Folia Malacol. 21(2): 73–86
FOLIA MALACOLOGICA
ISSN 1506-7629
The Association of Polish Malacologists
& Faculty of Biology, Adam Mickiewicz University
Poznań 2013
http://dx.doi.org/10.12657/folmal.021.008

MOLLUSCS OF THE MIDDLE AND LOWER ODRA: THE ROLE OF THE RIVER IN THE EXPANSION OF ALIEN SPECIES IN POLAND

ANDRZEJ PIECHOCKI[1*], AGNIESZKA SZLAUER-ŁUKASZEWSKA[2]

[1]Department of Invertebrate Zoology and Hydrobiology, University of Łódź, Banacha 12/16, 90-237 Łódź, Poland (e-mail: piech@biol.uni.lodz.pl)
[2]Department of Invertebrate Zoology and Limnology, University of Szczecin, Wąska 13, 71-415 Szczecin, Poland (e-mail: aszlauer@gmail.com)
*corresponding author

ABSTRACT: The malacofauna of the middle and lower Odra (Oder River), a large river degraded by human activities, is still rich and diversified. Fifty five mollusc species were recorded from 31 studied localities: 32 Gastropoda and 23 Bivalvia. The highest number of species (47) inhabited the areas between groynes, whereas the fewest species (20) were found in the river current outside groynes. As many as 14.5% of the recorded species were alien to the Polish fauna: *Lithoglyphus naticoides*, *Potamopyrgus antipodarum, Physella acuta, Ferrissia fragilis, Menetus dilatatus, Corbicula fluminalis, C. fluminea*, and *Dreissena polymorpha*. The presence of so many alien species shows that the Odra, together with the system of canals (which through the Spree and the Havel connect it to the drainage basin of the Elbe), is a major route along which alien molluscs migrate to Poland.

KEY WORDS: molluscs, river, oxbows, groynes, canals, alien species

INTRODUCTION

The molluscan fauna of the Odra (Oder River), like those of the other large Polish rivers, has not been sufficiently studied. This is reflected, for instance, by the absence of monographic studies on the whole molluscan fauna inhabiting the largest rivers that would take into account the habitats of the current, the river margin, and water bodies situated in the flood plains. So far, the most extensive data on the occurrence of benthic macrofauna in the upper, middle, and lower courses of the Odra and its tributaries have been provided by the surveys of the International Commission for the Protection of the Odra against Pollution (SCHÖLL et al. 2003). That study features 26 snail species and 14 bivalve species detected along the whole river course, but unfortunately the localities of particular species (names of towns or villages) are not mentioned. More or less comprehensive contributions to the knowledge about molluscs of selected stretches of the Odra and its valley have been made by LEHMANN (1873), BOETTGER (1926), JAECKEL (1955), TETENS & ZEISSLER (1964), HASTRICH (1994), BRINKMANN et al. (1997), SCHMID (1999), JANICKI (2002), DOMAGAŁA et al. (2003, 2004), ŁABĘCKA et al. (2005), MÜLLER et al. (2007), WAWRZYNIAK-WYDROWSKA (2007), WILKE (2007) and ZETTLER (2012).

In 2009–2011, research was carried out within the project "Groynes as a factor shaping anthropogenic habitats in rivers: an analysis of the complex of benthos, plankton and periphyton in isolated still-water bodies between groynes as exemplified by the middle and lower course of the Odra River". It focused on the specific, anthropogenic river habitat with a slow current, between groynes protecting the river banks. Activities of the research team were coordinated by the second author of this paper. The major aim of the project was to evaluate the areas between groynes, referred to as groyne fields, in this

large lowland river as habitats contributing to an increase in biological biodiversity. Among benthic organisms, molluscs constituted ca. 25% of the total number of collected specimens (1.7% Bivalvia and 23% Gastropoda). The rich malacological material of 335 snail and bivalve samples provided a reliable basis for publishing the research results. The examined malacofauna of the middle and lower Odra contained a large proportion of alien species, suggesting a crucial role of the water route in their expansion over the territory of Poland. This assumption is supported by the presence of the Odra-Spree Canal and the Odra-Havel Canal, connecting the river system of the Elbe to those of the Odra and Vistula (via the Bydgoszcz Canal).

STUDY AREA

The Odra, the second largest Polish river, constitutes one of the six largest river systems of Europe. It is 854.3 km long (741.9 km situated at least partly within Poland), and its drainage basin encompasses 118,861 km^2 (106,821 km^2 in Poland). The average annual flow, according to a water gauge in Hohensaaten-Finow, amounts to ca. 17 milliard m^3, which corresponds to the average flow rate of 540 m^{3}s^{-1} (DUBICKI & BŁACHUTA 1999). The character of the Odra is determined by extensive regulatory works conducted along its course and the fact that it has been connected by canals to the other river systems of Europe. Since the beginning of the 18th century, stone groynes have been constructed in order to move the main current away from the river banks; altogether, ca. 10,000 such groynes have been built (RAST et al. 2000). Between the groynes, especially the longest ones, groyne fields have formed, characterised by slow water flow and in some places even the absence of any flow. In such areas, organic and mineral matter accumulates. In the course of the regulation works, as a result of shortening and straightening of the river course, many former meanders became oxbow lakes. Some of them are still permanently connected to the main course of the river. Groyne fields and oxbow lakes represent lentic environments in the river system of the Odra.

Our research was conducted along a 306-km stretch of the river: from Uraz near Wrocław (51°14'55.5"N, 16°50'46.57"E) to Ognica near Szczecin (53°3'33.6"N, 14°21'14.3"E) (Fig. 1). In this stretch, the Odra is a large, well-developed lowland river, 120–270 m wide. The depth of the river-bed at average water level is 0.8–1.9 m in the upper section and 3.5–4.3 m in the lower section (MARSZAŁEK 2003). The river-bed is mostly covered by sand and gravel sediment.

The banks of the studied stretch of the Odra are protected by groynes along almost all of its length (Fig. 2). Because of considerable length and height of the groynes, large isolated still-water bodies – groyne fields – form between them. Where the current is weak, crevices between the stone blocks as well as their surfaces become covered by sand or silt sediments, whereas in places exposed to a stronger current, the blocks remain bare.

In the groyne fields (Fig. 3), silt sediment prevails; littoral vegetation is dominated by reed canarygrass (*Phalaris arundinacea*), and elodeid communities also frequently develop there. In the groyne fields, especially at the bases of groynes, the current is slow, and sand and silt fractions prevail in the bottom sediments. The areas in front of groynes, especially at their tips, are characterised by heavy turbulence and the bottom composed of gravel and sand. Conditions in groyne fields somewhat resemble those found in lake littoral. Lentic habitats develop at the bases of groynes, with the bottom composed of fine-grained sediments, rich in organic matter, similar to the littoral of a eutrophic lake. The central, deepest parts of the groyne fields resemble lake sublittoral. They are characterised by sandy sediments, often with traces of deoxidation, and the presence of large boulders and shell debris (Fig. 3).

The studied oxbow lakes (Fig. 4) are permanently connected to the Odra and most of them retain the shape of former meanders. Their length varies from 520 to 5,000 m, whereas their width ranges between 20 and 630 m. In the oxbows sand and silt sediments prevail, characterised by high organic matter content. Sedges (*Carex* spp.) dominate in the littoral zone, accompanied by elodeids, nymphaeids and helophytes, and also meadow vegetation when the water level is high.

MATERIAL AND METHODS

Benthos samples were collected from 31 localities distributed along the middle and lower courses of the Odra (Fig. 1, Table 1). Molluscs were collected from groyne fields (g, 15 sampling sites); from the current at the tips of the groynes (s, 15); control sites (c, 4); and oxbow lakes (o, 12). The control sites were situated in the area of the Odra without groynes, but close to the research sites, so that they reflected the character of the river.

