ALGOFLORA AND VASCULAR FLORA OF A LIMESTONE SPRING IN THE WARTA RIVER VALLEY

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ABSTRACT

Qualitative analysis of algae, including microhabitats and vascular vegetation in a spring niche, together with basic physical and chemical characteristics is presented. 175 diatom taxa as well as taxa of macroalgae and vascular plants were determined in the spring niche, and the community types were defined. Seasonal variability of diatom communities was observed. The influence of a flood as a catastrophe on the community of diatoms and macroalgae was noticed.

KEY WORDS: spring diatoms, macroalgae, vascular plants, and environmental preferences.

INTRODUCTION

From among as many as 250 springs few were inventoried in the Krakowsko-Wieluńska Upland in 1967 and 1968 (Kleczkowski 1972) and some had been examined algologically. Algae of the region were investigated by Skalska (1966a, b), Skalna (1969, 1973) and Kubik (1970). The water gap of the Warta River in the Częstochowska Upland was studied by Waszkiewicz (1999), and the springs of the Pilica river by Kadłubowska (1964).

The examined spring is situated in the old riverbed of the Warta River, in the northern part of the Krakowsko-Wieluńska Upland in Działoszyn, 3 km east from the border of the Załęczański Landscape Park.

The article presents the results of studies on communities of algae in microhabitats, in association with patches of vascular vegetation colonising them. Additionally the type of communities occurring in the spring is defined. Spring vegetation is an element of central Poland's plant cover, which is poorly explored. Fragmentary findings deal with localities of plant species associated with spring habitats and offer descriptions of the occurring vegetation (Kucharski and Filipiak 1999).

Based on qualitative and quantitative diatom analysis, the differentiation within three microhabitats of the spring-niche communities has been determined. To determine the habitat character, the indicator value for trophic state and pH (Van Dam, Mertens and Sinkeldam 1994) has been attributed to the defined taxa.

STUDY AREA

The Warta River at the latitude of Działoszyn exemplifies a large natural upland and lowland river, abounding both in islands at different stages of formation and overgrowing, and in old river beds of different age. The landscape is rich in karst springs, concentrated in the Warta valley, as well as defluent springs flowing from sands (Olaczek and Czyżewska 1986).

The examined spring is situated 500 meters south of the Działoszyn-Grądy-Łazy road. Geographic co-ordinates of this spring are: longitude 18°54' east and latitude 51°06' north. The spring flows out at the foot of the slope (12 m high; gradient 52.2°). Slope aspect is 28.8° southwest.

The water-bearing layer consists of massy and platy limestone, marls and Rauracin. Spring water flows out close to the Warta old riverbed. As a result of headward erosion, the niche is slightly receded towards the slope. The spring is natural and not used (Dynowska 1983). The bottom is sandy with infrequent rock pieces of limestone origin.

The water flowing from the spring is transparent; the fluvial flow is 6.47 l/s. Water temperature in the spring ranges between 8.6 and 10.3°C (Fig. 1); pH: 6.99 and 7.4 (Fig. 2); electrolyte conductivity: 511 and 728 μS (Fig. 3). The water level in the examined spring fluctuates between 11.5 and 29 cm, and reached 93 cm on 24 April 2001 during the flood-stage on the Warta River.

The properties described were different in April 2001 when waters from the Warta River flew into the old river

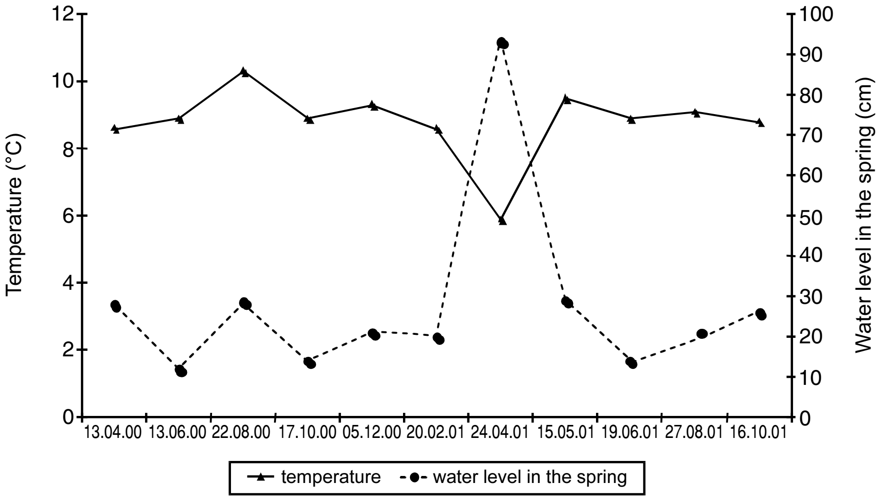

Fig. 1. Temperature and water level in the spring in individual months.

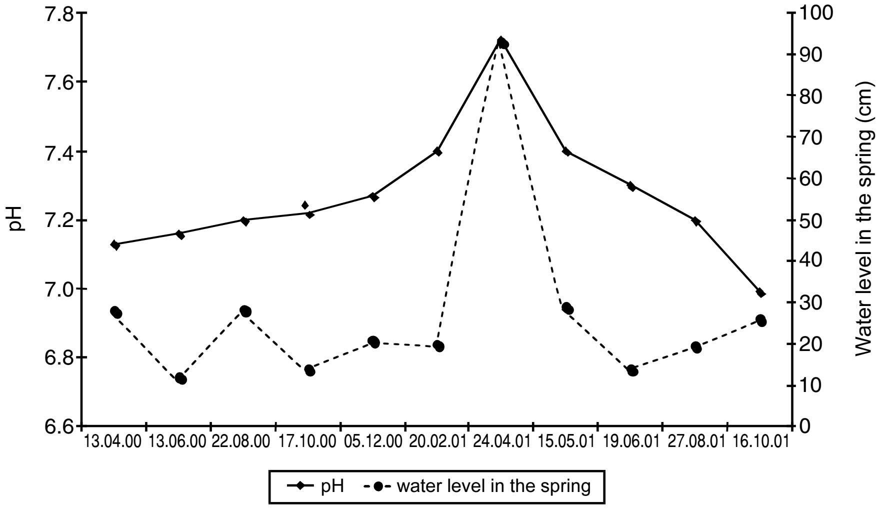

Fig. 2. pH and water level in the spring in individual months.

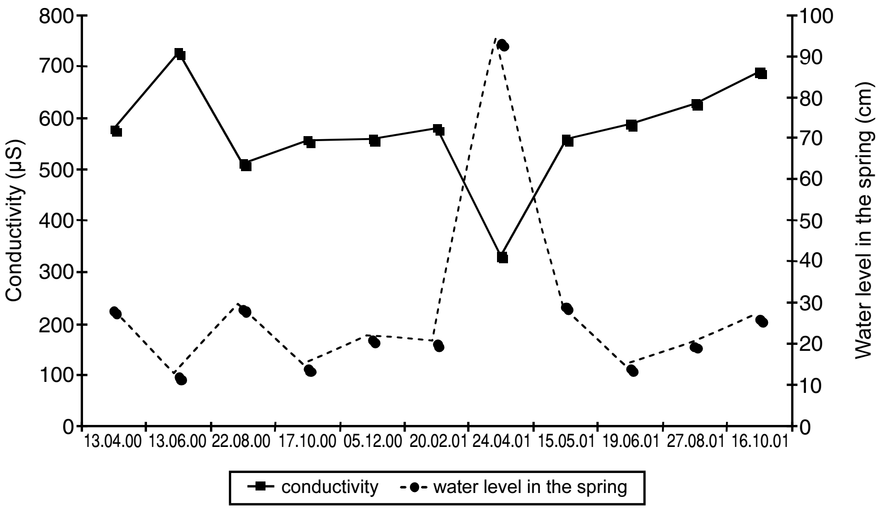

Fig. 3. Conductivity and water level in the spring in individual months.

bed. Water temperature was 5.9°C, pH 7.72, and conductivity 331 µS (Figs 1-3).

