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# THE INFLUENCE OF INDUSTRIAL ENVIRONMENT ON THE DISTRIBUTION OF FRESHWATER SNAILS IN UPPER SILESIAN INDUSTRIAL REGION

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ABSTRACT: The gastropod fauna of man-made reservoirs of the Upper Silesian Coal Basin (4 sinkhole ponds, 7 sand pits, 4 storage reservoirs) was studied. The author found the occurrence of 19 species. The most important environmental disturbances of the sinkhole ponds effected in the qualitative impoverishment of their gastropod fauna (10 species found), whereas the fauna of the sand pits and storage reservoirs, due to their more favourable water chemistry and physical conditions, was richer (15 and 17 species respectively). In all the types of reservoirs only certain species were observed to occur in mass. The analysis of influence of some environmental factors has shown that the total water hardness and the contents of calcium, iron, sulphates, chlorides, ammonia nitrogen, as well as age, size, and kind of bottom of the reservoirs do not affect the diversity of their malacofauna, what differs industrial reservoirs from natural ones. Excess of $Mg^{++}$ ions in water seems a considerably limiting factor for most of the gastropod species found, this being especially distinct in sinkhole ponds.

KEY WORDS: freshwater malacofauna, Gastropoda, water chemistry, Silesia, Poland

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# THE INFLUENCE OF INDUSTRIAL ENVIRONMENT ON THE DISTRIBUTION OF FRESHWATER SNAILS IN UPPERSILESIAN INDUSTRIAL REGION

Abstract: The gastropod fauna of man-made reservoirs of the Upper Silesian Coal Basin (4 sinkhole ponds, 7 sand pits, 4 storage reservoirs) was studied. The author found the occurrence of 19 species. The most important environmental disturbances of the sinkhole ponds effected in the qualitative impoverishment of their gastropod fauna (10 species found), whereas the fauna of the sand pits and storage reservoirs, due to their more favourable water chemistry and physical conditions, was richer (15 and 17 species respectively). In all the types of reservoirs only certain species were observed to occur in mass. The analysis of influence of some environmental factors has shown that the total water hardness and the contents of calcium, iron, sulphates, chlorides, ammonia nitrogen, as well as age, size, and kind of bottom of the reservoirs do not affect the diversity of their malacofauna, what differs industrial reservoirs from natural ones. Excess of $Mg^{++}$ ions in water seems a considerably limiting factor for most of the gastropod species found, this being especially distinct in sinkhole ponds.

## INTRODUCTION

Only a few references from the rather extensive Polish malacological literature consider the malacofauna of Upper Silesia. As Pax (1921) pointed out the environment of this area devastated by industrial activity was never the matter of biologists´ interest. In Urbański´s (1947) review of Polish malacofauna any paper on the period 1918-1939 has not referred to this region.

The biological studies were generally undertaken not earlier than in the previous two decades in consequence of the iniciated programme of environmental protection in industrial regions. However, water bodies created in a result of the activity of various branches of indu-

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stry were not the object of those investigations although the number of these habitats is incessantly increasing. According to Piechocki (1979) one of the major tasks of malacology should be to recognize the faunistic relations in this type of water bodies.

In the last several years some papers devoted to the malacofauna of Uppersilesian Industrial Region (Strzelec in press; Strzelec, Serafiński 1984) or to the influence of some factors of the industrial environment on freshwater snails (Serafiński et al. 1977, 1978a, b, 1979) have been published. In these papers only fragmentary data were included whereas the problem should be comprehensively elaborated.

The great divergence of opinions on the significance of different factors conditioning the distribution of water snails in freshwater bodies is the reason why the question which physiographic conditions or physico-chemical factors are responsible for greater or lesser species diversity in different habitats has not been explicitely answered yet.

Since the snail fauna of anthropogenic industrial water reservoirs was rarely described in malacological literature the aim of the present study is to investigate that fauna living in specific conditions of industrial habitats and to determine the environmental factors which probably affect the fauna.

## STUDY AREA

The subject of the study was the snail fauna of 15 anthropogenic ponds, situated in Uppersilesian Industrial Region. According to their origin they may be divided into 3 groups: 4 sinkhole ponds, 7 sand pits and 4 storage reservoirs. The detailed characteristics of these habitats were published previously (Strzelec, Serafiński 1984).

The explored water bodies are different in various respects (physiographical characters, water chemistry, age, bottom type etc.) but they all are under direct or indirect influence of the industrial activity (Tab. 1 and 2).

These ponds are a direct result of coal-mining industry (sinkhole ponds), or created as water reservoirs for industry (storage reservoirs), or originated from the inflow of atmospheric or ground water to sand and clay excavations. Some of them are utilized as recreational facilities.

Table 1

Characteristics of the explored reservoirs

| Reservoirs | | Localization in Town | Age (years) | Area (ha.) | Maximal depth | Bottom | Vegetation (according to Tab. 10) |
|---|---|---|---|---|---|---|---|
| Sinkhole ponds | Magiera | Swiętochłowice | 80 | 6.25 | 2.00 | mud | 5,9,10,12,15,22 |
| | Janik | Bytom | 20 | 3.20 | 4.15 | mud | 4,9,10,12,15,22,23 |
| | Zagórze | Sosnowiec | 50 | 0.10 | 1.00 | detritus | 1,4,5,7,8,9,12,13,22,24,26 |
| | Stawiki | Sosnowiec | 50 | 7.75 | 2.40 | sand-clay | 4,6,9,11,12,13,15 |
| Sand pits | ZOO | Chorzów | 25 | 0.28 | 0.70 | mud | 3,4,5,9,11,12,13,14,15,23 |
| | Pławniowice | Pyskowice | 25 | 8.00 | 5.00 | sand-clay | 5,6,9,13,15,16,26 |
| | Gliniak | Sosnowiec | 30 | 40.00 | 4.70 | detritus | 3,4,5,9,11,12,13,15,18 |
| | Hubert | Sosnowiec | 50 | 7.10 | 4.00 | mud | 4,6,9,11,12,13 |
| | Borki | Sosnowiec | 50 | 14.00 | 4.30 | sand-clay | 4,5,6,9,11,12,13,15 |
| | Morawa | Sosnowiec | 50 | 35.50 | 4.00 | sand-clay | 3,4,5,6,7,9,11,12,13,15 |
| | Dzierżno Małe | Gliwice | 50 | 50.00 | 6.00 | sand-clay | 1,5,6,13,17,19,24 |
| Storage reservoirs | Paprocany | Tychy | 170 | 130.00 | 7.00 | mud | 4,5,6,9,12,13,15,20,21 |
| | Rybnik | Rybnik | 10 | 625.50 | 9.00 | sand-clay | 2,4,6,9,10,16,25 |
| | Gzel | Rybnik | 10 | 29.20 | 5.20 | sand-clay | 1,2,4,5,6,10,13,22 |
| | Przeczyce | Siewierz | 50 | 430.00 | 8.00 | sand-clay | 1,2,4,5,7,9,12,13,15,19,24,25 |