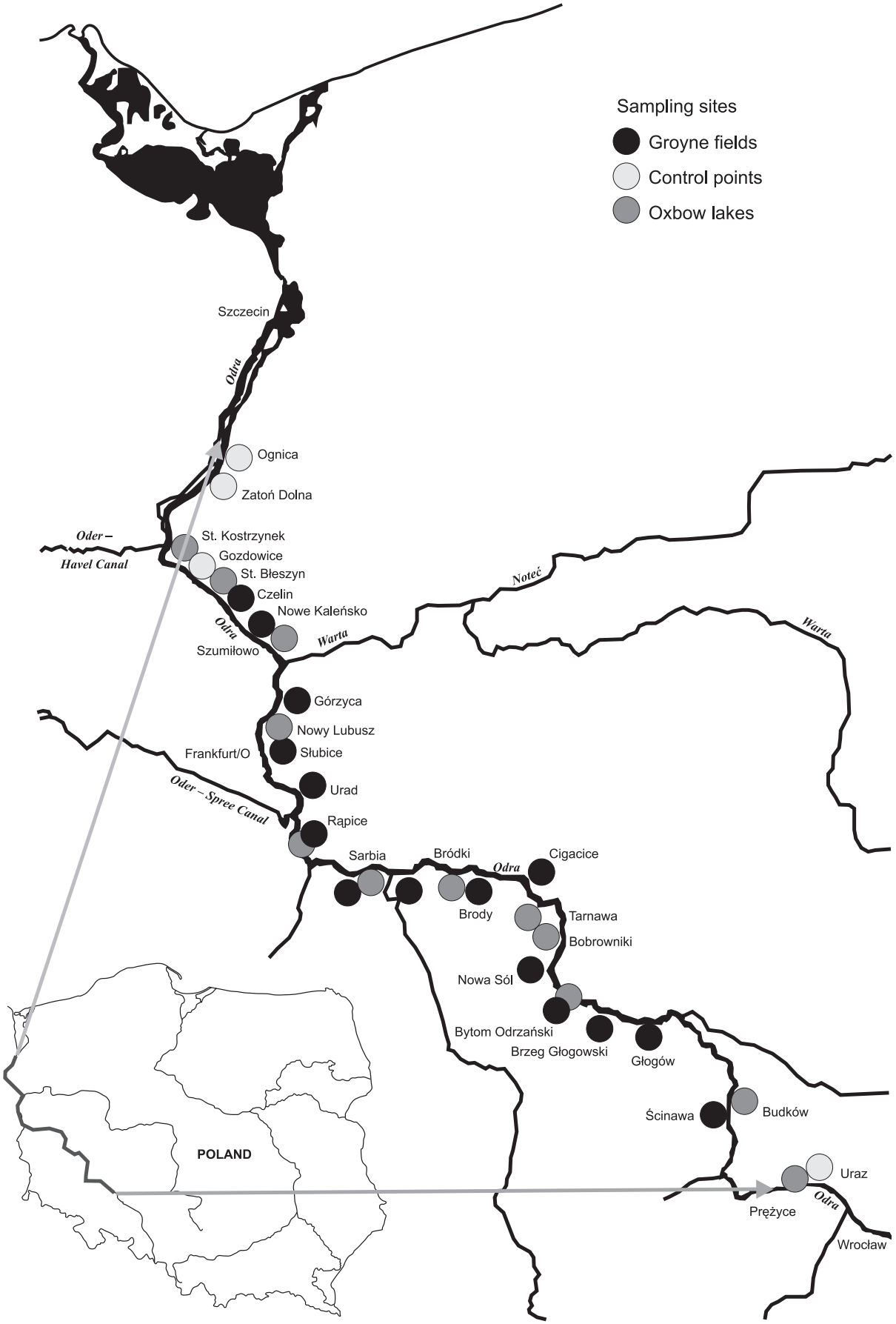

Fig. 1. The studied stretch of the Odra River with research sites

Fig. 2. The Odra River in Nowa Sól, with visible groynes (Photo: A. SZLAUER-ŁUKASZEWSKA)

Material was collected in 2009–2010, in the spring, summer, and autumn. In total, 335 mollusc-containing samples were collected, including 242 samples from the area of groynes, i.e. 213 from groyne fields and 29 from the current at the tips of the groynes; 35 samples from control sites and 58 from oxbow lakes.

The material was collected with a triangular drag net, side length of 25 cm, maximum handle length

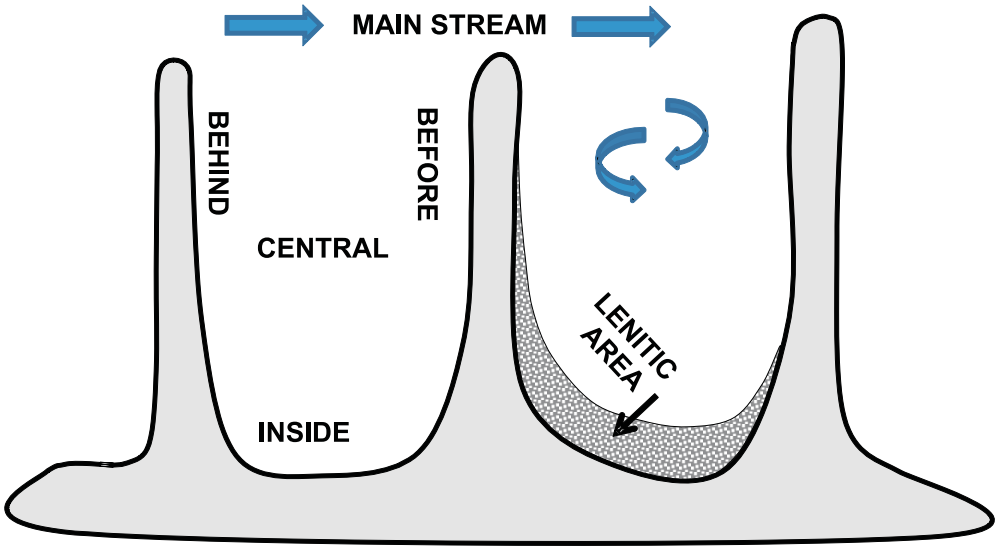

Fig. 3. Diagram showing distribution of particular habitat zones within groyne fields. Blue arrows show directions of water movement

Fig. 4. An oxbow lake of the Odra River in Błeszyn (Photo: A. SZLAUER-ŁUKASZEWSKA)

4 m, which allowed penetration of sediments between stone blocks and collection of samples from greater depths. In the field, silt was rinsed off the samples placed on the 50-µm net, and larger debris (e.g. pieces of rock, timber and leaves) was removed on a sieve with mesh size of 5 mm (larger macrobenthic organisms were collected by hand at that stage). Sand and gravel sediments were subjected to sedimentation by stirring the sediment in a water-filled container and decanting from the surface of the sediment the organisms whose specific weight was smaller than the weight of the sediment. The procedure was repeated many times in order to remove mineral fraction. Then the samples were fractioned on a sieve with mesh size of 3.0 mm into macro- and meiobenthos and preserved in 98% ethanol. In the laboratory, molluscs were collected from samples prepared in this way.

RESULTS

Fifty five mollusc species were identified in the studied material (32 Gastropoda and 23 Bivalvia) (Table 1). Species alien to Poland, as well as species protected in Poland, constituted a considerable part of the malacofauna. Alien species were represented by the snails *Lithoglyphus naticoides*, *Potamopyrgus antipodarum, Physella acuta, Ferrissia fragilis, Menetus dilatatus*, and the bivalves *Corbicula fluminalis*, *C. fluminea,* and *Dreissena polymorpha*. Protected species included *Borysthenia naticina* (Gastropoda) as well as *Anodonta cygnea, Sphaerium rivicola*, and *S. solidum* (Bivalvia). Alien mollusc species constituted 14.5% of all detected species, but in terms of density they accounted for as much as 80% of the total catch.

