Title: Occurrence and morphological variability of Gyraulus crista (Gastropoda: Pulmonata: Planorbidae) on different types of substratum in woodland ponds

Author: Aneta Spyra, Małgorzata Strzelec

Citation style: Spyra Aneta, Strzelec Małgorzata. (2013). Occurrence and morphological variability of Gyraulus crista (Gastropoda: Pulmonata: Planorbidae) on different types of substratum in woodland ponds. "Biologia" (2013, no. 4, s. 679-686), doi 10.2478/s11756-013-0197-z

Biologia **68**/4: 679—686, 2013
Section Zoology
DOI: 10.2478/s11756-013-0197-z

Occurrence and morphological variability of *Gyraulus crista* (Gastropoda: Pulmonata: Planorbidae) on different types of substratum in woodland ponds

Aneta Spyra & Małgorzata Strzelec

Department of Hydrobiology, Faculty of Biology and Environmental Protection, University of Silesia, Bankowa 9, 40-007, Katowice, Poland; e-mail: aneta.spyra@us.edu.pl

Abstract: *Gyraulus crista* is often a dominant component of lentic freshwater snail communities because it may occur in densities of hundreds of individuals/m^2 across continents and in lentic water types. A study on the occurrence and conchological variability of the shell of *G. crista* was carried out on five different types of substrates in the anthropogenic woodland ponds at thirteen study sites. In order to answer the question of whether the existence of this species in different forms is affected by the quality of the inhabited substrates, various physico-chemical properties of the water, different bottom sediments and water level fluctuations, we examined the variation of forms across 5990 specimens of *G. crista* in woodland ponds. This research, which was supported by Redundancy Analysis (RDA), showed a highly significant association of *G. c. spinulosus* with leaf deposits and *G. c. cristatus* for *T. latifolia* remains. *G. crista nautileus* was mainly associated with *T. latifolia* and also with *G. aquatica* remains. They also showed no statistically significant relationship between the occurrence of particular conchological *G. crista* forms and different physico-chemical properties of water.

Key words: freshwater snails; woodland ponds; morphological form; *Gyraulus crista*; shell

Introduction

Planorbidae are a large morphologically diverse group that are found in a wide variety of habitats, both permanent and temporary, from springs to large lakes, with some groups preferring fast-flowing water while most prefer slower flowing to still waters (Perez 2004). Among them *Gyraulus crista* (L., 1753) is characterized by a large morphological variability of its shell which permits three forms of this species to be distinguished.

Gyraulus crista is often a dominant component of a lentic freshwater snail benthos because it can occur in densities of hundreds of individuals/m^2 across continents and in lentic water types. *G. crista* is found in various types of stagnant waters, e.g. in small ponds overgrown by rich vegetation, lakes and drainage ditches (Glöer & Meier-Brook 1998; Brauns et al. 2008), as well as in highly eutrophic or polluted reservoirs (Beran 2002). Although it can be found in all types of wetlands (Niggebrugge et al. 2007), the species is particularly associated with ponds. It avoids flowing waters, with the exception of lentic parts of rivers with water plants, where the water flow is slow. According to Piechocki (1979), Glöer & Meier-Brook (1998) and Kerney (1999), it also avoids temporary water bodies and those that are exposed to desiccation, and prefers waters with pH above 7.4 (Økland 1990).

Gyraulus crista inhabits various types of substrates, but mostly aquatic plants such as macrophytes stems, *Nuphar* sp. and *Nymphaea* sp. leaves and the remains of aquatic plants covering bottom sediments. It is also found in leaf detritus (Spyra 2010), on muddy sediments and stones (Hubendick 1947; Piechocki 1979) as well as on anthropogenic rubbish (Jatulewicz 2007).

It is regarded as a common and frequently occurring species in Poland (Piechocki 1979). It does not belong to the endangered species, even in the anthropogenic water reservoirs (Serafiński et al. 2001). Despite this, there is a lack of information connected with the occurrence of different forms of *G. crista* in various water environments, including woodland ponds. The relationships of specific forms with environmental conditions remains unknown. In the literature, there are only descriptions of the shell of *G. crista* (Piechocki 1979; Glöer & Meier-Brook 1998; Glöer 2002) and its participation in snail communities, but no data on the ecological characteristics of its different conchological forms. As we are involved in ecological researches in Polish woodland ponds, we had the opportunity to examine 5,628 specimens in different morphological forms of this species. Therefore, the aim of this study was to answer the question of whether the existence of different forms of this species is affected by the quality of inhabited substrates, various physico-chemical properties of water, different bottom sediments and water level fluctuations. In this research, we also aimed to examine the characteristics of conchological variability of the shell of *G. crista* in small woodland water bodies.

Table 1. The characteristics of the woodland ponds studied.

Number of water body	Max. depth (m)	Surface area (ha)	Number of site	Type of substratum	Geographic co-ordinates	Bottom sediment	Persistence
I	1.8	23	1 2	*Glyceria maxima* remains Leaf deposit	N:50°06′151′, E:18°56′287′ N:50°06′156′, E:18°56′252′	mud	artificially drained*
II	1.9	6.17	3	Leaf deposit	N:50°06′214′, E:18°56′302′	mud	artificially drained*
III	3.5	11.4	4 5 6 7	*Phragmites australis* remains *Nuphar lutea* leaves Leaf deposit *Typha latifolia* remains	N:50°04′206′, E:18°59′496′ N:50°04′226′, E:18°59′558′ N:50°04′233′, E:18°59′574′ N:50°04′246′, E:18°59′628′	Sand-mud	permanent
IV	1.9	12.35	8 9	*Typha latifolia* remains Leaf deposit	N: 50°12′35′, E: 18°37′53′ N: 50°12′20′, E: 18°37′42′	Sand-mud	temporary
V	1.6	1.2	10 11	*Typha latifolia* remains Leaf deposit	N: 50°13′19′, E: 18°37′28′ N: 50°13′21′, E: 18°37′33	Sand-mud	temporary
VI	3.0	12.3	12 13	*Glyceria maxima* remains Leaf deposit	N: 50°15′31′, E: 18°46′39 N: 50°13′31, E: 18 °46′ 30	mud	permanent

