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

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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./m². 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. FROMING 1956, STAŃCZYKOWSKA 1959a, b, 1960a, PIECHOCKI 1979, FALNIOWSKI 1989a, b, JURKIEWICZ-KARNKOWSKA 1989, HAISTRICH 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 (PIECHOCI 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, PIECHOCI 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 (Mileńska 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 ox-bows. 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 m²), 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).

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 m² of the river bottom (Table 1). The highest densities were observed in small bays and ox-bows, 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.
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.

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%).

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).

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.
(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.

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

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.

**DISCUSSION**

The sex ratio (females:males) in populations of *V. viviparus* is about 3:1 (STAŃCZYKOWSKA 1960a, PIECZOCKI 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 (STAŃCZYKOWSKA 1960a, PIECZOCKI 1979).
started to reproduce at 17 mm of shell height (E Leu-
teridias & Lazaridou-Dimitriadou (1995) reported that the sex ratio in V. con-
tectus (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 fe-
males belonged to class III, while the males repre-
sented mainly class II. The very low proportion of the
smallest snails (class I) was noted also by other authors:
Stańczyowska et al. (1971), 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 Cristo-
fori 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 pre-
dominated, 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 corre-
lation 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. Samochwa-
lenko & Stańczyowska 1972, Eleutheridias & Lazari-
dou-Dimitriadou 1995). In V. malleatus the average
number of embryos was found to increase
with the size of the females (Stańczyowska et al.
1971, 1972). According to Browne (1978) who stud-
ied the relationship between the age and fecundity of
V. georgianus in four lakes near New York, the oldest fe-
males (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 (Eleu-
theridias & 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 chinensis (Gray).

Data on the relation between the population den-
sity and the number of embryos per female are con-
tradictory. In our study, comparison of reproduction
rate at the sites of various densities of V. viviparus
revealed no considerable density-dependent differ-
ces: the percentage of non-gravid females was simi-
lar at the sites of high and low density. Stańczy-
owska (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, Jarkubik (1989) reported that V. viviparus liv-
ing 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 sea-
son, and the results do not allow for the evaluation of
seasonal changes of the studied population parame-
ters. Viviparity probably plays a crucial role in popula-
tion functioning of this species. The studies focused
mainly on embryonic development and sexual matu-
rination of V. viviparus have been already started.

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