes in temperature and to impacts of pollution (Smol 2008).

Until now Himalayan diatoms have been studied mainly in streams and ponds, and several new species and one new genus have been described (e.g., Jüttner *et al*. 2000; Jüttner *et al*. 2003; Jüttner *et al*. 2004; Rai 2006; Simkhada *et al*. 2006; Jüttner *et al*. 2010). The first studies on diatoms in Everest National Park were conducted in the 1960s and 1970s (Suxena & Venkateswarlu 1968; Suxena *et al*. 1972), and recently studies on the gomphonemoid and cymbelloid diatoms were conducted near Mount Everest in China (Li *et al*. 2004, 2007a). During the present investigations of aquatic and terrestrial habitats in the Gokyo and Dudh Koshi Valleys, samples from subaerial habitats, such as wet terrestrial bryophytes, rocks, soil and sand, contained a well-developed semi-aquatic diatom flora dominated by *Eunotia*, *Pinnularia*, fragilarioid, achnanthoid, and especially cymbelloid species. Analysis of the latter group revealed the presence of more than 20 different taxa belonging to *Encyonema*, *Encyonopsis*, *Cymbopleura* and *Cymbella*, of which several could not be identified using the currently available literature.

In this paper we describe two new species related to the complex of *Cymbella aspera* (Ehrenberg) H. Peragallo, a new variety of *Cymbella neocistula* Krammer, and the new species *Cymbella yakii*. We also give a detailed morphological description of a taxon similar to *Cymbella hantzschiana* Krammer.

METHODS

STUDY AREA

In October 2008, diatoms were collected from available substrates (bryophytes, rock, sand, soil) in subaerial habitats such as damp areas and vegetation of stream and lake margins, in or near springs, on a wet rock wall, and from submerged substrates such as stones, macrophytes, sediment and sand in lakes, streams and springs. The sites were located in the Gokyo Valley, Everest National Park, Nepal, at altitudes between 4700 and 4800 m a.s.l. at the inflows and lake margins of the first lake, second lake (Taboche Tsho or Taujung) and third lake (Dudh Pokhari or Gokyo Lake, Fig. 1). The springs were located on the southern slope of the mountain Gokyo Ri within an altitude range of *ca* 50 m above the northern margin of the 3rd lake (*ca* 27°56.6′ – 27°57.3′N and 86°41.3′ – 86°42.1′E). One site was located in the Dudh Koshi Valley, Everest National Park, at 2840 m a.s.l. It was a rock wall adjacent to the first tributary from the east of the Dudh Koshi River, south of the confluence between the Bhote Koshi River and the Dudh Koshi River (Imja Khola), and the Larja Bridge, and north of the village of Jorsale (27°46.797′N, 86°43.071′E).

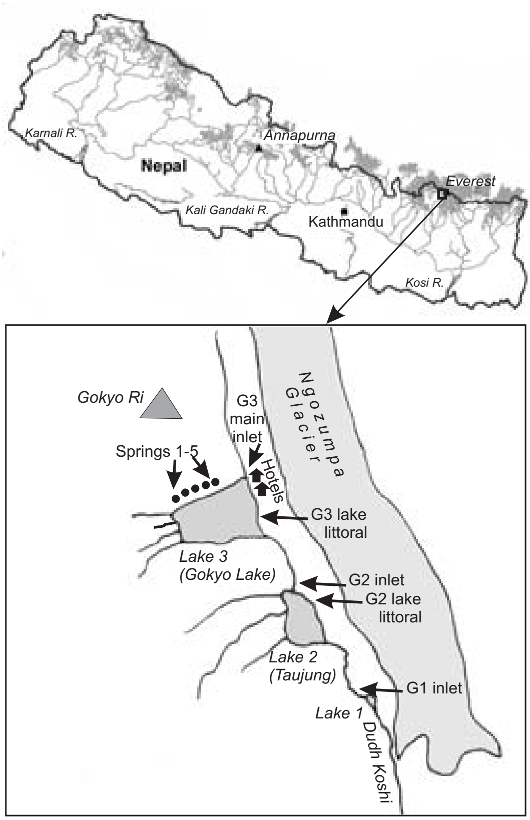

Fig. 1. Location of the study area in Nepal, and location of sites in the Gokyo Valley; the location (not shown) of site 'ES 08 Aero7 rock' in the Dudh Koshi Valley is *ca* 16 km further south of the Gokyo wetlands.

LABORATORY PROCEDURES

Diatom samples were processed using hot H_2O_2 oxidation and mounted in Naphrax. For light microscopy we used an Olympus BX51 and a Nikon E600, equipped with differential interference contrast (Nomarski, 1000×, oil immersion). For scanning electron microscopy

(SEM), part of the suspension was filtered through polycarbonate membrane filters (pore diam. 3 µm), pieces of which were fixed on aluminium stubs after air-drying. The stubs were sputter-coated with 50 nm gold and studied in a JEOL-5800LV at 20 kV.

Holotype slides and cleaned samples are held at the National Museum of Wales (Cardiff, U.K.), and isotype slides at the National Botanic Garden of Belgium (Meise, Belgium), at Kathmandu University (Dhulikhel, Nepal), in the Hustedt Collection of the Alfred-Wegener-Institut für Polar- und Meeresforschung (Bremerhaven, Germany) and in The Natural History Museum (London, U.K.).

OBSERVATIONS

During a detailed morphological analysis of the cymbelloid diatom taxa from the Gokyo and Dudh Koshi Valleys, several taxa could not be identified. Three of them are described as new *Cymbella* species based on their valve shape, symmetry, raphe and areola characteristics: *Cymbella himalaspera* Jüttner & Van de Vijver *sp. nov*., *Cymbella subhimalaspera* Jüttner & Van de Vijver *sp. nov*., and *Cymbella yakii* Jüttner & Van de Vijver *sp. nov*. One taxon is described as a new variety: *Cymbella neocistula* var. *nepalensis* Jüttner & Van de Vijver *var. nov*. The morphology of another species, similar to *C. hantzschiana* Krammer, is also shown in detail.

Cymbella himalaspera Jüttner & Van de Vijver, ***sp. nov.***

Valvae dorsiventrales, margine dorsali moderate arcuata, apicibus non protractis et rotundatis. Margo ventralis paene recta cum levi inflatione in medio. Longitudo 150–280 µm, latitudo 35–49 µm. Area axialis, circiter 1/6–1/4 latitudinis valvae, linearis marginibus paene parallellis ad leviter undulatis et cum constrictione levi in polis. Area centralis elliptica, 1/3 ad minus latitudinis valvae. Stigmata ventralia rotunda ad leviter elongata multa, separata striis ventralibus curtis ab area hyalina angustissima. Raphe claro lateralis, ad aream centralem et ad apices sensim filiformis. Terminationes raphis centrales expansae, deflexae ad latus ventrale. Fissurae distales falcatae, deflexae ad latus dorsale valvae. Striae radiatae, aliquando leviter curvatae, 7–8 in 10 µm (*striae dorsales*)*, 7–9 in 10 µm* (*striae ventrales*)*, distincte punctatae* (*10–12 in 10 µm*)*.*

TYPE: NEPAL, Everest National Park. Spring 4 on the southern slope of the mountain Gokyo Ri near the northern margin of the 3rd lake, 19 Oct. 2008, *coll. S. Gurung* [HOLOTYPE: slide NMW.C.2009.003 G3 spring 4 bryophytes, National Museum of Wales, Cardiff, U.K. (NMW); ISOTYPES: National Botanic Garden of Belgium, Meise, Belgium (BR-4182); Kathmandu University, Aquatic Ecology Centre, Dhulikhel, Nepal; Hustedt Collection, Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany (BRM ZU7); The Natural History Museum, London, U.K. (BM)].

ETYMOLOGY: the specific epithet refers to the similarity with taxa in the species complex of *Cymbella aspera* and the type locality in the Himalayas.

LIGHT MICROSCOPY (Fig. 2: 1–4). Valves are dorsiventral with a moderately arched, convex dorsal margin gradually tapering towards the broadly rounded poles. The ventral margin is almost straight except for a slightly gibbous valve centre. Length 150–280 µm, width 35–49 µm, length/width ratio 4.1–5.6. The linear axial area has almost parallel to weakly undulating margins and a slight constriction at the poles, between 1/6 and 1/4 of the maximum valve width. The central area is elliptic, 1/3 or slightly less of the valve width. On the ventral side of the central nodule are a larger number of small, round to slightly elongate stigmata separated from the shortened ventral striae by a very narrow, sometimes almost absent hyaline area. The raphe is clearly lateral, tapering near the proximal and distal ends (Pl. 67, fig. 3 type b, in Krammer 2002) and positioned slightly eccentrically. The proximal raphe endings are widened and deflected towards the ventral side; the polar raphe endings appear sickle-shaped and are deflected to the dorsal side of the valve. The striae are radiate and sometimes slightly curved; dorsal striae density 7–8 in 10 µm, ventral striae density 7–9 in 10 µm. The areolae are visible, 10–12 in 10 µm.

