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Effect of artificially elevated water temperature on growth and fecundity of *Potamopyrgus antipodarum* (GRAY) in anthropogenic water bodies in Southern Poland (Gastropoda: Prosobranchia: Hydrobiidae)

With 2 figures and 5 tables

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Abstract. In the two last decades the New Zealand snail *Potamopyrgus antipodarum* (GRAY) colonized very intensively the freshwater reservoirs in Southern Poland, even these polluted by industry to a great degree. The Rybnik dam reservoir is a water-body, containing water heated by power plant, in which *P. antipodarum* forms a large population. Studies on effect of elevated temperature have shown its direct influence on growth rate and fecundity of this snail. The individuals from heated environment are in average smaller but their fecundity is greater than compared with individuals living in thermally unpolluted habitat. Both differences are statistically significant.

Kurzfassung. **Einfluß der erhöhten Wassertemperatur auf Wachstum und Fruchtbarkeit von *Potamopyrgus antipodarum* (GRAY) in künstlichen Wasserbecken in Südpolen (Gastropoda: Prosobranchia: Hydrobiidae).** – Im Verlauf der letzten zwanzig Jahre besiedelte die neuseeländische Süßwasserschnecke *Potamopyrgus antipodarum* (GRAY) sehr rasch künstlich angelegte Wasserbecken in Südpolen, sogar dann, wenn deren Wasser durch die Industrie hochgradig verschmutzt war. Das Sperrenreservoir von Rybnik enthält durch ein Kraftwerk erwärmtes Wasser, in welchem *P. antipodarum* eine große Population entwickelt hat. Untersuchungen über den Einfluß der erhöhten Wassertemperatur haben gezeigt, daß diese direkten Einfluß auf Wachstum und Fruchtbarkeit dieser Schnecke aufweist. Die Individuen aus dem erwärmten Wasser waren durchschnittlich kleiner, aber ihre Fruchtbarkeit war größer im Vergleich zu Individuen, welche unter natürlichen Bedingungen leben. Diese Unterschiede sind statistisch signifikant.

Introduction

In two foregoing papers the expansion in Southern Poland (STRZELEC & KRODKIEWSKA 1994) and some aspects of biology and ecology in environmental conditions of recently colonized area in Poland (STRZELEC & SERAFIŃSKI 1996) of *Potamopyrgus antipodarum* (GRAY 1843) have been presented. All data concerned the natural conditions of different habitats undisturbed in respect to thermal regime.

In the last years the large populations of *P. antipodarum* inhabiting two neighbouring water bodies were studied. In the first of them (Rybnik dam reservoir) water is polluted thermally by discharge of warm water from a power plant, whereas in the second one (Gzel reservoir) it is thermally undisturbed. In both reservoirs these snails have appeared in 1994 an during two years became the dominant in snail fauna (STRZELEC in press a). Similarly as in other water bodies the increase in population size was very rapid. In the first year only few individuals were found, whereas in the next years the mass occurrence was observed

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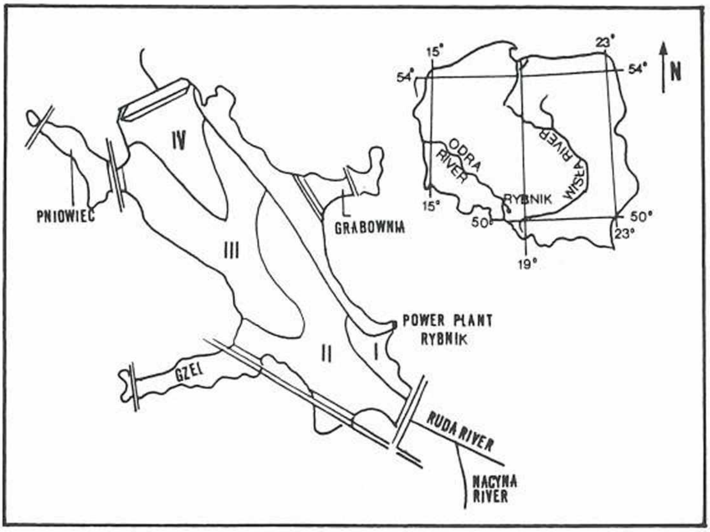

Fig. 1: Thermal zones in Rybnik dam reservoir.

in all studied cases as a rule (STRZELEC 1993, STRZELEC & KRODKIEWSKA 1994, STRZELEC & SERAFIŃSKI 1996). This fact results from parthenogenetic reproduction and great fecundity of these snails as well as from early achieved maturity and ability to rapid expansion in newly colonised regions (WINTERBOURN 1970a, b, FRETTER & GRAHAM 1962, FRENZEL 1979, STRZELEC & SERAFIŃSKI 1996).