METHODS

Samples for algological studies were collected from a spring situated in the Warta riverbed near Działoszyn. Three sampling sites were established: spring outflow (1.1), one meter downstream from the outflow (1.2), and a stone on the left bank, ca. 0.5 meter from the outflow (1.3).

Sampling in sites 1.1 and 1.2 was carried out every two months: 13 April; 13 June; 22 Aug.; 17 Oct.; 02 Dec. 2000; 20 Feb.; 15 May; 19 June; 27 Aug.; 16 Oct. 2001 (samples were not collected in April 2001 due to the excessively high river stage – flood in the Warta river basin), while in site 1.3, sampling was conducted on 13 June, 22 Aug., 17 Oct. 2000, 19 June, 27 Aug., 16 Oct. 2001.

TABLE 1. Chemical properties of water collected from the spring.

Day	17 Sept. 1998	18 Oct. 2000
pH	7.5	7.22
Dissolved oxygen mg O_2 /dm^3	4.6	–
Nitrates mg NO_3/l	6.0	6.63
Organic nitrogen mg N org/l	0.2	0.61
Sulfates mg SO_4/dm^3	40	33
Phosphorus mg P/dm^3	0.06	0.08
Sodium mg Na/dm^3	14.2	–
Potassium mg K/dm^3	3.62	–
Calcium mg Ca/dm^3	94	100.5
Magnesium mg Mg/dm^3	5.6	6.0
Chlorine mg Cl/dm^3	–	27.2
Total hardness mg $CaCO_3$/dm^3	260	275
Alkalinity to methyl orange mgCaCO/dm^3	–	221

The benthos was collected with a pipette from the surface layer of the substrate, at the outflow, one meter from the outflow and from the stone. Occurring filamentous algae were also collected. Samples were kept in a refrigerator for no longer than three days for purposes of observation and classification of live material. Temperature, water pH, electrolyte conductivity, water level in the spring, and water level in the Warta were measured at time of sampling.

The specification of chemical properties in the spring is based on the water analysis performed in the laboratory of the Province Inspectorate of Environmental Protection in Łódź on 17 Sept. 1998 and 18 Oct. 2000 (Table 1).

The spring niche was charted in the scale of 1:20 on each event (Fig. 4), and the vegetation distribution was presented on map.

Macroalgae were observed and determined live, using microscope magnification 12.5×10 and 12.5×40. All slides were viewed whole in parallel lines from left to right. The samples were then fixed in 40% formalin. In order to obtain clean diatom frustules, the collected benthic material was digested. To make permanent slides, the diatom material was mounted in synthetic resin Naphrax (NBS).

Microscopic slides were examined by MB-30 microscope, using magnification 12.5×10, 12.5×40 and 12.5×100. The slides were viewed and examined using three lines located at 1/4, 1/2 and 3/4 of the width of the cover glass 20×20 mm.

Diatoms were classified following Krammer and Lange-Bertalot (1986, 1988, 1991a, b), Lange-Bertalot (2001), Lange-Bertalot and Metzeltin (1996), macroalge by Starmach (1968, 1972, 1977), whereas vascular plants using Szafer et al. (1986).

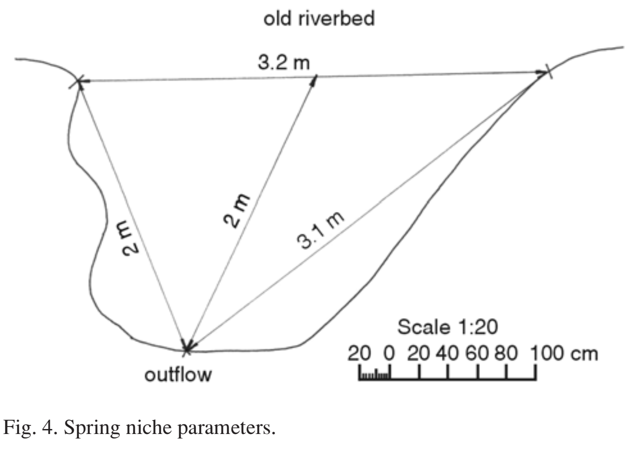

Fig. 4. Spring niche parameters.

The following issues were considered in the analysis of diatom communities on the basis of permanent slides:

– quantitative differentiation expressed in percentage participation of individual species;

– occurrence constancy according to the V-grade Braun-Blanquet scale: 81-100% (V class), 61-80% (IV class), 41-60% (III class), 21-40% (II class), 1-20% (I class); for site 1.1 and site 1.2 based on 10 samples, for site 1.3 based on 6 samples;

– dominant species with the participation above 5% individuals, subdominant species 2-5%, influents 1-2%, accessory and alien species below 1% (Trojan 1975);

– the Kulczyński similarity index was used to determine degree of similarity of the communities in individual months (Kawecka and Eloranta 1994):

$$K= (c/2)\ (1/a+1/b)$$

a – number of species in community A; b – number of species in community B; c – number of species common for both communities.

To the identified diatom taxa, indicatory values determining their tolerance to trophic state (TS), pH, based on Van Dam et al. (1994) checklist were attributed:

– TS 1 – oligotraphentic, 2 – oligo-mesotraphentic, 3 – mesotraphentic, 4 – meso-eutraphentic, 5 – eutraphentic, 6 – hypereutraphentic, 7 – oligo- to eutraphentic (hypereutraphentic);

– pH 1 – acidobiontic, 2 – acidophilus, 3 – circumneutral, 4 – alkaliphilous, 5 – alkalibiontic, 6 – indifferent;

0 – marked taxa with undetermined indicator value.

RESULTS

The studied spring is characterized by low, stabile annual water temperature, their high conductivity; water effluents from marvel rocks are medium hard with high calcium concentration, with appearing gain of organic nitrogen during the period of the study.

In 26 samples 208 taxa of diatoms were determined. In site 1.1., 174 taxa of diatoms were determined. The taxa that occur exclusively in this place were: *Achnanthes ploenensis*, *Campylodiscus hibernicus*, *Cyclotella stelligera*, *Cymbella aspera*, *C. cistula*, *Gomphonema tenue*, *Hippodonta hungarica*, *Navicula rostellata*, *Nitzschia pellucida* (Table 2). In site 1.2., 191 taxa were determined. The taxa that occur exclusively in site 1.2 were: *Achnanthes nodosa*, *Caloneis leptosoma*, *Cymbella amphicephala*, *C. microcephala*, *C. proxima*, *Diatoma mesodon*, *Diploneis ovalis*, *Eunotia soleirolii*, *Gomphonema productum*, *Luticola nivalis*, *Nitzschia sigmoidea*, *N. sinuata*, *Pinnularia gibba*, *P. legumen*, *Surirella biseriata*, *S. linearis* (Table 2). In site 1.3., 172 taxa were identified. The taxa found exclusively in this place were: *Achnanthes rechtensis*, *Mayamea excelsa*, *Navicula capitatoradiata*, *N. veneta* (Table 2). For these three sampling sites 150 taxa were common.