Material and methods

Study area

For the present study, 13 water bodies were selected. Their origin is the result of intentional or unintentional mining activity in the forested areas of Southern Poland (Upper Silesia). We selected six woodland ponds in which *G. crista* occur for further research. The riparian zone of these ponds was composed of deciduous trees (mainly *Alnus glutinosa* L., *Betula pubescens* L., *Fragnula alnus* Mill, *Quercus robur* L., *Quercus rubra* L. and *Salix* sp.). They were completely or partly ice-covered from December to February and they partly dry out in the summer. The ponds differ in the types of bottom sediments, size and permanency. They are supplied with water form different sources: surface run-off, woodland ditches and rainwater. Table 1 summarizes the environmental features of the woodland ponds studied.

Site selection

We selected five different types of substrate in the woodland ponds in which *G. crista* occurred depending on the extent of the coverage by plant debris or live plants. Being surrounded by a deciduous forest results in an accumulation of tree leaves on the bottom. For this reason, we selected one site with leaf deposits in each pond (sites: 2, 3, 6, 9, 11 and 13) (Table 1). There are almost no elodeids, however, rushes occur frequently and therefore we designated two sites with *Glyceria aquatica* (sites 1 and 12), *Phragmites australis* (site 4 – pond 3) and three sites with *Typha latifolia* debris (site 7 – pond 3, site 8 – pond 4 and site 10 – pond 5). We also chose one site with a substrate of the leaves of *Nuphar lutea* (site 5-pond 3). In general, the samples were taken from 13 sites for this research. Woodland ponds are often surrounded by wetlands or bog areas, which sometimes makes the selection of sampling sites impossible in a specific location. For that reason, the sites were selected in available places that were as diverse as possible.

Data collection and analysis

The fieldwork of this study was carried out in six woodland ponds in which quantitative samples were taken using standard hydrobiological methods (frame 50 × 50 cm – sample area 0.25 m^2) during one year. The samples were taken once a month except for January and February when the water bodies being studied were covered with a relatively thick layer of ice, which made it impossible to collect them. A total of ten samples were taken at each of sampling sites (totally 130 samples) during the study period.

Due to the minute size of *G. crista*, samples were sieved with a mesh diameter of 0.23 mm. The collected specimens were preserved in 75% alcohol and identified to the proper conchological form according to Piechocki (1979) and Glöer (2002).

Water samples were taken at each of the study sites once a month during the study period. Physico-chemical analyses of the water parameters that affect snail occurrence were performed: temperature, conductivity, pH, total hardness as well as the concentrations of nitrites, nitrates, ammonium, phosphates, chlorides, calcium and alkalinity.

Statistical analysis

Snail and environmental data were analyzed using CANOCO software ver. 4.5 (Ter Braak & Šmilauer 2002). The linear or unimodal relationship between variables and treatments was tested using Detrended Correspondence Analysis (DCA). DCA showed that the species respond linearly to the gradient (gradient was 1.98 SD). According to Ter Braak & Šmilauer (2002), a Canonical Correspondence Analysis (CCA) that assumes a unimodal distribution of the data is not adequate when the length of the gradient (estimated using DCA) is smaller than 3. Therefore, we used a linear, direct ordination method, Redundancy Analysis (RDA). Such an analysis is a direct extension of multiple regression to the modeling of multivariate response data. Prior to the analysis, environmental data were log transformed $\ln(x + 1)$. The significance of the relationships between the three forms of *G. crista* ordination and environmental variables, as well as the axes, were tested within the forward selection procedure using the Monte Carlo permutation test. An ordination diagram, which was based on the variables that statistically significantly influenced the occurrence of *G. crista* in the woodland ponds studied, was made using CanoDraw.

The significance of differences in the occurrence of *G. crista spinulosus* Clessin, *G. crista cristatus* Draparnaud, 1805 and *G. crista nautileus* L., 1767 at the different types of sites being studied were evaluated using the Kruskal-Wallis