SCANNING ELECTRON MICROSCOPY (Fig. 3: 1–8). Externally the raphe slit is located on a rib, a thickened part of the axial and central areas (Fig. 3: 1). The large proximal raphe endings are drop-like and ventrally deflected, only rarely curved

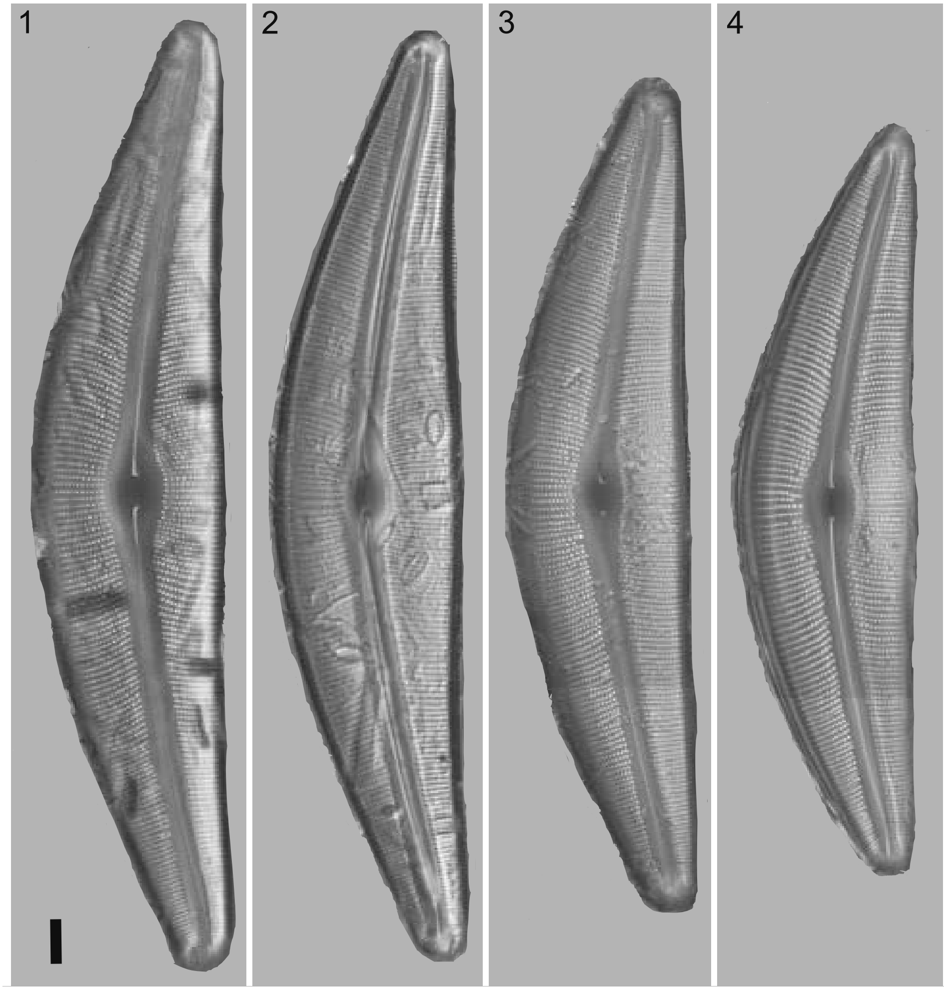

Fig. 2. *Cymbella himalaspera* Jüttner & Van de Vijver, *sp. nov.* 1–4 – holotype slide: NMW.C.2009.003 G3 spring 4 bryophytes; 3rd lake, Gokyo Valley, Nepal; Valve views (LM). Scale bar = 10 μm.

backwards (Fig. 3: 2). The raphe towards the poles is sometimes undulate and the raphe endings are dorsally deflected, terminating in a large apical pore field with a small hyaline area on one or both sides of the raphe slit (Fig. 3: 3, 4). The apical pore fields consist of a large number of very small round pores forming parallel vertical lines (Fig. 3: 3). A large number of round or slightly elongate stigmata are present on the ventral side of the central nodule; on the dorsal side, 7–8 areolae adjacent to the central area are widened, forming round, elongate or irregular pores (Fig. 3: 1, 2). Occasionally a second row of smaller pores is present between the stigmata and the ventral striae (Fig. 3: 2). The external areola openings are X-, Y-, star- or tree-shaped towards the valve centre across the entire valve face and along the axial area, becoming mostly apically elongate slits towards the valve ends (Fig. 3: 1, 4, 5). Internally the ventral stigma openings are seen as a series of narrow elongated furrows without teeth-like ingrowths and directly adjacent to the striae. Dorsally some of the alveoli are elongate and slightly widened adjacent to the central nodule (Fig. 3: 6). Broad costae and narrow alveoli with struts are present (Fig. 3: 7). The apical pore field alveoli are radi-

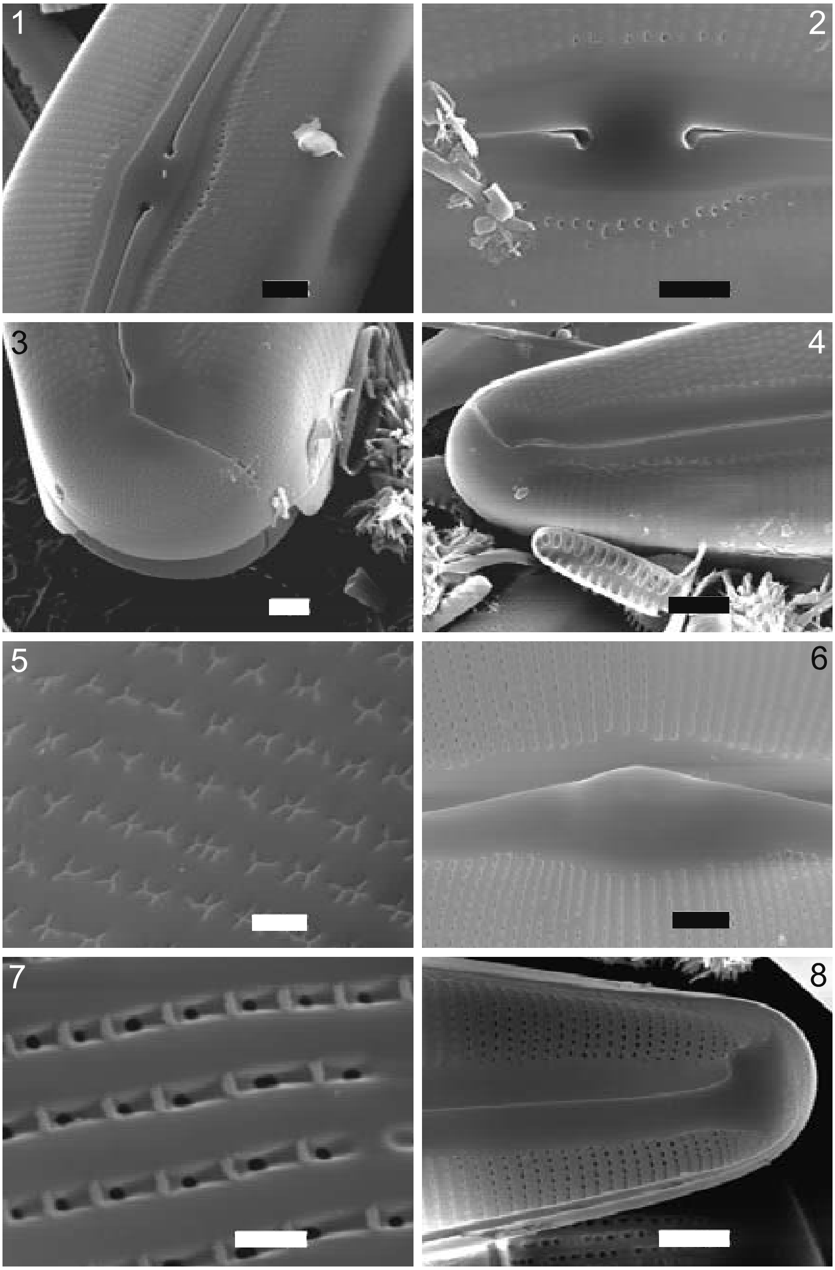

Fig. 3. *Cymbella himalaspera* Jüttner & Van de Vijver, *sp. nov.* (G3 spring 4 bryophytes, 3rd lake, Gokyo Valley, Nepal, prepared from type material). 1–5 – External views, 6–8 – Internal views (SEM). 1 – Central area with raphe located on rib and stigmata. 2 – Central area with ventrally deflected raphe endings, ventral and dorsal stigmata. 3 – Pole with raphe fissure ending in large apical pore field. 4 – Valve towards the poles with X, Y-shaped areolae along the axial area, otherwise elongated slits, and dorsally deflected raphe endings. 5 – Areolae X- Y, star- or tree-shaped towards the valve centre across the valve face. 6 – Central area with central nodule and stigma openings appearing as furrows adjacent to the striae. 7 – Broad costae and narrow alveoli with struts between areola openings. 8 – Apical pore field alveoli radially arranged around the terminal nodule, and helictoglossa. Scale bars 1, 2, 4, 6, 8 = 5 µm, 3 = 2 µm, 5 & 7 = 1 µm.

Table 1. Morphological characters of *Cymbella himalaspera* Jüttner & Van de Vijver, *sp. nov.*, *C. subhimalaspera* Jüttner & Van de Vijver, *sp. nov.*, and related species in the *C. aspera* group.