The most common species in the studied stretch of the Odra, present in the highest percentage of mollusc-containing samples (n = 335) and found in the highest number of sites (out of the total of 31), included:

1. *Potamopyrgus antipodarum* – 49.1% of samples, 21 sites
2. *Viviparus viviparus* – 39.8%, 21

Table 1. List of molluscs recorded in groyne fields (g), in the stream at the tips of groynes (s), control sites (c), and oxbow lakes (o) of the middle and lower Odra River

	Uraz	Prężyce	Ścinawa	Budków	Głogów	Brzeg Głogowski	Bytom Odrzański	Nowa Sól	Bobrowniki	Tarnawa	Cigacice	Brody	Bródki	Krosno Odrzańskie	Sarbia	Połęcko	Rapice	Urad	Słubice	Górzyca	Nowe Kaleńsko	Szumiłowo	Czelin	Gozdowice	Stary Błeszyn	Stary Kostrzynek	Zatoń Dolna	Ognica
Gastropoda																												
Neritidae																												
1. *Theodoxus fluviatilis* (Linnaeus, 1758)																g												
Viviparidae																												
2. *Viviparus contectus* (Millet, 1813)				o													g			g				c				
3. *Viviparus viviparus* (Linnaeus, 1758)	c	o		o	g	g		g, s			g	g, s		g		g, s	g, o, s	g, s	g, s	g, s	g		g	c	o	o	c	c
Bithyniidae																												
4. *Bithynia leachii* (Sheppard, 1823)		o															o								o			
5. *Bithynia tentaculata* (Linnaeus, 1758)	c	o	g	o	g, s		g	g, s	o	o	g	g, s	o	g		g	g, o	g	g	g	g	o	g	c	o	o		c
5a. *Bithynia tentaculata* f. *producta* Menke, 1828					g						g			g														
Hydrobiidae																												
6. *Lithoglyphus naticoides* (C. Pfeiffer, 1828)	c							g				g		g		g	g											
7. *Potamopyrgus antipodarum* (Gray, 1843)	c	o	g, s		g, s	g, s	g	g, s	o		g, s	g, s		g, s		g	g, o, s	g, s	g, s	g, s	g, s		g	c		o		c
Valvatidae																												
8. *Borysthenia naticina* (Menke, 1845)					g																							
9. *Valvata cristata* O. F. Müller, 1774	c	o		o								g	o													o		
10. *Valvata piscinalis* (O. F. Müller, 1774)	c	o	g		g		g	g	o	o	g	g, s	o	g	o	g	g, o, s	g		g, s	g	o	g	c		o		c
Acroloxidae																												
11. *Acroloxus lacustris* (Linnaeus, 1758)												g, s																
Lymnaeidae																												
12. *Galba truncatula* (O. F. Müller, 1774)		o	g		g	g		g	o		g	g		g		g	g	g, s		g	g		g					
13. *Lymnaea stagnalis* (Linnaeus, 1758)		o		o	g			g	o	o	g	g	o	g		g	g, o, s	g, s	g	g	g	o	g	c	o	o		c
14. *Radix auricularia* (Linnaeus, 1758)		o									g					g	g, o	g	g	g	g		g	c				c
15. *Radix balthica* (Linnaeus, 1758)	c	o		o	g					o	g		o			g	g, o		g		g, s	o	g	c	o	o		
16. *Stagnicola palustris* (O. F. Müller, 1774)											g	g		g		g				g			g					c
Physidae																												
17. *Physa fontinalis* (Linnaeus, 1758)	c			o					o	o	g		o						g	g	g	o	g		o	o		
18. *Physella acuta* (Say, 1817)	c	o			g				o		g, s	g		g		g	g, s	g, s	g, s	g, s	g		g	c		o		c
Planorbidae																												
19. *Ancylus fluviatilis* O. F. Müller, 1774								g								g							g					c
20. *Anisus leucostoma* (Millet, 1813)																										o		
21. *Anisus spirorbis* (Linnaeus, 1758)						g				o										g						o		
22. *Anisus vortex* (Linnaeus, 1758)				o					o	o	g		o	g		g	g, o				g	o		c	o	o		
23. *Bathyomphalus contortus* (Linnaeus, 1758)	c																								o			
24. *Ferrissia fragilis* (Tryon, 1863)																	g											
25. *Gyraulus albus* (O. F. Müller, 1774)						g			o	o	g		o	g	o		g, o			g	g, s	o						c

	Uraz	Prężyce	Ścinawa	Budków	Głogów	Brzeg Głogowski	Bytom Odrzański	Nowa Sól	Bobrowniki	Tarnawa	Cigacice	Brody	Bródki	Krosno Odrzańskie	Sarbia	Połęcko	Rapice	Urad	Słubice	Górzyca	Nowe Kaleńsko	Szumiłowo	Czelin	Gozdowice	Stary Błeszyn	Stary Kostrzynek	Zatoń Dolna	Ognica
26. *Gyraulus crista* (Linnaeus, 1758)				o									o				g											
27. *Hippeutis complanatus* (Linnaeus, 1758)										o			o								g	o						
28. *Menetus dilatatus* (Gould, 1841)																	g											
29. *Planorbarius corneus* (Linnaeus, 1758)	c										g		o			g	g, o	g		g	g			c	o	o		
30. *Planorbis carinatus* O. F. Müller, 1774																					s	o						
31. *Planorbis planorbis* (Linnaeus, 1758)	c	o		o	g	g			o	o	g	g		g		g	g, o	g	g	g	g	o		c	o	o		c
32. *Segmentina nitida* (O. F. Müller, 1774)																									o		c	
Bivalvia																												
Unionidae																												
1. *Anodonta anatina* (Linnaeus, 1758)								g	o					g		g	g				g			c				
2. *Anodonta cygnea* (Linnaeus, 1758)								g																				
3. *Unio pictorum* (Linnaeus, 1758)		o	g					g	o		g						g, o	g		s					o			
4. *Unio tumidus* Philipsson, 1788		o			g			g	o		g	g		g		g		g		g	g			c				
Corbiculidae																												
5. *Corbicula fluminalis* (O. F. Müller, 1774)					g																							
6. *Corbicula fluminea* (O. F. Müller, 1774)					g	g, s	g	g, s			g, s	g		g, s		g, s	s	g, s	g									
Sphaeriidae																												
7. *Musculium lacustre* (O. F. Müller, 1774)	c	o			g							g			o	g	g			g								
8. *Pisidium amnicum* (O. F. Müller, 1774)																					g							
9. *Pisidium casertanum* (Poli, 1791)	c	o			g						g, s				o		g											
10. *Pisidium crassum* Stelfox, 1918																g			g									
11. *Pisidium henslowanum* (Sheppard, 1823)	c	o			g	g	g	g			g, s	g, s		g	o	g	g, s	g	g, s	s								
12. *Pisidium milium* Held, 1836														g														
13. *Pisidium moitessierianum* (Paladilhe, 1866)	c				g	g		g			g	g		g		g			g									
14. *Pisidium nitidum* Jenyns, 1832	c																g											
15. *Pisidium personatum* Malm, 1855		o																										
16. *Pisidium ponderosum* (Stelfox, 1918)	c															g												
17. *Pisidium pulchellum* Jenyns, 1832							g										g				g							
18. *Pisidium subtruncatum* Malm, 1855	c	o		o	g			g	o	o	g	g, s		g, s	o	g	g, o			g	g							
19. *Pisidium supinum* A. Schmidt, 1851	c				g	g	g	g			g	g, s		g, s		g	g	g, s	g				g					
20. *Sphaerium corneum* (Linnaeus, 1758)	c			o									o				g	g		g	g		g					
21. *Sphaerium rivicola* (Lamarck, 1818)	c	o	g		g		g	g, s				g, s		g		g, s		g	s	g	g			c				
22. *Sphaerium solidum* (Normand, 1844)	c				g		g	g, s			g, s	g, s		g		g			g									
Dreissenidae																												
23. *Dreissena polymorpha* (Pallas, 1771)	c	o	g		g	g, s		g, s				g, s		g		g, s	g, o, s	g	g	g				c			c	c

