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ON THE WIDE ECOLOGICAL NICHE OF *FRAGILARIA REICHELTII* (BACILLARIOPHYCEAE)

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Abstract: Ombro- and oligominerotrophic acid bogs and spring environments in Lower Silesia are reported for the first time as uncommon habitats of occurrence of *Fragilaria reicheltii* (Voigt) Lange-Bert. Characteristics of these habitats including water chemistry, plant cover and dominant diatom species are given. The morphological traits of cells of the organism from the two habitats are described. The present results are compared with those from the literature, using multivariate statistical methods.

Key words: Bacillariophyta, *Fragilaria reicheltii*, morphology, ecology, Sudety Mts, Lower Silesia, Poland

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INTRODUCTION

Fragilaria reicheltii (Voigt) Lange-Bert. (= *Centronella reicheltii* Voigt, *Centronella rostafinskii* Wol.) is most frequently reported from lowland limnetic environments (Krieger 1927; Wysocka 1959a, b; Marvan & Hindák 1989). Very little is known about its occurrence in lotic environments and it is not known from mountain oligominerotrophic peat bogs. It is usually recorded as a component of the pelagic zone, although a periphytic habit of growth in its life cycle has been reported (Wysocka 1959b). *F. reicheltii* was denoted a eurytopic organism inhabiting waters with different trophic levels; oligotrophic (Wojciechowski 1964), slightly eutrophic (Marvan & Hindák 1989) as well as eutrophic (Wysocka 1959b). In a study of the periodicity of this diatom, it showed a eurythermic character also (Półtoracka 1964). Marvan and Hindák (1989) referred to this diatom as a Nordic species gradually expanding its range southward. Morphological cellular traits, mainly angle measures, arm dimensions and the shape of the central part of the frustule, were often dealt with in the literature cited.

Records of *F. reicheltii* in Polish lakes have been frequent since the pioneer work of Seligo (1908). In his key, Ernest (1936) reported the diatom in Poland from freshwater and the Baltic Sea. The diatom was found in small lakes near Gdańsk (Schultz 1928), in many lakes of the Pojezierze Mazurskie lakelands in northeast Poland (Czeczuga 1959; Wysocka 1959a; Półtoracka 1964; Bohr 1965; Chudyba 1975, 1979) and in lakes of the Wielkopolska region (Wawrzyniak 1923; Dąmbska *et al.* 1978; Koczorowska & Wetula 1984; Burchardt *et al.* 1987). It was also given from a number of lakes in the Kujawy region (Wołoszyńska 1913). Records of *F. reicheltii* from Lublin district in eastern Poland were given by Wojciechowski (1964). Schröder (1923) reported the organism from lakes in Lower Silesia near Wrocław. Records of this diatom from Polish rivers are rare; it was given from the Warta River at downstream localities by Bennin (1923).

Fragilaria reicheltii has been designated a cosmopolite (Germain 1981; Lange-Bertalot 1991). World records include Western Andes lakes in the Chilean Lake District (Thomasson 1963), some lakes of Djursland in Italy (Foged 1963) and in western Slovakia (Marvan & Hindák 1989).

The present work reports a more extended ecological range for *F. reicheltii*, with acidic high-altitude extremely oligominerotrophic and ombrotrophic bogs as well as mountain and submontane springs and lowland eutrophic rivers.

MATERIALS AND METHODS

Algae samples from which *Fragilaria reicheltii* was recorded were collected during investigations of the periphyton of peat bogs in the Karkonosze Mts in 1996 and 1997. Periphyton samples were also collected from the Ślęża River at its montane springs and throughout its profile during 1996. The study area lies in southwest Poland (Fig. 1).

The Upa peat bog, site 1, is an ombrotrophic mire located at alt. 1440 m; it originates mainly from rain and in part from underground water. Samples from this bog were collected from a group of shallow (10–30 cm) erosional depressions around which the plant cover consisted mainly of *Carex rostrata* Stokes, *C. limosa* L. *Drepanocladus exanulatus* (B.S.G.) Warnst., *Gymnocolea inflata* (Huds.) Dum. and *Sphagnum lindbergii* Schimp. *ex* Lindb., *S. cuspidatum* Ehrh. *ex* Hoffm., *S. majus* (Russ.) C. Janes.

