# THE DIATOM FLORA OF EPHEMERAL HEADWATER STREAMS IN THE ELBSANDSTEINGEBIRGE REGION OF THE CZECH REPUBLIC.

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## ABSTRACT

The diatom flora of 15 headwater streams in the Elbsandsteingebirge region of the Czech Republic was studied. This region is dominated by sandstone, but a few areas have a mixed geology with some combination of sandstone, limestone, and granite. Diatoms were collected from a mixture of substrates whenever available, including stone, wood, bryophyte, and sediment. A total of 307 diatom taxa were observed, including one species new to science, *Chamaepinnularia rexii.* Taxa particularly characteristic for the region, or lacking previous indicator status, or rare or otherwise interesting are illustrated and discussed. Abundance weighted means for both pH and conductivity are reported for all taxa which occurred in more than four samples.

## INTRODUCTION

The Elbsandsteingebirge (Elbe Sandstone Mountains) is a hilly region of north Bohemia and Saxony in the Elbe River drainage that is characterized by a massive Cretaceous sandstone formation about 300 m high. Deep gorges have been cut into the sandstone, and the streams draining the region are forested, shaded and cold. The region includes four protected areas: Bohemian Switzerland National park, Elbe Sandstone Mountains Protected Landscape Area, Saxon Switzerland National Park and Saxon Switzerland Protected Landscape Area. Rabenhorst (1851) described *Frustulia saxonica* from wet-walls in the Elbsandsteingebirge. The cryptogamic communities (lichens, bryophytes, eukaryotic algae, cyanobacteria) of this region were first studied in some detail by Schorler (1915) and Schade (1923), who both examined wet walls. The diatoms of the wet walls were studied subsequently by Friedrich Hustedt, who described several diatom taxa from the region (Hustedt 1930). However, the flora of the region was not treated in a separate publication so we do not have a record of all the taxa Hustedt may have seen there.

More recently, peat bogs (Nováková 2003, Nováková *et al*. 2004) and some streams (Skácelová 1998, Heteša *et al*. 2000) were studied with respect to their algae, particularly siliceous heterokont algae. Veselá (2006) studied the seasonal succession and spatial variability of algae in one drainage, Suchá Bělá. She found 48 taxa in just two sites in the brook. These studies demonstrated that the region was of interest, particularly because it possess pristine habitat and clean water in much of its range. However, a systematic study of the diatoms of the Elbsandsteingebirge remains to be done.

In the present study such a systematic study is reported. We examined 161 samples in 30 sites in 15 streams in the region. Most of the streams are ephemeral headwater streams with either a cobbly, rocky channel or channel lying directly in sandstone bedrock. The purpose of this study is to 1) document diatom taxa present in the streams 2) illustrate rare and interesting taxa, 3) describe a taxon new to science, and 4) document optima and tolerance (pH, conductivity) of aquatic and aerophilic diatom taxa.

## MATERIALS AND METHODS

Fifteen streams and brooks in the Czech part of Elbsandsteingebirge were sampled (Fig. 1). Most of the sites were within Bohemian Switzerland National Park. The streams were headwater streams (mostly first and second order), and most were ephemeral for much of their drainage. Many of the sites were in unnamed tributaries. Streams were sampled between October 2004 and June 2006, and both an upper reach near the origin and a lower reach above the confluence with a named stream were sampled. The distance between sites varied among streams. Conductivity, pH and temperature were measured using a Hanna Combo HI 98129 pH/EC/TDS.

Samples were taken from all available substrates, and included epilithon (from rocks), epixylon (from wood), epiphyton (among bryophytes and filamentous algae), and epipelon/epipsamnon (from sediment and sand). This yielded 5-6 samples per sampling site, for a total of 161 samples in all (62 sediment, 49 rock, 23 wood, 4 filamentous algae and 23 bryophytes). Diatom samples were cleaned using the hydrogen peroxide-potassium permanganate method (Krammer & Lange-Bertalot 1986), rinsed, and mounted in Naphrax

diatom mountant. Initial identification and estimation of species abundance was determined using an Olympus BX 31 brightfield microscope. Diatoms were scored on a semi-quantitative scale: rare (one or two cells per sample), uncommon (less than 5% of the cells), common (5-25%), frequent (25-50%) and dominant (more than 50%). Identification of difficult (small, finely striated, etc.) taxa was confirmed or established in an Olympus BX 60 photomicroscope with high resolution Nomarski DIC optics and Spot digital camera. A scanning electron microscope, SEM JEOL 6380, was used to identify and illustrate the most difficult taxa, such as *Diadesmis* and *Chamaepinnularia.* Diatom taxa were identified according to Alles *et al*. (1991), Houk (2003), Houk & Klee (2007), Krammer (1992, 1997a,b, 2000, 2002, 2003), Krammer & Lange-Bertalot (1985, 1986, 1988, 1989, 1991a,b), Lange-Bertalot (1993, 2001), Lange-Bertalot & Metzeltin (1996), Lange-Bertalot & Moser (1994), Werum & Lange-Bertalot (2004).

Optima and tolerance values for both pH and conductivity were determined by using the weighted averaging program in WA CALIB (Line *et al*. 1994). Abundances of taxa were estimated using a semi-quantitative scale (see above). Saprobity and trophic state of streams were reconstructed from indices based on diatom composition (Lange-Bertalot 1979, Hofmann 1994, Van Dam *et al*. 1994), all of which use indicator values and abundance weighted means (AWM). Sites were ordinated using Detrended Correspondence Analysis in CANOCO (ter Braak & Šmilauer 1998). Bray-Curtis and Dice-Sørensen similarity indices and one-way analysis of variance (ANOVA) and non parametric Kruskal-Wallis test were calculated using PAST-software ver. 4.5 (Hammer *et al*. 2001). Box plot diagrams were constructed using STATISTICA-software ver. 8. A Mantel and partial Mantel test (zt-software, Bonnet & Van de Peer 2002) were used to uncover associations between pairs of measurements in consideration of spatial autocorrelation (geographic distance). The Mantel test is a nonparametric test for simultaneous comparisons between two dissimilarity matrices (Mantel, 1967; Legendre & Legendre, 1998). Partial Mantel analysis computed the partial correlation between two distance matrices while controlling for the effect of a third matrix (Smouse *et al*. 1986).

## RESULTS

A total number of 307 intraspecific diatom taxa (Table 1) were recorded in 161 samples from 15 streams. Species richness was low in many samples, ranging from 3-72 taxa, with an average of 27 taxa (Table 2). The greatest number of species per sampling site (109 taxa) and stream (128 taxa) was found in Vlčí potok. The most diverse genera of diatoms in the streams were *Pinnularia* (34 taxa) and *Eunotia* (31 taxa).

Measured stream water parameters varied between 3.30 and 8.30 for pH and conductivity varied between 52 $\mu S \cdot cm^{-1}$ and 229 $\mu S \cdot cm^{-1}$ (Table 3).

Abundance weighted means (AWM) were calculated for both pH and conductivity for the taxa which occurred in more than four samples using the semi-quantitative scale described above (Table 1). Van Dam's ecological (indication) values of pH (Van Dam *et al*. 1994) are listed in Table 1 for comparison with the calculated values of AWM pH optima. The species moisture preferences (desiccation resistant and aerophytic species) are also according to Van Dam's list. In total 45 diatom taxa were previously reported as subaerophytic, while 64 taxa were not listed in his paper. Aerophytic genera represented by the greatest number of intraspecific taxa were *Diadesmis* (8 taxa) and *Chamaepinnularia* (6 taxa).

The first four axes of detrended correspondence analysis (DCA) explained 25.4% of variance in species data. The first axis (13.3%) of the ordination (Fig. 207) appears to represent pH, trophic level, and saprobity (the latter two factors estimated from stream AWM indices), with higher value streams (localities 6, 10-13) to the left containing species characteristic of more alkaline and more nutrient rich conditions (*Amphora pediculus*, *Cocconeis placentula*, *Eolimna minima*, *Melosira varians*, *Navicula gregaria*, *N. lanceolata*, *Reimeria sinuata*). More acidic streams (3, 4, 7, 8) with both acidophilic and oligotrophic taxa are clustered to the right (characteristic species: *Chamaepinnularia soehrensis*, *Eunotia incisa*, *E. paludosa*, *E. rhomboidea*, *E. trinacria*, *E. ursamaioris*, *Frustulia saxonica, Microcostatus krasskei*). The second DCA axis explained 5.0% of variation in species data and no clear gradient is evident along this axis (Fig. 207).

The results of a Mantel and partial Mantel permutation test, used for assessment of the correlation between the species matrix and a matrix of geographical distance, were not significant ($p>0.05$). We interpret this to mean that localities in close proximity to one another are not more similar than localities that are spatially removed from one another. This finding is consistent with results from the DCA diagram that indicated the arrangement of localities along the first axis is rather dependent on the pH and concentration of nutrients than on geographical distance. However, species similarity indices between sites were not significantly correlated with pH differences between sites.

Variability of similarity indices within and among groups was tested at the level of whole streams (Table 2) and sampling sites within streams (Table 3). Similarity within streams is significantly higher than between streams (one-way ANOVA, $p<0.001$). However, significant differences between upstream and downstream samples were still found in twelve of the fifteen streams (Kruskal-Wallis test).

Diatoms showed significant differences (Kruskal-Wallis test, $p<0.001$) in species diversity and species similarity on different substrate types (Fig. 208). Hard substrates (epilithon, epixylon) had lower species richness than soft substrates (epiphyton, epipelon; Table 2). Specificity of diatoms was higher for soft substrates than for hard substrates.

**Taxonomic Part**

In the interest of space, we have not illustrated all taxa observed in this study. We provide micrographs of taxa within the characteristic genera of the site (*Eunotia, Chamaepinnularia, Diadesmis, Neidium,* etc.), taxa lacking indicator values in Van Dam *et al*. (1994), aerophilic taxa, and rare or otherwise interesting taxa. We comment on these taxa below. Authorities for taxa given in Table 1 are not repeated here.

***Eunotia* Figs. 2-57.**

This difficult genus was one of the most diverse and abundant taxa in the study, and for this reason most taxa are figured in this paper. The prevalence of *Eunotia* reflects the oligotrophic and acidic nature of the water in the studied streams. At least one *Eunotia* species was recovered from every stream (Table 1), with at least 6 species in 13 of the 15 streams. Seven of the streams had 12 or more (up to 20) taxa. The most widespread species were *Eunotia bilunaris* (Figs. 6, 7), *E. botuliformis* (Figs. 42-44), *E. exigua* (Figs. 24-26), *E. tenella* (Fig. 27-30), *E. incisa* (Fig. 16), *E.* cf. *minor* (Fig. 2, 3), *E. paludosa* (Figs. 48, 49), and *E. rhomboidea* (Fig. 45). All taxa were acidophils, with only 3 of our taxa having an AWM $> 6.0$ for pH (Table 1). While *Eunotia bilunaris* is considered

indifferent to pH in Van Dam *et al*. (1994), it was an acidophil in our study, with a pH optimum of 5.3 (Table 1). In agreement with our findings, Denys (2004) considered *Eunotia bilunaris* acidophilous instead of pH-indifferent after personal communication with H. van Dam and A. Mertens. According to Alles *et al*. (1991), *Eunotia bilunaris* has two optima, suggesting the existence of acidobiontic and circumneutral populations or cryptic species. We suspect multiple species are contained in the current circumscription of *Eunotia bilunaris*, an idea which is in agreement with Vanormelingen *et al*. (2007, 2008), and that our populations belong to an acidobiontic species within the complex. Our pH optima were in most instances in good agreement with the optima found for the same *Eunotia* species in Alles *et al*. (1991). The most taxonomically problematic taxa were the small *Eunotia* species in the *E. exigua-E. tenella* complex (Figs. 24-30). Some of our specimens seemed transitional between the two taxa, although they clearly were in the complex. We illustrate specimens of which we are confident in identification. Given the cosmopolitan nature of this group, we suspect there may be cryptic diversity in the complex.

*Eunotia ursamaioris* was illustrated as *E. septentrionalis* Østrup in Krammer & Lange-Bertalot (1991a, Tafel 157:17-18) and Lange-Bertalot & Metzeltin (1996, Tafel 16:25-30). Lange-Bertalot & Genkal (1999) examined the type material of *E. septentrionalis,* and realized that Hustedt's concept of *E. septentrionalis* (Hustedt 1930, 1959) and their earlier concept was not consistent with the type. They described *Eunotia ursamaioris* to circumscribe the Siberian and European material. Our specimens (Figs. 11-13) are very similar to the material illustrated in Werum & Lange-Bertalot (2004, Plate 8:12-13). We suspect that others have reported *Eunotia septentrionalis* when in fact they had *E. ursamaioris.*

***Encyonopsis* Figs. 58-66.**

We observed two taxa of diminutive *Encyonopsis* which appear to be different from any described taxa. We do not name these taxa because they were very rare in the samples and we could not find any valves in the SEM. Given their fine structure that is scarcely visible in LM, we prefer to wait until such time that larger populations are found. It is possible that some of these specimens were teratological assymetrical forms of *Achnanthidium* (Figs. 58-60).

***Encyonema perpusillum* Figs. 67-68.**

This taxon has been observed as an aerophytic taxon in other studies. It was widespread in our samples, but always rare or uncommon (Table 1). It has been considered acidophilic (Van Dam *et al*. 1994), but had an optimum near neutrality in our study.

***Psammothidium altaicum* Figs. 69-70.**

*Psammothidium altaicum* was recently transferred from *Achnanthes* by Bukhtiyarova (Bukhtiyarova & Round 1996). It was found only in one stream, Písečná rokle.

***Eucocconeis laevis* Figs. 71-72.**

This taxon is typically found aerophilic on sandstone wet walls. It was common only in one site.

***Nupela lapidosa* Figs. 73-74.**

*Nupela* is commonly found in wet wall habitats. This species is the most commonly reported species in the genus. Siver & Hamilton (2005) suggested that heterovalvar *Nupela* species (e.g. *N. lapidosa*) needs to be established as a new genus, because the original

description of the genus does not include the heterovalvar state and the type species for the genus is isovalvar.

***Sellaphora stauroneioides* (Lange-Bertalot) nov. comb. Figs. 75-76.** Basionym: *Naviculadicta stauroneioides* Lange-Bertalot in Lange-Bertalot & Metzeltin 1996, p. 89, plate 109, fig. 22-27.

This taxon bears the hyaline areas at the apices and curved striae characteristic of *Sellaphora*. The striae are fine for this genus, but Lange-Bertalot published an internal view of the striae in *Naviculadicta stauroneioides* (Lange-Bertalot & Metzeltin 1996, plate 89, fig. 27), and the ultrastructure of the striae and central area is identical to that shown for *Sellaphora* (Round *et al*. 1990, p. 553, fig. j). Lange-Bertalot indicated his population contained specimens 5.5-6.5 µm wide by 20-27 µm long, with 35-40 striae in 10 µm. *Sellaphora stauroneioides* was rare in our material, and our specimens were slightly smaller (5.0-6.0 µm wide by 20-21 µm long, striae too fine to enumerate in LM).

***Luticola* Figs. 77-78.**

Most of the species within this genus are aerophilic. *Luticola acidoclinata* and *L. mutica* were both widely distributed in the streams of the Elbsandsteingebirge.

***Fallacia vitrea* Figs. 79, 197.**

This acidobiontic species typically occurs in very dry sites. The conopeum was evident in SEM (Fig. 197).

**Diminutive naviculoid taxa Figs. 80-91, 140, 141.**

A number of rare and interesting taxa in a diverse group of taxa from *Navicula sensu lato* occurred in the Elbsandsteingebirge. Most of the illustrated taxa were found in more than one stream, but only *Microcostatus krasskei* and *Stauroneis thermicola* were widespread.