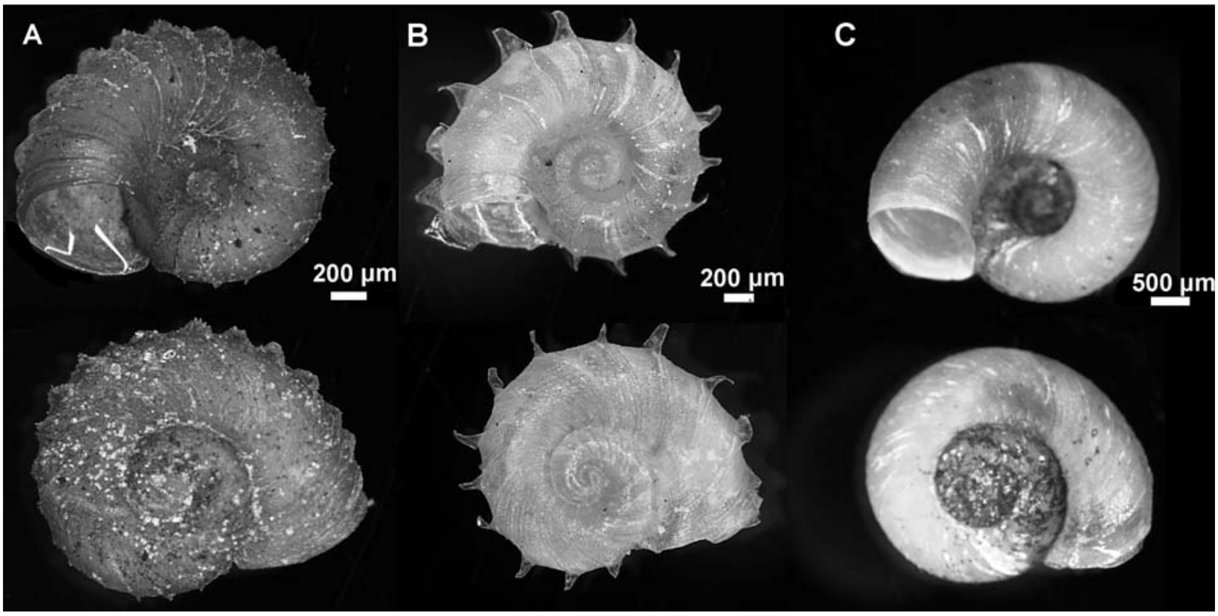

Fig. 1. Conchological form of *Gyraulus crista*, view of the upper and underside parts of the shell. A – *Gyraulus crista cristatus*, B – *Gyraulus crista spinulosus*, C – *Gyraulus crista nautileus.*

one-way analysis of variance ANOVA test (Statistica ver. 9.0). When significant differences were indicated, tests of multiple comparisons (post hoc) were used in order to locate statistically important differences. Only statistically significant relationships ($P < 0.05$) and differences were taken into account.

Results

Conchological form of Gyraulus crista
A total of 5,990 live *G. crista* with three morphological types of shell forms were collected. These were present in the samples from May to November.

Gyraulus crista f. cristatus (61.7% of total collection): The shell was thicker in comparison to *G. c. spinulosus* with numerous and variously formed ridges projecting above the shell surface. In this research, we observed different ribs, from delicate but always clearly visible ones to ribs that were quite well and clearly shaped (Fig. 1A).

Gyraulus crista f. spinulosus (26.1% of total collection): The specimens collected had a thin-walled and much more delicate shell in comparison to *G. c. cristatus.* The upper part of the shell was very flat with an edge that was not very sharpened. Strongly convex whorls were observed on the underside of the shell. The spines of adult specimens were formed differently, and were always visible and sometimes very large (Fig. 1B). We observed that young individuals had small spines but that they were always present and visible. The apex of shell and the second to the last whorl were slightly raised. For most individuals located in a straight line with aperture lowered in relation to the spire. Whorls were very rounded and their edges were sharper in comparison to specimens with other forms. Some specimens had an edge with a sharp or very sharp peripheral keel. The underside of the shell was very recessed.

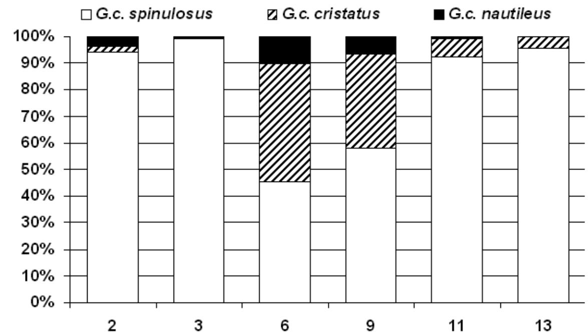

Fig. 2. The percentage of *G. c. spinulosus*, *G. c cristatus* and *G. c. nautileus* in leaf deposits. 2, 3, 6, 9, 11 and 13 – number of study sites (2 – pond 1; 3 – pond 2; 6 – ponds 3 and 9 – pond 4; 11 – pond 5; 13 – pond 6).

Gyraulus crista f. nautileus (12.2% of total collection): The shell was smooth with no visible ribs or spines (Fig. 1C). The aperture was large and whorls were located in a straight line. In our study, we observed that the apex of some shells did not extend to more than one plane. In other specimens, it was slightly raised (together with the final whorls). The specimens collected had a blunt edge on final whorls.

Occurrence and conchological shell variability of G. crista in relation to the substratum
In the ponds and at the distinguished study sites, all three forms of the *G. crista* shell were found, and they were specific to a particular type of substrate (Figs 2, 3). Redundancy Analysis (RDA) based on species data and environmental variables showed that the first and second axes explain almost 48% of the variance in the occurrence of conchological *G. crista* forms, and almost 98% of the variance of *G. crista* and environmental relationships (Table 2, Fig. 4).

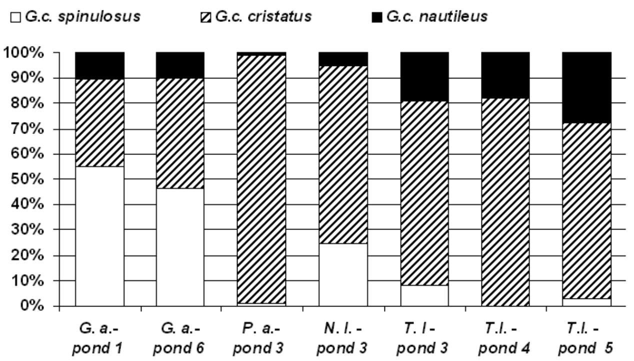

Fig. 3. The percentage of *G. c. spinulosus*, *G. c cristatus*, and *G. c. nautileus* on other types of study sites: *G. a.* – *Glyceria aquatica*, *P.a.* – *Phragmites australis*, *N. l.* – *Nuphar lutea*, T. l. – *Typha latifolia*

Gyraulus c. cristatus comprised the largest percentage at all three sites with *Typha* remains (from 69.5% of the total collection – pond 5 to 82.8% – pond 4) (Table 3, Fig. 3). Redundancy analysis (RDA) showed a significant relationship between *G. c. cristatus* and *Typha* debris (Fig. 4). The number of *G. c. cristatus* specimens collected on this type of substratum was significantly higher in comparison to other substrates [ANOVA: H = (4, N = 76) = 20.113, P = 0.00104].