The peat bog named Pielgrzymy, site 2, is an extremely oligotrophic fen, situated on a Karkonosze Mts slope at 1100 m, developed through the action of slowly running waters of mountain springs. Algal samples from this bog were collected from small depressions near which the vegetation was dominated by *Sphagnum riparium* Angstr., *S. fallax* (Klinggr.) Klinggr., *Calamagrostis villosa* (Chix) J. F. Gemel., *Equisetum palustre* L., *Carex nigra* (L.) Reichard, *C. canescens* L., *Oxycoccus quadripetalus* Gilib. and *Vaccinum uliginosum* L.

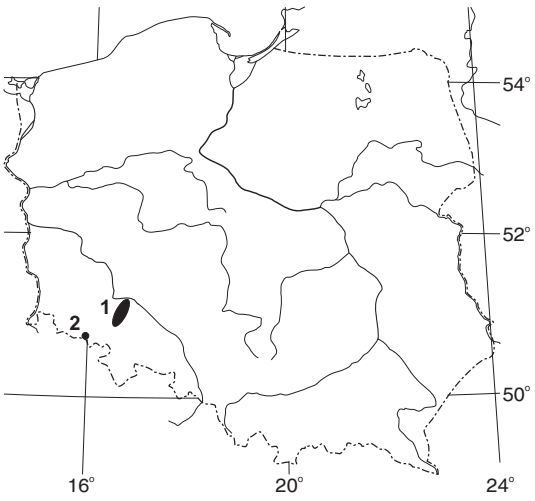

Fig. 1. *Fragilaria reicheltii* study sites. 1 – Ślęża River, 2 – Upa and Pielgrzymy peat bogs.

The Ślęża River is a left tributary of the Odra River originating from the submontane district of the Sudety Mts at 520 m (Fig. 1). The river was investigated at sites 3–6 for sessile algae. Springs of the river were found in an alder forest, passing downstream through an agricultural area where the vegetation on the bank sides was dominated by *Phalaris arundinacea* L., *Urtica dioica* L., *Glyceria aquatica* L. and *Phragmitis communis* Trin.

Samples for water analysis were collected and analyzed according to the methods reported by Golterman *et al.* (1978) and Moor and Chapman (1986). Algal samples were macerated in chromic acid and hydrogen peroxide in order to prepare permanent slides of diatoms (Barber & Haworth 1981). Slides were prepared by spreading 50 µl of the macerated material (at three times the concentration of the field samples) on a 22 mm square cover slip which after desiccation was inverted on a glass slide with Eljaszew resin (Pająk 1986) as the closing medium. Angles between arms were measured at the point of intersection of the long axes, and arm length was measured from the tips to the beginning of the geniculate bends (Wysocka 1959b). Samples of 100 cells were randomly chosen from each of the habitats for measurements and statistical analysis of cell morphology. Morphological data on cells of *F. reicheltii* reported by Wysocka (1959), Wojciechowski (1964) and Marvan and Hindák (1989) were used to construct a matrix for principal component analysis (Statgraphics ver. 5.0) in order to compare present and previously reported results. This matrix gave the mean values of angle size, arm length, breadth of arms of cells, range of angle size and range of arm length. The angle size range was obtained by subtracting the mean small angle value from the mean large one, and the arm length range was obtained by subtracting the mean length of the short arm from the mean length of the long one.

RESULTS AND DISCUSSION

Light microscopy revealed considerable populations of *Fragilaria reicheltii* in the studied material; four to eight individuals appeared in each microscopic field (at 400×). The diatoms *Eunotia exigua* (Bréb.) Raben., *E. bilunaris* (Ehr.) Mills, *Pinnularia interrupta* W. Smith and *P. sudetica* (Hilse) M. Peragallo were associated with *F. reicheltii* in peat bogs. In spring habitats, *Eunotia exigua* (Bréb.) Raben., *Achnanthes minutissima* Kütz. and *A. lanceolata* (Bréb.) Grun. were the

Table 1. Physicochemical properties of water in the studied habitats of *Fragilaria reicheltii*. Values are means of three replicates. SD – standard deviation.