***Chamaepinnularia soehrensis* Figs. 92-103, 195.**

Our specimens correspond well to the lectotype of *Navicula soehrensis* Krasske established by Lange-Bertalot *et al*. (1996), as well as to the type for *Navicula soehrensis* var. *septentrionalis* Hustedt (1924) illustrated by Simonsen (1987a, plate 123, figs 11-12). They were 10-13 µm long by 2.1-2.3 µm wide with 18-20 striae in 10 µm. During our studies we considered these varieties separate, but concluded that it is only the Krasske material from Chile attributed to *Navicula soehrensis* (Lange-Bertalot *et al*. 1996, plate 22, fig. 18) that likely represents a different species. The Chilean specimens have much broader, more distinctly capitate apices. Our specimens were all distinctly triundulate.

***Chamaepinnularia soehrensis* var. *capitata* Figs. 104-107.**

This taxon was less represented in the Bohemian Switzerland National Park than other *Chamaepinnularia* taxa. Our specimens correspond to the holotype (compare Figs. 104-105 with Lange-Bertalot *et al*. 1996, plate 22, figs 20-22) and to Krasske's material from *Sphagnum squarrosum* (compare Figs. 102-103 with Lange-Bertalot *et al*. 1996, plate 22, figs 23-26). They were 10.0-11.3 µm long by 2.3-2.7 µm wide with 18-20 striae in 10 µm. The latter material (Figs. 102-103) has flat parallel sides and is more distinct from var. *soehrensis*. In our material, *Chamaepinnularia soehrensis* var. *capitata* seems to be a set of forms intermediate between *C. soehrensis* and *C. tongatensis* (Hustedt) Lange-Bertalot. We question whether or not this taxon is truly genetically distinct from the nominate variety, but studies of cultured material of both are likely required before this question can be resolved.

***Chamaepinnularia tongatensis* Figs. 108-116.**

Our specimens correspond well to the type material of this species as illustrated in Simonsen (1987b). They are not triundulate, and are capitate in all but the smallest specimens, which are rostrate at the ends. Our specimens were 6.3-9.3 µm long by 2.3-3.0 µm wide, with 18-21 striae in 10 µm. There is a discrepancy between Hustedt's description of this taxon (Hustedt 1962, p. 227) and the holotype material shown in Simonsen (1987b, plate 728, figs. 21-32). Hustedt indicates the dimensions for this taxon as 6-8 µm long by 2.5 µm wide, with 26-28 striae in 10 µm. However, when we measured photographs of the specimens from the type material (Simonsen 1987b), they were 8.7-10.3 µm long by 2.3-3.3 µm wide, with 18-20 striae in 10 µm. The shape of our material and the type material are identical, with the exception of a few teratological forms asymmetric with regards to the apical axis. These forms could easily be confused with *Chamaepinnularia soehrensis* var. *capitata* if a large population was not observed. The possibility certainly exists that minimal genetic distance exists between the two taxa, and that we have simply documented the morphology over the whole size range of one taxon.

***Chamaepinnularia mediocris* Figs. 117-119, 196.**

Our specimens were typical for this taxon. Dimensions were 10-12 µm long by 2.7 µm wide with 18-21 striae in 10 µm. Krasske reported finer striae 22-24 in 10 µm, but measurements of specimens from his type material (Lange-Bertalot *et al*. 1996) gave 18-20 in 10 µm.

***Chamaepinnularia rexii* nov. sp. Figs. 120-135, 192-194.**

**Diagnosis:** *Chamaepinnularia wiktoriae* affinis, a qua differt apicibus acuminatioribus, area centrali grandiore et striis tenuioribus. *Chamaepinnularia evanida* aemulans, a qua differt amplitudine parviore et striis subparallelis. *Chamaepinnularia vyvermanii* aemulans, a qua differt amplitudine parviore, striis tenuioribus et depressionibus rotundatis conspicuis secus aream axialem destitutis.

Akin to *Chamaepinnularia wiktoriae,* from which it differs in its more acuminate ends, larger central area, and finer striation. Similar to *Chamaepinnularia evanida,* from which it differs by its smaller size and nearly parallel striae. Similar to *Chamaepinnularia vyvermanii*, from which it differs by smaller size, finer striae, and absence of conspicuous rounded areole-like depressions along the axial area.

**Descriptio:** Valvae lanceolatae, apicibus acutirotundatis vel raro protractis, 5.7-9.7 µm longae, 2.5-3.0 µm latae. Area axialis angusta, linearis. Area centralis distincta, striis abbreviatis uno vel duobus in quoque lato formatibus. Raphe filiformis poris centralibus rotundatis leniter deflexis et fissuris ternimalibus uncatis. Striae indistincte radiatae, leviter distantiores in centro, membrana externo, depressionibus linearibus externis aream axialem contiguis, in partibus duobus area hyalina longitudinali prope limbum divisiae, 21-23-(24) in 10 µm.

Valves lanceolate with sharply rounded, rarely protracted ends, 5.7-9.7 µm, width 2.5-3.0 µm wide. Axial area narrow, linear. Central area distinct, formed by one or two shortened striae on each side. Raphe filiform with weakly deflected, rounded central pores and hooked terminal fissures. Striae slightly radiate, subtly more distantly placed in the center, with an external hymen, with linear external depressions adjacent to the axial area, divided into two parts by a long hyaline area near the mantle, 21-23-(24) in 10 µm.

Type Locality: Písečná rokle (Sandy Gorge, Site 4, downstream locality, 50°52'05"N, 14°16'31"E), tributary of Kamenice River, Bohemian Switzerland National Park, Czech Republic. Holotype here designated: circled specimen, slide number B 40 0040624, pellet

material number B 40 0040625, Berlin Collection (Botanic Garden and Botanical Museum Berlin-Dahlem).
Etymology: Named in honor Rex L. Lowe

In the light microscope, this species most closely resembles *Chamaepinnularia evanida* (Hustedt) Lange-Bertalot in shape, size, and striae density. However, *Chamaepinnularia evanida* is distinguished by the interruption of the valve striae along the mantle edge by a long hyaline area, as well as the distinctly radiate striae (Simonsen 1987, plate 396, figs. 12-18, Werum & Lange-Bertalot 2004, plate 83, fig. 6, Van de Vijver *et al*. 2002, plate 85, figs. 8-10). The interruption in *Chamaepinnularia rexii* is closer to the mantle edge, and generally visible only in TEM or in the SEM internal valve view (Fig. 194). A single specimen attributed to *Chamaepinnularia evanida* has been published with external hymen intact and linear depressions along the axial area (Werum & Lange-Bertalot 2004, plate 81, fig. 7). We think that this specimen likely belongs to *Chamaepinnularia rexii*, as the striae appear to be only slightly radiate. The valves illustrated in SEM by other authors all have missing (eroded?) hymens, and so direct comparison of depressions is difficult.

*Chamaepinnularia rexii* appears identical to *Chamaepinnularia* (?nov.) spec. Nr. 2 from the Finnish dystrophic lake Julma Ölkky (Lange-Bertalot & Metzeltin 1996, plate 28, fig. 37-39c). These specimens were recognized by the authors as distinctive, but not named in that work due to the paucity of specimens seen. *Chamaepinnularia rexii* was additionally compared to *Chamaepinnularia* species illustrated in Witkowski (1994), Metzeltin & Lange-Bertalot (1998), Moser *et al*. (1998), Rumrich *et al*. (2000), Witkowski *et al*. (2000), Lange-Bertalot *et al*. (2003), Reichardt (2004), and Siver *et al*. (2005).

A large population of *Chamaepinnularia rexii* was found in a headwater stream of low pH (3.30-3.95) and low conductivity (148 µS). The stream is subject to frequent drying, and so we suspect this diatom is a desiccation-tolerant aerophile, as is typical for many species in this genus. It co-occurred with *Chamaepinnularia septentrionalis, C. tongatensis, Microcostatus krasskei, Caloneis aerophila, Diadesmis paracontenta* and *Eunotia exigua*. It occurred very rarely in the other drainages examined in this study.

***Diadesmis* Figs. 136-139, 142-153, 199-206.**

This aerophilic genus is cosmopolitan in wet, acidic to neutral subaerial habitats. Species in the genus occur both epilithically and epiphytically on bryophytes. Surface ultrastructure of the valves is critical for correct species determination, and we provide SEM's of most of our taxa to verify their identification (Figs. 199-206).

***Neidium* Figs. 154-166.**

The *Neidium* species encountered in this study were problematic. While we had some taxa easily identifiable, there were a number of taxa we designated with *cf.* because they were not quite a match to the taxa to which they were identified as being similar. There is also some problem because even in the literature, *Neidium* are not always identified with certainty. For example, our *Neidium* cf. *ampliatum* was very similar species to specimens found in Julma Ölkky designated as *Neidium* spec. Nr. 4 cf. *ampliatum* (Lange-Bertalot & Metzeltin 1996, Plate 41, figs. 3-6). Our specimens had very similar size ranges and overlapping striae densities, although the densities in our specimens were lower (22-25 in 10 µm compared to 23-30 in 10 µm). *Neidium ampliatum* has been found to contain a number of reproductively isolated populations (Mann & Chepurnov 2005). Consequently, it represents several semicryptic species (a species complex in which minute variation has indeed taxonomic and phylogenetic significance). We also had a very diminutive form of

*Neidium hercynicum* that we designated *N*. cf. *hercynicum* (Figs. 163, 165). We highly doubt this is the same species as *Neidium hercynicum* recovered from the Elbsandsteingebirge (Fig. 154).

***Cavinula* Figs. 167, 183.**

Four species in this genus were observed, all occurring only rarely. *Cavinula variostriata* and *C. lapidosa* are shown (Figs. 167, 183).

***Frustulia weinholdii* Fig. 168.**

Four *Frustulia* species were observed. *Frustulia crassinervia* and *F. saxonica* are common species in acidic water and subaerial habitats. We illustrate only the rarest taxon, *Frustulia weinholdii* (Fig. 168).

***Caloneis* and *Pinnularia* Figs. 169-182, 188-191.**

*Caloneis* taxa typical of springs and subaerial sandstone wet substrates were observed, including *C. aerophila, C. vasileyevae* and *C. fontinalis*. With our populations of *Pinnularia subinterrupta* we enlarge the range of length and width reported for this taxon by Krammer (2000), from 20-24 x 4.3-4.6 µm to 16.0-26.5 x 4.0-4.6 µm.

***Brachysira brebissonii* Fig. 184.**

This taxon was common in one site, Písečná rokle (Table 1), but rare or absent in other sites.

***Muelleria* cf. *gibbula* Fig. 185.**

This species was extremely rare, occurring in only one sample. We were not able to resolve the valve structure well in our specimens, but what we could see appeared to be consistent with *Muelleria gibbula.* Most *Muelleria* species are restricted to high latitudes of either the southern or northern hemisphere, except *M. terrestris* (Petersen) Spauding et Stoermer and the cosmopolitan *M. gibbula* (Cleve) Spauding et Stoermer (Spaulding *et al*. 1999).

***Diploneis fontanella* Fig. 186.**

*Diploneis fontanella* was rare in our samples. This species was only recently described from springs in central Europe (Werum & Lange-Bertalot 2004).

***Placoneis hambergii* Fig. 187.**

Bruder & Medlin (2007) recently transferred *Navicula hambergii* Hustedt to *Placoneis* based upon phylogenetic analysis of a number of diatom taxa. Three different loci (SSU rRNA, LSU rRNA, *rbcL*) all indicated that this taxon was at the base of the *Placoneis* clade. We were struck by the similarity of this taxon to *Geissleria*. In particular, the central area of this taxon bears a strong resemblance to that of *Geissleria decussis.* We were not able to resolve any apical irregularities in the striae such as those visible in other *Geissleria* species, but suspect that *Geissleria* and *Placoneis* may be sister taxa (for external SEM see Werum & Lange-Bertalot 2004: plate 87, figs 24-25). Bruder & Medlin (2007) did not have access to sequences of any *Geissleria* species, but this potential relationship is worthy of further analysis.

## DISCUSSION

The diatom diversity of the 15 streams in the Elbsandsteingebirge area was relatively high (307 taxa). It is difficult to find comparable studies to make this evaluation, as species richness is related to number of sites, number of samples, and level of taxonomic effort. However, Cantonati (1998) found only 254 diatom taxa in 30 streams in an area in

the Southern Alps of very similar size and scale to the Elbsandsteingebirge, and with similar geological complexity (carbonates and siliceous). Cantonati's (1998) study is additionally similar to our study in that he sampled multiple substrates and the sites were headwater streams that sometimes dried down during the year. The scale of these two studies and the level of effort is likely similar, but the fact that we had half the number of streams and yet 20% more taxa indicates to us that the higher richness in Elbsandsteingebirge likely has some significance. In a study of much greater scope and effort (400 springs in south and central Hessen, Germany) only 416 taxa were found, despite the fact that this region is much more geologically complex and much larger in area (Werum & Lange-Bertalot 2004).

Diatom diversity in the Elbsandsteingebirge area is possibly high due to heterogeneity of microhabitats (e.g. geology, trophic level, pH, amount of humic acids, desiccation, and anthropogenic impact). One of the key variables in this study was the sampling of four different substrate types at all sites where they were present. Preferences of diatom taxa to specific substrata have been observed in studies of Stevenson & Hashim (1989); Maier (1994); Pringle (1990); Sabater *et al*. (1998); Cantonati (2001), Potapova & Charles (2005). The specific substrate preferences of diatoms found in a single stream, Suchá Bělá (our locality 3) in the Elbsandsteingebirge are discussed elsewhere. Veselá (in press) found that algal substrate preferences fell into two main categories, hard substrates (wood, stone) and soft substrates (bryophytes, sediment). The hard substrates were poor in species richness and species fidelity, with only 20% of common taxa in Suchá Bělá specific for this substrate type. Soft substrates had higher richness, and a higher percentage (46%) of common algae was specific to those surfaces. In particular, *Eunotia* spp. and *Pinnularia* spp. were primarily found on soft substrates. In the streams studied, stone surfaces were typically covered by abundant green algae, while wood surfaces had high numbers of fungi. We suspect these other microscopic organisms prevented good epilithic and epidendric diatom communities from forming, a finding reported by others (Ledger & Hildrew 1998, Sabater *et al*. 1998, Soininen 2003, Potapova & Charles 2005, Greenwood & Lowe 2006). The patterns seen in Suchá Bělá were present in this study of fifteen streams as well (Fig. 208). One outcome of this study is consequently that bryophytes in particular should be studied in headwater streams if diversity is an issue, as they harbor many interesting and rare taxa.

The geographic distance among streams had a more minor effect on similarity of diatom assemblages than pH value, which was tied directly to the eutrophication levels of the watershed. This result is not surprising given similar results in other studies where researchers found pH and enrichment to be determiners of diatom distribution (Mölder 1964; Cantonati 1998; Werum & Lange-Bertalot 2004; Soininen 2007). Casamatta *et al*. (2002) reported that the algal assemblages from sandstone wet walls also showed little geographical grouping of sites, and moisture levels appeared to have the greatest congruence with clustering of sites based on species composition. Significant effects on species composition attributable primarily to geographic distance have only been observed on larger spatial scales (Potapova & Charles 2002; Foerster *et al*. 2004; Charles *et al*. 2006).

