FOLIA MALACOLOGICA
Vol. 20(4): 279–287
ISSN 1506-7629
The Association of Polish Malacologists
& Faculty of Biology, Adam Mickiewicz University
Poznań 2012
doi: 10.2478/v10125-012-0023-1

CONTRIBUTION TO THE BIOLOGY OF *HIPPEUTIS COMPLANATUS* (LINNAEUS, 1758) (GASTROPODA: PLANORBIDAE): LIFE CYCLE IN SILESIAN WOODLAND PONDS (SOUTHERN POLAND)

ANETA SPYRA

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: In spite of the common occurrence of *Hippeutis complanatus* (L.) in some regions of Poland, it is considered to be a rare species with scattered sites. A study on its life cycle and shell growth in various conditions was possible due to the existence of very abundant populations in several woodland ponds of Silesia. The snails breed twice in a lifetime, and two generations reproduce in one year. The main breeding period is July/August. Some individuals breed also in the spring of the next year. The first appearance of the smallest individuals is clearly related to the water temperature.

KEY WORDS: *Hippeutis complanatus*, reproductive biology, life history, freshwater snails, Planorbidae

INTRODUCTION

Hippeutis complanatus (Linnaeus, 1758) is a Palaearctic species, mostly inhabiting small, well-vegetated water bodies with a muddy bottom (PIECHOCKI 1979, ØKLAND 1990, KERNEY 1999). It lives in lakes of different size and trophic level, including dystrophic environments (AHO 1966) as well as bogs (BÁBA 1991). It is found in water bodies surrounded by fields and deciduous forests (ØKLAND 1990). An extensive survey in Hamburg showed that the species preferred well-vegetated ditches (45% of 399 sampling sites) (GLÖER & DIERCKING 2009). Its shell is lenticular, very flat, finely ribbed and shows a small shape variation (PIECHOCKI 1979).

Some authors (MERKEL 1894, ZEISSLER 1987, STRZELEC 1993) regard *H. complanatus* as a rare species which occurs in scattered sites, mainly because of the degradation of the freshwater environments as a result of drainage of wetlands and riverside meadows, eutrophication and pollution. In the Polish Red List it is regarded as a species with an established but unspecified risk, deserving the endangered status due to the decline of wetland environments (PIECHOCKI 2002). In Poland it usually occurs in small numbers but for example in Germany (Hamburg) it could be found in 29% of 14,000 sampling sites (GLÖER & DIERCKING 2009) and is not regarded as endangered. Previous studies (SPYRA 2010) showed that in Polish woodland ponds the species may form abundant populations (up to 11,136 of collected specimens).

Most planorbids have a one-year life cycle and reproduce only once. Their reproduction starts in spring and juveniles hatch in early summer (PIECHOCKI 1979). The parental generation dies having laid eggs in July and August (e.g. *Anisus leucostoma* (Millet, 1813), *A. vortex* (Linnaeus, 1758), *Bathyomphalus contortus* (Linnaeus, 1758), *Gyraulus crista* (Linnaeus, 1758) and *G. albus* (O. F. Müller 1774)). There are no literature data on the biology of *H. complanatus* (L.), including its life cycle, reproduction, breeding season or size structure. Some information can be found in NEKRASSOW (1928) and BONDENSEN (1950). The aim of this study was to ascertain the course of its life cycle, the breeding period and the size structure dynamics during the year. The existence of very dense populations in several anthropogenic woodland ponds in Silesia made such investigations possible.

MATERIAL AND METHODS

STUDY SITES

The investigations were carried out from June 2009 to May 2010 in five woodland ponds in a forested area of Upper Silesia (Silesian Upland, Southern Poland) (Fig. 1). The ponds are stocked with *Carassius auratus* (L.), *C. auratus gibelio* (Bloch), *Cyprinus carpio* (L.), *Tinca tinca* (L.), *Anguilla anguilla* (L.), *Esox lucius* (L.) and *Perca fluviatilis* (L.); ponds 3 and 4 are emptied during fish catches (Figs 2–5). Allochthonous leaf deposits form in the riparian zone of the ponds (Fig. 2).