Table 2

Chemistry of water

| Reservoirs | | Total hardness $^{o}g$ | $Ca^{++}$ (mg/l) | $Mg^{++}$ (mg/l) | Mg:Ca | pH | Chlorides (mg/l) | Sulphates (mg/l) | $N_{NH_4}$ (mg/l) | $N_{NO_3}$ (mg/l) | $Fe^{+++}$ (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sinkhole ponds | Magiera | 38.5 | 105.80 | 102.00 | 0.97 | 7.00 | 140.36 | 313.5 | 0.25 | 2.00 | trace |
| | Janik | 47.60 | 142.68 | 120.16 | 0.84 | 7.40 | 66.00 | 450.00 | 0.39 | 3.00 | 0.50 |
| | Zagórze | 51.96 | 171.54 | 42.25 | 0.25 | 6.50 | 37.40 | 425.60 | 0.21 | 1.00 | 0.80 |
| | Stawiki | 15.00 | 3.60 | 62.96 | 17.48 | 8.00 | 25.80 | 113.10 | - | - | trace |
| Sand pits | ZOO | 19.27 | 68.30 | 42.25 | 0.62 | 6.80 | 104.10 | 147.60 | 0.33 | 0.50 | 0.20 |
| | Pławniowice | 4.20 | 7.25 | 13.98 | 1.93 | 8.30 | 70.40 | 86.40 | - | - | 0.80 |
| | Gliniak′ | 19.26 | 65.73 | 43.74 | 0.67 | 7.20 | 26.40 | 121.70 | 0.29 | 1.50 | trace |
| | Hubert — | 15.80 | .70 | 65.12 | 11.42 | 8.00 | 103.00 | 274.53 | - | - | 0.40 |
| | Borki | 12.20 | 8.60 | 47.80 | 5.56 | 7.50 | 20.00 | 124.30 | - | - | 0.20 |
| | Morawa | 16.20 | 4.30 | 67.80 | 15.76 | 7.50 | 38.00 | 181.90 | - | - | 0.10 |
| | Dzierżno Małe | 21.20 | 105.00 | 28.20 | 0.27 | 7.20 | 86.40 | 120.60 | 1.06 | 1.00 | 0.37 |
| Storage reservoirs | Paprocany | 7.48 | 31.01 | 13.67 | 0.44 | 7.50 | 18.00 | 3.60 | 0.44 | 0.40 | 0.30 |
| | Rybnik | 13.59 | 80.46 | 10.20 | 0.13 | 7.20 | 160.00 | 107.00 | 0.60 | 0.90 | 0.50 |
| | Gzel | 6.99 | 36.10 | 8.50 | 0.24 | 8.00 | 96.70 | 71.00 | 0.92 | 0.50 | 0.10 |
| | Przeczyce | 12.20 | 66.90 | 12.40 | 1.18 | 7.30 | 66.00 | 40.70 | - | - | - |

## MATERIAL AND METHODS

The materials were collected during 1976-1982, from May to September each year, by means of commonly used qualitative hydrobiological methods. The samples were taken in each water-body from all the microhabitats.

The nomenclature of the species collected is acknowledged after Macan (1969) and Piechocki (1979).

All the results were statistically analysed, i.e. SD, variability index, correlations for all the pairs of features and t-test were calculated (Balaam 1972).

The water chemistry was analysed by means of standard methods (acc. to Standard Methods for the Examination of Water and Wastewater, Washington 1972), in relation to total hardness, pH and ions content ($Ca^{++}$, $Mg^{++}$, $Fe^{+++}$, sulphates, chlorides, $N_{NH_4}$, $N_{NO_3}$).

## RESULTS

### Snails of sinkhole ponds

During the study period 14 530 living specimens belonging to 10 species were collected in sinkhole ponds (Tab. 3). In this habitat on-

Table 3

Snails of sinkhole ponds (in % of the collection)

| Species | Janik | Magiera | Stawiki | Zagórze | Mean % |
|---|---|---|---|---|---|
| Valvata piscinalis (O.F.Müller) | | | | 0.21 | 0.05 |
| Lymnaea stagnalis (Linnaeus) | 5.84 | | 16.18 | 6.08 | 7.02 |
| Lymnaea peregra (O.F.Müller) | 3.96 | 31.40 | 41.30 | 11.10 | 21.94 |
| Lymnaea auricularia (Linnaeus) | | | 6.50 | | 1.62 |
| Lymnaea corvus (Gmelin) | 1.20 | | | | 0.30 |
| Planorbis planorbis (Linnaeus) | 82.84 | 66.45 | 9.10 | 22.16 | 45.13 |
| Anisus spirorbis (Linnaeus) | 1.17 | 0.13 | | 4.32 | 1.40 |
| Anisus contortus (Linnaeus) | 0.19 | 0.22 | | 18.73 | 4.78 |
| Gyraulus albus (O.F.Müller) | 0.41 | 0.55 | 9.10 | | 2.52 |
| Planorbarius corneus (Linnaeus) | 4.22 | 1.24 | 17.77 | 37.40 | 15.15 |
| No of specimens | 2649 | 3078 | 6.92 | 8111 | 14530 |
| No of species | 8 | 6 | 6 | 7 | |

ly 7 species occurred constantly, their numbers pointing out the population stability and viability. Six species occurring there are rather ubiquitous, inhabiting all kinds of freshwater bodies, viz. L. stagnalis, L. peregra, P. planorbis, A. contortus, G. albus and P. corneus.

Very interesting is the occurrence in sinkhole ponds of A. spirorbis, which is living in great numbers in one pond with very hard water in Zagórze by Sosnowiec, whereas is absent in an untypical pond of alkaline water (Stawiki). This has confirmed the recorded pH range tolerated by this snail (Piechocki 1979).

Three species, viz. V. piscinalis, L. auricularia and L. corvus occur in some ponds, but in small numbers, what might show that the environmental conditions are there far from their optimum; it is probable that the collected specimens were accidentally introduced, most likely by birds.