Species concepts in diatoms based almost exclusively on the morphology of the frustules are frequently too broad (Mann 1999). In fact, many of the described species are complexes of different species within which have been found reproductive barriers,

differences in life cycle, morphological variability, and genetic divergence (Droop *et al*. 2000; Pappas & Stoermer 2003; Mann *et al*. 2004; Poulíčková & Mann 2006; Vanomerlingen *et al*. 2007). If an evolutionary species concept (Simpson 1953, 1961; Wiley & Mayden 2000) or phylogenetic species concept (Mischler & Theriot 2000) is adopted, then it is possible to recognize even more species than is permitted by the biological species concept Mann (1999) and Mann *et al.* (2004) advocate. The ability for two lineages to reproduce sexually is a symplesiomorphy, and consequently not ideal to use as evidence of conspecificity. Reproductive barriers are apomorphic, and thus good for separation. By more modern species concepts, it is easy to imagine that two morphologically or ecologically similar but genetically divergent lineages could be recognized as separate species even if they retain the ability to reproduce sexually. Morphological dissimilarity within a species complex is sometimes detectable using morphometric techniques, and consequently the species are semicryptic (pseudocryptic) rather than cryptic. In this study we found many diatoms which obviously varied in minute ways from descriptions or illustrations of species in the literature, and these may indeed represent new taxa. Additionally, we had a number of "cf." taxa that, had they been part of larger populations, would likely have been considered worthy of taxonomic recognition.

The observed morphological divergence of our natural populations from published records is due to some combination of phenotypic plasticity and genetic differentiation, but it is difficult in the absence of experimental evidence to know the relative importance of these two sources of variation. Potapova & Hamilton (2007) studied natural populations within the *Achnanthidium minutissimum* species complex in North American rivers using morphometric and ecological data. Their morphometric analysis did not reveal discontinuities among all morphological groups corresponding to the historical taxa. However, they did find six morphotypes which were correlated with water chemistry, and the implication is that at least some of the morphological variation observed is due to genetic differentiation. Evidence for plasticity was not given, although different stages of the life cycle may be responsible for description of too many species historically.

As we struggled with the identification of taxa in the Elbsandsteingebirge, we confirmed our opinion that diatom taxonomy and ecology is problematic. Valve outline, an important species criterion, changes during the life cycle as valves get progressively smaller. Cryptic species may have only minor (or no) morphological differences that are easily masked by life-cycle changes. Finally, there may be ecophenotypic variation, although beyond the formation of teratological valves this has not been extensively documented. There are instances of polymorphism in diatom cells which demonstrate species-level changes in morphology tied to environmental stimuli (Stoermer 1967). The combination of apparent tight genetic control of morphology within species combined with the morphological changes that occur during the life cycle and the possible impacts of environmental stressors on morphology make any morphology-based taxonomy difficult. Still, diatom morphotypes, whatever we call them, are regularly correlated with water chemistry and consequently are ecologically informative. Careful taxonomic work will be of high value at least for the foreseeable future.

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Table 1. List of diatom taxa and their semi-quantitative scale of abundance in streams: r = rare. u = uncommon. c = common. f = frequent. d = dominant. Van Dam's indication values: pH. 1 = acidobiontic. 2 = acidophilic. 3 = neutrophilic. 4 = alkaliphilous. 5 = alkalibiontic. 6 = indifferent. Moisture. dry = moist or temporarily dry places. ae = aerophytic. un = not listed. Calculated AWM optimum ± tolerance values.

| | Studený potok 1 | Dolnožlebský p. 2 | Suchá Bělá 3 | Písečná rokle 4 | Kachní potok 5 | Ponova louka 6 | Hluboký důl 7 | Mlýnská rokle 8 | Červený potok 9 | Studenec 10 | Doubický potok 11 | Bílý potok 12 | Brtnický potok 13 | Vlčí potok 14 | Panský potok 15 | pH indication values | moisture indication v. | abundance weighted mean pH ± tolerance values | abundance weighted mean conductivity ± tolerance values |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Adlafia bryophila* (Petersen) Moser, Lange-Bertalot et Metzeltin | - | r | - | - | u | - | - | - | - | - | - | r | r | c | u | 3 | ae | 6.9 ± 0.5 | 146 ± 22 |
| *Adlafia minuscula* (Grunow) Lange-Bertalot | - | - | - | - | - | u | - | - | - | u | - | r | u | - | - | 4 | dry | 7.1 ± 0.6 | 166 ± 34 |
| *Achnanthes lutherii* (Hustedt) | - | - | - | - | - | - | - | - | r | - | - | - | - | - | - | 2 | dry | - | - |
| *Achnanthes* spp. | u | u | - | u | - | u | - | - | - | u | | u | u | - | u | - | - | - | - |
| *Achnanthidium exiguum* (Grunow) Czarnecki | - | - | - | - | - | - | - | - | - | r | - | - | - | - | - | 4 | - | - | - |
| *Achnanthidium minutissimum* (Kützing) Czarn. *sensu lato* | f | f | - | r | u | c | r | - | u | f | u | c | f | f | f | 3 | - | 6.8 ± 0.7 | 159 ± 32 |
| *Amphipleura pellucida* (Kützing) Kützing | - | - | - | - | - | - | - | - | - | - | r | - | - | - | - | 4 | - | - | - |
| *Amphora libyca* Ehrenberg | - | - | - | - | - | r | - | - | - | r | r | r | u | u | - | 4 | - | 7.2 ± 0.3 | 172 ± 20 |
| *Amphora normanii* Rabenhorst | - | - | - | - | - | - | - | - | - | - | - | - | - | - | r | 3 | - | - | - |
| *Amphora pediculus* (Kützing) Grunow | r | r | - | - | r | - | - | - | - | u | u | c | f | u | u | 4 | - | 7.3 ± 0.5 | 172 ± 33 |
| *Asterionella formosa* Hassall | - | - | - | - | - | - | - | - | - | - | u | - | - | - | - | 4 | - | 7.2 ± 0.1 | 198 ± 11 |
| *Aulacoseira ambigua* (Grunow) Simonsen | - | - | - | - | - | - | - | - | - | - | f | - | - | - | - | 4 | - | 7.1 ± 0.2 | 189 ± 14 |
| *Aulacoseira italica* (Ehrenberg) Simonsen | - | - | - | - | - | - | - | - | - | - | - | u | - | - | - | 3 | - | - | - |
| *Aulacoseira* cf. *laevissima* (Grunow) Krammer | - | - | - | - | - | - | - | - | - | - | - | - | - | u | - | - | un | 7.3 ± 0.2 | 160 ± 5 |
| *Aulacoseira* cf. *perglabra* (Østrup) Haworth | - | - | - | - | - | - | - | - | - | r | - | - | - | - | - | - | un | - | - |
| *Brachysira brebissonii* Ross | r | - | u | c | - | - | r | - | - | - | - | - | r | - | - | 2 | - | 4.3 ± 1.1 | 123 ± 42 |
| *Brachysira vitrea* (Grunow) Ross | - | - | - | - | - | - | - | - | - | - | u | r | - | u | u | 2 | - | 7.0 ± 0.1 | 150 ± 23 |
| *Brachysira* spp. | - | - | r | - | - | r | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Caloneis aerophila* Bock | - | - | - | c | - | - | - | - | - | - | - | - | - | r | r | - | ae | 4.3 ± 1.5 | 147 ± 7 |
| *Caloneis fontinalis* (Grunow) Lange-Bertalot et Reichardt | - | - | - | - | - | r | - | - | - | - | - | r | r | r | - | - | un | 7.3 ± 0.2 | 153 ± 22 |

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| *Caloneis silicula* (Ehrenberg) Cleve | - | - | - | - | r | r | - | - | - | - | r | - | - | - | - | 4 | - | - | - |
| *Caloneis tenuis* (Gregory) Krammer | r | - | - | - | - | - | - | - | - | - | - | - | - | - | r | 3 | dry | - | - |
| *Caloneis vasileyevae* Lange-Bertalot, Genkal et Vekhov | - | - | u | - | r | - | - | u | r | - | - | - | - | - | r | - | un | 5.0 ± 1.3 | 94 ± 49 |
| *Caloneis* spp. | - | - | - | - | - | r | - | - | - | - | - | - | - | - | r | - | - | - | - |
| *Cavinula cocconeiformis* (Gregory) Mann et Stickle | - | - | - | - | u | - | - | r | - | - | - | - | - | r | - | 3 | - | 5.8 ± 0.8 | 113 ± 34 |
| *Cavinula lapidosa* (Krasske) Lange-Bertalot | - | - | - | - | - | - | - | - | r | - | - | r | - | r | r | 2 | dry | 6.9 ± 0.2 | 143 ± 13 |
| *Cavinula variostriata* (Krasske) Mann | - | - | - | - | - | - | - | - | - | - | - | r | - | - | - | 2 | dry | - | - |
| *Cavinula* sp. | - | - | - | - | r | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Chamaepinnularia mediocris* (Krasske) Lange-Bertalot | - | r | r | u | - | - | - | - | u | - | - | - | - | - | - | 2 | un | 4.2 ± 1.0 | 134 ± 34 |
| *Chamaepinnularia rexii* nov. sp. | - | r | r | c | - | - | - | - | - | - | - | - | - | - | - | | un | 4.0 ± 0.1 | 143 ± 22 |
| *Cham. soehrensis* (Krasske) Lange-Bert. et Krammer | r | r | c | c | - | - | u | c | u | - | - | - | - | - | - | 2 | dry | 4.6 ± 1.0 | 101 ± 47 |
| *Chamaepinnularia soehrensis* var. *capitata* (Krasske) Lange-Bertalot et Krammer | - | - | r | r | - | - | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Chamaepinnularia soehrensis* var. *muscicola* (Petersen) Lange-Bertalot et Krammer | - | - | - | - | - | - | - | - | r | - | - | - | - | - | - | 2 | dry | - | - |
| *Chamaepinnularia tongatensis* (Hustedt) Lange-Bertalot | - | - | u | u | - | - | r | r | r | - | - | - | - | r | - | - | un | 4.5 ± 0.9 | 121 ± 45 |
| *Cocconeis placentula* Ehrenberg var. *placentula* | - | - | - | - | - | - | - | - | - | - | u | c | f | - | - | 4 | - | 7.4 ± 0.2 | 173 ± 18 |
| *Cocconeis placentula* var. *klinoraphis* Geitler | - | - | - | - | - | - | - | - | - | - | - | - | - | r | - | 4 | - | - | - |
| *Cocconeis placentula* var. *lineata* (Ehrenberg) Cleve | u | r | - | - | - | r | r | - | - | u | - | c | c | u | u | 4 | - | - | - |
| *Cocconeis pseudolineata* (Geitler) Lange-Bertalot and *C. euglypta* (Ehrenberg) Cleve | r | - | - | - | - | r | - | r | - | u | u | f | u | u | u | 4 | - | 7.2 ± 0.5 | 165 ± 34 |
| *Craticula molestiformis* (Hustedt) Lange-Bertalot | - | - | - | - | - | u | - | - | - | - | r | - | - | - | - | 4 | - | - | - |
| *Craticula riparia* (Hustedt) Lange-Bertalot var. *riparia* | - | - | - | r | - | - | - | - | u | - | - | - | - | - | - | 2 | - | 4.8 ± 0.9 | 72 ± 42 |
| *Cymatopleura solea* (Brébisson) W. Smith | - | - | - | - | - | - | - | - | - | - | r | - | - | - | - | 4 | - | - | - |
| *Cymbella subaequalis* Grunow | - | - | - | - | - | - | - | - | - | - | - | - | - | u | u | 3 | - | 7.1 ± 0.2 | 146 ± 15 |
| *Cymbopleura naviculiformis* (Auerswald) Krammer | r | u | - | - | r | r | r | - | u | u | u | u | r | c | c | 3 | - | 6.9 ± 0.6 | 146 ± 32 |
| *Denticula tenuis* Kützing | u | - | - | - | - | - | - | - | - | - | r | - | - | r | - | 4 | - | 6.7 ± 0.5 | 155 ± 27 |
| *Diadesmis biceps* Arnott | - | - | r | r | - | - | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Diadesmis brekkaensis* (Petersen) Mann | - | - | u | - | - | r | - | r | - | - | - | r | - | - | - | 3 | un | 5.5 ± 1.5 | 97 ± 66 |
| *Diadesmis contenta* (Grunow) Mann | - | - | r | - | - | u | - | - | - | - | - | - | - | - | - | 4 | dry | - | - |
| *Diadesmis contenta* var. *parallela* (Petersen) Spaulding | - | - | r | - | - | - | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Diadesmis gallica* W. Smith | - | - | u | - | - | - | - | - | - | - | - | - | - | - | - | - | ae | - | - |
| *Diadesmis laevissima* (Cleve) Mann | - | - | c | - | - | - | - | - | - | - | - | - | - | - | r | - | ae | 4.8 ± 0.7 | 69 ± 16 |
| *Diadesmis paracontenta* Lange-Bertalot et Werum | u | - | c | u | - | u | - | r | r | r | - | u | r | r | u | - | un | 5.4 ± 1.3 | 107 ± 55 |

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| *Diadesmis perpusilla* (Grunow) Mann | - | u | u | - | u | u | u | - | r | r | u | r | u | u | u | 3 | ae | 6.6 ± 1.1 | 145 ± 49 |
| *Diadesmis* cf. *perpusilla* (Grunow) Mann | - | - | r | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Diatoma mesodon* Kützing | c | d | u | - | u | - | - | - | - | c | - | u | u | u | r | 3 | - | 6.4 ± 0.5 | 152 ± 29 |
| *Diploneis fontanella* Lange-Bertalot | r | u | - | - | - | u | - | - | r | u | - | r | r | u | u | - | un | 6.9 ± 0.6 | 158 ± 36 |
| *Diploneis* cf. *fontium* Reichardt et Lange-Bertalot | - | r | - | - | - | r | - | - | - | u | - | u | r | u | r | - | un | 7.3 ± 0.3 | 157 ± 5 |
| *Diploneis oculata* (Brebisson) Cleve | u | u | - | - | r | - | - | - | - | r | - | r | r | u | r | 3 | - | 6.8 ± 0.4 | 154 ± 21 |
| *Diploneis ovalis* (Hilse) Cleve | - | - | - | - | - | - | - | - | - | r | - | - | - | - | - | 4 | dry | - | - |
| *Discostella pseudostelligera* (Hustedt) Houk et Klee | - | - | - | - | - | - | - | - | - | - | u | r | - | r | - | 3 | - | 7.3 ± 0.2 | 187 ± 21 |
| *Discostella steligera* (Cleve et Grunow) Houk et Klee | - | - | - | - | - | - | - | - | - | - | u | - | - | - | - | - | - | - | - |
| *Encyonema minutum* (Hilse) Mann and *E. silesiacum* (Bleisch) Mann | - | u | - | - | r | - | r | r | - | c | f | u | c | f | c | - | - | 7.0 ± 0.4 | 166 ± 28 |
| *Encyonema perpusillum* (A. Cleve) Mann | - | r | - | r | r | u | - | r | r | u | u | r | r | r | r | 2 | dry | 6.9 ± 1.3 | 162 ± 59 |
| *Encyonopsis falaisensis* (Grunow) Krammer | c | u | - | - | - | - | - | - | - | r | r | - | - | c | c | - | - | 6.8 ± 0.4 | 144 ± 21 |
| *Encyonopsis* sp. 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | r | r | - | - | - | - |
| *Encyonopsis* sp. 2 | - | - | - | - | - | u | - | - | - | - | u | u | u | r | r | - | - | 7.6 ± 0.4 | 190 ± 31 |
| *Encyonopsis* sp. 3 | r | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Entomoneis ornata* (Bailey) Reimer | - | - | - | - | - | - | - | - | - | - | r | - | - | r | - | 3 | - | - | - |
| *Eolimna minima* (Grunow) Lange-Bertalot | - | - | - | - | - | c | r | r | - | c | u | u | c | - | u | 4 | - | 7.1 ± 0.7 | 167 ± 42 |
| *Epithemia adnata* (Kützing) Brébisson | - | - | - | - | - | - | - | - | - | - | - | r | - | - | - | 5 | - | - | - |
| *Eucocconeis laevis* (Østrup) Lange-Bertalot | - | - | - | u | - | - | - | - | - | - | - | - | - | c | u | 4 | dry | 6.4 ± 1.7 | 163 ± 27 |
| *Eunotia angusta* (Grunow) Berg | - | - | - | - | r | - | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Eunotia arculus* Lange-Bertalot et Nörpel | - | - | - | - | r | - | - | - | - | - | - | - | - | - | - | 2 | un | - | - |
| *Eunotia bigibba* Kützing | - | - | u | r | r | - | - | - | - | - | - | - | - | - | r | 2 | dry | 5.0 ± 1.2 | 99 ± 37 |
| *Eunotia bilunaris* (Ehrenberg) Mills | c | u | u | u | r | - | d | f | u | r | - | - | r | u | u | 6 | - | 5.3 ± 1.2 | 110 ± 46 |
| *Eunotia botuliformis* Wild, Nörpel et Lange-Bertalot | r | r | u | - | u | r | - | - | u | r | - | r | r | u | r | - | un | 6.2 ± 0.9 | 124 ± 45 |
| *Eunotia circumborealis* Lange-Bertalot et Nörpel | - | - | - | r | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Eunotia curtagrunowii* Nörpel-Schempp et Lange-Bert. | - | - | - | - | r | - | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Eunotia exigua* (Bréb.) Rabenh. and *E. tenella* (Grun.) Hust. | c | u | f | f | c | - | f | c | c | u | u | u | u | u | u | - | - | 5.5 ± 1.2 | 115 ± 45 |
| *Eunotia faba* Ehrenberg | - | r | - | - | - | - | - | r | - | - | - | - | - | - | - | 2 | - | - | - |
| *Eunotia fallax* A. Cleve | r | - | - | - | - | - | r | u | - | r | - | - | - | - | r | 2 | dry | 4.7 ± 1.1 | 89 ± 37 |
| *Eunotia fennica* (Hustedt) Lange-Bertalot | - | - | - | - | - | - | - | u | - | - | - | - | - | - | - | - | un | - | - |
| *Eunotia glacialis* Meister | - | r | - | - | - | - | - | r | - | - | - | - | - | - | - | 2 | - | 4.9 ± 1.2 | 123 ± 37 |
| *Eunotia groenlandica* (Grun.) Nörpel-Sch. et Lange-Bert. | - | - | - | r | r | - | - | - | - | - | - | - | - | - | - | 2 | dry | - | - |
| *Eunotia implicata* Nörpel, Alles et Lange-Bertalot | c | u | - | - | - | - | - | - | - | - | - | r | r | u | u | 2 | - | 6.6 ± 0.5 | 144 ± 19 |

