Oceanological and Hydrobiological Studies
Vol. XXXII, No. 4

Institute of Oceanography (159-170) University of Gdańsk
2003

Research Article

DISPERSION OF *DIDYMOSPHAENIA GEMINATA* IN THE FLOWING WATERS OF SOUTHERN POLAND - NEW SITES OF SPECIES OCCURRENCE IN THE ORAWSKA WATERSHED AND THE ORAWSKA BASIN

TERESA NOGA

Zdzisław Czeppe Department of Polar Research and Documentation,
Institute of Botany, Jagiellonian University,
Kopernika 27, 31-501 Kraków, Poland
noga@fagus.ib.uj.edu.pl

Key words: *Didymosphaenia geminata*, water courses, ecology, southern Poland, Orawa region

Abstract

To date, *Didymosphaenia geminata* has been recorded in boreal and montane regions in Europe, Asia and North America. It has been recorded only rarely in central Europe in cold, oligotrophic montane water bodies with a moderately low electrolyte content.
In Poland, it occurred in the streams in the Tatra Mountains and in the Dunajec River but abundance was low. During the 1990s this species appeared in the Carpathian tributaries of the Vistula River (Soła, Skawa and Raba). Very high *Didymosphaenia geminata* abundance was noted in the San River below the dams in mezotrophic environments.
Didymosphaenia geminata was recorded for the first time in mezotrophic environments in the Czarna Orawa River and its tributaries, most of which - Zubrzyca, Sylec and Lipnica - come from Babia Góra Mountain. The highest abundance was noted in the Zubrzyca stream where there were macroscopic aggregations. The most common species in these aggregations were *Navicula*

capitatoradiata, *N. lanceolata*, *Cymbella minuta*, *Achnanthes biasolettiana* var. *biasolettiana*, *Fragilaria arcus* var. *arcus*, *F. ulna*, *Diatoma vulgaris* and *Cocconeis placentula* var. *euglypta*

INTRODUCTION

To date, *Didymosphaenia geminata* has been recorded in boreal and montane regions in Europe, Asia and North America. It has been recorded only rarely in central Europe in cold and oligotrophic montane water bodies with a moderately low electrolyte content.
These characteristics are consistent with the fact that this diatom species lives in clear waters in Scandinavia (Cleve-Euler 1955). *Didymosphaenia geminata* was also recorded in the streams of Finland (Kawecka and Eloranta 1987) and Sweden (Johanson 1980), as well as in Norway, where it occurs in the Glåma River, which is believed to be the natural habitat of this species (Skulberg and Lillehammer 1984).

In the 1960s a low abundance of *Didymosphaenia geminata* was recorded in oligotrophic streams in the Tatra Mountains (Siemińska 1964) and in the rivers of the Tatra foothills (e.g. the Białka Tatrzańska River (Kawecka 1965). Unexpectedly, the occurrence of this species was recorded in the 1990s in several Carpathian rivers - the San, Soła, Skawa and Raba (WIOŚ 1996, 2000). Abundance of it was high in numerous jelly-like aggregations in the San River below the artificial Solina and Myczkowce reservoirs (Kawecka and Sanecki 2003). It was also noted in the Vistula River seston in the same period (Bucka 2000, Kasza and Galas 2000). The species continued to disperse and is now found in the Lepietnica, Kamienica, Łopuszna, Jaszcze and Jamne streams of the Gorce Mountains (Wayda pers. comm.). It also reached high abundance in 2002 in the Białka Tatrzańska River in the Tatra region (Kawecka pers. comm.). It has been recorded in the streams of the Orawa region in the Czarna Orawa River and its tributaries, the Zubrzyca, Sylec, and Lipnica in 2002.
The objective of this study was to examine the distribution of *Didymosphaenia geminata* in the Orawa region, to analyze the population taxonomically and to identify the environmental conditions which permit the occurrence of *Didymosphaenia geminata*.