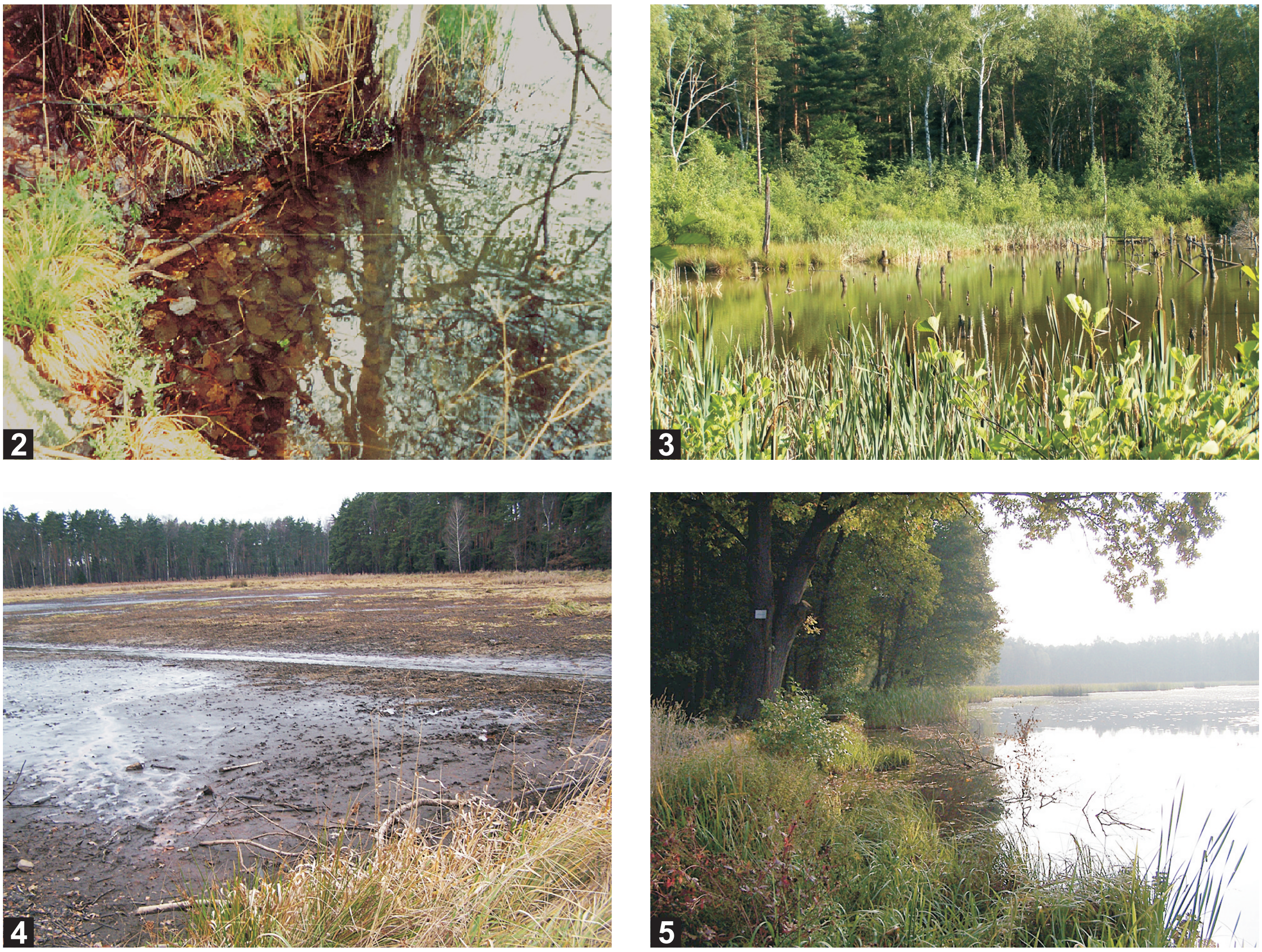
The ponds are 11.4 to 67 ha (Table 1) in area, and the water level varies between months, especially in summer. The ponds are shallow, with maximum depth of 3.5 m. Being subsidence ponds resulting from coal mining, they are supplied with water from different sources: surface run-off, woodland ditches (ponds 3 and 4) and rain waters, contrary to typical

Table 1. Characteristics of the investigated woodland ponds

	Pond				
	1	2	3	4	5
Kind of pond	subsidence pond	subsidence pond	fish pond	fish pond	storage reservoir
Surface area in ha	22.3	6.7	23	6.17	11.4
Maximal depth in m	3	3	1.8	1.9	3.5
Bottom sediment	sand-mud	sand-mud	mud	mud	sand-mud
Persistence	permanent	permanent	artificially drained*	artificially drained*	permanent
Calcium content (mg/L)	20–31	14–34	19–30	29–33	13–22
Total hardness (dH)	7–7.2	3–7.3	4.2–7	4.3–7	2.1–5.8
Temperature (°C)	4–30	4–26	6.4–21	6.3–21.2	6.1–23.4

* water level regulated artificially every few years

Fig. 1. Location of the study area



Figs 2–5. Woodland ponds in the study area: 2 – leaf deposits in pond 1, 3 – site of *Hippeutis complanatus* in pond 3; 4 – woodland pond 4, artificially drained in November 2009; 5 – sampling site in pond 5

fish ponds. In winter they freeze over partially or completely to the bottom.

