FOLIA MALACOLOGICA
Vol. 7(2): 93–98
ISSN 1506-7629
The Association of Polish Malacologists
& Faculty of Biology, Adam Mickiewicz University
Poznań 1999

THE EFFECT OF ELEVATED WATER TEMPERATURE ON THE OCCURRENCE OF FRESHWATER SNAILS IN THE RYBNIK DAM RESERVOIR (UPPER SILESIA, POLAND)

MAŁGORZATA STRZELEC

Silesian University, Faculty of Biology and Environment Protection, Bankowa 9, 40-007 Katowice, Poland

ABSTRACT: In the Rybnik dam reservoir (S Poland), as a result of elevated water temperature, the freshwater snail fauna is rather poor. The most characteristic is the dominance of introduced species: *Physella acuta* (Drap.) and *Potamopyrgus antipodarum* (Gray), which occur abundantly and cause a progressive reduction in abundance of native snail species.

KEY WORDS: thermal pollution, dam reservoir, freshwater snails, *Potamopyrgus antipodarum*, *Physella acuta*

INTRODUCTION

In contemporary studies on bottom fauna of freshwater habitats with artificially heated water (e.g. by power plant discharge) the effect of temperature on selected invertebrate communities was the main focus of fairly many publications (e.g. SOSZKA & SOSZKA 1976, KRZYŻANEK 1991 and references contained therein).

Water utilized as coolant in industrial processes elevates the temperature of lakes and rivers which it enters, often with serious ecological consequences. The latter may even include death of animals as a result of an increased oxygen consumption, with a simultaneous decrease in oxygen content in the water (AKERLUND 1969). Under such conditions the resistance to toxins is decreased (CAIRNS 1970) whereas the toxicity of some pollutants (e. g. zinc) increases (HARMAN 1974).

Freshwater snails are numerously represented in the fauna of heated lakes and reservoirs. My earlier investigations concerning the snail fauna of natural lakes with artificially elevated water temperature (Gosławickie, Pątnowskie and Licheńskie lakes in the Polish lakeland; STRZELEC in press) revealed a significant influence of water temperature on the formation of snail associations. The general tendency in such conditions is a progressive impoverishment of snail fauna. Phytophilous species inhabiting shallow littoral zone are the first to disappear (STRZELEC in press) whereas some other species (especially introduced) increase in abundance. Such a general regularity was observed in the mentioned natural lakes.

With respect to its surface area, the Rybnik dam reservoir which was the object of the present study, is comparable to natural lakes. Heated water is discharged to it from a power plant. The reservoir was repeatedly investigated from hydrological viewpoint while hydrobiological and ecological research was scarce, the malacofauna being only incidentally studied.

My earlier studies on freshwater snails of Silesian Uppland and the influence of various factors that are active in an industrial area on their distribution revealed the presence of some introduced snail species in the Rybnik dam reservoir; in another study (STRZELEC 1993) their effect on the structure of native snail communities was described.

The initially collected materials and several observations related to the environmental conditions in the Rybnik dam reservoir and their influence on aquatic life were so interesting that they encouraged me to study the problem more thoroughly.

The aim of this study was: 1. recognition of quantitative and qualitative distribution of snails in thermal zones of the dam reservoir and determination of factors governing their occurrence; 2. evaluation of temperature effects on the biology and ecology of introduced foreign species of freshwater snails.

STUDY AREA

The dam reservoir of the power plant "Rybnik" has been exploited since 1972. It has appeared as a result of dam construction on the river Ruda (tributary to the Odra river). The reservoir is additionally supplied in water by several small streams (Ochojec, Gzel, Pniowiec). It plays a variety of roles: source of cooling water for the power plant; storage reservoir during flood periods; recreational place for the local people; accumulation of pollutants brought by the Ruda river and the streams (JANKOWSKI & KUCZERA 1992).