All informations on the occurrence and biology of *Potamopyrgus antipodarum* indicate its adaptability to different environmental conditions, resulting from small habitat and feeding needs (FRETTER & GRAHAM 1962, REAVEL 1980), resistence to industrial pollutions (TOMKINS & SCOTT 1986) and the lack of competition with native snail fauna (STRZELEC in press b). Some data (QUINN et. al. 1994) indicate the influence of water temperature on some morphological an biological characters of *P. antipodarum*.

The aim of present paper is the comparison of morphology, reproduction an fecundity of specimens living in natural thermal conditions with that in thermally polluted habitats and the determination of direct or indirect effect of temperature on these snails.

Characteristics of studied water-bodies

Rybnik dam reservoir

The reservoir has been built in 1972 as the storage reservoir of water for power plant installations. It is supplied in water by several small rivers and streams, mostly by Ruda river (tributary of Odra river). Its area amounts to 355 ha and depth to 4.3 m.

Amount of heated water discharged from power plant to the reservoir amounts to 25–30 m^3/sec. what is the cause of the increase of water temperature in it, which is on average about 5 °C higher than in adjacent Gzel reservoir and even in ground layer it falls never below +5 °C (KRZYŻANEK 1991). In summer temperature of water in some parts of reservoir often exceeds +35 °C. In the same month water temperature in Gzel reservoir reaches +24 °C at most.

Water in Rybnik reservoir is highly eutrophic and in last decade the blooms of Cyanophyta and green algae are observed almost every year.

Basing on water temperature and bathometry, four thermal zones in the reservoir have been distinguished (Fig. 1):

	Reservoir	
	Rybnik	Gzel
Total hardness ^{0}dH	8.00	7.00
pH	7.00	7.20
$Fe^{2+,3+}$ mg/dm^3	0.50	0.30
Ca^{2+} mg/dm^3	38.00	44.00
Mg^{2+} mg/dm^3	11.60	3.80
Cl^- mg/dm^3	150.00	75.00
Zn^{2+} mg/dm^3	0.10	0.30
H_2S mg/dm^3	0.10	0.00
N_{NH4} mg/dm^3	1.10	0.03
NO_4^{2-} mg/dm^3	0.24	0.70

Table 1: Physico-chemical characteristics of water in studied reservoirs.

- zone of discharge, in which the temperature is almost the same as the temperature of water flowing from power plant;
- zone of water mixing, the water temperature is lower than in preceding zone in result of intensive mixing of discharged water with river water;
- zone of water cooling, where heat intensively escapes from water surface;
- quasi natural zone, the habitat conditions similar to that in thermally unpolluted waters.

The vegetation of vascular plants is in dam reservoir rather scarce, because of banks covered with stones and concrete plates, fluctuations of water level, specific chemistry of water and high water temperature in most part of habitat. Now in some parts of water-body only *Phragmites communis* and *Typha latifolia* form greater or smaller clusters. Rarely in small bays occur *Glyceria aquatica*, *Hydrocharis morsus-ranae* and *Lemna minor*. Physico-chemical characteristics of water are shown in Table 1.

The freswater snail fauna in Rybnik dam reservoir is poorly differentiated. Dominate there two introduced species: *Potamopyrgus antipodarum* (GRAY) and *Physella acuta* (DRAP.), which form together more than 90 % of total collection. Apart from mentioned species there occured during study period: *Bithynia tentaculata* (L.), *Radix peregra* (O. F. MÜLLER), *Planorbis planorbis* (L.)., *Gyraulus albus* (O. F. MÜLLER), *Segmentina nitida* (O. F. MÜLLER), *Planorbarius corneus* (L.) and *Ferrissia wautieri* (MIROLLI), all in very small number of individuals (STRZELEC 1999).