SAMPLING AND DATA COLLECTION

In each pond monthly samples of freshwater snails were taken using a frame (50×50 cm – sample area 0.25 m^2). The material was collected from leaf debris and remains of water plants. The material was transported to the laboratory where the samples were sieved through a 0.23 mm mesh sieve, which ensured that newly hatched *H. complanatus* were retained. The snails were sorted under a stereomicroscope, and the specimens of *H. complanatus* were separated from other snails. The snails were preserved in 75% ethanol and identified using GLÖER (2002). The density of individuals per 1 m^2 was estimated.

Immediately prior to the sampling, water samples were taken in each site. Some physical and chemical parameters of the water, affecting the occurrence of the snails (e.g. temperature, total hardness, calcium content), were analysed with standard methods, according to HERMANOWICZ et al. (1999). The water temperature was measured in the field using Hanna Instruments portable meters.

Cocoons were collected from leaf deposits and remains of water plants during sample sorting. They were visible on the underside of the leaves and plant remains. In addition, specimens of *H. complanatus* were collected, which were then used in the laboratory breeding experiments. The cocoons laid on the aquarium walls and on the submerged leaves were compared with those found in the field samples; this confirmed the identity of the field-collected eggs.

BIOMETRICAL DATA AND STATISTICAL ANALYSIS

The shell height and width were measured and the whorls were counted. In total 4,013 individuals of *H. complanatus* were collected and measured, which allowed a detailed characterisation of the shell size variation in the studied ponds. Five size classes (shell diameter) were distinguished: class 1 – ≤1 mm, class 2 –

1.1–2 mm, class 3 – 2.1–3 mm, class 4 – 3.1–4 mm, and class 5 – ≥4.1 mm. Individuals larger than 5 mm were very rare.

The results were statistically analysed using Statistica for Windows (Version 9.0). Correlation between the water temperature and the abundance of the smallest specimens was determined using the Spearman Rank Correlation Coefficient r^2. Non-parametric Kruskal-Wallis one-way ANOVA and multiple comparisons tests (post-hoc) were used to determine the significance of the differences between the shell size among different months. Only the differences at $p<0.05$ were regarded as statistically significant.

RESULTS

POPULATION STRUCTURE

Though the samples were collected during 12 months, *H. complanatus* was present only in the samples from April to November. It co-occurred with five snail species in pond 2 and 12 species in pond 5 (Table 2). The density of *H. complanatus* was high, and varied among the ponds and months of research. The highest densities were observed in ponds 1 and 4 in September (1,124 ind./m^2 and 1,936 ind./m^2, respectively), and in pond 5 (2,324 ind./m^2) in October (Table 3).

The biggest shells of *H. complanatus* were 5.40 mm wide (Table 4) and had 4 whorls. The shells of newly hatched individuals were 0.33 mm wide and 0.11 mm high, and had 1.5 whorls. The shell surface was spi-

Table 2. Gastropod species co-occurring with *Hippeutis complanatus* in the investigated woodland ponds

	Pond				
	1	2	3	4	5
Lymnaea stagnalis	+			+	+
Stagnicola corvus					+
Radix balthica	+	+	+	+	+
Galba truncatula					+
Planorbarius corneus	+	+	+	+	+
Planorbis planorbis			+	+	+
Bathyomphalus contortus	+		+	+	+
Gyraulus albus	+	+	+	+	+
Gyraulus crista	+		+	+	+
Anisus spirorbis		+			
Anisus vortex				+	+
Segmentina nitida			+	+	+
Ferrissia wautieri	+	+	+	+	+
Physa fontinalis	+				

Table 3. Density of *Hippeutis complanatus* in the investigated woodland ponds (ind./m^2)

Months	Pond				
	1	2	3	4	5
April	8	4	24	440	48
May	16	12	120	72	1,068
June	124	224	72	80	680
July	548	92	52	24	948
August	380	64	152	228	1,860
September	1,124	32	276	1,936	1,644
October	332	44	136	300	2,324
November	212	24	36	208	124

Table 4. Variation in shell diameter (width in mm) of *Hippeutis complanatus* in woodland ponds during the study period

		Month							
		30 V	29 VI	30 VII	16 VIII	23 IX	22 X	19 XI	22 IV
Pond 1	min-max	2.71–4.22	0.80–3.71	0.56–3.25	0.44–2.61	0.72–2.99	0.92–2.64	0.66–2.35	3.19–3.41
	N	4	31	135	95	279	83	52	4
Pond 2	min-max	3.19–4.30	0.55–3.26	0.77–3.43	0.99–2.49	1.23–2.49	1.58–2.32	1.23–2.33	3.19–4.30
	N	3	51	23	16	8	11	6	6
Pond 3	min-max	1.51–4.80	0.77–4.31	1.43–2.20	0.70–3.08	0.76–2.64	1.59–3.41	1.98–2.47	3.00–3.40
	N	30	18	13	38	69	34	9	6
Pond 4	min-max	1.14–3.98	0.74–4.60	0.77–4.46	0.70–3.52	0.88–2.75	1.18–3.08	1.60–2.68	3.00–3.70
	N	18	20	6	57	484	75	52	110
Pond 5	min-max	0.55–5.40	0.63–5.06	0.37–4.86	0.33–4.26	0.88–3.05	0.77–3.38	1.16–2.20	3.01–3.75
	N	262	170	238	462	411	581	31	12

