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Research article

The gravel snail, *Lithoglyphus naticoides* (Gastropoda: Hydrobiidae), a new Ponto-Caspian species in Lake Lukomskoe (Belarus)

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Abstract

On 23 July 2003, a new, previously unreported, molluscan species *Lithoglyphus naticoides* (gravel snail) was found in the benthos of Lake Lukomskoe, Belarus. As *Dreissena polymorpha* (zebra mussel) is also present, *Lithoglyphus naticoides* is the second Ponto-Caspian species recorded in this waterbody. Previous long-term observations on benthos and *L. naticoides* abundance data obtained in 2003-2005 imply that this species appeared in the lake in approximately 2000 and that currently its population is growing. We review available information on distribution of the snail in both Belarus and in adjacent countries and also discuss possible invasion pathway into Lake Lukomskoe.

Key words: *Lithoglyphus naticoides*, gravel snail, Ponto-Caspian species, range expansion, invasion corridor, Belarus, Lake Lukomskoe

Introduction

The eutrophic glacial Lake Lukomskoe is one of the biggest waterbodies in Belarus (surface area: 36.7 km^2; length: 10.4 km; width: 6.5 km; maximal depth: 11.5 m; mean depth: 6.7 m; volume: 243 millions m^3). It is located in northern part of the country and belongs to the Zapadnaya Dvina River basin (Figure 1). Since 1969, Lake Lukomskoe has been used as a cooling reservoir for the 2400-MW Lukomskaya Regional Power Plant (LPP). Heated waters discharged by LPP influence the thermal regime of the waterbody making the latter a proper model for temperature-related hydrobiological investigations. Extensive research programmes were initiated soon after the launch of LPP, and to-date the taxonomical composition of the main ecological groups of hydrobiota in Lake Lukom-skoe is well studied, especially macrozoobenthos (summarised in Lyakhnovich et al. 1982, Karatayev 1988, 1992). However, during a 2003 monitoring survey (July 23), we found a new molluscan species in the benthos of the lake, the gravel snail *Lithoglyphus naticoides* (Annex 2), which originates from the Ponto-Caspian region (Starobogatov 1970). An extensive literature review revealed well documented findings of this snail in the River Dnieper basin, but seldom records from other regions of Belarus. There was also very little information on the snail's ecology. This paper presents the first data on the spatial distribution and dynamics of *L. naticoides* population in Lake Lukomskoe during the summer-autumn period of three consecutive years, starting from its initial discovery in 2003. The most probable pathway for its invasion into this waterbody is also discussed.

Materials and Methods

Benthic samples were taken with Petersen grab (hard substrates) or Eckman grab (soft sediments) (0.025 m^2) three times a year, i.e. twice in summer and in autumn, from 2003 through to 2005. As benthic studies were not the main research goal at Lake Lukomskoe, the number of samples and transects along which they were taken differed both between years and seasons (Annex 1; Figure 2). Usually we sampled depths of 1, 2, 4, 5, 7 and 9 m, with 1-2 replicates per station. Collected macroinvertebrates were preserved in 4% formaldehyde for subsequent identification, and were counted and weighed (to the nearest 0.01 g, wet weight).

To quantify the density and biomass of *L. naticoides* for each sampling date, the weighted means for each of these parameters were calculated, taking into account the ‘weight’ of each depth zone. The same approach was used to find the mean yearly density and biomass, but the specific contribution of sampling dates was taken into consideration. The standard errors of weighted means were derived as for stratified sampling design (Manly 1992). To characterize the relative abundance of the gravel snail, we also calculated its percentage of the total density and biomass of all macrozoobenthos biota. In addition, the percentage of samples containing gravel snails was used to compare its occurrence between years.

Kruskal-Wallis ANOVA by ranks was applied to test whether density and biomass of *L. naticoides* varied between sampling dates and years. Difference in occurrence of snails was estimated with the G-test of independence. All tests were performed using STATISTICA 6.0 software (StatSoft, Inc.). Significance level α = 0.05 was accepted for all tests.