In site 1.1, the number of taxa gradually decreased from 89 in April 2000 to 65 in Dec. 2000. The number of taxa increased between Feb. 2001 and June 2001, when it reached its maximum level of 110 (Fig. 5). In site 1.2, the

TABLE 2. List of diatom taxa identified in this spring niche.
A – constancy class for species in site 1.1; B – constancy class for species in site 1.2; C – constancy class for species in site 1.3.
TS – trophic state (Van Dam et al. 1994); pH (Van Dam et al. 1994); 0 – unspecified

Taxa	A	B	C	TS	pH
Achnantheiopsis delicatula (Kutzing) Lange-Bertalot	I	I	II	0	5
Achnantheiopsis dubia (Grunow) Lange-Bertalot	V	V	V	0	0
Achnanthes biasolettiana var. *biasolettiana* Grunow	III	III	IV	0	0
Achnanthes biasolettiana var. *subatomus* Lange-Bertalot	I	I	II	3	4
Achnanthes bioretti Germain	IV	V	V	3	3
Achnanthes chlidanos Hohn & Hellerman	I		I	0	0
Achnanthes clevei var. *bottnica* Cleve	III	IV	IV	0	0
Achnanthes conspicua Mayer	IV	IV	III	7	3
Achnanthes hungarica (Grunow) Grunow	III	III	III	6	4
Achnanthes lauenburgiana Hustedt	II	I	I	2	3
Achnanthes nodosa Cleve		I		0	0
Achnanthes ploenensis Hustedt	I			4	4
Achnanthes rechtensis Leclerq			I	1	3
Achnanthes rossii Hustedt	I	II	I	1	3
Achnanthidium minutissimum (Kutzing) Czarnecki	V	V	V	7	3
Achnanthidium minutissimum var. *affinis*	V	IV	IV	0	4
Adlafia minuscula (Grunow) Lange-Bertalot	III	III	III	1	4
Amphora fogediana Krammer	III	IV	III	0	0
Amphora inariensis Krammer	V	V	V	1	0
Amphora libyca Ehrenberg	V	V	V	0	0
Amphora ovalis (Kützing) Kützing	III	V	V	5	4
Amphora pediculus (Kützing) Grunow	V	V	V	5	4
Anomoeoneis sphaerophora (Ehrenberg) Pfitzer	I	II		5	5
Aulacoseira granulata (Ehrenberg) Simonsen	II	I	I	5	4
Caloneis amphisbaena (Bory) Cleve	II	II	IV	5	4
Caloneis bacillum (Grunow) Cleve	III	III	III	4	4
Caloneis leptosoma (Grunow) Krammer		I		2	3
Caloneis silicula (Ehrenberg) Cleve	I	III	III	4	4
Campylodiscus hybernicus Ehrenberg	I			5	5
Cavinula lapidosa (Krasske) Lange-Bertalot		I	II	0	2
Cocconeis neodiminuta Krammer	IV	IV	IV	0	0
Cocconeis placentula var. *euglypta* (Ehrenberg) Grunow	IV	V	V	5	4
Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck	III	IV	II	5	4
Cocconeis placentula var. *placentula* Ehrenberg	V	V	V	5	4
Cocconeis placentula var. *pseudolineata* Geitler	II	III	III	0	0
Craticula cuspidata (Kützing) D.G. Mann	I	I	I	5	4
Cyclotella meneghiniana Kützing	III	III	IV	5	4
Cyclotella radiosa (Grunow) Lemmermann	III	III	II	5	4
Cyclotella stelligera Cleve & Grunow	I			0	0
Cymatopleura solea var. *apiculata* (Smith) Ralfs	II	I		0	0
Cymatopleura solea var. *solea* (Brebisson) Smith	III	III	II	5	4
Cymbella affinis Kützing		I	I	5	4
Cymbella amphicecephala Naegelt		I		2	3
Cymbella aspera (Ehrenberg) Peragello	I			7	4
Cymbella cistula (Ehrenberg) Kirchner	I			5	4
Cymbella cuspidata Kützing	I	I		0	3
Cymbella microcephala Grunow		I		4	4
Cymbella naviculiformis (Auerswald) Cleve	III	IV	III	5	3
Cymbella proxima Reimer		I		3	0
Diadesmis contenta (Grunow) D.G. Mann	III	I	II	7	4
Diadesmis perpusilla (Grunow) D.G. Mann	I		I	1	3
Diatoma mesodon (Ehrenberg) Kützing		I		3	3
Diatoma tenuis Agardh	I	III	I	5	4
Diatoma vulgaris Bory	II	II	II	4	5
Diploneis oblongella (Naegeli) Cleve-Euler	III	III	V	0	4
Diploneis oculata (Brebisson) Cleve	I	II	I	0	3
Diploneis ovalis (Hilse) Cleve		I		0	4
Encyonema minutum (Hilse) Mann		I	I	0	3
Encyonema silesiacum (Bleisch) Mann	IV	IV	IV	7	3
Epithemia adnata (Kützing) Brebisson	III	II	I	4	5
Eunotia bilunaris var. *bilunaris* (Ehrenberg) Mills	V	V	V	7	6
Eunotia bilunaris var. *mucophila* Lange-Bertalot & Nörpel	II	II		2	2
Eunotia incisa var. *incisa* Gregory	I	I	I	1	2
Eunotia minor (Kützing) Grunow	IV	II	III	0	2
Eunotia soleiriolii (Kützing) Rabenhorst		II		1	3

TABLE 2. Cont.