The Rybnik dam reservoir is 355 ha in area. It is a shallow water body of maximum depth of 11 m and average depth of 4.3 m. The water exchange period lasts 108 days. The catchment area of the reservoir is 280 km^2. Its northern part is wooded, the southern one is agriculturally exploited. The whole area is to a great extent urbanised and industrialised which contributes considerably to industrial and communal pollution of the lake (KASZA 1992).

The main reservoir has three side bays, separated from it with dams and receiving water supply from their own catchment areas. The direction of water current is from the bays to the reservoir. As a result the water in the bays is thermally undisturbed.

The volume of heated water discharged from the power plant to the reservoir (its temperature is about +34°C) amounts to 25–30 m^3/sec. which is the cause of increase in the water temperature in the reservoir. It is on an average by about 5°C higher than in the neighbouring unheated water bodies and even in bottom layer never falls below +5°C (KRZYŻANEK 1991). In summer the water temperature in the lake sometimes exceeds +36°C (JANKOWSKI & KUCZERA 1992). Since its origin, the reservoir has been receiving a high load of biogens. As a result, within the last decades common events were blooms of *Microcystis aeruginosa* and frequent mass occurrences of Bacillariophyceae and Chlorophyta. Consequently, during the warm period of the year an increase in pH values (up to 10.3) was regularly observed. In autumn pH ranges from 8 to 8.2.

Based on the distribution of water temperature and bathymetry of the reservoir, JANKOWSKI & KUCZERA (1992) distinguished in it four thermal zones (Fig. 1):

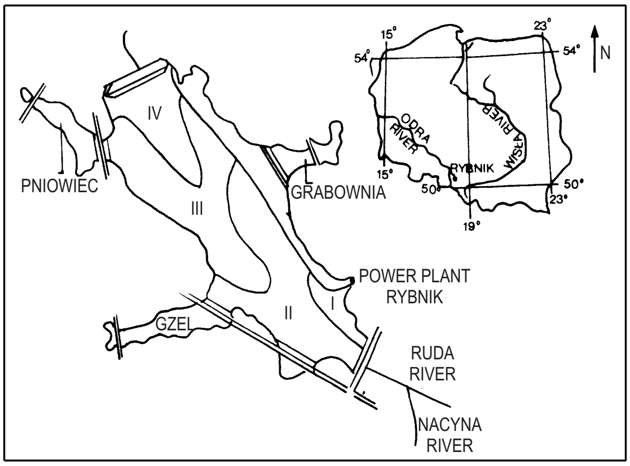

Fig. 1. Location of the Rybnik dam reservoir (right) and its thermal zones (left): I – discharge zone, II – mixing zone, III – cooling zone, IV – quasi-natural zone

I. Discharge zone where the water temperature depends on the temperature of water discharged from the power plant. It covers about 6% reservoir area.
II. Mixing zone – which covers 43% reservoir area. The water temperature in this zone is lower than in the preceding one as a result of intense mixing of discharged and unheated water.
III. Cooling zone covers 37% reservoir area and may be characterised as the zone of heat escape from the water surface.
IV. Quasi-natural zone (about 14% reservoir area) in which the habitat conditions are similar to those found in natural water bodies.

The macrophytes in the reservoir are affected by various factors (e. g. banks covered with stones or concrete plates, absence of ice throughout the year, waving and fluctuations of water level, specific water chemistry, sandy-muddy bottom) which bring

Table 1. Chemistry of water in the Rybnik dam reservoir

Parameter	Value
Total hardness in °dH	6–13.1
Chlorides mg × dm^{-3}	40–208
Ca^{++} mg × dm^{-3}	38–66
Mg^{++} mg × dm^{-3}	4.3–66
Total phosphorus mg × dm^{-3}	0.11
Zn^{++} mg × dm^{-3}	0.1
H_2S mg × dm^{-3}	0.1
Fe^{2+} + Fe^{3+} mg × dm^{-3}	0.2–0.5
Alkalinity mval × dm^{-3}	1.3–2.8

about a qualitative and quantitative differentiation of plant associations. It is noteworthy that the vegetation period in the reservoir is about 2.5 months longer than in other water bodies of the region (KASZA 1992).