Results

L. naticoides occurred in all parts of Lake Lukomskoe but was mainly concentrated in the south-west. The highest density and biomass of the snail were recorded in the southern part (see below), which is characterised by abundant macrophytes and a silty sand substrate. *Lithoglyphus* was found only once and in small numbers in eastern part of the lake, namely at 6 m depth in the vicinity of the discharge zone of LPP heated waters (14.08.2005, Transect E; Figure 2).

Figure 1. Location of Lake Lukomskoe in Belarus (highlighted with square). Dashed lines on the map of Belarus correspond to borders of basins of the largest rivers: Lovat (L), Zapadnaya Dvina (ZD), Neman (N), Dnieper (D), Pripyat (P) and Zapadnyi Bug (ZB) (modified from Karatayev et al. 2000)

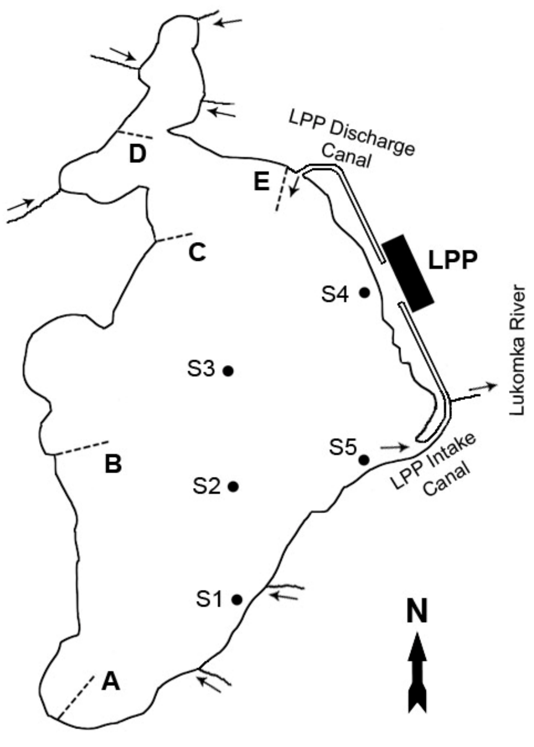

Figure 2. Lake Lukomskoe: benthic samples were taken along transects A to E and, occasionally, at stations shown as filled circles

To reveal the pattern in bathymetric distribution of density and biomass of the snail, we used data from August 2005, when the most detailed survey was conducted. Figures 3 and 4 indicate that the mean values of both parameters were negatively correlated with depth. Maximal development of the *L. naticoides* population was observed at depth of 1 m. At deeper sites, the abundance of snails gradually declined and at 10 m they were completely absent.

There was a statistically significant difference between yearly densities of the snail (P=0.049, Kruskal-Wallis ANOVA), with the highest one observed in 2005 (Table 1). However yearly values of the biomass did not differ significantly (P=0.061, Kruskal-Wallis ANOVA; Table 1). Compared to other years, in August of 2005 we observed the highest number and biomass of *L. naticoides* per separate sample, i.e. up to 1000 indiv./m^2 and 56.4 g/m^2 (Annex 1: Transect B, depth 2 m; Figure 2). Occurrence of the snail demonstrated between-years variation similar to that of density (P < 0.05, G-test; Table 1).

The mean yearly proportion of *L. naticoides* with respect to total density of macrozoobenthos was very low and varied from 0.1±0.1% in 2004 to 3.6±1.2% in 2005. The mean proportion of the total biomass was slightly higher, varying from 1.4±1.4% in 2004 to 7.9±2.8% in 2005. In August 2005, we recorded the highest contribution of *L. naticoides* to total density and biomass of macrozoobenthos in a particular sample, i.e., 40% and 81.3%, respectively.

