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Occurrence, dispersion and habitat preferences of Amur sleeper (*Perccottus glenii*) in oxbow lakes of a large river and its tributary

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Abstract Amur sleeper (*Perccottus glenii*) is currently one of the most invasive fish species in Europe. This inspired our research to identify potential channels of emigration in two rivers, the Vistula and the Wieprz. Amur sleeper occurrence, abundance, population size structure and impact on indicators of diversity were examined in oxbow lakes of both rivers. Amur sleeper was recorded for the first time in floodplain areas located between two rivers, which may serve as main travel corridors. Amur sleeper was noted in four out of six oxbow lakes in each river. Its relative abundance varied depending on the oxbow lake, ranging from 0.002 to 1.60 ind. m^{-2} in the basin of the Vistula River and from 0.04 to 0.35 ind. m^{-2} in the basin of the Wieprz River. Percentage share in the dominance structure ranged from 2.42 to 100 % and from 40 to over 67 % in the oxbow lakes of the Vistula River and Wieprz River, respectively. The size structure of the Amur sleeper populations was dominated by young individuals (Tl < 50 mm), which is characteristic of developing populations. The presence of Amur sleeper did not significantly affect biodiversity indicators. Its occurrence was related to the amount of vegetative cover.

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Introduction

In recent years, Amur sleeper, *Perccottus glenii* Dybowski, 1877 (Odontobutidae), has been one of the most invasive fish species in Europe. It has been reported for the first time in the water bodies of many countries (Koščo et al. 2003; Nalbant et al. 2004; Reshetnikov 2004; Jurajda et al. 2006; Simonović et al. 2006; Năstase 2007; Ćaleta et al. 2011; Covaciu-Marcov et al. 2011). Reshetnikov (2013) reports that the range of Amur sleeper in Europe is continually increasing.

The problem of this species' movement and spread to new areas is important in terms of the phenomenon of invasiveness. Precise information about the occurrence and abundance of this non-native fish species is still lacking (Reshetnikov 2010; Wałowski and Wolnicki 2010). In case of Amur sleeper, this is probably due to the difficulty of conducting field research in small water bodies, where the species most often occurs, as they are often inaccessible and heavily overgrown with vegetation.

Thus far Poland, specifically the Vistula River, has constituted the western boundary of the range of occurrence of this invasive species (Reshetnikov 2010;

Reshetnikov and Ficetola 2011). A few publications have reported the occurrence of Amur sleeper in the Vistula River (Antychowicz 1994; Terlecki and Pałka 1999; Nowak et al. 2008), as well as a few individuals in the Bug River basin (Marszał et al. 2009; Penczak et al. 2010). In the years 2010–2011 isolated individuals were also recorded in the Warta River, to the west of the Vistula River (Andrzejewski et al. 2011).

The biology of this species is fairly well established, including food preferences, growth rate and questions related to reproduction (Koščo et al. 2008; Grabowska et al. 2009; Wałowski and Wolnicki 2010). We also have some knowledge of its impact on aquatic ecosystems and organisms living in them. Due to its predatory lifestyle and invasiveness, in new regions this species can significantly affect many groups of aquatic organisms (Orlova et al. 2006). It particularly affects amphibians and fish, causing a significant decrease in their biodiversity and abundance by eating their eggs or eliminating juvenile forms (Reshetnikov 2001, 2003, 2008). In addition, due to its high resistance, low habitat requirements and reproductive effectiveness, it is a serious competitor with native fish species for habitats and food in new areas. However, dispersal into new regions and the lack of precise knowledge of habitat preferences remain a major problem requiring further research.

Hence the purpose of the study was (1) to record the occurrence of Amur sleeper in a new, previously unknown location (the valley of the middle course of the Wieprz River) and to verify potential channels of migration from a known location occupied by this species (the oxbow lakes of the Vistula River); (2) to determine the relative abundance and proportion of Amur sleeper in the ichthyofauna of oxbow lakes of the Vistula and Wieprz Rivers and to compare indicators of diversity of the fish community with or without Amur sleeper in the oxbow lakes; and (3) to attempt to determine the habitat preferences of the Amur sleeper based on abiotic and water parameters in the oxbow lakes in the valley of a large river and its tributary.