Taxa	A	B	C	TS	pH
*Fallacia insociabilis (*Krasske) D.G. Mann		I	II	3	3
Fallacia lenzii (Hustedt) Lange-Bertalot	II	III	II	0	4
Fragilaria biceps (Kützing) Lange-Bertalot		I	I	5	4
Fragilaria brevistriata Grunow	I	III	IV	7	4
Fragilaria capucina var. *vaucheriae* (Kützing) Lange-Bertalot	II	II	II	5	4
Fragilaria capucina var. *capucina* Desmazieres	II	II	I	3	3
Fragilaria capucina var. *gracilis* (Oestrup) Hustedt	III	IV	I	2	3
Fragilaria capucina var. *mesolepta* (Rabenhorst) Rabenhorst	II	II	III	0	0
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot	I	I	I	2	3
Fragilaria construens f. *binodis* (Ehrenberg) Hustedt	III	III	V	4	4
Fragilaria construens f. *construens* (Ehrenberg) Grunow	III	III	III	4	4
Fragilaria construens f. *venter* (Ehrenberg) Hustedt	IV	IV	V	4	4
Fragilaria delicatissima (Brebisson) Lange-Bertalot	I		I	3	3
Fragilaria dilatata (Brebisson) Lange-Bertalot		I	I	5	4
Fragilaria leptostauron var. *leptostauron* (Ehrenberg) Hustedt	V	V	V	4	4
Fragilaria nitzschioides Grunow		I	I	0	0
Fragilaria parasitica var. *parasitica* (Smith) Grunow	II	III	IV	4	4
Fragilaria parasitica var. *subconstricta* Grunow	II	IV	III	4	4
Fragilaria pinnata var. *intercedens* (Grunow) Hustedt	IV	IV	V	0	0
Fragilaria pinnata var. *pinnata* Ehrenberg	V	V	V	7	4
Fragilaria ulna var. *acus* (Kützing) Lange-Bertalot	III	I	IV	5	4
Fragilaria ulna var. *ulna* (Nitzsch) Lange-Bertalot	V	V	V	7	4
Frustulia vulgaris (Thwaites) De Toni	V	V	IV	4	4
Geissleria decussis (Ostrup) Lange-Bertalot et Metzeltin s.l.	III	V	V	4	4
Gomphonema acuminatum Ehrenberg	III	IV	IV	5	4
Gomphonema angustum Agardh	II	I	II	1	4
Gomphonema clavatum Ehrenberg	III	III	I	4	3
Gomphonema gracile Ehrenberg	I	I		3	3
Gomphonema insigne Gregory	I	I	I	0	0
Gomphonema micropus Kützing	IV	V	V	5	4
Gomphonema minutum (Agardh) Agardh	II	I	I	5	3
Gomphonema olivaceum (Hornemann) Brebisson	III	III	IV	5	5
Gomphonema parvulum (Kützing) Kützing	IV	V	V	5	3
Gomphonema productum (Grunow) Lange-Bertalot & Raichardt		I		2	3
Gomphonema sarcophagus Gregory	IV	IV	V	3	4
Gomphonema tenue Fricke	I			0	0
Gomphonema truncatum Ehrenberg	IV	V	I	4	4
Gyrosigma acuminatum (Kützing) Rabenhorst	V	V	V	5	5
Hantzschia amphioxys (Ehrenberg) Grunow	I	III	IV	7	3
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski	V	V	V	4	4
Hippodonta costulata (Grunow) Lange-Bertalot, Metzeltin et Witkowski	IV	V	V	0	4
Hippodonta hungarica (Grunow) Lange-Bertalot, Metzeltin et Witkowski	I			4	4
Luticola mutica (Kützing) D. G. Mann		II	I	5	3
Luticola nivalis (Ehrenberg) D.G. Mann		I		5	3
Mayamaea fossalis (Krasske) Lange-Bertalot var. *fossalis*	I	I	I	0	3
Mayamea asellus (Weinhold) Lange-Bertalot		I	I	0	4
Mayamea atomus (Kützing) Lange-Bertalot	I	I		6	4
Mayamea excelsa (Krasske) Lange-Bertalot			I	6	3
Melosira varians Agardh	V	V	V	5	4
Meridion circulare (Greville) Agardh	V	V	V	7	4
Navicula capitatoradiata Germain			I	5	4
Navicula cari Ehrenberg		I	II	7	0
Navicula cincta (Ehrenberg) Ralf	I	II	IV	5	4
Navicula cryptocephala Kützing	IV	V	V	7	3
Navicula cryptotenella Lange-Bertalot	IV	IV	V	7	4
Navicula exilis Kützing	V	V	V	0	0
Navicula graciloides Mayer	II	IV	IV	5	5
Navicula gregaria Donkin	V	V	V	5	4
Navicula integra (Smith) Ralfs	II	V	III	5	3
Navicula joubaudii Germain	V	V	V	0	0
Navicula lanceolata (Agardh) Ehrenberg	III	III	III	5	4
Navicula menisculus Schumann	IV	IV	IV	5	4
Navicula minima Grunow	V	V	V	5	4
Navicula moskali Witkowski & Lange-Bertalot	V	V	V	0	0
Navicula oblonga (Kützing) Kützing	II	IV	II	5	4
Navicula oppungata Hustedt		II	I	0	0
Navicula protracta (Grunow) Cleve	IV	IV	V	5	3

TABLE 2. Cont.

Taxa	A	B	C	TS	pH
Navicula pygmaea Kützing	II	II	I	5	5
Navicula radiosa Kützing	III	V	II	4	3
Navicula reinhardtii (Grunow) Grunow & Möller	IV	V	V	5	5
Navicula rhynchocephala Kützing	I	II	I	7	4
Navicula rostellata (Kützing) Lange-Bertalot	I			5	4
Navicula seminulum Grunow	II	I	IV	5	3
Navicula slesvicensis Grunow	I	II		5	4
Navicula tenelloides Hustedt	III	IV	V	5	4
Navicula tripunctata (O.F. Müller) Bory	III	I	II	5	4
Navicula trivialis Lange-Bertalot	I	II		5	4
Navicula upsaliensis Grunow	V	V	V	0	4
Navicula veneta Kützing			I	5	4
Neidium affine (Ehrenberg) Pfitzer	III	II	II	4	3
Neidium ampliatum (Ehrenberg) Krammer	II	IV	III	2	3
Neidium binodeforme Krammer	IV	IV	IV	0	0
Neidium bisulcatum (Lagerstedt) Cleve	I	IV		1	3
Neidium dubium (Ehrenberg) Cleve	V	V	V	4	3
Nitzschia acicularis (Kützing) Smith	II	II		5	4
Nitzschia acidoclinata Lange-Bertalot	I	II	II	3	3
Nitzschia agnita Hustedt	II	II		0	0
Nitzschia amphibia Grunow	IV	V	V	5	4
Nitzschia capitellata Hustedt	IV	V	V	6	4
Nitzschia constricta (Kützing) Ralfs	V	V	V	5	4
Nitzschia debilis (Arnott) Grunow & Grunow	III	II	II	0	4
Nitzschia dissipata var. *dissipata* (Kützing) Grunow	IV	V	V	4	4
Nitzschia dissipata var. *media* (Hantzsch) Grunow	IV	III	II	0	4
Nitzschia dubia Smith	V	IV	I	5	3
Nitzschia fonticola Grunow	IV	V	V	4	4
Nitzschia fossilis (Grunow) Grunow		I	I	0	2
Nitzschia frustulum (Kützing) Grunow	III	III	II	5	4
Nitzschia gracilis Hantzsch	III	II	II	3	3
Nitzschia hungarica Grunow	III	III	II	5	4
Nitzschia inconspicua Grunow	I	II	III	5	4
Nitzschia levidensis var. *levidensis* (Smith) Grunow	I	II	I	5	4
Nitzschia linearis var. *linearis* (Agardh) Smith	V	V	V	4	4
Nitzschia linearis var. *subtilis* (Grunow) Hustedt	II	II	I	0	0
Nitzschia palea (Kützing) Smith	IV	V	V	6	3
Nitzschia paleacea (Grunow) Grunow	IV	IV	IV	5	4
Nitzschia pellucida Grunow	I			0	0
Nitzschia pusilla Grunow	V	III	V	7	3
Nitzschia recta Hantzsch	II	III	I	7	4
Nitzschia sigmoidea (Nitzsch) Smith		I		5	4
Nitzschia sinuata (Thwaites) Grunow		I		5	4
Nitzschia sociabilis Hustedt	I		II	5	3
Nitzschia tubicola Grunow	I	II	I	0	0
Paconeis elginensis (Gregory) Cox	I	III	III	5	4
Pinnularia appendiculata (Agardh) Cleve		I	II	2	2
Pinnularia borealis var. *rectangularis* Carison	II	II	II	0	0
Pinnularia gibba Ehrenberg		I		7	3
Pinnularia legumen (Ehrenberg) Ehrenberg		I		1	3
Pinnularia lundi var. *linearis* Hustedt	III	IV	II	3	2
Pinnularia maior (Kützing) Rabenhorst	I	I	I	4	3
Pinnularia microstauron (Ehrenberg) Cleve		II	II	7	3
Pinnularia nodosa (Ehrenberg) Smith	II	I	I	1	2
Pinnularia viridis (Nitzsch) Ehrenberg	III	III	II	7	3
Placoneis clementis (Grunow) Cox	I	II	II	4	4
Placoneis gastrum (Ehrenberg) Mereschkowsky	I	II	III	5	4
Placoneis placentula (Ehrenberg) Cox	II	III	IV	5	4
Placoneis subplacentula Hustedt	III	IV	V	0	0
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	V	V	V	7	4
Planothidium lanceolatum (Brebisson) Lange-Bertalot	V	V	V	5	4
Rhoicosphaenia abbreviata (Agardh) Lange-Bertalot	V	V	V	5	4
Sellaphora bacillum (Ehrenberg) Mann	III	IV	IV	4	4
Sellaphora laevissima (Kützing) Lange-Bertalot	III	IV	IV	3	3
Sellaphora pupula (Kutzing) Mereschkowsky s.l.	V	V	V	4	3
Stauroneis anceps Ehrenberg	II	V	V	4	3
Stauroneis kriegerii Patrick	V	V	V	4	3

TABLE 2. Cont.

