

Oceanological and Hydrobiological Studies

International Journal of Oceanography and Hydrobiology

Volume 40, Issue 1

ISSN 1730-413X
eISSN 1897-3191

(57–67)
2011



DOI: 10.2478/s13545-011-0007-6
Original research paper

Received: February 08, 2010
Accepted: December 12, 2010

Non-native fish in Belarusian and Polish areas of the European central invasion corridor

Vitaliy Semenchenko¹, Joanna Grabowska^{2,*},
Michał Grabowski³, Viktor Rizevsky¹,
Michail Pluta¹

¹*Institute of Zoology National Academy of Sciences
27 Akademicheskaya St, 220072 Minsk
Republic of Belarus*

²*Department of Ecology and Vertebrate Zoology, University of
Łódź, ul. Banacha 12/16, 90-237 Łódź, Poland*

³*Department of Invertebrate Zoology and Hydrobiology,
University of Łódź, ul. Banacha 12/16, 90-237 Łódź,
Poland*

Key words: non-native species, invasions, Ponto-Caspian, gobies

Abstract

This is the first comprehensive review to examine the role of the central European invasion corridor on fish introductions into Belarusian and Polish inland waters (Dnieper-Bug-Vistula-Oder-Elbe-Spre-Havel). Historical and recent data were assessed, including the results of a 2003–2008 survey along the Belarusian and Polish sections of the corridor. Since the eighteenth century, at least six fish species of Ponto-Caspian origin have spread via the corridor and migrated westwards to the Baltic basin, with five species found in recent surveys, namely the monkey goby *Neogobius fluviatilis*, round goby *N. melanostomus*, racer goby *N. gymnotrachelus*, tubenose goby *Proterorhinus marmoratus* and the white eye-bream *Abramis sapa*. Four other non-native species

were also found within the corridor – the Amur sleeper *Percottus glenii*, gibel carp *Carassius gibelio*, brown bullhead *Ameiurus nebulosus* and the topmouth gudgeon *Pseudorasbora parva*. Their presence is related to numerous accidental introductions to many localities in Belarus and Poland, rather than from using the corridor as an invasion route. One species, the ninespine stickleback, *Pungitius pungitius*, has migrated from the Baltic basin to the Black Sea drainage systems.

INTRODUCTION

The current freshwater fish fauna of Northern and Central Europe began to form about 11,000 years ago, after the retreat of the last Würmian glaciation, and is therefore relatively young. As a result, the fauna is characterised by low endemism and a smaller number of species compared to Southern and South-eastern Europe (Rolik, Rembiszewski 1987). Northern and Central Europe's current fish fauna composition is a result of various post-glacial recolonisation processes, and human activities. In the case of Poland and Belarus, the native fauna consists of species from both the Arctic and Ponto-Caspian regions, with a predominance of species of Ponto-Caspian origin such as that found in the Vistula and Dnieper river basins (Zhukov 1965; Rolik, Rembiszewski 1987).

Post-glacial fish migration from the Ponto-Caspian refuge to rivers in the Baltic basin occurred through vast meltdown lakes that formed temporary connections between the Dnieper, Neman and Vistula rivers, as well as between upper Dniester and San (Zhukov 1965; Mahon 1984; Rolik, Rembiszewski 1987). Many limnophilic species migrated at that stage. After the lakes had receded and river valleys began to form, migration of rheophilic species occurred. Traces of these connections and colonisation processes are seen not only in geomorphology, but also in morphological similarities between fish populations of species from

* Corresponding author: joko@biol.uni.lodz.pl

the middle section of the rivers Vistula and Neman (Witkowski 1984). Moreover, the fish fauna of the two main river catchments in Poland, i.e. the Vistula and Oder, differ in composition, with the Vistula being the northern or north-western border of geographical range for many species that do not occur in the Oder (Rolik, Rembiszewski 1987).

In the Holocene, the three main sea basins (the North Sea, Baltic Sea and Black Sea) and their fauna were isolated until the eighteenth century, when artificial waterways were constructed to facilitate transportation between the river basins. In 2002, after adoption of the European Agreement on Main Inland Waters of International Importance (AGN) by the Russian Federation, the international network of European waterways consisted altogether of approximately 28,000 km of main navigable rivers and canals, extending from the Atlantic Ocean to the Ural Mountains (Panov et al. 2007).

The earliest, and still some of most important canals, are those connecting the rivers Elbe, Spree, Havel and Oder (opened in 1746); the rivers Oder and Vistula (1774); the Vistula and Dnieper catchments (Dnieper-Bug Canal) (1784) (Jazdzewski 1980, Olenin 2002); and the Rhine-Weser (1899) and Weser-Elbe (1938) canals, which were constructed later. The aforementioned connections formed one of the most important migratory routes for Ponto-Caspian hydrobionts, known as the central invasion corridor. This route consists of the following sections: the rivers Dnieper and Pripyat, the Dnieper-Bug Canal, the Western River Bug, the River Vistula, the Bydgoski Canal, the rivers Notec, Warta, and Oder, the Oder-Spree and Oder-Havel canals, and the River Rhine (Bij de Vaate et al. 2002).

Many invertebrate species have dispersed via the central corridor into the Baltic and North Sea basins e.g. *Dreissena polymorpha*, *Chelicorophium curvispinum*, *Dikerogammarus haemobaphes*, *Dikerogammarus villosus* (Jazdzewski et al. 2002, Semenchenko et al. 2007, Karatayev et al. 2008). In recent decades, several new records of non-native fish in Belarus and Poland have shown that this continues to be an important pathway for species invasions (Gulugin, Kunitsky 1999; Rizevsky et al. 2007; Grabowska et al. 2008).

Here, the present state of non-native fish fauna in the eastern and middle sections of the central invasion corridor, i.e. in Poland and Belarus, based on previously published data and surveys done in 2007 in the Pripyat River, Dnieper – Bug Canal as well as in the rivers Bug, Vistula, Notec and Warta during 2003, 2007 and 2008, are reviewed.

