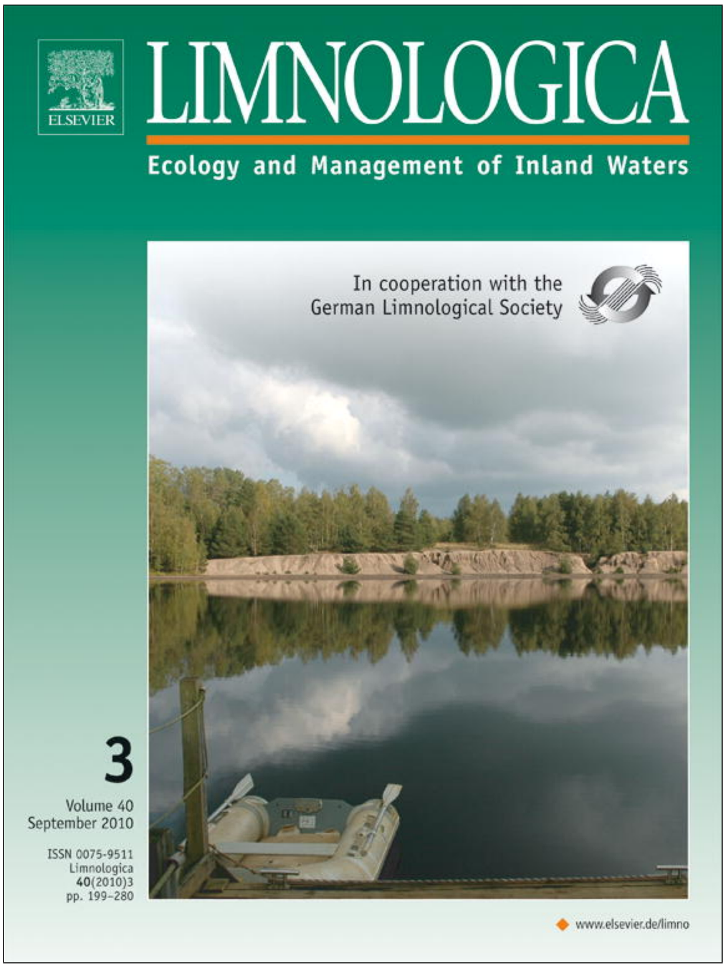
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Urban environments as habitats for rare aquatic species: The case of leeches (*Euhirudinea*, *Clitellata*) in Warsaw freshwaters

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ABSTRACT

Reduced biological diversity in freshwater habitats situated in urban areas has been discussed in numerous studies. Certain municipal areas, however, can help save animal diversity of freshwater invertebrates. In the present study animals were collected or observed alive in 13 freshwater environments localized in Warsaw – the second largest city of Central Europe – in a densely populated, urban building complex close to the city, and also in suburban areas. Leech assemblages in all the environments under observation were numerically dominated by a few common species, but on the whole 19 species were collected or observed. The populations of six rare leech species inhabit both flowing and standing waters in Warsaw. Five of these species are on the Polish Red List of Species and one is strictly protected. The shallow Lake Powsinkowskie is the richest freshwater environment in the studied area in terms of species richness and rarity and also one of the richest lakes in Poland. Taxonomic diversity in the environments under study seems not to be directly related to the size of the water body or the level of degradation but rather to the habitat complexity, especially the diversity of the bottom in littoral zone. Certain freshwater habitats located inside this great urban complex still create good conditions for rare, highly specialized species.

Introduction

In terms of biological diversity, urban habitats are usually regarded as poorer due to their high anthropogenic degradation. Reduced diversity in terrestrial and aquatic urban habitats, as compared with agricultural or forestry neighborhood areas, has appeared in numerous studies: on vertebrates (Melles et al. 2003; Mahan and O'Connell 2005; Luniak 2008), estuarine benthos (Pagliosa and Rodrigues Barbosa 2006) and on lotic invertebrates (Diamond and Serveiss 2001; Moore and Palmer 2005; Smith and Lamp 2008). Freshwater habitats situated in urban areas are particularly endangered by various types of human activity. Urbanization leads to enhanced runoff in streams, channel erosion and reduced water quality due to inputs of metals, oils, and road salts (Moore and Palmer 2005). Standing waters in urban complexes are put to danger by various types of pollution. One of the most important factors negatively impacting environmental quality of water and threatening biological diversity is the suburban (urban) sprawl – the creeping of residential neighborhoods and commerce into rural or natural landscapes surrounding urban centers (August et al. 2002).

