Teka Kom. Ochr. Kszt. Środ. Przyr., 2006, 3, 187-194

FRESHWATER SNAILS OF THE SAND-PITS IN UPPERSILESIAN INDUSTRIAL AREA (POLAND)

Małgorzata Strzelec, Aneta Spyra, Mariola Krodkiewska

Department of Hydrobiology, University of Silesia
Bankowa str. 9, 40-007 Katowice, Poland, e-mail: strzelec@us.edu.pl

Summary. The structure and domination pattern in freshwater snail communities were investigated in 16 sand-pits in Upper Silesia, Southern Poland. It is an over-industrialised region of Poland, where natural lakes are absent and anthropogenic water-bodies provide interesting habitats for freshwater gastropods. 25 species of snails were found in the investigated sand-pits. None of the analysed environmental factors (e.g. size of reservoir, plant species richness or physical and chemical water characteristics) were found to have any significant influence on freshwater snails community structure. Only the appearance of two invasive species *Potamopyrgus antipodarum* and *Physella acuta* had a negative impact on native snails. After the invasion of *Potamopyrgus antipodarum* the value of the Simpson diversity index decreased significantly.

Key words: sand-pits, freshwater snails, anthropogenic habitats.

INTRODUCTION

As a consequence of industrial development, intensified over the last two centuries, there began two opposite processes in relation to the hydrology of industrialised area. Simultaneously to the disappearance of natural lakes and ponds, new water bodies originated as a result of human activity, particularly of coal and ore mining and metallurgy. In many parts of the Earth such disturbed or devastated areas become more and more extensive.

In Poland one of the most hydrologically transformed areas is the Uppersilesian Industrial Region, where numerous coal mines and metallurgical works are concentrated on a small area. Similar regions are also to be found in other countries (e.g. Ruhrgebiet in Germany or Northumberland in England).

The underground exploitation of minerals is the cause of the rise of hollow rooms and galleries, which may result in earth surface depressions that have to be filled, most often with sand. For this reason, in mining areas the excavation of sand is necessary. In places from which sand has been excavated, sand pits arise, and after flooding with ground or rainfall waters they become valuable habitats for many plants and animals.

Typical for the sand-pits is almost total bareness of their water and bottom in the initial period of existence, and very slow eutrophication process in subsequent years. It is the consequence of their filling mainly with ground water, in which living things are most often absent and the content of biogenic substances is very low. It is also the reason of rather slow rate of plants and animals succession to these habitats.

As the object of malacological studies, sand-pits are almost totally neglected. Some data can be found in Beran's monograph [2002] and in several publications from our department [Strzelec 1988, 1993, Strzelec and Serafiński 1984, 2004, Strzelec *et al.* 1991, Serafiński *et al.* 1994].

STUDY AREA

All of the studied sand-pits are situated in the Uppersilesian Coal Mining Basin, on an area of about 400 km^2. It is the most urbanised and industrialised area, where 68% of the coal mines and 58% of the iron plants in Poland are located. Moreover, more than 70 sand-pits exist there. Among those studied by us there were 9 small sand-pits (surface area below 15 ha) and 7 of larger size. All originated after the Second World War and are currently are employed for various purposes, mainly recreation, and in some cases as communal water reservoirs.

Because of sandy steep borders, the littoral zone is reduced and in consequence the rush vegetation is rather poor in most sand-pits and occurs in some places along the borders only. That is the cause why habitats suitable for freshwater snails occur sparsely in these water-bodies. Besides, the barren sandy bottom in all the studied pits makes the life of rooted macrophytes and, consequently, of many animal species, difficult. In general the abundance and diversity of vegetation were low in comparison with that in other kinds of anthropogenic water-bodies.

The water in the investigated sand-pits was of good quality, eutrophic in all sites where the materials were sampled. More information about the sand-pits is compiled in Table 1.