The most abundant species in the sinkhole ponds is undoubtedly P. planorbis, which constituted 82.8% of the collection from different sites. Regarding the whole collection of snails from this habitat there is no doubt that P. planorbis is the most resistant to the extremely hard conditions existing gere.

Snails of sand pits

A higher quality (in terms of chemical pollution) of water in sand pits than in sinkhole ponds brings about some more favourable conditions for snails and it is the cause of the greater species richness and abundance in the former.

In this habitat 17 460 living specimens were collected, which belong to 15 species, 10 of which form a constant faunistic element (Tab. 4).

The dominating species is L. peregra which participates in the whole collection in 28.14%, however, its proportion in particular water bodies is differentiated (from 56.82% in Hubert to 1.91% in Dzierżno Małe, whereas in the ZOO pond it is absent). It is interesting that in the latter two reservoirs the dominating species is P. planorbis, generally occurring very abundantly in this kind of ponds (24.49% of the whole collection). Similarly as in the case of L. peregra its occurrence is irregular. The variable domination is one of the characteristic features of sand pits.

Basides the ubiquitous species, which are known from the previously described type of water bodies, in particular sand pits P. fontinalis, P. acuta, A. vortex, L. truncatula, S. nitida and A. crista were found.

Table 4

Snails of sand pits (in % of the collection)

| Species | Borki | Dzier-żno | Gliniak | Hu-bert | Morawa | Pław-niowice | ZOO | Mean % |
|---|---|---|---|---|---|---|---|---|
| Physa fontinalis (Linnaeus) | | | | | | 2.00 | | 0.29 |
| Physa acuta Draparnaud | | | | | | 1.30 | | 0.19 |
| Lymnaea stagnalis (Linnaeus) | 21.61 | 5.74 | 30.91 | 19.55 | 22.98 | 1.90 | 19.82 | 17.50 |
| Lymnaea peregra (O.F. Müller) | 54.66 | 1.91 | 31.46 | 56.82 | 50.47 | 1.80 | | 28.14 |
| Lymnaea auricularia (Linnnaeus) | | 5.25 | | | | 14.40 | | 1.88 |
| Lymnaea corvus (Gmelin) | 0.84 | | 4.65 | | 1.88 | | 1.30 | 1.24 |
| Lymnaea truncatula (O.F. Müller) | 2.22 | | 0.39 | | 1.31 | 74.40 | | 11.18 |
| Planorbis planorbis (Linnaeus) | 8.12 | 72.14 | 16.01 | 6.86 | 10.51 | | 57.77 | 24.49 |
| Anisus spirorbis (Linnaeus) | | | | | | 0.40 | | 0.06 |
| Anisus vortex (Linnaeus) | | 3.64 | 1.40 | | | | | 0.72 |
| Anisus contortus (Linnaeus) | 1.76 | 0.31 | 5.13 | | 3.28 | 0.20 | | 1.53 |
| Gyraulus albus (O.F. Müller) | | 0.43 | | 5.04 | | 3.60 | 1.22 | 1.74 |
| Armiger crista (Linnaeus) | 0.31 | 3.58 | | 1.65 | | | 0.08 | 0.80 |
| Segmentina nitida (O.F. Müller) | | 6.49 | 5.21 | | | | | 1.67 |
| Planorbarius corneus (Linnaeus) | 10.57 | 0.49 | 4.63 | 10.08 | 9.57 | | 19.82 | 7.88 |
| No of specimens | 1305 | 1619 | 6551 | 1551 | 1066 | 4056 | 1312 | 17460 |
| No of species | 8 | 10 | 9 | 6 | 7 | 9 | 6 | |

Seemingly remarkable is a verry great participation of *L. truncatula* being, however, the result of the mass occurrence of this snail in only one reservoir (Pławniowice).

Generally speaking, the snail fauna of sand pits is characterized by its considerable diversity: out of 15 species occurring, the particular reservoirs are inhabited by 6 - 10 species.

Snails of storage reservoirs

The storage reservoirs on the studied area have worse water quality than sand pits but the snail fauna is here the richest (Tab. 5). There are 22.653 specimens collected, belonging to 16 species. In the particular reservoirs there live 10 or 11 species.

The dominating species is *P. planorbis*, which participates in the collection in up to 67.7%. The next abundant species (*L. stagnalis*) reached 11.25% only.

*V. contectus*, *A. hypnorum*, *P. fontinalis*, *P. acuta* and *A. spirorbis* are found sporadically in this habitat. They live in a small number in particular water hodies and are not a constant element of the snail fauna in storage reservoirs.

## SOME ENVIRONMENTAL FACTORS AND THE WATER SNAIL FAUNA

### Total hardness

In many papers a great role in the diversity rise of snail fauna in freshwater is ascribed to total hardness (Boycott 1936, Macan 1950, 1957, 1969, Russell-Hunter 1957, 1978, Klimowicz 1962, Aho 1966, Haley and Gibson 1971, Young and Harris 1974, Dussart 1976, Brown 1979, Dussart and Kay 1980).

To verify this common opinion in relation to anthropogenic water bodies the studied reservoirs were divided into four groups according to the increasing water hardness:

class I - soft water (to $10^{o}$g); class II - moderately hard water - (10.1 - $15^{o}$g); class III - hard water (15.1 - $20^{o}$g); class IV - very hard water (over $20^{o}$g).

The data on the occurrence of snails with regard to water hardness are given in Table 6.

The most diverse snail fauna occurs in "soft water". Among 19 species found in the studied region 17 are distributed in soft water habitats. The commonest species is *P. planorbis* constituting 41.71% of