Taxa	A	B	C	TS	pH
Stauroneis lauenburgiana Hustedt	I	I	I	0	0
Stauroneis legumen (Ehrenberg) Kützing	II	II	I	4	3
Stauroneis phoenicentron (Nitzsch) Ehrenberg	III	IV	II	4	3
Stauroneis smithii Grunow	V	V	V	7	4
Stephanodiscus hantzschii Grunow	V	IV	IV	6	5
Surirella angusta Kützing	IV	V	IV	5	4
Surirella biseriata Brebisson		I		5	4
Surirella briebissoni var. *kuetzingii* Krammer & Lange-Bertalot	II	III	III	5	4
Surirella linearis Smith		II		2	3

number of taxa also decreased from its maximum number of 126 in April 2000, to reach the lowest number of 73 in Feb. 2001. Their number started to increase in May 2001 to reach the number of 122 in Oct. 2001 (Fig. 5). In site 1.3, the number of taxa was constant in June and Oct. 2000, and equalled 89. A slight increase to 93 taxa was recorded in August. In 2001, the number of taxa increased from 94 in June to the maximum number of 121 in Aug., and decreased to 100 in October (Fig. 5).

The following groups of diatom taxa were differentiated: dominants, subdominants, influents, accessory and rare species. Dominants were differentiated and are presented in Figure 6, in order to present the taxa that characterise a given diatom community the best. Dominant species were: *Achnantheiopsis dubia* (with max. participation – 70.1%), *Melosira varians* (60.9%), *Nitzschia linearis* var. *linearis* (46.5%), *Navicula joubaudii* (45.23%), *Planothidium lanceolatum* (15.95%), *Hippodonta capitata* (15.79%), *Fragilaria ulna* var. *ulna* (12.15%), *Achnanthes biasolettiana* var. *biasolettiana* (9.54%), *Nitzschia capitellata* (9.54%), *Fragilaria pinnata* (8.78%), *Nitzschia fonticola* (7.73%), *Achnanthidium minutissimum* (7.13%), *Stephanodiscus hantzschii* (7.05%), *Amphora pediculus* (6.3%), *Meridion circulare* (5.43%), *Cocconeis placentula* var. *placentula* (5.33%).

For the diatom taxa determined the constancy grades were ascribed according to the Braun-Blanquet method, commonly used in phytosociology. For sites 1.1, 1.2 and 1.3, the taxa occurring in individual classes were grouped together and are presented in Table 3.

In site 1.1, the number of specimens fluctuations was recorded, reaching the highest value in June 2001-4412. The lowest number of specimens values was recorded in Oct.

TABLE 3. Number of taxa in sites 1.1, 1.2 and 1.3 with ascribed constancy classes.

Number of taxa in sites	Constancy classes				
	V	IV	III	II	I
1.1	34	26	38	32	45
1.2	49	31	29	35	47
1.3	54	25	31	20	42

2001-375 (Fig. 7). In site 1.2, a high number of specimens was recorded in Oct. 2000-7385. Whereas the lowest one in May 2001-602 (Fig. 7). In site 1.3, the number of specimens did not fluctuate greatly in the months of June, August and October 2000, and ranged between 2865 and 3059. In June 2001, a frequency increase was observed and as many as 4469 specimens were recorded. Afterwards, the number of specimens began to fall and reached its lowest value of 827 in October (Fig. 7).

Diatom communities, representing three microhabitats, were compared on the basis of the qualitative comparison index, called the Kulczyński similarity index (Kawecka and Eloranta 1994). The greatest value of the similarity coefficient 0.82, was recorded in June 2001 between the outflow and one meter from the outflow, while the smallest one 0.65 in Feb. 2001, between the same sites. In other cases, the similarity coefficient was constant (0.71-0.78).

To the identified diatom taxa, indicator values for pH and trophic state (Table 2) have been attributed. According to trophic state, most taxa belong to meso- and eutraphentic, however in respect of – to alkalophilic (Fig. 8). The trophic state for 45 identified taxa as well as pH value for 31 taxa, have not been determined, so far.

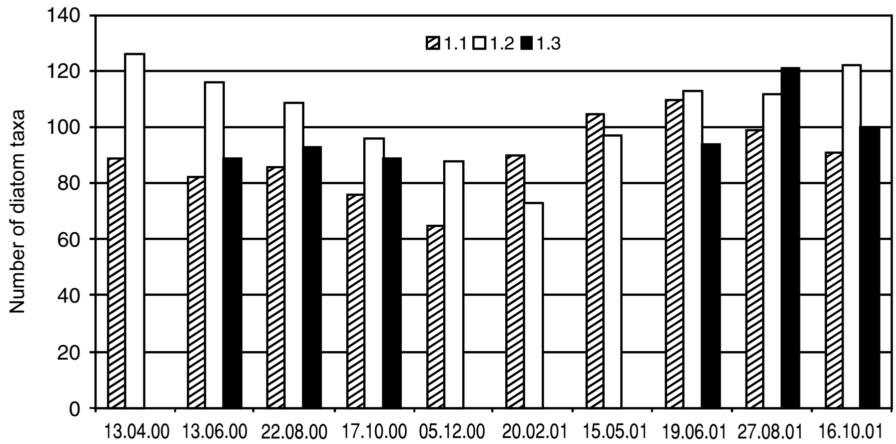

Fig. 5. Number of diatom taxa in individual samples.