STUDY AREA

The Orawa region has an area of more than 1600 km^2 and is divided into the Dolna Orawa (entirely in Slovakia) and the Górna Orawa. Most of the Górna Orawa is also located in Slovakia; however, a small section of it in the Czarna Orawa river basin is located within Polish borders. The Polish Orawa is

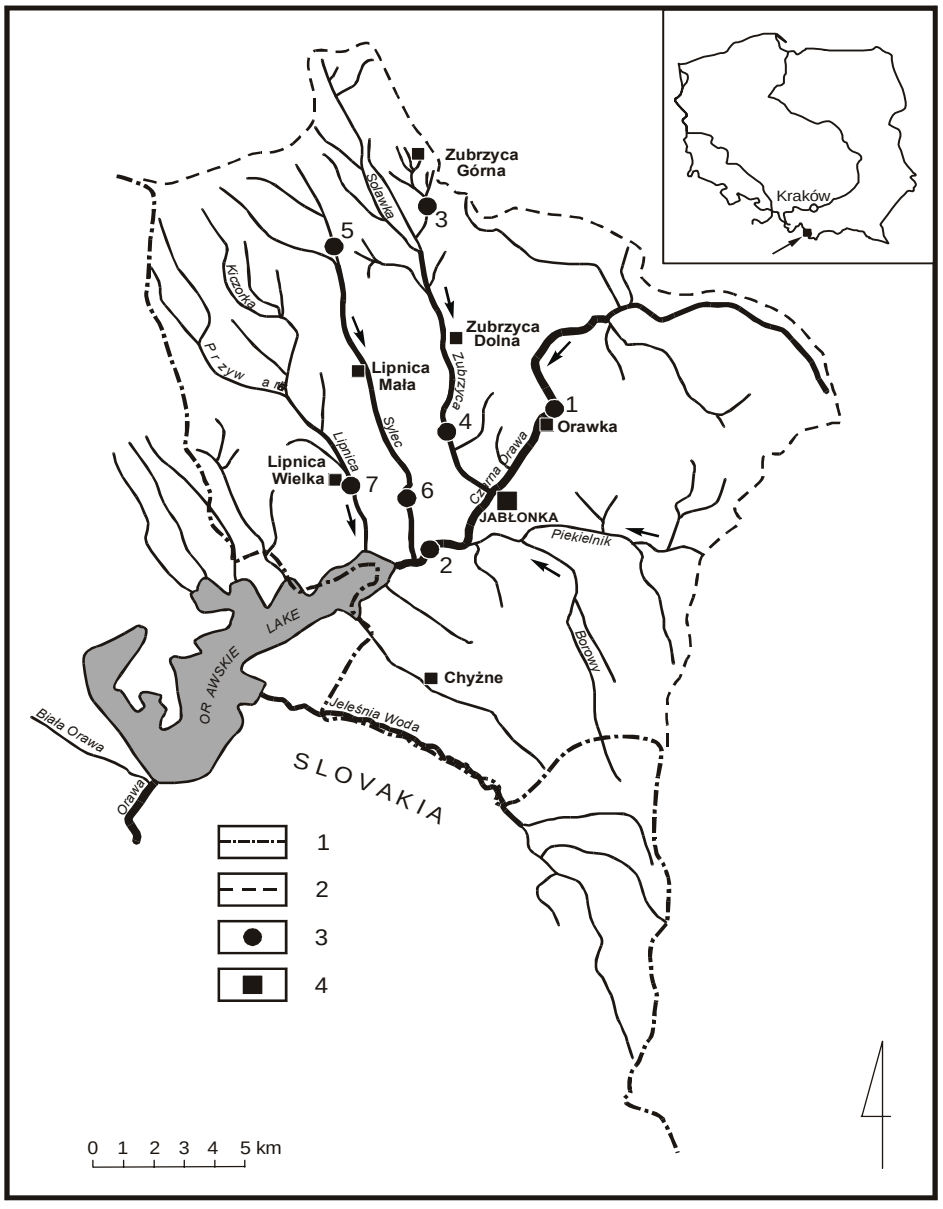

Fig. 1. The distribution of positions from *Didymosphaenia geminata* in Czarna Orawa River and her tributaries: 1 – the state boundary, 2 – the border of terrain of investigations, 3 – position from *Didymosphaenia geminata*, 4 – more important localities on Orawa terrain.

the northeastern part of the Orawa region located between the border with Slovakia and the watershed between the Orawa and Dunajec river basins.

In terms of physio-geographical characteristics, the area examined encompasses several geographical units. The northern part is located in the Orawa watershed and the Beskid Orawsko-Podhalanski region, whereas the southern part is situated in the Orawsko-Nowotarska Basin (Kondracki 1998).