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| *Eunotia incisa* Gregory | r | r | c | c | r | - | c | r | r | - | - | r | - | - | - | 2 | - | 5.1 ± 1.1 | 108 ± 53 |
| *Eunotia islandica* Østrup | - | - | - | - | u | - | - | r | - | - | - | - | - | - | - | 2 | dry | 5.3 ± 0.9 | 95 ± 40 |
| *Eunotia levistriata* Hustedt | - | - | - | - | - | - | - | r | - | - | - | - | - | - | - | - | un | - | - |
| *Eunotia meisteri* Hustedt | - | - | - | - | - | - | r | r | u | - | - | - | - | - | - | 2 | dry | 5.2 ± 0.5 | 65 ± 42 |
| *Eunotia microcephala* Krasske | - | - | - | - | - | - | r | r | - | - | - | - | - | - | - | 2 | dry | - | - |
| *Eunotia minor* (Kützing) Grunow | - | c | u | r | r | - | u | r | u | u | - | u | u | u | r | 2 | dry | 4.2 ± 0.8 | 129 ± 47 |
| *Eunotia* cf. *minor* (Kützing) Grunow | - | r | - | - | - | - | - | r | - | - | - | - | - | - | - | 2 | dry | - | - |
| *Eunotia muscicola* var. *tridentula* Nörpel et Lange-Bert. | r | c | u | r | - | - | - | - | - | r | - | - | - | - | - | - | un | 5.8 ± 0.8 | 140 ± 58 |
| *Eunotia nymanniana* Grunow | - | r | - | u | - | - | - | - | u | - | - | - | - | - | - | 2 | un | 4.8 ± 0.9 | 96 ± 55 |
| *Eunotia paludosa* Grunow | u | u | u | c | - | - | u | c | u | - | - | r | r | r | u | 1 | - | 4.9 ± 1.3 | 112 ± 48 |
| *Eunotia praerupta* Ehrenberg | - | - | r | r | u | - | r | - | - | - | - | - | - | - | - | 2 | - | 5.4 ± 1.0 | 119 ± 45 |
| *Eunotia* cf. *praerupta* Ehrenberg | - | - | r | - | r | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - |
| *Eunotia rhomboidea* Hustedt | - | r | u | c | - | - | f | - | c | - | - | r | r | - | - | 2 | - | 4.9 ± 1.2 | 130 ± 50 |
| *Eunotia steineckei* Petersen | - | r | - | r | - | - | - | r | - | - | - | - | - | r | - | - | un | 5.2 ± 1.5 | 140 ± 30 |
| *Eunotia subarcuatoides* Alles, Nörpel et Lange-Bertalot | - | - | - | - | - | - | - | r | - | - | - | - | - | - | - | 1 | - | - | - |
| *Eunotia sudetica* Muller | - | r | - | - | r | - | - | - | - | - | - | u | u | - | - | 2 | - | 6.8 ± 1.0 | 155 ± 43 |
| *Eunotia tenella* (Grunow) Hustedt - long cells | - | r | u | - | r | - | u | u | u | - | - | - | - | r | - | - | - | - | - |
| *Eunotia tetraodon* Ehrenberg | - | - | - | - | r | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - |
| *Eunotia trinacria* Krasske | - | - | u | - | - | - | c | c | u | - | - | - | - | - | - | 1 | dry | 4.7 ± 0.8 | 82 ± 40 |
| *Eunotia ursamaioris* Lange-Bertalot et Nörpel-Schempp | u | - | f | - | u | - | f | u | r | - | - | - | - | - | - | - | un | 5.1 ± 0.8 | 93 ± 39 |
| *Eunotia valida* Hustedt | - | r | - | r | r | - | r | r | - | - | - | - | - | - | r | 2 | - | 5.0 ± 1.2 | 96 ± 45 |
| *Eunotia* spp. | - | - | r | r | - | r | - | u | - | - | - | - | - | r | - | - | - | - | - |
| *Fallacia insociabilis* (Krasske) Mann | - | - | - | - | - | - | - | - | r | - | - | - | - | - | - | 3 | dry | - | - |
| *Fallacia vitrea* (Østrup) Mann | - | r | r | u | - | - | - | - | - | - | - | - | - | - | - | 1 | dry | 4.2 ± 1.1 | 137 ± 34 |
| *Fragilaria capucina* Desmazieres *sensu lato* | c | c | u | r | r | - | - | - | r | r | c | u | u | c | c | 3 | - | 6.8 ± 0.7 | 157 ± 30 |
| *Fragilaria vaucheriae* (Grunow) Jørgensen | - | - | - | - | r | - | - | - | - | - | r | - | c | - | - | 4 | - | - | - |
| *Fragilaria* sp. | - | - | - | r | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Fragilariforma virescens* (Ralfs) Williams et Round | - | - | f | u | c | - | u | u | - | u | - | u | r | - | r | 3 | - | 5.5 ± 1.0 | 102 ± 44 |
| *Frustulia crassinervia* (Bréb.) Lange-Bert. et Krammer | - | - | u | u | - | - | - | r | - | - | - | - | - | - | - | 1 | - | 4.0 ± 0.7 | 116 ± 45 |
| *Frustulia saxonica* Rabenhorst | r | - | u | c | - | - | u | u | u | - | - | - | - | - | u | 1 | - | 4.9 ± 1.1 | 110 ± 48 |
| *Frustulia vulgaris* (Thwaites) De Toni | r | c | - | - | u | u | - | - | - | u | r | u | u | c | - | 4 | - | 6.9 ± 0.5 | 164 ± 26 |
| *Frustulia weinholdii* Hustedt | - | - | - | - | - | - | - | - | - | - | - | r | - | u | - | 3 | - | 7.1 ± 0.2 | 154 ± 4 |
| *Geissleria decussis* (Oestrup) Lange-Bertalot et Metzeltin | - | - | - | - | - | - | r | - | - | - | - | r | - | - | - | 4 | - | - | - |
| *Gessleria paludosa* (Hustedt) Lange-Bertalot et Metzeltin | - | - | - | - | - | u | - | - | - | - | - | r | - | - | - | 3 | dry | - | - |

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| *Gomphonema acuminatum* Ehrenberg | - | - | - | - | - | - | - | - | - | - | r | r | r | u | - | 4 | - | 7.4 ± 0.6 | 184 ± 34 |
| *Gomphonema angustum* (Kützing) Rabenhorst | - | - | - | - | - | u | r | - | - | - | - | - | u | - | r | 4 | un | 6.6 ± 0.4 | 167 ± 29 |
| *Gomphonema clavatum* Ehrenberg | u | u | r | r | r | - | - | - | r | u | - | u | u | c | u | 3 | - | 6.7 ± 0.7 | 146 ± 24 |
| *Gomphonema gracile* Ehrenberg | u | u | r | r | r | - | u | - | u | r | r | - | - | u | u | 3 | - | 6.4 ± 0.7 | 141 ± 33 |
| *Gomphonema minutum* (Agardh) Agardh | u | - | - | - | - | - | - | - | r | - | u | r | u | u | - | 3 | un | 6.8 ± 0.7 | 146 ± 42 |
| *Gomphonema olivaceoides* Hustedt | - | - | - | - | - | - | - | - | - | u | - | r | u | r | - | 3 | - | 6.8 ± 0.4 | 168 ± 26 |
| *Gomphonema parvulum* (Kützing) Kützing *sensu lato* | c | u | u | r | u | f | - | r | u | c | u | c | c | f | u | 3 | - | 6.8 ± 0.8 | 153 ± 37 |
| *Gomphonema truncatum* Ehrenberg | - | - | - | - | - | - | - | - | - | - | - | - | u | u | - | 4 | - | 7.3 ± 0.2 | 178 ± 17 |
| *Hannaea arcus* (Ehrenberg) Patrick | r | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | - |
| *Hantzschia amphioxys* (Ehrenberg) Grunow | - | - | - | - | - | - | - | r | - | - | - | - | - | r | - | 3 | dry | - | - |
| *Hantzschia graciosa* Lange-Bertalot | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Hippodonta capitata* (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski | - | - | - | - | - | - | - | - | - | r | u | - | u | u | - | 4 | - | 7.2 ± 0.3 | 164 ± 20 |
| *Karayevia clevei* (Grunow) Round et Bukhtiyarova | - | - | - | - | - | - | - | - | - | r | r | r | u | - | - | 4 | - | 7.4 ± 0.3 | 163 ± 21 |
| *Karayevia laterostrata* (Hustedt) Round et Bukhtiyarova | - | - | - | - | - | - | - | - | - | - | r | r | u | - | - | 3 | - | 7.4 ± 0.2 | 174 ± 12 |
| *Kobayasiella* cf. *jaagii* Meister | - | - | - | - | - | - | - | - | - | r | - | r | - | - | - | - | un | - | - |
| *Kobayasiella subtilissima* (Cleve) Lange-Bertalot | - | - | - | u | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - |
| *Luticola acidoclinata* Lange-Bertalot | - | - | - | - | - | r | r | - | r | - | - | r | r | - | - | - | un | - | - |
| *Luticola mutica* (Kützing) Mann | - | - | u | - | - | u | r | u | r | - | - | r | r | r | - | 3 | dry | 5.9 ± 1.8 | 125 ± 74 |
| *Mayamaea recondita* (Hustedt) Lange-Bertalot | - | - | r | - | - | u | - | - | - | - | r | - | - | - | r | - | ae | 7.2 ± 1.0 | 154 ± 52 |
| *Mayamaea atomus* var. *permitis* (Hustedt) Lange-Bertalot | - | - | - | - | - | u | - | - | - | u | r | - | u | - | - | 4 | - | 6.9 ± 0.6 | 174 ± 36 |
| *Melosira varians* Agardh | - | - | - | - | - | - | - | - | - | - | u | u | f | f | - | 4 | - | 7.3 ± 0.2 | 169 ± 16 |
| *Meridion circulare* (Greville) Agardh | r | r | r | - | u | f | r | r | u | c | u | c | c | c | u | 4 | - | 7.0 ± 0.6 | 156 ± 33 |
| *Microcostatus krasskei* (Hustedt) Johansen et Sray | r | r | c | c | u | r | - | r | u | - | - | - | r | r | r | 2 | dry | 5.1 ± 1.2 | 115 ± 47 |
| *Microcostatus* sp. | - | u | - | - | - | - | - | - | - | - | - | - | - | r | - | - | - | - | - |
| *Muelleria* sp. | - | - | - | - | - | - | - | - | - | - | - | - | - | r | - | - | - | - | - |
| *Navicula exilis* Kützing | - | u | - | - | - | - | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Navicula angusta* Grunow | - | u | - | - | - | - | - | - | - | - | - | - | - | u | c | 2 | - | 6.8 ± 0.3 | 144 ± 25 |
| *Navicula antonii* Lange-Bertalot | - | r | - | - | - | c | - | - | - | - | - | u | - | - | - | 4 | - | 7.8 ± 0.6 | 191 ± 43 |
| *Navicula cryptocephala* Kützing | - | - | - | - | u | u | - | - | u | c | u | u | u | c | c | 3 | - | 6.9 ± 0.5 | 156 ± 31 |
| *Navicula cryptotenella* Lange-Bertalot | - | r | - | - | r | - | - | - | - | - | - | r | - | u | r | 4 | - | 6.9 ± 0.6 | 146 ± 18 |
| *Navicula difficillima* Hustedt | - | r | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - |
| *Navicula gregaria* Donkin | - | - | - | - | u | c | - | - | u | c | c | c | f | c | u | 4 | - | 7.2 ± 0.5 | 168 ± 34 |
| *Navicula lanceolata* (Agardh) Ehrenberg | - | - | - | - | - | r | r | - | - | u | d | f | f | c | - | 4 | - | 7.2 ± 0.4 | 171 ± 28 |