3. *Bithynia tentaculata* – 32.9%, 25
4. *Valvata piscinalis* - 25.7%, 23
5. *Lymnaea stagnalis* – 24.2%, 22
6. *Physella acuta* – 23.3%, 17
7. *Corbicula* spp. (*C. fluminalis* + *C. fluminea*) – 17.7%, 12[1]
8. *Dreissena polymorpha* – 15.3%, 16
9. *Planorbis planorbis* – 12.9%, 21
10. *Galba truncatula* – 11.4%, 15

Most of these species occurred along the whole studied part of the river. *Bithynia tentaculata* f. *producta* and *Menetus dilatatus* had never been reported from the Odra before.

The richest malacofauna inhabited the groyne fields (g), where 51 mollusc species were recorded (29 Gastropoda, 22 Bivalvia) (Table 1). The following species were found solely in such fields: *B. tentaculata* f. *producta*, *B. naticina*, *M. dilatatus*, *F. fragilis*, and *A. cygnea*. The most abundant snail species included: *P. antipodarum* (80% !), *V. piscinalis* (2.7%), *G. truncatula* (2.4%), and *B. tentaculata* (2.3%). Furthermore, a high representation of the Sphaeriidae (15 species) was significant, including such orb mussels as *S. rivicola* and *S. solidum*.

Samples from the current at the tips of the groynes (s) yielded the poorest fauna: 20 species (11 Gastropoda, 9 Bivalvia) (Table 1). The most abundant snail species were *P. antipodarum* (45%) and *B. tentaculata* (8%), whereas the most abundant bivalve was *Pisidium henslowanum* (6%).

Almost equal numbers of mollusc species were detected in the oxbow lakes (o) and control sites (c) situated outside the area with groynes: 36 and 35, respectively (Table 1). Stagnophilous snails, such as *P. acuta, P. planorbis,* and *V. piscinalis*, dominated in the oxbows; each of these species constituted ca. 10% of the total number of collected snails. Interestingly, *P. antipodarum* constituted merely 4% of the total. In the control zone, *P. antipodarum* and *V. viviparus* dominated, each of them accounting for 17% of the total number of detected snails. Both reophilous (*L. naticoides*, *Ancylus fluviatilis*, *S. rivicola*) and stagnophilous species (e.g. *P. planorbis*) were found in the control zone.

The presence of *Lithoglyphus naticoides* (Fig. 5) among alien species is worth mentioning, as it represents the Ponto-Caspian element in the Polish fauna. It was found in six localities along the stretches of the river between Nowa Sól and Urad. The distance from the Odra-Spree Canal (marked by the earlier presence of that snail species) was 13 km downriver and 123 km upriver (Table 1). The species was most frequent in groyne fields, where its density ranged from 1 to over 500 indiv.m^{-2}.

[1] Considered jointly due to the fact that reliable identification of young individuals was impossible.

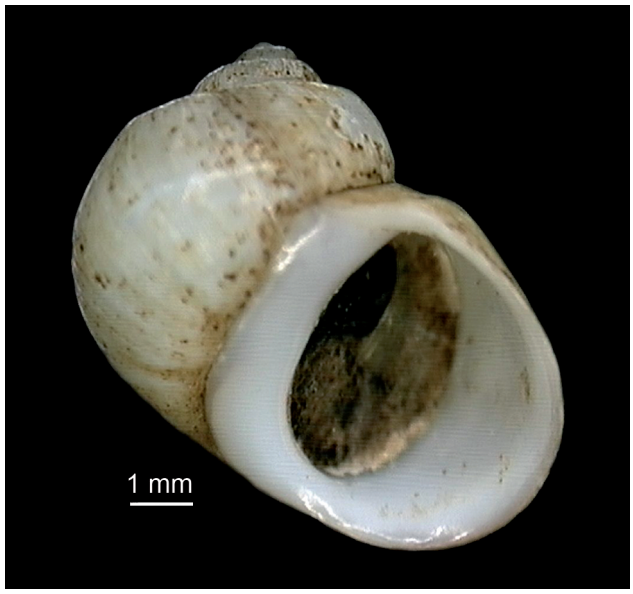

Fig. 5. *Lithoglyphus naticoides*, a Ponto-Caspian element in the fauna of the Odra River (Photo: B. WAWRZYNIAK-WYDROWSKA)

Fig. 6. *Potamopyrgus antipodarum*, an invasive species originating from New Zealand (Photo: B. WAWRZYNIAK-WYDROWSKA)

Potamopyrgus antipodarum (Fig. 6), an invasive species originating from New Zealand, is presently the most common and most abundant snail species in the Odra. Its mass occurrence was recorded along the whole river course, where it inhabited groyne fields as well as oxbow lakes and the river current near the tips of groynes. However, in the groyne fields its relative abundance was the highest, namely 80%, and in the oxbow lakes it was the lowest, amounting to only 4%. In many locations the abundance of *P. antipodarum* was considerable, reaching up to 6,800 indiv.m^{-2}, while the average density amounted to 260 indiv.m^{-2}. The highest density of that snail species was found in the material collected in the upper part of the studied stretch of the river, between Ścinawa and Połęcko. *P. antipodarum* was found on sandy bottom, bottom composed of sand and silt, on pieces of rock, and on aquatic plants.

Physella acuta (Fig. 7), a snail species introduced in Europe probably from North America, was found along the whole course of the Odra and inhabited all the studied parts of the river (Table 1). However, its relative abundance was the highest in the oxbow lakes (11%) and control sites (4%). Adult specimens were characterised by significant shell sizes (up to 15.5 mm high), and the spire/aperture height ratio was, on average, 1:2.05 (from 1:1.63 to 2:2.4). Such proportions are typical of the bladder snail identified as *P. heterostropha* (GLÖER 2002). However, since the specific rank of this taxon has recently been questioned (see Discussion), it is here classified as *P. acuta*.

Fig. 7. *Physella acuta*, a cosmopolitan species of North American origin (Photo: B. WAWRZYNIAK-WYDROWSKA)

Ferrissia fragilis, the species most often referred to under synonymous names *F. clessiniana* (Jickeli, 1882) and *F. wautieri* (Mirolli, 1960), also represents the North American element in the Polish fauna. A single specimen found in groyne fields in Rąpice, near the mouth of the Odra-Spree Canal, represented the so-called septal form, with a horizontal septum which is believed to develop under adverse conditions, e.g. low water level, oxygen deficit, etc. (RICHARDOT 1976). *F. fragilis* is known from a number of locations scattered over Greater Poland, Mazovian Lowland and Upper Silesia (STRZELEC 2011), where it occurs as an ancylid form devoid of septum. The only other record of the septal form in Poland is a flooded subsidence basin surrounded by forest, situated near Zabrze (SPYRA 2008).

Menetus dilatatus (Fig. 8A–C) is another North American introduction. In North America it occurs along the Atlantic coast, from Nova Scotia to Florida, ranging west to the Mexican Plateau, Texas, Oklahoma, and central and northern California (JOKINEN 1992). Previously, in Poland it had been found only in the Konin Lakes, fed by heated effluent water discharged by a power plant (BERGER & DZIĘCZKOWSKI 1977). A single specimen of this rare freshwater snail was found in the groyne fields in Rąpice, where it occurred together with *F. fragilis*.