Table 5

Snails of storage reservoirs (in % of the collection)

| Species | Gzel | Rybnik | Paprocany | Przeczyce | Mean % |
|---|---|---|---|---|---|
| Viviparus contectus (Millet) | | | 0.90 | | 0.22 |
| Valvata cristata O.F. Müller | | | 4.60 | | 1.15 |
| Aplexa hypnorum (Linnnaeus) | | | 0.60 | | 0.15 |
| Physa fontinalis (Linnaeus) | 4.75 | | | | 1.18 |
| Physa acuta Draparnaud | | 0.10 | | | 0.02 |
| Lymnaea stagnalis (Linnaeus) | 3.44 | 2.40 | 7.70 | 31.45 | 11.25 |
| Lymnaea peregra (O.F. Müller) | 1.59 | 5.40 | 1.30 | 0.30 | 2.15 |
| Lymnaea auricularia (Linnaeus) | 0.11 | 0.70 | | 16.91 | 4.43 |
| Lymnaea corvus (Gmelin) | 4.66 | | | | 1.17 |
| Lymnaea truncatula (O.F. Müller) | | 3.30 | 0.40 | | 0.92 |
| Planorbis planorbis (Linnaeus) | 60.22 | 67.70 | 64.90 | 17.66 | 52.62 |
| Anisus spirorbis (Linnaeus) | | | | 0.10 | 0.02 |
| Anisus vortex (Linnaeus) | 18.55 | 0.10 | | 9.79 | 7.11 |
| Anisus contortus (Linnaeus) | | | 1.80 | 11.18 | 3.25 |
| Gyraulus albus (O.F. Müller) | 0.05 | 0.10 | 1.10 | 0.30 | 0.40 |
| Segmentina nitida (O.F. Müller) | 3.95 | 1.90 | 4.70 | 6.92 | 4.37 |
| Planorbarius corneus (Linnaeus) | 2.66 | 18.30 | 11.60 | 5.39 | 9.56 |
| No of specimens | 8104 | 9065 | 3394 | 2090 | 22 653 |
| No of species | 10 | 10 | 11 | 10 | . |

the snail fauna of this environment. V. contectus, V. cristata, A. hypnorum and P. fontinalis occur constantly as well.

In the water of the second class 14 species are the inhabitants, 10 of them occurring permanently. The most abundant are P. planorbis and L. peregra (25.7% and 25.4% of the whole collection respectively).

In hard water 11 species have been found, of which L. truncatula, A. vortex, and A. crista are rare and participate in small numbers in the collection. All the species found here occur in the previous classes as well. The most common are: L. peregra, L. stagnalis and P. planorbis.

In very hard water 13 species occur, among which V. piscinalis lives only, but in a small number, in this habitat. All the other species are also found in the preceding classes of water hardness. The dominating species is here *P. planorbis* (60.9% of the whole collection), what results from its mass occurrence in sinkhole ponds containing in most cases a very hard water.

Table 6

Species occurrence in relation to total hardness
(in % of the collection)

| Species | CLASS | | | |
|---|---|---|---|---|
| | I<br>to 10°g | II<br>10.1 - 15.0°g | III<br>15.1 - 20.0°g | IV<br>over 20.1°g |
| Viviparus contectus (Millet) | 0.30 | | | |
| Valvata cristata O.F. Müller | 1.53 | | | |
| Valvata piscinalis (O.F. Müller) | | | | 0.55 |
| Aplexa hypnorum (Linnaeus) | 0.20 | | | |
| Physa fontinalis (Linnaeus) | 2.24 | | | |
| Physa acuta Draparnaud | 0.43 | 0.02 | | |
| Lymnaea stagnalis (Linnaeus) | 4.35 | 17.91 | 23.31 | 4.42 |
| Lymnaea peregra (O.F. Müller) | 1.56 | 25.40 | 34.68 | 12.09 |
| Lymnaea auricularia (Linnaeus) | 4.84 | 6.02 | | 1.31 |
| Lymnaea corvus (Gmelin) | 1.55 | 0.21 | 1.95 | 0.40 |
| Lymnaea truncatula (O.F. Müller) | 24.93 | 1.38 | 0.48 | |
| Planorbis planorbis (Linnaeus) | 41.71 | 25.63 | 22.79 | 60.90 |
| Anisus spirorbis (Linnaeus) | 0.13 | 0.03 | | 1.41 |
| Anisus vortex (Linnaeus) | 6.18 | 2.47 | 0.35 | 0.91 |
| Anisus contortus (Linnaeus) | 0.67 | 3.23 | 2.00 | 4.86 |
| Gyraulus albus (O.F. Müller) | 1.58 | 2.37 | 1.57 | 0.35 |
| Armiger crista (Linnaeus) | | 0.08 | 0.43 | 0.90 |
| Segmentina nitida (O.F. Müller) | 2.88 | 2.21 | 1.30 | 1.62 |
| Planorbarius corneus (Linnaeus) | 4.75 | 13.00 | 11.03 | 10.91 |
| No of species | 17 | 14 | 11 | 13 |
| Reservoirs | Pławniowice<br>Gzel<br>Paprocany | Przeczyce<br>Borki<br>Rybnik<br>Stawiki | Hubert<br>Morawa<br>Gliniak<br>ZOO | Dzierżno<br>Magiera<br>Janik<br>Zagórze |

The fauna of very hard water bodies is characterized not by the markedly reduced number of species but by peculiar quantitative relations. As a rule a single species only occurs numerously whereas the others in no more than a small number.

Concerning the reservoirs studied, no significant correlation between total water hardness and the number of occurring species was found.

$Ca^{++}$ content

In numerous papers the dependence of snails distribution upon $Ca^{++}$ content in water was emphasized. Alsterberg (1930), Macan (1950), Greenaway (1971), Thomas and Lough (1974), Dussart and Kay (1980) explain the occurrence of some snails by their preference of a determined calcium ions concentration in water, but other authors present the converse opinion (e.g. Harman and Berg 1971, Lassen 1975).

To examine critically those points of view all the water bodies studied were divided into four classes in respect of increasing $Ca^{++}$ concentration in water:

class I: to 10 mg/l; class II: 10.1 - 50 mg/l; class III: 50.1 - 100 mg/l; - 100 mg/l; class IV: over 100 mg/l.

The distribution of snails according to $Ca^{++}$ concentration in water is shown in Table 7.

It is interesting that P. planorbis is the dominating species in the water of classes II-IV but occurs less abundantly in less calcareous water, what shows its greater needs in this respect.

In the water class I the dominating species is L. peregra, which constitutes 40.99% of the whole collection. P. fontinalis, P. acuta, L. corvus, A. spirorbis and A. crista occur sporadically.

In the water of class II 15 species are found. Since only two reservoirs belong to this class, the results are questionable. Only the quantitative dominance of P. planorbis over all the other species being accessory or ewen fortuitous elements is clear. Three species, viz. V. contectus, V. cristata and A. hypnorum are found only in the waters of that class. Nine species are the constant element in this habitat.

In the water of class III 14 species are collected, among which P. planorbis (39.75%) and L. stagnalis (21.15%) dominate. L. peregra, A. vortex, A. contortus, S. nitida and P. corneus occur there constantly as well.