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| *Navicula* cf. *lundii* Reichardt | - | r | r | - | - | u | - | - | r | u | u | u | u | u | u | 4 | - | 7.2 ± 0.6 | 161 ± 36 |
| *Navicula medioconvexa* (Hustedt) | - | - | - | r | - | - | - | - | - | - | - | - | - | r | - | 3 | un | - | - |
| *Navicula protracta* (Grunow) Cleve | - | - | - | - | - | - | - | - | - | u | - | - | u | - | - | 3 | - | 6.9 ± 0.4 | 126 ± 31 |
| *Navicula radiosa* Kützing | - | - | - | - | - | - | - | - | - | - | u | r | r | c | - | 3 | - | 7.2 ± 0.2 | 168 ± 19 |
| *Navicula reinhardtii* Grunow | - | - | - | - | - | - | - | - | - | - | u | - | - | - | - | 5 | - | - | - |
| *Navicula rhynchocephala* Kützing | - | r | - | - | u | - | - | - | r | u | u | c | u | c | u | 4 | - | 7.0 ± 0.5 | 146 ± 27 |
| *Navicula slesvicensis* Grunow | - | - | - | - | - | - | - | - | - | - | r | - | - | - | - | 4 | - | - | - |
| *Navicula tridentula* Krasske | - | r | - | - | - | r | - | r | - | r | - | - | - | r | - | 2 | dry | 6.8 ± 1.2 | 145 ± 56 |
| *Navicula tripunctata* (Müller) Bory | - | - | - | - | - | u | - | - | - | - | - | r | r | - | - | 4 | - | 7.9 ± 0.5 | 201 ± 33 |
| *Navicula ventralis* Krasske | - | - | - | - | - | - | - | - | - | - | - | r | - | - | - | 2 | - | - | - |
| *Navicula* spp. | - | u | - | - | - | - | - | - | - | r | - | u | - | r | - | - | - | - | - |
| *Neidium affine* (Ehrenberg) Pfitzer | - | u | - | r | c | - | - | - | r | r | - | - | - | u | - | 3 | - | 6.1 ± 0.7 | 140 ± 25 |
| *Neidium affine* var. *amphirhynchus* (Ehrenberg) Cleve | - | - | - | - | - | - | - | - | - | - | - | - | - | r | - | - | un | - | - |
| *Neidium alpinum* Hustedt | - | - | r | r | c | - | r | r | r | - | - | - | - | r | u | 2 | - | 5.9 ± 0.8 | 117 ± 34 |
| *Neidium ampliatum* (Ehrenberg) Krammer | - | - | - | - | - | - | - | - | - | r | u | - | r | - | - | 3 | - | - | - |
| *Neidium* cf. *ampliatum* (Ehrenberg) Krammer | - | r | - | - | c | - | r | r | u | r | - | - | - | r | r | 3 | - | 6.2 ± 0.7 | 129 ± 39 |
| *Neidium binodeforme* Krammer | - | - | - | - | - | r | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Neidium bisulcatum* (Lagerstedt) Cleve | - | - | - | - | - | - | - | - | r | - | r | - | - | r | - | 3 | - | 6.3 ± 0.6 | 135 ± 33 |
| *Neidium carterii* Krammer | - | - | - | r | - | - | - | - | - | - | - | - | - | - | - | 2 | un | - | - |
| *Neidium hercynicum* A. Mayer | - | r | - | r | u | - | r | u | u | - | r | - | - | - | u | 2 | un | 5.5 ± 1.1 | 103 ± 48 |
| *Neidium* cf. *hercynicum* A. Mayer | - | - | - | - | r | - | - | - | - | - | - | - | - | - | - | 2 | un | - | - |
| *Neidium longiceps* (Gregory) Cleve-Euler | - | - | - | - | u | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - |
| *Neidium productum* (W.M. Smith) Cleve | - | - | - | - | r | - | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Neidium* cf. *productum* (W. M. Smith) Cleve | - | - | - | - | - | r | r | - | - | - | - | - | - | - | - | - | un | - | - |
| *Neidium* sp. | - | - | r | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Nitzschia acicularis* (Kützing) W. M. Smith | - | - | - | - | - | - | - | - | - | - | u | - | r | r | - | 4 | - | 7.3 ± 0.3 | 177 ± 13 |
| *Nitzschia debilis* (Arnott) Grunow | - | - | - | - | - | r | - | - | - | - | - | r | r | u | - | 4 | dry | 7.3 ± 0.4 | 166 ± 22 |
| *Nitzschia dissipata* (Kützing) Grunow | - | r | - | - | - | r | - | - | - | r | u | u | u | c | r | 4 | - | 7.3 ± 0.4 | 172 ± 26 |
| *Nitzschia linearis* (Agardh) W. Smith | - | - | - | - | - | u | - | - | - | - | - | - | - | - | r | 4 | - | - | - |
| *Nitzschia sinuata* var. *sinuata* (Thwaites) Grunow | - | - | - | - | - | - | - | - | - | - | - | - | - | r | - | 4 | - | - | - |
| *Nitzschia sinuata* var. *tabellaria* (Grunow) Grunow | - | - | - | - | - | - | - | - | - | - | r | - | - | - | - | 3 | - | - | - |
| *Nitzschia* cf. *subconstricta* Grunow | - | - | - | - | u | - | - | - | r | - | - | - | - | - | - | - | un | 6.1 ± 0.3 | 129 ± 11 |
| *Nitzschia* spp. | - | u | - | r | u | c | u | - | u | f | c | u | c | c | u | - | - | - | - |
| *Nupela lapidosa* (Krasske) Lange-Bertalot | u | - | - | - | - | - | - | - | - | r | - | u | - | - | - | 2 | dry | 6.6 ± 0.8 | 136 ± 24 |

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| *Pinnularia borealis* Ehrenberg | - | - | u | - | - | u | r | u | r | r | r | - | r | r | - | 4 | dry | - | - |
| *Pinnularia borealis* var. *scalaris* (Ehrenberg) Rabenhorst | - | - | - | - | r | - | - | r | - | - | - | - | - | r | r | - | un | 6.1 ± 1.3 | 126 ± 52 |
| *Pinnularia brebisonii* (Kützing) Rabenhorst | - | - | - | - | - | - | - | - | u | - | u | - | - | u | r | 3 | dry | 6.9 ± 0.6 | 154 ± 38 |
| *Pinnularia divergens* (W. Smith) var. *media* Krammer | - | - | - | - | - | - | - | - | - | r | - | r | - | - | - | - | - | - | - |
| *Pinnularia dornii* Metzeltin | - | - | - | - | - | - | - | r | - | - | - | - | - | - | - | - | un | - | - |
| *Pinnularia frequentis* Krammer | r | u | - | r | - | r | - | r | - | r | - | u | r | r | r | - | - | 6.3 ± 1.2 | 136 ± 42 |
| *Pinnularia gibba* Ehrenberg | - | - | - | - | u | - | - | - | r | - | r | - | - | - | - | 3 | - | 6.1 ± 0.7 | 130 ± 49 |
| *Pinnularia grunowii* Krammer | - | r | - | - | r | r | - | - | - | r | - | - | - | u | r | - | un | 6.8 ± 0.5 | 149 ± 21 |
| *Pinnularia lata* (Brébisson) Rabenhorst | - | - | - | - | r | - | r | r | - | - | - | - | - | - | - | 2 | ae | - | - |
| *Pinnularia lundii* var. *linearis* Krammer | - | - | - | - | - | - | - | - | - | - | - | - | - | r | - | - | un | - | - |
| *Pinnularia macilenta* Ehrenberg | - | - | - | - | - | - | u | - | - | - | - | - | - | - | - | - | un | - | - |
| *Pinnularia microstauron* (Ehrenberg) Cleve | - | r | - | - | u | u | c | - | r | u | u | r | r | u | r | 3 | - | 6.2 ± 1.1 | 127 ± 40 |
| *Pinnularia neomajor* Krammer | - | r | - | - | - | - | - | - | - | - | - | - | - | - | r | - | un | - | - |
| *Pinnularia nodosa* (Ehrenberg) W. Smith | - | - | - | - | - | r | r | - | - | - | - | - | - | r | r | 2 | - | - | - |
| *Pinnularia notabilis* Krammer | - | - | - | - | - | - | - | - | - | - | - | - | - | u | r | - | un | 7.2 ± 0.3 | 162 ± 31 |
| *Pinnularia obscura* Krasske | r | - | - | c | u | r | - | r | u | u | - | r | - | u | - | 3 | dry | 5.3 ± 1.5 | 137 ± 29 |
| *Pinnularia perrirorata* Krammer and *P. silvatica* Petersen | u | u | c | f | u | r | - | u | u | u | - | u | r | r | u | - | un | 5.2 ± 1.3 | 115 ± 46 |
| *Pinnularia pseudogibba* Krammer | - | u | - | u | c | - | - | u | u | - | r | - | - | r | - | - | un | 5.2 ± 1.2 | 120 ± 41 |
| *Pinnularia rabenhorstii* var. *franconica* (Grun.) Krammer | - | - | - | - | - | - | - | - | - | - | - | - | - | r | - | - | un | - | - |
| *Pinnularia renata* Krammer | - | - | - | - | - | - | r | - | - | - | - | r | - | - | - | - | un | - | - |
| *Pinnularia rupestris* Hantzsch | - | r | r | - | - | - | u | c | r | r | - | - | - | - | - | 3 | - | 4.2 ± 1.0 | 92 ± 36 |
| *Pinnularia schoenfelderi* Krammer | - | r | u | u | u | u | r | u | u | u | r | u | - | u | u | - | un | 5.5 ± 1.4 | 116 ± 46 |
| *Pinnularia schroederii* (Hustedt) Krammer | r | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Pinnularia sinistra* Krammer | - | - | - | - | r | u | u | - | - | - | r | r | r | - | - | - | un | 4.0 ± 0.6 | 81 ± 26 |
| *Pinnularia stomatophora* (Grunow) Cleve | - | r | - | - | - | - | - | - | - | - | - | r | - | - | - | 2 | dry | - | - |
| *Pinnularia subcapitata* Gregory and *P. sinistra* Krammer | u | u | c | c | c | - | f | f | c | u | u | u | u | u | c | - | - | 5.6 ± 1.3 | 112 ± 46 |
| *Pinnularia subcommutata* Krammer | - | - | - | - | - | u | - | - | - | r | - | - | - | r | - | - | un | 7.4 ± 0.7 | 165 ± 49 |
| *Pinnularia subgibba* Krammer | - | - | - | - | - | - | - | - | - | - | u | - | r | u | u | - | un | 7.1 ± 0.2 | 158 ± 26 |
| *Pinnularia subinterrupta* Krammer et Schroeter | - | - | r | r | - | - | r | u | - | - | - | - | - | - | - | 1 | dry | - | - |
| *Pinnularia submicrostauron* Schroeter | - | - | - | - | - | - | u | r | u | - | - | - | - | - | - | - | un | 4.8 ± 0.4 | 62 ± 13 |
| *Pinnularia* cf. *subrupestris* Krammer | - | - | - | - | - | - | - | - | - | r | - | - | - | - | - | - | un | - | - |
| *Pinnularia viridiformis* Krammer | - | r | - | u | r | - | c | - | u | u | r | r | r | u | u | - | un | 5.8 ± 1.3 | 125 ± 41 |
| *Pinnularia viridis* (Nitzsch) Ehrenberg | - | - | - | - | u | r | r | - | - | r | r | - | - | r | r | 3 | - | 6.3 ± 1.0 | 124 ± 37 |
| *Pinnularia* spp. | - | r | - | - | r | r | - | - | r | - | - | u | - | - | u | - | - | - | - |

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| *Placoneis hambergii* (Hustedt) Bruder | - | - | - | - | - | r | - | - | - | - | - | - | - | u | u | 2 | dry | 7.2 ± 0.4 | 149 ± 31 |
| *Placoneis ignorata* (Schimanski) Lange-Bertalot | - | - | - | - | - | - | - | - | - | - | - | r | - | r | - | 4 | - | - | - |
| *Placoneis paraelginensis* Lange-Bertalot | - | - | - | r | - | c | - | - | r | u | r | r | r | r | r | - | - | 7.2 ± 1.0 | 169 ± 41 |
| *Planothidium lanceolatum* (Brébisson) Round et Bukhtiyarova *sensu lato* | u | u | - | r | u | f | u | u | u | f | c | f | f | c | c | 4 | - | 7.0 ± 0.7 | 161 ± 37 |
| *Psammothidium altaicum* Bukhtiyarova | - | - | - | u | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - |
| *Psammothidium bioretii* (Germain) Bukht. et Round | - | - | - | - | - | - | - | - | - | - | c | - | - | - | - | 3 | dry | 7.1 ± 0.2 | 189 ± 14 |
| *Psammothidium helveticum* (Hustedt) Bukht. et Round | - | u | u | c | f | u | r | - | c | u | c | - | - | c | - | 4 | - | 5.9 ± 1.0 | 120 ± 39 |
| *Psammothidum marginulatum* (Grunow) Bukht. et Round | f | u | - | u | - | - | - | - | - | r | r | - | - | r | u | 2 | dry | 5.9 ±1.3 | 138 ± 14 |
| *Psammothidium oblongellum* (Oestrup) Van de Vijver | - | c | r | r | - | - | - | - | - | - | - | r | - | r | - | 3 | - | 6.1 ± 0.9 | 157 ± 37 |
| *Psammothidium subatomoides* (Hust.) Bukht. et Round | - | r | - | - | r | - | - | - | - | r | - | r | c | u | c | 2 | - | 7.1 ± 0.4 | 151 ± 26 |
| *Puncticulata comta* (Ehrenberg) Håkansson | - | - | - | - | - | - | - | - | - | - | r | - | - | - | - | 4 | - | - | - |
| *Reimeria sinuata* (Gregory) Kociolek et Stoermer | - | - | - | - | - | r | - | - | - | u | c | u | c | u | u | - | un | 7.3 ± 0.4 | 176 ± 29 |
| *Reimeria uniseriata* Sala, Guerrero et Ferrario | - | - | - | - | - | - | - | - | - | - | - | - | - | - | r | - | un | - | - |
| *Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot | r | - | - | - | - | r | - | - | - | u | - | u | c | - | - | 4 | - | 7.1 ± 0.5 | 180 ± 19 |
| *Rhopalodia gibba* (Ehrenberg) O. Muller | - | - | - | - | - | - | - | - | - | - | - | - | r | - | - | 5 | - | - | - |
| *Sellaphora psedopupula* (Krasske) Lange-Bertalot | - | - | - | - | r | u | - | - | - | - | r | - | - | - | - | - | un | - | - |
| *Sellaphora pupula* (Kützing) Mereschkovsky *sensu lato* | - | - | - | - | - | - | - | - | r | u | r | - | r | u | - | 3 | - | 6.9 ± 0.5 | 155 ± 29 |
| *Sellaphora seminulum* (Grunow) Mann | - | - | - | - | - | c | - | - | - | u | - | r | u | - | r | 3 | - | 7.3 ± 0.6 | 170 ± 38 |
| *Sellaphora stauroneioides* (Lange-Bertalot) nov comb. | - | - | - | - | u | - | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Sellaphora* sp. | - | - | - | - | - | - | - | - | - | - | - | - | - | r | - | - | - | - | - |
| *Stauroneis anceps* Ehrenberg *sensu lato* | - | r | - | u | u | u | u | - | u | u | r | u | u | u | u | 3 | - | 6.5 ± 1.0 | 141 ± 33 |
| *Stauroneis gracillima* Hustedt | - | - | - | - | - | r | - | - | - | - | - | - | - | - | - | - | un | - | - |
| *Stauroneis kriegeri* Patrick | - | - | - | - | - | r | - | - | - | r | u | r | u | r | u | 3 | - | 7.4 ± 0.5 | 184 ± 37 |
| *Stauroneis legumen* (Ehrenberg) Kützing | - | - | - | u | u | - | - | - | - | - | - | - | - | - | - | 3 | - | 4.9 ± 1.2 | 124 ± 34 |
| *Stauroneis obtusa* Lagerstedt | - | - | - | - | - | u | - | r | - | - | - | - | - | - | - | 3 | dry | - | - |
| *Stauroneis phoenicenteron* (Nitzsch) Ehrenberg | - | - | - | - | u | - | r | - | - | u | - | u | r | u | u | 3 | - | 6.8 ± 0.5 | 143 ± 24 |
| *Stauroneis smithii* Grunow | - | - | - | - | r | - | - | - | - | - | - | - | - | r | - | 4 | - | - | - |
| *Stauroneis thermicola* (Petersen) Lund | - | u | r | u | u | u | - | r | r | r | - | r | r | r | u | 3 | dry | 6.4 ± 1.4 | 148 ± 43 |
| *Stauroneis thermicola* fo. *lanceolata* (Hust.; Hust.) Hust. | - | r | - | - | r | - | - | - | r | - | - | - | r | r | - | - | un | 6.6 ± 0.5 | 161 ± 24 |
| *Staurosirella lapponica* (Grunow) Williams et Round | - | - | - | - | - | - | - | - | - | - | - | r | - | - | - | 4 | - | - | - |
| *Staurosirella martyi* (Héribaud) Morales et Manoylov | - | - | - | - | - | - | - | - | - | - | - | r | - | - | - | 4 | - | - | - |
| *Stephanocyclus menenghiniana* (Kützing) Skabitschevsky | - | - | - | - | - | - | - | - | - | r | u | r | - | r | - | 4 | - | 7.1 ± 0.3 | 181 ± 18 |
| *Stephanodiscus hantzschii* Grunow | - | - | - | - | - | - | r | - | - | - | - | - | - | - | - | 5 | - | - | - |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Surirella angusta* Kützing | - | u | - | - | r | c | - | - | r | u | u | u | c | c | u | 4 | - | 7.1 ± 0.4 | 159 ± 28 |
| *Surirella brebisonii* Krammer et Lange-Bertalot | - | - | - | - | r | u | - | - | - | u | r | u | c | c | u | 4 | un | 7.3 ± 0.4 | 153 ± 24 |
| *Surirella helvetica* Brun | - | - | - | - | - | - | - | - | - | - | - | u | u | - | - | - | un | - | - |
| *Surirella linearis* W. M. Smith | - | - | - | u | - | r | - | - | - | - | r | - | - | - | - | 3 | - | - | - |
| *Surirella minuta* Brébisson | - | - | - | - | u | u | - | - | r | u | u | - | - | - | - | 4 | - | 6.8 ± 0.7 | 144 ± 33 |
| *Surirella ovalis* Brébisson | - | - | - | - | - | - | - | - | - | - | c | - | r | - | - | 4 | - | 7.2 ± 0.2 | 190 ± 15 |
| *Surirella roba* Leclercq | f | c | - | - | u | - | r | - | u | r | - | - | - | c | c | 2 | un | 6.5 ± 0.5 | 138 ± 20 |
| *Surirella splendida* (Ehrenberg) Kützing | - | - | - | r | - | - | u | - | - | - | - | - | r | - | - | 4 | - | 5.9 ± 1.4 | 174 ± 14 |
| *Surirella tenera* Gregory | - | u | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | - |
| *Synedra ulna* (Nitzsch) Ehrenberg | c | r | - | - | - | - | r | - | - | - | r | c | c | f | c | 4 | - | 7.0 ± 0.5 | 150 ± 20 |
| *Tabellaria flocculosa* (Roth) Kützing | - | u | u | u | u | - | f | c | u | u | c | - | r | c | - | 2 | - | 5.8 ± 1.1 | 123 ± 54 |