Authors of some studies, however, emphasize the significant role of certain municipal areas in saving animal diversity. The presence of urban parks, park ponds and suburban gardens can help protect rare and endangered species of invertebrates (Erseus et al. 1999; Talley et al. 2007). Man-driven moderate disturbance of natural landscape can create high landscape diversity, which in its turn is claimed to lead to high species diversity. What it does, however, is promotes wide-ranging taxa and increase the probability of extinction of species inhabiting isolated patches (August et al. 2002). Overall, the theoretical priorities for conservationists are to direct resources to those species that are most threatened, or to the areas of highest biodiversity. However, in reality, small animals with stashed life-style, like most freshwater invertebrates, are rarely an object of conservation activity in urban environments (Macdonald et al. 2007).

Common leech species, treated as highly tolerant organisms, typically dwell in large numbers in littoral zones of lakes, ponds and rivers. These highly important, from the ecological point of view, predators and parasites also abundantly inhabit urban freshwater environments, even those significantly degraded and highly transformed for human requirements. Some species of this group, however, are ecologically highly specialized, e.g. those predominantly inhabiting small, astatic pools or unpolluted flowing waters. Twelve out of 44 species found in Polish freshwaters are on the IUCN Red List of threatened animals in Poland (Jażdżewska and Wiedeńska 2002). One of them, *Hirudo*

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medicinalis L., 1758, is under strict protection on the territory of Poland as well as being covered by the CITES convention.

Leech fauna recorded in previous studies on biological diversity in urban environments was poor in terms of species richness and rare species richness (rarity) (Pawłowski 1951; Sandner 1951; Erseus et al. 1999); however, a certain new species was discovered even within the boundaries of a big city (Hughes and Siddall 2007). The main aim of this study was to discover taxonomic diversity of small, often neglected freshwater animals in urban environments in order to compare it with the data from natural environments. It can help to evaluate the importance of particular types of anthropogenic threats to the occurrence of such organisms exemplified by leech species, especially rare and specialized ones.

Study area

Warsaw (Warszawa), the capital of Poland, is the second largest city in Central Europe in terms of its surface area (517 km^2) and the number of inhabitants (after different evaluations between 1.8×10^6 and 4×10^6 inhabitants). In the last years, the growth and sprawling of the Warsaw urban complex has been significant and very fast (http://www.um.warszawa.pl). The terrestrial fauna in Warsaw is relatively well known, birds and insects in particular have been an object of intensive studies and metaanalyses (review in Luniak 2008). The leech fauna examined in certain parts of the Vistula River in Warsaw was presented by Pawłowski (1951). Detailed information on the invertebrate fauna in freshwater environments in the area of Warsaw is practically absent in modern international scientific journals. The only exceptions are the data about the morphology and the invertebrate fauna (Mollusca) of Warsaw lakes (Wilanowskie, Czerniakowskie and Powsinkowskie) presented by Kołodziejczyk and Dołęga (2004).

For the purpose of the present study, samples of leeches were collected between May 2002 and May 2008 at 15 sites set in 13 freshwater environments localized within the Warsaw urban complex – in a densely populated, urban building complex close to the city and also in suburban area used for industry and recreation. Two sites are placed on the coast of a large lowland river flowing through the city, two others on an artificial channel flowing through the suburbia and finally two more on small tributaries of the river (Fig. 1). Three water bodies are more or less degraded shallow, eutrophic lakes, one site is a small semi-natural oxbow pond. The other sites are typical park ponds – completely man-made or semi-natural and highly transformed ones (Tables 1 and 2). The data on the type of land use in the vicinity of each site, on their surface area, length and detailed localities have been worked out on the basis of satellite and hybrid maps presented online at Ortofotomapa Warszawy (2008). The information on water level variability, types of natural and artificial bottom, types of shoreline and additional factors is based on the author's own observations.

Following are short characteristics of the environments under study accompanied by name abbreviations used in the text; quantitative data are presented in Tables 1 and 2.

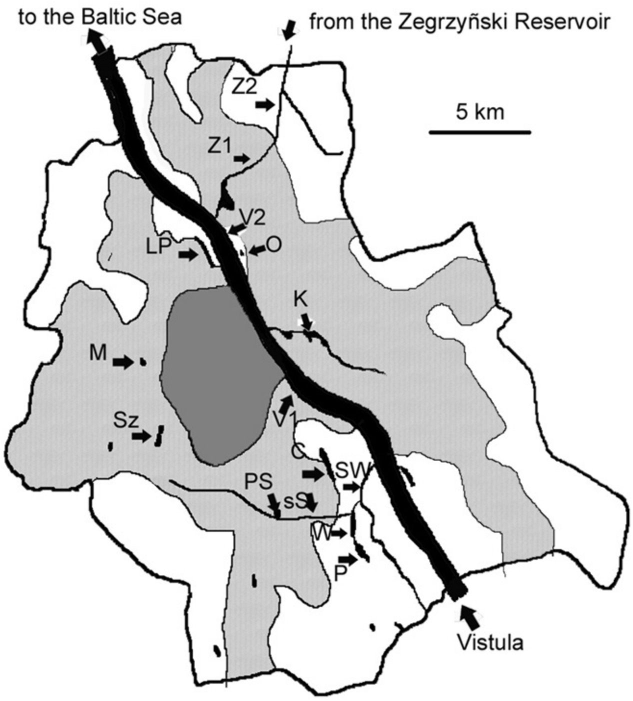

Fig. 1. The area of Warsaw with sampling sites marked by abbreviations (see study area for details). Black line – the area of the Warsaw municipality, dark grey – the city and light grey – built-up area outside the city.