Gzel reservoir

It is a side bay of Rybnik reservoir, separated from it by a artificial dam, which prevents its environment from the inflow of heated water from the adjacent reservoir (Fig. 1). It is supplied in water by a small stream Gzel and the water level in reservoir is constant during year. The banks are strenghtened with stones and fascina in some places with concrete plates.

The vegetation is rich and differentiated, with domination of vascular plant species characteristic for eutrophic water bodies (*Polygonum amphibium*, *Ceratopyllum demersum*, *Myriophyllum spicatum*, *Alisma plantago-aquatica*, *Hydrocharis morsus-ranae*, *Eleodea canadensis*, *Carex riparia*, *Phragmites communis*, *Typha latifolia* and *Lemna minor*). Physico-chemical characteristics of water are given in Table 1.

In the snail fauna the only dominant species is *P. antipodarum* (GRAY), whereas the remaining 14 species occur in very small number of individuals (STRZELEC in press a). Similarly as in the case of Rybnik dam reservoir one may observe the reduction of native snail fauna since the appearance of *P. antipodarum* in Gzel (STRZELEC 1999).

	Month				
	V	VI	VII	VIII	IX
min	2.0	2.3	1.0	1.1	3.5
$\bar{x}$	4.04	3.91	3.65	2.99	4.36
max	5.2	4.6	5.2	4.5	5.5
SD±	0.73	0.36	0.96	1.05	0.44
v%	18.1	9.2	26.3	35.1	10.1
n	50	50	50	30	50

Table 2: Shell height of *Potamopyrgus antipodarum* in particular months in Rybnik reservoir.

	Month				
	V	VI	VII	VIII	IX
min	2.4	2.7	2.0	2.5	2.5
$\bar{x}$	4.25	3.99	3.79	4.03	3.97
max	5.3	4.5	4.6	4.7	4.7
SD±	0.53	0.32	0.81	0.52	0.41
v%	12.4	8.0	21.4	12.8	1.03
n	50	50	50	50	50

Table 3: Shell of *Potamopyrgus antipodarum* in particular months in Gzel reservoir.

Material and methods

The investigations were carried out at 1997. Materials were gathered from May to September by use of quantitative methods from 4 sites in zone of water mixing in Rybnik, where the temperature is significantly higher than in natural conditions (average water temperature in period May – September +25.9 °C), and from 4 sites in Gzel (average water temperature in the same period +19.6 °C). From each locality 4 samples (from area 25×25 cm) in every month were collected and the number of individuals was converted on 1 m².
From each monthly sample 50 randomly selected individuals were measured, dissected and the number of embryos in brood pouch was counted.
All results were statistically tested.

Results and discussion

Shell size

The shell heights of *P. antipodarum* living in both studied reservoirs differ significantly. For 230 measured specimens from Rybnik dam reservoir it amounts in average to 3.84 ± 0,92 mm, and for 250 specimens from Gzel – 4.00 ± 0.56 mm ($t = 2.33$, $p < 0.001$).
The insignificant differences were found only in June and July (Tab. 2, 3), because of the reconstruction of Rybnik population resulting from the second reproductive period. The structure of both populations in particular months is shown on Fig. 2.

The smaller size of shells from Rybnik population can not be a result of greater density of individuals (to this factor pay attention LUMBYE & LUMBYE 1965) because in both reservoirs the population density is similar (in average 282 vs. 271 individuals/m² in Rybnik and Gzel respectively). It seems that the smaller size of snails from heated water-body is caused by the shorter life span in unfavourable conditions (smaller oxygen content in water, toxic metabolites of blue- green algae etc.). The maximal size of individuals living in heated water is nearly the same as in thermally undisturbed environments (STRZELEC & SERAFIŃSKI 1996), among other in Gzel as well as in natural but industrially heated Konin lakes

Table 4: Fecundity of *Potamopyrgus antipodarum* in particular months in Rybnik reservoir.

size class (mm)	Month														
	V			VI			VII			VIII			IX		
	Min	$\bar{x}$	Max	Min	$\bar{x}$	Max	Min	$\bar{x}$	Max	Min	$\bar{x}$	Max	Min	$\bar{x}$	Max
2.1-2.5										3	8	30			
2.6-3.0											5				
3.1-3.5		36		8	9	10				4	11	20	8	13	22
3.6-4.0	6	39	62	18	22	30	2	26	50		40		2	13	50
4.1-4.5	5	39	63	5	24	50	2	12	30	10	27	50	7	21	50
4.6-5.0	7	41	62	17	30	36		2					2	15	32
5.1-5.5	60	60	61										16	18	20
Average number of embryos/snail		40			23			15			18			17	
% of snails with embryos		94			78			56			63			84	
Potential fecundity		3757			1763			857			1139			1451	