Borysthenia naticina (Fig. 9), a protected species, one of the rarest in the Polish malacofauna, was observed only in Głogów, where six adult specimens were found in two samples collected from the groyne fields. The find confirmed the results of a recent research conducted by ZETTLER (2012), who recorded *B. naticina* near the town of Stützkow, in the lower course of the river. The coincident observations indicate that the Odra is still a refugium of this interesting and poorly studied species.

Another noteworthy mollusc is the rare form of *Bithynia tentaculata* f. *producta*, found near the groynes in Głogów, Cigacice and Krosno Odrzańskie. The form is characterised by larger shell dimensions than the typical *B. tentaculata* and a narrowing of the body whorl. The largest specimen was 13.2 mm high and 7.4 mm wide. As for smaller bivalves, the pill-clam *Pisidium crassum* is worth mentioning; encountered mainly in Polish lakes (PIECHOCKI 1989), it was found in the groyne fields in Połęcko and Słubice.

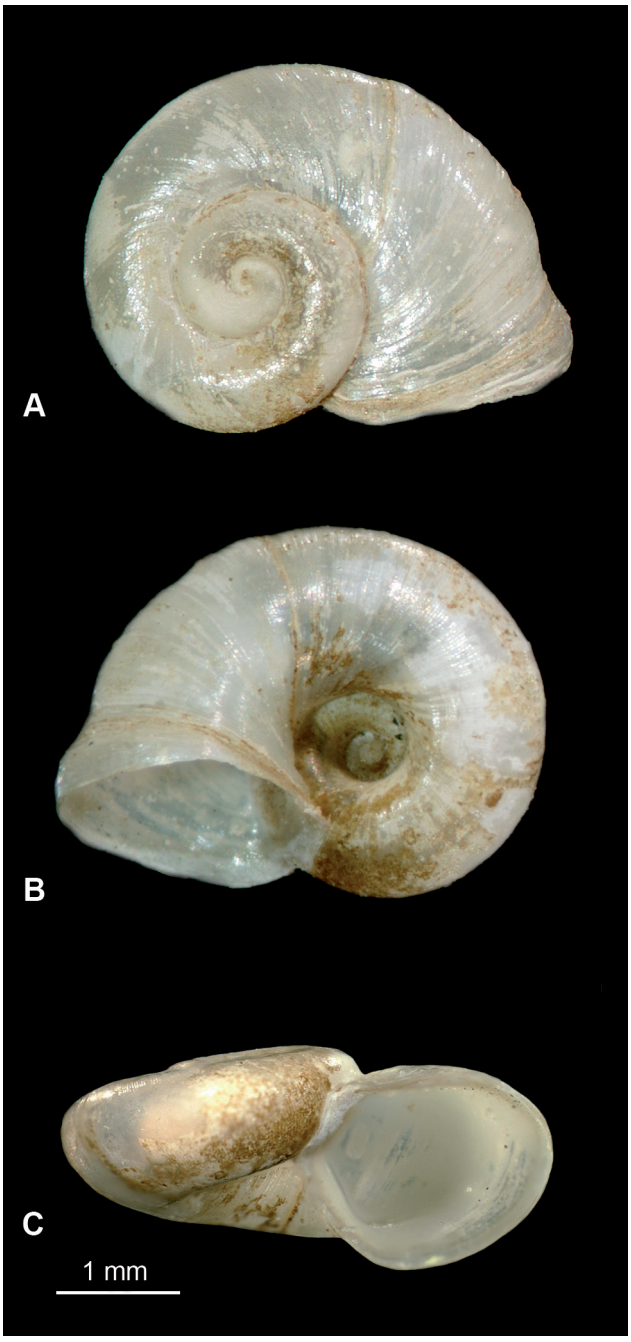

Fig. 8. *Menetus dilatatus*, a recent immigrant from North America: A – apical view, B – umbilical view, C – apertural view (Photo: B. WAWRZYNIAK-WYDROWSKA)

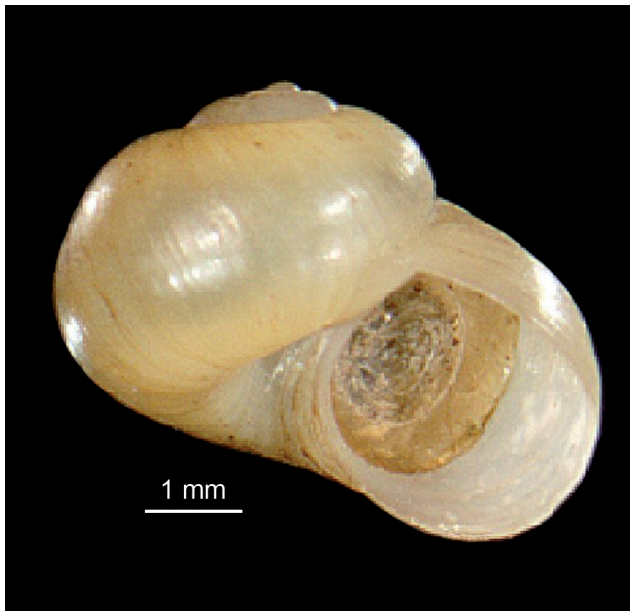

Fig. 9. *Borysthenia naticina*, a protected species, one of the rarest snails in Poland (Photo: B. WAWRZYNIAK-WYDROWSKA)

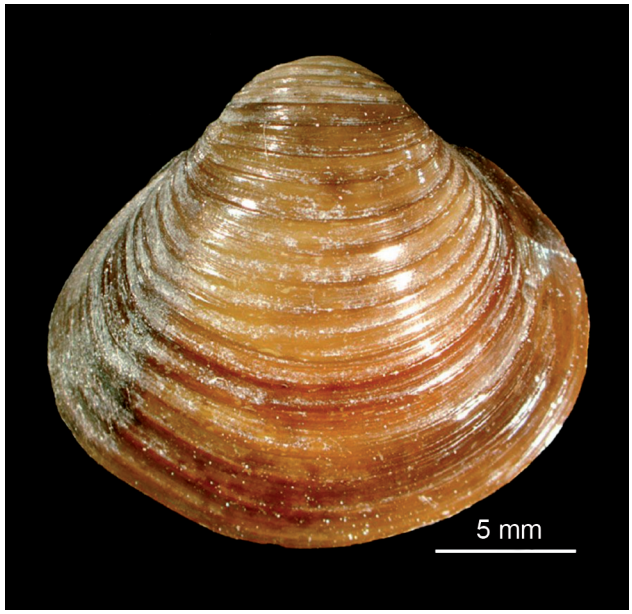

Fig. 10. *Corbicula fluminea*, an invasive species originating from the drainage basin of the Ussuri River (Photo: B. WAWRZYNIAK-WYDROWSKA)

Bivalves of the genus *Corbicula* (Figs 10 and 11) occurred frequently and in large numbers along almost the whole middle stretch of the Odra, from Uraz to Słubice. In most locations they were represented by *C. fluminea*, but in Głogów, Rąpice, and Urad, *C. fluminalis* was also recorded (Table 1). Most of the collected specimens were juvenile; due to insufficiently developed taxonomic features they could not be reliably identified and thus it was impossible to trace possible differences in distribution of the two species along the river course. The considerable number of young specimens is a proof of *Corbicula*'s expansion over the drainage basin of the Odra. According to KOŁODZIEJCZYK & ŁABĘCKA (2011), *C. fluminalis* is an Asian species, whose native range encompasses northern Iran, Afghanistan, a considerable part of Mesopotamia (Iraq, Syria, Kuwait, Turkey), South Caucasus, India, and Kashmir, whereas *C. fluminea* originates from the drainage basin of the Ussuri River, the south-eastern part of China and Korea (STAŃCZYKOWSKA & KOŁODZIEJCZYK 2011).