Despite the presence of large numbers of *G. c. cristatus* on *Nuphar lutea* leaves and on *Ph. australis* debris, Redundancy Analysis showed no statistically significant associations with these substrates. *Gyraulus c. cristatus* occurred in small numbers on leaf deposits with the exception of site 6 (pond 3). Its percentage on this type of substrate ranged from 0 (pond 2) to 45% (pond 3) (Fig. 2).

Gyraulus c. spinulosus were most numerous on deposits of leaves (from 44.5% of the total collection – pond 3 to 99.3% – pond 2) (Table 3, Fig. 2). It also appeared numerously on *G. aquatica* remains (55% of the

Table 2. Summary of Redundancy Analysis (RDA) performed on the *G. crista* forms and environmental data.

Axes	1	2	3	4	Total variance
Eigenvalues	0.322	0.134	0.009	0.380	1.000
Species-environment correlations	0.688	0.729	0.383	0.000	
Cumulative percentage variance					
of species data	32.6	47.8	46.7	84.7	
of species-environment relation	69.8	98.4	100.0	0.0	
Sum of all Eigenvalues					1.000
Sum of all canonical Eigenvalues					0.466
Summary of Monte Carlo test					
Test of significance of first canonical axis: Eigenvalues = 0.398					
F-ratio = 59.551					
P-value = 0.0020					
Test of significance of all canonical axes: Trace = 0.476					
F-ratio = 12.103					
P-value = 0.0020					

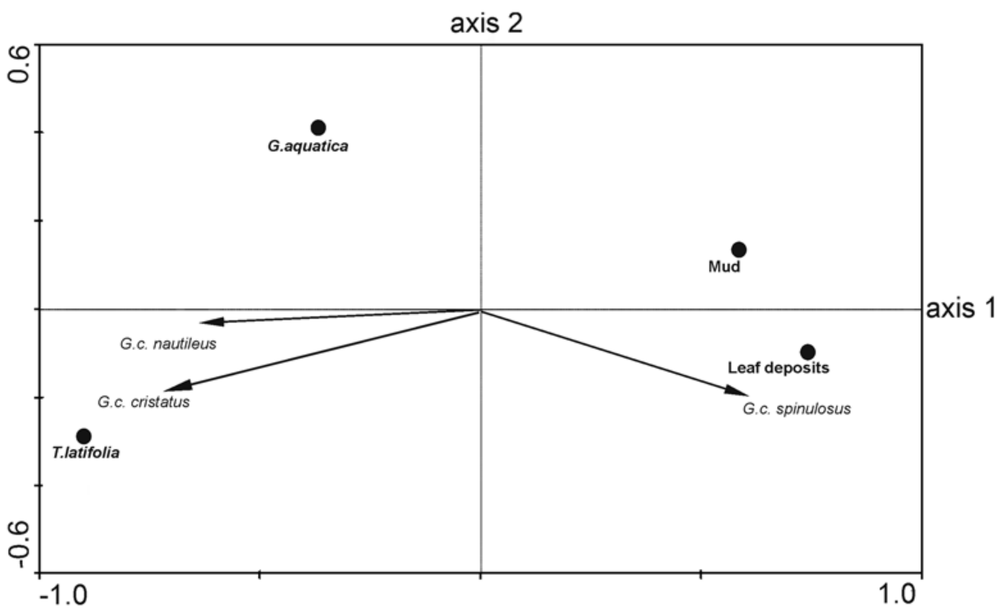

Fig. 4. Redundancy Analysis (RDA) ordination diagram based on the freshwater snail *G. crista* and environmental variables. The arrows represent the three conchological forms of *G. crista*.

total collection in pond 1 and 46.3% in pond 6) and on *T. latifolia* remains in pond 3, but with a small percentage (8%). We did not find its presence on *T. latifolia* in pond 4, and only a small number occurred on *Ph. australis* (Table 3, Fig. 3). The RDA showed a strong significant association of *G. c. spinulosus* with leaf deposits, while it was smaller for muddy bottom (Fig. 4). One way ANOVA showed significant differences in the mean number of specimens collected on leaf deposits in comparison with other types of substrates [ANOVA: H (4, $N = 76$) = 17.989, $P = 0.0012$].

Gyraulus c. nautileus only occurred in small numbers in the collection, but our research indicated sites where its occurrence is more numerous, e.g., *Typha* debris (27.7% of collection – pond 5 and 19.2% – pond 3), *G. aquatica* debris (10% in pond 1) (Table 3, Fig. 3). We found only single specimens in leaf deposits except for site 6 (pond 3) (Table 3, Fig. 2). *Gyraulus c. nautileus* was strongly associated with the remains of *Typha* as was indicated by the statistically significant results in Redundancy Analysis (RDA). It also showed lower association of *G. c. nautileus* with *G. aquatica* debris (Fig. 4). Its abundance on the remains of *Typha* is statistically higher than on the other types of substrates [ANOVA: H (4, $N = 76$) = 10.377, $P = 0.00171$].