In all the years of this study, neither mean density nor biomass differed statistically significantly between the three samples taken (P>0.05, Kruskal-Wallis ANOVAs). However, in 2004 and 2005 both parameters demonstrated some tendency for increase in August as compared to other months (Figures 5-6).

Table 1. Population dynamics of *L. naticoides* in Lake Lukomskoe in 2003-2005

Year (sample size)	Density (indiv./m^2)	Biomass (g/m^2)	Occurrence (%)
2003 (n=27)	37±24	2.3±1.4	11.1
2004 (n=26)	3±2	0.22±0.17	7.7
2005 (n=50)	86±30	2.9±1.2	28.0

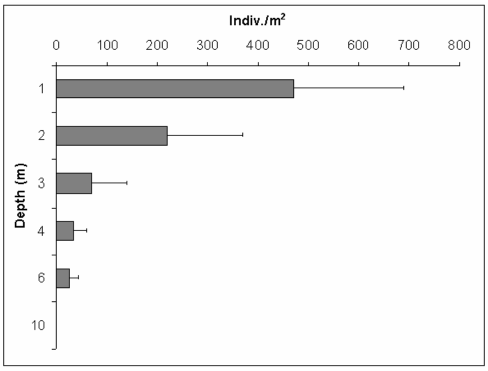

Figure 3. Bathymetric distribution of the mean density (±SE) of *L. naticoides* in Lake Lukomskoe, August 2005

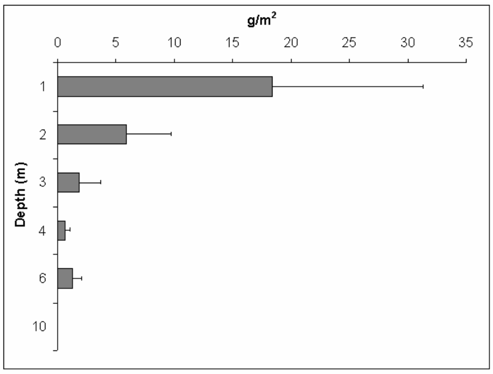

Figure 4. Bathymetric distribution of the mean biomass (±SE) of *L. naticoides* in Lake Lukomskoe, August 2005

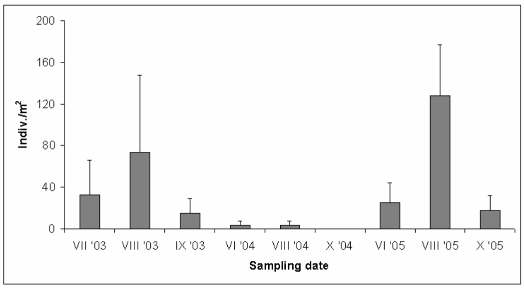

Figure 5. Mean (±SE) density of *L. naticoides* in Lake Lukomskoe from July 2003 to October 2005

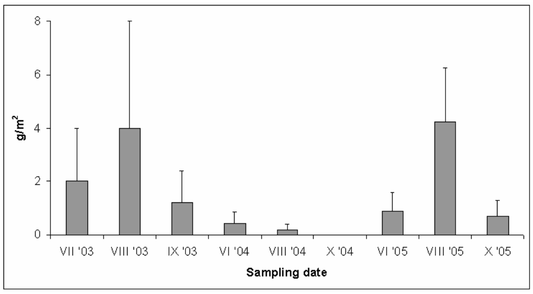

Figure 6. Mean (±SE) biomass of *L. naticoides* in Lake Lukomskoe from July 2003 to October 2005