Table 1. Characteristics of investigated sand-pits
Tabela 1. Charakterystyka badanych powyrobisk piaskowych

Characteristics Charakterystyki	Sand-pit Powyrobisko piaskowe															
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
Area in ha Powierzchnia (ha)	1	2.5	4	6	8	8	10	11.5	14	30	35	40	45	50	51	433
Maximal depth in m Maksymalna głebokość	1.8	3.0	1.5	2.5	2	6	2.5	2	4	3	4	5	3	6	3	14
Plant species number Liczba gatunków roślin	8	6	8	8	6	6-8	7	9	6-8	8	10	11	11	7	8	14
pH of the water pH wody	7.5	7.9	7.5	7.5	7.5	6.5	7.5	7.5	7.5	8.1	7.5	7.2	7.6	7.2	8.5	7.8
Total hardness (mval) Twardość ogólna (mval)	6.1	6.4	5.9	4.4	7.5	4.9	3.9	4.2	4.4	2.5	5.8	6.9	28.0	7.6	4.3	9.2
Ca mg dm^{-3}	–	–	74.0	72.0	–	–	53.0	70.1	8.6	–	4.3	65.7	–	105.8	60.9	39.1
Mg mg dm^{-3}	–	–	26.0	9.3	–	–	14.0	9.2	47.8	–	64.8	43.7	–	28.2	18.5	93.6
Cl mg dm^{-3}	–	29.2	15.0	30.0	–	10.0	30.0	40.0	20.0	414.0	38.0	26.4	410.0	86.4	18.0	15.2
SO_4 mg dm^{-3}	–	123.5	110.0	110.0	–	95.0	162.0	140.0	124.3	30.0	181.9	121.7	–	120.6	195.0	135.0
N of species Liczba gatunków	8	15	9	7	19	6	14	14	9	13	6	10	12	10	11	5

MATERIAL AND METHODS

In the study period, 67166 freshwater snails were collected. In seven sand-pits the collections were repeated two or three times (in particular pits from 506 to 6563 specimens were collected). All materials were gathered qualitatively by hand.

The method of sampling enables the estimation of domination (D) pattern in the whole materials, the frequency of particular snail species (F), and their commonness index (ecological value), calculated as Q= $\sqrt{D \cdot F}$, as well as the Simpson diversity index in particular collections.

Basing on the obtained data, the correlations between snail fauna and various environmental conditions were estimated.

RESULTS AND DISCUSSION

The collected materials represent 25 snail species, however in small sand-pits 22 and in the large ones 24 species were found (Tabs 2, 3). *Viviparus contectus* occurred only in small habitats, while *Aplexa hypnorum, Anisus leucostomus* and *Gyraulus rossmaessleri* only in the larger.

Table 2. Domination patterns (in %) and diversity of snail assemblages in small sand-pits
Tabela 2. Struktura dominacji i różnorodność gatunkowa zespołów ślimaków w małych powyrobiskach piaskowych

Species Gatunek	No. of pit Nr powyrobiska piaskowego								
Year of collection	I	II	III	IV	V	VI	VII	VIII	IX
Rok zbioru	2002	1998	1997	1981	2003	1991	1998	1996	1991
Viviparus contectus (Millet, 1813)		0.1					0.4		
Valvata cristata O.F. Müller, 1774		8.6			0.05	0.05			
Valvata piscinalis (O.F. Müller, 1774)		4.0			0.03		27.2		
Potamopyrgus antipodarum (Gray, 1843)	86.7	76.4	85.9		0.6		29.5		
Aplexa hypnorum (Linnaeus, 1758)									
Physa fontinalis (Linnaeus, 1758)			0.1						
Physella acuta (Draparnaud, 1805)		3.7			39.9	27.7	16.3		6.6
Lymnaea stagnalis (Linnaeus, 1758)	0.3			23.0	0.4			5.0	1.2
Radix peregra (O.F. Müller, 1774)	0.7	0.7		50.5	10.4	61.4	3.1	32.7	62.7
Radix auricularia (Linnaeus, 1758)	0.8	0.4	2.1		0.7		0.4		
Stagnicola corvus (Gmelin, 1791)		0.1			3.2		1.8	10.9	
Stagnicola palustris (O.F. Müller, 1774)			0.05	1.9	0.4			12.6	
Galba truncatula (O.F. Müller, 1774)				1.3	0.1	0.6		0.1	
Planorbis planorbis (Linnaeus, 1758)	0.3	0.2	1.7	10.5	35.7		0.2	2.5	12.1
Anisus spirorbis (Linnaeus, 1758)					0.8			1.7	
Anisus leucostomus (Millet, 1813)								3.3	
Anisus vortex (Linnaeus, 1758)	10.2				0.1				
Bathyomphalus contortus (Linnaeus, 1758)		0.4	4.2	3.3	1.2			2.5	1.0
Gyraulus albus (O.F. Müller, 1774)	1.0	1.8	4.1		2.6	8.6	4.8	14.1	7.3
Gyraulus rossmaessleri (Auerswald, 1852)								0.1	
Armiger crista (Linnaeus, 1758)		0.2	0.1		0.5		0.4	13.5	0.3
Segmentina nitida (O.F. Müller, 1774)		0.3			0.8	1.6	15.6	0.1	0.1
Planorbarius corneus (Linnaeus, 1758)	0.1	0.1	1.8	9.6	3.3		0.4	1.0	
Ferrissia clessiniana (Jickeli, 1802)		0.1			0.2		1.2		8.5
Acroloxus lacustris (Linnaeus, 1758)							1.0		
Number of species Liczba gatunków	8	15	9	7	19	6	14	14	9
Simpson's diversity index Wskaźnik różnorodności gatunkowej Simpsona	0.25	0.40	0.26	0.67	0.70	0.54	0.78	0.82	0.58