N – number of specimens

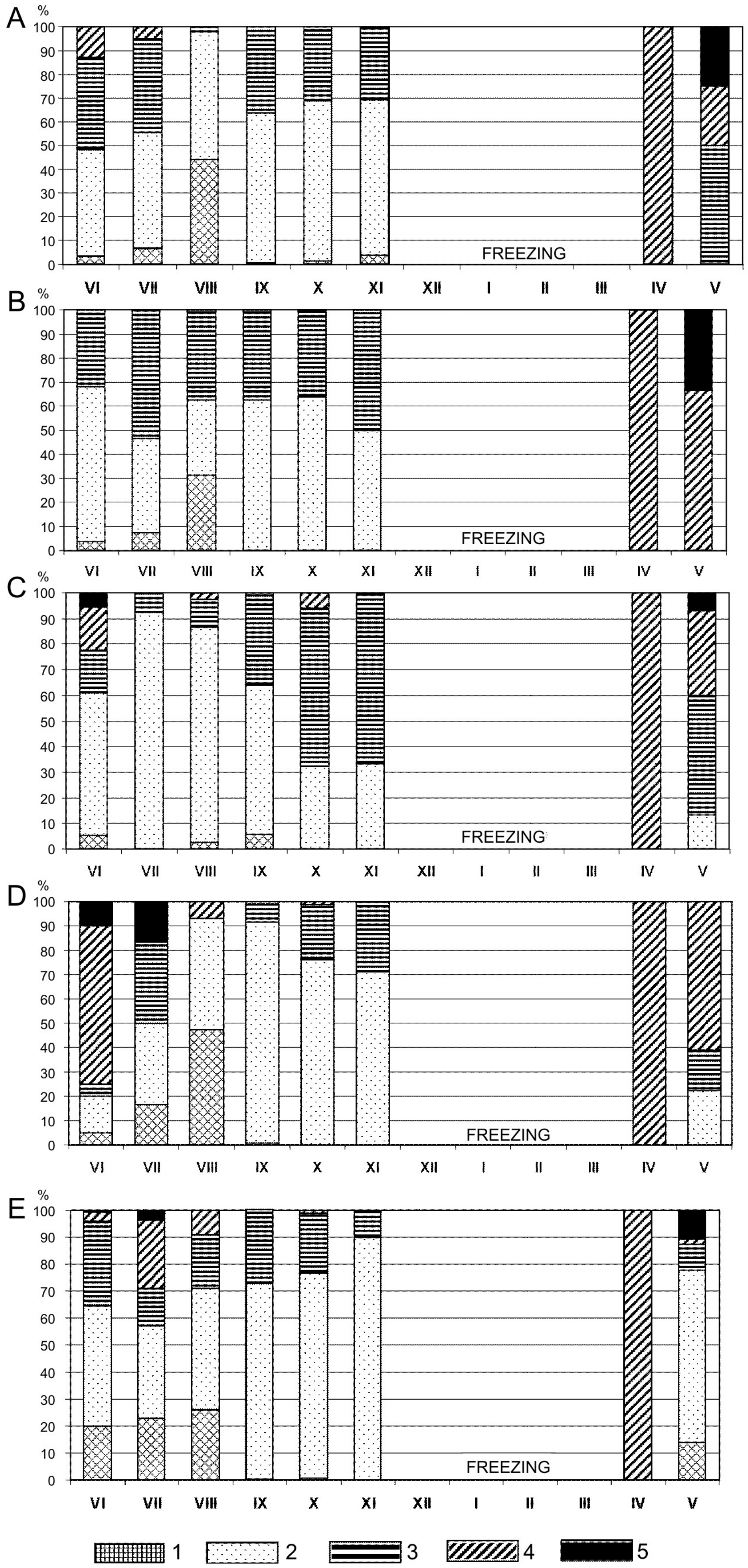


Fig. 6. Size structure of *Hippeutis complanatus* population during the year in woodland ponds: 1–5 – size classes; I–XII – months of research; A – pond 1, B – pond 2, C – pond 3, D – pond 4, E – pond 5