1. Lakes
   Czerniakowskie (C; 52,189 N; 21,072 E) is the largest and deepest standing water body in Warsaw. Its shoreline and bottom are severely damaged in parts as a result of a combined heat and power plant operating nearby.
   Powsinkowskie (P; 21,131 E; 52,128 N) is an eutrophic lake localized just outside the densely built-up zone of the city. Leeches were sampled at its southern, shallower part, with dense patches of emerged and submerged macrophytes and with numerous populations of freshwater fish and water birds. The shoreline of the lake is dominated by divergent riparian vegetation and extensive agriculture.
   Wilanowskie (W; 52, 1644 N; 21,0941 E) is an eutrophic and shallow lake connected with Lake Powsinkowskie by a short outflow. Since 17th century the lake has been significantly rearranged forming part of the large Royal Park and assuming the role of a sizable park pond. The shoreline and bottom are partially transformed. The lake is dwelled by rich populations of native and introduced fish.
2. Flowing waters
   Stream Służewiecki (SS; 21,072 E; 52,168 N) is a regulated stream, ca. 9.5 km in length, flowing partially through industrial area and later through intensively built-up residential districts. It has completely artificial bottom substrate made of concrete blocks and has been irregularly polluted by chemicals. Extremely variable water level is typical for the stream, due to its being the storm-water drainage for a large area. At the sampling site its bottom is full of trash.
   Stream Wilanówka (SW) is a small tributary of the Vistula, 13.5 km in length, for the most part slowly flowing through the willow bush and garden area. The sampling site (52,178 N; 21,097 E) is situated in the section not degraded by human pressure, with natural, divergent bottom and dense riparian vegetation.
   The Vistula (Wisła) (V) is the longest (1047 km in length) and the largest river in Poland and the whole basin of the Baltic Sea. In spite of its occasional, significant chemical pollution the Vistula is called "the last wild great river of Central Europe". In its middle course it flows through the Warsaw as only partially regulated and narrowed river (site V2; 21,049 E; 52,223 N). At a distance of ca. 8 km downstream (site V1; 52,286 N; 20,999 E) it becomes visibly wider and bended. Sand is the most important type of natural bottom material in the river-course but the shoreline and shallow bottom at both

Table 1
Main characteristics of the studied environments (abbreviations – see study area) with the types of the land using in distance of ca. 100 m around a site: R – residentials, I – industrial buildings, roads and bridges, A – agricultural areas (small gardens, crops), O – open developed areas (parks, promenades, playgrounds), RV – riparian vegetation (forest, willow bush, weeds).

Sampling site	Type of environment	Distance to the city (km)	Land using (%)					Additional factors			
			R	I	A	O	RV	1	2	3	4
C	Lake	5	15	5	25	25	30	+	+	+	–
P	Lake	11	5	0	35	0	60	–	–	–	Intensive angling
W	Park pond/lake	10	10	0	10	30	50	–	–	–	Fish introduction
K	Park pond	2	10	15	0	45	30	+	+	–	–
ŁP	Park pond	1.5	0	10	30	45	15	–	–	–	–
M	Park pond	2	20	10	0	35	35	+	–	–	Removing of macrophytes
O	Oxbow pond	2.5	0	0	0	10	90	–	–	+	–
S	Park pond	4	0	15	25	35	25	+	+	–	–
Sz	Park pond	3	10	5	10	50	25	+	–	–	Removing of macrophytes
SS	Regulated stream	9	40	25	10	0	25	+	+	+	–
SW	Stream	10	0	0	15	0	85	–	–	–	–
V1	Large river	2.5	0	25	0	0	75	–	+	+	Intensive angling
V2	Large river	1	0	30	0	35	35	–	+	+	Intensive angling
Ż1	Artificial channel	6	0	45	5	15	35	–	+	+	Intensive angling
Ż2	Artificial channel	13	10	20	5	20	45	–	–	+	Intensive angling

Additional pressuring factors: 1. multi-apartments buildings, 2. thrash, 3. chemical pollution, 4. other factors.

Table 2
Main characteristics of the studied environments, cont. (abbreviations – see study area).