Table 2. Basic statistics of diatom taxa per sample, sampling site and locality and Bray-Curtis similarity index between and within localities and within different substrate types. Minimum (min), maximum (max), mean, standard deviation (SD), number of objects (n).

| | min | max | mean | SD | n |
|---|---|---|---|---|---|
| number of diatom taxa | | | | | |
| sample | 3 | 72 | 27 | 14 | 161 |
| sampling site | 28 | 109 | 59 | 19 | 30 |
| locality | 53 | 128 | 82 | 21 | 15 |
| Bray-Curtis index | | | | | |
| between localities | 0.00 | 0.711 | 0.192 | 0.127 | 12080 |
| within localities | 0.04 | 0.839 | 0.465 | 0.155 | 760 |
| epilithon | 0.00 | 0.776 | 0.187 | 0.160 | 1176 |
| epixylon | 0.00 | 0.615 | 0.150 | 0.127 | 253 |
| epiphyton | 0.00 | 0.774 | 0.248 | 0.155 | 351 |
| epipelon | 0.00 | 0.786 | 0.228 | 0.144 | 1830 |

Table 3. Chemical and physical parameters of the sampling sites (upstream headwaters site = US, downstream site near confluence with larger stream =DS) in 15 streams in the Elbsandsteingebirge of Bohemian Switzerland National Park. Results of the Kruskal-Wallis test between Bray-Curtis similarity index of different reaches of the stream are indicated as: ns = p>0.05. * = p<0.05. ** = p<0.01. *** = p<0.001.

| | locality | pH (upstream/ downstream) | | conductivity (US/DS, $\mu S \cdot cm^{-1}$) | | temperature (US/DS, °C) | | species similarity index (US vs. DS) |
|---|---|---|---|---|---|---|---|---|
| 1 | Studený potok | 6.27 | 6.20 | 136 | 135 | 9.2 | 9.5 | *** |
| 2 | Dolnožlebský p. | 6.31 | 6.31 | 184 | 155 | 12.2 | 14.1 | *** |
| 3 | Suchá Bělá | 5.31 | 4.43 | 53 | 70 | 6.1 | 5.8 | *** |
| 4 | Písečná rokle | 3.30 | 3.95 | 147 | 148 | 9.1 | 9.3 | * |
| 5 | Kachní potok | 6.13 | 5.91 | 135 | 118 | 7.9 | 8.7 | * |
| 6 | Ponova louka | 7.30 | 8.30 | 130 | 229 | 11.5 | 9.4 | *** |
| 7 | Hluboký důl | 4.74 | 6.20 | 78 | 181 | 9.0 | 9.1 | *** |
| 8 | Mlýnská rokle | 3.62 | 4.39 | 82 | 52 | 5.1 | 5.5 | *** |
| 9 | Červený potok | 6.71 | 5.22 | 146 | 53 | 9.5 | 7.8 | ** |
| 10 | Studenec | 6.54 | 6.66 | 184 | 109 | 15.4 | 16.0 | *** |
| 11 | Doubický potok | 7.28 | 6.95 | 202 | 175 | 13.9 | 11.3 | ns |
| 12 | Bílý potok | 7.21 | 7.61 | 154 | 153 | 14.6 | 14.5 | ns |
| 13 | Brtnický potok | 7.36 | 7.50 | 190 | 173 | 15.3 | 15.7 | ns |
| 14 | Vlčí potok | 7.35 | 6.94 | 162 | 152 | 5.8 | 6.9 | ** |
| 15 | Panský potok | 7.84 | 7.02 | 229 | 125 | 7.3 | 7.4 | *** |

## FIGURE LEGENDS

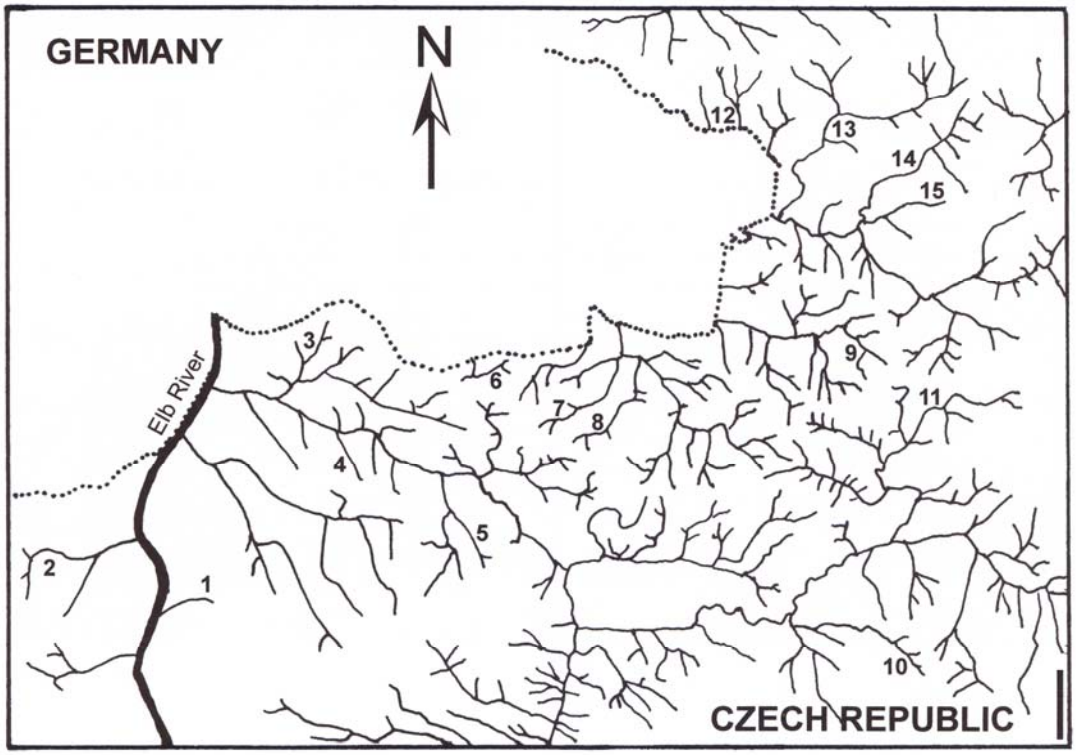
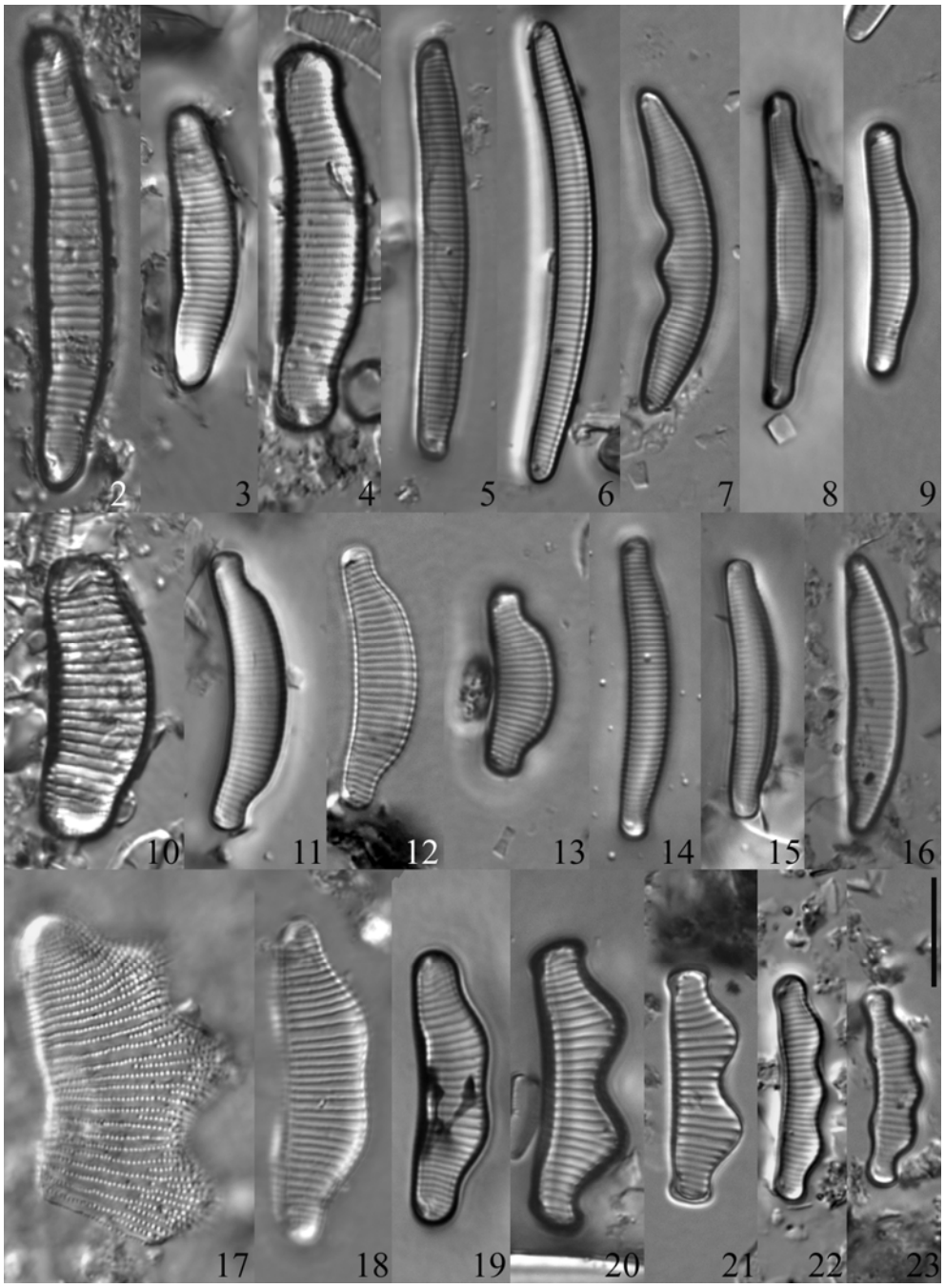
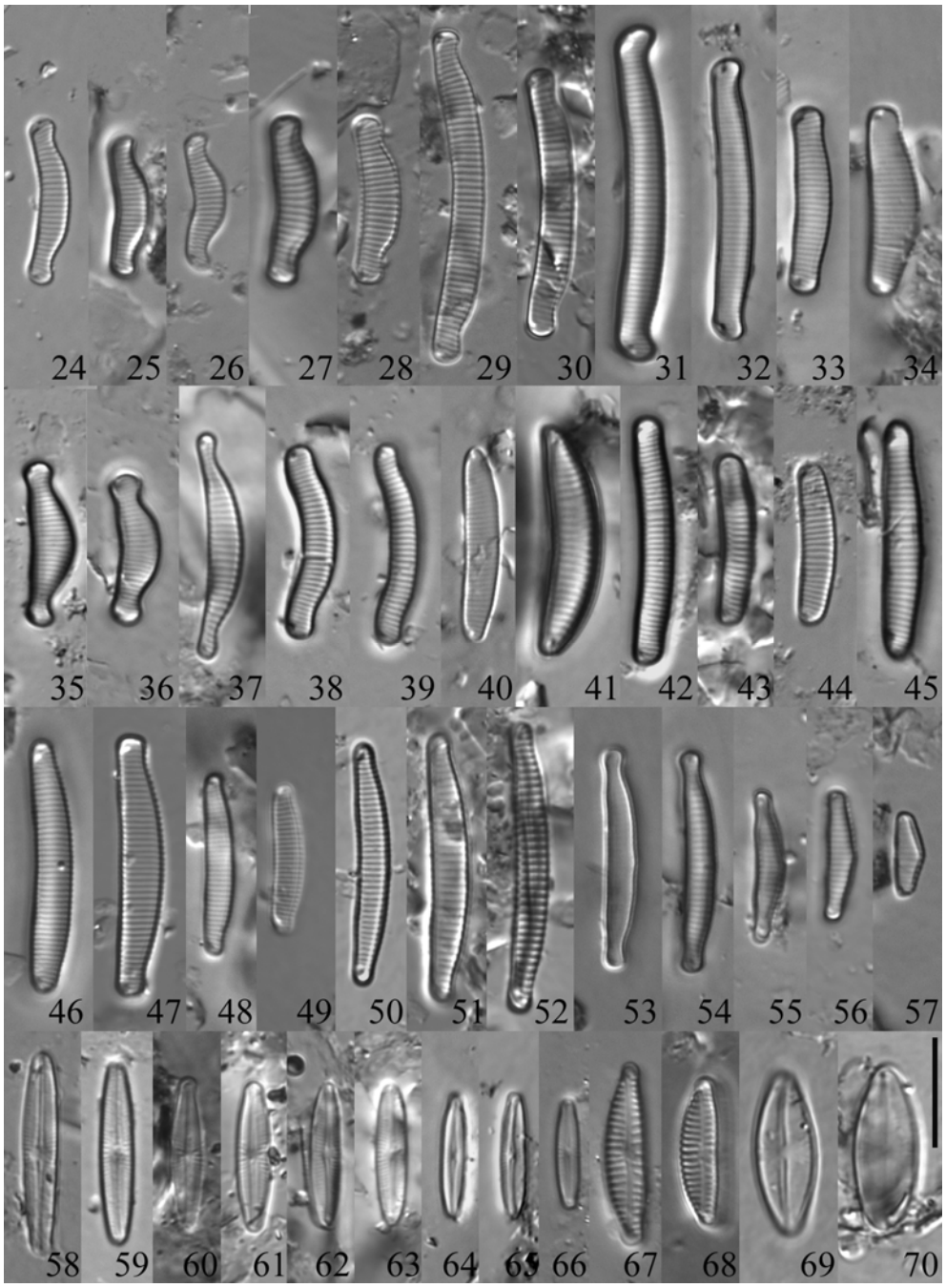