In the first years of the reservoir's existence (1972–73) there occurred only small patches of *Polygonum amphibium* L., *Lemna minor* L., *Phragmites australis* (Cav.) Trin. ex Steud and *Glyceria maxima* (Hartm.) Holmb. As a result of introduction of grass carp (*Ctenopharyngodon idella* Vall.) in the lake, all plant species were exterminated and the macrophytes regenerated partly only after 25 years. Now in some parts of the Rybnik reservoir *Phragmites australis* (Cav.) Trin. ex Steud and *Typha latifolia* L. form greater or smaller patches. Rarely in small bays there occur *Glyceria maxima* (Hartm.) Holmb., *Hydrocharis morsus-ranae* L. and *Lemna minor* L.

Physico-chemical characteristics of water is shown in Table 1. Only those parameters which directly or indirectly affect snails are included (OEKLAND 1990, STRZELEC 1993).

MATERIALS AND METHODS

The studies were carried out in 1995–1996. Quantitative samples were taken from May to September each year, from study sites, situated in all the thermal zones of the reservoir and from its side bays. Sites were selected considering the diversity of habitat conditions and the influence of anthropogenic transformations. At each locality 16 samples were taken with a square frame of 25×25 cm; the density of snails was converted to 1 m^2.

Ecological traits of the snail communities were determined with the use of adequate indices, as described in STRZELEC (1993).

RESULTS AND DISCUSSION

The freshwater snail fauna of the Rybnik dam reservoir is not very diverse. Only 9 snail species have been found during the study period. Two introduced species (*Physella acuta* and *Potamopyrgus antipodarum*) are common and abundant, while the indigenous species, mainly those characteristic of small water bodies and living as a rule in shallow littoral zone, ecologically ubiquistic, form here the accidental component of the fauna (Table 2).

In the discharge zone the main factor limiting the occurrence of snails is water temperature which affects directly the chemical and physical characteristics of water and indirectly the whole biological environment. Banks in this zone are polstered with perforated concrete plates covered with a thin layer of green algae. In places where the heated water enters the reservoir only *Physella acuta* occurred. This species, introduced from southern Europe in the last century, colonised successfully various waters in central and north-eastern parts of the continent, particularly anthropogenic reservoirs (STRZELEC 1993) and lakes with artificially heated water. It is known from ponds in the vicinity of Łódź where the temperature was

Table 2. Percentage of particular species in thermal zones and in total collection of the Rybnik dam reservoir

Species	Zone I	Zone II	Zone III	Zone IV	Total collection
Potamopyrgus antipodarum (Gray)	–	26.9	72.8	41.3	43.0
Bithynia tentaculata (L.)	–	5.3	9.0	0.5	4.2
Radix peregra (O. F. Müller)	–	2.1	0.8	0.3	0.8
Planorbis planorbis (L.)	–	3.7	1.6	0.6	1.5
Gyraulus albus (O. F. Müller)	–	2.1	–	–	0.4
Segmentina nitida (O. F. Müller)	–	1.6	–	–	0.3
Planorbarius corneus (L.)	–	0.5	–	0.3	0.2
Ferrissia wautieri (Mirolli)	–	18.2	0.2	–	3.6
Physella acuta (Drap.)	100	39.5	15.5	56.9	45.9
$\sum$ specimens	265	375	619	634	1893
Simpson's index	0	0.37	0.43	0.50	0.60

higher than in the Rybnik dam reservoir, and amounted to 40°C in summer and 25°C in winter (FELIKSIAK 1939). Similar data were published by FORCART (1948) for thermal springs in Baden.