MATERIALS AND METHODS

Field surveys were conducted in Belarus and Poland at 50 sites in the eastern and middle sections of the central invasion corridor (Fig. 1). The surveyed area in Belarus included 475 km of the River Pripyat (sites 1–8); 196 km of the Dnieper-Bug Canal, including 74 km of the canalised section (sites 9–10) of the River Pina, a tributary of the Pripyat; 58 km of the Korolevskiy Canal (sites 11–12), which crosses the watershed between the Black Sea and Baltic Sea basins and is known also as Pripyat-Bug Canal; and 64 km of the canalised section of the River Mukhavets, a tributary of the River Bug (site 13). In Poland, surveys were undertaken along 269 km of the River Bug (sites 14–32); 50 km of the Zegrzynski Reservoir (sites 34 and 35); 221 km of the River Vistula (sites 36–39); 38 km of the Bydgoski Canal (sites 40–42); 199 km of the River Notec (sites 43–49); and 68 km of the River Warta (site 50). Field studies in the Belarusian section of the River Pripyat and the Dnieper-Bug Canal (Fig. 1, Table 1), including the river ports, were conducted in August 2007 and 2008. Fish samples (from five to seven replicates per locations, two minutes per sample) were collected using a large hand-net (60×60 cm, mesh size 5 mm) from depths of 0.3 to 0.5 m. These data were supplemented by information from an earlier survey undertaken on the River Pripyat in 1993 (Gulugin, Kunitsky 1999). In Poland, samples were collected in October 2003, April and December 2008, using a battery-powered electrofishing unit (350 V, 20–100 Hz) at depths of 0.3 to 0.7 m, whereas in August 2007, electrofishing was undertaken from a boat along 500 m stretches using a full-waved rectified, pulse DC electro-shocker (3kW, 230 V) in water depths of 0.5 – 3.0 m (Table 1).

RESULTS AND DISCUSSION

Forty-seven native and 13 non-native fish species were found in the rivers and lakes of Belarusia (Rizevsky et al. 2009). Eight of the non-native species were recorded in the Belarusian section of the central invasive corridor (Table 2), six of these during surveys in 2007 – 2008 (Table 1). The most widespread and abundant species in the Belarusian section were the round goby *Neogobius melanostomus*, followed by the monkey goby *Neogobius fluviatilis* and the tubenose goby *Proterorhinus marmoratus* (Table 1). Three less-frequently encountered species were the

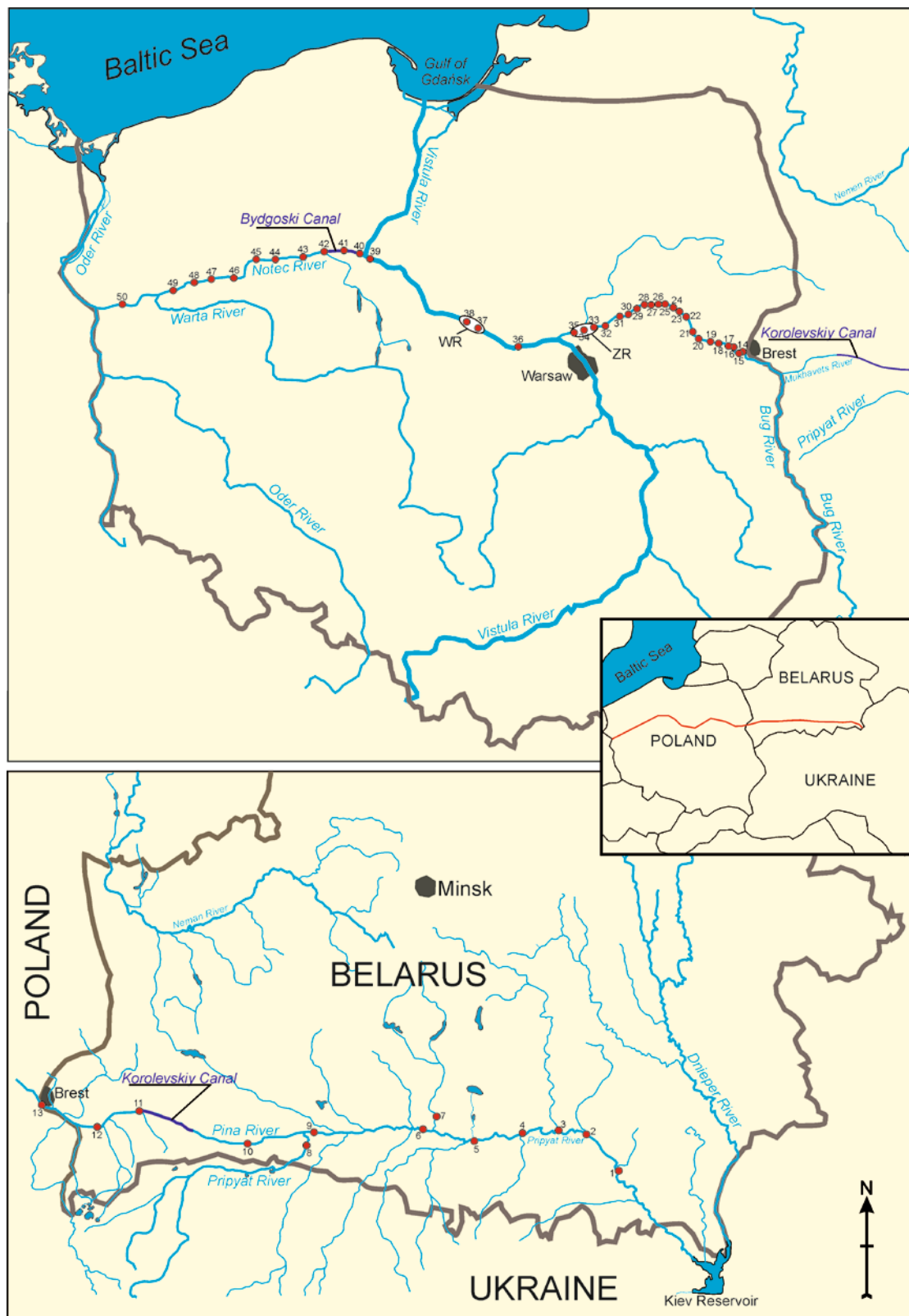


Fig. 1. Locations of sampling sites during the 2007 survey on the River Pripjat (sites 1–8) and Dnieper-Bug Canal (sites 9–13) and during the 2003, 2007 and 2008 surveys on the River Bug (sites 14–33), Zegrzynski Reservoir (sites 34–35), River Vistula (sites 36–39), Bydgoski Canal (sites 40–42), River Noteć (sites 43–49) and the River Warta (site 50).

Table 1

Distribution and abundance of alien species (number of individuals in each sample) in the River Pripjat (sites 1–8), Dnieper-Bug Canal (sites 9–13, Bug River (sites 14–35), River Vistula (sites 36–39) based on surveys in 2003, 2007 and 2008. N. flu. – monkey goby, N. mel. – round goby, N. gym. – racer goby, P. mar. – tubenose goby, A. sap. – white-eye bream, P. gle. – Amur sleeper, P. par. – topmouth gudgeon, C. gib. – gibel.