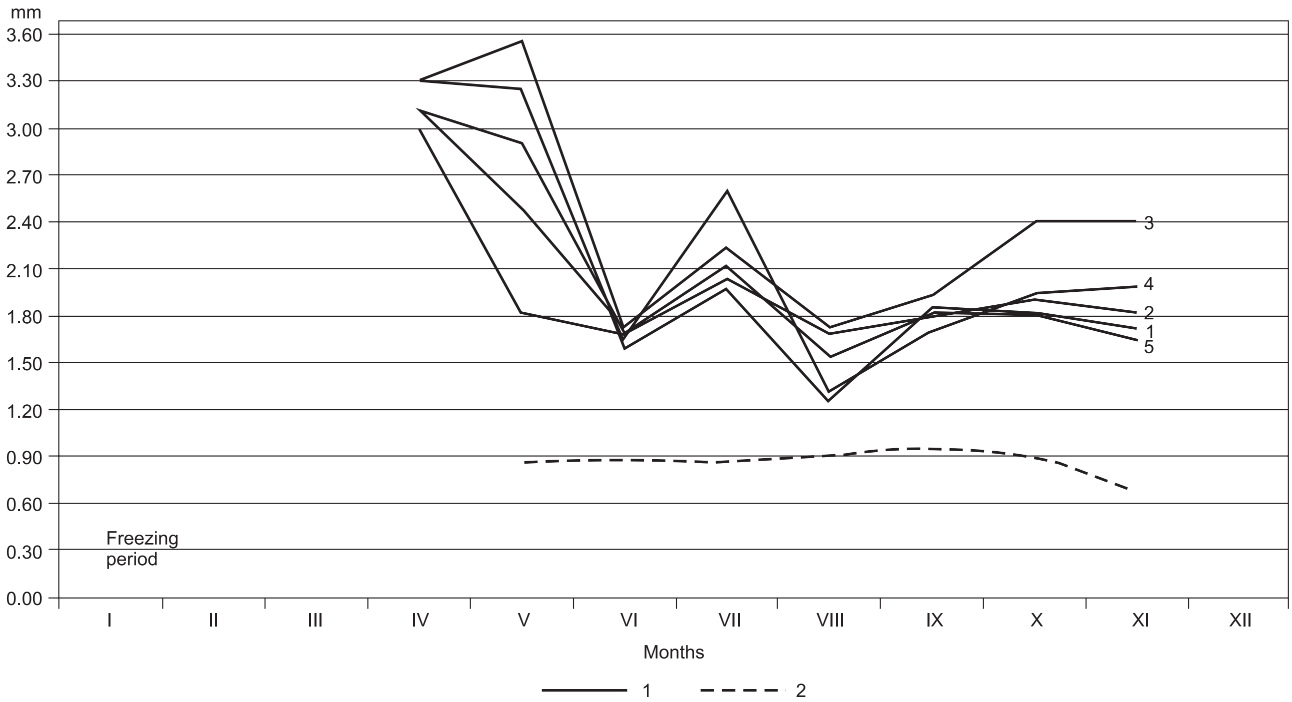


Fig. 7. The mean shell width in mm during the study period in the woodland ponds studied: 1 – mean shell width in particular months in woodland ponds 1–5; 2 – mean shell width of smallest specimens during the period of their appearance

rally and radially striated, whereas on adult shells only the spiral striae were present.

All the age classes were found in the ponds. Individuals of the second size class (52% to 69% of the collections) were the most numerous. Slightly fewer specimens represented the third class, in most ponds they formed about 30% of the collection, except for pond 4 where they constituted 9.5%. The largest and smallest specimens formed a small percentage of the collection in each pond.

The population structure in each of the ponds studied was similar. In ponds 1, 2 and 4 the smallest specimens were most numerous in August (Fig. 6). In pond 3 most specimens of the first size class were observed in September, while in pond 5 such individuals were observed from May to October and were most abundant in August (Fig. 7). In most ponds the biggest specimens (fifth size class) appeared from May to July.

REPRODUCTIVE SEASON

The smallest individuals first appeared in June, except in pond 5, where they were observed before the end of May. In most ponds the youngest specimens did not appear in great numbers before August. A positive, statistically significant correlation between the abundance of the youngest specimens and the water temperature was observed in all the ponds (r_s=0.60, $p<0.05$, n=39). In April in all of the ponds only large specimens of the fourth size class occurred, and their numbers were small; they laid cocoons in late spring and then died (Fig. 6). This may account for the low number of the youngest individuals during May, June and July.

The numerous young snails which appeared in August laid cocoons in July of the following year (young individuals of the new generation appeared abundantly in August). As fully grown individuals they laid eggs for the second time in April/May (cocoons were observed in that period) of the following year and then died. The analysis of the mean shell size in each month confirms the existence of two reproductive periods, including the main one in July/August (Fig. 7). One-way ANOVA showed statistically significant differences in the shell width of specimens collected in June and August in comparison with the other months: H (7, N=4,013) = 427.65, $p<0.0001$ and H (7, N=4,013) = 402,38 $p<0.0001$, respectively, post hoc $p<0.0001$.