The sole dominant in the waters of IV class is P. planorbis, reaching 60.9% of all the specimens collected. V. piscinalis occurs only here but in a small number, what allows to include it together with L. corvus, A. cristata and G. albus to the accessory species in this habitat.

The results mentioned above show that the occurrence of most species of snails is not related to the amount of $Ca^{++}$ in water and the correlation between $Ca^{++}$ content in water and the number of snail species is insignificant.

Table 7

Species occurrence in relation to $Ca^{++}$ content (in % of the colletion)

| Species | Class | | | |
|---|---|---|---|---|
| | I to 10.0 mg/l | II 10.1-50.0 mg/l | III 50.1-100 mg/l | IV over 100.0 mg/l |
| Viviparus contectus (Millet) | | 0.45 | | |
| Valvata cristata O.F. Müller | | 2.30 | | |
| Valvata piscinalis (O.F. Müller) | | | | 0.05 |
| Aplexa hypnorum (Linnaeus) | | 0.30 | | |
| Physa fontinalis (Linnaeus) | 0.40 | 2.37 | | |
| Physa acuta Draparnaud | 0.26 | | 0.03 | |
| Lymnaea stagnalis (Linnaeus) | 16.44 | 5.57 | 21.15 | 4.42 |
| Lymnaea peregra (O.F. Müller) | 40.99 | 1.44 | 9.29 | 12.09 |
| Lymnaea auricularia (Linnaeus) | 4.18 | 0.05 | 4.40 | 1.31 |
| Lymnaea corvus (Gmelin) | 0.54 | 2.33 | 1.49 | 0.30 |
| Lymnaea truncatula (O.F. Müller) | 15.99 | 0.20 | 0.92 | |
| Planorbis planorbis (Linnaeus) | 6.92 | 62.56 | 39.79 | 60.90 |
| Anisus spirorbis (Linnaeus) | 0.08 | | 0.03 | 1.41 |
| Anisus vortex (Linnaeus) | | 9.28 | 2.82 | 0.91 |
| Anisus contortus (Linnaeus) | 1.05 | 0.90 | 4.80 | 4.86 |
| Gyraulus albus (O.F. Müller) | 3.55 | 0.58 | 0.41 | 0.35 |
| Armiger crista (Linnaeus) | 0.39 | | 0.02 | 0.90 |
| Segmentina nitida (O.F. Müller) | | 4.32 | 3.51 | 1.62 |
| Planorbarius corneus (Linnaeus) | 9.60 | 7.13 | 12.04 | 10.84 |
| No of species | 13 | 15 | 14 | 13 |
| Reservoirs | Stawiki Morawa Pławniowice Hubert Borki | Paprocany Gzel | Gliniak ZOO Rybnik | Dzierżno Magiera Janik Zagórze |

$Mg^{++}$ content

Water in most of anthropogenic reservoirs in Uppersilesian Industrial Region is characterized by a great magnesium hardness and very high Mg : Ca ratio. In natural closed water bodies (lakes and ponds) this ratio amounts in average to 1 : 4 (Livingstone 1963, Dodd and Crisp 1982) whereas in the studied area in sinkhole ponds it amounts to 4.9 : 1, in sand pits 5.2 : 1 and only in storage reservoirs 1 : 4, as in natural lakes. A very high Mg : Ca ratio in the water of sinkhole ponds and sand pits is caused by their location on carbon deposits, which contain a great amount of magnesium compounds easily leaking from rocks and particularly from heaps of coal mining deads. A better solubility of magnesium than calcium slats results in 4 - 5 times greater content of magnesium than calcium in water. The first one is therefore the main factor determining water hardness. Mineral compounds come from the percolating coal mine ground water and the water running off from heaps (Strzyszcz 1975).

The great content of magnesium ions in the water of the reservoirs studied together with the observed paucity of the snail species suggest that these ions may be one of the main factors limiting the distribution of the snails.

To test this supposition all the water bodies investigated were grouped according to $Mg^{++}$ content in water into four classes:

class I: to 20 mg/l (it is the permissible upper limit of magnesium content in drinking water); class II: 20.1 - 50 mg/l; class III: : 50.1 - 100 mg/l; class IV: over 100 mg/l.

The occurrence of snails in relation to the classes is shown in Table 8.

The results of the investigations have shown that the richest snail fauna occurs in the water bodies with small $Mg^{++}$ content and that the number of species is decreasing as the $Mg^{++}$ content increases.

In the water of class I 17 species were found, 11 of which occurred permanently with the domination of P. planorbis. Species occurring exclusively in water of this class are: V. contectus, V. cristata, A. hypnorum, P. fontinalis and P. acuta. Only P. fontinalis is abundant, whereas the other species mentioned are accessory only.

Among 12 species occurring in the water of class II P. planorbis and L. peregra dominate. Nine species have been collected permanently whereas G. albus, A. crista and L. truncatula have been found sporadically.

Table 8

Species occurrence in relation to $Mg^{++}$ content
(in % of the collection)

| Species | Class I to 20.0 mg/l | Class II 20.1-50.0 mg/l | Class III 50.1-100.0 mg/l | Class IV over 100 mg/l |
|---|---|---|---|---|
| Viviparus contectus (Millet) | 0.18 | | | |
| Valvata cristata O.F. Müller | 0.92 | | | |
| Valvata piscinalis (O.F. Müller) | | | | 0.07 |
| Aplexa hypnorum (Linnaeus) | 0.12 | | | |
| Physa fontinalis (Linnaeus) | 1.35 | | | |
| Physa acuta Draparnaud | 0.28 | | | |
| Lymnaea stagnalis (Linnaeus) | 9.38 | 19.52 | 19.57 | 3.97 |
| Lymnaea peregra (O.F. Müller) | 2.08 | 21.98 | 49.54 | 15.49 |
| Lymnaea auricularia (Linnaeus) | 6.42 | 1.31 | 2.17 | |
| Lymnaea corvus (Gmelin) | 0.93 | 1.70 | 0.63 | 0.40 |
| Lymnaea truncatula (O.F. Müller) | 15.60 | 0.65 | 0.44 | |
| Planorbis planorbis (Linnaeus) | 42.10 | 38.26 | 8.82 | 57.15 |
| Anisus spirorbis (Linnaeus) | 0.10 | | | 1.87 |
| Anisus vortex (Linnaeus) | 5.59 | 1.26 | | |
| Anisus contortus (Linnaeus) | 2.64 | 1.80 | 1.09 | 6.38 |
| Gyraulus albus (O.F. Müller) | 1.03 | 0.41 | 4.71 | 0.32 |
| Armiger crista (Linnaeus) | | 0.99 | 0.55 | |
| Segmentina nitida (O.F. Müller) | 3.49 | 2.92 | | |
| Planorbarius corneus (Linnaeus) | 7.59 | 8.89 | 12.47 | 14.28 |
| No of species | 17 | 12 | 10 | 9 |
| Reservoirs | Gzel<br>Rybnik<br>Prze-czyce<br>Papro-cany<br>Pław-niowi-ce | Dzierżno<br>Zagórze<br>ZOO<br>Gliniak<br>Borki | Stawiki<br>Hubert<br>Morawa | Magiera<br>Janik |

In the water of class III 10 species live, 7 of which occur permanently and the dominating species is L. peregra. In this $Mg^{++}$ concentration the lack of A. vortex and S. nitida has been found, whereas in the previous classes they are a constant faunistic component.