In other zones of the reservoir diversity and abundance of the snail fauna do not seem to be affected by thermal conditions. The decrease in water temperature towards the dam is generated by mixing of hot water with unheated one from the reservoir parts that are remote from the power plant. It favours generally the occurrence of several snail species as a result of the richness of macrophytes and the layer of plant debris covering the bottom in cooler zones.

The highest density and species diversity of gastropod fauna were found in the littoral zone of central and lower parts of the reservoir. The banks polstered with stones, a great amount of plant debris, whirls of green algae and the bottom covered with detritus form the habitat abundantly populated by *Potamopyrgus antipodarum*. *Ferrissia wautieri*, which is a rare species in the snail fauna of Poland (STRZELEC & LEWIN 1996) is frequent on stems and leaves of *Typha latifolia* L. Other species were found either on the sandy-muddy bottom or on single submerged stones, or else on fascine strenghtening the banks. It seems that the snail fauna in the Rybnik dam reservoir is still unstabilised; this follows from the comparison with results obtained in 1974-1981 by KRZYŻANEK (1991). In the whole period of observations only *Physella acuta* was found constantly and abundantly, and *Planorbarius corneus* only rarely. Since 1975 *Gyraulus albus* has been an accidental component in that fauna. After further 15 years a mass occurrence of *Potamopyrgus antipodarum* was observed, as well as fairly numerous specimens of *Ferrissia wautieri* and *Bithynia tentaculata* and few individuals of *Planorbis planorbis* and *Segmentina nitida*. All these observations point at a particular efficiency of introduced species in colonisation of the new reservoir (Table 3).

Introduced species cause deep changes in the structure of indigenous snail communities. In one of the previous papers (STRZELEC 1992), I described the effect of the appearance of *P. antipodarum* in several water bodies. Such an influence generally leads to a reduction in the diversity and abundance of other snails, and to consequent formation of specific transitory communities. A similar effect was observed in the case of heated reservoir.

The occurrence of abundant populations of *P. antipodarum* and *Ph. acuta* in the sampling sites in the Rybnik dam reservoir confirm the data on their resistance to industrial pollution, enabling them to colonise reservoirs which are inaccessible to other snail species because of environmental toxicity (TOMKINS & SCOTT 1986, STRZELEC & KRODKIEWSKA 1994, STRZELEC & SERAFIŃSKI 1996).

A comparison of snail faunae living in thermally polluted natural and anthropogenic lakes reveals distinct similarities. They involve the dominance of introduced species and the value of diversity index in both types of reservoirs. For example, in some of the heated Konin lakes (STRZELEC in press) the proportion of introduced species in the total collection was as follows: Gosławickie lake – *P. antipodarum* 23.8%, *Ph. acuta* 3.9% (diversity index 0.32); Pątnowskie lake – *P. antipodarum* 70.7%, *Ph. acuta* 0.0% (div. index 0.52); Licheńskie lake – *P. antipodarum* 3.5%, *Ph. acuta* 80.3% (div. index 0.65), whereas in the anthropogenic Rybnik reservoir *P. antipodarum* constitutes 43% and *Ph. acuta* 46%. In all cases the native fauna included phytophilous snail species, characteristic of eutrophic habitats.

In all the mentioned cases the community diversity is rather low, which indicates that the habitat conditions in the studied lakes are similar, enabling exist-

Table 3. Occurrence of particular species in the study years

Species	Year								
	‘74	‘75	‘76	‘77	‘78	‘79	‘80	‘81	‘96
Potamopyrgus antipodarum									+++
Bithynia tentaculata									+++
Radix peregra		+	+	+	+	+	+	++	++
Planorbis planorbis									++
Anisus vortex	+		+	+					
Gyraulus albus		+	+	+	+	+	+	+	+
Segmentina nitida									+
Planorbarius corneus	+	+	+	+	+	+	+	+	+
Ferrissia wautieri									+++
Physa fontinalis			+	+	+	+	+	+	
Physella acuta	+	+	+	+	+	+	++	+++	+++