Species / Feature	*C. aspera* (Ehrenberg) H. Peragallo	*C. peraspera* Krammer	*C. peraspera* var. *colombiana* Krammer & Lange-Bertalot	*C. halophila* Krammer	*C. neogena* (Grunow) Krammer	*C. amelieana* Van de Vijver & Lange-Bertalot	*C. himalaspera* *sp. nov.*	*C. subhimala-spera sp. nov.*
Valve length, µm	110–200	(130)154–320	163–228	140–215	90–185	160–270	150–280	104–133
Valve width, µm	26–35	44–52	38–41	37–42	28–35	40–46	35–49	21–25
Length/width ratio	max. 5.7	max. 6	max. 6	max. 5.1	max. 5.4	5.5–6.0	4.1–5.6	4.9–5.8
Striae in 10 µm	6.5–8(10 near poles)	5–8 (10 near poles)	5–8 (10 near poles)	6–8 (10 near poles)	6–9 (13 near poles)	7–8 (11–12 near poles)	7–9	8–11 (10–12 near poles)
Areolae in 10 µm	8–10(11)	7–10(11)	7–10	9–10	12–15	10–11	10–12	10–12 (15 near poles)
Areolae	I-shaped	I-shaped	X-, I-shaped	almost round	not known	X-, I-shaped, slit-like weakly curved	X-, Y-, star-, tree-shaped	X-, I-shaped, oval, curved
Stigmata	7–10	large number, round	large number, transapical slits	large number, small round	7–10	large number, small round	large number, round to slightly elon-gate	8–11 elongate
Apical pore field	not known	large, many small round pores	large, many small round pores	not known	not known	large, many small round pores	large, many small round pores, vertical lines	large, many small round pores, hori-zontal lines
Central raphe endings	moderately large, round, almost straight or slightly ven-trally deflected	moderately large, round, almost straight or slightly ven-trally deflected	moderately large, almost round, slightly ventrally de-flected	large, round, close together	large, round, almost straight to slightly ven-trally deflected	crook-shaped, curved back-wards	large drop-like, ventrally deflected	large drop-like, straigth or slightly ven-trally deflected
Reference	Krammer 2002	Krammer 2002	Krammer 2002	Krammer 2002	Krammer 2002	Van de Vijver & Lange-Ber-talot 2008	this study	this study

ally arranged around the terminal nodule and the elongated helictoglossa (Fig. 3: 8).

TAXONOMIC REMARKS. Based on its valve morphology, *Cymbella himalaspera* belongs to the complex of taxa around *C. aspera* (Table 1). Some taxa in this group can only be distinguished using features seen exclusively in SEM. The most similar taxon is *C. amelieana* Van de Vijver & Lange-Bertalot, recently described from Sweden (Van de Vijver & Lange-Bertalot 2008). It has X- to I-shaped areolae openings in the middle of the valve and elsewhere they are slit-like and weakly curved, resembling primitive silhouettes of flying birds with a slightly expanded middle part. The latter type of areolae is not found in *C. himalaspera*. *Cymbella amelieana* also has crook-shaped proximal raphe endings and on average a larger length/width ratio. *Cymbella himalaspera* is also very similar to *C. peraspera* Krammer and its variety *colombiana* Krammer & Lange-Bertalot. *Cymbella peraspera*, known from North Germany and Finland, has I-shaped external areolae openings and the proximal raphe endings are not or only very slightly ventrally deflected (Pl. 131, fig. 5, 7, Pl. 133, fig. 1 in Krammer 2002). The variety *colombiana*, only known from Colombia, has X-shaped external areola openings, similar to *C. himalaspera*, and the proximal raphe endings are slightly ventrally deflected. However, the external ventral stigma openings are transapical slits (Pl. 134, fig. 5 in Krammer 2002) while they are round or only slightly elongate in *C. himalaspera*. *Cymbella peraspera* var. *colombiana* has also coarser puncta (7–10 in 10 µm vs. 10–12 in 10 µm). X-shaped external areola openings are rarely observed in the genus *Cymbella*. Other taxa with this feature include *C. mexicana* (Ehrenberg) Cleve, *C. tumida* (Brébisson) Van Heurck, *C. schimanskii* Krammer and *C. cantonatii* Lange-Bertalot, which differ clearly from the *C. aspera* complex. *Cymbella aspera* has I-shaped external areola openings (Pl. 8, fig. 2 in Krammer & Lange-Bertalot 1986) and the proximal raphe endings appear not or slightly ventrally deflected (Pl. 131, fig. 1b in Krammer & Lange-Bertalot 1986). The ventral stigma openings appear more slit-like in LM but are similar to those of *C. himalaspera* in SEM (Pl. 138, fig. 7 in Krammer 2002). *Cymbella aspera* (Pl. 10, fig. 2 in Patrick & Reimer 1975, and Pl. 124, figs 1–8, Pl. 125, figs 1–4, Pl. 126, figs 1–5, Pl. 127, fig. 7 [iconotype *Cocconema asperum* Ehrenberg] in Krammer 2002) is also smaller than *C. himalaspera* (110–200 µm vs. 150–280 µm, 26–35 µm vs. 35–49 µm). Krammer (2002) mentioned 8–10(11) in 10 µm puncta in *C. aspera*; that is slightly more coarsely punctate than in *C. himalaspera* (10–12 in 10 µm), but Patrick and Reimer (1975) noted *ca* 11–15 in 10 µm in *C. aspera*. *Cymbella neogena* (Grunow) Krammer, a more widely distributed taxon and known especially from the European Alps, has central raphe endings that are not or very slightly deflected, has fewer ventral stigmata (7–10) and is more finely punctate (12–15 in 10 µm), and the striae appear parallel punctate close to the central area (Pl. 129, figs 2–6 in Krammer 2002). Krammer (2002) mentioned 'puncta more or less roundish' but the areolae shape in SEM must be confirmed by further work. *Cymbella halophila* Krammer is distinguished by its proximal raphe endings, positioned closer to each other, and by its round areolae (Pl. 135, figs 1–4, 6, 7, Pl. 142, fig. 1 in Krammer 2002). Other taxa such as *C. dubravicensis* (Grunow) Pantocsek, *C. bengaliformis* Krammer, *C. bengalensis* Grunow, *C. crassa* (Grunow) Krammer, *C. subaspera* Krammer and *C. lanceolata* (Agardh) Agardh differ sufficiently in their valve outline, size, raphe structure, shape of areolae and pore field that they should not be confused with *C. himalaspera*.

ECOLOGY. Large populations were found in springs on the southern slope of Gokyo Ri on submerged and non-submerged bryophytes. The species was also found on moist non-submerged sand adjacent to a stream channel of the main inlet to the 3rd lake. At the type locality, where *C. himalaspera* was most abundant, associated taxa included *Denticula kuetzingii* Grunow, *Encyonema brevicapitatum* Krammer, *Encyonema minutum* (Hilse) D. G. Mann, *Diatoma mesodon* (Ehrenberg) Kützing, *D. hyemalis* (Roth) Heiberg and several unidentified fragilarioid species.

Cymbella subhimalaspera Jüttner & Van de Vijver, ***sp. nov.***

Valvae dorsiventrales, margine dorsali moderate arcuata, apicibus non protractis et rotundatis. Margo ventralis paene recta cum levi inflatione in medio. Longitudo 104–133 µm, latitudo 21–25 µm. Area axialis, circiter 1/6–1/7 latitudinis valvae, linearis marginibus paene parallellis. Area centralis elliptica, parva, 1/3–1/4 latitudinis valvae, aliquando vix distincta area axiali. Stigmata ventralia transapicaliter elongata multa, separata striis ventralibus curtis. Raphe distincte lateralis, ad aream centralem et ad apices sensim filiformis. Terminationes raphis centrales claro expansae, leviter deflexae ad latus ventrale. Fissurae distales falcatae, deflexae ad latus dorsale valvae. Striae radiatae omnino, 8–11 in 10 µm, ad apices 10–12 in 10 µm, distincte punctatae, 10–12 in 10 µm, ad apices usque ad 15 in 10 µm.

TYPE: NEPAL, Everest National Park. Aero 7, rock wall adjacent to the first tributary from the east to the Dudh Koshi River south of the confluence between the Bhote Koshi River and the Dudh Koshi River (Imja Khola), and the Larja Bridge, and north of the village Jorsale, 27°46.797′N, 86°43.071′E, *coll. S. Gurung*, 23 Oct. 2008 [HOLOTYPE: slide NMW.C.2009.004 ES 08 Aero7 rock, National Museum of Wales, Cardiff, U.K. (NMW); ISOTYPES: National Botanic Garden of Belgium, Meise, Belgium (BR-4183); Kathmandu University, Aquatic Ecology Centre, Dhulikhel, Nepal; Hustedt Collection, Alfred-Wegener-Institut für Polar- und

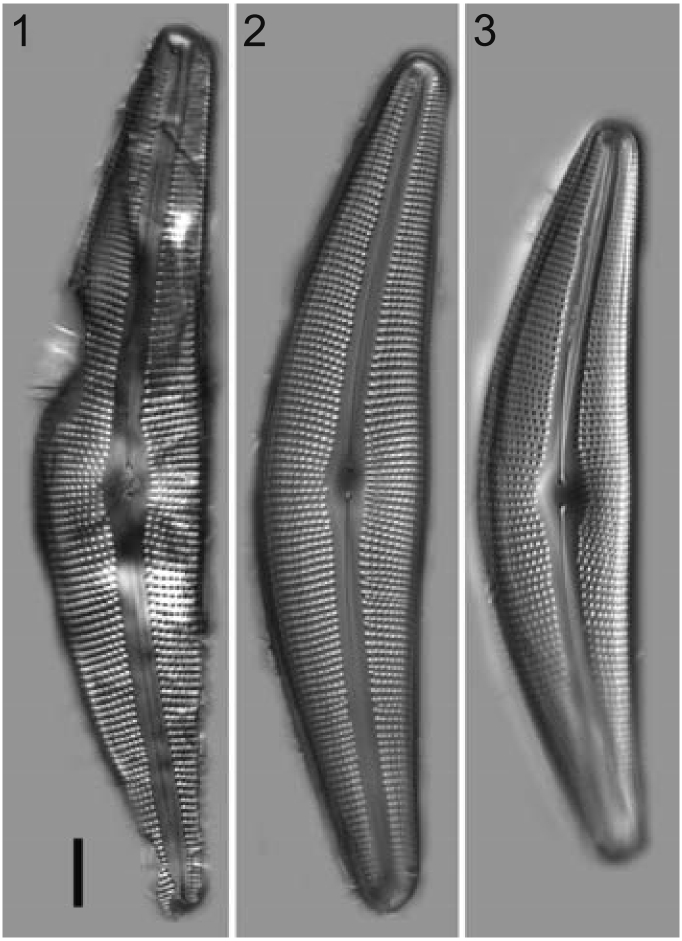

Fig. 4. *Cymbella subhimalaspera* Jüttner & Van de Vijver, *sp. nov*. 1–3 – holotype slide: NMW.C.2009.004 ES 08 Aero7 rock; Dudh Koshi Valley, Nepal. Valve views (LM). Scale bar = 10 µm.