Sampling site	Water level variability	Natural bottom	Artificial bottom	Shore line	Area (m^2)	Width (m)
C	Small	Macrophytes, silt	No	Weeds	1.97×10^5	–
P	Small	Macrophytes, silt	No	Weeds/bush	1.4×10^5	–
W	Small	Macrophytes, silt	No	Lawns/weeds	1.28×10^5	–
K	Small	Silt, stones	Fascine, concrete blocks	Lawns	9×10^4	–
ŁP	Moderate	Macrophytes	Concrete blocks	Lawns/footways	5×10^4	–
M	Moderate	Sand, silt	Concrete blocks	Lawns/footways	1.2×10^4	–
O	High	Macrophytes, sand, silt	Concrete blocks	Weeds	5×10^3	–
S	High	Macrophytes, sand, silt	No	Lawns/footways	7×10^3	–
Sz	Small	Sand, silt	Stones, gravel	Lawns/footways	2.5×10^4	–
SS	Extremely high	No	Concrete blocks	Lawns/footways	–	6
SW	Moderate	Sand, silt	No	Weeds/bush	–	11
V1	High, natural floods	No	Stones	Stone piles	–	320
V2	High, natural floods	No	Stones	Stone piles		270
Ż1	Moderate	Macrophytes, silt	Stones, concrete blocks	Stone piles	–	70
Ż2	Moderate	Macrophytes, silt	Stones, concrete blocks	Stone piles	–	70

sampling sites are artificially reinforced with large stones. The shoreline is full of trash, especially at site V2. Part of the leech collection was sampled from large sheets of plastic foil used in construction industry, which sank close to the shore.

—Żerański (Z) is an artificial channel connecting the Vistula with the man-made reservoir Zegrzyñski on the Narew River. It was finally constructed in 1951 but the history of this water system goes back to 17th century. It is 17.6 km long, shallow and flowing slowly almost in a straight line. Its silty bottom and shoreline are reinforced with large stones and concrete blocks, and the bottom is partially covered with various macrophytes. The first sampling site (Z1; 52,321 N; 21,022 E) is located at industrially used area, the second one (Z2; 52,366 N; 21,034 E) between a forest and a residential district.

3. Ponds

Kamionkowski (K; 21,051 E; 52,246 N), Moczydło (M; 52,207 N; 20,962 E) and Szczęśliwicki (SZ; 52,242 N; 20,951 E) are typical man-made ponds localized in the centre of large parks. They are moderately eutrophic, dwelled by numerous populations of fish and birds. Their naturally silty and sandy bottoms are covered with sparse patches of macrophytes and their shorelines are reinforced with fascine, stones and concrete blocks.

Łacha Potocka (ŁP; 20,983 E; 52,283 N) is a park pond, 2.5 km in length but very narrow, being in fact a strongly transformed oxbow of the Vistula, with artificial, concrete shoreline. It is a moderately eutrophic pond, inhabited by numerous populations of fish, and partially covered with dense patches of submerged macrophytes.

No-named Oxbow (O; 21,002 E; 52,281 N) – small and shallow water body, separated from the Vistula with a narrow dike. The oxbow periodically connects with the river water. The bottom is silty but the shoreline is partly artificial – reinforced with large stones.

Służew (S; 21,038 E; 52,171 N). Small, semi-natural park pond, the biggest of the four ponds connected with Stream Służewiecki. The pond is moderately polluted by the inflow from the stream, eutrophic, with natural silt bottom and populations of bentivorous fish. The pond's shore is covered with sparse littoral macrophytes (emerged and submerged) and a large amount of trash.

Methods

In shallow water leeches were collected by hand from stones, sticks and wood as well as from some anthropogenic remnants – bottles, cans and plastic bags. The dip net was used for sampling at those sites whose shoreline was dominated by macrophytes or concrete blocks. At first leeches were anesthetized in 10% ethanol and after 10 min preserved in 80% ethanol. Since 2005, individuals of rare and easy to recognize species were identified alive visually and counted without killing.

Frequency of occurrence of each species was calculated per sites and per samples. Total species richness and rarity (rare species richness) as well as the values of Shannon–Weaver index of diversity ($\hat{H}$) were calculated for each sampling site on the basis of all the pooled data. To reduce the error related to high differences in numbers of sampled individuals at particular sites, the values of Shannon–Weaver index were also calculated on the basis of modified data – 30 individuals were first chosen at random (Excel 2000) from all the individuals sampled at each site and then percentages of particular species were calculated (30 is the minimum number of individuals sampled at one site).

To compare the leech assemblages sampled in particular environments an analysis of similarity between sites [non-hybrid, multidimensional scaling (MDS) based on Jaccard function (Community Analysis Package by Pisces Inc.) was used.