The cocoons collected in this study in May and July from the underside of oak leaves contained 10–21 eggs each (in May 10–12 and in July 17–21 eggs). The length of cocoons ranged from 1.98 to 3.06 mm, whereas the size of the eggs ranged from 0.44×0.54 to 0.52×0.61 mm.

DISCUSSION

Research on the reproductive biology of freshwater snails provides knowledge about different species in various habitat conditions. Such research is especially important for species usually found in small numbers and those for which such data are scanty or absent. This is the first comprehensive study on the size structure of populations of *H. complanatus* and on its breeding periods.

Most freshwater pulmonates have an annual life cycle and one offspring generation during a lifetime, for example in *Anisus vorticulus* (TERRIER et al. 2006, GLÖER & GROH 2007) or *Bathyomphalus contortus* (STRZELEC & SERAFIŃSKI 1994), or two breeding seasons during one year as in most lymnaeids (ISLAM et al. 2001). According to YOUNG (1975) freshwater pulmonates have a simple one-year life cycle, but in some kinds of habitats they may live longer. DUSSART (1979) found that the reproductive periods of *Gyraulus albus* were July and September, and some adults, having reproduced, survived winter.

In some planorbid snails consecutive generations may overlap. This research shows that this is true of *H. complanatus*. RICHARDOT-COULET & ALFARO-TEJERA (1985) found that *Gyraulus crista* had an annual life cycle with three different breeding periods. The summer and autumn generations wintered over and died after reproduction the next spring. A different situation was observed in this study. The youngest individuals of *H. complanatus* appear very abundantly in August; perhaps the snails hide in the deeper parts of bottom sediments or spend the winter in the deepest parts of ponds (1.8–3.5 m). This problem requires further studies. In April of the next year they crawl out from their winter shelters, grow and in July lay cocoons for the first time. From this finding alone it is possible to conclude that, after the second wintering, they reproduce in late April and early May and the offspring appears at the end of May and in June. Thereafter, overlapping generations participate in the reproduction. The course of life cycle of *H. complanatus* suggests a life span of more than one year. The lack of literature information on the species' life-cycle makes it impossible to compare the results with data of other authors. According to DILLON (2000) the annual semelparous life cycle is most common among freshwater pulmonate populations. They often produce two generations per year, rarely three generations per year or one generation in two years. The results of this study show that *H. complanatus* breeds twice in a lifetime, and individuals of two generations reproduce during one year. The main breeding period is July/August. Based on RUSSEL-HUNTER's (1961) and CALOW's (1978) classification of freshwater gastropod life cycles, DILLON (2000) pointed out that if the two generations per year were the norm, both the first (usually spring) and the second (summer or autumn) generation could be semelparous or iteroparous. *H. complanatus* seems to be in the category which included populations reproducing twice in a lifetime, with individuals surviving the first reproduction, and dying after the second one (the following year).

Life strategies among gastropods are known to depend on, among other factors, water temperature (RUSSEL-HUNTER 1961). The temperature determines the moment of emergence of the snails from their winter shelters and the course of their life-cycle (TERRIER et al. 2006). It is generally agreed that the water temperature initiates deposition of cocoons. The freshwater gastropod reproduction is known to start at 10–12°C (BOERGER 1975, EVERSOLE 1978). In their study on the life cycle of four planorbid species from anthropogenic water bodies, STRZELEC & SERAFIŃSKI (1994) showed that water temperature had a greater effect on the layout of generations than the other environmental factors. In the ponds investigated the individuals of *H. complanatus* appeared from April, when the water temperature increased. The temperature influenced the appearance of the smallest individuals, which constituted the largest proportion of the collection in months with higher water temperatures.

Other important factors affecting the reproduction are probably water hardness and calcium content. In his study on the influence of these factors on the life cycle of six snail species, YOUNG (1975) found that *H. complanatus* completed its life cycle only in hard waters with a high calcium content, whereas in calcium-poor water the snails died before reproduction. This may be due to *H. complanatus* being a calciphile (ØKLAND 1990, KERNEY 1999, BRIERS 2003). YOUNG (1975) recorded it from waters with 50 mg Ca/l. AHO (1966) found the species in freshwater habitats with calcium content exceeding 20 mg/l. The ponds investigated are characterised by soft or very soft water (2.1–7.3 dH) with low calcium content – from 13 to 43 mg/l in most ponds. Individual growth rates of pulmonate species can be slower in soft waters and this may cause a delay in the onset of egg laying which DUSSART (1979) observed in the soft water populations of *Gyraulus albus*.