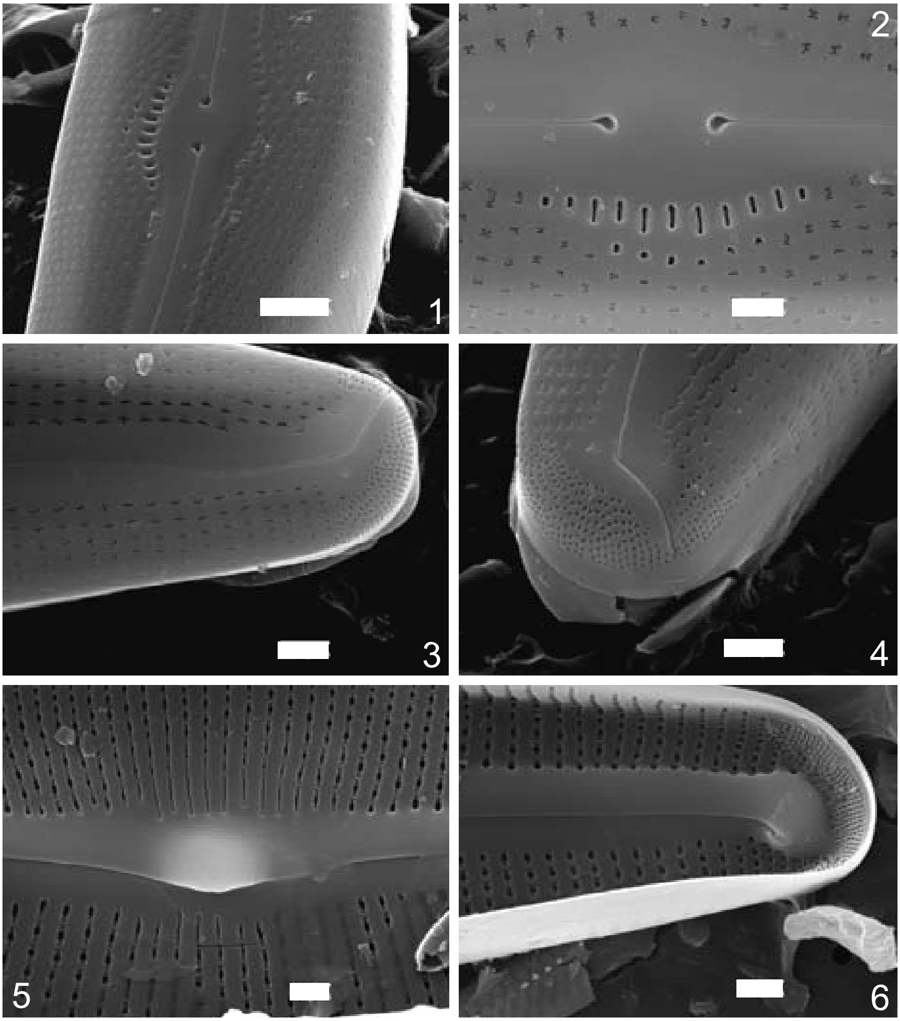

Fig. 5. *Cymbella subhimalaspera* Jüttner & Van de Vijver, *sp. nov*. (ES 08 Aero7 rock, Dudh Koshi Valley, Nepal, prepared from type material). 1–4 – External views, 5–6 – Internal views (SEM). 1 – Central area with raphe located on inconspicuous rib and stigmata. 2 – Central area with almost straight raphe endings, ventral stigmata and X-shaped areola openings. 3–4 – I-shaped, oval, or flying-bird-shaped areolae towards the poles, dorsally deflected raphe and apical pore fields. 5 – Central area with central nodule and stigma openings appearing as furrows adjacent to the striae. 6 – Apical pore field alveoli radially arranged around the terminal nodule, and helictoglossa. Scale bars 1 = 5 µm, 2–6 = 2 µm.

Meeresforschung, Bremerhaven, Germany (BRM ZU7); The Natural History Museum, London, U.K. (BM)].

ETYMOLOGY: the specific epithet refers to the similarity with taxa in the species complex around *Cymbella aspera*, the type locality in the Himalayas, and its size, smaller than *C. himalaspera*.

LIGHT MICROSCOPY (Fig. 4: 1–3). Valves are dorsiventral with a moderately arched, convex dorsal margin gradually tapering towards the broadly rounded poles. The ventral margin is almost straight except for a slightly gibbous part in the valve centre. Length 104–133 µm, width 21–25 µm, length/width ratio 4.9–5.8. The axial area is linear with almost parallel margins, between 1/6 and 1/7 of the total valve width. The small oval central area is sometimes barely distinguished from the axial area, 1/4–1/3 of the valve centre width. On the ventral side of the central area are a larger number of transapically elongate stigmata, separated from the shortened central striae by a narrow hyaline line. The raphe is clearly lateral, tapering near the proximal and distal ends (Pl. 67, fig. 3, type b in Krammer 2002) and positioned nearly in the mid-line of the valve. The proximal raphe endings are widened and only very slightly deflected to the ventral side; the polar raphe endings appear sickle-shaped and are deflected to the dorsal side. The striae are radiate throughout, 8–11 in 10 µm in the valve centre, becoming 10–12 near the poles. The areolae appear large and round, 10–12 in 10 µm, up to 15 near the poles.

SCANNING ELECTRON MICROSCOPY (Fig. 5: 1–6). Externally the raphe slit is located on an inconspicuous rib, a slightly thickened part of the axial and central areas (Fig. 5: 1). The large proximal raphe endings are drop-like, straight or only very slightly ventrally deflected (Fig. 5: 1, 2). The polar raphe endings are abruptly dorsally deflected, terminating in a large apical pore field with a prominent hyaline area on one side of the raphe slit (Fig. 5: 3, 4). The apical pore fields consist of a large number of round pores forming straight or undulating horizontal lines (Fig. 5: 4). Visible on the ventral side of the central nodule are 8–11 mostly transapically elongated stigmata (Fig. 5: 1, 2). A second row of smaller rounded pores is present between the stigmata and the striae (Fig. 5: 2). In the valve centre the external areola openings closer to the central area are X-shaped; those closer to the margin of the valve face and towards the poles are I-shaped, transapically elongate and oval, or curved, resembling primitive silhouettes of flying birds (Fig. 5: 1–4). Internally the ventral stigma openings are seen as a series of narrow elongated furrows adjacent to the striae without teeth-like ingrowths. Broad costae and narrow alveoli with struts are present (Fig. 5: 5). The apical pore field alveoli are radially arranged around the terminal nodule with the elongated helictoglossa (Fig. 5: 6).

TAXONOMIC REMARKS. *Cymbella subhimalaspera* is similar to *C. himalaspera* but can be separated by its smaller size (104–133 µm, 21–25 µm vs. 150–280 µm, 35–49 µm), the presence of elongate stigmata, almost straight proximal raphe endings, and the shape and pattern of the external areola openings on the valve. In *C. himalaspera* the X-, Y-, star- or tree-shaped areolae towards the valve centre are located across the entire valve face, while those in *C. subhimalaspera* towards the central and axial areas are mostly X-shaped and towards the margins and poles I-shaped, elongate or oval.

The smaller taxa in the *C. aspera* complex differ from *C. subhimalaspera*. *Cymbella subaspera* has simple slit-like areolae openings (Pl. 142, fig. 4 in Krammer 2002). *Cymbella bengaliformis* and *C. bengalensis* have a different valve shape. The larger *C. amelieana* has similarly shaped areola openings but crook-shaped proximal raphe endings. *Cymbella peraspera*, its varieties, *C. neogena* and *C. aspera* are larger, and *C. peraspera* and *C. aspera* have I-shaped areola openings.

ECOLOGY AND ASSOCIATED TAXA. The species was found on a rock wall in a waterfall spray zone of a tributary to the Dudh Kosi River at *ca* 2840 m a.s.l. Associated species included *Encyonema neogracile* Krammer, *Fragilaria vaucheriae* (Kützing) Petersen, *Diatoma mesodon*, *D. hyemalis*, *Gomphonema parvulum* Kützing and several unidentified species of *Eunotia* and *Epithemia*.

Cymbella neocistula var. ***nepalensis*** Jüttner & Van de Vijver, ***var. nov.***

Differt a varietate nominata proprie forma valvarum, latitudine semper maiore, 37–118 µm long, 14.7–26.7 µm latae et ratione longitudinis/latitudinis.

TYPE: NEPAL, Everest National Park, Gokyo lake 2–3 inlet, margin of stream flowing into the 2nd lake in the Gokyo Valley at the northern lake margin, 17 Oct. 2008, *coll. S. Gurung* [HOLOTYPE: NMW.C.2009.003 G2-3 inlet exposed stones, National Museum of Wales, Cardiff, U.K. (NMW); ISOTYPES: National Botanic Garden of Belgium, Meise, Belgium (BR-4184); Kathmandu University, Aquatic Ecology Centre, Dhulikhel, Nepal; Hustedt Collection, Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany (BRM ZU7); The Natural History Museum, London, U.K. (BM)].

