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Species richness and diversity of caddisflies (Trichoptera) in a selected area in mid-western Poland (Lubuskie Province)

Bogactwo i różnorodność chruścików (Trichoptera) na wybranym obszarze środkowo-zachodniej Polski (województwo lubuskie)

SUMMARY

The information about the distribution of caddisflies (Trichoptera) in mid-western Poland being a part of the Wielkopolsko-Kujawska Lowland (WKL) faunistic region is still scarce compared to other regions. To close the knowledge gap, we investigated caddisflies larvae and occasionally imagines in a selected area in mid-western Poland in 2011. The aim was the preliminary estimation of species richness and abundance of protected, rare and endangered species in this part of WKL. For the study 63 sampling sites representing broad spectrum of habitat types were chosen and analysed with various ecological indices. In total, 75 species: 46 as larvae and 51 as imagines were found in the area. Among them, one protected species (*Crunoecia irrorata*), 5 listed in the Polish Red List (*Erotesis baltica*, *Hydropsyche bulgaromanorum*, *Ylodes simulans*, *Limnephulus borealis* and *L. fuscinervis*), and 11 species not reported for WKL yet were found in the area. In the whole material, the most frequent and dominant species was *Limnephilus flavicornis*. In contrast, 50 species were recorded in less than 5% of sites. The highest species richness was found in rivers and fish ponds with total number of 33 and 32 species, respectively, whereas the lowest one in springs (5 species) and bogs (6 species). The highest species diversity obtained with probability of intraspecific encounter (PIE) Index was found in fish ponds (0.90) and rivers (0.85) as well. In contrast, streams had the lowest PIE value (0.60) in the area. The most valuable habitat types with regard to protected, endangered and rare species were rivers and fish ponds, as well as lakes and streams of lower importance. To conclude, our investigation indicated a high species richness and diversity in the area, which was related to high habitat heterogeneity, thus having significant importance for biodiversity preservation in mid-western Poland. Moreover, fish ponds and rivers were the most valuable habitat types significantly contributing to species richness, diversity and preservation of rare and endangered species in this area.

Keywords: diversity, species richness, rivers, ponds, springs, rare species, endangered species, protected species

STRESZCZENIE

Wiedza na temat rozmieszczenia chruścików (Trichoptera) w środkowo-zachodniej Polsce, będącej częścią krainy faunistycznej Niziny Wielkopolsko-Kujawskiej (WKL) jest wciąż uboga w porównaniu do innych regionów. W celu uzupełnienia tej informacyjnej luki w roku 2011 przeprowadzono inwentaryzację wybranego obszaru w tej części kraju. Celem pracy było wstępne określenie różnorodności gatunkowej oraz gatunków chronionych, zagrożonych i rzadkich w tej części WKL. Próby pobrano z 63 stanowisk obejmujących szerokie spektrum typów siedlisk a następnie przeanalizowano przy użyciu różnych wskaźników ekologicznych. Ogółem stwierdzono 75 gatunków chruścików, w tym 46 i 51 odpowiednio w postaci larw i osobników dorosłych. Wśród stwierdzonych gatunków jeden jest chroniony (*Crunoecia irrorata*), 5 znajduje się na Polskiej Czerwonej Liście (*Erotesis baltica*, *Hydropsyche bulgaromanorum*, *Ylodes simulans*, *Limnephulus borealis* and *L. fuscinervis*) a 11 nie było dotychczas podanych z WKL. Z całości materiału gatunkiem o najwyższej dominacji i frekwencji był *Limnephilus flavicornis*. Natomiast aż 50 gatunków stwierdzono w mniej niż 5% stanowisk. Najwyższą liczbę gatunków zanotowano w rzekach i stawach rybnych, odpowiednio 33 i 32, natomiast najmniejszą w źródłach (5 gatunków) oraz na torfowiskach (6 gatunków). Najwyższą różnorodnością gatunkową mierzoną według wskaźnika PIE charakteryzowały się również stawy rybne (0.90) i rzeki (0.85), natomiast najniższą wartość PIE (0.60) stwierdzono w strumieniach. Pod względem udziału gatunków chronionych, zagrożonych i rzadkich najbardziej cenne okazały się rzeki oraz stawy rybne, a także w mniejszym stopniu jeziora oraz źródła. Reasumując, badany obszar charakteryzuje się dużym bogactwem oraz różnorodnością gatunkową chruścików mających znaczenie dla ochrony bioróżnorodności w środkowo-zachodniej Polsce. Najbardziej cennymi typami siedlisk dla zachowania bogactwa, różnorodności oraz dla gatunków rzadkich i zagrożonych są rzeki oraz stawy hodowlane.

Słowa kluczowe: różnorodność, bogactwo gatunkowe, rzeki, stawy, źródła, gatunki rzadkie, gatunki zagrożone, gatunki chronione

INTRODUCTION

Caddisflies (Trichoptera) are an important compound of benthic community in freshwater systems due to the substantial role in the food web chains, as bioindicators for environmental quality assessment (12, 19, 23), consequently contributing to the biodiversity on the regional and global scale. In addition to that, many species are currently endangered as a result of restricted distribution or advanced habitat changes (39). Despite this, in many regions of Poland, the knowledge about the distribution of caddisfly species in general as well as of rare and endangered species is still low (18, 25, 40). Related to this, available information from the mid-western Poland, being a part of the Wielkopolsko-Kujawska Lowland (WKL), is based generally on historical data obtained more than 45 years ago (40) and one brief note (13). Since that time, detailed information has been provided from Drawieński National Park (19), and few species have been reported from the Oder River (22) and small mining lakes near to Łęknica (10).

Pertaining to this, the main purpose of our preliminary study was 1) to obtain the species richness and participation of protected, endangered and rare species of caddisflies, 2) to analyse the diversity of species and assemblages of caddisflies among various habitat types, 3) to indicate the

most valuable habitats for the development of Trichoptera in a lowland area with different types of waters, either natural or anthropogenic ones. For this an area rich in diverse water bodies and habitat types in the mid-western Poland has been chosen.

