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REPRODUCTION OF *VIVIPARUS VIVIPARUS* (LINNAEUS, 1758) IN THE MID AND LOWER SECTIONS OF THE NAREW RIVER

ANNA AUGUSTYNIUK[1] & BEATA JAKUBIK[2]

[1] Department of Agrocenology, Institute of Ecology, Polish Academy of Sciences, Konopnickiej 1, 05-092 Łomianki, Poland

[2] Department of Ecology and Environment Protection, University of Podlasie, B. Prusa 12, 08-110 Siedlce, Poland

ABSTRACT: The population of *V. viviparus* (L.) was studied at 16 sites situated along the mid and lower sections of the Narew River, with respect to the population density, sex ratio, size structure and fecundity. The density ranged from 50 to 600 indiv./m^2. The females comprised 53–90% of population, and represented mainly the largest size classes (III and IV), while most of the males were of size class II. The smallest snails (class I) were found only among the males (up to 50%). In all the sites gravid females predominated, being the most abundant in size class IV (80%–100%). The average number of embryos per female was 18 (range 1–59) and increased with the shell height and body mass.

KEY WORDS: *V. viviparus*, reproduction, density, sex ratio, size structure, fecundity

INTRODUCTION

Viviparus viviparus (Linnaeus, 1758), an ovoviviparous and long-lived species of large body size and pronounced sexual dimorphism, occurs in various types of freshwater habitats, usually in high densities (e.g. FRÖMING 1956, STAŃCZYKOWSKA 1959a, b, 1960a, PIECHOCKI 1979, FALNIOWSKI 1989a, b, JURKIEWICZ-KARNKOWSKA 1989, HASTRICH 1994, JAKUBIK & STAŃCZYKOWSKA 1996, ZETTLER 1996).

In rivers *V. viviparus* usually inhabits mid and lower sections. The snails are found in the main current of rapid flow, and in the shore zone, small bays, oxbows and shoals, in slowly flowing or stagnant water (PIECHOCKI 1979, FALNIOWSKI 1989a).

Fluviatile and still-water *V. viviparus* differ in their shell shape, size and in body coloration (FALNIOWSKI 1989a). In both types of waters the species is not directly vegetation-dependent but may find refuge among aquatic plants (STAŃCZYKOWSKA 1960b, c). *V. viviparus* shows no clear preference towards muddy bottom, but according to JANKOWSKI (1933), on such a bottom it reaches the highest densities.

In spite of the fact that viviparids, and especially members of the genus *Viviparus*, are often subject to various ecological and/or biological studies, separately or as components of freshwater biocenoses (e.g. ZHADIN 1925, STAŃCZYKOWSKA 1960a, PIECHOCKI 1969, 1972, 1979, STAŃCZYKOWSKA et al. 1971, SAMOCHWALENKO & STAŃCZYKOWSKA 1972, AVOLIZZI 1976, DE BERNARDI et al. 1976a, b, BROWNE 1978, BUCKLEY 1986, RIBI & GEBHARDT 1986, KHMELEVA et al. 1995, ELEUTHERIDIAS & LAZARIDOU-DIMITRIADOU 1995), data on the distribution and life cycle of *V. viviparus* in fluviatile habitats of Poland are still scarce. An analysis of several population parameters of *V. viviparus* in the mid and lower sections of the Narew River was the objective of our study.

MATERIALS AND METHODS

The Narew River is a right tributary to the Vistula River, flowing in North Podlasie and North Mazovia lowlands (MILESKA 1996). The length of the Polish section of the river is 448.1 km. The river valley is wide, the banks are low and muddy, is some parts inaccessible, covered by common reed (*Phragmites australis* Trin.) and bulrush (*Scirpus radicans* Schkr.). The river has many branches and shoals.