Only nine species have been found in the water of class IV. Markedly bound up with this environment are L. stagnalis, L. peregra, P. planorbis, A. spirorbis (which was absent in the water of the previous classes) and P. corneus. The latter species is characterized by the successive increase in number with the increase of $Mg^{++}$ content. P. corneus is apparently more resistant to this ion than the other species. A. contortus is here more numerous than in the former classes and V. piscinalis occurs only in the water of class IV, whereas L. auricularia and L. truncatula are absent there.

The results mentioned above show that magnesium ions are the limiting factor, reducing the species diversity of water snails. The correlation between magnesium content in water and species number is negative and amounts to $r = -0.76$.

The bottom

Boycott (1936), Hubendick (1947), Verdcourt (1949), Klimowicz (1962), Bovbjerg (1970) and Piechocki (1979) related the occurrence of particular species of snails and the diversity of malacofauna to the bottom kind.

In the water bodies studied three kinds of bottom occur:

- muddy bottom - covered with very fine, generally dark mud, occurs in ponds: ZOO, Hubert, Magiera, Janik, Paprocany;
- detritus bottom - sand covered with a layer of organic remains, found in Gliniak and Zagórze;
- sand-clay bottom - the most common, occurs in Pławniowice, Borki, Morawa, Dzierżno Małe, Stawiki, Rybnik, Gzel, Przeczyce.

Species paucity is a characteristic feature of reservoirs with the detritus bottom (Tab. 9). Only 11 species have been found there, among which L. peregra, P. corneus, P. planorbis and L. stagnalis occur in similar forming almost 80% of the whole collection. A. contortus is rather numerous there but L. corvus, A. spirorbis, and S. nitida are also the constant element of the malacofauna.

On the muddy bottom there live populations of 14 species, hovever, only five of them: P. planorbis, L. peregra, L. stagnalis, P. corneus and G. albus occur numerously. The other nine species are distributed

Table 9

Species occurrence in relation to the bottom
(in % of the collection)

| Species | Detritus | Mud | Sand-clay |
|---|---|---|---|
| Viviparus contectus (Millet) | | 0.18 | |
| Valvata cristata O.F. Müller | | 0.92 | |
| Valvata piscinalis (O.F. Müller) | 0.11 | | |
| Aplexa hypnorum (Linnaeus) | | 0.12 | |
| Physa fontinalis (Linnaeus) | | | 0.84 |
| Physa acuta Draparnaud | | | 0.18 |
| Lymnaea stagnalis (Linnaeus) | 18.49 | 10.58 | 13.21 |
| Lymnaea peregra (O.F. Müller) | 21.28 | 18.69 | 19.67 |
| Lymnaea auricularia (Linnaeus) | | | 5.48 |
| Lymnaea corvus (Gmelin) | 2.32 | 0.50 | 0.92 |
| Lymnaea truncatula (O.F. Müller) | 0.19 | 0.08 | 10.16 |
| Planorbis planorbis (Linnaeus) | 19.09 | 55.76 | 30.68 |
| Anisus spirorbis (Linnaeus) | 2.16 | 0.26 | 0.06 |
| Anisus vortex (Linnaeus) | 0.70 | | 4.01 |
| Anisus contortus (Linnaeus) | 11.93 | 0.44 | 2.09 |
| Gyraulus albus (O.F. Müller) | | 1.66 | 1.70 |
| Armiger crista (Linnaeus) | | 0.35 | 0.49 |
| Segmentina nitida (O.F. Müller) | 2.60 | 0.94 | 2.41 |
| Planorbarius corneus (Linnaeus) | 21.00 | 11.39 | 8.09 |
| No of species | 11 | 14 | 15 |
| Reservoirs | Gliniak<br>Zagórze | ZOO<br>Hubert<br>Magiera<br>Janik<br>Paprocany | Pławniowice<br>Borki<br>Morawa<br>Dzierżno<br>Stawiki<br>Rybnik<br>Gzel<br>Przeczyce |

only in small numbers in particular ponds. V. contectus, V. cristata and A. hypnorum are found only on this bottom.

It seems that the most favourable conditions for most of water snails bears the sand-clay bottom, where 15 species are found. P. acuta, P. fontinalis and L. auricularia are connected entirely with this kind of bottom. Besides those, 10 other species occur there constantly and numerously. Only V. contectus, V. cristata, V. piscinalis and A. hypnorum avoid this this kind of bottom. P. corneus occurs there in a smaller number than on other kinds of bottom.

## AREA, AGE AND VEGETATION

No relation has been found between the area, age and vegetation of a water body and the occurrence and diversity of snail fauna. The vegetation of the water bodies studied is shown in Table 10.

Table 10

Vegetation of the studied water bodies

1. Sagittaria sagittifolia L., 2. Alisma plantago-aquatica L., 3. Hydrocharis morsus-ranae L., 4. Elodea canadensis Rich., 5. Potamogeton natans L., 6. Juncus sp., 7. Scirpus lacustric L., 8. Carex sp., 9. Phragmites communis Trin., 10. Glyceria aquatica (L.) Wahlb., 11. Lemna trisulca L., 12. Lemna minor L., 13. Acours calamus L., 14. Sparganium ramosum Huds., 15. Typha latifolia L., 16. Polygonum amphibium L., 17. Callitricbe verna L., 18. Batrachium circinatum (Sibth) Fr., 19. Ranunculus Lingua L., 20. Nymphaea alba L., 21. Nuphar luteum (L.) Sm., 22. Ceratophyllum demersum L., 23. Myriophyllum verticilatum L., 24. Myosotis palustris (L.) Nathorst, 25. Bidens tripartitus L., 26. Equisetum limosum L.