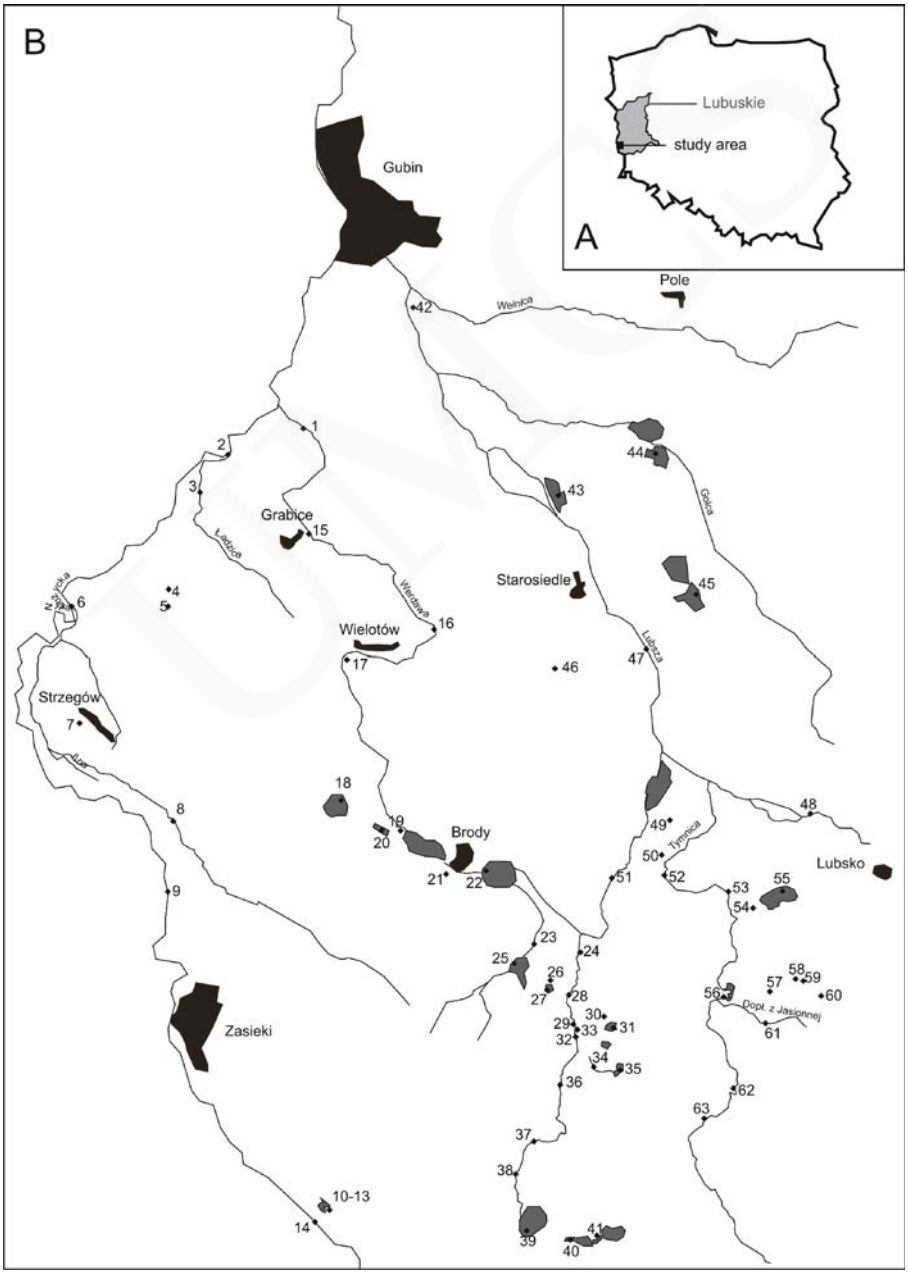

Fig. 1. Location of study area: A – location in Poland; B – location of study sites in the area.

STUDY AREA

The study was carried out in an area between Gubin, Lubsko and Zasieki, in the south-western part of the Lubuskie Province (Fig. 1). All details concerning its administrative division and geographical regionalisation are given elsewhere (35).

The investigated area is characterised by large forest complex with domination of pine trees (*Pinus silvestris* L.). Only next to Brody, Starosiedle and Wielotów agricultures dominate the landscape. Further, it is rich in running and standing waters with various hydromorphological features. The largest river is Nysa Łużycka – classified as a mid-sized upland river (34). Other rivers represent the type of lowland rivers dominated either by sandy (Ładzica, Werdawa, Mała Młynówka, Pstrąg,

Table 1. Information on the geographical names (if present), habitat type (Sp – spring, Di – ditch, St – stream, Ri – river, Sw – small water body, Po – pond, Bo – bog, Lt – light trap), the nearest village/town, UTM codes, and geographical coordinates (latitude and longitude) of sampling sites.

Site no.	Geographical name	Habitat type	Nearest village/ town	UTM	Latitude (N)	Longitude (E)
1	Werdawa	Ri	Sękowice	VT74	51°53’51”	14°42’00”
2	Nysa Łużycka	Ri	Sadzarzewice	VT74	51°51’57”	14°38’23”
3	Ładzica	Ri	Sadzarzewice	VT74	51°52’47”	14°39’45”
4	-	Sw	Markosice	VT74	51°51’10”	14°39’05”
5	-	Po	Markosice	VT74	51°51’14”	14°39’00”
6	Nysa Łużycka	Ri	Późna	VT74	51°42’33”	14°41’23”
7	-	Lt	Strzegów	VT74	51°49’23”	14°36’54”
8	Mała Młynówka	Ri	Mielno	VT73	51°47’47”	14°39’13”
9	Nysa Łużycka	Ri	Janiszowice	VT73	51°46’58”	14°39’14”
10	-	Sw	Brożek	VT82	51°41’55”	14°43’04”
11	-	Sw	Brożek	VT82	51°41’55”	14°43’02”
12	-	Po	Brożek	VT82	51°41’55”	14°43’04”
13	-	Sw	Brożek	VT82	51°41’53”	14°43’17”
14	Nysa Łużycka	Ri	Brożek	VT72/82	51°41’45”	14°43’02”
15	Werdawa	Ri	Grabice	VT74	51°52’13”	14°42’26”
16	Werdawa	Ri	Wierzchno	VT84	51°50’46”	14°45’41”
17	-	Lt	Wielotów	VT84	51°50’03”	14°43’47”
18	Suchodół	La	Suchodół	VT83	51°47’57”	14°43’31”
19	-	Di	Jeziory Dolne	VT83	51°47’35”	14°44’48”
20	-	Po	Suchodół	VT83	51°47’42”	14°44’22”
21	-	Lt	Wielotów	VT84	51°47’06”	14°45’40”
22	-	Po	Nabłoto	VT83	51°47’08”	14°47’19”
23	-	St	Proszów	VT83	51°45’55”	14°48’16”
24	-	Lt	Żytni Młyn	VT83	51°45’49”	14°49’27”
25	Ruskie Stawy	Po	Proszów	VT83	51°45’43”	14°47’57”
26	-	Bo	Proszów	VT83	51°45’21”	14°48’49”
27	-	La	Proszów	VT83	51°45’20”	14°48’45”
28	Pstrąg	Ri	Proszów	VT83	51°45’09”	14°49’11”
29	-	Sp	Proszów	VT83	51°45’21”	14°48’49”