Fig. 11. *Corbicula fluminalis*, an invasive species originating from Asia (Photo: B. WAWRZYNIAK-WYDROWSKA)

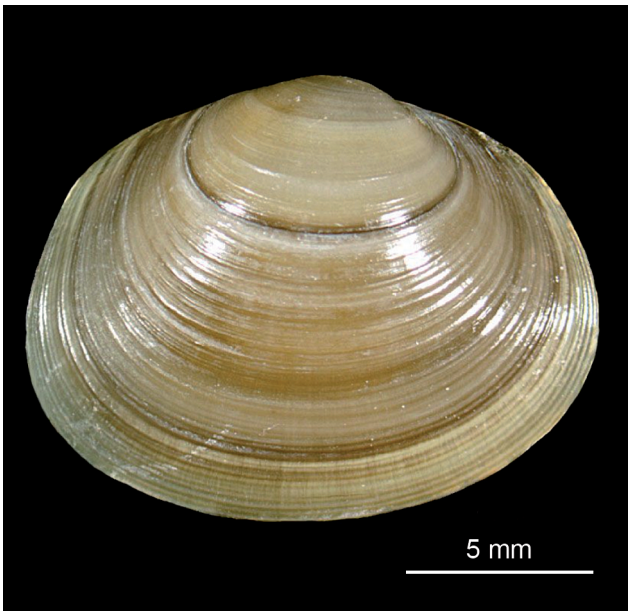

Fig. 12. *Sphaerium rivicola*, a protected species, common along the course of the Odra River (Photo: B. WAWRZYNIAK-WYDROWSKA)

Dreissena polymorpha, an invasive species native to the Ponto-Caspian area, is presently widespread across Poland and Europe, and since 1985 also in North America (STAŃCZYKOWSKA & LEWANDOWSKI 2011). In the middle and lower Odra it was one of the most frequent molluscs, but in the collected samples it was not abundant. This could be associated with the sampling method, which focused on loose sediments (sand, silt) and not on hard surfaces to which the mussel attaches itself with byssus threads. *D. polymorpha* was recorded in the groyne fields, oxbow lakes, and at the tips of groynes. Its recordes from the environs of Wrocław (Uraz, Prężyce, Ścinawa) extended the range of the species southward in comparison to recently published data (STAŃCZYKOWSKA & LEWANDOWSKI 2011).

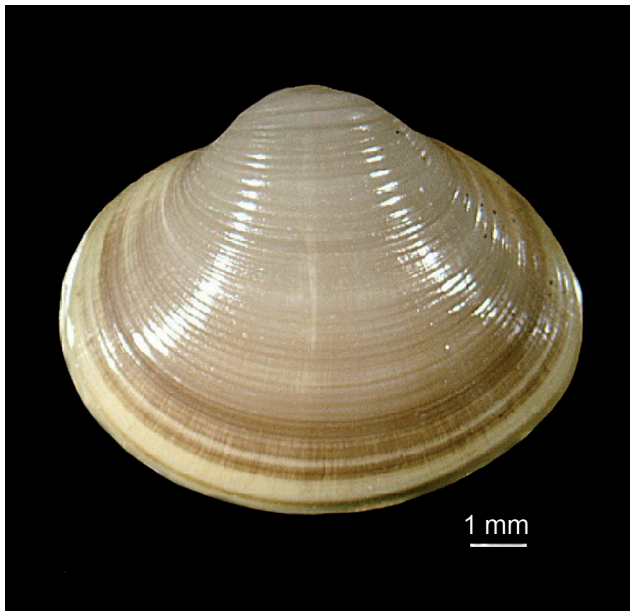

Fig. 13. *Sphaerium solidum*, a protected species, one of the rarest Polish bivalves, still relatively frequent and abundant in the Odra River (Photo: B. WAWRZYNIAK-WYDROWSKA)

Bivalves of the genus *Sphaerium*, *S. rivicola* (Fig. 12) and *S. solidum* (Fig. 13), believed to be endangered with extinction in Poland (VU and EN categories; DYDUCH-FALNIOWSKA & ZAJĄC 2002), were relatively abundant and frequent in the studied stretch of the Odra. *S. rivicola* was recorded in 14 sites along almost the whole river course, whereas *S. solidum* was encountered in nine localities (Table 1). Both species inhabited the groyne fields and control sites. A single occurrence of *S. rivicola* was recorded in an oxbow lake. However, both species were most frequent in the groyne fields.

The swan mussel (*Anodonta cygnea*) was found only in the sand and silt sediment in the groyne field in Nowa Sól. Habitats of that type, distributed along the river course, are characteristic of the occurrence of *A. cygnea*, and the species is likely to be found in a greater number of localities. Other protected mussels – *Pseudanodonta complanata* and *Unio crassus* – undetected in our research, still occur in the Odra. This is suggested by the data published by GLÖER & MEIER-BROOK (2003: distribution map, p. 74), SCHÖLL et al. (2003), ZAJĄC (2004), and ZETTLER (1997: distribution map, p. 215).

DISCUSSION

In spite of the common opinion that pollution and regulation of the river-bed have an adverse effect on benthic organisms, the malacofauna of the Odra – a heavily degraded river – is still rich and diversified. The total number of species recorded in the Odra (including those recorded by other authors and undetected in this study) is 67 (40 Gastropoda, 27 Bivalvia), which constitutes 76.1% of the total freshwater malacofauna of Poland (PIECHOCKI & SULIKOWSKA-DROZD 2008). Species complementing the list of 55 taxa in Table 1 include *Bithynia troscheli*, *Marstoniopsis scholtzi*, *Valvata macrostoma*, *Stagnicola corvus*, *Myxas glutinosa*, *Aplexa hypnorum*, *Anisus vorticulus*, *Gyraulus riparius*, *Unio crassus*, *Pseudanodonta complanata*, *Sinanodonta woodiana* and *Pisidium obtusale*. It ought to be remembered, however, that the research carried out in 2009–2011 did not encompass the whole course of the Odra.

We did not take into account three species occurring in the Odra according to JEACKEL (1955) and SCHÖLL et al. (2003): *Radix ovata*, *R. peregra* and *Physella heterostropha*. According to GLÖER (2002) *R. ovata* is a junior synonym of *R. balthica,* while *R. peregra* – a synonym of *R. labiata* – does not occur in the river, and *P. heterostropha* is a synonym of *Physella acuta* (see below). The occurrence in the Odra of such species as *Stagnicola fuscus* and *S. turricula*, listed by BOETTGER (1926) as forms of *S. palustris*, and *Omphiscola glabra* recorded by SCHÖLL et al. (2003), is dubious. According to BARGUES et al. (2006), *S. turricula* is identical with *S. palustris*, whereas the remaining two species do not occur in Poland (JACKIEWICZ 1998).

Our research has shown that groyne fields provide an exceedingly favourable habitat for molluscs. This is probably associated with the presence of various kinds of bottom (silty, sandy, rocky, and vegetated) in a small area, so that species of various ecological requirements can exist in close proximity. An additional favourable factor is probably that of diversified water flow velocity, making it possible for reophilous species to exist alongside stagnophilous ones.

The strikingly high proportion of alien species (13.4%, including *Sinanodonta woodiana*, not recorded in this study) indicates that the Odra River system is of crucial significance in the expansion of these species over the territory of Poland. A major role in the process of dispersal of new arrivals is certainly played by the canals: the Odra-Spree Canal and the Odra-Havel Canal, connecting the drainage basins of the Odra and the Elbe. The highest number of alien species was detected in places where these canals entered the Odra, including, among other species, *M. dilatatus* (the second record in Poland), *F. fragilis*, *P. acuta*, *C. fluminea*, and *C. fluminalis*. The above-mentioned species were also recorded in the drainage basin of the Elbe (FALKNER et al. 2001, ARLT 2005, MÜLLER et al. 2005). They represent the North American element in the European fauna.