The snails were sampled from June 7th to 10th, 1993 from 16 sites situated along the mid and lower sections of the Narew River, upstream of the Zegrzyński Reservoir (Fig. 1). The sites were evenly distributed, most of them situated near the main current. Some were located in small bays, shoals or oxbows. Site 4 was situated downstream of the sewage discharge of the "Celuloza" factory and the power plant in Ostrołęka.

In most sites, the bottom was sandy or sandy and gravelly, covered by a mud layer; the water depth ranged from 30 to 100 cm. The banks were natural, in some places steep, usually sandy. The rather abundant vegetation consisted mainly of *Elodea canadensis* (Rich.), *Myriophyllum* sp., *Lemna* sp., and *Hydrocharis morsus ranae* (L.).

The snails were collected manually from the sampling area bordered with 25 × 25 cm frame (1/16 m^2), and at deeper sites (40–100 cm) a drag-net of 40 cm length was used. The drag-net was towed on a distance of 1 m, along the shoreline (semi-quantitative method applied by LEWANDOWSKI & STAŃCZYKOWSKA 1975). The mesh size of the drag-net and the sieve was 1 mm, allowing collection of snails of all size-classes. Depending on the bottom configuration and slope, one or both sampling methods were applied. The density of *V. viviparus* at each depth was calculated as the average of both samples. The density at each site was an average from all the depths.

Live specimens were transported to the laboratory, and preserved with 4% formaldehyde solution. The following parameters were analysed: density, sex ratio, size structure of males and gravid and non-gravid females, fecundity, relationship between the shell size, body mass and fecundity. A total number of 752 individuals were analysed.

The snails were sexed based on the differences in tentacle size (in the male the right tentacle is thicker, in the females both tentacles are identical; PIECHOCKI 1979).

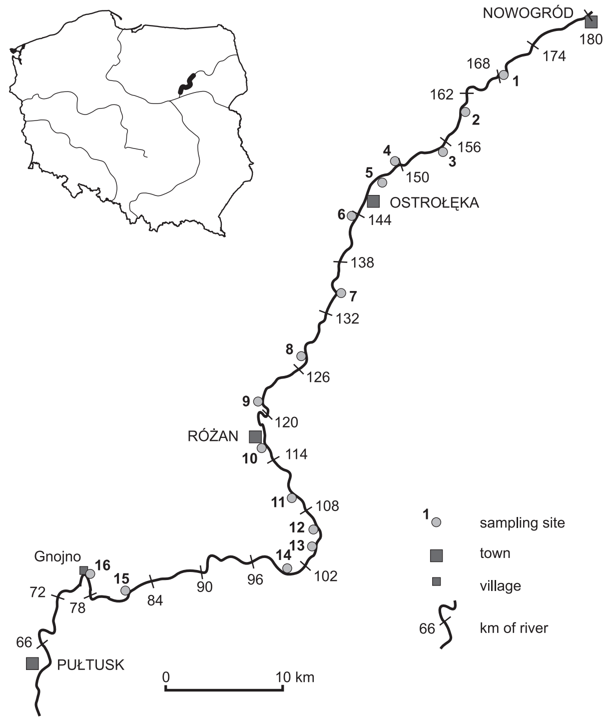

Fig. 1. Location of the sampling sites

For the size structure assessment 50 individuals were randomly selected from each sample, and shell height and width were measured with the accuracy of 0.1 mm. The snails were then divided into 4 size-classes, according to their shell height (STAŃCZYKOWSKA 1960a): class I – up to 8 mm, II – 8.1–12.0 mm, III – 12.1–25 mm, IV – 25.1 mm or higher.

The females were dissected for the assessment of the number of embryos; gravid and non-gravid animals, as well as the embryos removed from the uteri were counted.

After blot-drying of the snails, the bodies were removed from the shells, and placed at 60°C for 24 hours until they reached constant mass. Then they were weighed using electronic balance CHYO YMC MK-50C (accuracy 0.001 g).

Correlation between the shell height and the number of embryos per female was calculated using Pearson's test.