30	-	Bo	Proszów	VT83	51°44’59’’	14°50’18’’
31	Głębokie	La	Proszów	VT83	51°44’44’’	14°50’09’’
32	Pstrąg	Ri	Proszów	VT83	51°44’34’’	14°49’26’’
33	-	Sp	Proszów	VT83	51°44’38’’	14°49’25’’
34	-	St	Proszów	VT83	51°44’05’’	14°49’52’’
35	Niwa	La	Grężawa	VT83	51°44’08’’	14°50’36’’
36	Pstrąg	Ri	Grężawa	VT83	51°43’52’’	14°49’06’’
37	Pstrąg	St	Tuplice	VT82	51°42’54’’	14°48’21’’
38	Pstrąg	St	Tuplice	VT82	51°42’13’’	14°48’00’’
39	Duży Staw	Po	Tuplice	VT82	51°41’43’’	14°48’17’’
40	-	Po	Tuplice	VT82	51°41’28’’	14°49’27’’
41	-	Di	Tuplice	VT82	51°41’26’’	14°50’04’’
42	-	Lt	Żenichów	VT85	51°55’45’’	14°44’55’’
43	-	Po	Gębice	VT84	51°52’47’’	14°48’48’’
44	-	Po	Łazy	VT84/94	51°53’28’’	14°51’17’’
45	-	Po	Lasek	VT94	51°51’19’’	14°52’03’’
46	-	Sw	Jasienica	VT84	51°50’18’’	14°48’45’’
47	Lubsza	Ri	Jałowice	VT84	51°50’35’’	14°50’55’’
48	Lubsza	Ri	Mierków	VT93	51°48’04’’	14°55’00’’
49	-	Bo	Biecz	VT93	51°47’24’’	14°51’35’’
50	-	Bo	Tarnów	VT93	51°47’25’’	14°51’36’’
51	Pstrąg	Ri	Tarnów	VT93	51°47’10’’	14°50’30’’
52	Tymnica	Ri	Tarnów	VT93	51°47’07’’	14°51’34’’
53	Tymnica	Ri	Tarnów	VT93	51°48’59’’	14°53’00’’
54	-	Sw	Chełm Żarski	VT93	51°46’37’’	14°53’39’’
55	-	Po	Chełm Żarski	VT93	51°41’55’’	14°43’04’’
56	Tymnica	Ri	Nowa Rola	VT93	51°45’06’’	14°53’05’’
57	-	Di	Nowa Rola	VT93	51°45’19’’	14°54’28’’
58	-	Sw	Dłużek	VT93	51°46’07’’	14°55’36’’
59	-	Sp	Nowa Rola	VT93	51°46’08’’	14°55’31’’
60	-	Po	Nowa Rola	VT93	51°45’18’’	14°55’30’’
61	-	St	Nowa Rola	VT93	51°44’49’’	14°54’12’’
62	Tymnica	Ri	Nowa Rola	VT93	51°43’50’’	14°53’20’’
63	Tymnica	Ri	Grabówek	VT93	51°43’20’’	14°52’42’’

Tymnica) or sandy-clayey (Lubsza) channel substrates (34). Standing waters are represented by fish ponds, small water bodies and peat bogs. Additionally, only two lakes descending from the Vistulian glacial period are present next to Brody (31). Currently they are shallow (with maximum depths < 2 m), eutrophic, and partially with swampy shores. Further, four small lakes are localised next to river Pstrąg (Fig. 1), which are probably of the anthropogenic origin.

For the present study 63 sampling sites with broad spectrum of habitat types have been chosen to investigate the caddisflies (Table 1). In particular, springs (Sp) were investigated in 3 localities (No. 29, 33, 59); ditches (Di) – 3 (No. 19, 41, 57); streams (St) – 5 (No. 23, 34, 37, 38, 61); rivers (Ri) – 20 (No. 1, 2, 3, 6, 8, 9, 14, 15, 16, 28, 32, 36, 47, 48, 51, 52, 53, 56, 62, 63); small water bodies (Sw) – 7 (No. 4, 10, 11, 13, 46, 54, 58); ponds (Po) – 12 (No. 5, 12, 20, 22, 25, 39, 40, 43, 44, 45, 55,

60); lakes (La) – 4 (No. 18, 27, 31, 35); *Sphagnum* bogs (Bo) – 4 (No. 26, 30, 49, 50), and light traps (Lt) 5 (No. 7, 17, 21, 24, 42) respectively (Fig. 1). Natural running waters fulfilling the assumptions of Water Directive were defined as rivers (34), whereas small natural running waters narrower than 1 m and with a small catchment (< 20 km^2) were defined as streams. Artificial depressions used for water drainage were defined as ditches. Further, standing waters with the surface < 0.5 ha and no fish management were classified as small water bodies, whereas bigger than >0.5 ha, artificial standing waters were classified as ponds. The sample sites with light traps were not classified to particular habitat types, because they might attract species from a long distance.

MATERIAL AND METHODS

Caddisflies were collected from the end of April to September 2011. Larvae were caught with a net (diameter 35 cm, mesh size 1x1mm) as well as picked up from bottom sediments, stones, and plants. Imagines were caught occasionally with an entomological net from shore vegetation. Additionally, a light trap (150 W) was used in 5 sites for sampling imagines. In most of the sites, samples were taken once, exceptionally at 11 sites (No. 18, 20, 27, 31, 35, 42, 45, 50, 55, 56, 60) – 2 times, at 3 sites (No. 11, 12, 25) – 3 times, and at No. 21 – 5 times. In total, 84 samples were taken. All individuals were stored in 70% ethanol and preserved for further identification. In total, 1,649 larvae and 889 imagines were collected (Sp – 65, St – 171, Ri – 893, Di – 130, Sw – 100, Po – 703, La – 214, Bo – 25, Lt – 237). 399 larvae and 22 imagines could be identified only to the genus/family level.

DATA ANALYSIS

In faunistic analyses, following ecological indices: frequency (F), dominance (D) with the division into classes according to Biesiadka (5), species richness defined as the species number per site or/and habitat type, and species diversity with the use of probability of intraspecific encounter (PIE) index (27) were used. In addition, similarity analyses between habitat types based on species presence/absence as well as abundances data according to formulas of Jaccard and Bray-Curtis, respectively, were performed according to BioDiversity Pro programme (30). Light traps were excluded from the similarity analyses as they contained imagines only, particularly not associated with a distinct habitat type.

To evaluate the study area and habitat types, species 1) protected by Polish law (33), 2) from the Polish Red List of caddisflies (38), 3) proposed to the Red List of Pomerania (19) – the region localised next to WKL, 4) caddisfly umbrella species (24), as well as 5) species new for WKL were taken.