The Czarna Orawa river basin is located in two geological regions. The southern part extends from the Polish-Slovakian border to the town of Jabłonka and is situated in the so-called Pieninski Rocky Belt, whereas the northern part extends from Jabłonka to the border of the river basin in the so-called Magurska Shield (Książkiewicz and Samsonowicz 1952). The main soil types here are dusty (from Jabłonka to Chyżne), clay and loam (areas in the north-east), and peat-like (in the watershed of the Czarny Dunajec and Czarna Orawa). Sedimentary and dusty soils occur in the river valleys. Clay soils are also formed on the slopes of Babia Góra Mountain where sandstones and slates are exposed to wind erosion.

The climate in the Orawsko-Nowotarska Basin is dry continental-montane. The mean annual precipitation fluctuates from 800 to 850 mm. Snow cover duration is approximately 100-140 days and lasts until April (and until May at higher altitudes).

The Czarna Orawa River is the main river in the region, and its basin, with a total area of 340km^2, is part of the Danube basin. The Czarna Orawa and Biała Orawa rivers form the Orawa River that flows through Slovakia (Fig. 1). It empties into the Wag River, which is a tributary of the Danube. The total length of the Czarna Orawa is 51 km, 31.75 km of which is within Polish borders.

In 1941-1953, a 41-meter high dam was built where the Czarna Orawa and Biała Orawa rivers join to form the Orawa River. This created Orawska Lake - a large water reservoir with an area of 3500 ha and a depth of 35 m. Almost the entire reservoir is located within Slovakian borders with just the upper part near the mouth of the Lipnica tributary located in Poland (Matuszczyk 1993).

The Zubrzyca stream is the largest right-bank tributary of the Czarna Orawa. It is 14.7 km long, originates at an altitude of 840 m above sea level, flows down the eastern slopes of the Babia Góra mountain chain, and empties near Jabłonka at an altitude of 619 m above sea level.

Another montane tributary of the Czarna Orawa is the Sylec stream. It originates on the southeastern slopes of Babia Góra Mountain (at 1367 m above sea level) and is 17.3 km long.

The third largest tributary is the Lipnica stream that starts at 1300 m above sea level on the southern slopes of Babia Góra Mountain. It is formed by two smaller streams, the Kiczorka and Lipniczanka, and has a length of 16.3 km.

Table 1

Morphological and phisics- chemical profile of Orawa streams on chosen positions in period from IV. 2002 to X. 2002r.

Position	**1** CZARNA ORAWA (above village Orawka)	**2** CZARNA ORAWA (in village Jabłonka)	**3** ZUBRZYCA (above village Zubrzyca Górna)	**4** ZUBRZYCA (in village Zubrzyca Dolna)	**5** SYLEC (below Babia Góra)	**6** SYLEC – (below village Lipnica Mała)	**7** LIPNICA (in village Lipnica Wielka)
Insolation	large	large	low	large	average	average	large
Character gout	stony – homogeneous	stony, overgrown with algae here and there, site inshore muddy	stony, muddy	stony, overgrown with algae's mats	stony inshore muddy	stony inshore muddy	stony, inshore muddy
Width m	2 – 3	10 – 15	0.5 – 1	8 – 10	0.5 – 0.7	2.5 – 3	2 – 2.5
Depth m	0.2 – 0.5	0.8 – 1	0.2 – 0.5	0.3 – 0.5	0.2 – 0.3	0.4 – 0.6	0.2 – 0.4
Temperature ^{0}C	9.0 – 19.2	10.8 – 23.3	9.2 – 18.8	10.1 – 22.1	8.2 – 17.5	11.2 – 22.4	10.6 – 23.6
pH	7.8 – 8.0	7.9 – 8.4	7.6 – 7.8	8.0 – 8.9	7.5 – 7.8	7.8 – 8.0	8.3 – 8.8
Conductivity µS cm $^{-3}$	172 – 294	155 – 316	113 – 228	130 – 263	95 – 125	160 – 258	200 – 305
Oxygen dissolve mg O_2 L^{-1}	9.0 – 10.1	7.2 – 10	8.4 – 10.2	8.8 – 10.3	8.7 – 10.6	8.3 – 10.1	8.6 – 10.1
BOD_5 mg L^{-1}	0.6 – 0.9	1.3 – 1.5	0.3 – 0.9	0.7 – 1.3	0.3 – 1.1	1.0 – 1.2	1.1 – 1.2
Cl mg L^{-1}	2 – 4	5	2 – 3	3	2	3 – 4	3 – 5
SO_4 –S mg L^{-1}	13 – 19	13 – 14	10 – 14	14 – 16	10 – 16	15 – 16	16 – 19
PO_4 –P mg L^{-1}	0.02 – 0.08	0.025 – 0.1	< 0.01 – 0.04	< 0.01 –0.05	< 0.01 – 0.01	< 0.01 – 0.03	0.01 – 0.04
Total P mg L^{-1}	0.01 – 0.04	0.02 – 0.08	< 0.01 – 0.03	0.01 – 0.04	<0.01 – 0.03	0.02 – 0.03	0.03 – 0.06
Ca mg L^{-1}	39.0 – 46.2	30.9 – 42.9	22.8 – 31.3	34.2 – 34.6	14.6 – 16.5	34.2 – 39.6	40.7 – 44.5
Mg mg L^{-1}	5.0 – 6.7	5.8 – 7.9	5.9 – 6.7	5.9 – 6.7	1.9 – 4	4 – 6.7	5.9 – 7.7
N_{NH4} -N mg L^{-1}	0.06 – 0.16	0.33	0.05 – 0.2	0.05 – 0.23	0.06 – 0.13	0.06 – 0.14	0.11 – 0.12
N_{NO2} – N mg L^{-1}	0. 008 – 0.019	0.011 – 0.036	< 0.001	< 0.001-0.03	< 0.001	0.007 - 0.008	0.004
N_{NO3} – N mg L^{-1}	0.52 – 0.7	0.45 – 0.71	0.27 – 0.47	<0.1 – 0.47	0.28 – 0.31	0.26 – 0.78	0.29 – 0.53