Habitats	Ślęża River				Peat bogs			
	spring		estuary		Upa		Pielgrzymy	
Parameters	mean	SD	mean	SD	mean	SD	mean	SD
pH	8.08	0.08	7.56	0.11	3.48	0.12	4.67	0.30
Electric conductivity μS cm^{-1}	146.00	4.64	533.70	14.04	36.50	3.00	27.50	0.71
$N\text{-}NH_4^+$ $mg.l^{-1}$	0.00	0.00	2.45	0.15	0.61	0.17	0.21	0.08
$N\text{-}NO_3^-$ $mg.l^{-1}$	1.17	0.07	0.80	0.06	0.58	0.09	0.15	0.11
$P\text{-}PO_4^{3-}$ $mg.l^{-1}$	0.01	0.00	0.37	0.05	0.007	0.00	0.06	0.00
Na^+ $mg.l^{-1}$	14.41	0.52	54.90	1.84	0.49	0.84	2.29	0.27
K^+ $mg.l^{-1}$	2.38	0.16	37.71	1.45	0.19	0.08	0.39	0.04
Ca^{2+} $mg.l^{-1}$	23.45	0.14	46.76	1.13	1.11	0.14	1.18	0.20
Mg^{2+} $mg.l^{-1}$	3.50	0.262	0.32	0.57	0.39	0.05	0.24	0.11

most dominant, while downstream the diatoms *Navicula viridula* Kütz., *Gomphonema parvulum* (Kütz.) Grun,, *G. olivaceum* (Lyngb.) Kütz, *Nitzschia linearis* W. Smith and *N. palea* (Kütz.) W. Smith predominated.

F. reicheltii was recorded in the Karkonosze Mts, in the submontane area of the Sudety Mts and the lowland of Lower Silesia; earlier it was given from lowlands of Central Europe (Marvan & Hindák 1989) and North America (Krammer & Lange-Bertalot 1991). The elevation of the localities in the present study, reaching 1400 m, shows the wide range of niches of the diatom. *F. reicheltii* was found as a periphyton component of peat bogs and of the fast water of the Ślęża River, indicating that it passes through a periphytic phase during its life cycle. A similar sedentary phase of the species on stabile substrata has been reported (Wysocka 1959b). On the other hand, it has been reported often as a planktonic component of limnetic environments (e.g., Wojciechowski 1964; Krammer & Lange-Bertalot 1991). Data on the occurrence of the species of lotic habitats are sparse. Bennin (1923) reported it from downstream localities of the Warta River in Poland.

The studied habitats varied in their physicochemical properties. The Upa peat bog is more acidic, with higher values of nitrogen and magnesium and less phosphorus, Na^+ and K^+, than Pielgrzymy. On the other hand, the peat bog waters had much lower pH and electrical conductivity, and less mineral constituents, than the river habitats in springs and near the estuary (Table 1). The variety of trophic statuses of these habitats give an indication of the eurytopic character of the organism, a feature frequently emphasized (Półtoracka 1964; Marvan & Hindák 1989). Unfortunately, most published data do not give the pH of the studied waters (Wysocka 1959b; Wojciechowski 1964) but, being lowland lakes, these areas should be less acidic than the peat bogs covered here. Moreover, Polish lakes with some dystrophic features have been reported as habitats of *F. reicheltii* (Wysocka 1959b; Wojciechowski 1964). Wojciechowski (1964) gave no data on water pH but referred to the similarity of Bialskie and Ferlejowskie lakes, which are close to each other and formed by the same geologic events. Wojciechowski (1967) gave pH 7.7 for Ferlejowskie lake, supporting the expectation that dystrophic Polish lakes are less acidic than peat bogs.