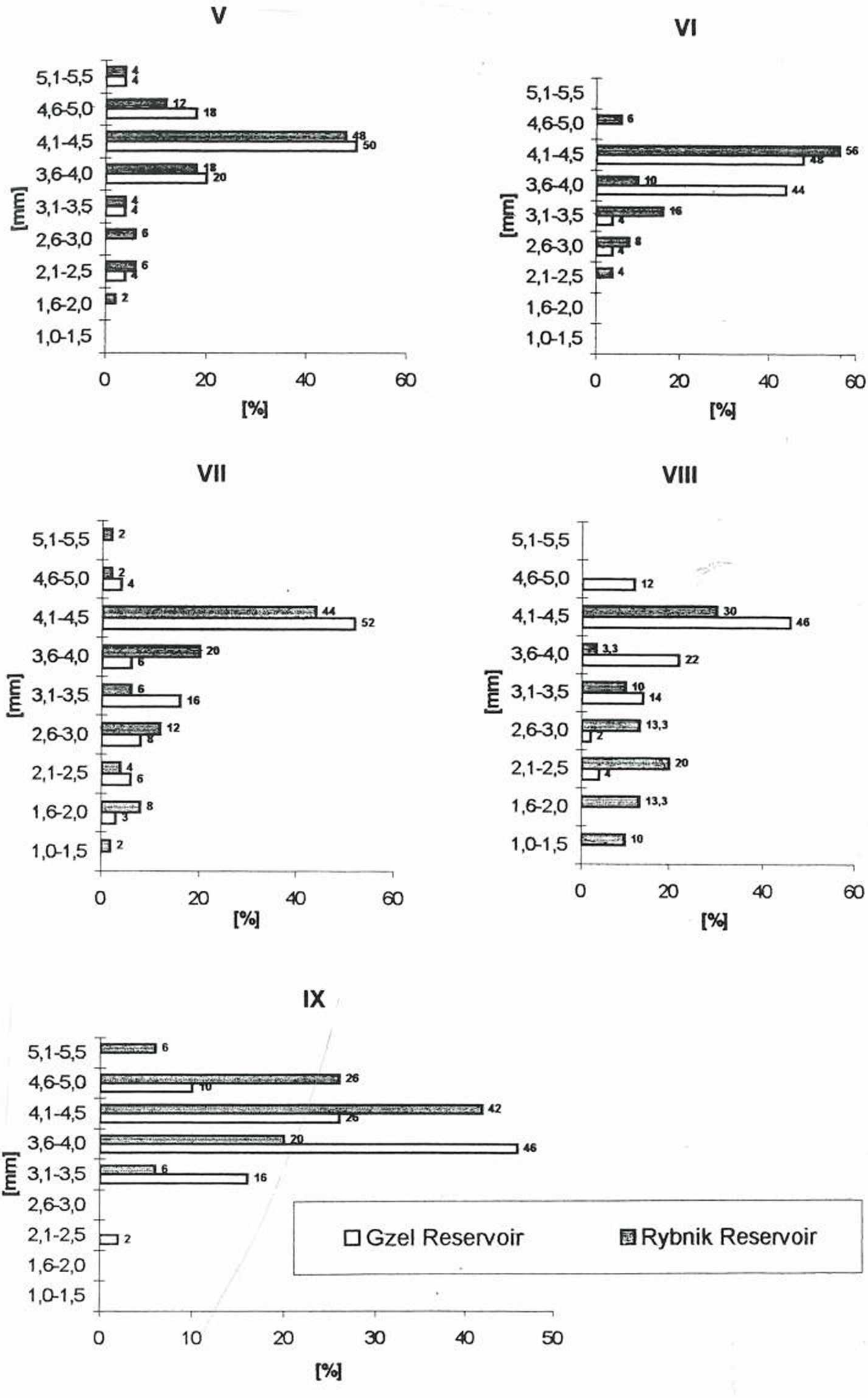

Fig. 2: Size structure of populations studied in particular months.