Results

Overall, 4066 individuals of 19 leech species were found. One thousand seventy-five of them (26%), representing 10 species were identified and counted alive. Leech assemblages in all the studied environments were numerically dominated by common, frequent and ubiquitous species: *Erpobdella octoculata* (L. 1758), *E. nigricollis* (Brandes, 1900), *Glossiphonia complanata* (L. 1758), *Helobdella stagnalis* (L. 1758) and *Alboglossiphonia heteroclita* (L., 1761). The specimens of each species found during study are deposited in collection in Department of Hydrobiology, University of Warsaw, Poland. Six rare leech species, being 32% of total species richness, were found in 5 out of 13 studied environments (38%). Five of them are on the Polish Red List of Species (Jażdżewska and Wiedeńska 2002) and one is strictly protected. However, the number of collected and observed specimens of rare species contains only 2.1% of the total number of sampled leeches. These rare species include (Fig. 2):

1. *Dina apathyi* (Gedroyc, 1916), collected and observed in the Vistula. It dwells a limited part of eastern coast of the river (site V1) probably as a stable, numerous and reproducing population – 20 individuals 20–70mm in length were collected between 2002 and 2006, and 28 young and adult specimens were observed in 2007 and 2008. One young individual was also collected in 2006 in the —Żerañski channel.
2. The medicinal leech *H. medicinalis* was observed in Lake Powsinkowskie in June 2006 (one individual, 55 mm in length) and April 2008 (one individual, 120 mm in length) and in the no-named oxbow in May 2007 – one individual (30 mm).
3. *Batracobdelloides moogi* (Nesemann and Csanyi, 1995) was found in Lake Powsinkowskie. This species probably lived there as a stable population (ca. 30 individuals collected and observed in 2002, 2003 and 2005).
4. *Glossiphonia nebulosa* (Kalbe, 1964) was found once in a sample from Stream Wilanówka (seven individuals 14–17 mm in length collected in June 2007) and once in 2008 in Lake Powsinkowskie, which is connected with the stream (1 ind. 12 mm in length).
5. *Dina lineata* (O.F. Müller, 1774) was found at both sites on the —Żerañski channel (three species collected in 2003, two in 2005 and two in 2007).

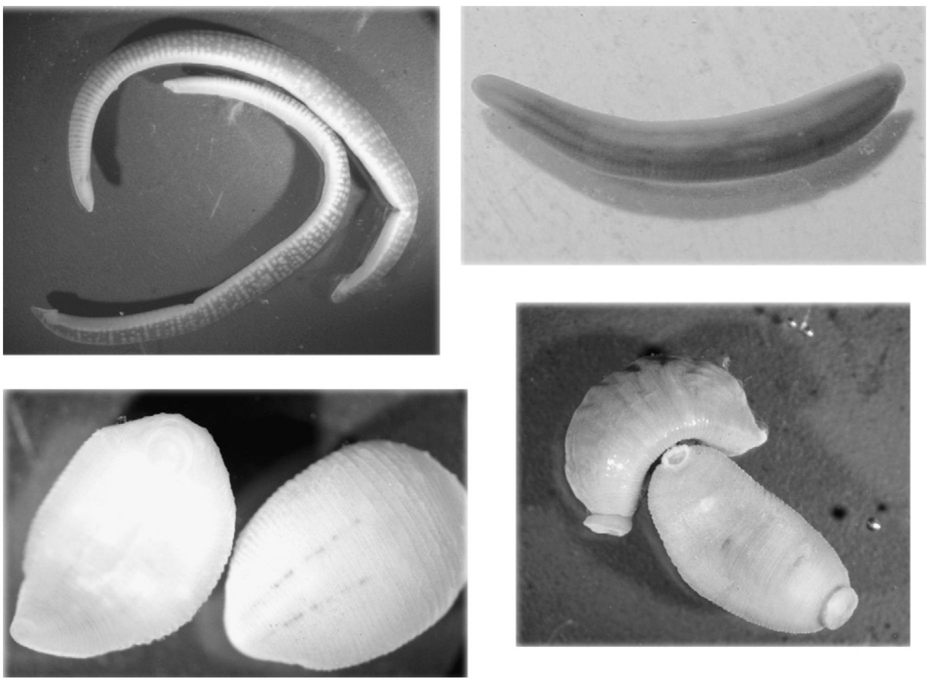

Fig. 2. Rare leech species found in Warsaw freshwaters: (a) *Dina apathyi* upper left, (b) *Dina linaeata* upper right, (c) *Glossiphonia nebulosa* bottom left, and (d) *Batracobdelloides moogi* bottom right.

Table 3
Main characteristics of the leech assemblages in studied environments (abbreviations – see study area).