The cocoons of *H. complanatus* are oval or round and generally contain fewer than 25 eggs (BONDENSEN 1950). It the studied populations the cocoons contained from 10 to 21 eggs. NEKRASSOW (1928) described the cocoons as flat, oval, or disc-shaped, with 5–10 eggs. The length of cocoons and the egg size were comparable to those described by BONDENSEN (1950) but departed from NEKRASSOW's data (1928). The cocoons described by BONDENSEN (1950) were characterised by a short, adnate terminal tail contrary to those described by NEKRASSOW (1928). Not all of the cocoons collected in this study had a terminal tail.

Various authors (e.g. PIECHOCKI 1979) described the shell of *H. complanatus* as little variable. According to ØKLAND (1990) in Norway the shell height ranges from 1.0 to 1.6 mm and the width from 3.5 to 5.3 mm. According to LOŽEK (1964) and GLÖER (2002) the shell width reaches 4-5 mm, whereas ZHADIN (1952) reported width up to 6 mm. In the woodland ponds investigated the largest shells were mostly 4.8 mm, and sporadically 5.4 mm in width. Both gastropod growth and maximum size depend on temperature and food availability in the habitat (RUSSEL-HUNTER 1961). According to DILLON (2000) the juvenile size in freshwater molluscs varies from 0.4 to 15 mm and depends on the genus or family. In *H. complanatus* the smallest collected juveniles were 0.33 mm in width and 0.1 mm in height.

In Finland, *H. complanatus* is known to be frequent (constancy up to 45%), although it always occurs in small numbers (AHO 1966). BERAN (1999, 2007) recorded it from 18 sites in permanent stagnant waters only as single specimens (2–10 individuals). The highest abundance in Hamburg (GLÖER & DIERCKING 2009) amounted to 213 ind./m^2, but usually it was about 20. In Poland *H. complanatus* was previously recorded from single sites, where it always occurred in small numbers (e.g. KLIMOWICZ 1959, 1962, REMBECKA 1989, STRZELEC 1993, WŁOSIK-BIEŃCZAK 2001). However, SPYRA (2010) showed that the species could be abundant (from 224 to 11,136 collected specimens) in woodland ponds in Poland. The density of *H. complanatus* in this study was high. The highest densities were observed in ponds 1, 4 and 5: 1,124 ind./m^2, 1,936 ind./m^2, 2,324 ind./m^2, respectively.

This researches contributes important data on the life cycle of *H. complanatus* as well as its breeding periods and size structure of its population during the year. A more extensive study on the species' life cycle in temporary water bodies may provide information on its course in ephemeral environments.

REFERENCES

AHO J. 1966. Ecological basis of the distribution of the littoral freshwater molluscs in the vicinity of Tampere, South Finland. Ann. Zool. Fen. 3: 287–322.

BÁBA K. 1991. Untersuchung der Sukzessionsverhältnisse der Wasser-Mollusken im Tisza-Tal. Proc. Tenth International Malacological Congress: 367–372.

BERAN L.1999. Vodni měkkýši CHKO Poodří (Česká republika). Čas. Slez. Muz. Opava. 48: 65–71.

BERAN L. 2007. Vodní měkkýši přehradní nádrẄ slapy (Česká republika). Malacol. Bohemosl. 6: 11–16.

BOERGER H. 1975. A comparison of the life cycles, reproductive ecologies and size-weight relationship of *Helisoma anceps*, *H. companulatum*, and *H. trivolvis* (Gastropoda, Planorbidae). Can. J. Zool. Rev. 53: 1812–1824. doi: 10.1139/z75-215

BONDENSEN P. 1950. A comparative morphological-biological analysis of the egg capsules of freshwater pulmonate gastropods. Natura Jutlandica 3: 1-208.

BRIERS R. A. 2003. Range size and environmental calcium requirements of British freshwater gastropods. Gl. Ecol. Biogeogr. 12: 47–51. doi: 10.1046/j.1466-822X.2003.00316.x

CALOW P. 1978. The evolution of life-cycle strategies in freshwater gastropods. Malacologia 17: 351–364.

DILLON R. T. JR. 2000. The ecology of freshwater molluscs. Cambridge University Press, Cambridge, UK. doi: 10.1017/CBO9780511542008

DUSSART G. B. J. 1979. Life cycles and distribution of the aquatic gastropod molluscs *Bithynia tentaculata* (L.), *Gyraulus albus* (Muller), *Planorbis planorbis* (L.) and *Lymnaea peregra* (Muller) in relation to water chemistry. Hydrobiologia 67: 223–239. doi: 10.1007/BF00023179

EVERSOLE A. G. 1978. Life-cycles, growth and population bioenergetics in the snail *Helisoma trivolvis* (Say). J. Moll. Stud. 44: 209–222.