## DISTRIBUTION OF PARTICULAR SPECIES IN RELATION TO HABITAT

Both Viviparus contectus and Valvata cristata occur only in storage reservoirs, on mud, in soft water with $Ca^{++}$ content 10 - 50 mg/l and $Mg^{++}$ content below 20 mg/l.

Valvata piscinalis is found only in sinkhole ponds ondetritus, in very haro water with $Ca^{++}$ and $Mg^{++}$ content over 100 mg/l.

Aplexa hypnorum lives in the same habitat as V. contectus and V. cristata.

Physa fontinalis is common in storage reservoirs, rare in sand pits on sand and clay, in soft water with $Ca^{++}$ content below 50 mg/l and $Mg^{++}$ content below 20 mg/l.

Physa acuta is found in small numbers in sand pits and storage reservoirs, on sand and clay, in soft or moderately hard water with $Ca^{++}$ content up to 100 mg/l and $Mg^{++}$ content below 20 mg/l.

Both Lymnaea stagnalis and L. peregra occur in all the types of water bodies, on various bottom, independently on water hardness and calcium and magnesium concentration.

Lymnaea auricularia was found in all the types of reservoirs on sand and clay, independently on water hardness and $Ca^{++}$ content but with the $Mg^{++}$ content below 100 mg/l.

Lymnaea corvus is distributed mainly in sand pits and storage reservoirs, rarely in sinkhole ponds, on various bottom, independently on water hardness and $Ca^{++}$ and $Mg^{++}$ concentrations.

Lymnaea truncatula lives in sand pits, sporadically in storage reservoirs,, on various bottom, in water from soft to hard and with both the $Ca^{++}$ and $Mg^{++}$ content below 100 mg/l.

Planorbis planorbis was recorded from all the types of water bodies, independently on the physico-chemical conditions and type of bottom.

Anisus spirorbis is the most numerous in sinkhole ponds, rarely occurs in sand pits and storage reservoirs, mostly on detritus, in very hard water with the $Ca^{++}$ and $Mg^{++}$ content over 100 mg/l.

Anisus vortex occurs mainly in storage reservoirs, in smaller numbers in sand pits, on sand and clay, rarely on detritus, independently on total hardness and $Ca^{++}$ content, with the $Mg^{++}$ concentration below 50 mg/l.

Anisus contortus is common in all the types of water bodies, mainly on sand, clay and detritus with various water chemistry.

Gyraulus albus favours sinkhole ponds and sand pits with muddy, sandy and clayey bottom, independently on physico-chemical conditions.

Armiger crista is equally rare in sand pits and storage reservoirs, on sand, clay and mud, in moderately to very hard water, with the $Ca^{++}$ content over 100 mg/l and $Mg^{++}$ content 20 - 100 mg/l.

Segmentina nitida occurs in similar numbers in storage reservoirs and sand pits, independently on bottom kind and water hardness, by $Ca^{++}$ content from 10 to over 100 mg/l and $Mg^{++}$ content to 50 mg/l.

Planorbarius corneus was found abundantly in all the types of water bodies, in various environmental conditions, scarcelly on sand.

DISCUSSION

No more than a few papers from the rich malacological literature deal with the malacofauna of anthropogenic water bodies, being a result of the industrial activity. For this reason the discussion is difficult and has to be limited to the comparison of the influence of particular environmental factors on the snail fauna in freshwater reservoirs.

In the previous paper (Strzelec in press) it was observed that factors determining composition and abundance of malacofauna in natural water bodies are not of the same importance for anthropogenic reservoirs studied in Uppersilesian Industrial Region and it is necessary to find which factors are actually significant in that habitat. The results obtained confirm this opinion.

Most of the previous studies of different authors stress the relation of snail fauna to water hardness, calcium content, kind of bottom, pH of water, and some authors point out that the area of water body and its age are of primary significance as well.

It was shown in a lot of papers that the number of snail species is increasing with the increase in water hardness and calcium concentration in water (Boycott 1936, Macan 1950, 1957, Russel-Hunter 1957, Young and Harris 1974, Young 1975). In this respect the $Ca^{++}$ concentration of 20 mg/l was sometimes accepted as the lower limit. Interesting and somewhat different are the results of Dussart's study (1976) showing that the most favourable conditions for snails are in a moderately hard water (20 - 40 mg $Ca^{++}$/l), where most species may occur, whereas in hard water (over 40 mg/l) some species achieve the greatest numbers but the number of species is smaller. This fact is confirmed in the present study: in a very hard water some species are very abundant, but the number of species is always small.

The opinion of Aho (1966) that the number of snail species is strongly correlated with water hardness seems to be inconclusive. Unfortunately, it is not known which scale of water hardness was used by Aho, what makes the comparison of his results almost impossible. According to his data the water hardness of 1.6 - 1.7$^{o}$ creates the optimal conditions for snails (in average 16.6 species per reservoir) whereas in the present study the minimal hardness of water in the explored water bodies amounts to 4.2$^{o}$g.

It is remarkable that Brown (1979) found no relation between the occurrence of particular species and water hardness, for in his investigations the ponds with the hardest water were not richer in snail species than the others. Lassen (1975) has obtained similar results in his study on inland water bodies of Denmark.

It can be supposed, therefore, that the lack of conformity of the present observations with the results of most of other authors cited was caused by different components of water hardness, which in natural lakes is the effect of the calcium predominance, while in the explored water bodies in Uppersilesian Industrial Region it results often from the presence of magnesium salts. The statement of Boycott (1936): "... the beneficial influence of calcium may be overridden by other unfavourable circumstances..." is then true in relation to the present results. The ooze of mineralized mine water, infiltration of mineral salts from heaps etc. can be undoubtedly regarded as "unfavourable circumstances".

The resutls of the water qualitative examination and calculated correlation coefficients between several ions concentrations and the number of snail species seem to show the neither the calcium deficiency the excess of chlorides and sulphates are the factors limiting the diversity of snail fauna. The only limiting factor seems to be the overabundance of magnesium ions. This environmental factor has never been taken into consideration in faunistic and ecological studies so far. Therefore the arguments for or against this supposition are absent in the malacological literature.

The direct influence of calcium ions is as doubtful as that of water hardness. The opinions on its importance for snails are differentiated. In his review Hubendick (1947) wrote: "Basing on numerous water analyses and on a lot of own observations from South Sweden and other countries I am convinced that calcium is the main factor of environment and that its lack is the main cause limiting the occurrence of snails". Many authors studying the malacofauna of natural lakes and ponds agree with this opinion (Aho 1966, Thomas, Benjamin, Lough and Aram 1974, Russell-Hunter 1978, Dussart and Kay 1980), but most of them emphasize that the detailed studies upon the relation has not been completed so far.