Discussion

Distribution of L. naticoides in Belarus and adjacent countries

Palaeontological data show that in the Pliocene, snails of the genus *Lithoglyphus* were widely distributed in different geographic parts of the Palearctic, including, for example, the north of Italy, the basins of the Rivers Danube and Volga, the Black Sea region, and Western Siberia. During the Pleistocene, most representatives of the genus expired or were forced out by glaciers to downstream parts of rivers belonging to basins of the Black Sea and Azov Sea (Starobogatov 1970). Due to warming of climate in the Holocene, many macroinvertebrate hydrobionts were able to recolonise the European parts of their ranges. However, for a long time *L. naticoides* maintained its habitat in the Ponto-Caspian region, particularly in the western part of the Black Sea (Bij de Vaate et al. 2002). This situation dramatically changed approximately two centuries ago after the interconnection of river basins through man-made shipping canals (Starobogatov 1970, Bij de Vaate et al. 2002). Bij de Vaate et al. (2002) distinguish three main corridors of migration of macroinvertebrates from Ponto-Caspian region to Europe: (i) a northern corridor: Volga River > Lake Beloye > Lake Onega > Lake Ladoga > Neva River > Baltic Sea; (ii) a central corridor: rivers Dnieper > Vistula > Oder > Elbe > Rhine, and (iii) a southern corridor connecting the rivers Danube and Rhine. The modern pattern of *L. naticoides* distribution in Europe implies that the northern and central corridors could have been the main routs of its migration (Starobogatov 1970, Bij de Vaate et al. 2002).

A considerable part of the central invasion corridor, i.e. Dnieper River with its large tributaries Pripyat, Berezina and Sozh, goes through Belarus (Figure 1). It is most probable that *L. naticoides* arrived in Belarusian waterbodies via this corridor from Ukraine, where it is very common (Markevich et al. 1976, Afanas'ev et al. 2002, Gural 2004, Sverlova and Gural 2004). The presence of the gravel snail in the Belarusian part of the Dnieper River and its tributaries was well documented (Ovchinnikov 1928, Adamowicz 1939, Drako 1956, Vladimirova et al. 1965, Chernogorenko 1983, Rozumenko 1983, Arabina et al. 1988, Tischikov and Tischikov 1999, Kurandina and Nizovskaya 2002). However, published findings of the snail from other regions of Belarus are much more seldom and include several waterbodies belonging to the basins of the rivers Zapadnaya Dvina (Guseva 1936, Nekhaeva and Shevtsova 1982, Mitrakhovich et al. 1987) and Zapadnyi Bug (Tischikov and Tischikov 2005).

The present paper reports about a new locality for the gravel snail in Belarus. Along with the bivalve mollusc *Dreissena polymorpha*, *L. naticoides* has become a second Ponto-Caspian species in Lake Lukomskoe. It is interesting that *D. polymorpha* appeared in the lake much earlier than the gravel snail, i.e. approximately 40 years ago (Lyakhnovich et al. 1982). We hypothesize that the reason for such a time difference may lie in the different vectors through which each species reached the lake. *D. polymorpha* is considered to have been unintentionally introduced into Lake Lukomskoe on fishing nets by man (Lyakhnovich et al. 1984), while invasion of *L. naticoides* is likely to be a natural process. The gravel snail is known mainly as riverine species (Starobogatov 1970, Piechocki 1979) and thus it could come from one of the rivers connected with the lake. Several of them, which are quite small and resemble streams, flow in the lake and one larger river, Lukomka, flows out at the eastern shore (Figure 2). Despite it flows out, we regard the Lukomka River as the most probable way of *L. naticoides* invasion into Lake Lukomskoe because it merges with Ulla River. This in turn, flows from the closely north-west located Lake Lepelskoe, which is inhabited by the gravel snail (Guseva 1936, Mitrakhovich et al. 1987). Future sampling of rivers connected with Lake Lukomskoe will help to verify this hypothesis.