RESULTS

POPULATION DENSITY

The density of *V. viviparus* at the 16 studied sites was similar; at most sites it ranged from 50 to 600 individuals per m^2 of the river bottom (Table 1). The highest densities were observed in small bays and oxbows, where the bottom was covered with a thick layer of mud, and abundantly grown with emerged and submerged vegetation. At the sites with sandy or gravelly-sandy bottom and scarce or no vegetation the density was low.

Table 1. Density of *V. viviparus* at the sites of the Narew River, and habitat conditions

individuals/m^2	site number	site features
50–200	5, 11, 12	sandy bottom, slightly muddy, no vegetation
201–300	2, 4, 8, 10, 13	sandy or gravelly bottom, scanty shore vegetation
301–500	3, 6, 7, 9, 14, 15	muddy bottom, shore vegetation
501–600	1, 16	stagnant places, very muddy bottom, abundant vegetation

SEX RATIO

The sex ratio of *V. viviparus* varied between the sampling sites, the females being usually more numerous than the males (from 53% to 90% at site 9) (Fig. 2). Only at three sites (3, 11, 15) the males prevailed over the females, and at two sites (5, 16) the proportion was equal.

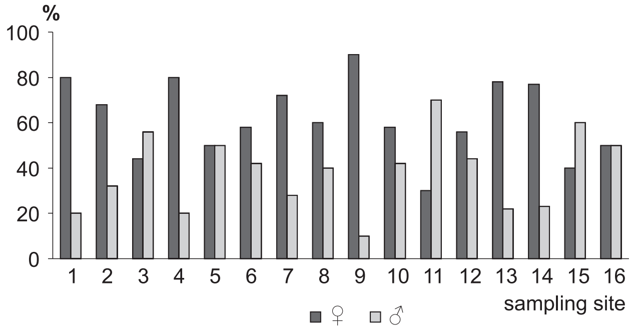

Fig. 2. Percentage of *V. viviparus* females and males at the sampling sites

SIZE STRUCTURE

The population of *V. viviparus* was divided into four size-classes (Fig. 3). The individuals of classes II (shell height 8.1–12 mm) and III (shell height 12.1–25 mm) predominated. Their percentage was 36% and 32%, respectively. The individuals of size-class I constituted the lowest proportion (14%).

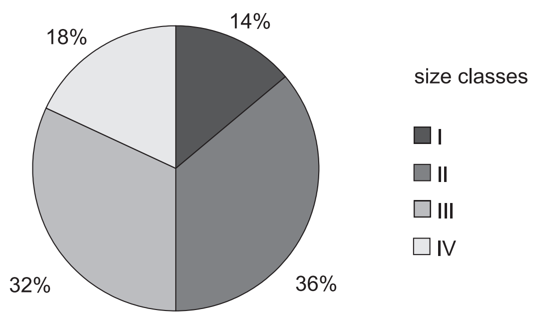

Fig. 3. Percentage of *V. viviparus* individuals in size-classes I–IV

The size structure differed between the sexes (Fig. 4). Among the females, individuals of classes III and IV predominated, while most males represented class II. The smallest snails (class I) were numerous only among males (sites 3, 11, 12, 15) and constituted up to 50% (sites 3, 11).