Occurrence of different forms of G. crista in relation to water chemistry

The results of our study showed that *G. crista* occurs in a relatively wide range of pH (from 5.6 in pond 5 to 9 in pond 4) (Table 4). Water conductivity is low except for ponds 4 and 5 which, because of their location in a mining area, is periodically supplied with mining waters, which results in a higher content of chlorides in the water. The water is soft (pond 2) or very soft (ponds 1 and 3) with a relatively low calcium content in the ponds studied. The exceptions are ponds 4 and 5, where the water is characterized by very high values of hardness and a higher content of calcium. Redundancy analysis (RDA) showed no statistically significant relationship between the occurrence of particular *G. crista* forms and various physico-chemical parameters of water.

Discussion

Planorbidae tend to occur in bodies of water with a mud bottom and with high levels of decaying organic matter (Perez 2004). Studies of their prevalence are largely restricted to describing new sites of its occurrence in specified regions (Beran & Glöer 2006; Glöer & Pesic 2007; Glöer & Nasser 2007; Glöer & Rähle 2009) and its contribution to the biology and ecology of threatened species like, e.g., *Anisus vorticulus* (Troschel, 1834) (Terrier et al. 2006; Glöer & Groh 2007) and other species (Olsson 1988; Watson & Ormerod 2004) as well as to planorbid taxonomy (Jørgensen et al. 2004; Glöer & Bouzid 2008; Glöer & Meier-Brook 2008). Because of the small size of *G. crista* and its scarce distribution, little information is available concerning its life

Table 3. Occurrence of *G. crista spinulosus*, *G. crista cristatus* and *G. crista nautileus* on different types of substratum.

Gyraulus crista	Pond 1		Pond 2	Pond 3				Pond 4		Pond 5		Pond 6	
	G. aquatica remains	Leaf deposit	Leaf deposit	*Ph. australis* remains	*N. lutea*	Leaf deposit	*T. latifolia* remains	*T. latifolia* remains	Leaf deposit	*T. latifolia* remains	Leaf deposit	*G. aquatica* remains	Leaf deposit
f. spinulosus	203	129	279	5	167	318	218	0	18	3	160	19	47
f. cristatus	128	3	0	608	481	313	1195	51	11	70	12	18	2
f. nautileus	38	5	2	7	34	74	526	11	2	28	1	4	0
Σ	369	137	281	620	682	705	2739	62	31	101	173	41	49

Table 4. Physical and chemical characteristics of the water in the woodland ponds studied.

Number of pond	Number of site	Temp. °C	pH	NH_4 mg L^{-1}	NO_2 mg L^{-1}	NO_3 mg L^{-1}	PO_4 mg L^{-1}	Ca mg L^{-1}	Hardness dH°	Cl mg L^{-1}	Alkalinity mg $CaCO_3$ L^{-1}	Conductivity µS cm^{-1}
I	1	6.4–21.0	6.5–7.5	0.05–0.55	0–0.02	4.8–15.0	0.01–0.2	23–32	5.3–7	18–28	30–95	180–450
	2	6.7–21.0	6.6–7.4	0.06–1.97	0–0.02	0,9–20.8	0.02–0.16	19–34	4.2–6.8	10–18	30–100	150–240
II	3	13.3–22.1	6.6–7.2	0.03–0.49	0.02–0.33	0.1–16.8	0.03–0.35	29–33	4.3–7	9–17	55–80	160–200
III	4	6.1–21.3	6.2–7.4	0.03–0.64	0.01–0.05	0.5–21.7	0.01–0.52	15–23	2.01–3.9	8–16	31–70	70–90
	5	7.2–23.4	6.1–7.2	0.05–0.89	0.003–0.44	1.9–27.5	0.02–26.0	13–22	2.4–3.9	5–15	28–60	70–90
	6	7.0–22.9	6.1–7.1	0.07–0.4	0.01–0.07	1.4–50.0	0.01–0.16	15–22	2.1–4.8	6–12	24–55	60–84
	7	6.6–23.3	6.2–7.1	0.1–0.47	0.03–0.1	1.4–12	0.02–0.29	14–22	2.3–5.8	4–18	17–50	70–112
IV	8	7–28	6.5–9	0.05–1.0	0–0.02	0–10.0	0.23–0.52	38–190	12–44.2	169–210	28–60	2092–2260
	9	6–28	6.5–9	0.05–3.0	0–0.02	0–10.2	0.20–0.50	37–187	11–43.9	189–210	35–60	2010–2370
V	10	4–30	6.0–7.0	0.05–0.42	0.02–0.16	0–10	0–0.26	19–79	19–25.9	110–160	50–90	720–2140
	11	4–28	5.6–6.5	0.04–0.51	0.02–0.04	0–10	0–0.34	10–54	19–24	74–143	42–91	800–1900
VI	12	4.4–28	6.0–7.0	0.05–1.0	0.02–0.1	0–23.9	0.1–0.41	32–81	7–17.8	34–78	40–90	380–890
	13	4.5–29	6.0–7.0	0.08–1.2	0.02–0.04	0–16	0.1–0.51	38–75	7–16.9	30–93	40–80	340–800

cycle (Richardot-Coulet & Alfaro-Tejera 1983) or its biology, ecology and conchological variability. In this paper, the main aim was to test whether environmental conditions affect the formation of three different morphologic forms.