Table 3. Domination patterns (in %) and diversity of snail assemblages in large sand-pits
Tabela 3. Struktura dominacji (w %) i różnorodności gatunkowej zaespołów ślimaków w dużych powyrobiskach piaskowych

Species Gatunek	No. of pit Nr powyrobiska piaskowego						
	X	XI	XII	XIII	XIV	XV	XVI
Year of collection Rok zbioru	1998	1991	1992	2002	1990	1998	1991
Viviparus contectus (Millet, 1813)							
Valvata cristata O.F. Müller, 1774							
Valvata piscinalis (O.F. Müller, 1774)				1.0			
Potamopyrgus antipodarum (Gray, 1843)		95.7	4.5	43.7			
Aplexa hypnorum (Linnaeus, 1758)							
Physa fontinalis (Linnaeus, 1758)				1.8			9.9
Physella acuta (Draparnaud, 1805)	27.9	0.4	0.4		0.2	0.04	0.4
Lymnaea stagnalis (Linnaeus, 1758)	26.7		0.2	9.2	5.4	9.2	
Radix peregra (O.F. Müller, 1774)	11.3	1.9	74.5	6.4	25.7	2.1	
Radix auricularia (Linnaeus, 1758)	5.9			0.9		0.7	
Stagnicola corvus (Gmelin, 1791)							
Stagnicola palustris (O.F. Müller, 1774)			0.3				
Galba truncatula (O.F. Müller, 1774)			0.05		0.2	0.02	
Planorbis planorbis (Linnaeus, 1758)	0.5	0.7		5.6	3.0	6.9	88.2
Anisus spirorbis (Linnaeus, 1758)	0.1			18.4			
Anisus leucostomus (Millet, 1813)							
Anisus vortex (Linnaeus, 1758)	0.1			0.2			
Bathyomphalus contortus (Linnaeus, 1758)	4.9			0.2			
Gyraulus albus (O.F. Müller, 1774)	17.3	0.8	16.2	2.7	22.7	46.2	0.9
Gyraulus rossmaessleri (Auerswald, 1852)							
Armiger crista (Linnaeus, 1758)	3.4				34.4	13.7	
Segmentina nitida (O.F. Müller, 1774)	0.1	0.3	0.1		1.0	18.8	
Planorbarius corneus (Linnaeus, 1758)	0.5			10.6	3.6	0.2	0.4
Ferrissia clessiniana (Jickeli, 1802)	1.2		0.5			1.8	
Acroloxus lacustris (Linnaeus, 1758)			3.5		3.7		
Number of species Liczba gatunków	13	6	10	12	10	11	5
Simpson's diversity index Wskaźnik różnorodności gatunkowej Simpsona	0.80	0.08	0.42	0.75	0.76	0.75	0.21

All the species were found on single sites only and their percentages in collections were always low. Beran [2002], in larger sand-pits of the Czech Republic, found 22 snail species, but among those were *Gyraulus parvus* (Say) and *Menetus dilatatus,* absent as yet in Upper Silesia. In small sand-pits he found 24 snail species, among those 10 species on single sites. Interesting is the occurrence of *Anisus vorticulus* (Troschel) in his collection, because it is known to inhabit mainly clean waters with a high Ca content. The sand-pits studied by Beran differ from the Uppersilesian ones in the occurrence of *Hippeutis complanatus*, absent in our collection; however in other regions of Southern Poland it was found in small, old sand-pits [Strzelec and Serafiński 2004].