Russell-Hunter (1978) compiled the results of earlier studies and concluded that freshwater snails are distributed in waters containing 2 - 120 mg Ca/l. It is in disagreement with the results of the laboratory studies on Biomphalaria glabrata Say (Nduku and Harrison 1976). The authors found that the minimal calcium content in water enabling the survival of this species amounts to 4 mg Ca/l. In the present study the occurrence of snails was found in the waters containing 4.3 - - 171.5 mg Ca/l. The number of snails species was never correlated with the calcium content in the inhabited water. The last observation is in agreement with the data of Harman and Berg (1971) who concluded, basing on 650 water bodies, that calcium itself is not a determining factor of malacofauna diversity.

In the studied ponds the probable influence of the commonly very great amount of calcium compounds is limited or overridden by other factors arising from the coal-mining activity. It can be supposed that they originate in the same way as in the colliery reservoirs in USA described by Bell (1956). He analysed the way in which mineral salts penetrate water bodies and found that the main source of mineralization are the chemical compounds flowing in with surface water from heaps. The influx of calcium and magnesium compounds together with natrium sulphate result in the total salt concentration in water reaching 200 - - 4.000 p.p.m.

In another USA region, Minear and Aschants (1976) observed greater concentrations of calcium and magnesium in water bodies located in an immediate vicinity of a mine than in neighbouring natural reservoirs, what was the cause of great differences of water hardness. There was observed a great increase of sulphates content whereas the chlorides content was almost constant. It was the cause of the neutralization or even alkalization of water in mine neighbouring reservoirs. This observation is confirmed by the present study. In no more than two young and distant from heaps reservoirs the pH of water did not surpass 7, whereas in most of the investigated water bodies it amounts to 7 - 8.3.

Lewis and Peters (1954) refer the origin of specificity of water chemistry to the bottom kind. This factor may be of a great significance in the area which has been the subject of the present investigations because in carbon deposits on which Uppersilesian Industrial Region is situated the magnesium compounds occur in great amounts and may penetrate the reservoirs with ground water.

All the chemical factors mentioned above are usually supposed to be the determining factors of malacofauna in water bodies. Nobody presented the opposite view but Frömming (1956), who concluded that neither water chemistry nor the chemical influence of bottom affect the occurrence and the shell form and formation of freshwater snails.

Boycott (1936), Verdcourt (1949), Klimowicz (1962) and Harman (1972) showed the connection between the occurrence of snails and differentiation of bottom and concluded that the lack of suitable bottom sediments determines the distribution of water snails. In the investigated anthropogenic reservoirs the bottom differentiation affects in some degree the number of snail species. The results obtained show that most of the species prefer sand and clay. It is in disagreement with Hubendick (1947). He found that the mean number of snail species on sand and clay is rather low, while somewhat higher on clay.

The similar opinion is presented by Aho (1966). Calow (1974) observes, however, that the result of snail sensitiveness to bottom sediments is their absence in the reservoirs with the bottom covered with fine-grained sediments.

The muddy bottom (besides of the purely calcareous one) is,according to Hubendick (1947), the most favourable habitat for water snails.On this type of bottom he found 3 - 10 species in each reservoir. In this respect the investigated anthropogenic ponds do not differ from natural lakes. In the studied water bodies 6 - 10 species have been found. As Green (1971) has pointed out the advantageous life conditions on the muddy bottom are a result of a decrease in $Ca^{++}$ content in water through the exchange of bases and the colloidal absorption which causes the origin of colloidal calcium particles acting as ions. It is possible that calcium in the colloidal form is easily assimilable in the alimentary tract of a snail.

The least differentiated malacofauna occurs in the water bodies with bottom covered with a thick layer of detritus. It is possible that the gaseous substances originated here from plant tissues decay are a limiting factor (Bovbjerg 1970).

It seems that the kinds of bottom mentioned above do not affect directly the distribution of snails. They affect rather as a substratum the growth of microflora, which on different bottoms occurs in different abundance (Russell-Hunter 1978).

The distribution and numbers of most animals may be related to different environmental factors (Bovbjerg 1970). In relation to water snails they are conditioned by the ability of colonization of a new habitat and the survival in it (Dussart 1979). As the life conditions differ to a high degree from the optimal ones, a species which has invaded a water body may die out in the result of the competition with other species, more resistant against such conditions. It seems that it is the cause of the species paucity in anthropogenic reservoirs.

It is the way to explain the difference between Boycott's (1936) observations that in new created water bodies one species apppears every nine years, and own results where no correlation between the age of pond and species number was found.

It can be supposed that in industrial reservoirs only some immigrants are able to survive.

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## WPŁYW ŚRODOWISKA PRZEMYSŁOWEGO NA ROZMIESZCZENIE ŚLIMAKÓW SŁODKOWODNYCH W GÓRNOŚLĄSKIM OKRĘGU PRZEMYSŁOWYM

Streszczenie: Autorka przeprowadziła badania nad fauną ślimaków zbiorników antropogenicznych Górnośląskiego Okręgu Przemysłowego (4 zapadliska, 7 powyrobisk i 4 zbiorniki zaporowe) i stwierdziła występowanie w nich 19 gatunków. Największe zakłócenia środowiska zbiorników zapadliskowych powodują w nich ubóstwo jakościowe fauny ślimaków (10 gatunków), natomiast w zbiornikach powyrobiskowych i zaporowych, mających korzystniejsze warunki fizykochemiczne wody, fauna jest bogatsza (odpowiednio - 15 i 17 gatunków). W zbiornikach wszystkich typów obserwuje się masowe występowanie tylko niektórych gatunków.

Analiza wpływu poszczególnych czynników środowiska wykazała, że twardość ogólna wody, zawartość w niej wapnia, żelaza, siarczanów, chlorków, azotu amoniakalnego, a także wiek, wielkość zbiorników oraz rodzaj ich podłoża nie mają wpływu na różnorodność malakofauny, co odróżnia zbiorniki przemysłowe od naturalnych.

Czynnikiem wyraźnie ograniczającym możliwości życiowe większości gatunków ślimaków jest nadmiar jonów $Mg^{++}$ w wodzie, co szczególnie widoczne jest w zbiornikach zapadliskowych.