Littoral zones of small woodland water bodies are spatially heterogeneous habitats (Heino 2000). These types of water bodies usually offer a mosaic structure that is mainly determined by allochthonous plant material and macrophytes (Oertli 1995). Leaves and fragments serve as microhabitats for pond inhabitants in small forest ponds (e.g., as a physical substrate for microorganisms, and as shelter and attachment sites for invertebrates) (Tank & Winterbourn 1995; Williams 2005; Ikely et al. 2008). Leaves may consist of much unchanged leaf material, some partly broken down leaf material, microbial secretions (e.g., enzymes) and excretions as well as microbial cells (Bärlocher & Kendrick 1975). For this reason, woodland ponds create specific habitats for the occurrence of invertebrates including freshwater snails. This was also confirmed in previous studies (Spyra 2010, 2011). In this research, we found *G. crista* in only six ponds. Most specimens were collected in reservoir 3 (4,746 individuals). According to Prescott & Curteanu (2004), it is most often observed to be "uncommon" (2–10 individuals), but occasionally reaches a high abundance (maximum of 778 individuals at a site). Čejka (2011) stated its scarce occurrence in small water bodies, whereas Oertli (1995) found most individuals of *G. crista* in woodland ponds on *Chara* sp. (787 specimens), less in leaf detritus (157 specimens) and the least on *Typha latifolia* (36 specimens).

Previous studies that were carried out in woodland ponds (Spyra 2010) demonstrated that exposition to sunlight had no impact on the occurrenceof *G. crista*, and that individuals of this species were much more numerous in the autochthonous plant matter (*Typha* debris) as compared to allochthonous. *Phragmites* litter is nutritionally poor and an unfavorable food source for invertebrate detritivores (Kulesza et al. 2008). This is probably the reason for the more numerous colonization of soft vegetation by snails, *G. crista* among them. In this research *G. crista* occurred in different numbers depending on the months. The most specimens were collected in June, and the fewest in November.

Species of the genus *Gyraulus* prefer water with a higher content of dissolved solids (Sharpe 2002). Briers (2003) classified *G. crista* as a non-calciphile species. Prescott & Curteanu (2004) found living specimens over a pH range of 7.7 to 9.5, and conductivities ranging from 0.45 to 3.01 µS cm^{-1}. This was also confirmed in a previous study by Økland (1990). Williams & Gormally (2009) observed a statistically positive correlation of *G. crista* to pH and a negative relationship with dissolved oxygen. According to Carlsson (2001), *G. crista* prefers soft waters. This was confirmed in our study. We found that *G. crista* occurs more numerously in soft waters with low calcium content and in a wide range of pH.

Gyraulus species can be distinguished by the morphology of their shells as well as by their prostate gland, a very important feature that is used to separate *Gyraulus* species from each other (Odhner 1956; Meier-Brook 1983). *Gyraulus crista* exhibits a high level of polymorphism for shell shape. The shell spines may be lacking or more or less developed. According to Piechocki (1979) and Økland (1990), the species includes 3 different forms: a smooth shell, scarcely carinated or not carinated at all (*G. crista nautileus*), a weakly ribbed shell (*G. crista cristatus*) and a shell with well-developed spines (*G. crista spinulosus*). Due to the lack of prior information about the three conchological forms of *G. crista* and their connection with ecological and environmental factors, as well as with different types of inhabited sites, it is difficult to compare our results with other studies. The results of our study suggest that water chemistry and the permanency of ponds have no influence on the occurrence of *G. c. spinulosus*, *G. c. nautileus* and *G. c cristatus*.

Three types of the shell shapes were found by Richardot-Coulet & Alfaro-Tejera (1983), although smooth or weakly ribbed shells were more numerous. The authors inferred that the juvenile shells are always smooth from their results. The highest percentage of strongly ribbed shells occurred in winter when the population was made up of a large number of overwintering adults. According to Clarke (1973), the development of costae may be correlated with age. However, it is not possible to confirm that from our findings alone. In the material collected, we found the presence of both young and adult specimens of each form. All three conchological forms of this species occurred in both the samples collected during the summer and in autumn. It seems improbable that the creation of ribs and spines on the shell is dependent on the season or the age of the individuals. The hypothesis that one form is transformed into other depending on environmental conditions should be excluded because in our study we found the occurrence of both small and large individuals belonging to each of the forms in different months of research independent of any changing physico-chemical properties of water. Our research, which is supported by Redundancy analysis (RDA), showed a strong significant association of *G. c. spinulosus* with leaf deposits, and *G. c. cristatus* with *T. latifolia* remains. *Gyraulus c. nautileus* was associated mainly with *T. latifolia* and also with *G. aquatica* remains. According to Økland (1990), the different shell forms cannot be related to geographical factors.

We found the presence of representatives of all *G. crista* forms in all of the ponds. We can conclude from the literature that the same population often contains two or sometimes all three forms. Ciobou (www.oen-iad.org/conference/docs/6-invertebrates/ciobou.pdf) observed the prevalence of all three forms of *G. crista* in both rivers and lakes, whereas in Romania only *G. c. nautileus* were identified in a low number of rivers. In Norway, Økland (1990) found all three forms of this species. The most numerous was *G. c. cristatus* (50% of specimens), then *G. c. nautileus* (about 30%) of specimens and *G. c. spinulosus* (about 20%). In this study, we found that *G. c. cristatus* was the most numerous (about 61 % of specimens), less numerous – *G. c. spinulosus* (26.1%) and the least numerous *G. c. spinulosus* (12.2%). In research on phytophilous fauna in dam reservoir, Kuflikowski (1974) noted only the presence of *G. c. spinulosus* and *G. c. nautileus*, but he recorded more numerous occurrences of *G. c. nautileus* on *G. aquatica*.

Piechocki (1979) and Økland (1990) stated that the three distinct forms may occur together or that a population may exhibit all of the intermediate shells. In the material collected, we rarely found the occurrence of specimens with an anomaly of last whorls that did not adjoin to the shell. According to Piechocki (1979), this is possible in specimens of that species. We did not observe any specimens with different parts of the shell belonging to different forms in our study, but that such an anomaly is also possible was confirmed by Økland (1990).