But how did *L. naticoides* invade Lake Lepelskoe? All available data on this snail's distribution in Belarus (see above) suggest that it used the same waterways for spread as *D. polymorpha* did. According to Karatayev et al. (2000, 2003), the spread of zebra mussel in Belarus began about 200 years ago and was associated with construction of three shipping canals, which connected rivers of the Black Sea and Baltic Sea basins: (i) Dnieper and Zapadnyi Bug (1775); (ii) Dnieper and Neman (1804); and (iii) Dnieper and Zapadnaya Dvina (1805) (Figure 1). *L. naticoides* could appear in Lake Lepelskoe because the latter was a part of the Dnieper-Zapadnaya Dvina Canal for almost a century following its construction (Karatayev et al. 2000). Besides the Dnieper-Zapadnaya Dvina Canal, two other canals were also likely used by *L. naticoides* for its spread westward. In particular, the snail through the Dnieper-Zapadnyi Bug Canal could invade Poland, where it has been widely recorded (Piechocki 1979, Jazdzewski and Konopacka 2002, Kołodziejczyk 2001, 2004). It should be noted that the latter route is considered as the main one for the *D. polymorpha* invasion into Central and Western Europe (Kinzelbach 1992). Through the Dnieper-Neman Canal, *L. naticoides* reached Lithuania (Gasiunas 1968), where it was found both in inland waters (Kumsare et al. 1964, Pliūraitė 2001, Pliūraitė and Kesminas 2004) and in lagoons of the Baltic Sea (Leppäkoski et al. 2002).

Our finding of *L. naticoides* in Lake Lukomskoe indicates that snail is still spreading across Belarus. Similarly, it continues to colonise upstream water-reservoirs of the Volga River in Russia (Zhokhov and Pugacheva 2001, Yakovlev and Yakovleva 2005). At the same time, the Polish population of *L. naticoides* is declining and is considered an endangered species, due to water pollution (Kołodziejczyk 2004, Zajac 2005).

Distribution of L. naticoides within Lake Lukomskoe

L. naticoides is known to mainly inhabit slow flowing lowland rivers (Starobogatov 1970, Piechocki 1979). Reservoirs (Kumsare et al. 1964, Gontya 1983, Chernogorenko et al. 1992) and lakes (Guseva 1936, Drako 1956, Piechocki 1979, Nekhaeva and Shevtsova 1982, Mitrakhovich et al. 1987, Kołodziejczyk 2001, 2003, 2004) were also reported as its habitats albeit more rarely. In this sense, the finding of *L. naticoides* in Lake Lukomskoe was not surprising, except that, to our knowledge, this is only the second waterbody serving as a power station cooler, where *Lithoglyphus* has been recorded. The other such waterbody is the Kuchurganskoe Reservoir, Moldova (Vladimirov 1983, Filipenko 1999).

Throughout the entire period of our study, the highest abundance of the snail was commonly observed in the south-western littoral part of the lake, which is characterised by abundant macrophytes and a silty sand substrate. Several researchers also observed that *Lithoglyphus* preferred silted substrates, sometimes with a fraction of dead molluscan shells and coarse macrophyte debris (Vladimirova 1965, Markevich et al. 1976, Piechocki 1979, Rozumenko 1983, Vladimirov 1983, Kołodziejczyk 2001, 2003). The snail was sampled only once near the discharge canal of LPP (Transect E; Figure 1). Other studies suggest that its low abundance there was related to increased water temperature: Vladimirov (1983) and Filipenko (1999) did not find *L. naticoides* in the discharge canal of Kuchurganskaya Power Plant, Moldova.

The density and biomass of gravel snail in Lake Lukomskoe were negatively correlated with depth, with no individuals found at 10 m (Figures 3-4). Similar negative correlation was observed in Polish Lake Mikołajskie. Maximal depths where the snail could be observed in this waterbody in 1997 and 2003 were 5.5 m (Kołodziejczyk 2001) and 4 m (Kołodziejczyk 2003), respectively. In rivers, *L. naticoides* also prefers shallow waters (Ovchinnikov 1928, Drako 1956, Piechocki 1979, Rozumenko 1983).