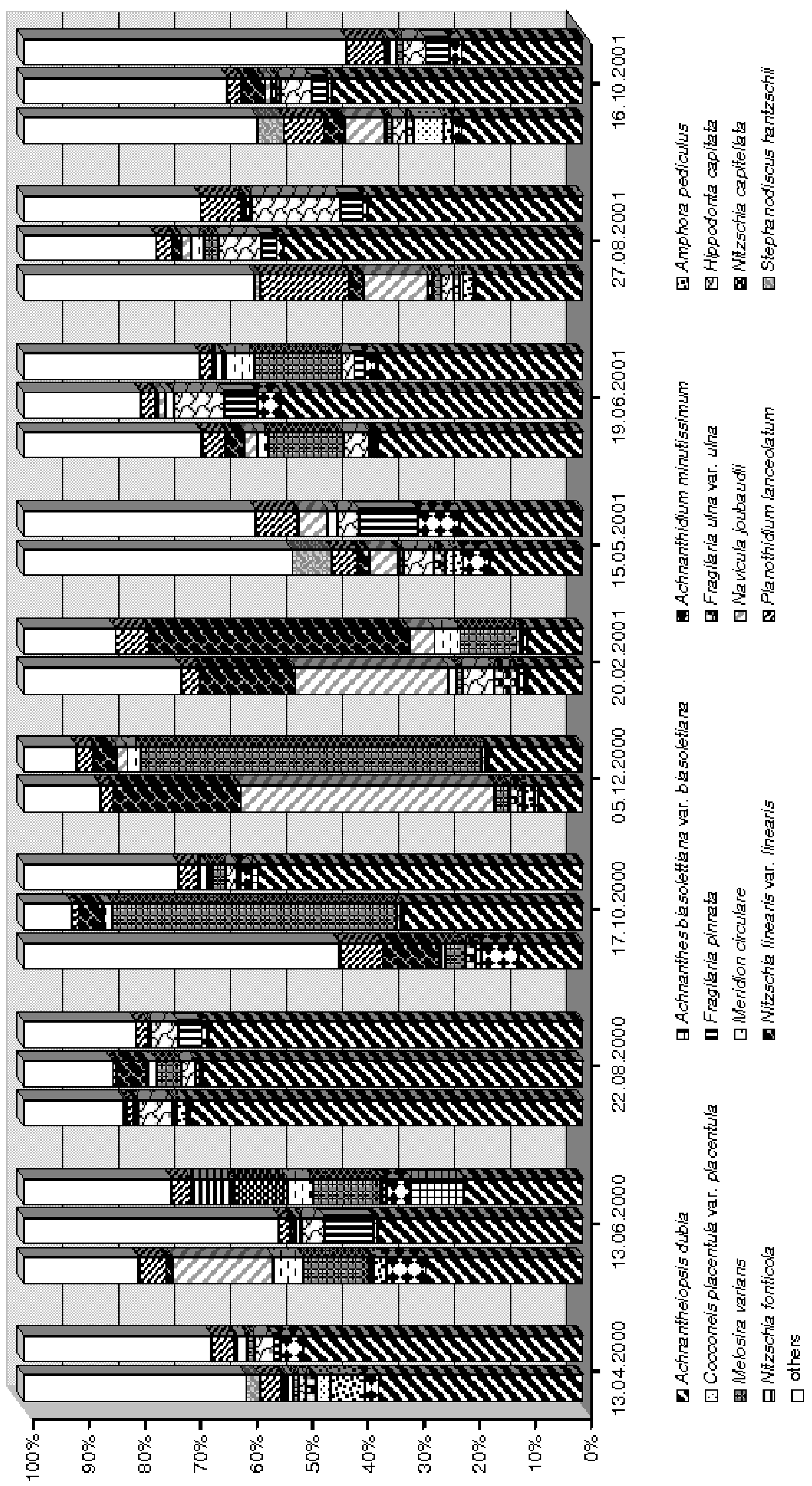

Fig. 6. Participation of dominant taxa in three sites of samples collection in the analyzed spring niche during the study time.

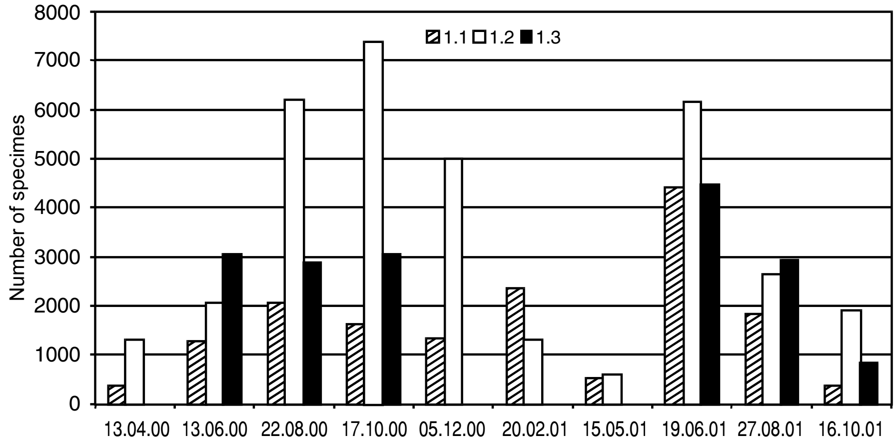

Fig. 7. Number of specimens in individual samples.

Macroalgae

Eleven species of macroalgae belonging to the phyla Chlorophyta, Chrysophyta, Rhodophyta were determined in all the samples.

The phylum *Chlorophyta* is represented by four taxa: *Draparnaldia acuta* (Agarth) Kütz, *Stigeoclonium subsecundum* Kütz., *Ulothrix* sp. Kütz., *Vaucheria sessilis* (Vaucher) De Candolle. Three species were identified in the phylum *Chrysophyta*: *Tribonema elegans* Pascher, *Tribonema viride* Pascher, *Tribonema vulgare* Pascher, The phylum *Rhodophyta* is represented by three species: *Batrachospermum moniliforme* Roth, *Batrachospermum vagum* (Roth) Ag., *Chantransia chalybaea* (Roth) Fries.

In site 1.1, 7 species of macroalgae were determined. Two species occurred exclusively in the outflow. These are: *Batrachospermum moniliforme*, *Chantransia chalybaea*. Eight species occurred in site 1.2, 3 of them were found exclusive-

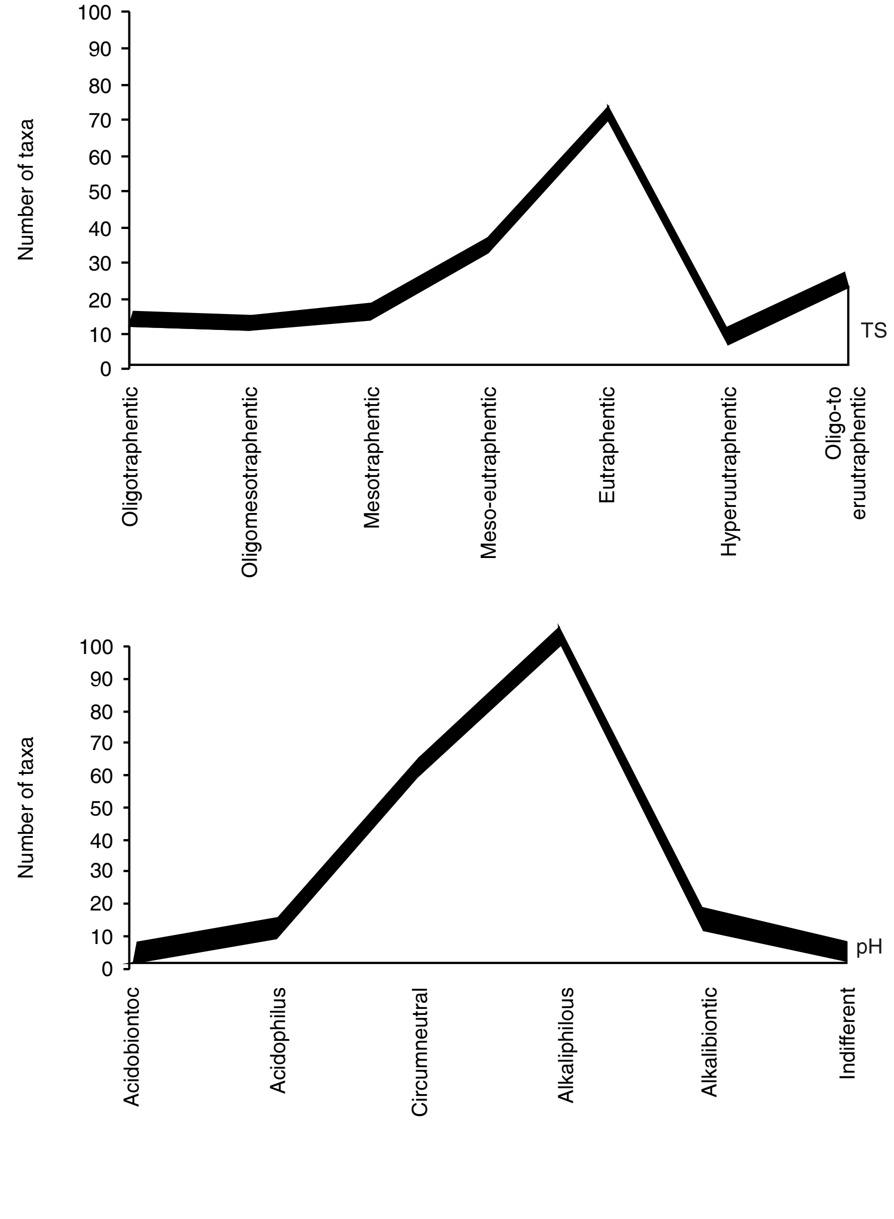

Fig. 8. Ecological indicator value of diatoms in the springs niche.

ly one meter from the outflow. These are: *Batrachospermum vagum*, *Tribonema elegans*, *Tribonema viride*. In site 1.3, 4 species of macroalgae were noted: *Stigeoclonium subsecundum*, *Ulothrix* sp., *Tribonema vulgare*, *Vaucheria sessilis*.