Years 1974 – 1981 after KRZYŻANEK (1991), Year 1996 – own study, + – rare, ++ – numerous, +++ – abundant ence of euryoecious species. On the other hand, in such similar conditions, the similarity indices for snail communities from natural lakes and the Rybnik reservoir are very low: Rybnik and Gosławickie lake – 0.13, Rybnik and Pątnowskie lake – 0.21, Rybnik and Licheńskie lake 0.29, which indicates the separate character and specificity of the snail community in the dam reservoir. It seems that the reason is quite a different character of vegetation which results in the entirely different type of periphyton and thus different feeding conditions for snails. As a rule, in anthropogenic water bodies the diversity of gastropod fauna depends on the stability and richness of niches (STRZELEC 1993). The Rybnik dam reservoir, unstable in many respects (changes of water level, temperature, vegetation) is what BOYCOTT (1936) defined as the "bad habitat" for freshwater snails.

It seems that other environmental factors (e. g. pH values) only insignificantly affect the distribution of snails in artificially heated water bodies. In my previous study, which included 148 localities (STRZELEC 1993), snails were found in waters of pH 6.9–8.3. HARMAN & BERG (1971) described the occurrence of pulmonates at pH 7.0–8.4 and of prosobranchs at 7.4–8.3. In the investigated dam reservoir snails occurred even at pH up to 10.3, which was characteristic of periods of algal blooms. At such high pH values a mass occurrence of *P. antipodarum* was observed in spite of the common opinion that this species tolerates only pH 6.5–8.5 (FALNIOWSKI 1987).

CONCLUDING REMARKS

The small qualitative and quantitative diversity of freshwater snail fauna in the Rybnik dam reservoir is the effect of: slight diversity of habitats; scarcity of macrophytes; temporal variation in physico-chemical water properties, resulting from technical processes (use of the water in cooling systems of the Rybnik power plant), concerning the water temperature and, consequently, the amount of dissolved O_2 and CO_2 and various minerals; fluctuations of water level.

Because of scarcity of vegetation in most of the reservoir, its artificially formed banks are exploited by snails as favourable habitat.

In all the study sites the snail communities were impoverished, characterised by a low number of species, only one or few of them being represented by numerous individuals.

Comparative studies on gastropod fauna have revealed an instability of snail communities in the investigated reservoir. During the study period, a general decrease in the number of species was observed, with a simultaneous increase in the number of individuals in some species adapted to peculiar conditions of heated reservoirs. *Physella acuta*, forming great and permanent populations even in discharge zone of the reservoir, has been finding the most favourable habitats for years.

The other introduced species – *Potamopyrgus antipodarum* – affects the native snail fauna, causing the reduction in abundance of some native species and then extinction of some of them. This case, discussed also in one of the previous papers (STRZELEC 1992), has been recently observed in the Rybnik dam reservoir.

Both the mentioned introduced species are able to survive in unstable freshwater environments.

Ferrissia wautieri, rare in the fauna of Poland, occurred in the reservoir only at some study sites, on partly decayed stems of *Typha latifolia*, under the water surface. Only the ancyloid form has been found, despite the observed variation in water chemistry and physical properties which cause the septum formation in natural conditions (RICHARDOT 1977).

According to SLADEČEK'S (1977) toxicity system the Rybnik dam reservoir is limnotoxic on metatoxic level. Biocenoses of such environments are heavily damaged. Because of the absence of competitive species, chemoresistant snails may achieve here enormous abundance. In anthropogenic water bodies of Poland such species are among others the foreign colonisers – *P. antipodarum* and *Ph. acuta*.

REFERENCES

AKERLUND G. 1969. Oxygen consumption of the ampullarid snail *Marisa cornuarietis* L. in relation to body weight and temperature. Oikos 20: 529–533.

BOYCOTT A. F. 1936. The habitats of freshwater molluscs in Britain. J. Animal. Ecol. 5: 116–186.