Species	Site															Frequency (%)	Total
	C	P	W	K	ŁP	M	O	S	Sz	SS	SW	V1	V2	Z1	Z2	Sites/samples	
Dina lineate														+	+	13.3/5.4	7
D. apathyi												+			+	13.3/24.3	46
Erpobdella monostriata												+				6.7/2.7	2
E. nigricollis	+	+	+	+	+	+	+	+	+		+	+	+	+	+	93.3/90.5	367
E. octoculata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	100/100	2754
E. testacea		+	+					+						+	+	33.3/29	111
Alboglossiphonia heteroclita	+	+	+		+	+		+				+	+	+	+	66.7/73	97
A. hyalina		+														13.3/4.1	3
A. striata		+			+			+						+	+	33.3/28.3	9
Batracobdelloides moogi		+														6.7/13.5	21
Glossiphonia complanata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	100/91.8	241
G. concolor		+														6.7/4.1	2
G. nebulosa		+									+					13.3/2.7	8
Helobdella stagnalis	+	+	+	+	+	+		+			+	+	+	+	+	80/81.1	405
Hemiclepsis marginata		+			+			+							+	26.6/13.5	50
Theromyzon tessulatum		+						+			+			+	+	33.3/12.2	9
Haemopis sanguisuga		+										+				13.3/6.8	6
Hirudo medicinalis		+					+									13.3/4.1	3
Piscicola geometra					+							+				13.3/6.8	6
Samples	1	16	1	1	5	1	1	5	1	2	2	9	5	8	8		72
Individuals sampled	114	1067	104	34	277	101	36	297	30	111	90	905	174	358	367		4066
Species	5	15	6	4	8	5	4	9	2	4	6	10	5	9	11		19
Rare species	0	4	0	0	0	0	1	0	0	0	1	1	0	1	2		6
Shannon–Weaver Index 1	0.73	1.71	1.12	0.95	1.13	0.62	0.89	0.91	0.59	0.42	0.84	0.73	0.38	1.51	1.91		
Shannon–Weaver Index 2	0.68	1.46	1.05	0.74	1.05	0.53	0.89	0.64	0.50	0.27	0.70	0.51	0.14	1.43	1.77		

6. *Alboglossiphonia hyalina* (O.F. Müller, 1774) was found in 2005 and 2007 in Lake Powsinkowskie (three individuals).

Lake Powsinkowskie was the richest freshwater environment studied in the area of Warsaw (Table 3) in terms of total species number and the number of rare species. The Vistula and the Żerański channel are also taxonomically rich habitats inhabited by two rare species. The same number of species as in the Vistula (725 individuals identified) was found in the small pond Służew (297 ind.); however, these were only the common ones. In the remaining environments the species richness was lower, but it can partially be the effect of lower number of individuals sampled.

Taxonomic diversity of leeches, expressed as the values of Shannon–Weaver index, was very divergent at particular sites. Species diversity was visibly highest in the Żerański channel and Lake Powsinkowskie while it was a few times lower in the Vistula, Stream Służewiecki and in some park ponds. Such differences in diversity were not attributed to high differences in number of sampled animals, because the values of modified index (based on randomly chosen 30 individuals, see Methods) for particular sites have almost the same order (Table 3).

The analysis of similarities between leech assemblages in particular freshwater environments based on Jaccard function showed that they were low in freshwaters inhabited by rare species (Fig. 3). Consequently, the freshwaters with no rare species were more similar in terms of taxonomic composition. A highly similar group of sites in terms of taxonomic composition was that of all park ponds.

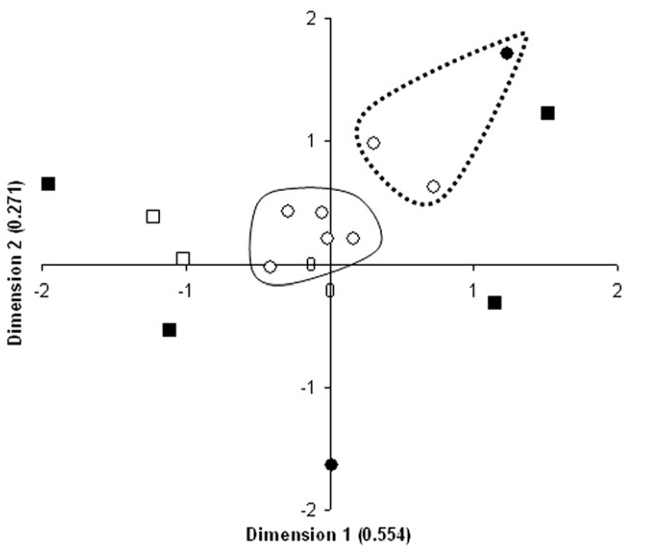

Fig. 3. The plot of non-hybrid, multidimensional scaling based on Jaccard function presenting similarity in taxonomic composition between leech samples collected at particular sites in Warsaw freshwaters. Black figures – environments where rare leech species were found, circles – standing waters, squares – flowing waters. Solid line separates park ponds, dotted line separates lakes.