Fourteen species were found in more than 50% of the study sites (Tab. 4); among these *Planorbis planorbis, Armiger crista,* and *Planorbarius corneus* occurred in all the small sand-pits, whereas only *Radix peregra* in all the large ones. Taking into account whole materials from 16 water-bodies, the commonest snail species were *Radix peregra, Planorbis planorbis, Gyraulus albus* and *Planorbarius corneus*, similarly as in other kinds of anthropogenic water-bodies in Poland [Strzelec and Serafiński 2004]. The snail species number is in general not related to the surface area of the habitat, however some species are clearly more frequent in small pits (e.g. *Radix auricularia, Ferrissia clessiniana*) while *Stagnicola palustris* and *Galba truncatula* in the larger ones (Tab. 3).

Table 4. Frequency of common species (found in at least 50% of studied sites)
Tabela 4. Częstość występowania pospolitych gatunków ślimaków (stwierdzonych co najmniej w 50% badanych zbiorników)

Species Gatunek	Small habitats % Małe zbiorniki %	Large habitats % Duże zbiorniki %	In the whole % Ogółem %
Potamopyrgus antipodarum	44	56	50
Physella acuta	88	70	81
Lymnaea stagnalis	66	84	75
Radix peregra	88	100	93.7
Radix auricularia	66	28	50
Stagnicola palustris	22	84	50
Galba truncatula	44	84	62.5
Planorbis planorbis	100	70	87.5
Bathyomphalus contortus	55	70	62.5
Gyraulus albus	100	84	93.7
Armiger crista	77	56	68.7
Segmentina nitida	66	70	68.7
Planorbarius corneus	100	70	87.5
Ferrissia clessiniana	88	14	56.2

Taking into account the data pertaining to the 25 collections separately we acquire somewhat other results.

Thus the species of high ecological value are now *Potamopyrgus antipodarum*, *Physella acuta*, *Lymnaea stagnalis*, *Radix peregra*, *Planorbis planorbis*, *Gyraulus albus*.

The domination patterns in materials from sand-pits are difficult to interpret. Taking into account the whole materials, the dominants (i.e. species comprising more than 10% of individuals in the collection) were *Potamopyrgus antipodarum* and *Radix peregra* only. However, in collections from small and large sand-pits eleven species in each group were dominant. Common in both groups were: *Potamopyrgus antipodarum*, *Physella acuta*, *Lymnaea stagnalis*, *Radix peregra, Galba truncatula, Planorbis planorbis, Gyraulus albus* and *Armiger crista*. Beside these, in some small sand-pits *Bathyomphalus contortus, Segmentina nitida* and *Planorbarius corneus,* while in large *Stagnicola corvus, Stagnicola palustris* and *Anisus votrex* dominated. Only *Radix peregra* and *Planorbis planorbis* were the dominants in more than 50% of large sand-pits, whereas in small habitats the dominant patterns were strongly varied (Tab. 5). It is still more complicated when the comparisons refers to materials from particular years of the same pit: e.g. *Lymnaea stagnalis*, which was the dominant in six pits in the early years of investigations, became very rare in later years. Similar observations concern some other species. In some instances these changes may result from the invasion of alien species *Physella acuta,* and first of all *Potamopyrgus antipodarum*. The negative impact of *Potamopyrgus antipodarum* on native snails in anthropogenic habitats is well known [Strzelec 2005]. Similar changes relate to the species diversity. After the invasion of *Potamopyrgus antipodarum,* the value of the Simpson index decreased significantly. The negative correlation of *Potamopyrgus antipodarum* percentage and the Simpson index value is highly significant ($r = -0.75$, $p < 0.01$).