Plant associations

The spring niche was charted on each occasion and the vegetation distribution was presented on a map in the scale 1:20 (Fig. 9).

The type of the community Ranunculo – Sietum erecto – submersi (Roll. 1939) Mull. 1962 was determined on the basis of *Berula erecta* (Huds.) Coville, *Callitriche cophocarpa* Sendtner and *Elodea canadensis* Rich. species. The Ranunculo – Sietum erecto – submersi association occurs in very clean and well oxygenated waters on the limestone substrate; in the upland's areas and in the foothills of the Sudeten and the Carpathian Mountains, as well as in young glacial regions, in streams flowing on the till substrate rich in calcium (Matuszkiewicz 1981).

The Ranunculion fluitantis association comprises ecologically specialised communities of hydrophytes rooted in the bottom of flowing waters. They occur in the lowland and in the mountains: in rivers, streams and brooks with different current flow rates and current force and different water properties, and show a high differentiation dependent on the local habitat factors and a low regional variability. Communities forming the Ranunculion association may be significant bioindicators of water pollution in rivers and thus should be examined more closely from the point of view of phytosociology and ecology. These communities are underexplored in Poland (Matuszkiewicz 1981).

The order Potamogetonetalia represents communities of freshwater macrophytes in meso- and eutrophic inland water reservoirs (Matuszkiewicz 1981).

The observed changes in the distribution of vegetation patches are indicative of the process of replicative secondary succession (Falińska 1996). The Ranunculo – Sietum erecto – submersi association remains at the first succession stage – initial stage. Amplitude of the water level fluctuations is the most fundamental environmental condition that inhibits the development of next succession stages.

The following species of bryophytes were collected around the spring niche: *Brachythecium salebrosum* (Web. et Mohr) Schimp., *Bryum pseudotriquetrum* (Hedw.) Gaertn., Meyer et Scherb., *Calliergonella cuspidata* (Hedw.) Loeske, *Leptodictyum riparium* (Hedw.) Warnst., *Marchantia polymorpha* var. *aquatica* Nees, *Plagiomnium ellipticum* (Brid.) T. Kop, *Pseudoscleropodium purum* (Hedw.) Fleisch. in Broth.

DISCUSSION

The examined spring was characterized by constant physical and chemical conditions throughout the study period. However, the sudden changes brought by the rise of the water level in the spring during the flood in the Warta River valley occurred periodically.

Other authors show that the constancy of conditions is typical for springs, which undoubtedly differentiates them from surface waters (Odum 1971).

Three microhabitats, the outflow, a stone (situated 0.5 m from the outflow) and one meter from the outflow, were examined in the spring niche. Both the outflow and the site located one meter from it are situated in the spring mainstream, while the stone is located outside the mainstream, on the left bank of the spring niche. The substrate in the outflow consists of fine rock material and sand; sand is the substrate one meter from the outflow.

Cantonati and Pipp (2000) researched Borzago and Malaga Nambi Mountain streams in the Adamello-Brenta Regional Park in the Southern Alps. They established three sampling sites in each case; the first one – spring, the two other some few hundred meters downstream. As they observed, diatoms were characterised by a greater diversity downstream.

The spring outflow is a more stable habitat than those situated downstream. Habitat differentiation is observed along the stream. Downstream sections are characterised by unstable conditions such as floods, fast current, glacial formations, river acceleration and deceleration as well as temperature. These factors influence the algae communities. The author suggests that the faster current in the upstream sections may reduce species diversity and limit the accumulation of periphyton, which leads to an impoverishment of algae species as a result of a strong selection of rheophile species (Cantonati 1999, 2001).

The results of the studies on the spring in Działoszyn show an increase in the diversity of diatom communities in microhabitats as the distance from the spring increases. Fewer taxa occurred in the outflow and the frequency there was lower than that for one meter from the outflow. The number of species and individuals on the stone was greater than that in the outflow, but smaller than that, one meter from the outflow.

The diatom community in the outflow was characterised by a high diversity: 175 determined taxa. Waszkiewicz (1999) determined the total number of 77 species in her study of three karst springs in the Warta valley near Częstochowa. Such a relatively high diversity in the examined spring may be connected with the hydrological type of the spring (slope-channel), and its location near an old riverbed.

Budede 1928, Whitford and Schumacher 1963 (after Cantonati 1999) draw attention to the fact that periphyton communities become stable as a result of constant physical and chemical properties. Some researchers point out that seasonal changes of algae in the initial stream course are only slightly significant, while others prove that seasonality is distinctive when light is considered as a factor that brings about seasonal changes (Cantonati and Pipp 2000).

Seasonal variability of the diatom community, conditioned by the duration of the day and access to light, was clearly visible in the studies on the spring in Działoszyn throughout the period of study. The number of individuals and taxa diminished between October and December, when the day was short, while it began to increase in February as the daytime lengthened, despite constant physical and chemical parameters.

In his study on the ecology of cyanobacteria in mountain springs in the southern Alps, Cantonati et al. (1996) showed that the diversity and seasonal variability increased from the spring to a streamlet situated downstream, which suggests that the water current may also play a significant role.

Similar relationships were observed in the spring studied. Seasonal variability was more conspicuous as the distance from the outflow increased. The increases and decreases in the number of individuals and taxa taking place in the outflow were not as drastic as those in the other microhabitats.