Site	Name	Latitude,°N	Longitude,°E	Year	N. flu.	N. mel.	N. gym.	P. mar.	A. sap.	P. gle.	P. pun.	C. gib.
1	Pripyat River	Mozyr port	51°52.01'	29°29.21'	2007	5	9					
2			52°08.76'	29°18.51'	2007	7	11					
3			52°06.53'	28°32.72'	2007		12					
4		Pripyatski Nat. Park	52°07.03'	29°01.84'	2007	4	4	1	1		1	
5			52°11.73'	27°23.05'	2007		58	2	1			
6		Mykashevichy port & canal	52°11.73'	27°23.05'	2007	6	25		1			
7			52°06.62'	26°06.27'	2007	23	26	5	17		2	
8			52°09.48'	27°20.33'	2007	6			10		2	
9	Dnieper-Bug Canal	Pina River, Pinsk river port	52°03.10'	26°09.86'	2007	3	13					
10		Pina River	52°03.10'	26°09.86'	2007		1					
11		Korolevskiy Canal	52°08.88'	24°42.91'	2007		6					8
12			52°03.56'	23°56.49'	2007		8	4				80
13		R. Mukhavets, Brest river port	52°04.94'	23°41.69'	2007	2	9					
14	Bug River		52°16.86'	23°10.04'	2007	11						
				2008	2		1	1				
15			52°16.56'	23°10.19'	2007	12		2				
16			52°17.75'	23°03.03'	2007	13		6				
17			52°22.32	22°55.85	2007	40		4				
18			52°21.57'	22°50.84'	2003	12		7				
					2007	48		12				
19			52°23.59'	22°42.34'	2007	47		69			3	
					2003	16						
20			52°23.56'	22°34.78'	2007	3		12				
21			52°26.49'	22°32.49'	2007	51		36				
22			52°31.56'	22°31.10'	2007	35						
23			52°35.65'	22°25.78'	2003	31		4				
					2007	13		4				
24			52°37.42'	22°22.24'	2007	8		10				
25			52°37.92'	22°15.45'	2007	42		6				
26			52°42.15'	22°09.33'	2007	72		28				
27			52°40.44'	22°01.01'	2003	15		5				
					2007	18		28				
28			52°40.44'	22°01.01'	2003	3		7				
					2007	40		38				
29			52°39.40'	21°44.19'	2007	23		3				
30			52°37.42'	21°35.07'	2007	63		45		3	3	
					2003	18		2				
31			52°35.48'	21°30.66'	2007	12		18				
32			52°32.87'	21°23.48'	2007	44		52		2		
33			52°28.74'	22°30.67'	2003	22		8				
					2007	40		62				
34	Zegrzynski Reservoir		52°30.29'	21°04.35'	2003	19		15				
35			52°27.27'	21°00.57'	2003	5		7				
					2003	10		6				
36	Vistula River		52°23.07'	20°11.58'	2008	2		2				
37			52°32.08'	19°41.20'	2008	2		45	6			
38			52°35.10'	19°30.25'	2003	65		22			2	7
39			53°00.38'	18°29.90'	2003	5		2				
40	Bydgoski Canal		53°08.67'	17°53.68'	2003							
41			53°08.82'	17°52.90'	2003							
42			53°07.96'	17°40.57'	2003							
43	Notec River		53°04.96'	17°18.28'	2003							
44			53°04.47'	17°07.48'	2003							
45			53°03.33'	16°43.28'	2003							
46			52°52.88'	16°26.92'	2003							
47			52°53.93'	16°09.85'	2003							
48			52°50.80'	15°54.90'	2003							
49	Warta River		52°46.48'	15°38.31'	2003							
50			52°37.87'	14°54.77'	2003							
Total number of sites where species was present					43	12	36	7	2	6	2	1

Table 2

Check-list of alien species of fish in the Belarusian and Polish parts of the central invasion corridor.

	Scientific name	Species name	Origin	Date of first observation in central corridor		Reference
				Belarusian part	Polish part	
1	<i>Neogobius fluviatilis</i>	Monkey goby	Ponto-Caspian	About 1950	1997	Vorontzov 1937 Danilkiewicz 1998
2	<i>Neogobius melanostomus</i>	Round goby	Ponto-Caspian	1993	-	Gulugin, Kunitsky 1999
3	<i>Neogobius gymnotrachelus</i>	Racer goby	Ponto-Caspian	1993	1995	Gulugin, Kunitsky 1999 Danilkiewicz 1996
4	<i>Proterorhinus marmoratus</i>	Tubenose goby	Ponto-Caspian	2007	2008	Rizevsky et al. 2007 Grabowska et al. 2008
5	<i>Clupeonella cultriventris</i>	Black Sea sprat	Ponto-Caspian	1986	-	Rizevsky, Pluta (unpublished data)
6	<i>Abramis sapo</i>	White-eye bream	Ponto-Caspian	Native in Belarus	1989	Terlecki 1990
7	<i>Percottus glenii</i>	Amur sleeper	Far East	1972	1996	Rizevsky et al. 1999 Woźniewski 1997
8	<i>Pungitius pungitius</i>	Nine-spined stickleback	Baltic Sea	1906	Native in Poland	Gratsyanov 1907
9	<i>Carrasius gibelio</i>	Gibel	Far East, China	After 1860	1940s	Zelensky 1864 Staff 1950
10	<i>Ameiurus nebulosus</i>	Brown bullhead	North America	*	1940s	Ivlev, Protasov 1948 Adamczyk 1975
11	<i>Ictalurus punctatus</i>	Channel catfish	North America	*	-	Alekhnovich (personal communication)
12	<i>Pseudorasbora parva</i>	Topmouth gudgeon	Far East	*	2000	Kunitsky, Pluta 1999 Czczuga et al. 2002

* - present in the River Pripyat basin but not recorded in the central corridor itself.

racer goby *Neogobius gymnotrachelus*, the Amur sleeper *Percottus glenii* and the ninespine stickleback, *Pungitius pungitius*, the latter being found close to the Polish border in the Dnieper-Bug Canal only.