The characteristics of the left-bank tributaries of the Czarna Orawa are slightly different. The most important of them is the Piekielnik stream which flows along the longitudinal axis of the Orawska Basin. There are numerous peatlands in the Piekielnik basin and around its tributary - the Borowy stream. The Jeleśnia Woda is another left-bank tributary of Czarna Orawa. The Polish-Slovakian border runs along this stream which originates in Slovakia (Orawska Basin). Jeleśnia Woda empties into Orawska Lake in Slovakia.
The study was conducted at seven sites located on the Czarna Orawa River and its Zubrzyca, Sylec and Lipnica tributaries (Fig. 1, Tab. 1).

MATERIALS AND METHODS

Material was collected in the spring, summer and autumn of 2002. Samples were collected from stones, sediment and aquatic plants. After collection, the material was stored in a 4% formalin solution. To obtain clean diatom shells, a portion of the samples were treated with a 3:1 mixture of sulfuric acid and potassium dichromate. Next, the material was rinsed in a centrifuge at 3000 rpm. The material was collected and described according to methods recommended by Kawecka (1980).

The diatoms were identified using a Nikon E 600 light microscope and the keys by Krammer and Lange-Bertalot (1986-1991) and Krammer (1992).
The abundance of particular species was estimated by counting the specimens in randomly chosen fields under the microscope until a total count of 250 cells was reached. Species which comprised more than 5% of all the species in an aggregation were classified as the most abundant, while the remainder were designated as sporadic.

RESULTS

1. Taxonomy of *Didymosphaenia geminata* (Lyngbe) M. Schmidt

The morphological characteristics of one hundred randomly chosen cells of *D. geminata* from all of the sites in the Orawian streams were compared. The length of the cells ranged from 80 to 117μm and the width from 33 to 41μm. The number of bands per 10μm fluctuated from 9 to 12, and the number of stigmas in the center field ranged from 1 to 5 (most frequently from 2 to 3) (Fig.2).

According to the key (Krammer and Lange-Bertalot 1986), the specimens from the Orawian streams were consistent morphologically with the accepted description of the species.