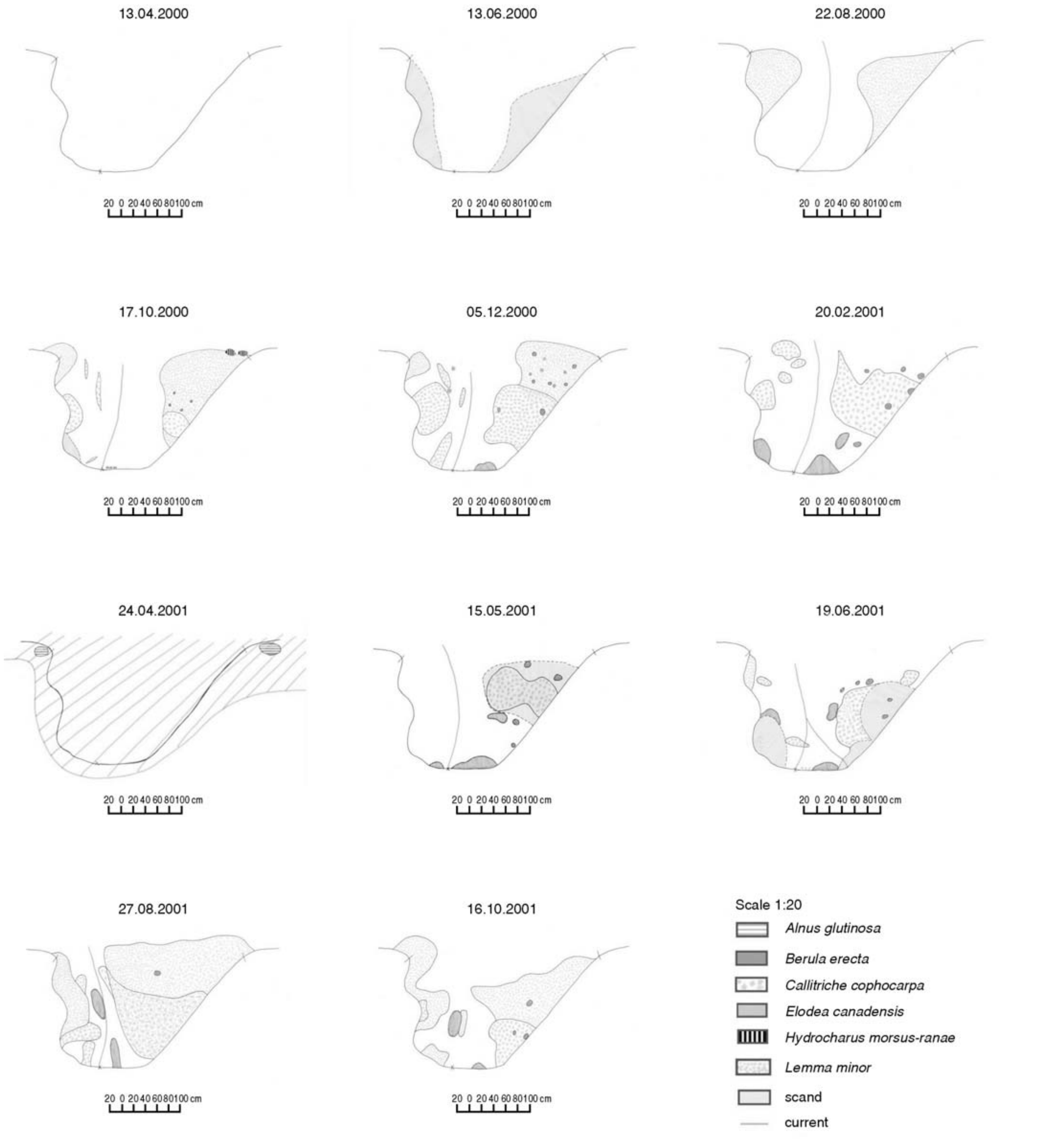

Fig. 9. Distribution of the vegetations flats in the spring niche from April 2000 till October 2001.

The flood in the Warta catchments in April 2001 was a catastrophic event in the representation of diatom communities in the spring studied. The spring niche changed completely after the waters of the Warta River flew into the spring. Consequently, the frequency of diatoms in the outflow and one meter from the outflow was similar in May.

The flood also affected the species composition of macroalgae. A species exchange took place between individual microhabitats. *Tribonema vulgare* and *Ulohtrix* sp. occurred in the outflow after the flood. *Draparnaldia acuta* and *Stigeoclonium subsecundum*, not recorded there before, occurred one meter from the outflow. *Batrachospermum vagum*, a species carried in by the water current, not recorded in any of the microhabitats before, occurred. These species disappear in habitats alien to them, and in October 2001 they were absent in the sampling sites in which they had been recorded earlier.

The development of the vegetation cover depends of habitat conditions (Siedlecka-Binder 1967). Even, amplitude of water level fluctuations, not only a flood, is one of the major factors conditioning seasonal variability of vascular plants. Vegetation patches undergo qualitative and quantitative changes in particular months. These conditions prevent the development of successive succession stages, as a result of which the Ranunculo – Sietum erecto – submersi association remains at the first succession stage.

Researchers of springs have attempted to decide whether stable conditions in springs select organisms specialised for the habitat (Round 1960). Some studies on diatom communities in springs show that these communities do not have specific species. In the case of diatoms, however, such species are recorded in springs (Cantonati 1996).

In his comparison of the algoflora of a spring with that of a small pond in a botanical garden, Round (1960) proved that both floras were generally similar. In his studies on other springs in England, he also showed that diatom flora consisted of species characteristic of flowing waters, and there were no algae occurrence would be limited to this habitat.

On the basis of determined domination of species in the spring outflow, such as *Achnantheiopsis dubia*, *Achnanthes biasolettiana*, *Achnanthidium minutissimum*, *Amphora pediculus*, *Cocconeis placentula* var. *placentula*, *Fragilaria pinnata*, *F. ulna* var. *ulna*, *Hippodonta capitata*, *Melosira varians*, *Meridion circulare*, *Navicula joubaudii*, *Nitzschia capitellata*, *N. fonticola*, *N. linearis* var. *linearis*, *Planothidium lanceolatum*, *Stephanodiscus hantzschii*, it can be concluded that these species are not characteristic for springs, even though they are recorded there; they are also found in other water ecosystems. Ecological indicator values of pH and trophic state of dominant diatom species reveal alkaline and eutrophic water features.

The occurrence of *Navicula joubaudii* in springs has been rarely noted (Wojtal 2001; Rakowska 2001) while it is one of the dominant taxa in the studied spring. The species forms communities with *Diadesmis perpusilla* and *Nitzschia amphibia*: these species occurred in the outflow and are accessory. *Navicula joubaudii* is an indicator of oligosaprobic to β-mesosaprobic waters, with small organic matter content (Krammer and Lange-Bertalot 1986). Wojtal (2001) noted *Navicula joubaudii* on mud of a karstic spring and among filamentous thalli of *Cladophora* sp. in the polluted part of the stream, where conductivity was medium 360-480 µS, and pH 6.1-8.0. Rakowska (2001) noted this species in two river springs (Bzura and Rawka) and in the limnokrenic karstic spring "Niebieskie Źródła". The species preferences were determined as oligotrophic in respect trophy, and alkaliphilic in respect of pH value. In the spring studied *Navicula joubaudii* was dominant and constant species; its presence can indicate alkaliphilic and oligo- to eutrophic water conditions.

Other authors suggest, however, that springs represent a geographically isolated system that can be a potential place of preservation of relic or endemic species. Such studies were conducted in springs in northern America: Florida, Utah, Texas, and Mexico, where the occurrence of endemic species was recorded (Alison and Sheath 1999).

Cantonati and Ortler (1998) shows in his studies that communities of algae in springs are characterised by these species that are often found in other springs and in similar habitats; however they are not, crenobionts or species limited to clean fast flowing waters. Cantonati and Pipp (2000) suggest that communities of algae should be considered in terms of the presence of crenophyles or as species known little that are usually subdominants, and are mostly in the group of rare species.

In the study on the spring in Działoszyn, the similarity between these three communities was determined to be high based on the qualitative comparative index of diatom communities, the Kulczyński coefficient, and ranges between 0.71 to 0.78.

Cantonati (2001) suggests that preferences of individual species are more important, if there are no obvious differences between diatom communities. Similar suggestions appear in Rakowska's (1996) article: in order to determine the conditions occurring in a habitat, the significance of species with a narrow tolerance range is greater than those that develop abundantly and whose tolerance for physical and chemical conditions in water is broad.

The analysis of rare species with a narrow tolerance range, conducted in this study, determines the habitat type. *Achnanthes biasolettiana* var. *subatomus*, *A. biasolettiana* var. *biasolettiana*, *A. lauenburgiana*, *A. rossi*, *Amphora fogediana*, *Eunotia incisa* var. *incisa*, *Gomphonema angustum*, *G. tenue*, *Diadesmis perpusilla*, *Fallacia lenzii*, *Nitzschia acidoclinata*, *Stauroneis lauenburgiana*, were rare species (below 1% of individuals) in the outflow. These species represent low constancy classes, chiefly I and II, and sporadically class III. Consequently, based on these species the place of the outflow can be determined as an oligo- to mesotrophic habitat, with low organic matter content, well oxygenated water, high limestone content, medium and high electrolyte presence, low sulphate content, pH neutral to alkaline.

Dominant species, which have clear pH and trophic preferences, can be used as indicators of alkaliphilous (4) and eutraphentic (5) features of water. We suggest that species co-occurring constantly in the studied spring (V class): *Achnantheiopsis dubia*, *Amphora libyca*, *Navicula exilis*, *Navicula moskali*, *Navicula upsalensis*, which do not have assigned indicator values, can also be treated as indicators of these water conditions.

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