CAIRNS J. 1970. Ecological management problem caused by heated wasted water discharge into the aquatic environment. Water Resources Bull. 6: 868–878.

FALNIOWSKI A. 1987. Hydrobioidea of Poland (Prosobranchia, Gastropoda). Folia Malacologica 1: 1–122.

FELIKSIAK S. 1939. *Physa acuta* Draparnaud in den Fabrikteichen von Lodz und ihre allgemeine Verbreitung. Fragm. Faun. 4: 243–258.

FORCART L. 1948: Ueber ein massenhaftes Auftreten von *Physa acuta* Drap. in den Thermen von Baden, sowie Untersuchungen ueber die Waermeexistenz dieser Art. Basteria 12: 24–28.

HARMAN W. N. 1974. Snails (Mollusca: Gastropoda). In: Pollution ecology of freshwater invertebrates (HART C. W. JR., FULLER S. L. H., eds), pp. 275–312, Academic Press, New York.

HARMAN W. N., BERG C. O. 1971. The freshwater snails of Central New York with illustrated keys to the genera and species. Search: Cornell Univ. Agric. Exp. Station Ithaca 1: 1–68.

JANKOWSKI A. F., KUCZERA A. 1992. The effect of discharging heated water to the Rybnik Reservoir on the thermal and oxygen conditions and on water transparence. Prace Nauk. Uniw. Śl. 1300: 1–79.

KASZA H. 1992. Changes in the aquatic environment over many years in three dam reservoirs in Silesia (Southern Poland) from the beginning of their existence; causes and effects. Acta Hydrobiol. 34: 65–114.

KRZYŻANEK E. 1991: The formation of bottom macrofauna communities in three dam reservoirs in Silesia (Southern Poland) from the beginning of their existence. Acta Hydrobiol. 33: 265–305.

OEKLAND J. 1990. Lakes and snails. Universal Book Services, Oegstgeest.

RICHARDOT M. 1977. Ecological factors inducing estivation in the freshwater limpet *Ferrissia wautieri* (Basommatophora: Ancylidae). I. Oxygen content, organic matter content and pH of the water. Malacol. Rev. 10: 7–13.

SLADEČEK V. 1973: System of water quality from the biological point of view. Arch. Hydrobiol. 7: 1–218.

SOSZKA H., SOSZKA J. S. 1976. Biocenosis reaction to heated water (in Polish with English summary). Wiad. Ekol. 22: 117–141.

STRZELEC M. 1992. Freshwater snails of planned ornithological sanctuary Żabie Doły in Bytom (in Polish with English summary). Kształt. Środ. Geogr. 4: 44–48.

STRZELEC M. 1993. Snails (Gastropoda) of anthropogenic water environments in Silesian Upland (in Polish with English summary). Prace. Nauk. Uniw. Śl. 1358: 1–104.

STRZELEC M. in press. Effects of thermal discharges from a power plant on freshwater snails fauna in three Polish lakes. Walkerana.

STRZELEC M., KRODKIEWSKA M. 1994. The rapid expansion of *Potamopyrgus jenkinsi* (E. A. Smith, 1889) in Upper Silesia (Southern Poland). Malak. Abh. 17: 33–36.

STRZELEC M., LEWIN I. 1996. Some data on the distribution and biology of *Ferrissia wautieri* (Mirolli, 1960) in Southern Poland (Gastropoda: Ancylidae). Mitt. dtsch. malakozool. Ges. 58: 23–26.

STRZELEC M., SERAFIŃSKI W. 1996. Population ecology of *Potamopyrgus antipodarum* (Gray) in recently colonised area: Upper Silesia (Southern Poland) (Gastropoda: Prosobranchia: Hydrobiidae). Malak. Abh. 18: 75–82.

TOMKINS A. R., SCOTT R. R. 1986: Effects of treated sevage effluent on the macroinvertebrates of a fine sediment substrate stream. Mauri Ora 13: 1–12.

received: November 20th, 1998
accepted: May 15th, 1999