The freshwater fish fauna in Poland consisted of 57 native and 26 non-native species (Witkowski 1996, Witkowski 2002, Grabowska et al. 2010), although only about 11 of the non-native species have become established in open water. Eight species have been recorded in the Polish section of the central corridor (Table 2) (Brylińska 2000, Czczuga et al. 2002, Kostrzewa et al. 2004, Grabowska et al. 2008). Six non-native species were found in the Polish section of the corridor during the present study - the gibel carp *Carassius gibelio*, Amur sleeper, white-eye bream *Abramis sapo*, tubenose goby, racer goby and the monkey goby (Table 1). The latter two species were present at nearly all of the sampling sites in the rivers Bug and Vistula, and the Zegrzynski Reservoir. Their abundance was influenced by local habitat characteristics. Monkey gobies were often found on sandy bottoms in areas of relatively strong water

current, whereas racer gobies frequently occurred in more sheltered habitats comprised of muddy substratum covered in mollusc shells, or where stones and pebbles provided hiding places. Tubenose gobies were found in one location in the River Bug, and at two sites in the River Vistula, along rip-rap sections. Amur sleepers were only recorded from three sites and in very low abundance (1–3 individuals). No non-native fish species were found in the Bydgoski Canal, or in the rivers Notec and Warta.

Below, non-native species occurring in natural and artificial waterways forming the central invasion corridor in Belarus and Poland, and their invasion history, are presented.

Ponto-Caspian species

Monkey gobies were the first of the three Ponto-Caspian gobiid species to invade the Belarusian section of the River Dnieper, where they were first observed in 1936 (Vorontzov 1937). They then

appeared in the River Pripyat in the early 1950s (Voronin 1957). The upstream migration of monkey gobies in the Dnieper began earlier, as they were recorded in the middle section of the river in 1856 and again in 1932, at locations currently within Ukraine territory (Berg 1933). The arrival of monkey gobies in Poland was first noted in 1997, in the middle section of the River Bug, only a few kilometres downstream of its convergence with the Dnieper-Bug canal (Danilkiewicz 1998). In subsequent years, monkey gobies were recorded at locations downstream of the River Vistula (Fig. 1), in the Włocławski Reservoir at site 38 in 2002 (Kostrzewa, Grabowski 2002, Kakareko et al. 2005), and at the river mouth in 2003 (Grabowska et al. 2008). The estimated mean rate of this dispersal is 122 km per year.

Round gobies were first recorded in 1932 in the lower course of the River Dnieper (Berg 1933) and in 1961 in the middle Dnieper (Babenko 1961), spreading at an estimated 10 km per year (between the Zaporozhskoe and Kiev reservoirs). The round goby was first recorded in 1993 in the River Pripyat in Belarus (Gulugin, Kunitsky 1999), but was probably present in the river earlier. They are now distributed along the entire Belarusian section of the central corridor, and are the most abundant of the non-native fish species (Table 1). Although not found in the Polish section of the River Bug in 2007 and 2008, the round goby is expected to migrate into Poland in the near future through the central corridor, where it is already present in high densities upstream of Brest (site 13; Fig. 1). Downstream expansion of the round goby will result in this species inhabiting the entire lower section of the River Vistula. Round gobies have already invaded the lower 130 km upstream of the Vistula (Kostrzewa, Grabowski 2002), having expanded there from the Gulf of Gdansk in the Baltic Sea, where they were first reported in 1990 (Skóra, Stolarski 1993).

In 1970, racer gobies were found in the middle section of the Dnieper River, followed by the upper section in 1978 (Smirnov 1986), the River Pripyat in 1993 (Gulugin, Kunitsky 1999), with recent records (Table 1) from Belarus including the River Pripyat (sites 4, 5 and 7) and the Dnieper – Bug Canal (Site 12). Migration into Poland was rapid, with an initial report from the middle River Bug (a few kilometres downstream from the Dnieper-Bug connection) in 1995 (Danilkiewicz 1996), followed by reports further downstream almost to the river mouth of the Vistula (Kostrzewa, Grabowski 2001; Kostrzewa at

al. 2004; Grabowska et al. 2008). The racer goby has established itself in the River Brda (T. Kakareko, personal communication), meaning it has already entered the Bydgoski Canal, the next crucial stretch of the central corridor that joins the Vistula and Oder river basins. Phylogeographic investigations with molecular markers have revealed that racer gobies in the Vistula basin derive from the River Dnieper, indicating the central corridor was the invasion pathway (Ohayon, Stepień 2007).

Tubenose gobies are the most recent of the Ponto-Caspian invaders in Belarus and Poland (Rizevsky et al. 2007, Grabowska et al. 2008). Prior to 1970, the tubenose goby was found only in the lower River Dnieper (Smirnov 1986), but by 1985, it had entered the Kiev Reservoir (Smirnov 1986, Naseka et al. 2005). Although not found in the Belarus Pripyat survey in 1993 (Gulugin, Kunitsky 1999), they were found in August 2007 for the first time in the middle and upper sections close to the Dnieper-Bug Canal (Rizevsky et al. 2007), between sites 4 and 8, with the highest numbers recorded at the river port of Mykashevichy (Table 1). In April 2008, a tubenose goby specimen was recorded in the Polish Bug (site 14) and in the lower Vistula River (site 37), approximately 405 km downstream of the Bug River-Dnieper-Bug convergence (Grabowska et al. 2008). This corresponds to an estimated dispersal rate of 608 km per year, making the tubenose goby the fastest spreading of the Ponto-Caspian invaders, followed by the monkey goby (122 km per year), the racer goby (68 km per year) and the round goby (10 km year⁻¹).

Black Sea sprats were recorded in the central section of the Pripyat River (sites 5 and 7) in 1986 (V. Rizevsky, M. Pluta, unpublished data), but were not found during the 2007 survey. Unexpected and casual appearance of this species (Gulugin, Kunitsky 1999) can only be attributed to transport via ships entering the Mykashevichy river port. Sprats entered the Zaporozhskoe Reservoir (previously named Dnieper Reservoir) in 1958, and are now distributed as far as the Kiev Reservoir, located 550 km downstream, and in other reservoirs along the River Dnieper (Romanenko et al. 2003). To date it has not been reported in Poland.

White-eye bream, native to Belarus, occur naturally in the River Dnieper and its tributaries, including the River Pripyat (Zhukov 1965). Outside its natural range, white-eye bream were first recorded in the River Volkov (Baltic Sea basin), which it invaded via the River Volga (Zhukov 1988). In the

1990s, the species was noted in the River Rhine, Germany (Freyhof 2003), probably accidentally introduced from the rivers Weser and Danube. It also migrated, most probably through the central corridor, from Belarus to Poland. Its occurrence in the Zegrzynski Reservoir (in the lower stretch of the River Bug) was first documented in the 1980s (Terlecki 1990), although local fishermen state that it was caught there much earlier. A few years later, white-eyed bream had established a thriving population in the Włocławski Reservoir (site 38; Fig. 1) in the lower River Vistula (Kakareko et al. 2008). During the present study, two or three specimens of white-eye bream were found at two sites in the River Bug (Table 1). The exact year of the white-eyed bream's arrival in Poland is difficult to determine because of its close physical resemblance to the native common bream *Abramis brama*, leading to misidentification of white-eyed bream as the native species.