Materials and methods

Study area

The research was conducted in June and September 2012. The catches were carried out in a total of 12 oxbow lakes—six located in the valley of the Vistula River and six in the valley of the Wieprz River (Fig. 1). The oxbow lakes were natural in character and eutrophic. They had an elongated shape and were 0.1–0.8 ha in size. Their depth ranged from 0.3 to 2.0 m. Most were highly overgrown with submerged and pleustonic vegetation. The bottom was covered with a large amount of sediment. The water pH ranged from 7.2 to 9.1 and conductivity from 348 to 811 $\mu S\ cm^{-1}$ (Table 1).

Sampling

To verify potential migration paths of the Amur sleeper, additional control collections were conducted midstream in both rivers. In the Vistula River, these catches were conducted at 18 sample sites on a stretch of about 40 km in the vicinity of the oxbow lakes. Five of these were located in the direct vicinity of the oxbow lakes in which Amur sleeper was observed for the first time in the late 1990s (Terlecki and Pałka 1999) (Fig. 1). In the Wieprz River, fish collection was conducted on 11 sample sites located on a stretch of about 100 km (Fig. 1).

Fish collections were made from a boat-mounted electrofisher (generator 1.6 kW, 250–350 V, 10 A) moving with the current along one of the river banks at a range of about 3 m from shore. The length of the research sites on both the Wieprz and Vistula rivers ranged from 500 to 1000 m. Fish sampling in the oxbow lakes was carried out using a boat-mounted electrofisher (IUP-12; 230–350 V, 10 A). In each oxbow lake electrofishing was conducted on two occasions (in June and September), with two samples on each occasion, for a period of 1 h.

The fish specimens caught were identified to species, and measurements were taken of their weight (*W*; to the nearest 0.1 g), total length (Tl) and standard length (Sl) (to the nearest 1 mm). Native fish species were put back into the water, and all *P. glenii* specimens were killed with an overdose of 2-phenoxyethanol, followed by immediate preservation in 4 % formaldehyde.

Basic environmental variables and water parameters were quantified for each water body. We collected 500 ml water samples for chemical analyses. Temperature, conductivity and pH were determined in situ with a multiparametric probe, and TOC, BOD and COD were determined in the laboratory with a PASTEL UV spectrophotometer. Additionally, submerged and

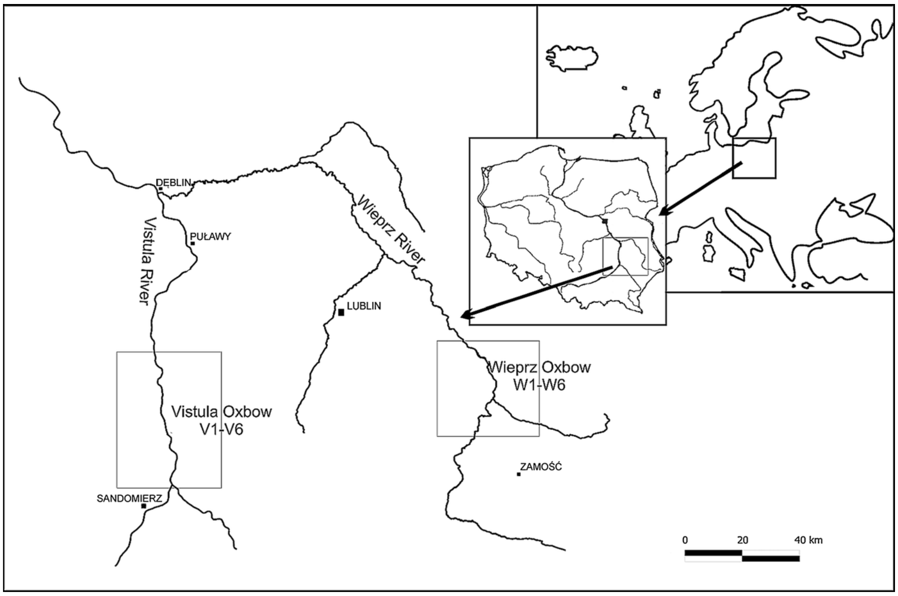

Fig. 1 Location of study area and the sampling station

pleustonic vegetation in each of the oxbow lakes were determined on the basis of five transects 20 m wide. Along each transect the percentage of the water surface covered by submerged and pleustonic vegetation was estimated (Ciecierska 2004).