The density of gravel snail in lakes is usually quite low. For example, in Lake Mikołajskie (Kołodziejczyk 2001, 2003) it did not exceed 112 indiv./m^2 per separate sample. In contrast, in rivers *L. naticoides* meets much more favor-able conditions and may form extremely dense populations, up to 8800 indiv./m^2 (Biserova 1990). For most of our study, the density of gravel snail in Lake Lukomskoe was similar to that of Lake Mikołajskie in Poland (Kołodziejczyk 2001, 2003). However, in August 2005, we registered very high density and biomass of the snail in an individual sample, i.e. 1000 indiv./m^2 and 56.4 g/m^2, respectively. This observation means that conditions of Lake Lukomskoe are very suitable for development of *L. naticoides* and that in future its abundance in this waterbody may increase further.

Mean yearly proportions of gravel snail in terms of the total density and biomass of macrozoobenthos of Lake Lukomskoe were quite low and did not exceed approximately 4% and 8%, correspondingly. If the proportion of *L. naticoides* expands, the snail could become a subdominant or even dominant zoobenthos species as was recorded in Kegumskoe Reservoir, Lithuania (Kumsare et al. 1964), Desna River, Ukraine (Chernogorenko 1964), Dnieper River, Belarus (Rozumenko 1983), the Volga River Delta, Russia (Biserova 1990) and in the Kuchurganskoe Reservoir, Moldova (Vladimirov 1983, Filipenko 1999).

Before this study, datasets for seasonal variations of *L. naticoides* populations in Belarusian waterbodies were absent. Possibly due to insufficient sample sizes, we failed to reveal statistically significant differences between mean monthly values of the snail's density and biomass in any of sampling years. However, in 2004 and 2005 both density and biomass demonstrated a tendency for certain increase in August (Figures 5-6). Information on seasonality of gravel snail from other regions is also scarce. We know the only similar study was performed in 1998 in the Lithuanian River Merkys (Pliūraitė 2001); *L. naticoides* was observed in benthic samples only in April and June with no data on density and biomass reported. Therefore, additional studies are required to characterise the snail's seasonal dynamics thoroughly.

The mean yearly density of gravel snail in this study was not uniform and showed a conspicuous depression in 2004 (Table 1). The occurrence of *L. naticoides* in samples demonstrated a similar variation. Although a statistically significant difference between the mean yearly values of the snail's biomass was not revealed, the tendency for decrease of this parameter in 2004 was also clear. The observed notable oscillation of *L. naticoides* population in Lake Lukomskoe may signify that it is at the early stage of establishment. We suggest that the gravel snail invaded the lake approximately in 2000 or 1-2 years earlier because in this particular year we did not encounter it during collection of *D. polymorpha* for parasitological studies (Mastitsky 2003). The identification of a species' establishment date in an ecosystem is relatively rare in invasion biology. Further monitoring of *L. naticoides* in Lake Lukomskoe may provide valuable data for modelling of population dynamics of aquatic invaders.

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Annex 1

Records of *Lithoglyphus naticoides* in Lake Lukomskoe (Belarus) in 2003-2005*
Collectors: SM – Sergey Mastitsky, VS – Vera Samoilenko