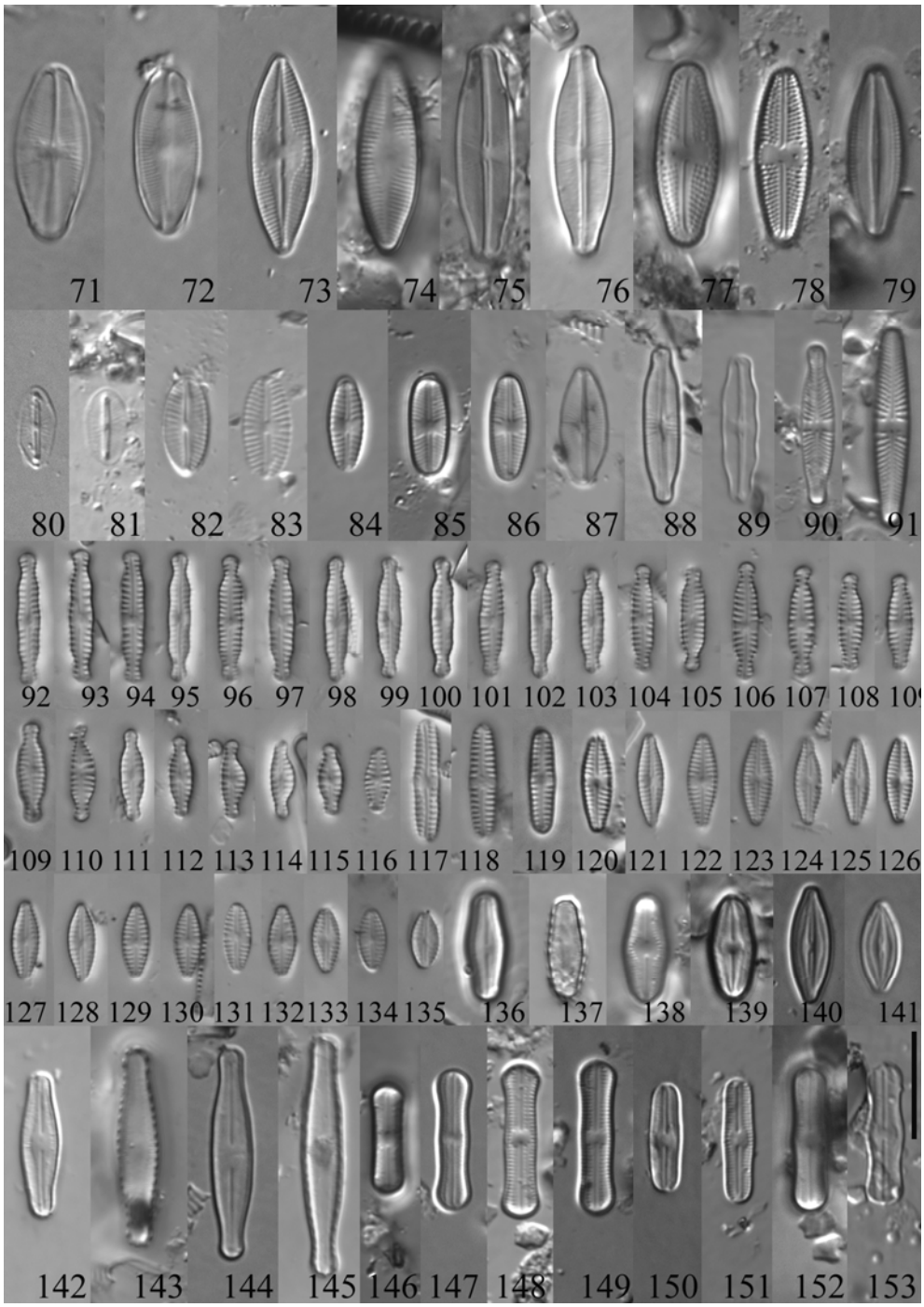

Figure 1. Map of the study area. Geographic locations of the 15 headwater streams sampled in the Elbsandsteingebirge Region. 1-Studený potok, 2-Dolnožlebský p., 3-Suchá Bělá, 4-Písečná rokle, 5-Kachní potok, 6-Ponova louka, 7- Hluboký důl, 8-Mlýnská rokle, 9-Červený potok, 10-Studenec, 11-Doubický potok, 12-Bílý p., 13-Brtnický p., 14-Vlčí p., 15-Panský p. Scale bar = 1.5 km.




Figures 2-23. *Eunotia* species from the Elbsandsteingebirge Region. Figs 2, 3. *Eunotia* cf. *minor*. Fig. 4. *Eunotia* cf. *praerupta*. Fig. 5. *Eunotia valida*. Figs 6, 7. *Eunotia bilunaris*. Figs 8, 9. *Eunotia implicata*. Fig. 10. *Eunotia curtagrunowii*. Figs 11-13. *Eunotia ursamaioris*. Figs 14, 15. *Eunotia fennica*. Fig. 16. *Eunotia incisa*. Fig. 17. *Eunotia tetraodon*. Fig. 18. *Eunotia islandica*. Fig. 19. *Eunotia circumborealis*. Figs 20, 21. *Eunotia bigibba*. Figs 22, 23. *Eunotia muscicola* var. *tridentula*. Scale bar = 10 µm.

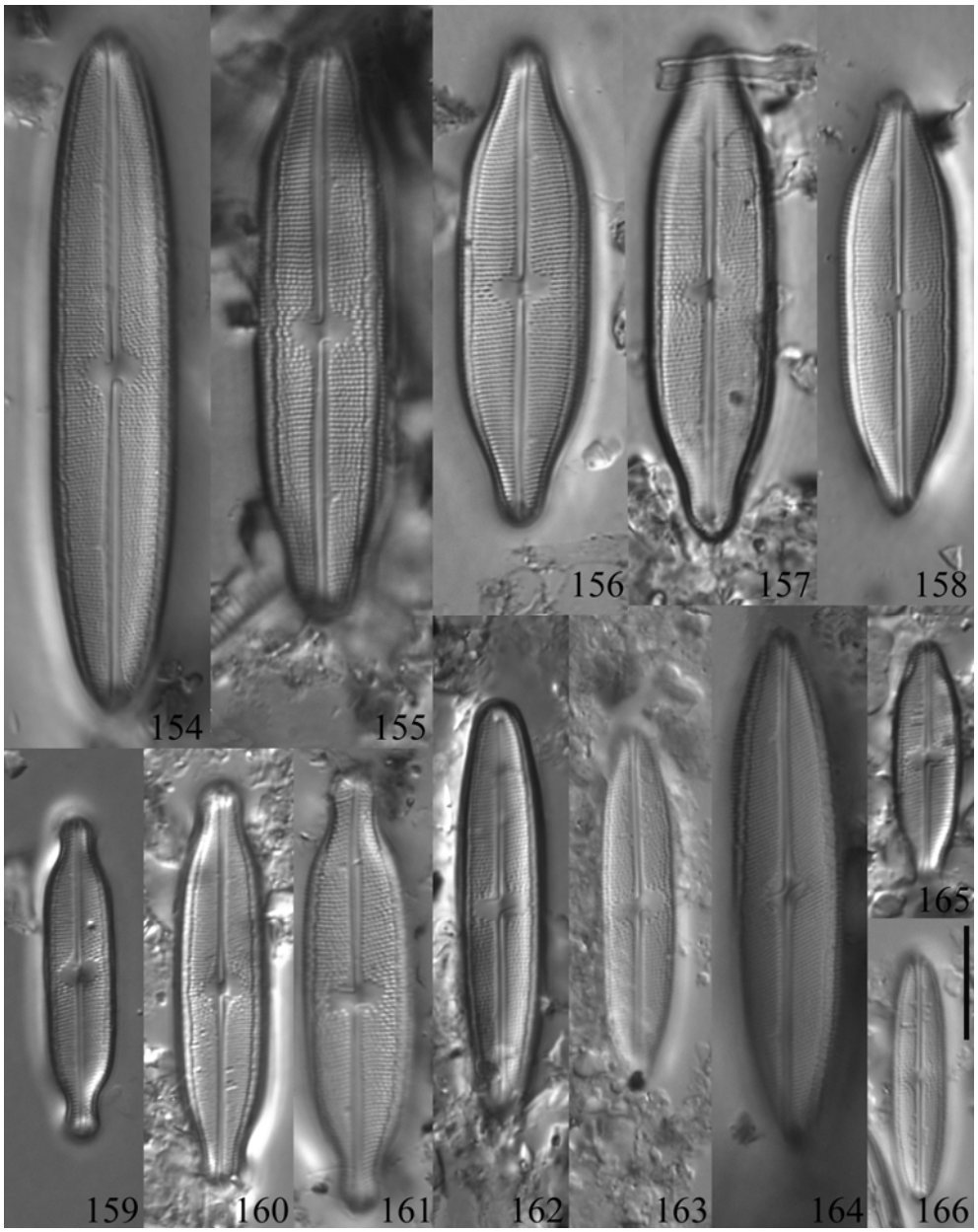



Figures 24-70. *Eunotia* species and other interesting species from the Elbsandsteingebirge Region. Figs 24-26. *Eunotia exigua*. Figs 27-30. *Eunotia tenella*. 31-33. *Eunotia nymanniana*. Fig. 34. *Eunotia levistriata*. Figs 35, 36. *Eunotia mesterii*. Fig. 37. *Eunotia arculus*. Figs 38, 39. *Eunotia steineckei*. Fig. 40. *Eunotia subarcuatoides*. Fig. 41. *Eunotia* sp. Figs 42-44. *Eunotia botuliformis*. Fig. 45. *Eunotia rhomboidea*. Fig. 46. *Eunotia* sp. Fig. 47. *Eunotia* sp. 48, 49. *Eunotia paludosa*. Fig. 50. *Eunotia groenlandica*. Figs. 51, 52. *Eunotia fallax*. Figs. 53-54. *Eunotia microcephala*. Figs. 55-57. *Eunotia trinacria*. Figs 58-61. *Encyonopsis* sp. 1. Figs 62-66. *Encyonopsis* sp. 2. Figs 67, 68. *Encyonema perpusillum*. Figs 69, 70. *Psammothidium altaicum*. Scale bar = 10 µm.

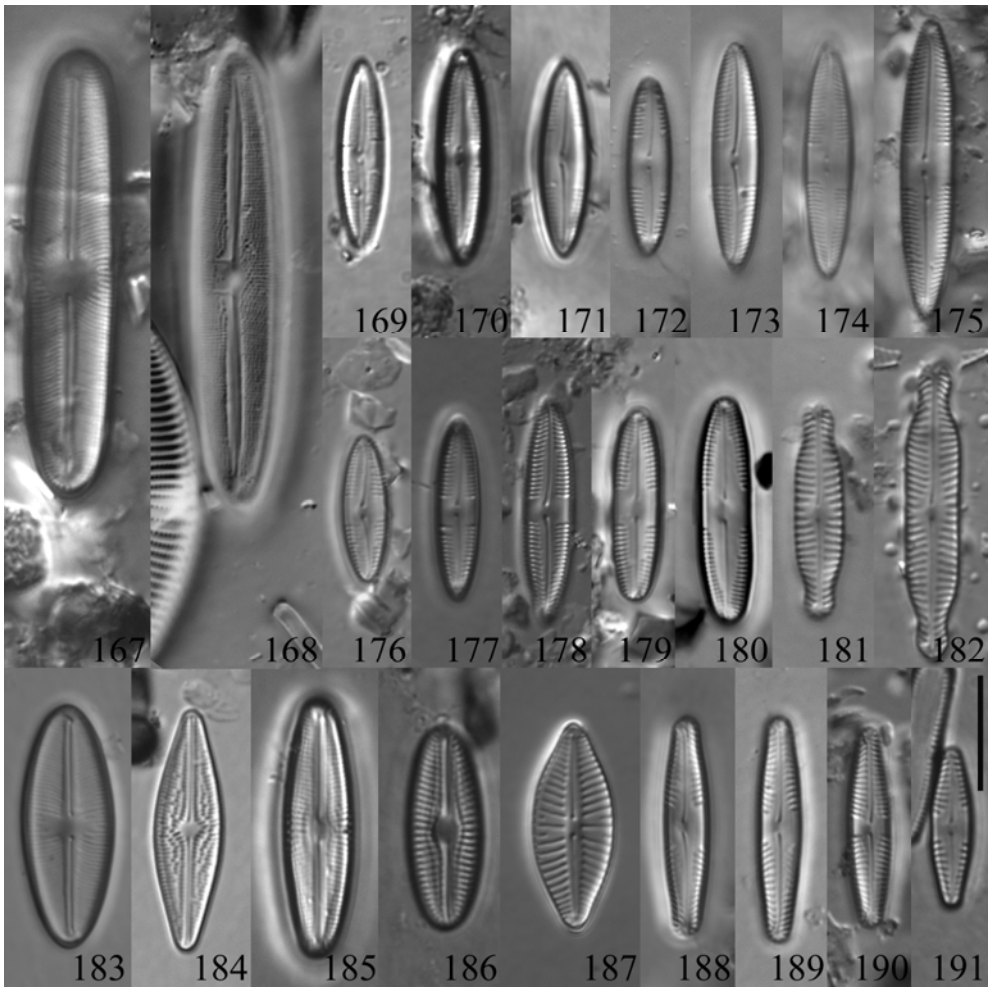



Figures 71-153. Finely striated diminutive taxa from the Elbsandsteingebirge Region. Figs 71, 72. *Eucocconeis laevis*. Figs 73, 74. *Nupela lapidosa*. Figs 75, 76. *Sellaphora stauroneioides*. Fig. 77. *Luticola acidoclinata*. Fig. 78. *Luticola mutica*. Fig. 79. *Fallacia vitrea*. Figs 80, 81. *Mayamaea atomus* var. *permitis*. Figs 82, 83. *Mayamaea recondita*. Fig. 84. *Sellaphora seminulum*. Figs 85, 86. *Eolimna minima*. Fig. 87. *Adlafia minuscula*. Fig. 88. *Adlafia bryophila*. Fig. 89. *Navicula tridentula*. Fig. 90. *Stauroneis thermicola*. Fig. 91. *Stauroneis thermicola* f. *lanceolata*. Figs 92-103. *Chamaepinnularia soehrensis*. Size diminution series. Figs 104-107. *Chamaepinnularia soehrensis* var. *capitata*. Figs 108-116. *Chamaepinnularia tongatensis*, size diminution series. Figs 117-119.