RESULTS

Faunistic analysis

In total, 75 species from 14 families were found in the area (Table 2). Moreover, 46 and 51 species were identified as larvae and imagines, respectively. The occurrence of 23 species was provided by both larvae and imagines in the area. In contrast, 28 species were found only as imagines without larval evidence. The most widespread species were *Limnephilus flavicornis* and *Halesus digitatus* with

Table 2. List of caddisfly species from the study area with addition of numbers of study sites, number of larvae (L) and adults (A), dominance (D), frequency index (F_i) and protection status (Ps): P – species protected by Polish law, RL – species from the Polish Red List (Szczęsny 2007) in category: EX? – probably extinct, LC – least concern; DD – data deficient; ! – species proposed to the Red List of Pomerania (Czachorowski and Pietrzak 2002); us – umbrella species (Czachorowski et al. 2000); * – new species for Wielkopolsko-Kujawska Lowland (WKL).

No.	Species	No. of study site	L	A	D	F_i	Ps
		Ecnomidae					
1	*Ecnomus tenellus* (Ramb.)	12, 17, 20, 27, 42, 44			2.52	9.5	
		Hydropsychidae					
2	*Hydropsyche angustipennis* (Curt.)	15, 16, 28, 32, 33, 36, 37, 38, 41, 48	76	2	3.07	15.9	
3	*H. bulgaromanorum* Mal.	21		8	0.31	1.6	LC
4	*H. incognita* Pitsch	21		24	0.94	1.6	*
5	*H. pellucidula* (Curt.)	6, 7, 17, 21, 62	6	18	0.94	7.9	
6	*H. saxonica* McL.	32	7	2	0.35	1.6	!, us
7	*H. siltalai* Doehl.	7, 44		2	0.07	3.2	!, *
	Hydropsyche sp.	1, 2, 7, 21, 24, 42, 44	5	22	1.06	11.1	
		Polycentropodidae					
8	*Cyrnus flavidus* McL.	12, 21, 44		3	0.11	4.8	
9	*C. insolutus* McL.	35	1		0.03	1.6	!
10	*C. trimaculatus* (Curt.)	14		2	0.07	1.6	
11	*Holocentropus dubius* (Ramb.)	12, 22, 47, 50, 58	6	1	0.27	7.9	
12	*H. picicornis* (Steph.)	55		34	1.33	1.6	
13	*Neureclipsis bimaculata* (L.)	21		8	0.31	1.6	
14	*Plectrocnemia conspersa* (Curt.)	28, 58, 59	8	1	0.35	4.8	
15	*Polycentropus flavomaculatus* (Pict.)	24		1	0.03	1.6	
16	*P. irroratus* Curt.	14		1	0.03	1.6	
		Psychomyiidae					
17	*Lype phaeopa* (Steph.)	14		50	1.97	1.6	
		Leptoceridae					
18	*Athripsodes aterrimus* (Steph.)	8, 10, 12, 18, 21, 30, 41, 43, 44, 60	41	3	1.73	15.9	
19	*Ceraclea dissimilis* (Steph.)	21, 44		2	0.07	3.2	!, *
20	*Erotesis baltica* McL.	21		1	0.03	1.6	EX?, !, us, *
21	*Leptocerus tineiformis* (Curt.)	42		1	0.03	1.6	
22	*Mystacides azurea* (L.)	6, 31		2	0.07	3.2	
23	*M. longicornis* (L.)	11, 12, 18, 21, 42, 44	73	153	8.90	9.5	
	Mystacides sp.	12	2		0.07	1.6	
24	*Oecetis furva* (Ramb.)	10, 11, 13, 44, 47	1	5	0.23	7.9	
25	*O. lacustris* (Pict.)	12, 21, 27, 42, 44, 55		19	0.74	9.5	

26	*O. ochracea* (Curt.)	18, 21, 47	2	32	1.33	4.8	
27	*Triaenodes bicolor* (Curt.)	4, 12, 55	1	24	0.98	4.8	
28	*Ylodes simulans* (Tjed.)	14		8	0.31	1.6	LC, *
		Molannidae					
29	*Molanna angustata* Curt.	1, 12, 20, 52	9	1	0.39	6.4	
	Molanna sp.	60	2		0.07	1.6	
		Brachycentridae					
30	*Brachycentrus subnubilus* Curt.	9	4		0.15	1.6	
		Goeridae					
31	*Silo pallipes* (Fabr.)	15	1		0.03	1.6	*
		Lepidostomatidae					
32	*Cruneocia irrorata* (Curt.)	33	1		0.03	1.6	P, !, us
33	*Lepidostoma basale* (Kolen.)	62, 63	46		1.81	3.2	
		Limnephilidae					
34	*Anabolia furcata* Brau.	56		1	0.03	1.6	
	Anabolia sp. (*furcata/laevis*)	2, 6, 12, 15, 16, 22, 36, 37, 46, 48, 60	160		6.30		
35	*Chaeropteryx villosa* (Fabr.)	32, 33	193		7.60	3.2	
36	*Glyphotaelius pellucidus* (Retz.)	21, 23, 24, 27, 34, 44	2	15	0.66	9.5	
37	*Halesus digitatus* (Schrank)	2, 15, 28, 32, 36, 38, 41, 48, 51, 52, 53, 56, 62, 63	82		3.23	22.2	
38	*H. radiatus* (Curt.)	9, 28, 48	7		0.27	4.8	
39	*H. tesselatus* (Ramb.)	1, 40	4		0.15	3.2	
	Halesus sp.	34	3		0.11	1.6	
40	*Ironoquia dubia* (Steph.)	28, 37, 48, 57, 61	12		0.47	7.9	
41	*Limnephilus auricula* Curt.	21, 25	3	2	0.19	3.2	*
42	*L. binotatus* Curt.	21, 45	2	1	0.11	3.2	
43	*L. borealis* (Zett.)	43	1		0.03	1.6	LC
44	*L. decipiens* (Kolen.)	4, 21, 25, 39	6	3	0.35	6.4	
45	*L. extricatus* McL.	3, 8	5		0.19	3.2	
46	*L. flavicornis* (Fabr.)	4, 5, 8, 10, 11, 12, 18, 20, 21, 22, 25, 27, 28, 31, 38, 39, 40, 41, 45, 46, 53, 57, 60	288	2	11.4	36.5	
47	*L. fuscinervis* (Zett.)	40	2		0.07	1.6	DD, !,*
48	*L. griseus* (L.)	25	3		0.11	1.6	
49	*L. ignavus* McL.	21		6	0.23	1.6	
50	*L. lunatus* Curt.	3, 4, 8, 15, 21, 34	11	4	0.59	9.5	
51	*L. nigriceps* (Zett.)	30	2		0.07	1.6	
52	*L. politus* McL.	12, 20, 22, 35	35		1.37	6.4	
53	*L. rhombicus* (L.)	1, 8, 10, 21, 28, 32, 34, 36, 48, 51, 52, 61	34	1	1.37	19.0	
54	*L. stigma* Curt.	30, 54	7		0.27	3.2	
55	*L. subcentralis* Brau.	5, 45, 53	6		0.23	4.8	