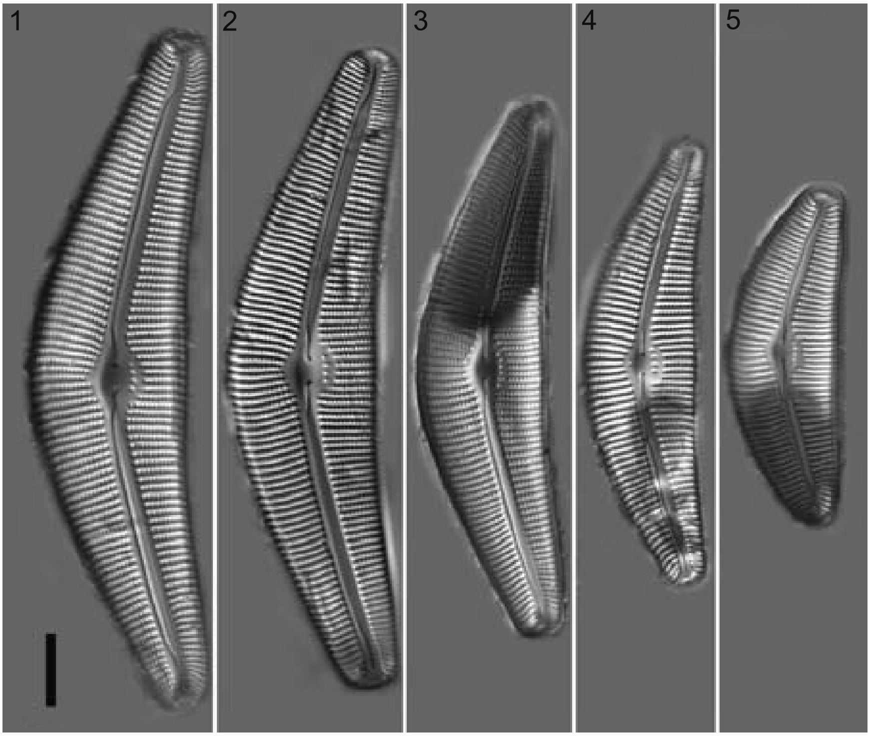

Fig. 6. *Cymbella neocistula* var. *nepalensis* Jüttner & Van de Vijver, *var. nov*. 1 & 2 – slide: NMW.C.2009.003 G3-3 main inlet exposed moist soil; 3rd lake, Gokyo Valley, Nepal. 3–5 – holotype slide: NMW.C.2009.003 G2-3 inlet exposed stones; 2nd lake, Gokyo Valley, Nepal. Valve views (LM). Scale bar = 10 µm.

ETYMOLOGY: the variety epithet refers to the type locality in the Himalayas of Nepal.

LIGHT MICROSCOPY (Fig. 6: 1–5). Valves are strongly dorsiventral with a convex dorsal margin, gradually tapering towards the broadly rounded poles. The ventral margin is straight to slightly concave, sometimes with a slightly gibbous part in the valve centre. Length 37–118 µm, width 15–27 µm, length/width ratio 2.8–5.4. The axial area is 2.1–3.3 µm wide, linear to linear-lanceolate, abruptly widening to form a round, sometimes slightly asymmetrical, central area, *ca* 1/3 of the valve width. On the ventral side of the central area are 4–6 rounded stigmata clearly set apart from the ventral shortened striae. The raphe is situated near the midline of the valve and is clearly lateral, becoming filiform towards the distal ends and reverse-lateral towards the valve centre (Pl. 67, fig. 3 type e in Krammer 2002). The proximal raphe endings are widened and deflected to the ventral side; the polar raphe endings appear sickle-shaped and are deflected to the dorsal side. The striae are parallel to slightly radiate, becoming more radiate and sometimes curved near the poles; in the middle of the valve 8–10 in 10 µm (dorsal and ventral), becoming 12–13 in 10 µm near the poles; areolae 18–20 in 10 µm.

SCANNING ELECTRON MICROSCOPY (Fig. 7: 1–4). Externally the proximal raphe endings are slightly widened and ventrally deflected (Fig. 7: 1). The polar raphe endings are dorsally deflected, terminating on the side of a large apical pore field with a hyaline area on both sides of the raphe slit. The apical pore fields are composed of small round pores arranged irregularly (Fig. 7: 2). On the ventral side of the central nodule are 4–6 round to slightly elongated stigmata; a second row of small round pores are sometimes present between the

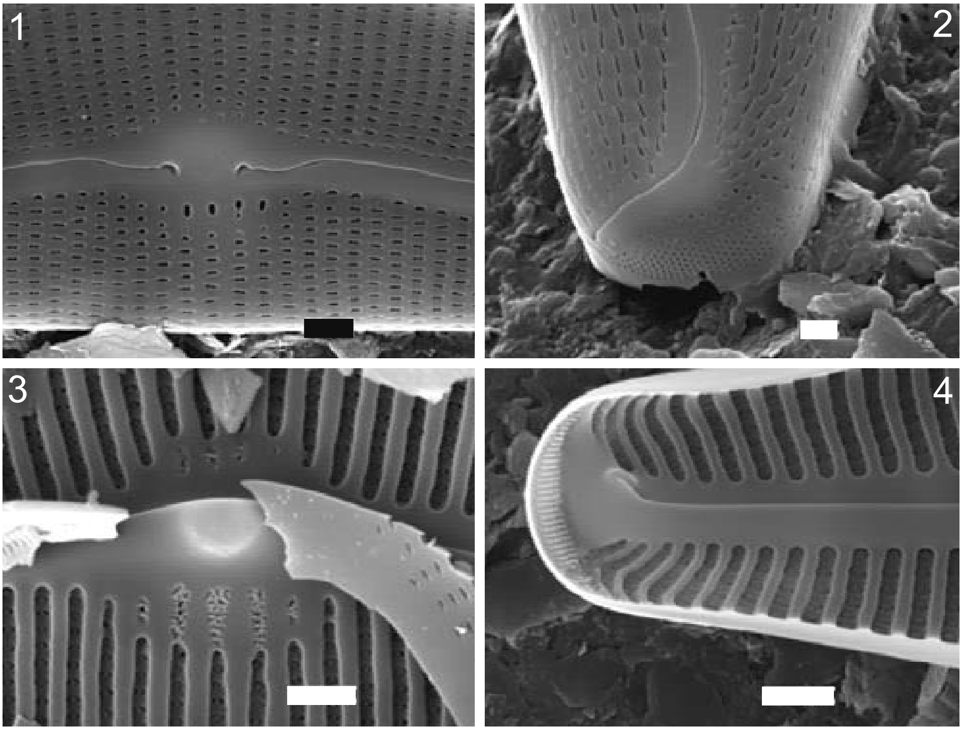

Fig. 7. *Cymbella neocistula* var. *nepalensis* Jüttner & Van de Vijver, *var. nov*. (G2-3 inlet exposed stones, 2nd lake, Gokyo Valley, Nepal, prepared from type material). 1–2 – External views, 3–4 – Internal views (SEM). 1 – Central area with ventrally deflected raphe endings, stigmata and oval or slit-like areolae. 2 – Valve near pole with slit-like areolae, pole with dorsally deflected raphe fissure ending on the side of the apical pore field. 3 – Central area with central nodule, ventral and dorsal stigma openings occluded by fine ingrowths. 4 – Apical pore field alveoli and helictoglossa. Scale bars 1, 3, 4 = 2 µm, 2 = 1 µm.

stigmata and the ventral striae (Fig. 7: 1); sometimes 2–3 stigmata are present on the dorsal side. The areola openings are apically elongated, oval or slit-like (Fig. 7: 1–2).

Internally the elongate stigma openings are occluded by fine ingrowths from their perimeter (Fig. 7: 3). The alveoli have no struts; the internal areola openings have round occlusions. Near the poles the raphe ends in a small elongate helictoglossa, clearly set apart from the large apical pore field (Fig. 7: 4).

Taxonomic remarks. *Cymbella neocistula* var. *nepalensis* differs slightly from the nominate form in valve shape, with its dorsal valve margin generally less tapering, and more broadly rounded poles. Its maximum width and length/width ratio is 27 µm and 5.4, respectively, in contrast to 19 µm and 6.1 in the nominate form. Krammer (2002) mentioned papilla-less areolae in the nominate form, but this is not clear given the images shown (Pl. 91, figs 4, 5). *Cymbella neocistula* var. *lunata* Krammer differs clearly in its lunate valve outline. *Cymbella neocistula* var. *islandica* Krammer is more coarsely punctate (13–16 in 10 µm vs. 18–20 in 10 µm) and has a more gibbous ventral valve margin and a more tapering dorsal margin. *Cymbella subcistula* Krammer has narrower valves (13–18 µm vs. 15–27 µm) and more pointed, sometimes slightly protracted poles, and is more finely punctate (19–24 in 10 µm vs. 18–20 in 10 µm). *Cymbella cymbiformis* Agardh has narrower valves (13–17 µm vs. 15–27 µm) and more pointed poles, and only one, rarely two stigmata (Krammer 2002). *Cymbella schimanskii* and its variety var. *excelsa* (Meister) Krammer are similar in valve outline but are larger (100–200 µm, 29–36 µm vs. 37–118 µm, 15–27 µm) and possess a series of small round pores between the ventral stigmata and the striae (Pl. 79, figs 1, 2 in Krammer 2002).