Data and statistical analysis

Species composition and richness, as well as numerical dominance, were determined for the fishes in the oxbow lakes. Stability of occurrence and the dominance index were calculated for the ichthyofauna of the rivers. Stability of occurrence (C_i) and the dominance index ($n\%$) were calculated by the following formulas: $C_i = 100 \times s_i/s_t$ and $n\% = 100 \times n_i/N$, where s_i is the number of sample sites where species 'i' was present, s_t is the total number of sample sites, n_i is the number of individuals of species 'i' and N is the total number of fish.

In addition, the percentage of *P. glenii* in collections and its abundance were determined. To compare the abundance of all fish and *P. glenii* in all oxbow lakes the catch per unit effort (CPUE) was calculated as fish individuals per 1 m (ind. m^{-2}). Moreover size structure for Amur sleeper was evaluated for both river valleys, allowing fish size classes to be determined in each population.

Species richness, estimated species richness (eS) and selected diversity indices, i.e. the Margalef index (R), the Shannon–Wiener index and the Simpson diversity index (D), were determined for each sampling site in the oxbow lakes. To calculate the estimated species richness (eS) the Jackknife 1 procedure was used. The Margalef index (R) was calculated by following formula: $R = S - 1/\ln(N)$, where S is species richness and N is the total number of observed individuals. The Shannon–Wiener index and the Simpson diversity index were determined using Biodiversity Pro software (McAleece et al. 1997).

Distribution of normality and homogeneity of variance for total fish abundance (total CPUE), abundance of Amur sleeper (As CPUE) and all diversity indices were calculated. The values obtained for diversity parameters, relative abundance of fish and relative abundance of Amur sleeper were tested by analysis of variance (two-way ANOVA), where the categorical predictors were the river, i.e. where the oxbow lakes were located, and the presence/absence of Amur sleeper in the fish community. The analyses and statistical tests described above were carried out using the Statsoft Statistica package for Windows at a significance level of $p \leq 0.05$.

Ordination techniques were used to describe the relationships between the species fish diversity and environmental variables. The indirect multivariate method, detrended correspondence analysis (DCA), was used to measure and illustrate gradients of fish

Table 1 Localization, characteristics and values of selected water parameters of oxbow lakes of Vistula and Wieprz rivers; means values for summer 2012

River	Oxbow lakes	Location GPS	Parameters						
			pH	Conductivity (μS cm^{-1})	Oxygen (mgO$_2$ dm^{-3})	TDS (mg dm^{-3})	ORP (mV)	Pleustonic plants (% area)	Emergent plants (% area)
Vistula River valley	V1	N50°58′40.49″ E21°49′51.74″	8.1	348	4.9	0.23	−169.1	5	92
	V2	N50°58′44.23″ E21°49′30.96″	9.1	479	6.9	0.31	−229.8	0	0
	V3	N50°58′57.77″ E21°49′31.78″	8.4	544	4.5	0.35	−168.5	5	7
	V4	N51°10′21.50″ E21°47′58.62″	7.7	404	4.6	0.26	−54.4	30	50
	V5	N51°10′54.03″ E21°48′11.22″	8.3	443	5.1	0.29	−155.4	90	100
	V6	N51°10′32.43″ E21°48′31.45″	8.4	467	5.3	0.30	−152.1	70	80
Wieprz River valley	W1	N50°57′24.8″ E23°10′0.95″	7.2	429	2.9	0.28	−51.0	10	30
	W2	N50°56′41.79″ E23°10′25.78″	8.5	416	3.5	0.27	7.4	10	35
	W3	N50°55′24.63″ E23°09′10.02″	7.4	811	4.2	0.53	12.9	20	60
	W4	N50°56′06.67″ E23°09′50.05″	7.7	553	4.0	0.36	−19.3	40	90
	W5	N50°55′05.33″ E23°08′13.68″	7.8	579	4.5	0.38	−78.1	100	60
	W6	N50°55′16.08″ E23°08′20.59″	7.6	533	5.0	0.35	12.1	90	80

communities. Due to the length of the gradient with a range up to four standard deviations (SD), we used canonical correspondence analysis (CCA) to determine the relationships between fishes and environment parameters. The parameters of the environment with the greatest impact on the occurrence of fish taxa were determined with a stepwise variable selection (Monte Carlo permutation test). Significant variables were selected by p value of <0.1 to <0.01. The analyses were performed in CANOCO 4.5 for Windows.