Discussion

Common species, mainly *E. octoculata* and *G. complanata*, typically strongly dominated leech assemblages not only in urban environments but also in most Polish flowing and standing waters (Koperski 2006). Like in natural environments, the subdominant species in Warsaw freshwaters were also typically *E. nigricollis*, *A. heteroclita* and *Helobdella stagnalis*. It is clearly visible that even strong human pressure: pollution, rearrangements of shore and bottom, removal of macrophytes (Table 1), does not negatively influence populations of common leech species. However, it must be emphasized that these resistant species also dominate leech assemblages in unpolluted environments, free of human activity (Koperski 2005). Rarity, alongside total species richness, is an important parameter used in biological assessment of the quality of freshwater environments (e.g. Cao et al. 1998; Chadd and Extence 2004). The taxonomic status of some rare species found in the present study is still not clear and numerous data on their geographic distributions are questionable. Nonetheless, some detailed characteristics of these species seem to be necessary.

D. apathyi, found in the Vistula and the Żerański channel, is regarded as very rare in Central Europe (Neubert and Nesemann 1999). It was previously found only at a few sites in Poland, but the distinction of its specimens from *D. stschegolewi* (Lukin and Epshtein, 1960) and *D. punctata* (Johansson, 1927) is difficult to establish (Grosser 2003) and should be confirmed by details of their reproductive system. In accordance with the latter article, the following characters, presented as typical for this species were observed in specimens from Vistula: semi-aquatic habitat; 8–10 light spots in row on each annulus except subdivided annulus b6 with two rows; extremely flattened posterio-lateral edges of the body which makes the body surface of preserved animals concave; the lack of median stripe. Life habitats of *D. apathyi* and the second species of this genus – *D. lineata* – in Warsaw freshwaters seems not to be typical for those presented in previous studies. Especially surprising is the presence of a stable population of very rare *D. apathyi* in the urban part of the Vistula – this species had been found in Poland in lakes, small ponds and bog pools (Pawłowski 1936; Sandner 1951; Hajduk 1988), but some mistakes in recognition of various species of *Dina* (especially *D. apathyi* and *D. stschegolewi*) found in Poland in different habitats and presented in previous papers are possible. Puky (1994) documented the occurrence of *D. apathyi* at numerous sites on the Danube, a large river similar in morphology and ecology to the Vistula, and likewise in Warsaw this species was absent in standing waters connected with the river. *D. lineata* (O.F. Müller, 1774) is widely distributed but rather not numerous in Poland and Central Europe and prefers natural small water bodies (Pawłowski 1968; Hajduk 1988), often astatic pools and fishless ponds (Koperski 2005). It is regarded as an endangered species because of man-induced disappearance of its natural habitats (Jażdżewska and Wiedeńska 2002).

H. medicinalis is a synanthropic species, which prefers small, shallow water bodies. It is commonly used in traditional medicine and thus cultivated. *H. medicinalis* is the only leech species strictly protected in Poland in spite of its occurrence in relatively numerous freshwater environments (Jażdżewska and Wiedeńska). Its distribution needs reassessment because of the presence of cultures of exotic *Hirudo* species in Poland (*H. verbana* Carena, 1820, *H. troctina* Johnson, 1816) (Koperski unpublished data), which are possibly able to penetrate natural freshwaters. In spite of its large morphological variability, *H. medicinalis* is easy to distinguish from *H. verbana* on the basis of the colouring patterns, especially on the presence of large, irregular black spots on the ventral side (Neubert and Nesemann 1999).

The taxonomic status of *B. moogi* and the case of its distribution in Poland are extremely complicated. This rare molluscivorous species was previously incorrectly identified as *Batracobdella paludosa* (Carena, 1824), and later as *Glossiphonia paludosa* and *G. slovaca*, in numerous faunistic papers from Poland. The subsequent presence of only *G. paludosa* on the Red List of Threatened Animals in Poland (Jażdżewska and Wiedeńska 2002) as the result of this error is related to both these rare species*: B. moogi* and *G. paludosa* sensu Carena, 1824 (= *Glossiphonia slovaca* Kosel, 1973, not *B. paludosa* and not *B. slovaca* [Jażdżewska 2004] – see discussion on its taxonomic status in the study of Bielecki et al. [1999]). Moreover, *G. paludosa* is also present on the territory of Poland, therefore numerous data published previously on the occurrence of the so-called "*B. paludosa*" in Poland must be revised.

For the last few years, *G. nebulosa* (Kalbe, 1964) has generally been treated as a valid species (Neubert and Nesemann 1999) and in previous papers it was often not distinguished from *G. complanata*. Distribution of this rare species in Poland is poorly known; it is found both in rivers and lakes (Agapow 1982; Bielecki et al. in press). *A. hyalina* is characterized as a rare species in whole Central Europe (Neubert and Nesemann 1999), but it was previously recorded in numerous lakes in Poland (as *Glossiphonia heteroclita f. hyalina*). Wilkialis (1964) states that this species ".occurs in ponds containing a large number of snails, but seldom in lakes". In the present study it was found in a small number only in Lake Powsinkowskie.