size class (mm)	Month														
	V			VI			VII			VIII			IX		
	Min	$\bar{x}$	Max	Min	$\bar{x}$	Max	Min	$\bar{x}$	Max	Min	$\bar{x}$	Max	Min	$\bar{x}$	Max
2.6-3.0															
3.1-3.5					20		3	4	5	3	4	7		6	
3.6-4.0	4	19	31	4	12	30		2		4	17	24	7	10	30
4.1-4.5	11	28	49	3	18	30	2	13	28	8	14	25	4	11	25
4.6-5.0	10	31	52				28	29	30	14	27	34	6	23	30
5.1-5.5	30	30	30												
Average number of embryos/snail		27			15			12			15			11	
% of snails with embryos		92			92			60			90			94	
Potential fecundity		2517			1397			742			1354			1034	

Table 5: Fecundity of *Potamopyrgus antipodarum* in particular months in Gzel reservoir.

(STRZELEC in press b). Thus, in colonized areas *P. antipodarum* is always smaller than at home in New Zealand, where its shells are 6–6.5 mm high (WINTERBOURN 1970b). WINTERBOURN's observations that in higher temperature the growth rate is more intensive what results in reaching of greater shell size in shorter time have been not confirmed in present study.

Fecundity

In whole collected material there occur significant differences in embryos number per female living in different reservoirs. The number of embryos per female amounts in average to 25.6 ± 5.06 in Rybnik and to 16.0 ± 4.05 in Gzel. Statistically significant differences in this respect have been oberseved in all months and for the whole materials ($t = 20.98$ by $df = 378$, $p < 0.001$).
Embryos number is significantly correlated with the female size. The correlation coefficient amounts to $r = 0.79$, $p < 0.001$ for Rybnik population and $r = 0.88$, $p < 0.001$ for Gzel (Tab. 4, 5).
Fully developed embryos in brood pouch were in both populations 0.2–0.3 mm wide and 0.1–0.15 mm high.

As a rule, the fecundity increases together with growth of a female. According to WINTERBOURN's (1970b) observations in New Zealand, the litter size is always correlated with individual size, therefore with the size of brood pouch. The greatest contribution in reproductive activity in populations from Rybnik and Gzel reservoirs have the individuals from the size class 4.1– 4.5 mm, which are in majority in both populations. Few individuals from two next size classes, despite of the fact that all of them are with embryos, play the insignificant role in production of new generation.
Maximal number of embryos per female in Rybnik reservoir amounted to 63 and in Gzel reservoir to 52. There exist interesting differences in size of smallest specimens containing embryos in both habitats. They belong to the class 2.1–2.5 mm in Rybnik and 3.1–3.5 mm in Gzel. Because in a prevoius study (STRZELEC & SERAFIŃSKI 1996) the growth rate of individuals has been estimated for 1 mm in height per month, these data may suggest that the elevated water temperature can accelerate the pubescence in this species. In studies on its reproduction in habitats unaffected by thermal pollution females with embryos have been never found in size classes below 3.1 mm in height.
According to common views, the reproduction period of *P. antipodarum* living in natural habitats of New Zealand is lasting the whole year, however, the main reproduction occurs in spring (WINTERBOURN 1970b). In climatic conditions of Central Europe, reproduction is

observed from spring to autumn. – In heated Rybnik reservoir the youngest free living individuals were found mainly in May and August what indicates the second reproductive period in this habitat.
Basing on the percent of females with embryos and on average number of embryos per female the potential fecundity was calculated for the modell populations containing 100 individuals each. Data given in tables 4 and 5 indicate the positive effect of elevated water temperature on reproduction possibilities of *P. antipodarum.*

Conclusions

1. The present study has shown the influence of elevated water temperature in Rybnik dam reservoir on the growth rate of *Potamopyrgus antipodarum* (GRAY) as well as on its fecundity both real and potential one.
2. The fecundity of this species is greater in heated Rybnik reservoir than in thermally natural Gzel reservoir, despite of the fact that in all months the percent of individuals with embryos in brood poruch is smaller in the first of them.
3. It seems that the higher water temperature accelerates the pubescence of individuals in *P. antipodarum.*
4. The main reproductive period in both reservoirs falls in spring.
5. Maximal size of shells as well as maximal number of embryos per snail in population from heated reservoir are still smaller than observed in populations living at home in New Zealand.

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