ECOLOGY AND ASSOCIATED TAXA. The species was found on non-submerged stones along the stream margin of the inlet to the 2nd lake, on moist soil adjacent to the main inlet of the 3rd lake, on stones in the lake littoral of the 3rd lake, and on stones in the inlet of the 1st lake. At the type locality, associated taxa included *Achnanthidium minutissimum* (Kützing) Czarnecki, *Fragilaria arcus* (Ehrenberg) Cleve and its variety *F. arcus* var. *recta* Cleve, *Gomphonema calcifugum* Lange-Bertalot & Reichardt, *Cocconeis placentula* Ehrenberg and *Encyonema brevicapitatum*.

Cymbella yakii **Jüttner & Van de Vijver, *sp. nov.***

Valvae distincte dorsiventrales margine dorsali magis convexa, margine ventrali recta ad leviter ventrali, aliquando cum levi inflatione in medio. Apices subcapitatae. Longitudo 20–36 µm, latitudo 6.8–8.0 µm. Area axialis angusta, linearis, leviter dilatata formans aream centralem parvam, asymmetricam, dorsaliter expansam, aliquando vix distinctam ab area axiali. Raphe claro lateralis, ad aream centralem reverso-lateralis ad apices sensim filiformis. Latere ventrali cum 2 stigmatis. Striae transapicales parallellae ad leviter radiatae, magis radiatae ad apices, 10–12 in 10 µm ad apices 12–15 in 10 µm. Puncta 28–30 in 10 µm.

TYPE: NEPAL, Everest National Park. Gokyo lake 2–3 inlet, margin of stream flowing into the 2nd lake in the Gokyo Valley at the northern lake margin, 17 Oct. 2008, *coll. S. Gurung* [HOLOTYPE: NMW.C.2009.003 G2-3 inlet exposed stones, National Museum of Wales, Cardiff, U.K. (NMW); ISOTYPES: National Botanic Garden of Belgium, Meise, Belgium (BR-4185); Kathmandu University, Aquatic Ecology Centre, Dhulikhel, Nepal; Hustedt Collection, Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany (BRM ZU7); The Natural History Museum, London, U.K. (BM)].

ETYMOLOGY: the specific epithet refers to the Central Asian bovine yak (*Bos grunniens* L.) whose head with horns resembles the valve shape of *C. yakii*.

LIGHT MICROSCOPY (Fig. 8: 1–8). Valves are strongly dorsiventral with a convex dorsal margin and a straight to slightly concave ventral margin, sometimes with a slightly gibbous part in the valve centre. The poles are subcapitate. Length 20–36 µm, width 7–8 µm, length/width ratio 3.1–4.7. The axial area is narrow and linear, slightly widening to form a small, asymmetrical,

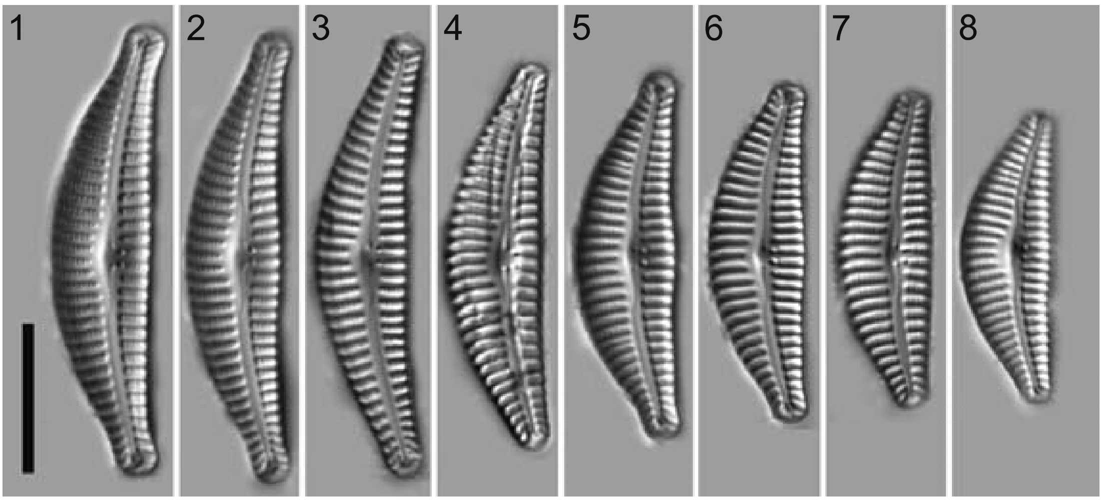

Fig. 8. *Cymbella yakii* Jüttner & Van de Vijver, *sp. nov*. 1, 2, 5–7 – holotype slide: NMW.C.2009.003 G2-3 inlet exposed stones; 2nd lake, Gokyo Valley, Nepal; 3, 4, 8 – slide: NMW.C.2009.003 G3 inlet north slope exposed sand; 3rd lake, Gokyo Valley, Nepal. Valve views (LM). Scale bar = 10 µm.

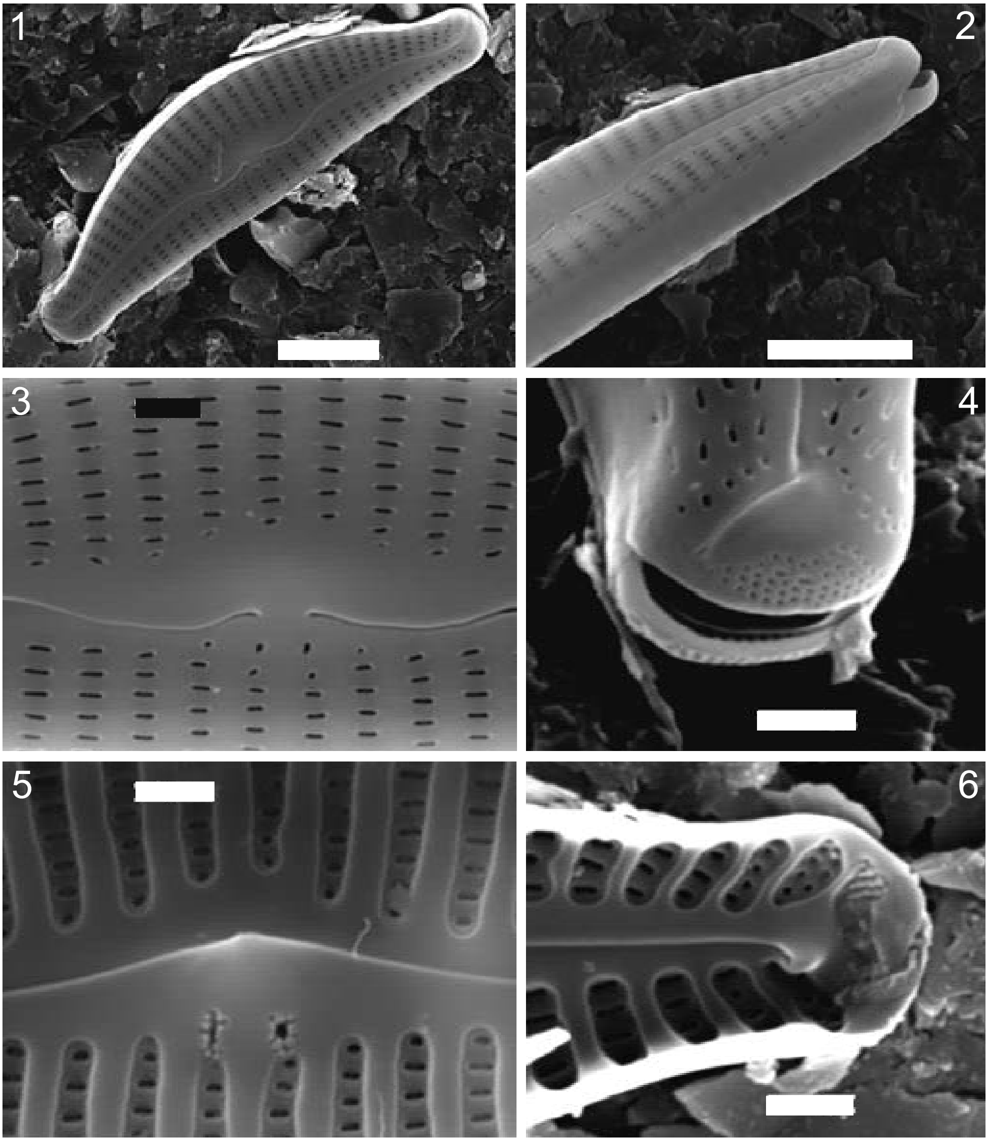

Fig. 9. *Cymbella yakii* Jüttner & Van de Vijver, *sp. nov*. (G2-3 inlet exposed stones, 2nd lake, Gokyo Valley, Nepal, prepared from type material). 1–4 – External views, 5–6 – Internal views (SEM). 1 – Whole valve with dorsally deflected raphe at the poles. 2 – Part girdle view showing the areolae on the ventral valve mantle separated from the valve face by a narrow hyaline area. 3 – Central area with two stigmata and four adjacent round pores. 4 – Pole with apical pore field set apart from the striae and located at the apex. 5 – Central area with central nodule, ventral stigma openings occluded by fine ingrowths. 6 – Valve near pole with terminal nodule and helictoglossa, note the biseriate stria before the apical pore field. Scale bars 1, 2 = 5 µm, 3–6 = 1 µm.

dorsally expanded central area, sometimes difficult to distinguish from the axial area. The raphe is clearly lateral, becoming filiform near the poles and reverse-lateral towards the valve centre. Two rounded stigmata are close to two slightly shortened ventral striae. The striae are parallel to slightly radiate, becoming more strongly radiate near the poles, 10–12 in 10 µm (dorsal and ventral) in the centre, 12–15 in 10 µm near the poles. The striae are finely punctuate, areolae 28–30 in 10 µm.