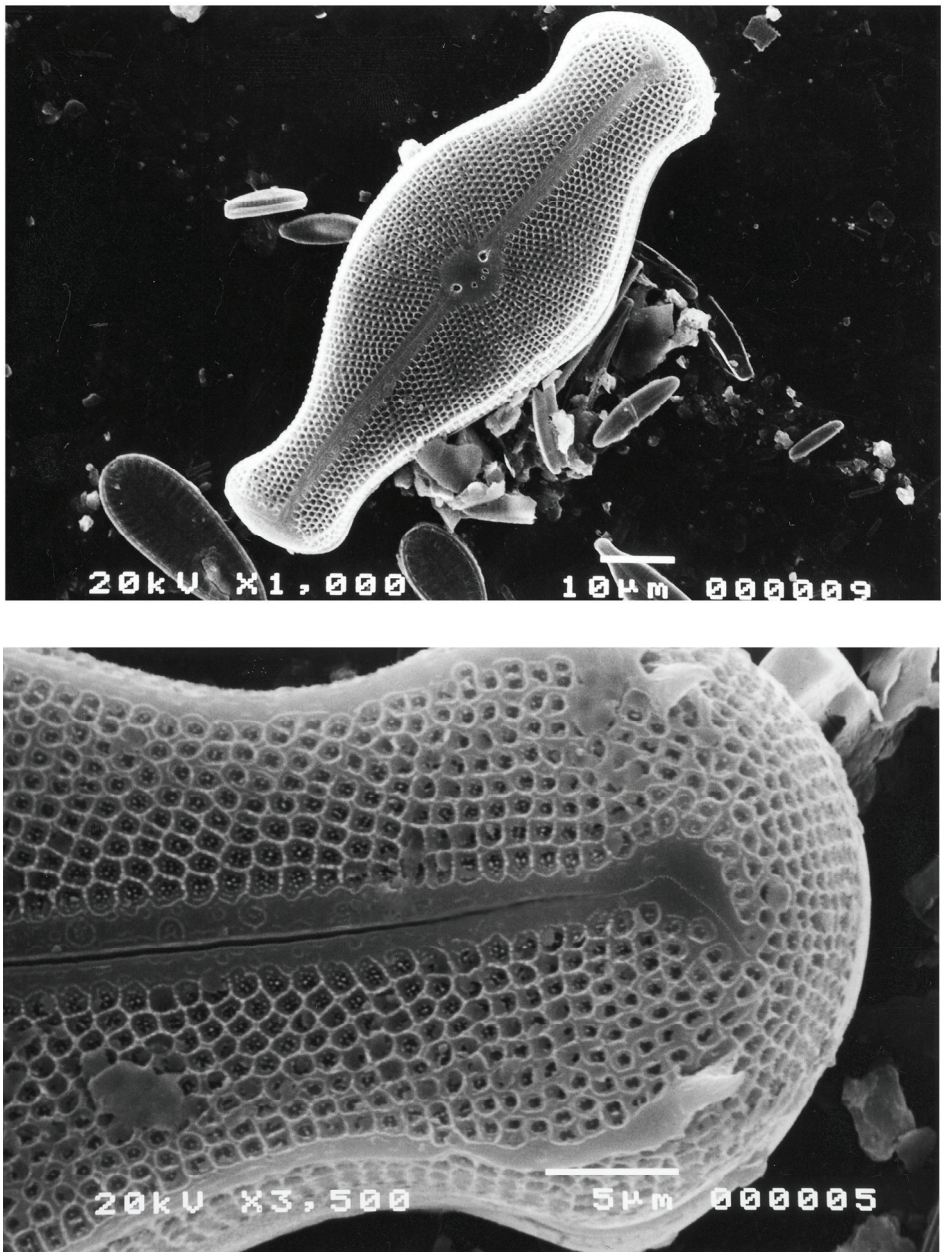

Fig. 2. Morphology of *Didymosphaenia geminata* (Lyngbe) M. Schmidt from Orawa streams. SEM photographs.

2. Occurrence of *Didymosphaenia geminata* in the Czarna Orawa River and its tributaries

The Czarna Orawa River and its main tributaries – the Zubrzyca, Sylec, Lipnica and Piekielnik - are the main water courses in the Orawa region. They are shallow with rocky bottoms, and aquatic vegetation occurs in patches. Right-bank tributaries, inflowing from the slopes of Babia Góra Mountain, have rapid currents and cold water temperatures especially in the upper waters. In comparison, the Czarna Orawa and its left-bank tributaries have slower currents and warmer water temperatures. The pH is usually high (7.5-8.9), as is the electrical conductivity and the amount of calcium ions (Tab. 1). The waters of most of the streams are mezotrophic, especially below populated areas. Only in the upper parts of streams do oligotrophic and oligo-mezotrophic waters dominate (Tab. 1).

This study revealed that *Didymosphaenia geminata* is present in the mid-stream and down-stream waters of the Czarna Orawa and in all right-bank tributaries inflowing from Babia Góra Mountain. However, it was not seen in the left-bank tributaries Piekielnik, Borowy or Borcok which originated in peatland areas.