Significantly higher values of leech species richness could be expected in lakes rather than in rivers and ponds, as it was explained in the previous study (Koperski 2006). Large lakes with dense stands of different macrophytes and with divergent types of bottom substrate, like Lake Powsinkowskie, seem to be especially rich habitats in terms of taxonomic diversity. The analysis of accumulation curves (Koperski 2006) showed that a complete list of leech species can be prepared on the basis of ca. 1000 individuals in a lake and a river and ca. 500 ind. in a pond. This number of sampled specimens was accomplished only in two freshwater environments researched in this study: Lake Powsinkowskie and the Vistula, therefore the lists of species may be declared as complete only for those two environments. However, intensive sampling in certain small water bodies, especially in park ponds, could result in disturbance or even extinction of less numerous leech populations. Oversampling seems to be a neglected (Farnsworth and Rosovsky 1993) yet potentially a very important problem related to studies on biological diversity in urban freshwaters.

The method of sampling used in the present study was inadequate to reveal the number and diversity of fish leeches (Piscicolidae) – these strictly parasite organisms spend most of the time attached to the skin of fish. Ecosystems of large rivers, with numerous populations of ecologically diverged, migrating fish, seems to be rich in species of fish leeches. Unfortunately this element of biological diversity was omitted from the present study. Their number, percentages and probably taxonomic diversity in the studied environments must be in fact much higher than those presented in the Results. In reference to taxonomic revisions of genus *Piscicola* (Bielecki 1997; Jüeg et al. 2004) more than one species (*P. geometra* L., 1758, the only species of Piscicolidae presented in this study) might be expected in the area of Warsaw, especially in the Vistula.

The total species richness and rarity of leech assemblages found in Warsaw freshwaters (19 and 6, respectively) seems to be high. Pawłowski (1951) found nine common species (out of ca. 20 known at that time in Poland) in the Vistula and artificial ponds connected with the river in Warsaw and Sandner (1951) found only 11 leech species in an intensive study of urban freshwaters in the vicinity of the Łódź municipality. Notwithstanding, not fewer than three forms of *G.complanata* and *G. heteroclita* L. 1761, distinguished by him are treated as valid species today. In no environment sampled by the scientist the number of species found was higher than 8 – in most of them this value ranged between 1 and 5, and only one rare species (*Dina lineata*, presented erroneously as *Erpobdella monostriata*) was found. Only eight common species out of 18 recorded in Sweden (Fauna Europaea Web Service 2004) were found by Erseus et al. (1999) in the area of Stockholm. Though, it will be noted, that rich, intensive, comparative study on leeches in freshwaters on surrounding, not-urbanized areas seems to be necessary to evaluate their diversity in Warsaw. This comparison will be important to decide if a specificity of urban environment or any local, geographic, climatic or historical features determines high diversity of leech fauna.

Taxonomic diversity in Warsaw freshwaters seems not to be directly related to the size of water body (note extremely low species diversity in the Vistula) nor the level of degradation (highest diversity in the artificial Żerański channel), but above all to habitat diversity. In particular, divergent littoral zone – the presence of variable macrophytes as well as mud and stones in shallow water – seems to be the main factor determining high taxonomic diversity of leech assemblages.

Certain freshwater habitats located inside the great urban complex still create favorable conditions for populations of rare, highly specialized leech species. The ecosystems of small flowing waters in urban areas are highly vulnerable to inputs of pollutants, which reduce both water quality and habitat quality (Nedeau et al. 2003). This phenomenon is easy to demonstrate on the example of two closely located streams, Wilanówka and Służewiecki, similar in length and width but treated by completely different intensity of human pressure (Table 2). The leech assemblage in the highly degraded Stream Służewiecki is visibly poorer in species and in rare species and less diverse than that in the unpolluted Stream Wilanówka (Table 3). In all park ponds only 10 common leech species were found, which equals 53% of species occurring in Warsaw. This proportion clearly complies with those presented by Luniak (2008) in metaanalysis of many animal groups – 55% of the total of 2005 species occurring in Warsaw were found in parks. Visibly higher similarity between leech taxonomic structure in Warsaw park ponds, showed in the results of MDS analysis (Fig. 3), illustrates the general effect of homogenization in animal communities observed in strongly degraded urban environments, which results mainly from higher homogeneity of the habitats and disappearance of specialized species (e.g. Blair 2008; Wolter 2008). Whereas the ponds in large parks and gardens, typically presented as reservoirs of biological diversity in cities (e.g. Stoianov et al. 2000), turned out to be rather poor in leech species (especially the rare ones recorded in the present study), the shallow eutrophic Lake Powsinkowskie became the most valuable environment. Compared with the previous data, this lake also appears as one of the richest lakes in Poland in terms of leech species richness. Unfortunately, at present, this water body is under greater and greater human pressure. Its shallow part was fenced off and dried, due to residential estates sprawling on the lakeshore, and the area of riparian vegetation continues to shrink out. No individual of *B. moogi* and *H. medicinalis* was observed in May and June 2008.

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