SCANNING ELECTRON MICROSCOPY (Fig. 9: 1–6). Externally the raphe is ventrally curved towards the valve centre with simple, non-widened proximal endings which are sometimes slightly deflected towards the ventral side (Fig. 9: 1–3). The distal raphe endings are deflected to the dorsal side, terminating on the side of the apical pore field with a hyaline area on both sides of the raphe slit (Fig. 9: 1, 2, 4). Two rounded stigmata are on the ventral side of the central nodule, separated from the striae. Additionally, four small round pores are situated on the side and ventrally of the stigmata (Fig. 9: 3). The striae are composed of apically elongated, narrow oval areolae, except for the striae at the poles which sometimes are biseriate with round areolae (Fig. 9: 1–4, 6). A row of striae areolae on the ventral valve mantle is separated from the areolae on the valve face by a narrow hyaline area (Fig. 9: 2). The apical pore field is set apart from the striae and located at and extends over 2/3 to 3/4 of the pole apex (Fig. 9: 4). Internally, small oval stigma openings are occluded by fine ingrowths from their perimeter (Fig. 9: 5). The areolae are not separated by small silica struts, and no occlusions are seen. Near the poles, the knob-like helictoglossa is adjacent to the alveoli of the last striae (Fig. 9: 6).

TAXONOMIC REMARKS. Based on its morphological features, *Cymbella yakii* belongs to the group around *C. parva* (W. Smith) Kirchner in Cohn and *C. excisa* Kützing. *Cymbella subtruncata* Krammer, *C. percapitata* Krammer and *C. excisiformis* Krammer have a dorsal valve margin which is less arched, and one stigma. *Cymbella subtruncata* has less dense, slit-like areolae (24–26 in 10 µm vs. 28–30 in 10 µm) which are more irregularly arranged near the poles, and *C. percapitata* is larger (40–52 µm, 9–10 µm vs. 20–36 µm, 7–8 µm). *Cymbella parva*, *C. excisa* and varieties, those taxa with one stigma, and *Cymbella affiniformis* Krammer with two stigmata, have an almost straight or slightly convex ventral valve margin. *Cymbella affiniformis* has less broadly rounded poles. *Cymbella parviformis* Krammer has one stigma and more pointed poles which are not protracted. *Cymbella perparva* Krammer with 1–3 stigmata has an almost straight ventral valve margin with a slightly gibbous centre and less broadly rounded poles. *Cymbella subturgidula* Krammer and *C. lancettuliformis* Krammer with two stigmata have almost straight ventral margins and wider valves (10–11 µm and 8–9 µm vs. 7–8 µm), and are more coarsely punctate (24 in 10 µm and 19–23 in 10 µm vs. 28–30 in 10 µm). *Cymbella lancettuliformis* has less broadly rounded poles. *Cymbella rumrichae* Krammer with 1–3 stigmata has an almost straight ventral valve margin with a slightly gibbous centre, less protracted poles, less dense striae in the valve centre (8–10 in 10 µm vs. 10–12 in 10 µm) and less dense puncta (24–26 in 10 µm vs. 28–30 in 10 µm). *Cymbella diversistigmata* Krammer with up to four stigmata, sometimes also on the dorsal side, is larger (32–67 µm, 10–13 µm vs. 20–36 µm, 7–8 µm) and more coarsely punctate (21–24 in 10 µm vs. 28–30 in 10 µm).

ECOLOGY AND ASSOCIATED TAXA. The species was found on non-submerged stones along the stream margin of the inlet to the 2nd lake, on sediment in the littoral of the 2nd lake close to the inlet, and on moist non-submerged sand adjacent to the stream channel close to the slope of Gokyo Ri of the main inlet to the 3rd lake. At the type locality, where *Cymbella yakii* was abundant, associated taxa included *Achnanthidium minutissimum*, *Fragilaria arcus* and its variety *F. arcus* var. *recta*, *Gomphonema calcifugum*, *Cocconeis placentula* and *Encyonema brevicapitatum*.

Cymbella cf. ***hantzschiana*** Krammer

LIGHT MICROSCOPY (Fig: 10: 1–10): Valves are dorsiventral with a convex dorsal and an almost straight ventral margin, sometimes very slightly gibbous at the valve centre. The poles are not or very slightly protracted. Length 27–47 µm, width 8–11 µm, length/width ratio 3.1–4.6. The axial area is narrow, linear to linear-lanceolate. The central area is either not distinguishable from the axial area or small oval-shaped, sometimes irregular and asymmetric. The raphe is clearly lateral, becoming filiform near the poles and reverse-lateral towards the valve centre. The striae are parallel to slightly radiate, becoming more strongly radiate near the poles, 8–10 in 10 µm (dorsal and ventral) in the centre, 12–14 in 10 µm near the poles. The striae are finely punctate, areolae 25–30 in 10 µm.

SCANNING ELECTRON MICROSCOPY (Fig. 11: 1–4): Externally the raphe is ventrally curved towards the valve centre, with simple, very slightly widened proximal endings which are sometimes slightly deflected ventrally (Fig. 11: 1). The distal raphe endings are deflected to the dorsal side, terminating on the side of the apical pore fields, with a hyaline area on both sides of the raphe slit. A pore field with pores forming vertical rows is located at the pole apices (Fig. 11: 2). There are no stigmata in the central area. The striae are composed of apically elongated, slit-like areolae (Fig. 11: 1). Internally the costae are broad and the alveoli narrow without struts, the areola openings apparently having no occlusions (Fig. 11: 3). The distal raphe endings terminate in knob-like helictoglossae adjacent to the alveoli of the last striae (Fig. 11: 4).

TAXONOMIC REMARKS. The identity of the Himalayan species is not entirely clear. It conforms with the description of *Cymbella hantzschiana* in Krammer (2002) except for a slight difference in the number of areolae, which are less dense in the latter (21–24 in 10 µm vs. 25–30 in 10 µm). It is not clear whether *C. hantzschiana* Krammer is identical with Rabenhorst's *Cocconema pachycephalum* 1861 because the figure presented by Krammer for this species is described as *Cymbella weslawskii*. The number of *Cymbella* species without stigmata is not very large. There is some similarity in valve outline with *C. subleptoceros* Krammer, *C. neoleptoceros* Krammer, *C. stigmaphora* Østrup and *Cymbella hustedtii* Krasske, although the ventral margin can be more gibbous in some of these taxa. The shape of the areolae differs in *C. subleptoceros* and *C. neoleptoceros*, and the raphe in *C. neoleptoceros* also lacks a reverse-lateral proximal part. *Cymbella stigmaphora* has wider valves (11–14 µm vs. 8–11 µm) and is more coarsely punctate (20–24 in 10 µm vs. 25–30 in 10 µm). *Cymbella hustedtii* has smaller valves (length 13–26 µm vs. 27–47 µm). Another similar species is *Cymbella hedinii* Krammer, which has the same number of areolae (27–30 in 10 µm) as the Himalayan species but slightly protracted poles (Pl. 29, figs 13–16 in Krammer 2002). The raphe in *C. hedinii* is described as lateral (Pl. 67, fig. 3d in Krammer 2002). There are inconsistencies in the

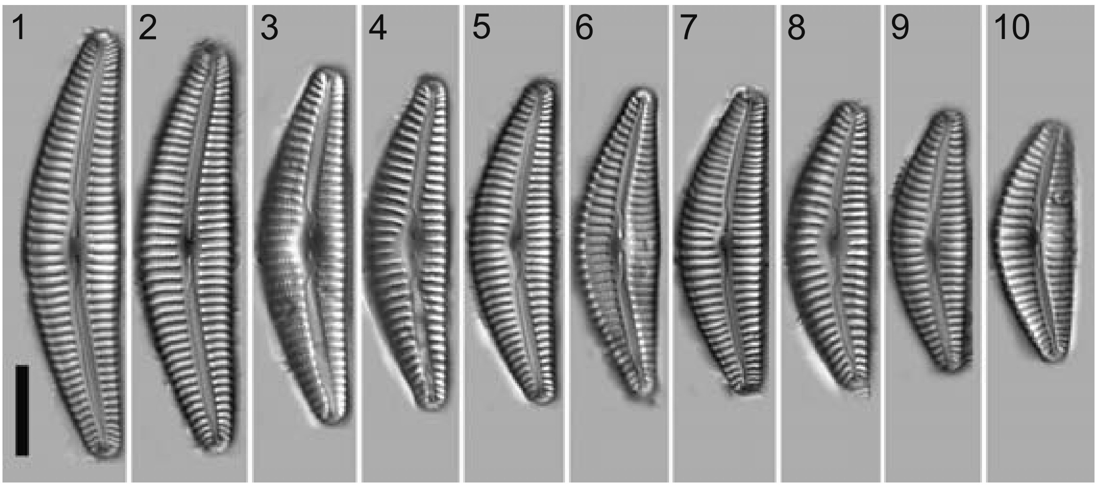

Fig. 10. *Cymbella* cf. *hantzschiana* Krammer 1, 2, 5, 6, 8–10 – slide: NMW.C.2009.003 G3 spring 1 bryophytes, 3rd lake, Gokyo Valley, Nepal; 3, 4, 7 – slide: NMW.C.2009.003 G3-3 main inlet exposed moist soil, 3rd lake, Gokyo Valley, Nepal. Valve views (LM). Scale bar = 10 µm.