Table 5. Characteristics of snail species occurrence in sand-pits studied
Tabela 5. Charakterystyka występowania gatunków ślimaków w badanych powyrobiskach

Snail species Gatunek	Frequency % Częstość %			Domination % Dominacja %			Ecological value Wartość ekologiczna		
	Small pits Małe zbiorniki	Large pits Duże zbiorniki	Total Ogółem	Small pits Małe zbiorniki	Large pits Duże zbiorniki	Total Ogółem	Small pits Małe zbiorniki	Large pits Duże zbiorniki	Total Ogółem
Viviparus contectus (Millet, 1813)	16.7	0	8.6	0.04	0	0.02	0.82	0	0.41
Valvata cristata (O.F. Müller, 1774)	16.7	9.1	13.0	0.72	0.00	0.39	3.47	0	2.25
Valvata piscinalis (O.F. Müller, 1774)	25.0	9.1	17.4	2.68	0.00	1.40	8.18	0	3.52
Potamopyrgus antipodarum (Gray, 1843)	33.3	36.4	34.8	19.62	17.04	18.4	25.26	24.9	25.30
Aplexa hypnorum (Linnaeus, 1758)	0	9.1	4.3	0	0.00	0.00	0	0.00	0.00
Physa fontinalis (Linnaeus, 1758)	33.3	18.2	26.1	1.15	0.15	0.67	6.19	1.10	4.18
Physella acuta (Draparnaud, 1805)	75.0	45.4	60.9	6.6	4.44	5.57	22.25	14.20	18.41
Lymnaea stagnalis (Linnaeus, 1758)	58.3	90.9	73.9	6.3	7.1	6.7	19.16	25.40	22.25
Radix peregra (O.F. Müller, 1774)	83.3	100.0	91.3	14.3	31.31	22.4	34.15	55.95	45.22
Radix auricularia (Linnaeus, 1758)	58.3	27.3	43.5	2.1	0.61	1.40	11.06	4.08	7.8
Stagnicola corvus (Gmelin, 1791)	16.7	27.3	21.7	0.1	2.28	1.20	1.29	7.89	5.10
Stagnicola palustris (O.F. Müller, 1774)	16.7	63.6	39.1	0.1	3.6	1.76	1.29	15.1	8.3
Galba truncatula (O.F. Müller, 1774)	41.7	63.6	52.2	1.7	0.9	1.34	8.42	7.56	8.36
Planorbis planorbis (Linnaeus, 1758)	81.8	83.3	82.6	13.9	13.8	13.86	33.72	33.90	33.83
Anisus spirorbis (Linnaeus, 1758)	25.0	27.3	26.1	1.6	0.3	0.97	6.32	2.86	5.03
Anisus leucostomus (Millet, 1813)	0	9.1	4.3	0	0.3	0.14	0	1.65	0.77
Anisus vortex (Linnaeus, 1758)	16.7	45.4	30.4	0.02	5.0	2.42	0.58	15.07	8.58
Bathyomphalus contortus (Linnaeus, 1758)	58.3	63.6	60.9	2.96	1.92	2.46	13.14	11.05	12.24
Gyraulus albus (O.F. Müller, 1774)	91.7	81.8	86.9	9.4	4.67	7.14	29.35	19.54	24.91
Gyraulus rossmaessleri (Auerswald, 1852)	0	9.1	4.3	0	0.01	0.0	0	0.30	0.0
Armiger crista (Linnaeus, 1758)	58.3	54.5	56.5	4.37	1.68	3.08	15.96	9.57	13.19
Segmentina nitida (O.F. Müller, 1774)	58.3	72.7	65.2	3.63	1.99	2.84	14.55	13.03	13.61
Planorbarius corneus (Linnaeus, 1758)	83.3	54.5	69.6	3.58	1.59	2.70	17.27	9.31	13.71
Ferrissia clessiniana (Jickeli, 1802)	33.3	18.2	26.1	0.34	0.06	0.22	3.36	1.04	2.40
Acroloxus lacustris (Linnaeus, 1758)	69.7	18.2	17.4	0.39	1.09	0.73	2.55	4.45	3.56

Looking for the causes of such a great variability in observed snail communities, the correlation of species number and diversity with particular environmental parameters (size of reservoir, plant-species richness, physical and chemical water characters) was calculated. In all instances the obtained values were insignificant.