Only single specimens of *Didymosphaenia geminata* occurred in the Czarna Orawa and it was more abundant in spring, and only individual cells of *D. geminata* where found in samples from the site located upstream from Orawka Village (Station 1). Although the species was slightly more abundant at Jabłonka (Station 2), it still comprised less than 5%. The most abundant diatom species at both of these sites were *Nitzschia palea*, *Cocconeis placentula* var. *euglypta* and *Achnanthes biasolettiana* var. and *biasolettiana*; the less abundant were *Cymbella minuta*, *Navicula gregaria*, *N. lanceolata*, *N. pupula* var. *pupula* and *Surirella minuta* (Tab. 2).

The mid-stream and down-stream waters of Czarna Orawa are both mezotrophic (Tab. 1). According to the research conducted by the Kraków WIOŚ in 2001, the water quality in Czarna Orawa is III class due to physio-chemical and bacteriological pollutants.

Didymosphaenia geminata was most common in the Zubrzyca stream (Station 4), which also has mezotrophic conditions. This site was located in the village of Zubrzyca Dolna close to where the Zubrzyca empties into the Czarna Orawa. The species was most abundant in spring when blooms occurred on the bottom of the stream (water temperature - 12^0C, pH - 8.2, electric conductivity - 130 μS $\times$ cm^{-1}, phosphates - 0.05 mg $\times$ 1^{-1}, total phosphorus - 0.018 mg P $\times$ 1^{-1}, nitrates - 0.32 mg N_{N03} $\times$ 1^{-1}). Upstream from the village Zubrzyca Górna, this species was found only sporadically as individual specimens in the waters of the Zubrzyca stream (Station 3). They were accompanied by numerous diatom

Table 2

Diatomms' the most frequent species concurrent *Didymosphaenia geminata* and them proportional part on indiwidual positions (average with three seasons): 1: <5 %; 2: 5 – 10 %; 3: 10 – 30 %; 4: 30 – 50 %; 5: over 50 %.

POSITION	1	2	3	4	5	6	7
Achnanthes biasolettiana *Grun. var.* biasolettiana	3	3	1	4	2	4	5
Achnanthes minutissima Kütz. var. *minutissima*	2	2	5	1	5	2	1
Amphora pediculus *(Kütz.) Grun.*	2	1	1	1	1	1	1
Cocconeis pediculus Ehr.	2	2	1	2	1	1	1
Cocconeis placentula var. *euglypta* (Ehr.) Grun.	4	5	1	2	1	3	3
Cymbella minuta Hilse	2	3	1	3	1	3	1
Diatoma mesodon (Ehr.) Kütz.	1	1	1	1	2	1	1
Diatoma vulgaris Bory	1	1	1	1	1	1	2
Didymosphaenia* geminata *(Lyngb.) Schmidt	**1**	**1**	**1**	**2**	**1**	**1**	**1**
Fragilaria arcus *(Ehr.) Cleve* var. *arcus*	1	1	1	2	2	1	1
Fragilaria capucina *Desmaziéres var.* capucina	1	1	1	1	2	1	1
Fragilaria ulna (Nitz.) Lange-Bertalot	1	1	1	1	3	1	1
Gomphonema angustum Agardh	1	1	1	1	1	1	1
Melosira varians Agardh	1	2	3	1	1	1	2
Meridion circulare (Grév.) Agar.	1	1	1	1	2	1	1
Navicula capitatoradiata Ger.	1	2	1	3	1	3	3
Navicula cryptocephala Kütz.	1	1	2	1	1	1	1
Navicula cryptotenella Lange-Bertalot	1	1	1	1	1	2	1
Navicula gregaria Donkin	2	3	2	1	1	1	2
Navicula lanceolata (Ag.) Ehr.	2	3	1	1	1	1	1
Navicula menisculus *Schumann var.* menisculus	1	2	1	1	1	1	1
Navicula menisculus var. *grunowii* Lange-Bertalot	1	1	3	1	1	1	1
Navicula pupula *Kütz.* var. *pupula*	1	3	1	1	1	1	1
Navicula reichardttiana *Lange-Bertalot var.* reichardttiana	1	2	1	1	1	1	2
Navicula subminuscula Manguin	2	1	1	1	1	1	1
Navicula tripunctata (Müll.) Bory	2	1	1	1	1	3	1
Nitzschia dissipata *(Kütz.) Grun. var.* dissipata	2	1	1	1	1	1	2
Nitzschia linearis (Ag) Smith var. *linearis*	1	1	3	1	1	1	1
Nitzschia palea (Kütz.) Smith	4	4	1	3	1	3	1
Surirella angusta Kütz	1	1	2	1	1	1	1
Surirella minuta Bréb.	2	3	1	3	1	1	2