56	*L. vittatus* (Fabr.)	4	1		0.03	1.6	
57	*Potamophylax rotundipennis* (Brau.)	63	1		0.03	1.6	
	Potamophylax sp.	56, 62	4		0.15	1.6	
	Limnephilidae	3, 28, 29, 35, 36, 37, 38, 48, 55, 56	382		15.0	15.9	
	Phryganeidae						
58	*Agrypnia obsoleta* (Hagen)	13		1	0.03	1.6	
59	*A. petegana* Curt.	35, 42	2	1	0.11	3.2	
60	*A. varia* (Fabr.)	12, 22, 31	3		0.11	4.8	
61	*Oligostomis reticulata* (L.)	19, 28, 61	15	2	0.66	4.8	
62	*Oligotricha striata* (L.)	13, 19, 21, 49, 50, 54, 58	37	1	1.49	11.1	
63	*Phryganea bipunctata* Retz.	17, 21, 47		6	0.23	4.8	
64	*P. grandis* L.	17, 21, 44		7	0.27	4.8	
65	*Trichostegia minor* (Curt.)	17, 21, 25, 26	1	3	1.15	6.4	
	Phryganeidae	8, 53, 58	3		0.11	4.8	
	Sericostomatidae						
66	*Notidobia ciliaris* (L.)	41	3		0.11	1.6	
67	*Sericostoma personatum* (Spence)	21		2	0.07	1.6	
68	*Sericostoma schneideri* (Kolen.)	28, 33, 37, 51	28		1.10	6.4	*
	Sericostoma sp.	1, 38	5		0.19	3.2	
	Hydroptilidae						
69	*Agraylea multipunctata* Curt.	17, 44, 55		11	0.43	4.8	
70	*A. sexmaculata* Curt.	21, 44		2	0.07	3.2	
71	*Hydroptila sparsa* Curt.	7, 44		10	0.39	3.2	
72	*Orthotrichia costalis* (Curt.)	11, 12, 20, 27, 42, 44, 55		199	7.84	11.1	
73	*O. tragetti* Mosely	27, 42, 44		32	1.26	4.8	*
74	*Oxyethira flavicornis* (Pict.)	27, 42, 44		78	3.07	4.8	
	Rhyacophilidae						
75	*Rhyacophila fasciata* (Hagen)	24, 32	1	5	0.23	3.2	*

36.5% and 22.2% frequency in the investigated sites, respectively (Table 2). Additionally, 5 other species (*Hydropsyche angustipennis*, *Athripsodes aterrimus*, *Limnephilus rhombicus*, *Oligotricha striata*, and *Orthotrichia costalis*) occurred in more than 10% of all sites. In contrast, 50 species were recorded in less than 5% of sites, including 31 species with only one record in the area.

The structure of dominance for the whole material was as follows: the class of eudominants was represented by *Limnephilus flavicornis* only, dominants encompassed 4 taxa: *Mystacides longicornis*, *Orthotrichia costalis*, *Chaetopteryx villosa* and *Anabolia* sp. (*furcata* or *laevis*) while *Halesus digitatus*, *Hydropsyche angustipennis*, *Oxyethira flavicornis* and *Ecnomus tenellus* belonged to subdominants. The remaining taxa were classified as recedents (Table 2).

Table 3. The dominance structure of caddisflies in particular habitat types: springs (Sp), streams (St), rivers (Ri), ditches (Di), small waters (Sw), ponds (Po), lakes (La), and bogs (Bo). The abreviations correspond to the names of the genus (the first capital) followed by 3 or 4 letters of the species name.

Habitat type	Dominance class			
	eudominants	dominants	subdominants	recedents
	>10%	5.01 – 10%	2.01 – 5%	≤ 2%
RUNNING WATERS				
Sp	*Ch. vil, S. schn*		*P. con*	*C. irr, H. ang*
St	*H. ang*		*I. dub, A. fur/lae, H. dig, G. pel, L. rho, O. ret*	*L. fla, L. lun, S. schn*
Ri	*Ch. vil, A. fur/lae*	*H. dig, L. fla, L. pha, L. bas*	*L. rho*	*A. ater, H. sax, Y. sim, L. lun, H. ang, H. rad, H. pel, R. fas, L. ext, S. schn, B. sub, H. tes, M. ang, I. dub, C. tri, S. pal, P. rot, P. irr, P. con, P. bip, O. ret, O. ochr*
Di	*L. fla, H. ang*	*O. ret, O. str*	*A. ater, N. cil*	*H. dig, I. dub*
STANDING WATERS				
Sw	*L. fla, A. fur/lae*	*O. stri*	*L. sti, P. con, O. fur,*	*A. obs, A. ater, H. dub, L. dec, L. lun, L. rho, L. vit, M. lon, O. cos, P. sp., T. bic*
Po	*M. lon, L. fla, O. cos*	*O. fla, A. fur/lae*	*E. ten, H. pic, L. pol, T. bic, O. tra, A. ater, L. juv*	*O. lac, H. spa, A. mul, M. ang, L. sub, L. dec, L. gri, L. aur, L. fusc, L. bin, C. flav, A. var, T. min, P. gra, O. fur, L. bor, H. silt, H. tes, G. pel, C. dis, A. sex*
La	*O. cos, M. lon*	*L. fla*	*O. fla*	*A. pat, A. var, A. ater, C. ins, E. ten, G. pel, L. pol, L. sp., M. azur, O. lac, O. ochr, O. tra*
Bo	*O. str*	*L. nig, L. sti*	*A. ater, H. dub., T. min*	

In springs, *Chaetopteryx villosa* and *Sericostoma schneideri* dominated, whereas *Crunoecia irrorata* and *Hydropsyche angustipennis* were recedent (Table 3). In streams, eudominants were represented only by *Hydropsyche angustipennis*. Other species were classified either to subdominants (7 species) or to recedents (5). In rivers, again *Ch. villosa* with *Anabolia* sp. *furcata*/*laevis* belonged to eudominants, followed by 4 dominants (*Halesus digitatus*, *Limnephilus flavicornis*, *Lype phaeopa* and *Lepidostoma basale*), and 1 subdominant (*Limnephilus rhombicus*). Other species represented recedents. In ditches, *L. flavicornis* and *H. angustipennis* were eudominants, whereas *H. digitatus* and *I. dubia* were recedent. In ponds and lakes, *Mystacides longilostris* and *Orthotrichia costalis* domi-