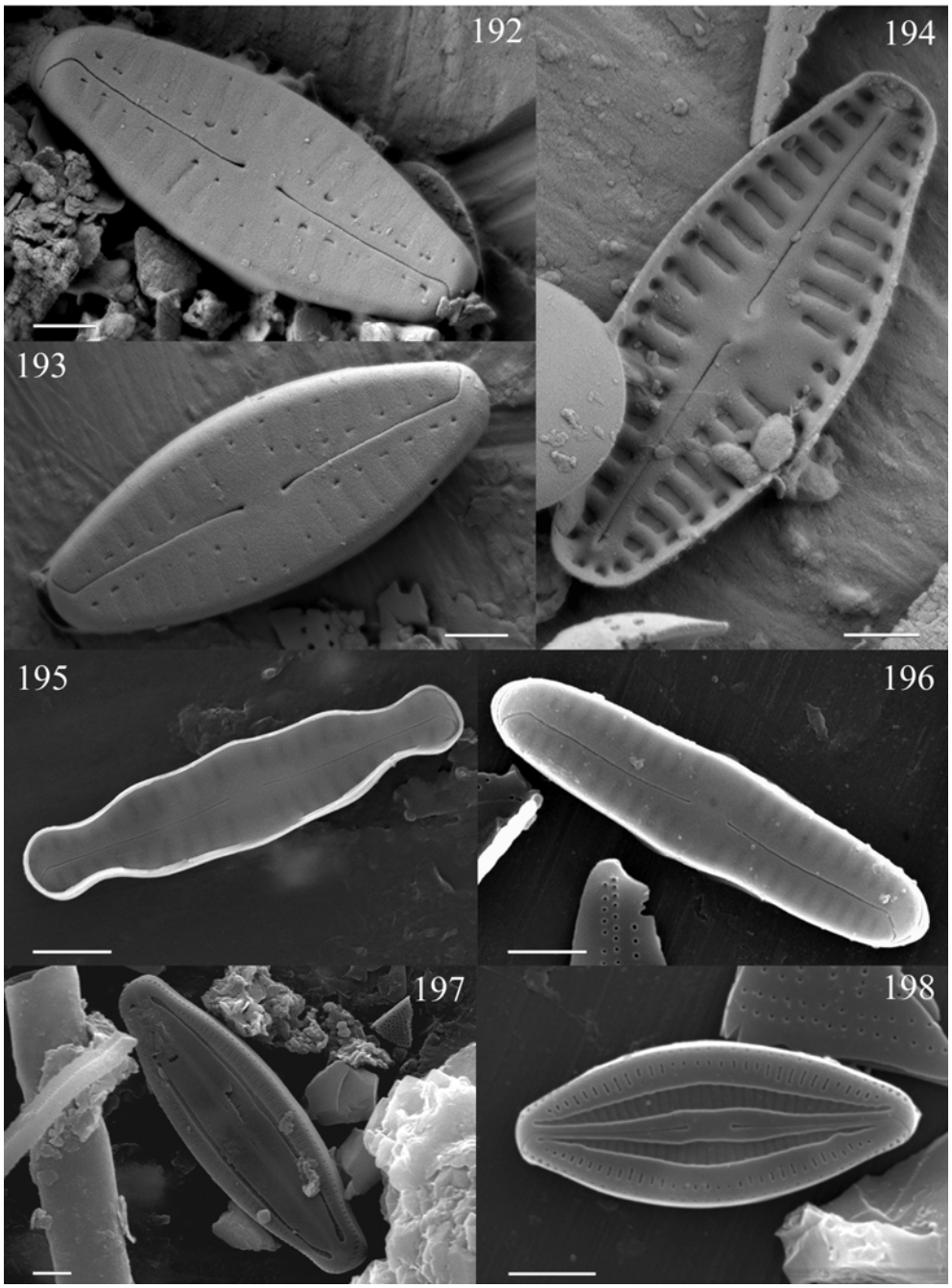
*Chamaepinnularia mediocris*. Figs 120-135. *Chamaepinnularia rexii*, size diminution series. Figs 136, 137. *Diadesmis gallica*. Figs 138, 139. *Diadesmis perpusilla*. Figs 140, 141. *Microcostatus krasskei*. Figs 142-145.*Diadesmis laevissima*. Fig. 146. *Diadesmis contenta*. Figs 147-149. *Diadesmis paracontenta*. Figs 150, 151. *Diadesmis brekkaensis*. Figs 152, 153. *Diadesmis biceps*. Scale bar = 10 µm.



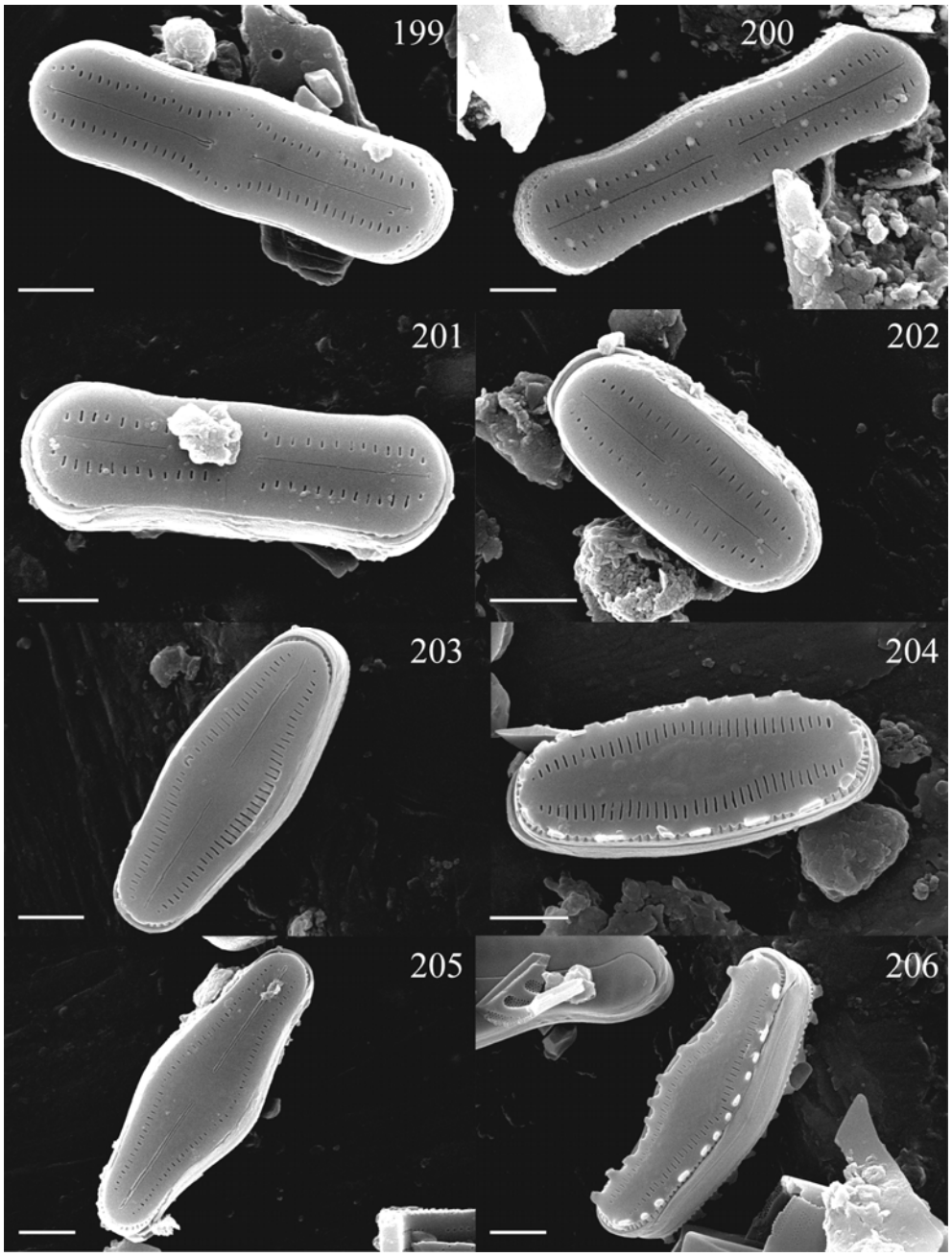

Figures 154-166. *Neidium* species from the Elbsandsteingebirge Region. Fig. 154. *Neidium hercynicum*. Figs 155-158. *Neidium* cf. *ampliatum*. Fig. 159. *Neidium longiceps*. Fig. 160. *Neidium* sp. Fig. 161. *Neidium affine* var. *amphirhynchus*. Fig. 162. *Neidium bisulcatum*. Fig. 163. *Neidium* cf. *hercynicum*. Fig. 164. *Neidium carterii*. Fig. 165. *Neidium* cf. *hercynicum*. Fig. 166. *Neidium alpinum*. Scale bar = 10 µm.




Figures 167-191. Naviculoid taxa from the Elbsandsteingebirge Region. Fig. 167. *Cavinula variostriata*. Fig. 168. *Frustulia weinholdii*. Figs 169-171. *Caloneis aerophila*. Figs 172-178. *Caloneis vasileyevae*. Figs 179, 180. *Caloneis fontinalis*. Figs 181, 182. *Pinnularia subinterrupta*. Fig. 183. *Cavinula lapidosa*. Fig. 184. *Brachysira brebissonii*. Fig. 185. *Muelleria* cf. *gibbula*. Fig. 186. *Diploneis fontanella*. Fig. 187. *Placoneis hambergii*. Figs 188-191. *Pinnularia perrirorata*. Scale bar = 10 µm.




Figures 192-198. SEM views of finely striated taxa. Figs 192-194. *Chamaepinnularia rexii*. Fig. 195. *Chamaepinnularia soehrensis*. Fig. 196. *Chamaepinnularia mediocris*. Fig. 197. *Fallacia vitrea*. Fig. 198. *Microcostatus krasskei*. Figs 192-194: scale bars = 1 µm. Figs 195-198: scale bars = 2 µm.




Figures 199-206. SEM views of *Diadesmis* species. Fig. 199. *Diadesmis biceps*. Figs 200, 201. *Diadesmis paracontenta*. Fig. 202. *Diadesmis contenta* var. *paralella*. Fig. 203. *Diadesmis* cf. *perpusilla*. Fig. 204. *Diadesmis gallica*. Figs 205, 206. *Diadesmis laevissima*. Scale bars = 2 µm.

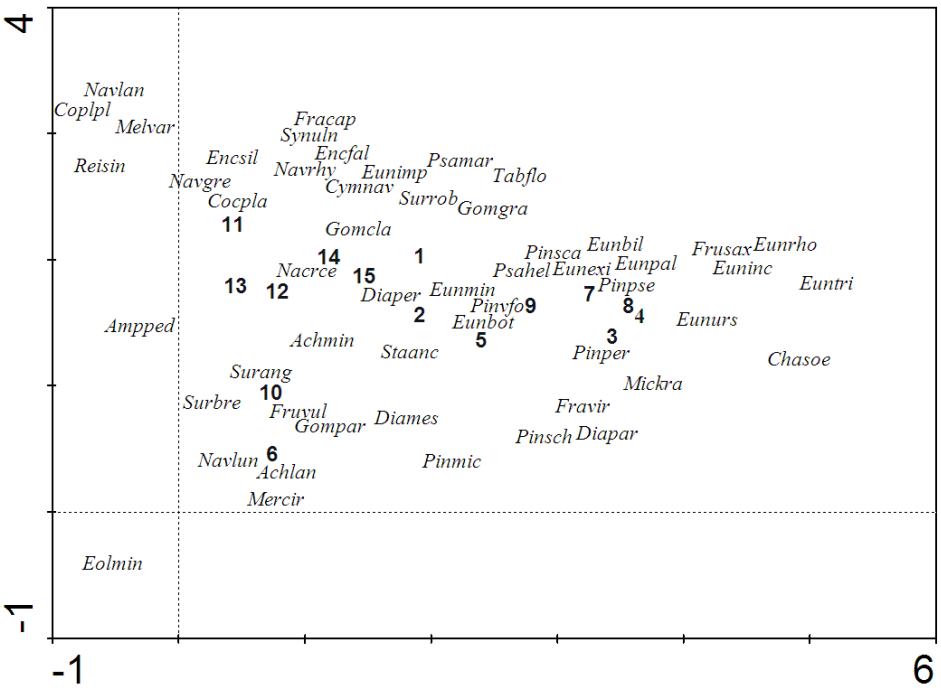



Fig. 207. DCA ordination biplot of 53 most important diatom taxa and streams as supplementary variables in the ordination space of the first (13.3%) and the second axes (5.0%). Ampped = *Amphora pediculus*. Achlan = *Planothidium lanceolatum sensu lato*. Achmin = *Achnanthidium minutissimum sensu lato*. Chasoe = *Chamaepinnularia soehrensis*. Cocpla = *Cocconeis placentula*. Cocplpl = *C. placentula* var. *placentula*. Cymnav = *Cymbopleura naviculiformis*. Diames = *Diatoma mesodon*. Diapar = *Diadesmis paracontenta*. Diaper = *D. perpusilla*. Encfal = *Encyonopsis falaisensis*. Encsil = *Encyonema silesiacum* + *E. minutum*. Eolmin = *Eolimna minima*. Eunbil = *Eunotia bilunaris*. Eunbot = *E. botuliformis*. Eunexi = *E. exigua* + *E. tenella*. Euninc = *E. incisa*. Eunimp = *E. implicata*. Eunmin = *E. minor*. Eunpal = *E. paludosa*. Euntri = *E. trinacria*. Eunrho = *E. rhomboidea*. Eunurs = *E. ursamaioris*. Fracap = *Fragilaria capucina*. Fravir = *Fragilariforma virescens*. Frusax = *Frustulia saxonica*. Fruvul = *F. vulgaris*. Gomcla = *Gomphonema clavatum*. Gomgra = *G. gracile*. Gompar = *G. parvulum*. Melvar = *Melosira varians*. Mercir = *Meridion circulare*. Mickra = *Microcostatus krasskei*. Navcrce = *Navicula cryptocephala*. Navgre = *N. gregaria*. Navlan = *N. lanceolata*. Navlun = *N. lundii*. Navrhy = *N. rhynchocephala*. Pinmic = *Pinnularia microstauron*. Pinper = *P. perrirorata* + *P. silvatica*. Pinpse = *P. pseudogibba*. Pinsca = *P. subcapitata* + *P. sinistra*. Pinsch = *P. schoenfelderii*. Pinvfo = *P. viridiformis*. Psahel = *Psammothidium helveticum*. Psamar = *P. marginestriatum*. Reisin = *Reimeria sinuata*. Staanc = *Stauroneis anceps*. Surang = *Surirella angusta*. Surbre = *S. brebissonii*. Surrob = *S. roba*. Synuln = *Synedra ulna*. Tabflo = *Tabellaria flocculosa*.

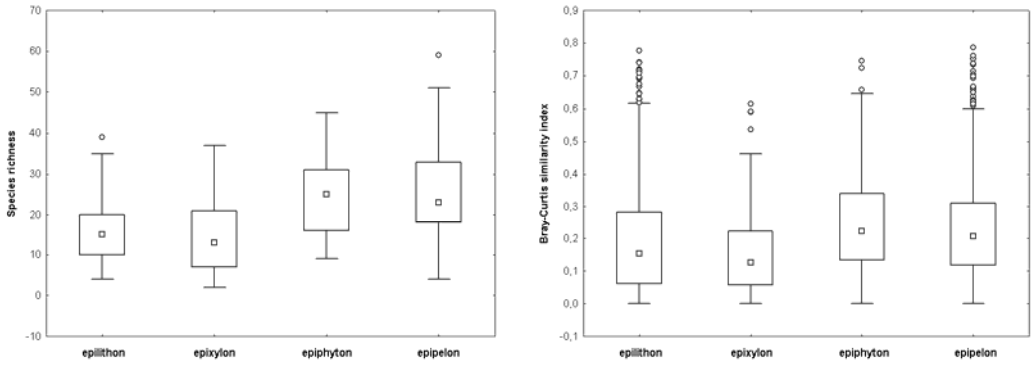



Figure 208. Box plot diagrams. Variation in species richness and Bray-Curtis similarity index in four microhabitats from 15 headwater streams. Both between-habitat pair-wise comparisons (Kruskal-Wallis test) were statistically significant at $p < 0.001$.