Transect/Station	Record coordinates**		Survey date	Range of abundance (indiv./m^2)	Range of biomass (g/m^2)	Collector
	Latitude, °N	Longitude, °E				
Transect A	54°37'	29°02'	23.07.2003	0	0	VS
Transect B	54°39'	29°02'	23.07.2003	0–360	0–22.3	VS
Transect C	54°41'	29°04'	23.07.2003	0	0	VS
Transect D	54°42'	29°04'	23.07.2003	0	0	VS
Station S1	54°38'	29°05'	23.07.2003	0	0	VS
Station S2	54°37'	29°05'	23.07.2003	0	0	VS
Transect A	54°37'	29°02'	20.08.2003	0–520	0–27.92	VS
Transect B	54°39'	29°02'	20.08.2003	0	0	VS
Transect C	54°41'	29°04'	20.08.2003	0	0	VS
Transect D	54°42'	29°04'	20.08.2003	0	0	VS
Station S1	54°38'	29°05'	20.08.2003	0	0	VS
Station S2	54°37'	29°05'	20.08.2003	0	0	VS
Transect B	54°39'	29°02'	19.09.2003	0	0	VS
Transect D	54°42'	29°04'	19.09.2003	0–120	0–9.7	VS
Station S1	54°38'	29°05'	19.09.2003	0	0	VS
Transect A	54°37'	29°02'	11.06.2004	0–40	0–3.9	VS
Transect C	54°41'	29°04'	11.06.2004	0	0	VS
Transect D	54°42'	29°04'	11.06.2004	0	0	VS
Station S1	54°38'	29°05'	11.06.2004	0	0	VS
Transect A	54°37'	29°02'	24.08.2004	0	0	VS
Transect B	54°39'	29°02'	24.08.2004	0	0	VS
Transect C	54°41'	29°04'	24.08.2004	0–40	0–1.7	VS
Transect D	54°42'	29°04'	24.08.2004	0	0	VS
Transect B	54°39'	29°02'	15.10.2004	0	0	VS
Station S1	54°38'	29°05'	15.10.2004	0	0	VS

Annex 1
(continued)

Transect/Station	Record coordinates**		Survey date	Range of abundance (indiv./m^2)	Range of biomass (g/m^2)	Collector
	Latitude, °N	Longitude, °E				
Transect A	54°37'	29°02'	04.06.2005	0	0	SM, VS
Transect B	54°39'	29°02'	04.06.2005	0	0	SM, VS
Transect C	54°41'	29°04'	04.06.2005	200	7.3	SM, VS
Transect D	54°42'	29°04'	04.06.2005	0	0	SM, VS
Station S1	54°38'	29°05'	04.06.2005	80	2.5	SM, VS
Station S2	54°37'	29°05'	04.06.2005	0	0	SM, VS
Station S5	54°39'	29°07'	04.06.2005	0	0	SM, VS
Transect A	54°37'	29°02'	14.08.2005	0–1000	0–56.4	SM, VS
Transect B	54°39'	29°02'	14.08.2005	0–880	0–21.4	SM, VS
Transect C	54°41'	29°04'	14.08.2005	0	0	SM, VS
Transect D	54°42'	29°04'	14.08.2005	0	0	SM, VS
Transect E	54°42'	29°06'	14.08.2005	0–40	0–3.8	SM, VS
Station S3	54°40'	29°05'	14.08.2005	0	0	SM, VS
Station S4	54°40'	29°07'	14.08.2005	0	0	SM, VS
Station S5	54°39'	29°07'	14.08.2005	0–640	0–12.9	SM, VS
Transect A	54°37'	29°02'	10.10.2005	0	0	SM, VS
Transect B	54°39'	29°02'	10.10.2005	0	0	SM, VS
Transect C	54°41'	29°04'	10.10.2005	120	5.4	SM, VS
Transect D	54°42'	29°04'	10.10.2005	0	0	SM, VS
Station S1	54°38'	29°05'	10.10.2005	40	0.72	SM, VS

*Full reference to the data: Mastitsky SE and Samoilenko VM (2006) The gravel snail, *Lithoglyphus naticoides* (Gastropoda: Hydrobiidae), a new Ponto-Caspian species in Lake Lukomskoe (Belarus). Aquatic Invasions 1(3): 161-170
**Coordinates are provided for initial transects' points and stations

Annex 2

Images of *L. naticoides* collected in Lake Lukomskoe: A: View from the orifice of the shell; B: View from the top of the shell, C: *L. naticoides* usually lay eggs onto the shells of each other. This photo shows an individual bearing five embryos (collected on 30 May 2006; 54°38'N, 29°06'E), D: Two juveniles of zebra mussels attached to adult individual of *L. naticoides (*photo by Sergey Mastitsky*)*