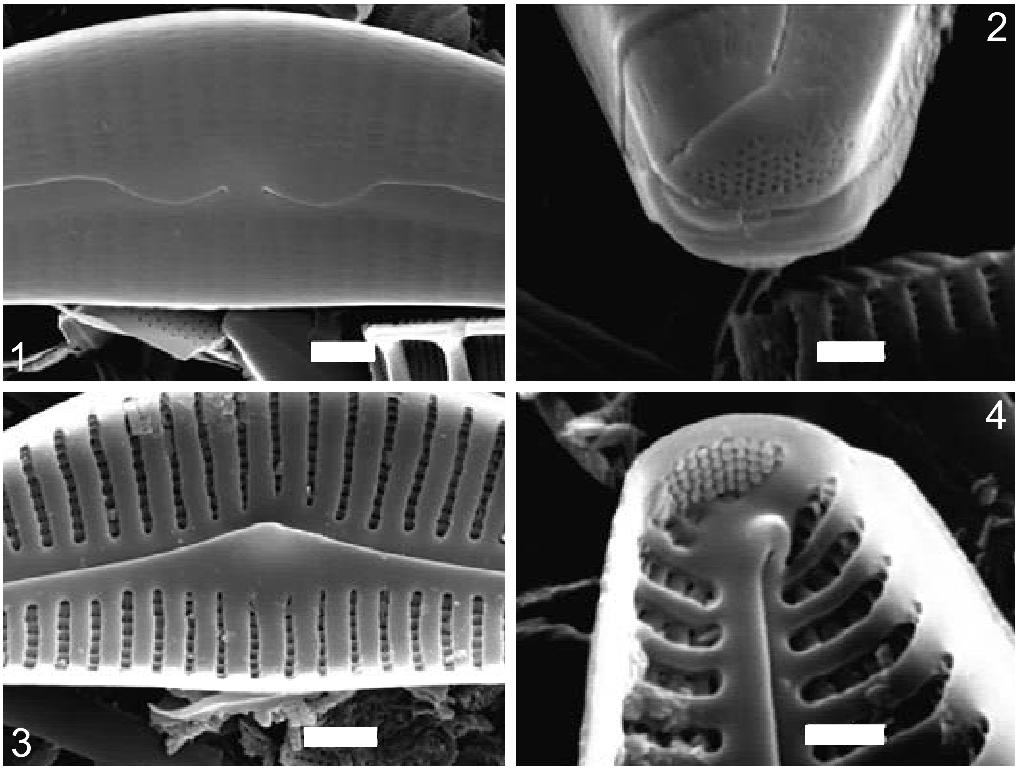

Fig. 11. *Cymbella* cf. *hantzschiana* Krammer (G3 spring 1 bryophytes, 3rd lake, Gokyo Valley, Nepal). 1 & 2 – External views, 3 & 4 – Internal views (SEM). 1 – Central part of the valve with ventrally deflected raphe and slit-like areolae. Note the absence of stigmata. 2 – Pole with dorsally deflected raphe fissure and apical pore field. 3 – Central area with central nodule, costae and alveoli. 4 – Pole with apical pore field, terminal nodule and helictoglossa. Scale bars 1 & 3 = 2 µm, 2 & 4 = 1 µm.

species description with respect to the presence of stigmata; none can be seen on the LM photos and no SEM images are shown. This taxon from Tibet should be reinvestigated to establish the relationship with the Himalayan species.

ECOLOGY AND ASSOCIATED TAXA. The species was found on submerged and non-submerged bryophytes in springs on the southern slope of Gokyo Ri, on moist soil adjacent to the main inlet of the 3rd lake, and on macrophytes in the main inlet of the 3rd lake. At the site G3 spring 1 on bryophytes, where *C*. cf. *hantzschiana* was most abundant, associated taxa included *Denticula kuetzingii*, *Fragilaria vaucheriae*, *Encyonema brevicapitatum*, *Diatoma hyemalis*, *Eolimna minima* (Grunow) Lange-Bertalot and several unidentified fragilarioid species.

DISCUSSION

Krammer (2002), Van de Vijver and Lange-Bertalot (2008) and this study described several new taxa in the *C. aspera* group. *Cymbella himalaspera* and its most closely related taxa differ from each other in morphological characters that can only be seen in SEM, such as the shape of the areolae, stigmata and proximal raphe endings. The two taxa most resembling *C. himalaspera*, both with X-shaped areolae, are *C. amelieana* and *C. peraspera* var. *colombiana*. *Cymbella amelieana* was found in three Swedish rivers, with the largest population occurring in the small oligotrophic Källsjöån River, located at 220 m a.s.l. in central Sweden. *Cymbella peraspera* var. *colombiana* was described from the high altitude lake Laguna Grande de los Verde, located at 4100 m a.s.l. in the Colombian Andes. These records indicate that this particular group in the *C. aspera* complex has a wide geographical range but might be characteristic for oligotrophic habitats in nordic or alpine areas. Krammer (2002) mentioned several related taxa from East Asia including *Cymbella aspera* var. *elongata* Skvortzow, *C. aspera* var. *manschurica* Skvortzow and *C. cantonensis* Voigt. These taxa as well as *C. aspera* and similar species recently reported from the Mount Everest region and the Hengduan Mountains region in China (Li *et al*. 2003, 2004, 2007a) should be re-examined using SEM to establish their identities and relationship with *C. himalaspera*. The latter might occur over a larger geographical area in Asia. This is supported by reports from Mongolia where specimens identified as *C. aspera* (Pls 111–114 in Metzeltin *et al*. 2009) have X-shaped areolae as in *C. himalaspera* and not I-shaped areolae as in *C. aspera*. The proximal raphe endings and stigmata also correspond to the species from the Himalayas, suggesting that the Mongolian species may in fact be *C. himalaspera*. Many other species identified as *C. aspera* reported from a variety of habitats and over a large geographical scale (e.g., Watanabe *et al*. 2005; Antoniades *et al*. 2008) should be re-examined by SEM to confirm their identities, and to review the biogeographical range and affinities to particular habitats in this group. It is interesting to note that the closely related species *C. subhimalaspera* was also found in Everest National Park. It is possible that this species is more typical of mid-altitudes, not yet studied in this area, since it was only found at one site at 2840 m a.s.l. and not at locations surveyed at higher altitudes.

According to Krammer (2002), *Cymbella neocistula* Krammer is the most widely distributed taxon of this species complex. It was reported, for example, from Scandinavia, Central Europe, Russia, China, Japan, the U.S.A. and the Canadian Arctic, and is frequently reported from mesotrophic waters (Krammer 2002; Genkal & Vekhov 2007; Li *et al*. 2007b; Antoniades *et al*. 2008). The geographical range of *C. neocistula* var. *nepalensis* is yet unknown since it has so far been found only in terrestrial habitats, one lake and one stream in the Gokyo Valley. The Himalayan variety differs from the two varieties described by Krammer (2002), *C. neocistula* var. *lunata* and *C. neocistula* var. *islandica*, in valve outline, but all three varieties might be more typical for oligotrophic habitats than the nominate form. A record of *Cymbella cistula* Grunow from a high altitude lake in Pakistan should be examined more closely to establish the relationship with the Himalayan species (Wazir 2002).

Several species morphologically most similar to *C. yakii* are known from Europe, Asia and South America. *Cymbella subtruncata* and *C. percapitata*, with broadly rounded capitate poles but only one stigma, were found in oligotrophic rivers with low electrolyte content of Finland and Norway and in oligo- to mesotrophic waters of the Austrian Alps and Mallorca, respectively (Krammer 2002). In Asia a similar species with two stigmata, *C. subturgidula*, is known from Korea, and *C. diversistigmata*, with 1–3 stigmata, is known as a fossil from Kamtchatka. *Cymbella rumrichae* with 1–3 stigmata is known from a high altitude stream in the Andes of Venezuela. Although some of these records are from nordic or alpine areas, the specimens found in Mallorca and Korea suggest a wider distribution of this group.

Previous taxonomic studies of the diatom flora in Himalayan streams reported eight new species in the genus *Gomphonema* and one new species in the genus *Navicula* (Jüttner *et al*. 2000, 2004). Most of these and three new species in the recently described genus *Oricymba* were confined to or most common in the central and eastern Himalayas of Nepal (Jüttner *et al*. 2010). A wider analysis of stream diatom assemblages revealed a major taxonomic change east of the Kali Gandaki River, a well-known biogeographical divide, confirming similar observations in other taxonomic groups (Ahrens 2007; Jüttner *et al*. in press). The Gokyo wetlands are also located in the eastern Himalayas, where they are relatively isolated at high altitudes in a remote valley of Everest National Park. Within the area there is a wide range of available habitats including streams, lakes, springs, seepages and marshy ground. There is also considerable seasonal variation in temperature and water availability.

The monsoon season in summer, with higher precipitation, is followed by a dry autumn; the winter is severe and followed by a very dry spring, when water levels in streams and lakes are at their lowest. The combination of isolation, variability of hydrological conditions and the variety of available habitats may produce an island effect whereby infrequent colonization by new taxa could lead to speciation and radiation. Preliminary studies suggest that new species are present in several genera. Of these, the cymbelloid taxa are particularly diverse. This is not unexpected because of the nordic-alpine distribution of many species in this group. It seems likely that investigation of the subaerial diatom flora could reveal further interesting results, not only with respect to the discovery of highly diverse and specific subaerial assemblages and species new to science (Lowe *et al*. 2007, 2009) but also in view of their potential to indicate temperature change. Subaerial habitats are likely to be more rapidly affected by ambient temperature than stream or lake habitats are. It would be instructive to investigate the species composition of these habitats over a larger altitude gradient. Species distribution in relation to altitude could have potential for monitoring climate change.

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