No completely symmetrical cells, that is, those having equal angles and arms, were observed throughout the whole investigation. Wojciechow-

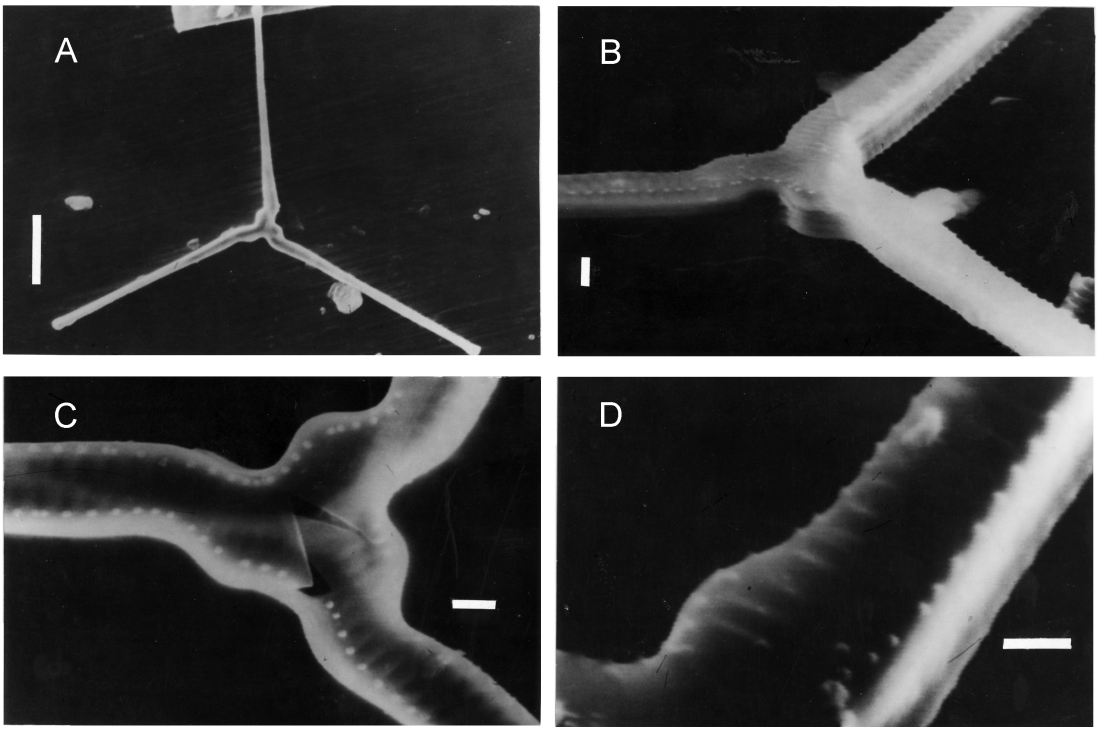

Fig. 2. SEM of *Fragilaria reicheltii* from Upa peat bog. Scale bars = 10 μm in A and 1 μm in B, C and D.

Table 2. Morphological characteristics of *Fragilaria reicheltii* cells. SD – standard deviation, n – number of cases.

Habitat / Cell traits	River				Peat bog			
	n	range	mean	SD	n	range	mean	SD
Angle size (°)								
large angle	91	121–146	127	2.60	92	124–143	128	3.05
medium angle	91	117–128	121	3.21	92	119–128	120	4.12
small angle	91	96–118	112	2.85	92	100–115	112	2.94
Arm length (μm)								
long arm	89	24–32	30.2	1.12	91	25–32	29.8	0.06
medium arm	89	23–31	28.4	1.86	91	22–30	28.0	0.92
short arm	89	22–30	25.9	0.96	91	24–30	26.1	1.21
Arm width (μm)	100	1.8–2.0	1.9	0.05	100	1.8–2.0	1.9	0.06
No. of striae/10 μm	100	19–22			100	20–22		

ski (1964) had the same finding, but Półtoracka (1964) mentioned that such cases were recorded, though rarely. There were 8 and 9 cells with equal angles per 100 cells in bog and river samples, respectively, and 9 and 11 cells with equal arms (28, 29 and 30 μm) per 100 cells in bog and river samples, respectively.

Morphologically the cells of bog and river habitats were largely similar (Table 2). Cells with different angle sizes were characterized by large angles of 121–146°, medium angles of 117–128° and small angles of 96–118° (Table 2). Cells with different arm lengths had long arms in the range of 24–32 μm, medium arms of 23–31 μm and short arms of 22–30 μm. Breadth of arms ranged from 1.8 to 2.0 μm, and the number of striae/10 μm ranged from 19 to 22. Cells were provided with spines (Fig. 2).