Other non-native fish species

There were five non-native fish species recorded in the central invasion corridor, whose dispersal was not directly related to canal connection between river basins. The Amur sleeper was intentionally introduced into Belarus by fishermen in 1972, and until now has been widely distributed throughout the country, mainly in artificial ponds, reservoirs and oxbows (Rizevsky et al. 1999), including the middle section of the Pripyat, with low abundance (Table 1). The route of introduction of the Amur sleeper to Poland is unknown, but it appeared in oxbow lakes of the River Vistula (Antychowicz 1994), upstream from the section of Vistula that belongs to the corridor. The species spread down the River Vistula (Terlecki, Palka 1999; Kakareko 1999; Wiśniewolski et al. 2001), and has also been recorded in the River Bug (Kostrzewa et al. 2004). Population densities are variable, but the species is dominant in some sheltered oxbows along the Vistula (Grabowska et al. 2009). The rate of the Amur sleeper's expansion in the River Vistula ranged from an initial 44 km per year, up to 197 km per year thereafter (mean = 88 km per year).

The gibel carp and brown bullhead *Ameiurus nebulosus* were intentionally introduced either to Belarus or Poland for stock enhancement, recreational and aquaculture purposes, and therefore the central corridor is at best a secondary dispersal route. During the present survey, gibel carp were not

found in the main riverbed of the River Pripyat, but occurred in its oxbows, although it was only caught in low numbers (two to three individuals per fishnet). In the Vistula and Bug river basins, gibel carp have been noted since the 1940s (Staff 1950); however during recent surveys (Table 1) it was present only in the Włocławski Reservoir (site 38), in the lower River Vistula (Fig. 1). The brown bullhead has been reported for waters in river basins that make up the central corridor (Adamczyk 1975, Danilkiewicz 1997, Brylińska 2000) but not in the corridor itself until the 1990s, when it was found in the main river bed of the River Bug (Danilkiewicz 1997).

Introduction and rapid spread of the topmouth gudgeon *Pseudorasbora parva* in Europe, including Poland and Belarus, was as a contaminant of fish consignments of Chinese carp (Witkowski 1991; Kunitsky, Pluta 1999). Topmouth gudgeons were first reported in Belarus in 1998, but not in the River Pripyat proper, only in its northern tributary, the River Ptych (Kunitskiy, Pluta 1999). In Poland, topmouth gudgeons have been recorded at many locations throughout the country, including the Vistula and Bug catchments (Witkowski 2002), the latter being in the main course of the Bug a few kilometres downstream of its confluence with the River Mukhavets (Czeczuga et al. 2002).

The only species of Boreal origin to have entered rivers of the Black Sea basin is the ninespine stickleback, a species native to Poland although present only in the northern and central part of the country, including lower parts of the Vistula River and the Bug River basins (Brylińska 2000). The ninespine stickleback is currently found mainly in the upper part of the Pripyat system, in particular in canals that connect the Baltic and Black Seas. Further expansion of ninespine sticklebacks into the Black Sea basin is likely to occur through the Oginskij Canal, which connects the River Yaselda (a tributary of the Pripyat) to the River Neman basin (Olenin 2002). During the 2007 survey, this species was found only in the Pripyat-Bug Canal (sites 11 and 12).

Potential future invasions

The Kiev Reservoir (Ukraine) is the likely source of future invasions because it has contributed previous invaders via the central corridor. Four such future invaders, all of Ponto-Caspian origin and already established in the reservoir, are the southern stickleback *Pungitius platygaster*, the bighead goby

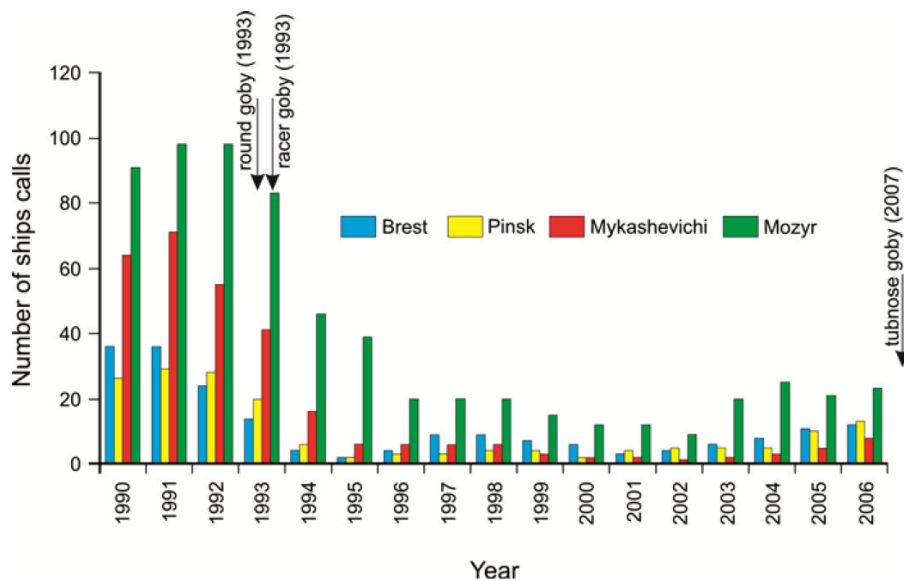


Fig. 2. Number of ships calls in river ports on the Pripyat River. Arrows indicate year of gobies' first records.

Neogobius kessleri, the black-striped pipefish, *Syngnathus nigrlineatus*, and the stellate tadpole goby *Benthophilus stellatus*.

During 2008, the southern stickleback and black-striped pipefish were found in the Belarusian section of the River Dnieper (upstream from the section of the river belonging to the central corridor) on the border between Belarus and Ukraine (V. Rizevsky, M. Pluta, unpublished data). The black-striped pipefish entered the Kiev Reservoir in 1990 from the southern part of the River Dnieper, and is now widely distributed in all Dnieper dam reservoirs in high abundance (Romanenko et al. 2003). The distribution of stellate tadpole gobies is related to the construction of reservoirs on the River Dnieper. This species entered the Kiev Reservoir immediately after its construction in the 1980s and was recently found in the reservoir's upstream section (Zimbalevskaya et al. 1989, Romanenko et al. 2003). The invasion history of the bighead goby shows its fast spread in the Ukrainian section of the River Dnieper also (Copp et al. 2005). Another non-native species, the channel catfish, *Ictalurus punctatus*, was introduced in 1979 to Lake Beloe, a power station cooling reservoir belonging to the River Pripyat basin (A. V. Alekhovich, personal communication). So far it has not been found in the main course of the central invasion corridor. Channel catfish cannot reproduce under natural conditions in the climatic zone of Belarus and Poland, and therefore its spread to other water bodies is unlikely.