The mechanisms of the formation of various conchological forms in freshwater snails remain unknown. Our studies contribute important data about their habitat preferences. Despite the fact that we found no influence of different physico-chemical water parameters on its formation, in summary, we have demonstrated that our research showed a relationship between different types of substrate and the morphological forms of the *G. crista* shell.

Acknowledgements

The authors are very grateful to the two anonymous reviewers for their constructive comments and suggestions and to Ms. Michele L. Simmons, BA, University Centre for English Teaching, English Language Centre (ELC) for improving the English style of manuscript.

References

Bärloeher F. & Kendrick B. 1975. Leaf-conditioning by microorganisms. Oecologia (Berl.) **20 (4):** 359–362. DOI: 10.1007/BF00345526

Beran L. 2002. Vodni měkkýši České republiky – rozšíření a jeho změny, stanoviště, šíření, ohrožení a ochrana, červený seznam [Aquatic molluscs of the Czech Republic – distribution and its changes, habitats, dispersal, threat and protection, Red List]. Sborník přírodovědného klubu Uh. Hradišti, Suppl. 10, 258 pp.

Beran L. & Gloer P. 2006. *Gyraulus chinensis* (Dunker, 1848) – a new greenhouse species for the Czech Republic (Gastropoda: Planorbidae). Malacol. Bohemoslov. **5:** 25–28.

Brauns M., Garcia F.X. & Pusch M.T. 2008. Potential effects of water-level fluctuations on littoral invertebrates in lowland lakes. Hydrobiologia **613 (1):** 5–12. DOI: 10.1007/s10750-008-9467-0

Briers R.A. 2003. Range size and environmental calcium requirements of British freshwater gastropods. Global Ecol. Biogeogr. **12 (1):** 47–51. DOI: 10.1046/j.1466-822X.2003.00316.x

Carlsson R. 2001. Freshwater snail communities and lake classification. An example from the Aland Islands, Southwestern Finland. Limnologica **31 (2):** 129–138. DOI: 10.1016/S0075-9511(01)80007-4,

Cioboiu O. www.oen-iad.org/conference/docs/6-invertebrates/ciobou.pdf (accessed 01.02.2012)

Clarke A.H. 1973. The freshwater molluscs of the Canadian interior basin. Malacologia 13, 509 pp. PMID: 4792034

Čejka T. 2011. Diversity patterns and freshwater molluscs similarities in small water reservoirs. Malacol. Bohemoslov. **10:** 5–9.

Glöer P. 2002. Süßwassergastropoden Nord- und Mitteleuropas. Die Tierwelt Deutschlands, 73, ConchBooks, Hackenheim, 327 pp. ISBN: 3925919600

Glöer P. & Bouzid S. 2008. Redescription of *Planorbis agraulus* Bourguignat, 1864 (Gastropoda: Planorbidae). J. Conchol. **39 (5):** 487–491.

Glöer P. & Groh K. 2007. A contribution to the biology and ecology of the threatened species *Anisus vorticulus* (Troschel, 1834) (Gastropoda: Pulmonata: Planorbidae). Mollusca **25 (1):** 33–40.

Glöer P. & Meier-Brook C. 1998. Süsswassermollusken. 12 Erw. Auf. DJN., Hamburg, 136 pp. ISBN: 3-923376-02-2

Glöer P. & Meier-Brook C. 2008. Redescription of *Anisus septemgyratus* (Rossmässler, 1835) and *Anisus leucostoma* (Millet, 1813) (Gastropoda: Planorbidae). Mollusca **26 (1):** 89–94.

Glöer P. & Naser M.D. 2007. *Gyraulus Huwaizahensis* n. sp. – a new species from Mesopotamia, Iraq (Mollusca: Gastropoda: Planorbidae). Mollusca **25 (2):** 147–152.

Glöer P. & Pešić V. 2007. *Gyraulus meierbrooki, G. ioanis,* and *G, shasi* – three new *Gyraulus* spp. from the Skadar Lake Basin, Montenegro (Gastropoda, Planorbidae). Mollusca **25 (2):** 131–137.

Glöer P. & Rähle W. 2009. *Gyraulus pamphylicus* n. sp. – a new species from Turkey (Mollusca: Gastropoda: Planorbidae). Mollusca **27 (1):** 57–60.

Heino J. 2000. Lentic macroinvertebrate assemblage structure along gradients in spatial heterogeneity, habitat size and water chemistry. Hydrobiologia **418:** 229–242. DOI: 10.1023/A:1003969217686

Hubendick B. 1947. Die Verbreitungswerhältnisse der limnishen Gastropoden in Südschwaden. Zool. Bird. Uppsala. **24:** 419–556.

Inkley M.D., Wissinger S.A. & Baros B.L. 2008. Effects of drying regime on microbial colonization and shredder preference in seasonal woodland wetlands. Freshwater Biol. **53 (3):** 435–445. DOI: 10.1111/j.1365-2427.2007.01908.x

Jatulewicz I. 2007. Comparison of macroinvertebrate communities associated with various habitats in anthropogenic reservoirs. Oceanol. Hydrobiol. Stud. **36** (Suppl. 4): 39–47.