The catchment area of the Odra and the canals connecting it with the Elbe and Vistula river systems were also of great importance for the westward spread of Ponto-Caspian species. This is shown by the recent distribution of *D. polymorpa* and *L. naticoides* in Poland and Germany (GLÖER & MEIER-BROOK 2003: distribution maps, PIECHOCKI 2004, KOŁODZIEJCZYK 2011, STAŃCZYKOWSKA & LEWANDOWSKI 2011). The numerous localities of *L. naticoides* situated between Nowa Sól and Urad suggest that the middle Odra constitutes a refugium of this species, once invasive and presently receding, which confirms the tentative view of KOŁODZIEJCZYK (2011) on the current status of this Ponto-Caspian mollusc in the Polish waters.

For many years, *P. acuta* was regarded as Mediterranean, but recent research has shown that the species, presently cosmopolitan, started its expansion from North America and continued spreading during the 19th and 20th centuries. In Europe it first appeared in Mediterranean countries and then colonised other areas. The analyses of alloenzymes and mitochondrial DNA have shown that bladder snails, earlier classified as *P. acuta, P. heterostropha* and *P. integra*, are conspecific (WETHINGTON & LYDEARD 2007).

Potamopyrgus antipodarum, at present one of the most common freshwater snails in Poland, probably colonised our country through the drainage basin of the Odra and the canals connecting the Odra to the Elbe. This is confirmed by the presence of this species in the system of Elbe-Havel-Spree water connections already at the time of World War I (JAECKEL 1955), its pioneer locations in Lake Trląg (catchment area of the Noteć River, 1933) (URBAŃSKI 1938), the Odra and its tributaries (JAECKEL 1955), and its expansion to the Upper Silesia (through the Gliwice Canal) (STRZELEC 2011) as well as its present mass occurrence along the whole course of the Odra.

The recent invasion of the Asian bivalves of the genus *Corbicula* has a similar and equally drastic character. Research conducted in 1998-2001 did not reveal the presence of *Corbicula* species in the Odra (SCHÖLL et al. 2003). They were first recorded in 2003 (*C. fluminea*) and 2004 (*C. fluminalis*) in heated waters of the Lower Odra Canal near Czarnów and Gryfino (DOMAGAŁA et al. 2004, ŁABĘCKA et al. 2005). In 2006 and 2007, a number of localities of *C. fluminea* were discovered in the upper, middle, and lower course of the river, where the species was represented both by live specimens and by empty shells (MÜLLER et al. 2007, WAWRZYNIAK-WYDROWSKA 2007, WILKE 2007). However, the cited authors did not encounter *C. fluminalis* in the course of field research. Studies of

the fauna of groyne-associated habitats indicate that both bivalve species quickly expand their range along the Odra, and at the same time highlight the importance of the Havel-Odra and Spree-Odra canals as immigration routes of invasive species into Poland. It is worth mentioning that *C. fluminea* has recently been recorded in the Vistula in Cracow (MAĆKIEWICZ 2013).

The presence of alien molluscs and mass occurrence of invasive species do not seem to have an unequivocally negative effect on the native malacofauna. This fact is reflected by both high species diversity of snails and bivalves and high abundance of such native molluscs as *V. viviparus*, *B. tentaculata* or *V. piscinalis*. The out-competing of *Physella fontinalis* by *P. acuta* may be an exception. Both species have similar ecological requirements and inhabit eutrophic waters with luxuriant vegetation, in locations where the bottom is covered with sand and silt. *P. acuta* was recorded in 16 locations, mainly in groyne fields, and *P. fontinalis* in 13; the latter species was more frequent in oxbow lakes. The two species co-occurred in only eight sites.

The river-bed of the Odra, diversified habitats of the areas between groynes, and numerous oxbow lakes provide favourable conditions for the occurrence of molluscs with various ecological requirements. This is confirmed, among other things, by the presence in the Odra of protected reophilous species, e.g. *B. naticina, S. rivicola*, and *S. solidum,* which have become extinct in many other Polish rivers.

ACKNOWLEDGEMENTS

The research was supported by the Polish Ministry of Science and Higher Education (grant no. N N304 327236). We would like to thank Dr BRYGIDA WAWRZYNIAK-WYDROWSKA (Institute of Marine Sciences, Department of Paleo-oceanology, University of Szczecin) for taking photographs of snails and bivalves. The English translation was verified by SYLWIA UFNALSKA.

REFERENCES

ARLT D. 2005. Süsswassermollusken des Biosphärenreservates Spreewald. Malak. Abh. 23: 41–54.

BARGUES M. D., ARTIGAS P., JACKIEWICZ M., POINTIER J. P., MAS-COMA S. 2006. Ribosomal DNA ITS-1 sequence analysis of European stagnicoline Lymnaeidae (Gastropoda). Heldia 6: 29–40.

BERGER L., DZIĘCZKOWSKI A. 1977. Bottom fauna of the heated Konin Lakes. In: WRÓBLEWSKI A. (ed.). VI Mollusca. Monografie Fauny Polski, 7, PWN, Warszawa, pp. 151–179.

BOETTGER C. R. 1926. Die Weichtierfauna des Gebietes von Frankfurt an der Oder. Helios 29: 13–45.

BRINKMANN R., OTTO C.-J., WIESE V. 1997. Zur Molluscenfauna der Alten Oder (Brandenburg). Schr. Malakozool. 10: 49–58.

DOMAGAŁA J., ŁABĘCKA A.-M., PILECKA-RAPACZ M., MIGDALSKA B. 2004. *Corbicula fluminea* (O. F. Müller, 1774) (Bivalvia: Corbiculidae) – a species new to the Polish malacofauna. Folia Malacol. 12: 145–148.

DOMAGAŁA J., MIGDALSKA B., ŁABĘCKA A.-M., PILECKA-RAPACZ M. 2003. *Anodonta woodiana* (Lea, 1834) na Pomorzu Zachodnim. Zesz. Nauk. Uniw. Szczec., Acta Biol. 10: 199–202.

DUBICKI A., BŁACHUTA J. 1999. Structure and function of the Odra River's ecosystem. Annual Report of Subproject 9 (Institute of Meteorology and Water Management, Wrocław). In: MEYER A. K. (ed.). The International Odra Project (IOP), 2. Interim Report, Annual Report 1998, pp. 239–255.

DYDUCH-FALNIOWSKA A., ZAJĄC K. 2002. Bivalvia małże. In: GŁOWACIŃSKI Z. (ed.). Czerwona lista zwierząt ginących i zagrożonych w Polsce. Instytut Ochrony Przyrody PAN, Kraków, pp. 23–26.

FALKNER G., OBRDLIK P., CASTELLA E., SPEIGHT M. C. D. 2001. Shelled Gastropoda of Western Europe. Friedrich Held Gesellschaft, München.

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

GLÖER P., MEIER-BROOK C. 2003. Süsswassermollusken. Deutscher Jugendbund für Naturbeobachtung, Hamburg.

HASTRICH A. 1994. Makrozoobenthos in der mittleren und unteren Odra im Herbst 1992 und im historischen Vergleich. Limnologica 24: 369–388.

JACKIEWICZ M. 1998. European species of the family Lymnaeidae (Gastropoda: Pulmonata: Basommatophora). Genus 9: 1–93.

JAECKEL S. 1955. Die Wassermollusken der Nuthe-Niederung und des Raumes zwischen mittlerer Elbe und Warthe. Abh. u. Ber. f. Naturkunde u. Vorgeschichte 9: 185–215.