species such as *Achnanthes biasolettiana* var. *biasolettiana* and *Cymbella minuta*, *Navicula capitatoradiata*, *Nitzschia palea*, *Surirella minuta*, *Cocconeis placentula* var. *euglypta*, *Cocconeis pediculus* and *Fragilaria arcus* var. *arcus* (Tab. 2).

The upper waters of the Sylec stream (Station 5) are comprised of a small water course that originates at Babia Góra Mountain. Station 5 was located in a pristine habitat free of human impact. *D. geminata* was found here only rarely (just a couple of specimens were identified in the samples). The waters were oligotrophic (Tab. 1), and the dominant species were *Achnanthes minutissima*

var. *minutissima*, *Fragilaria ulna*, *F. arcus* var. *arcus*, *Achnanthes biasolettiana* var. *biasolettiana* and *Meridion circulare* (Tab. 2).
D. geminata was a sporadic species in the mezotrophic conditions of the downstream waters of the Sylec and Lipnica streams at stations 6 and 7, respectively. The same was true for the Czarna Orawa. These findings were confirmed by the composition of dominant species at these sites, e.g., *Navicula capitatoradiata*, *N. tripunctata, Nitzschia palea*, *Cymbella minuta*, *Cocconeis placentula* var. *euglypta*, *Diatoma vulgaris*, *Melosira varians,* and the most abundant species was *Achnanthes biasolettiana* var. *biasolettiana* (Tab. 2).

DISCUSSION

The data presented above are the first which confirm that *Didymosphaenia geminata* occurs in the Czarna Orawa and its tributaries (the diatom flora of the Orawian streams has not been examined before). Until recently, *D. geminata* was believed to be a northern, mountain species (Krammer and Lange-Bertalot 1986) as well as a good indicator of very clean waters - a xenosaprobic species (Sladeček 1986). In Poland, it was a rare species occasionally found in the Tatra region and in the Dunajec River (Siemińska 1964). However, in recent years it is often found in water courses in southern Poland. Sometimes it occurs at a very high abundance, e.g., in the San River in the 1990s (Kawecka and Sanecki, 2003).
In the Orawa region, *D. geminata* was most abundant in the Zubrzyca stream (Station 4, downstream of the village) in mezotrophic conditions (Tab. 1). It bloomed in the spring and was one of the three dominant species (with *Achnanthes biasolettiana* var. *biasolettiana* and *Cymbella minuta*) (Tab. 2). In the Czarna Orawa and its other right-bank tributaries only individual specimens were noted throughout the year. It was not observed in streams which originated in peatlands, nor in those with brown-colored waters, which are typical for peatlands. These streams were small, yet deep (0.8-1.5 m), in comparison to those inflowing from Babia Góra Mountain.
These characteristics suggest that shallow streams with well-oxygenated water, a temperature which is not too high, and increased sunlight favor this diatom species. Water samples from chosen sites were subjected to chemical analysis (Tab. 1), which revealed that most Orawian streams are mezotrophic since the nutrient levels are elevated. There are large villages in the valleys of all the streams examined (Jabłonka, Zubrzyca Górna, Zubryca Dolna, Lipnica Mała and Lipnica Wielka). Only some of these villages have wastewater treatment plants, all of which went into operation only recently. At sites located far from populated areas, where the human impact on the natural environment was

minimal (stations 3 and 5), *D. geminata* was rarely found and only then as individual cells.

The composition of the most abundant species in Orawian streams indicates that prevailing conditions are mezotrophic. The species found at almost all sites are *Cymbella minuta* (pH of approximately 7), *Navicula gregaria*, *N. lanceolata*, *Surirella minuta*, *Cocconeis placentula* var. *euglypta*, *C. pediculus*, these are α-β - mezosaprobic species also found in eutrophic waters with pH > 7 (van Dam *et al*. 1994). The following species were often found among the dominant diatoms: *Navicula capitatoradiata* and *N. tripunctata* – eutrophic species, α-β - mezosaprobic and alkalophilic species (van Dam *et al*. 1994). Krammer and Lange-Bertalot (1986) considered them to be good indicators of α-β - mezosaprobic waters with an increased electrolyte content. Numerous *Achnanthes biasolettiana* var. *biasolettiana* were observed; they are typical of mezotrophic waters rich in calcium and with a pH > 7 (van Dam *et al*. 1994).