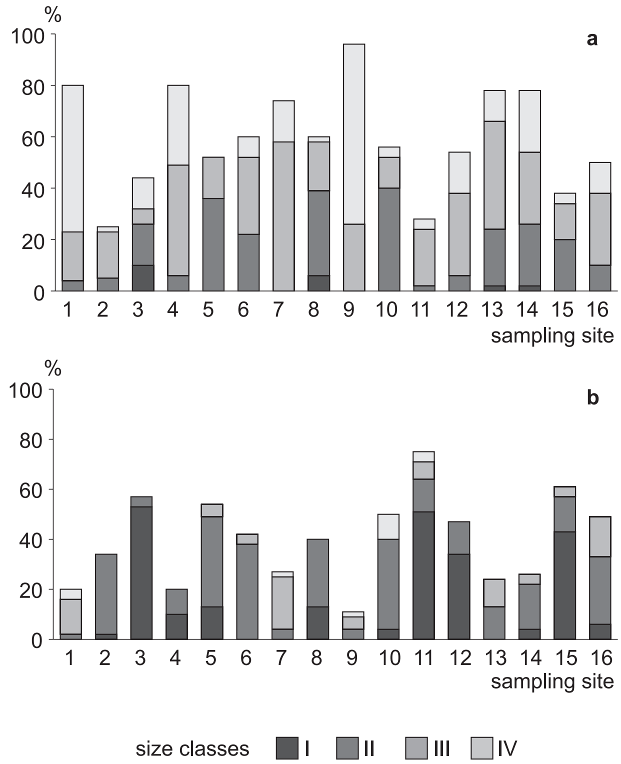

Fig. 4. Percentage of females (a) and males (b) of *V. viviparus* in size-classes I–IV.

FECUNDITY

The fecundity was expressed as the ratio of gravid to non-gravid females, and as the average number of embryos per female.

In all the sampling sites, irrespective from the size class, gravid females predominated (59–100%; Fig. 5). Their proportion varied between the classes. The percentage of gravid females was the lowest in class I

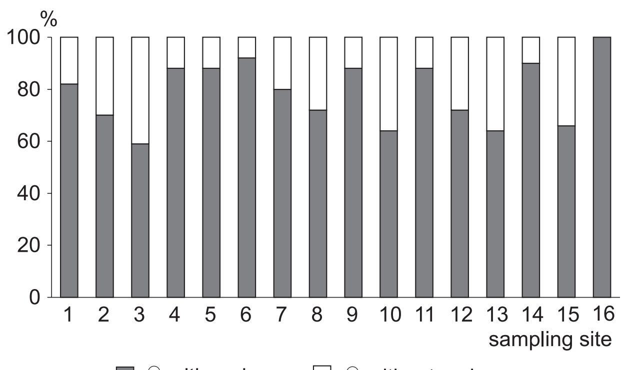

Fig. 5. Percentage of gravid and non-gravid females

(50%), and the highest in class IV (over 90%) (Table 2). In class I, gravid females constituted from 20 to 100% (Fig. 6). However, females belonging to that class were present at four sites only (3, 8, 13, 14). In class II gravid females formed 100% at three sites (4, 11, 16) (Fig. 6). Their percentage in that class ranged from 50% to 100%. At two sites (1, 12) 100% of the females were non-gravid. Likewise, in size class III gravid females predominated (Fig. 6), comprising from about 50% (sites 8, 10, 13) to 100% (sites 3, 16). Nearly all females of class IV were gravid – from 80% (site 3) to 100% (at most sites) (Fig. 6).

Table 2. Percentage of gravid and non-gravid females of *V. viviparus* in size-classes I–IV, mean number and range of embryos per female at the sampling sites of the Narew River

	size classes of females			
	I	II	III	IV
number of females	10	138	188	131
number of gravid females	5	103	144	124
percentage of gravid females	50.0	74.6	76.6	94.6
mean number of embryos per female (± SD)	7.6±0.3	13.5±0.8	16.6±2.5	18.5±3.3
range of number of embryos	3–12	2–28	1–39	2–59
number of non-gravid females	5	35	44	7
percentage of non-gravid females	50.0	25.4	23.4	5.4

At all the sites the highest number of the embryos per female was observed in classes IV and III. In class IV it averaged ca. 18, and in class III – ca. 16 embryos.

The maximum number of embryos found in a female was 59 (class IV), the minimum – 1 embryo (class III) (Table 2). The relationship between the average number of embryos, dry body mass and shell height indicates that the number of embryos in *V. viviparus* depends on the latter two parameters. The fecundity increased with shell height and dry body mass – larger females had more embryos. The relationship was confirmed by highly significant correlation.