Pathways

Together with natural spread, shipping appears to be an essential factor for dispersal of non-native fish species in the River Pripyat basin. Maximum shipping intensity dates from 1990 – 1995, followed by a period of decline from 1996 – 2002; however shipping intensity has increased again (Fig. 2). Mykashevichy and Mozyr are the busiest river ports. Mykashevichy port is connected to the River Pripyat via a 7 km long canal and is the main point on the River Pripyat where ships and barges discharge ballast water before loading. Five of six non-native fish species recorded in the Belarusian section of the central corridor occurred in high abundance in this canal. River shipping is known to have facilitated the spread of gobiids from the Danube, where goby densities were found to be highest in the vicinity of river harbours, which usually provide rip-rap habitats with an abundance of hiding and nesting places (Wiesner 2005). River shipping also facilitated the spread of non-native fish in Belarus, although in some cases it is difficult to differentiate between the natural dispersal of non-native fish along river basins, and that related to shipping. In the River Pripyat, Ponto-Caspian species display predominantly natural dispersal in the lower part of the river due to the short distance from the Kiev Reservoir, a donor area. Their further distribution along the River Pripyat has probably been aided by shipping.

The relationship between non-native species introduction dates and the number of ship calls (Fig.

2) suggests that some species (e.g. the round and racer goby, and probably also the tubenose goby) invaded the River Pripyat when shipping was at its most intense. As suggested by Weisner (2005), these species appear to have established new populations in the port areas, increased their abundance, and then spread naturally within the river basin. A similar lag-effect between time of introduction and establishment has also been observed in some non-native invertebrates (Semenchenko et al. 2007, Semenchenko & Laenko 2008). However, natural dispersal is the main form of expansion in the Polish section of the central corridor, where shipping intensity is very low. In fact, there are no river harbours on the River Bug. After World War II, a dam was built on the River Mukhavets at Brest (Belarus) in order to maintain a high water level in the Korolevskiy/Pripyat-Bug Canal (sites 11–13), and shipping traffic on the River Bug was halted (Blue Book of Belarus 1994). Since 1996, several barges were transported to Poland on a few occasions, by way of temporary openings in the connections between the rivers. This may have allowed some aquatic organisms to migrate across the watershed between the rivers Mukhavets and Bug (Karatajev et al. 2008). Surprisingly, the first Ponto-Caspian goby, the racer goby, to migrate from Belarus to the River Bug, was found there earlier, in 1995. Apparently it expanded its range by natural migration.

CONCLUSION

The central invasion corridor is an important route for expansion of four species of Ponto-Caspian gobies, the monkey goby, racer goby, round goby and the tubenose goby. Similar extensive upstream migration of these fish was observed along the rivers Don (Naseka et al. 2005) and the Danube (Ahnelt et al. 1998; Prášek, Jurajda 2005). Some of them have extended farther to the west through the opening of the Danube-Main-Rhine canal (van Beek 2006, von Landwüst 2006). Their rapid expansion has been noted since the early 1990s. The reason it did not occur earlier remains unknown. The expansion of gobies up the Danube could be interpreted as a combination of continuing post-glacial colonisation (i.e. active natural spread) and of passive dispersal facilitated by shipping (Ahnelt et al. 1998). Species spread in Europe and further afield is often related to shipping intensity (Ahnelt et al. 1998, Wiesner 2005). Additionally, river regulations (i.e. water retention structures) have dramatically changed the river

continuum (including temperature regimes), with new habitat types (e.g. dykes, rip-rap) presenting a much greater area of suitable habitat for colonisation by gobiid species (Wiesner 2005). These man-made factors, essential in the case of the Belarusian section of the corridor, are probably less important in the Polish section where the River Bug remains an example of a relatively natural lowland river. Similarly, the River Vistula has not been canalised in most of its course. The recent expansion of Ponto-Caspian gobies in Europe has been facilitated by a range of factors, including, but not limited to, species-specific traits such as phenotypic plasticity, reproductive tactics, and low parasite loads if compared to native species (Copp et al. 2005). At present, plans for reconstruction of the Dnieper-Bug Canal, including the Polish section of the River Bug, have been developed, including the construction of new navigation locks (Govorovsky 2008). The revitalisation of this trans-boundary waterway, and the subsequent shipping intensification, would greatly accelerate the exchange of fauna between the Black, Baltic and North Sea basins, and the expansion of non-native species in river systems along the central invasive corridor.

ACKNOWLEDGEMENTS

We thank G.H. Copp for essential comments and language corrections that improved the manuscript, as well as A. Leschenko, I. Ermolaeva, L. Marszał, G. Zięba, Dariusz Pietraszewski, S. Tybulczuk, Ł. Kapusta, A. Kruk, P. Szychalski and M. Molski for sampling assistance. This work was supported by the European Commission 6th Framework Program, Integrated Project ALARM (contract GOCE-CT-2003-506675), grants from the Polish Ministry of Science and Higher Education (project N 303 10163/4022 and N 305 10163), and an internal grant from the University of Łódź.

REFERENCES

- Adamczyk, L.H., 1975, *Brown bullhead Ictalurus nebulosus (Le Sueur, 1819) in a lake biocenosis*. Przegl. Zool., 19: 71–73, (in Polish with Engl. summ.)
- Antychowicz, J., 1994, *Percottus glehni in our waters*. Kom. Ryb., 2: 21–22, (in Polish)
- Ahnelt, H., Bănărescu, P., Spolwind, R., Harka, Á., Waidbacher, H., 1998, *Occurrence and distribution of three gobiid species (Pisces, Gobiidae) in the middle and upper Danube region – examples of dispersal patterns?* Biologia (Bratislava), 53: 665–678