Results

A total of 11,390 fish were caught during the research: 4728 in the Vistula River, 4328 in the Wieprz River and 2334 in the oxbows. The presence of Amur sleeper in the two rivers was not confirmed (Table 2). Amur sleeper was confirmed in the oxbow lakes of the Vistula River, and its presence was recorded for the first time in the oxbow lakes of the Wieprz River, a tributary of the Vistula River (Fig. 1). In the basins of both the Vistula and Wieprz rivers Amur sleeper was present in four of six of the oxbow lakes investigated. Moreover, the presence of a few individuals of another invasive species, the topmouth gudgeon (*Pseudorasbora parva*), was noted in both rivers (Table 2).

The catches in the rivers resulted in 24 species of fishes in the Vistula River and 21 in the Wieprz River, belonging to six families. There were 15 species recorded in the oxbow lakes of the Vistula River and 14 in those of the Wieprz River, all of which belonged

Table 2 Number (N), abundance ($n\%$), stability of occurrence (C_i) and morphological characteristics (Tl, in cm; W in g) of fish from Wieprz River (11 study stations, including five located in near Wieprz oxbow lakes region) and fish from Vistula River (18 study stations, including 12 located in near Vistula oxbow lakes region)

	Wieprz River					Vistula River				
	N	$n\%$	C_i	Tl (mean ± SD)	W (mean ± SD)	N	$n\%$	C_i	Tl (mean ± SD)	W (mean ± SD)
Aspius aspius (L.)	8	0.20 ± 0.38	36.36	29.50 ± 26.47	3.00–3650.00	107	3.72 ± 4.17	77.78	8.18 ± 9.12	55.92 ± 277.34
Leuciscus idus (L.)	20	0.45 ± 0.61	63.64	30.42 ± 6.65	101.00–1571.00	12	0.63 ± 1.53	33.33	16.55 ± 11.66	107.40 ± 230.15
Abramis brama (L.)	284	6.69 ± 10.31	72.73	10.07 ± 3.23	2.00–527.00	227	4.55 ± 6.87	66.67	11.73 ± 5.01	10.56 ± 17.21
Alburnus alburnus (L.)	2083	32.73 ± 28.04	90.91	9.62 ± 3.08	0.20–37.00	1835	32.17 ± 17.27	100.00	9.87 ± 3.20	3.96 ± 4.89
Leucaspius delineatus (Heckel, 1843)	30	0.38 ± 1.25	9.09	15.20 ± 0.30	27.00–27.00	499	11.47 ± 10.59	100.00	12.60 ± 2.40	26.39 ± 23.85
Rutilus rutilus L.	1248	32.09 ± 11.80	100.00	10.66 ± 3.41	1.00–273.00	326	8.80 ± 8.78	100.00	15.66 ± 4.88	54.04 ± 89.28
Leuciscus cephalus (L.)	59	1.51 ± 2.40	63.64	21.66 ± 6.60	4.00.851.00	803	19.13 ± 18.14	100.00	9.14 ± 2.39	9.82 ± 7.08
Gobio gobio (L.)	298	13.65 ± 19.38	63.64	11.38 ± 1.66	2.00–23.00	113	3.82 ± 4.43	72.22	11.53 ± 2.64	12.72 ± 27.28
Leuciscus leuciscus (L.)	11	0.57 ± 1.47	27.27	14.56 ± 3.70	10.00–117.00	6	0.22 ± 0.49	33.33	24.92 ± 15.26	97.00 ± 12.00
Barbus barbus (L.)	1	0.02 ± 0.05	9.09	72.00 ± 0.00	3481.00–3481.00	241	3.86 ± 5.76	66.67	11.58 ± 2.08	19.15 ± 13.39
Blicca bjoerkna (L.)	75	2.07 ± 4.65	27.27	10.43 ± 2.54	4.00–385.00	45	1.28 ± 1.54	55.56	8.29 ± 2.73	5.83 ± 4.00
Alburnoides bipunctatus (Bloch, 1782)	1	0.02 ± 0.05	9.09	9.40 ± 0.00	4.00–4.00	11	0.72 ± 2.39	22.22	5.32 ± 0.64	2.64 ± 0.67
Rhodeus sericeus (Bloch, 1782)	3	3.90 ± 12.92	9.09	5.00 ± 1.73	0.50–2.00	171	2.84 ± 5.78	61.11	7.90 ± 2.27	6.22 ± 3.34
Tinca tinca (L.)	1	0.03 ± 0.10	9.09	30.80 ± 0.00	539.00–539.00	4	0.11 ± 0.27	16.67	14.63 ± 9.91	3.00 ± 1.41
Pseudorasbora parva (Temminck & Schlegel, 1846)	1	0.11 ± 0.37	9.09	4.80 ± 0.00	2.00–2.00	1	0.01 ± 0.04	5.56	13.00 ± 0.00	49.00 ± 0.00
Esox lucius L.	42	2.41 ± 4.30	72.73	32.08 ± 9.65	7.00–837.00	3	0.33 ± 1.39	5.56	26.50 ± 2.18	290.00 ± 69.28
Sander lucioperca (L.)	7	0.26 ± 0.74	18.18	7.67 ± 0.67	3.00–7.00	8	0.20 ± 0.63	22.22	29.81 ± 11.40	360.00 ± 318.72
Perca fluviatilis L.	85	2.23 ± 3.48	63.64	11.56 ± 4.20	1.00–133.00	5	0.13 ± 0.31	22.22	32.40 ± 30.71	1657.75 ± 3228.23
Barbatula barbatula (L.)	1	0.01 ± 0.03	9.09	12.00 ± 0.00	15.00–15.00	182	4.17 ± 7.55	77.78	10.98 ± 2.38	19.86 ± 16.25
Cobitis taenia L.	35	0.68 ± 1.54	36.36	9.95 ± 1.36	2.00–6.00	2	0.06 ± 0.21	11.11	12.50 ± 0.00	24.50 ± 2.12
Lota lota (L.)	1	0.01 ± 0.03	9.09	27.10 ± 0.00	108.00–108.00	11	0.20 ± 0.33	33.33	33.41 ± 36.81	90.83 ± 96.03