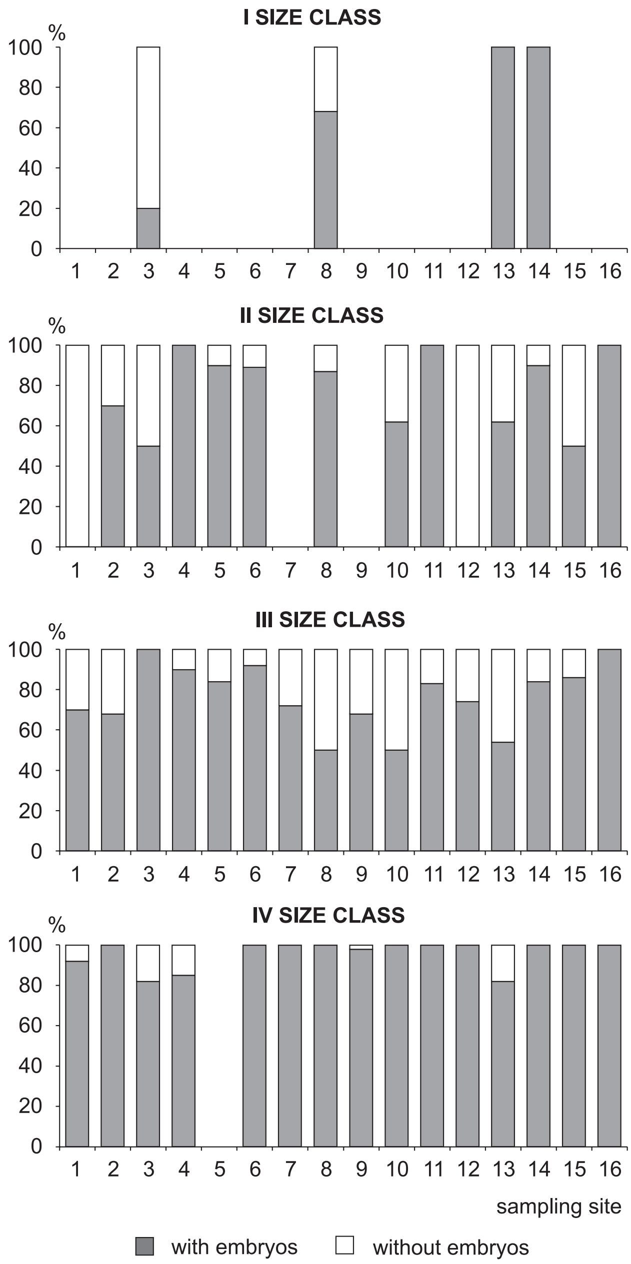

Fig. 6. Percentage of gravid and non-gravid females in size-classes I–IV at the sampling sites

DISCUSSION

The sex ratio (females:males) in populations of *V. viviparus* is about 3:1 (STAŃCZYKOWSKA 1960a, PIECHOCKI 1979). In the present study, the females predominated over males at most sampling sites, and only in several cases the males were more numerous, but the sex ratio varied rather widely between the sites and size classes. Since the samples were taken only in June, nothing can be said about its seasonal variation which is likely and was observed in some other members of the genus. In *V. malleatus* (Reeve) from two Canadian lakes the females predominated in May–July, the males being more numerous in the autumn (STAŃCZYKOW-

SKA et al. 1971). ELEUTHERIDIAS & LAZARIDOU-DIMITRIADOU (1995) reported that the sex ratio in *V. contectus* (Millet) from the Strymonas River was 1:1, and did not change over three years of studies. According to BROWNE (1978) and AVOLIZZI (1976), the sex ratio in the population of *V. georgianus* (Lea) from several lakes near New York in the summer was 4:1.