JANICKI D. 2002. Fauna bezkręgowa Parku Krajobrazowego Dolina Dolnej Odry. In: JASNOWSKA J. (ed.). Dolina Dolnej Odry, Monografia Parku Krajobrazowego. Szczecińskie Towarzystwo Naukowe, Szczecin, pp. 263–266.

JOKINEN E. H. 1992. The freshwater snails (Mollusca: Gastropoda) of New York State. New York State Mus. Bull., 482: VI, 112 pp.

KOŁODZIEJCZYK A. 2011. *Lithoglyphus naticoides* (C. Pfeiffer, 1828). In: GŁOWACIŃSKI Z., OKARMA H., PAWŁOWSKI J., SOLARZ W. (eds). Księga gatunków obcych i inwazyjnych w faunie Polski. Instytut Ochrony Przyrody PAN, Kraków, pp. 70–75.

KOŁODZIEJCZYK A., ŁABĘCKA A. M. 2011. *Corbicula fluminalis* (O. F. Müller, 1774). In: GŁOWACIŃSKI Z., OKARMA H.,

PAWŁOWSKI J., SOLARZ W. (eds). Gatunki obce w faunie Polski. Instytut Ochrony Przyrody PAN, Kraków, pp. 146–150.

ŁABĘCKA A. M., DOMAGAŁA J., PILECKA-RAPACZ M. 2005. First record of *Corbicula fluminalis* (O. F. Müller, 1774) (Bivalvia: Corbiculidae) in Poland. Folia Malacol. 13: 25–27.

LEHMANN R. 1873. Die lebenden Schnecken und Muscheln der Umgegend Stettins und in Pommern mit besonderer Berücksichtigung ihres anatomischen Baues. Th. Fischer, Cassel.

MAĆKIEWICZ J. J. 2013. The first record of the Asian clam *Corbicula fluminea* (Bivalvia: Veneroida: Corbiculidae) in the upper Vistula (South Poland). Folia Malacol. 21: 87–90. dx.doi: 10.12657/folmal.021.009

MARSZAŁEK E. 2003. Odrzański szlak wodny. Wyższa Szkoła Ekonomiczno-Turystyczna, Szczecin.

MÜLLER O., HERPICH J., ROSENBERGER S., MŐLLER F., MÜLLER N., NOSKE M., JÄHNERT K. 2007. Klimatisch begrenzte Invasion nach Osten? – Aktuelles Verbreitungsmuster von *Corbicula fluminea* in der Strom-Oder (Brandenburg). Lauterbornia 59: 133–139.

MÜLLER R., ANLAUF A., SCHLEUTER M. 2005. Nachweise der Neozoe *Menetus dilatatus* (Gould, 1841) in der Oberelbe, Mittelelbe, dem Mittellandkanal und dem Nehmitzsee (Sachsen, Sachsen-Anhalt, Brandenburg) (Gastropoda: Planorbidae). Malak. Abh. 23: 77–85.

PIECHOCKI A. 1989. The Sphaeriidae of Poland (Bivalvia, Eulamellibranchia). Ann. Zool. 42: 249–320.

PIECHOCKI A. 2004. *Lithoglyphus naticoides* (C. Pfeiffer, 1828) Namułek pospolity. In: GŁOWACIŃSKI Z., NOWACKI J. (eds). Polska czerwona księga zwierząt, Bezkręgowce. Instytut Ochrony Przyrody PAN, Kraków, pp. 318–319.

PIECHOCKI A., SULIKOWSKA-DROZD A. 2008. Mięczaki (Mollusca) w Fauna Polski – charakterystyka i wykaz gatunków. In: BOGDANOWICZ W., CHUDZICKA E., PILIPIUK I., SKIBIŃSKA E. (eds). Muzeum i Instytut Zoologii PAN, Warszawa, pp. 365–425.

RAST G., OBRDLIK P., NIEZNAŃSKI P. 2000. Atlas zalewanych obszarów Odry. Kraft-Druck, Etlingen.

RICHARDOT M. 1976. Déterminisme de la formation du septum chez *Ferrissia wautieri* (Mirolli). Donnés écologiques, biologiques et physiologiques. Thése Doct. Etat, Lyon, 76- 6: 1–273.

SCHMID U. 1999. Das Makrozoobenthos des Unteren Odertals – Faunenzusammensetzung und Besiedlungsdynamik in einer Flussaue. Limnologie aktuell 9: 317–336.

SCHÖLL F., BŁACHUTA J., SOLDÁN P. 2003. Makrozoobentos Odry 1998–2001. Międzynarodowa Komisja Ochrony Odry przed Zanieczyszczeniem, Wrocław.

SPYRA A. 2008. The septifer form of *Ferrissia wautieri* (Mirolli 1960) found for the first time in Poland. Mollusca 26: 95–98.

STAŃCZYKOWSKA A., KOŁODZIEJCZYK A. 2011. *Corbicula fluminea* (O. F. Müller, 1774). In: GŁOWACIŃSKI Z., OKARMA H., PAWŁOWSKI J., SOLARZ W. (eds). Gatunki obce w faunie Polski. Instytut Ochrony Przyrody PAN, Kraków, pp. 151–156.

STAŃCZYKOWSKA A., LEWANDOWSKI K. 2011. *Dreissena polymorpha* (Pallas, 1771). In: GŁOWACIŃSKI Z., OKARMA H., PAWŁOWSKI J., SOLARZ W. (eds). Gatunki obce w faunie Polski. Instytut Ochrony Przyrody PAN, Kraków, pp. 133–140.

STRZELEC M. 2011. *Ferrissia clessiniana* (Jickeli, 1882). In: GŁOWACIŃSKI Z., OKARMA H., PAWŁOWSKI J., SOLARZ W. (eds). Gatunki obce w faunie Polski. Instytut Ochrony Przyrody PAN, Kraków, pp. 91–92.

TETENS A., ZEISSLER H. 1964. Über das Vorkommen der seltenen Pisidienarten im Nord- deutsch-Polnischen Raum. Malak. Abh. 1: 89–133.

URBAŃSKI J. 1938. Materiały do fauny mięczaków województwa poznańskiego. II. Fragm. faun. Mus. zool. pol. 3: 439–467.

WAWRZYNIAK-WYDROWSKA B. 2007. Preliminary studies on the occurrence of the Asiatic clam *Corbicula fluminea* (O. F. Müller, 1774) (Bivalvia: Corbiculidae) in River Odra (Poland). World Congress of Malacology, Antwerp, Belgium, 15-20 July 2007, Abstracts: 238–239.

WETHINGTON A. R., LYDEARD C. 2007. A molecular phylogeny of Physidae (Gastropoda: Basommatophora) based on mitochondrial DNA sequences. J. Moll. Stud. 73: 241–257. doi: 10.1093/mollus/eym021

WILKE H.-J. 2007. Erstnachweis von *Corbicula fluminea* in der Hohensaaten-Friedrichsthaler-Wasserstraße/Oder (Brandenburg). Lauterbornia 59: 63–65.

ZAJĄC K. 2004. *Unio crassus* Philipsson, 1788. Skójka gruboskorupowa. In: GŁOWACIŃSKI Z., NOWACKI J. (eds). Polska czerwona księga zwierząt, Bezkręgowce. Instytut Ochrony Przyrody PAN, Kraków, pp. 353–355.

ZETTLER M. L. 1997. Morphometrische Untersuchungen an *Unio crassus* Philipsson 1788 aus dem nordeuropäischen Vereisungsgebiet (Bivalvia: Unionidae). Malak. Abh. 18: 213–232.

ZETTLER M. L. 2012. A remarkable record of a very rare freshwater snail *Borysthenia naticina* (Menke, 1845) in North-East Germany compared with three Lithuanian records. Folia Malacol. 20: 105–110. doi: 10.2478/v10125-012-0016-0

Received: January 1st, 2013
Revised: February 2nd, 2013
Accepted: February 15th, 2013