Jørgensen A., Kristensen T.K. & Stothard J.R. 2004. An investigation of the "Ancyloplanorbidae" (Gastropoda, Pulmonata, Hygrophila): preliminary evidence from DNA sequence data. Mol. Phylogenet. Evol. **32 (3):** 778–787. DOI: 10.1016/j.ympev.2004.02.011

Kerney M. 1999. Atlas of the Land and Freshwater Molluscs of Britain and Ireland. Harley Brooks, Martins, Great Harhesley, 264 pp. ISBN: 0946589488

Kulesza A.E., Holomuzki J.R. & Klarer D.M. 2008. Benthic community structure in stands of *Typha angustifolia* and herbicide–treated and untreated *Phragmites australis*. Wetlands **28 (1):** 40–56. DOI: 10.1672/07-63.1

Kuflikowski T. 1974. Fauna fitofilna zbiornika zaporowego w Goczałkowicach [The phytophilous fauna of the dam reservoir at Goczałkowice.] Acta Hydrobiol. **16 (2):** 189–207.

Meier-Brook C. 1983. Taxonomic studies on *Gyraulus* (Gastropoda: Planorbidae). Malacologia **24 (1–2):** 1–113.

Niggebrugge K., Durance I., Watson A.M., Leuven R.S.E.W. & Ormerod S.J. 2007. Applying landscape ecology to conservation biology: Spatially explicit analysis reveals dispersal limits on threatened wetland gastropods. Biol. Conserv. **139 (3-4):** 286–296. DOI: 10.1016/j.biocon.2007.07.003

Odhner N. 1956. Distinctions between *Anisus (armiger) crista* (l.) and *Anisus (gyraulus) riparius* (West.). J. Moll. Stud. **32 (3):** 127–131.

Oertli B. 1995. Spatial and temporal distribution of the zoobenthos community in a woodland pond (Switzerland). Hydrobiologia **300/301:** 195–204. DOI: 10.1007/BF00024461

Økland J. 1990. Lakes and Snails: Environment & Gastropoda in 1,500 Norwegian Lakes, Ponds and Rivers. Backhuys, The Netherlands, 516 pp. ISBN: 9073348021

Olsson T.I. 1988. The effect of wintering sites on the survival and reproduction of *Gyraulus acromcus* (Gastropoda) in a partly frozen river. Oecologia (Berl.) **74 (4):** 492–495. DOI: 10.1007/BF00380044

Perez K.E. 2004. Planorbidae, pp. 40–43. In: Perez K.E., Clark S. A. & Lydeard C. (eds), Freshwater Gastropod, Identification Workshop "Showing your Shells" A Primer to Freshwater Gastropod Identification, 15–18 March 2004, Freshwater Mollusk Conservation Society, University of Alabama, Tuscaloosa, Alabama.

Piechocki A. 1979. Mięczaki (Mollusca), Ślimaki (Gastropoda). Fauna słodkowodna Polski, 7, PWN, Warszawa-Poznań, 187 pp.

Prescott D.R.C. & Curteanu M.M. 2004. Survey of Aquatic Gastropods in the Central Parkland Subregion of Alberta. Alberta Species at Risk Report No. 92, Edmonton, Alberta, Canada, 63 pp. ISBN: 0-7785-3618-1

Richardot-Coulet M. & Alfaro– Tejera L. 1983. The life cycle and ecology of the freshwater planorbidae *Armiger crista* (L.) J. Moll. Stud. **51(1):** 35–51.

Serafiński W., Michalik-Kucharz A. & Strzelec M. 2001. Czerwona Lista Mięczaków słodkowodnych (Gastropoda i Bivalvia) Górnego Śląska [Red List of Upper Silesian freshwater Molluscs (Gastropoda and Bivalvia], pp. 37–49. In: Raporty, Opinie Tom. 5, Centrum Dziedzictwa Przyrody Górnego Śląska, Katowice.

Sharpe S.E. 2002. Solute Composition: a parameter affecting the distribution of freshwater gastropods. In: Conference Proceedings, Spring-fed Wetlands: Important Scientific and Cultural Resources of the Intermountain Region, 2002. http://www.wetlands.dri.edu (accessed 01.02.2012)

Spyra A. 2010. Environmental factors influencing the occurrence of freshwater snails in woodland water bodies. Biologia **65 (4):** 697–703. DOI: 10.2478/s11756-010-0063-1

Spyra A. 2011. Autochthonic and allochthonic plant detritus as zoobenthos habitat in anthropogenic woodland ponds. Oceanol. Hydrobiol. Stud. **40 (1):** 27–35. DOI: 10.2478/s13545-0110004-9

Tank J.R. & Winterbourn M.J. 1995. Biofilm development and invertebrate colonization of wood in four New Zealand streams of contrasting pH. Freshwater Biol. **34 (2)**: 303–315. DOI: 10.1111/j.1365-2427.1995.tb00890.x

Ter Braak C.J.F. & Šmilauer P. 2002. CANOCO Reference manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5), Microcomputer Power Ithaca, NY, USA, 499 pp.

Terrier A., Castella E., Falkner G. & Killeen I.J. 2006. Species account for *Anisus vorticulus* (Troschel, 1834) (Gastropoda: Planorbidae), a species listed in Annex II and IV of the Habitats Directive. J. Conchol. **39** (Part 2): 193–205.

Watson A.M. & Ormerod S.J. 2004. The distribution of three uncommon freshwater gastropods in the drainage ditches of British grazing marshes. Biol. Conserv. **118(4):** 455–466. DOI: 10.1016/j.biocon.2003.09.021

Williams C.D. & Gormally M.J. 2009. Spatio-temporal and environmental gradient effects on Mollusc communities in a unique wetland habitat (Turloughs). Wetlands **29 (3):** 854–865. DOI: 10.1672/08-185.1

Williams D.D. 2005. Temporary forest pools: can we see the water for the trees? Wettlands Ecol. Manage. **13 (3):** 213–233. DOI: 10.1007/s11273-004-7517-6

Received February 2, 2012
Accepted April 10, 2013