GLÖER P. 2002. Die Süßwassergastropoden Nord- und Mitteleuropas. Die Tierwelt Deutschlands, 73, ConchBooks, Hackenheim.

GLÖER P., DIERCKING R. 2009. Atlas der Süßwassermollusken Hamburg. Rote Liste, Verbreitung, Ökologie. Umweltbehörde, Hamburg (www.malaco.de/publications).

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: 33–40.

HERMANOWICZ W., DOJLIDO J., DOŻAŃSKA W., KOSIOROWSKI B., ZERZE J. 1999. Fizyczno-chemiczne badanie wody i ścieków. Arkady, Warszawa.

ISLAM M. N., PORT R., MCLACHLAN A. J. 2001. The biology of *Lymnaea peregra* (Müller) (Gastropoda: Pulmonata: Basommatophora) with special reference to the effects of herbicides on its reproduction. J. Biol. Sc. 1: 532–540. doi: 10.3923/jbs.2001.532.540

KERNEY M. 1999. Atlas of the land and freshwater molluscs of Britain and Ireland. Harley Books, Martins, Great Horkesley.

KLIMOWICZ H. 1959. Tentative classification of small water bodies on the basis of the differentiation of the molluscan fauna. Pol. Arch. Hydrobiol. 6: 85–103.

KLIMOWICZ H. 1962. The molluscs of impermanent water bodies in the environs of Warsaw. Pol. Arch. Hydrobiol. 10: 271–285.

LOŽEK V. 1964. Quartärmollusken der Tschechoslowakei. Rozpravy Ústředního Ústavu Geologického, Praha 31: 1–374.

MERKEL E. 1894. Molluskenfauna von Schlesien. 8, J. U. Kern's Verlag, Breslau. doi: 10.5962/bhl.title.12857

NEKRASSOW A. 1928. Vergleichende Morphologie der Laiche von Süßwassergastropoden. Zeitschr. Morphol. Ökol. Tiere 13: 1–35.

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

PIECHOCKI A. 1979. Mięczaki (Mollusca), Ślimaki (Gastropoda). Fauna Słodkowodna Polski 7. PWN, Warszawa–Poznań.

PIECHOCKI A. 2002. Mięczaki. Ślimaki: Gastropoda aquatica In: GŁOWACIŃSKI Z. (ed.) 2002. Czerwona lista zwierząt ginących i zagrożonych w Polsce. PAN IOP, Kraków, pp. 1–155.

REMBECKA I. 1989. Freshwater snails (Mollusca: Gastropoda) of fish ponds in Silesia (Southern Poland). Folia Malacol. 3: 131–137.

RICHARDOT-COULET M., ALFARO-TEJERA L. 1985. The life cycle and ecology of the freshwater Planorbidae *Armiger crista* (L.). J. Moll. Stud. 51: 35–51.

RUSSEL-HUNTER W. 1961. Life cycles of four freshwater snails in limited populations in Loch Lomond, with a discussion of infraspecific variation. Proc. Zool. Soc. London 137: 135–171. doi: 10.1111/j.1469-7998.1961.tb06166.x

SPYRA A. 2010. Environmental factors influencing the occurrence of freshwater snails in woodland water bodies. Biologia 65: 697–703. doi: 10.2478/s11756-010-0063-1

STRZELEC M. 1993. Ślimaki (Gastropoda) antropogenicznych środowisk wodnych Wyżyny Śląskiej. Prace nauk. Uniw. Śląskiego, Katowice 1358: 1–103.

STRZELEC M., SERAFIŃSKI W. 1994. Life cycles of freshwater planorbid snails in anthropogenic water bodies. Acta Biol. Sil. 26(43): 104–117.

TERRIER A., CASTELLA E., FALKNER G., KILLEEN I. J. 2006. Species account for *Anisus vorticulus* (Troschel, 1834) (Gastropoda: Planorbidae), a species listed in Annexes II and IV of the habitats directive. J. Conchol. 39: 193–206.

WŁOSIK- BIEŃCZAK E. 2001. Malakofauna rzeki Bogdanki w Poznaniu w latach 1994–1998. Bad. Fizjogr. Polska Zach. C zool. 48: 7–19.

YOUNG J. O. 1975. Preliminary field and laboratory studies on the survival and spawning of several species of Gastropoda in calcium-poor and calcium-rich waters. J. Moll. Stud. 41: 429–437.

ZEISSLER H. 1987. Mollusken im Naturschutzgebiet "Rohrbacher Teiche" (Kreis Grimma), Malak. Abh. 12: 153–159.

ZHADIN W. I. 1952. Mollyuski presnikh i solonovatykh vod SSSR. Opredeliteli po faune SSSR. Izdav. Zool. Instit. Akad. Nauk SSSR 46, Moskva.

Received: June 26th, 2012
Revised: August 13th, 2012
Accepted: September 9th, 2012