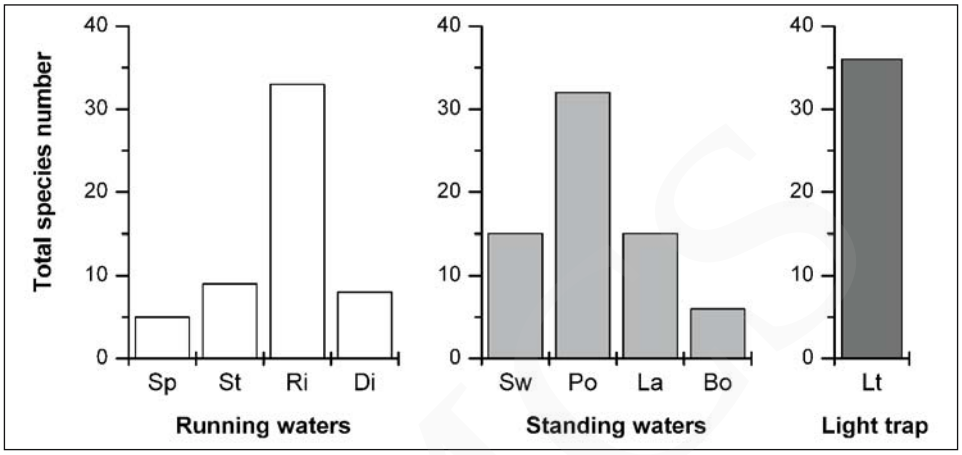

Fig. 2. Total species number of caddisflies found in particular habitat types: springs (Sp), streams (St), rivers (Ri), ditches (Di), small water bodies (Sw), ponds (Po), lakes (La), bogs (Bo) and light traps (Lt).

nated. In small waters, *Limnephilus flavicornis* and *Anabolia furcata/laevis* were the most abundant species. Bogs were characterised by the dominance of *Oligotricha striata*.

The most species-rich were rivers and ponds with total numbers of 33 and 32 species, respectively (Fig. 2). Further, 36 species could be found in light traps. In contrast, the lowest species richness was observed in springs (5 species) and bogs (6 species). Slightly higher numbers were found in ditches (8 species) and streams

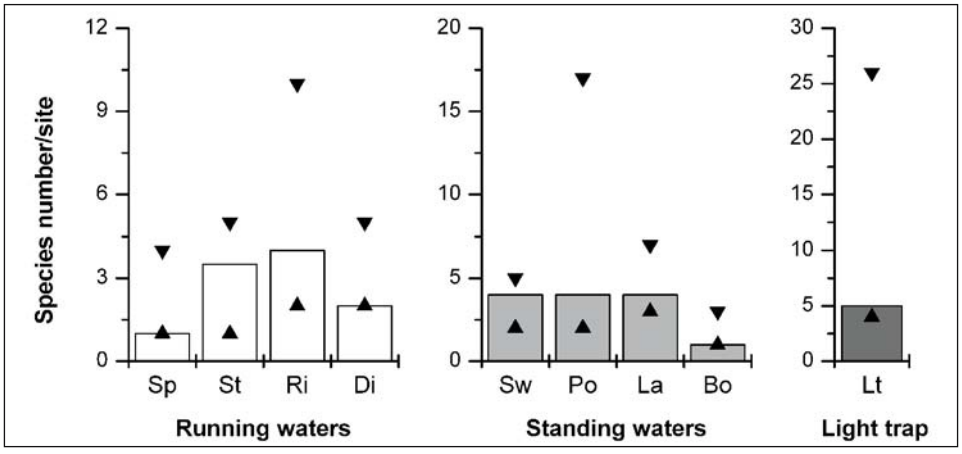

Fig. 3. Median (bars), minimum (upturned pyramids), and maximum (pyramids) values of species number of caddisflies per site in different habitat types: springs (Sp), streams (St), rivers (Ri), ditches (Di), small water bodies (Sw), ponds (Po), lakes (La), bogs (Bo) and light traps (Lt). Note different scales in graphs.

(9 species). Moderate species richness was observed in small waters and lakes (15 species each). On average, the median values within study sites did not exceed 5 species per site (Fig. 3). However, the maximum species number was found in ponds (17 species) and in rivers (10 species). Additionally, light traps provided information on maximal 27 species at one site. The lowest species number was found in bogs (1–3 species) and in springs (1–4 species).

Species diversity provided with the use of PIE Index for the examined types of habitats reached the values from 0.90 in ponds to 0.46 in bogs (Fig. 4). A bit

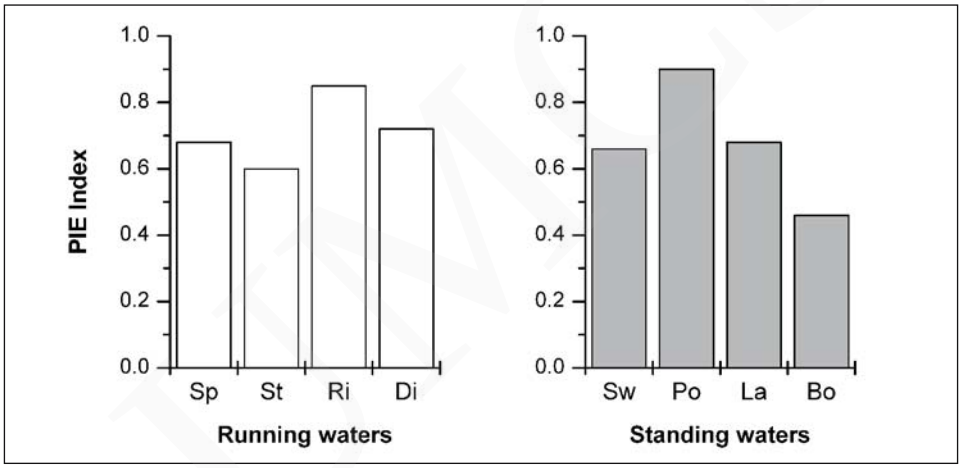

Fig. 4. The probability of intraspecific encounter (PIE) Index estimated for particular habitat types: springs (Sp), streams (St), rivers (Ri), ditches (Di), small water bodies (Sw), ponds (Po), lakes (La), and bogs (Bo).