CONCLUSIONS

1. Factors conditioning the abundance and structure of snail community in a sand-pit are as yet undefined. Probably unstable ecological conditions, namely the yearly fluctuations of water level, the seasonal variability of littoral zone breadth and scantiness of vegetation, together with unfavourable conditions on sandy bottom, are the cause of accidental composition and structure of snail communities in particular sand-pits (similar observations in Lodge and Kelly 1985).

2. It may well be that, after years, the oligotrophication of the same sand-pits together with habitat stabilisation will improve the life conditions for freshwater snails, among other animals, as observed by Garnier *et al*. [1992] in a sand pit in France.

REFERENCES

Beran L., 2002: Aquatic molluscs of the Czech Republic. Sb. Přirodavěd. Klubu v Uherskem Hradišti, Suppl., 10, pp. 258 (in Czech).

Garnier J., Chesterikof A., Tesard P., Garban B., 1992: Oligotrophication after a nutrient reduction in a shallow sand-pit lake (Creteil Lake, Paris suburbs, France): a case of rapid restoration. Ann. Limnol., 28, 253-262.

Lodge D.M., Kelly P., 1985: Habit disturbance and the stability of freshwater gastropod population. Oekologia, 68, 111-117.

Serafiński W., Strzelec M., Czekaj D., 1994: The changes in the freshwater snail fauna in an over-industrialised area in Poland. Walkerana, 7, 11-13.

Strzelec M., 1988: The influence of industrial environment on the distribution freshwater snails in Uppersilesian Industrial Region. Folia Malacologica, 2, 97-122.

Strzelec M., 1993: Snails (Gastropoda) of anthropogenic water environments in Silesian Upland. Prace Nauk. Uniw. Śląskiego, 1358, 1-104 (in Polish).

Strzelec M., 2005: Impact of the introduced *Potamopyrgus antipodarum* (Gastropoda) on the snail fauna in post-industrial ponds in Poland. Biologia (Bratislava) 60, 159-163.

Strzelec M., Serafiński W., 1984: Snails (Gastropoda) of water-reservoirs created by coal-mining industry in Uppersilesian Industrial Region. Prz. Zool., 28, 185-191 (in Polish).

Strzelec M., Serafiński W., 2004: Biology and Ecology of Snails in Anthropogenic Water-bodies. Centrum Dziedzictwa Przyrody Górnego Śląska, Katowice, pp. 90 (in Polish).

Strzelec M., Serafiński W., Steńko M., 1991: Snails (Gastropoda) of the sand-pit in Dziećkowice. Kszt. Środ. Geogr., 3, 48-52 (in Polish).

POWYROBISKA PIASKOWE JAKO ŚRODOWISKO ŻYCIA ŚLIMAKÓW SŁODKOWODNYCH NA TERENACH PRZEMYSŁOWYCH

Streszczenie. Przeprowadzono badania nad strukturą i stosunkami dominacji w zespołach ślimaków słodkowodnych w 16 powyrobiskach piaskowych na Górnym Śląsku. Jest to najsilniej uprzemysłowiony region Polski, gdzie brak jest naturalnych jezior, a antropogeniczne zbiorniki wodne zapewniają interesujące siedliska dla ślimaków słodkowodnych. W badanych powyrobiskach stwierdzono obecność 25 gatunków ślimaków. Nie stwierdzono wpływu żadnego z analizowanych czynników środowiskowych (wielkość zbiornika, bogactwo florystyczne i cechy chemiczne wody) na strukturę zespołów ślimaków. Jedynie pojawienie się dwóch inwazyjnych gatunków obcych (*Potamopyrgus antipodarum* i *Physella acuta*) wywierało negatywny wpływ na rodzime ślimaki. W następstwie inwazji *P. antipodarum* znacząco spadła wartość wskaźnika bioróżnorodności Simpsona.

Słowa kluczowe: powyrobiska piaskowe, ślimaki słodkowodne, siedliska antropogenne