- Babenko, L. O., 1961, *Records of round goby, new species in middle part of the Dnieper River*. Izvestia Kievskogo Universiteta, Biol. Nauki, 2: 116–117, (in Ukrainian)
- Berg, L.S., 1933, *Freshwater fish of USSR. Part 2*. pp. 546, (in Russian)
- Bij de Vaate, A., Jazdzewski, K., Ketelaars, H.A.M., Gollash, S., van der Velde, G., 2002, *Geographical patterns in range extension of Ponto-Caspian macroinvertebrate species in Europe*. Can. J. Fish. Aquat. Sci., 59: 1159–1174
- Brylińska, M. (ed.), 2000, *The Freshwater Fishes of Poland*. Warszawa, PWN, pp. 524, (in Polish)
- Copp, G.H., Bianco, P.G., Bogutskaya, N.G., Erös, T., Falka, I., et al. 2005, *To be, or not to be, a non-native freshwater fish?* J. Appl. Ichthyol., 21: 242–262
- Czczuga, B., Kiziewicz, B., Danilkiewicz, Z., 2002, *Zoosporic fungi growing on the specimens of certain fish species recently introduced to Polish waters*. Acta Ichthyol. et Piscat., 32 (2): 117–125
- Danilkiewicz, Z., 1996, *Racer goby Neogobius gymnotrachelus (Kessler, 1857) Perciformes, Gobiidae – a new species in the ichthyofauna of the Baltic Sea*. Kom. Ryb. 2: 27–29, (in Polish)
- Danilkiewicz, Z., 1997, *Lampreys and fishes of the Bug River and its Polish tributaries*. Arch. Ryb. Pol., 5: 5–82
- Danilkiewicz, Z., 1998, *Neogobius gymnotrachelus (Kessler, 1857) Perciformes, Gobiidae – a Pontic element new to the ichthyofauna of the Baltic basin*. Fragm. Faunist., 41: 269–277 (in Polish with Engl. summ.)
- Freyhof, J., 2003, *Immigration and potential impacts of invasive freshwater fishes in Germany*. Berichte des IGB 17: 51–58
- Govorovsky, B., 2008, *Environmental and transport aspects of transboundary co-operation in Belarus*. The 16th Meet. of the OSCE Econ. and Environ. Forum, Vienna, Austria
- Grabowska, J., Pietraszewski, D., Ondračková, M., 2008, *Tubenose goby Proterorhinus marmoratus (Pallas, 1814) has joined three other Ponto-Caspian gobies in the Vistula River (Poland)*. Aquat. Invasions, 3: 261–265
- Grabowska, J., Grabowski, M., Pietraszewski, D., Gmur, J., 2009, *Non-selective predator – versatile diet of Amur sleeper (Percottus glenii Dybowski, 1877) in the Vistula River (Poland), a newly invaded ecosystem*. J. Appl. Ichthyol., 25: 451–459
- Grabowska, J., Witkowski, A., Kotusz, J., 2010, *Alien invasive fish species in Polish waters: an overview*. Folia Zool., 59(1): 73–85
- Gratsyanov, V.I., 1907, *The essay of review fishes of Russian Imperia in systematic and geographical plan*. Doklady otdela ichtiologii Rossiyskogo Imperatorskogo obschestva acclimatizatsii zhivotnykh i rasteniy. Vol.4: 567, pp. (in Russian)
- Gulugin, S.Y., Kunitsky, D.F., 1999, *New data on spread of area family Neogobius: N. fluviatilis, N. melanostomus, N. gymnotrachelus*. Thesis of Inter. Scien. Conf., Kaliningrad, Russia, Vol.1: p.5, (in Russian)
- Ivlev, V.S., Protasov, A.A., 1948, *Brown Bullhead Catfish in the lakes Volyn' region*. Priroda, 8: 32–36, (in Russian)
- Jazdzewski, K., 1980, *Range extensions of some gammaridean species in European inland waters caused by human activity*. Crustaceana Suppl., 6: 84–107
- Jazdzewski, K., Konopacka, A., Grabowski, M., 2002, *Four Ponto-Caspian and one American gammarid species (Crustacea, Amphipoda) invading Polish waters*. Contrib. Zool., 71 (4): 115–122
- Kakareko, T., 1999, *Percottus glenii (Odontobutidae) – in the Włocławek Dam Reservoir on the lower Vistula River*. Przegl. Zool., 42: 107–110, (in Polish with Engl. summ.)
- Kakareko, T., Żbikowski, J., Żytkowicz, J., 2005, *Diel partitioning in summer of two syntopic neogobiids from two different habitats of the lower Vistula River, Poland*. J. Appl. Ichthyol., 21: 292–295
- Kakareko, T., Kobak, J., Terlecki, J., Hadowski M., 2008, *External morphology and growth rate of white-eye bream Ballerus sapa (Cyprinidae, Teleostei) in a lowland dam reservoir on the lower Vistula River (Włocławski Reservoir, central Poland)*. Folia Zool., 57(4): 435–451
- Karatayev, A.Y., Mastitsky, S.E., Burlakova L.E., Olenin S., 2008, *Past, current, and future of central European corridor for aquatic invasions in Belarus*. Biol. Invasions, 10: 215–232
- Kostrzewa, J., Grabowski, M., 2001, *Racer (goad) goby Neogobius gymnotrachelus (Kessler, 1857) (Gobiidae, Perciformes) – a new fish species in the Vistula River*. Przegl. Zool. 45: 101–102 (in Polish with Engl. summ.)
- Kostrzewa, J., Grabowski M., 2002, *Monkey goby, Neogobius fluviatilis (Pallas, 1811), in the Vistula River – a phenomenon of Ponto-Caspian Gobiidae invasion*. Przegl. Zool., 46: 235–242, (in Polish with Engl. summ.)
- Kostrzewa, J., Grabowski, M., Zięba G., 2004, *New invasive fish species in Polish waters*. Arch. Ryb. Pol., 12(Suppl. 2): 21–34, (in Polish with Engl. summ.)
- Kunitsky, D. F., Pluta M.V., 1999, *Stone morocco Pseudorasbora parva – new species in ichthyofauna of Belarus*. Izvestiya Akademii Nauk Belarusi, biologicheskie nauki, 3: 122–123, (in Russian with Engl. summ.)
- Mahon, R., 1984, *Divergent structure in fish taxocenes of north temperate streams*. Can. J. Fish. Aquat. Sci., 41: 330–350
- Naseka, A.M., Boldyrev, V.S., Bogutskaya N.G., Delitsyn, V.V., 2005, *New data on the historical and expanded range of Proterorhinus marmoratus (Pallas, 1814) (Teleostei: Gobiidae) in Eastern Europe*. J. Appl. Ichthyol., 21: 300–305
- Ohayon, J.L., Stepien, C.A., 2007, *Genetic and biogeographic relationships of the racer goby Neogobius gymnotrachelus (Gobiidae: Teleostei) from introduced and native Eurasian locations*. J. Fish. Biol., 71(Suppl. C): 360–370
- Olenin, S., 2002, *Black Sea - Baltic Sea invasion corridors*. [in:] *Alien marine organisms introduced by ships in the Mediterranean and Black Seas*. Ed. Briand, F., Comission Internationale pour l'Exploration Scientifique de la mer Mediterranee, Monaco, CIESM Workshops Monograph., pp. 29–33
- Panov, V.E., Dgebuadze Y.Y., Shiganova T.A., Filippov A.A., Minchin D., 2007, *A risk assessment of biological invasions in the inland waters of Europe : the northern invasion corridor case study*. [in:] *Biological invaders in inland waters: Profiles, distribution, and threats*. Ed. Gherardi, F., Dordrecht, Springer, pp. 639–656
- Prášek, V., Jurajda, P., 2005, *Expansion of Proterorhinus marmoratus in the Morava River basin (Czech Republic, Danube R. watershed)*. Folia Zool., 54: 189–192
- Rizevsky, V.K., Pluta, M.V. & Ermolaev, I., 1999, *Morphological data about Amur sleeper (Percottus glebni Dybowski) from reservoirs water-system of Minsk*. Izvestiya Akademii Nauk Belarusi, biologicheskie nauki, 3: 119–121, (in Russian with Engl. summ.)
- Rizevsky, V., Pluta, M., Leschenko, A., Ermolaeva, I., 2007, *First record of the invasive Ponto-Caspian tubenose goby Proterorhinus marmoratus (Pallas, 1814) from the River Pripyat, Belarus*. Aquat. Invasions, 2: 275–277
- Rizevsky, V., Pluta, M., Leschenko, A., Ermolaeva, I., Novik, I., 2009, *New species of fish in fauna of Belarus*. Doklady Akademii Nauk Belarusi, 53(3): 95–97, (in Russian)
- Rolik, H., Rembiszewski, J.M., 1987, *The freshwater fauna of Poland. Vol. 5. Fishes and lampreys - Pisces et ceclostomata*. Warszawa, PWN, pp. 317, (in Polish)