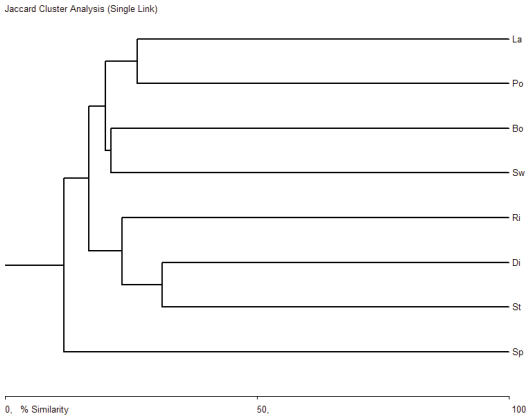

Fig. 5. Dendrite of qualitative faunistic similarities between particular habitats: springs (Sp), streams (St), rivers (Ri), ditches (Di), small water bodies (Sw), ponds (Po), lakes (La), and bogs (Bo).

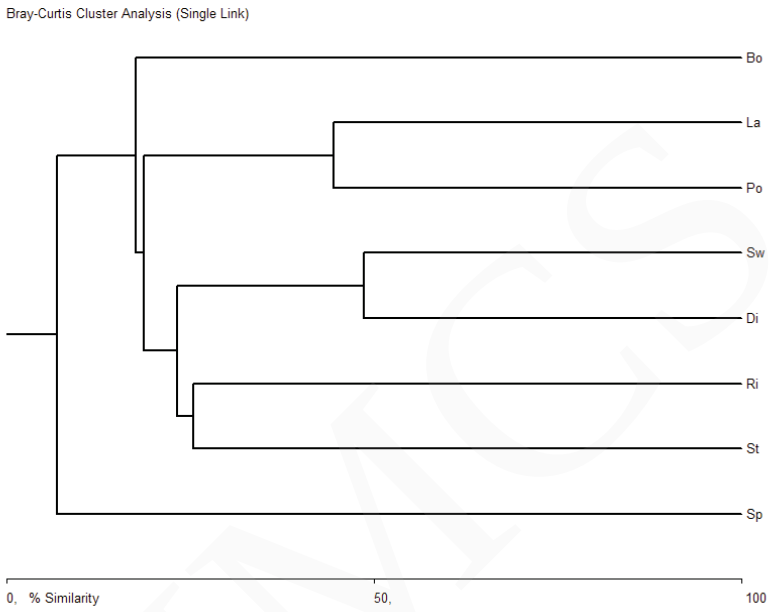

Fig. 6. Dendrite of quantitative faunistic similarities between particular habitats: springs (Sp), streams (St), rivers (Ri), ditches (Di), small water bodies (Sw), ponds (Po), lakes (La), and bogs (Bo).

lower than maximum value was found for rivers (0.85). Moderate values were obtained for ditches (0.72), lakes and springs (0.67 each), small water bodies (0.66) and streams (0.60).

The similarities between habitat types based on qualitative species data (Fig. 5) were relatively low – the highest similarity was found between the assemblages of ditches and streams (J=31%) as well as lakes and ponds (J=26%). However, two clear and separate blocks could be distinguished – one encompassed taxa inhabiting running waters, previously mentioned streams and ditches together with rivers and the second one grouping four types of standing waters: lakes and ponds together with also evidently joined bogs and small water bodies. Springs with not numerous but very specific fauna were clearly separated from the rest of habitats. The similarities between habitat types based on quantitative species data reached higher values and the arrangement of habitats was a bit different (Fig. 6). The highest similarity was recorded in case of ditches and small water bodies (B-C=48.5%) as well as lakes and ponds (B-C=44%). In the diagram, the division into the groups characteristic of running and standing waters is still visible as well as the separate position of the springs, however, the fauna of small water bodies seems to be the conjunctive element in the quantitative analysis.

Protected, endangered and rare species

In total, one species protected by law, 5 listed in the Polish Red List, 7 proposed for the regional Red List of Pomerania and 3 umbrella ones were found in the study area (Table 2). Empty cases of the only one species protected by Polish law, *Crunoecia irrorata*, were observed at one spring site (No. 33). Two Red List species: *Erotesis baltica* (cathegory EX?) and *Hydropsyche bulgaromanurum* (LC) were trapped as imagines at site No. 22, however the larval stages were not found in the surrounding habitats. Further, numerous imagines of *Ylodes simulans* (LC) were caught directly at the Nysa Łużycka River, suggesting its development in this habitat, however, the larvae were not found. Further Polish Red List species: *Limnephilus borealis* (LC) and *L. fuscinervis* (DD) occurred as the low number of larvae at one site each. The Red List species for Pomerania (19), the only regional compilation of this kind in Poland so far, can be used as a determinant for indicating rare and valuable species in the studied area where *Hydropsyche saxonica*, *H. siltalai*, *Cyrnus insolutus*, *Ceraclea dissimilis*, *E. baltica*, *C. irrorata*, and *L. fuscinervis* were found in low numbers of larvae or/and imagines at single sites. Additionally, the already mentioned *C. irrorata*, *H. saxonica* and *E. baltica* have been proposed as umbrella species for springs, running waters and lakes, respectively. Moreover, *Hydropsyche incognita*, *H. siltalai*, *C. dissimilis*, *E. baltica*, *Y. simulans*, *Silo pallipes*, *Limnephilus auricula*, *L. fuscinervis*, *Sericostoma schneideri*, *Orthotrichia tragetti*, and *Rhyacophila fasciata* have not been reported from the WKL so far (Table 2).

DISCUSSION

The identified number of 75 species constitutes 26% of the Polish caddisfly fauna and 62% of species reported from the faunistic region of WKL (40). However, the information on the distribution of caddisflies in the mid-western Poland is still very sparse. The only data summarising caddisfly fauna of WKL have been made more than 45 years ago (40), where 118 species were reported. The recent data contain so far observations of singular habitats located however in the northern part of this region (2, 3, 4, 13, 22), where additionally 3 new species were found. Further, a study in small mining lakes provided decent information on 26 caddisfly species occurring in the southern part of WKL (10). Therefore, the analysis of species richness can only be made in comparison to data published from other parts of Poland, mostly from protected areas. With regard to this, the species number was higher in the investigated area than in other protected regions situated in lowlands or highlands, e.g. in the Nadwieprzański Landscape Park (LP) with 35 species (8), in Krzczonowski LP – 35 (17), in Brudzeński LP – 45 (1), in Iława Lake District LP – 56 (37), in Lasy Janowskie LP – 63 (23). Moreover, in national parks (NP), 12–79 species could be found so far, and the species

richness only from the Bieszczadzki NP, which belongs to the mountain region, exceeded the one found in the investigated area (6, 18). Taking into consideration the landscape form, hydromorphology and the participation of different types of waters in the studied area, the obtained data can be best compared to the following regions – Roztocze where 110 species were found (7), the Łódź Region with 104 species (29) and the Lublin Region (25) with 99 species. Still, the number of species obtained during this study can be regarded as high, because the already mentioned results represent long-term observations. This suggests, that the final number of caddisfly species might be even higher in the studied area as well. It can be also emphasised, that 11 species have not been shown in the WKL so far, however, two of them (*H. incognita* and *O. tragetti*) have been described after 1965, thus they could not be taken into consideration in the Polish Catalogue of Fauna (40). Nevertheless, the relative high number of new species for the WKL indicates the urgent need for systematic exploratory studies in the mid-western Poland.