At all 16 sites of the Narew River individuals of size classes II and III were the most abundant. Most females belonged to class III, while the males represented mainly class II. The very low proportion of the smallest snails (class I) was noted also by other authors: STAŃCZYKOWSKA (1960a) and KHMELEVA et al. (1995) for *V. viviparus*, and by BROWNE (1978) and BUCKLEY (1986) for *V. georgianus*. DE BERNARDI et al. (1976a, b) reported that a population of *V. ater* Cristofori et Jan from the Alserio Lake (N Italy) in the early summer consisted of individuals of 30–57 mm shell height, whereas in August small snails of 12–30 mm appeared. In the population medium-sized snails predominated, called by the authors "mature ones".

In the studied population of *V. viviparus* 50% of the females of shell height below 18 mm were already reproducing. Larger females had a higher number of embryos, and almost all of them were reproducing. At all the sampling sites the average number of embryos per female increased with the shell height. The correlation between the number of embryos and dry body mass was also highly significant. The increase in the number of embryos with the female shell size seems to be the rule among the viviparids (e.g. SAMOCHWALENKO & STAŃCZYKOWSKA 1972, ELEUTHERIDIAS & LAZARIDOU-DIMITRIADOU 1995). In *V. malleatus* the average number of embryos was found to increase with the size of the females (STAŃCZYKOWSKA et al. 1971, 1972). According to BROWNE (1978) who studied the relationship between the age and fecundity of *V. georgianus* in four lakes near New York, the oldest females (2–3 years, shell height 20–30 mm) incubated the highest number of embryos, while the average number of embryos per gravid female ranged from 2 to 25. The females of *V. contectus* were mature and started to reproduce at 17 mm of shell height (ELEUTHERIDIAS & LAZARIDOU-DIMITRIADOU 1995). The snails born in the spring reached sexual maturity after three months, and those born in the autumn – after eight months. With regard to the relation between the shell size, body mass and the number of embryos, similar results were obtained by TAKI (1981) for *Cipangopaludina japonica* (Martens).

The average number of embryos per female in the studied population was similar to the values reported by other authors, and ranged from 8 to 18. The maximum number observed was 59 and differed from the values reported by some other authors, suggesting differences depending on the site and/or season. The maximum number of embryos of *V. viviparus* from the Konfederatka shoal in the Vistula River was 106 (STAŃCZYKOWSKA 1960a), and in a population from the Oka River – 85 (ZHADIN 1925). According to FRÖMING (1956), *V. viviparus* incubates up to 10 embryos; PIECHOCKI (1979) observed 80, and FALNIOWSKI (1989a) from 24 to 73 (50 on average) embryos per female. Much lower values (15–20 embryos) were reported by RIBI & GEBHARDT (1986) for *V. ater* from the Lake of Zurich and Lago Maggiore, and by TAKI (1981) for *C. japonica* (1—20 embryos). Considerably higher maximum numbers of embryos (101–162) per female were noted by JOKINEN (1982) for *Cipangopaludina chinensis* (Gray).

Data on the relation between the population density and the number of embryos per female are contradictory. In our study, comparison of reproduction rate at the sites of various densities of *V. viviparus* revealed no considerable density-dependent differences: the percentage of non-gravid females was similar at the sites of high and low density. STAŃCZYKOWSKA (1960a) analysed the effect of density on the fecundity of *V. viviparus* (as *V. fasciatus*) and found that the average and extreme values of the number of embryos per female, as well as the percentage of non-gravid females, were lower for the snails living in aggregations compared to lone individuals. On the contrary, JAKUBIK (1989) reported that *V. viviparus* living in groups showed a higher fecundity. She also found that at the time of aggregation development the snails showed the highest reproduction rate both in terms of the number of embryos per female and the proportion of reproducing females.

The present study concerned only the summer season, and the results do not allow for the evaluation of seasonal changes of the studied population parameters. Viviparity probably plays a crucial role in population functioning of this species. The studies focused mainly on embryonic development and sexual maturation of *V. viviparus* have been already started.

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