- Romanenko, V.D., Aphanasiev, S.A., Petukhov, V.B., Vasenko, A.G., Scherbak, S.D., Kumani, M.F., Kostousov, V.G., Evtushenko, N.Y., 2003, *The influence of fish farm on biological diversity in Dnieper River basin*. Kiev, Akademperiodika, pp. 188 (in Russian)
- Semenchenko, V., Laenko, T., 2008, *First record of the invasive North American gastropod Ferrissia fragilis (Tryon, 1863) from the Pripjat River basin, Belarus*. Aquat. Invasions, 3: 80–82
- Semenchenko, V., Raslutski, V., Vezhnovetz, V., 2007, *New invasive Ponto-Caspian mysid, Limnomysis benedeni, on Belarusian part of European central invasive corridor*. Aquat. Invasions, 2: 272–274
- Skóra, K.E., Stolarski J., 1993, *New fish species in the Gulf of Gdansk, Neogobius sp. [cf. Neogobius melanostomus (Pallas 1811)]*. Bull. Sea Fish. Inst., 1(128): 83–84
- Smirnov, A.I., 1986, *Fauna of Ukraine*. Kiev, Naukova dumka, Vol. 8(5), pp. 320, (in Russian)
- Staff, F., 1950, *Freshwater fishes of Poland and adjacent countries*. Warszawa, Trzaska, Evert & Michalski, pp. 286, (in Polish)
- Terlecki, J., 1990, *White-eye bream, Abramis sapa (Pallas, 1811) – first record in Poland, in man-made Zegrzyńskie Lake*. Acta Ichthyol. Piscat., 22(2): 97–108
- Terlecki, J., Palka, R., 1999, *Occurrence of Percottus glenii Dybowski 1877 (Perciformes, Odontobutidae) in the middle stretch of the Vistula River, Poland*. Arch. Ryb. Pol., 7: 141–150
- Van Beck, G.C.W., 2006, *The round goby Neogobius melanostomus first recorded in the Netherlands*. Aquat. Invasions, 1: 42–43
- Von Landwüst, C., 2006, *Expansion of Proterorhinus marmoratus (Teleostei, Gobiidae) into the River Moselle (Germany)*. Folia Zool., 55: 107–111
- Voronin, F.N., 1957, *Fish of Belarus*. Minsk, Universitetskoepp. pp. 83, (in Russian)
- Vorontsov, E.M., 1937, *Composition ichthyofauna of waterbodies of West region and BSSR, and characterization of ichthyofauna of the upper part of Dnieper River basin*. Smolensk, Fauna and Ecologia, 3: 59–86, (in Russian)
- Wiesner, C., 2005, *New records of non-indigenous gobies (Neogobius spp.) in the Austrian Danube*. J. Appl. Ichthyol., 21: 324–327
- Wiśniewolski, W., Borzęcka, I., Buras, P., Szlakowski, J., Woźniewski, M., 2001, *Fish fauna of the lower and middle Vistula River*. Roczn. Nauk PZW 14(Suppl.), 137–155, (in Polish with Engl. summ.)
- Witkowski, A., 1984, *An analysis of the ichthyofauna of the Biebrza River basin. Part I: the morphological and systematical characteristic of lampreys and fishes*. Wrocław, Acta Universitatis Wratislaviensis, 646: 1–110 (in Polish with Engl. summ.)
- Witkowski, A., 1991, *Pseudorasbora parva (Schlegel, 1842) (Cyprinidae, Gobiioninae) a new component of the Polish ichthyofauna*. Przegl. Zool., 35: 323–331, (in Polish with Engl. summ.)
- Witkowski, A., 1996, *Changes in the ichthyofauna of the Polish rivers: native and introduced species*. Zool. Poloniae 41(Suppl.): 29–40
- Witkowski, A., 2002, *Introduction of fishes into Poland: benefaction or plague?* Nature Conserv., 59: 41–52
- Woźniewski, M., 1997, *Amur sleeper – a new fish species in the Vistula River*. Wiadomości Wędkarskie, 12: 69, (in Polish)
- Zelensky, I., 1864, *Data for geography and statistics of Russia. Minsk Province. Vol. 2*, St. Petersburg, pp. 671, (in Russian)
- Zimbalevskaya, L.N., Sukhoyvan, P.G., Chernogorenko, M.I., Gurvich V.V., Gusynslaya S.L., Vyatchanina L.I., Nebrat A.A., Pligin Yu.V., Sherstiuk V.V., Severenchuk N.S., Kurandina D.P., Titar V.M., Boshko E.G. 1989, *Invertebrates and fishes of Dnieper River and its reservoirs*. Kiev, Naukova dumka, pp. 248, (in Russian)
- Zhukov, P.I., 1965, *The fishes of Belarus*. Minsk, Nauka i Tekhnika, pp. 415, (in Russian)
- Zhukov, P.I., 1988, *A background of the ecology of freshwater fish*. Minsk, Nauka i Tekhnika, pp. 443, (in Russian)