The general dominance structure reflects the hydrological character of the examined area: eudominating *Limnephilus flavicornis*, a species typical of standing and running waters with well developed helophyte vegetation (14), was absent only in bogs and springs. Moreover, in dominance structure for particular habitats, it belonged to eudominants in ponds, small water bodies and ditches as well as to dominants in lakes and rivers. The taxa that were categorised to general dominants and subdominants represent two groups: lacustrine species (preferring zones of elodeids – *Mystacides longicornis, Orthotrichia costalis, Oxyethira flavicornis, Ecnomus tenellus*) and species characteristic of running waters – typical rheobionts – *Chaetopteryx villosa, Hydropsyche angustipennis* as well as rheolimnophiles – *Anabolia* sp., *Halesus digitatus*. In addition, the similar participation of limnophiles and rheophiles in the whole material indicates the comparable importance of either standing or running waters for the development of Trichoptera in the study area. Clear grouping of habitats within these two categories of waters expressed in diagrams of faunistic similarities as well as species composition and PIE values may suggest that anthropogenic waters in this area, e.g. ponds, inhabited by the fauna typical of natural water bodies or courses are important habitats in the maintenance of high species diversity of caddisflies. It is well seen in case of ponds and lakes – the species with the highest values of dominance were the same for both of them (*Mystacides longicornis, Limnephilus flavicornis, Orthotrichia costalis, Oxyethira flavicornis*) and they can be regarded as typical of such habitats in this area. However, ponds were richer in species and reached higher value of PIE index than lakes, which corresponds with e.g. the results obtained for lakes and ponds in the Poleski National Park (9).

The second worth mentioning type of habitat with high species diversity and richness are rivers. The main feature of the caddisfly assemblages of the rivers in this area is the high participation of the representatives of the Limnephilidae

family in which *Cheatopteryx villosa* and *Anabolia* sp. larvae are eudominants while *Halesus digitatus* and *Limnephilus flavicornis* belong to dominants and *L. rhombicus* – to subdominants. The remaining species from the mentioned classes are *Lype phaeopa* and *Lepidostoma basale* (dominants). Significant is the lack of the genus *Hydropsyche* in these three classes, which is typical of the most lowland and upland rivers in Poland (e.g. 11, 21, 28, 29, 32, 36) as well as clear participation as recedents of species typical of streams and even springs (e.g. *Hydropsyche saxonica*, *Limnephilus extricatus*, *Sericostoma schneideri*, *Plectrocnemia conspersa*, *Rhyacophila fasciata*). Comparing the species composition and dominance structure of this habitat to available data on lowland and upland Polish rivers it can be concluded that the examined rivers are the most similar to the courses of Roztocze, especially to the River Wieprz in its middle course (7, 8).

The remaining habitats of running waters – streams and ditches – were distinguished by the presence of *Hydropsyche angustipennis* which was classified to eudominants. In both habitat types the significant participation of temporary water species – *Ironoqia dubia* and *Oligostomis reticulata* – was also observed. These taxa may be regarded as typical of ditches (8, 36) but their presence in streams also shows strong association with the fauna of fast running waters. It is also noticeable that artificial courses are more diverse than natural, like in case of standing waters. The caddisfly assemblages of springs, peat bogs and small water bodies were rather typical and poor in species. Bogs were dominated by acidophiles with *Oligotricha striata* as determined eudominant. Small water bodies were also influenced by species typical of different habitats, especially by rheophiles which can migrate from other sites. In springs, species richness and diversity was not impressive, however, the fauna of such habitat is very specific, which refers to helocrenes mainly (16). Crucial for these habitat types is finding of empty cases of *Crunoecia irrorata* – a vulnerable species, thus proposed as umbrella species for protection of springs (24). The lack of larvae of *C. irrorata* may suggest, that adverse changes have already started in this habitat type. However, the exact causes could not be detected during the sampling period. Because the springs are directly connected with river Pstrąg valley, in this case, the most probable explanation could be considerable fluctuations in water regime of the river caused either by seasonal climatic changes or by beavers' activity (enhancing permanently the water level) and human action (enhancing temporarily the water level due to upstream pond management).

The value of the investigated area with respect to caddisfly fauna can be considered due to a comparison with the data of the highest quality habitats and with the number of the rarest species. For caddisflies the reference area can be the Białowieża Forest where 79 species were found (15) – faunistic similarity between the faunas of both areas was 47%. This result indicates that overall one half of the species obtained in the studied area typically occur in habitats of natural

character. With regard to the species protected by law and included in the Polish Red List as the measure of the value of the investigated area, it can be concluded that these numbers are average. For instance, in the previously compared areas – Roztocze – there were 1 and 18 species respectively (7), in the Łódź Region – 1 and 11 (29), and in the Lublin Region 0 and 11 (25). However, in many protected areas, the occurrence of Red List species was much lower than in the investigated area (4, 17, 21, 37). Taking into consideration the distribution of these species as well as the taxa proposed for the Red List of Pomerania and umbrella ones, the most numerous were species associated with rivers, which also emphasizes the importance of this habitat type. The most crucial was *Hydropsyche bulgaromanorum*, a large river species inhabiting lower reaches of the courses like Oder, Vistula and Bug (22). The most probable development site of this species is Nysa Łużycka. The presence of two species – *C. irrorata* (protected and umbrella one) and *E. baltica* (redlisted and umbrella one) – may indicate the particular significance of two other habitat types in the area – springs and lakes, respectively, although the exact habitat of larval development of *E. baltica* in the investigated area has been unknown so far. Nevertheless, the future of rivers and lakes in this area is rather stable, more vulnerable are springs and small water bodies, habitats sensitive to even small environmental changes.

Based on the obtained results, it can be assumed that species richness of caddisflies in the investigated area is high, thus having significant importance for preservation of the biodiversity in the mid-western part of Poland. The most valuable habitat types for the maintenance of species diversity are ponds and rivers while for the rare and endangered species – rivers and springs. On the basis of the analysed assemblages it can be concluded that both natural or anthropogenic waters are important for caddisflies and – what is worth mentioning – anthropogenic waters have not been negatively transformed in this area, which most often results in drastic impoverishment of caddisfly assemblage of such environments. Moreover, a higher number of species can be expected in this area, as the sampling design allowed to investigate the selected sites, mostly with one sampling time per site. Therefore, for better understanding of distributional patterns of caddisfly fauna, including rare and endangered species, in western Poland intensified research should be carried out.

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