Cell morphology data reported here and in the literature was compared by principal component analysis (Fig. 3). This comparison indicated that the river and bog specimens were more related to each other than to those from the other populations. The population of Šašatin-Stráže reservoir (Marvan & Hindák 1989) seemed to resemble our specimens most, and the population reported from Bialskie lake least (Wojciechowski 1964). The differences between our populations and that of Bialskie lake involved the mean values of arm length and angle size, as well as the angle size range. The mean arm length values of the cells from our river samples were 30.2, 28.4 and 25.9 μm for the long, medium and short arms, respectively, much less than the measures of the Bialskie lake population, which were 39.2, 37.0 and 35.5 μm. Mean angle sizes from our river sample cells were 127, 121, and 112° for the large, medium and small angles, respectively, compared to 122, 120 and 118° given for Bialskie lake (Wojciechowski 1964); the latter also represent a narrower range than we found.

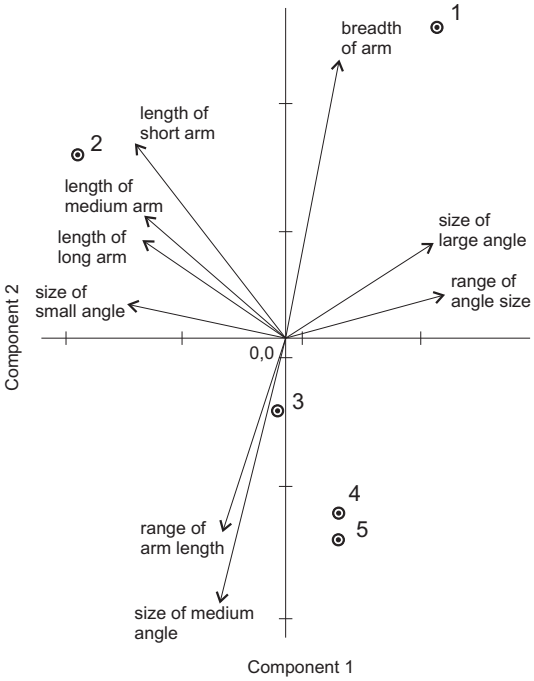

Fig. 3. Principal component analysis of cell trait data of *Fragilaria reicheltii* from this study and from literature. Numbers 1, 2 and 3 refer to data from Wysocka (1959), Wojciechowski (1964) and Marvan and Hindák (1989), respectively. Numbers 4 (river) and 5 (peat bog) refer to our specimens.

Table 3. Participation of arm pairs in different angles of *Fragilaria reicheltii*.

Habitat / Arm pairs	River (n = 80)			Peat bog (n = 83)		
forming the angles	Short & long	Short & medium	Medium & long	Short & long	Short & medium	Medium & long
large angle	48 (60%)	32 (40%)	0	51 (62%)	32 (48%)	0
medium angle	19 (24%)	8 (10%)	53 (66%)	21 (25%)	11 (13%)	51 (62%)
small angle	18 (22%)	39 (49%)	23 (29%)	19 (23%)	44 (53%)	20 (24%)

The Sukiel lake population also differed from our specimens in angle size and breadth of arms. The angle range of our specimens, 112–128°, is narrower than the data from Sukiel lake, 111–132°. The arms of our cells were thinner (mean 1.9 μm) than those from Sukiel lake (mean 2.3 μm) (Wysocka 1959b).

Participation of arm pairs in forming different angles (Table 3) showed that the long arm shared the large angle in 60.00% (river) and 66.44% (bog) of the cells. The medium arm shared the medium angle in 76.25% (river) and 74.70% (bog) of the cells. The short arm shared the small angle in 71.25% (river) and 75.90% (bog) of the cells. Marvan and Hindák (1989) generalized that in most cases the large, medium and small angles were involved the long, medium and short arms, respectively. This largely agrees with the present results, but the 60% and 66.44% figures for the large angle are too low to speak of 'most cases.'

It appears, therefore, that the ecological range of *F. reicheltii* now extends to the uplands, including the highly acidic habitats of peat bogs and fast-running streams. This feature should be included in the diagnosis of this diatom.

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