D. geminata emerged under similar conditions in other Carpathian rivers (WIOŚ 1996, 2000) and in the San River, where there were large aggregations, which, in some cases, covered 100% of the river bottom (Kawecka and Sanecki 2003).

The dispersion of *D. geminata* in southern Poland in recent years indicates that the species is a very good colonizer. The environmental conditions where *D. geminata* was found suggest that the species' adaptive abilities are much greater than was previously believed.

REFERENCES

Bucka H., 2002, *Upper Vistula River: response of aquatic communities to pollution and impoundment. VI. Net phytoseston communities*, Pol. J. Ecol., 50, 167-189

Cleve-Euler A., 1955, *Die Diatomeen von Schweden und Finnland*, Handl. K. Svenska Vetensk Akad., Fjärde Ser. 5(4), 1-232

Johanson C., 1980, *Attached algae vegetation in some streams from the Norssag area South Greenland*, Acta Phytogeogr. Svecica, 68, 89-96

Kasza H., Galas J., 2002, *Upper Vistula River: response of aquatic communities to pollution and impoundment. II. Chemical composition of water and sediment*, Pol. J. Ecol., 50, 123-135

Kawecka B., 1965, *Communities of benthic algae in the River Białka and its Tatra tributaries The Rybi Potok and Roztoka*, Komitet Zagosp. Ziem Górskich PAN, 11, 113-129

Kawecka B., 1980, *Sessile algae in European mountain streams. 1. The ecological characteristic of communities*, Acta Hydrobiol., 22, 361-420

Kawecka B., Eloranta P., 1987, *Communities of sessile algae in some small streams of Central Finland. Comparison of the algae of the high mountains of Europe and those of its northern regions*, Acta Hydrobiol., 29, 403-415

Kawecka B., Sanecki J., 2003, *Didymosphaenia geminata in running waters of southern Poland – symptoms of change in water quality?*, Hydrobiologia, 1952, 1-9

Kondracki J., 1998, *Geografia regionalna Polski*, Państwowe Wydawnictwo Naukowe, Warszawa, 441 pp.

Krammer K., Lange-Bertalot H., 1986-1991, *Bacillariophyceae,* [in:] *Mollenhauer Süβwasserflora von Mitteleuropa 2 (1-4)*, Ettl H., Gerloff J., Heynig H. (eds.), D. VEB G. Fischer Verlag, Jena

Krammer K., 1992, *Pinnularia. Eine Monographie der Europaischen Taxa*, Crammer. Berlin

Książkiewicz M., Samsonowicz J., 1952, *Zarys geologii polskiej*, Państwowe Wydawnictwo Naukowe, Warszawa, 378 pp.

Matuszczyk A., 1993, *Orawa i Pasmo Podhalańskie. Przewodnik monograficzny*, Wydawnictwo Górskie, Poronin, 175 pp.

Siemińska J., 1964, *Bacillariophyceae – Okrzemki*, [in:] *Flora Słodkowodna Polski, 6*, Starmach K. (eds.), Państwowe Wydawnictwo Naukowe, Warszawa, 610 pp.

Skulberg O. M. A., Lillehammer A., 1984, *Glåma*, [in:] *Ecology of European Rivers*, Whitton B.A. (eds.), Blackwell Sci. Publ. Oxford-Melbourne, 469-498

Sladeček V., 1986, *Diatoms as indicators of organic pollution*, Acta Hydrochim. Hydrobiol., 14(5), 555-566

Van Dam H., Martens A., Sinkeldam J., 1994, *A coded checklist and ecological indicator Values of freshwater diatoms from the Netherlands*, Netherlands J. Aquatic Ecol., 28, 117-133

WIOŚ – Jasło, 1996, *Raport o stanie środowiska w Województwie Podkarpackim. (Report on the environmental state of the Podkarpacki District).* WIOŚ – Kraków, 2000, *Raport o stanie środowiska w Województwie Krakowskim. (Report on the environmental state of the Cracow District*).

WIOŚ – Kraków, 2001, *Klasyfikacja jakości wód powierzchniowych płynących na terenie Województwa Małopolskiego*.