SD standard deviation

Table 3 Diversity indices, total abundance of fish (total CPUE) and abundance of Amur sleeper (As CPUE) in oxbow lakes in Vistula and Wieprz rivers

	Localization of oxbow lakes				Amur sleeper presence			
	Vistula River Valley ($n = 6$)		Wieprz River Valley ($n = 6$)		Oxbow lakes without Amur sleeper ($n = 4$)		Oxbow lakes with Amur sleeper ($n = 8$)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Species richness (*S*)	6.17 ± 3.71	1.00–9.00	4.83 ± 1.72	3.00–8.00	7.00 ± 2.16	4.00–9.00	4.75 ± 2.96	1.00–9.00
Estimated S (eS)	14.99 ± 4.97	5.60–19.17	13.89 ± 5.06	4.80–19.00	13.32 ± 6.05	4.80–19.00	15.00 ± 4.43	5.60–19.17
Margalef index (*R*)	0.93 ± 0.64	0.00–1.66	1.12 ± 0.30	0.77–1.54	0.83 ± 0.16	0.60–0.95	0.59 ± 0.32	0.00–0.95
Schannon–Wiener (*H′*)	0.80 ± 0.28	0.30–0.95	0.66 ± 0.14	0.48–0.90	0.40 ± 0.17	0.26–0.62	0.44 ± 0.25	0.22–1.00
Simpson diversity (*D*)	0.43 ± 0.30	0.22–1.00	0.42 ± 0.11	0.32–0.62	1.25 ± 0.27	0.90–1.54	0.91 ± 0.54	0.00–1.66
Total CPUE	0.95 ± 0.71	0.07–1.87	0.28 ± 0.30	0.01–0.67	0.49 ± 0.52	0.01–1.18	0.67 ± 0.70	0.07–1.86
As CPUE	0.38 ± 0.65	0.00–1.60	0.12 ± 0.15	0.00–0.36	–	–	0.37 ± 0.54	0.002–1.60

SD standard deviation

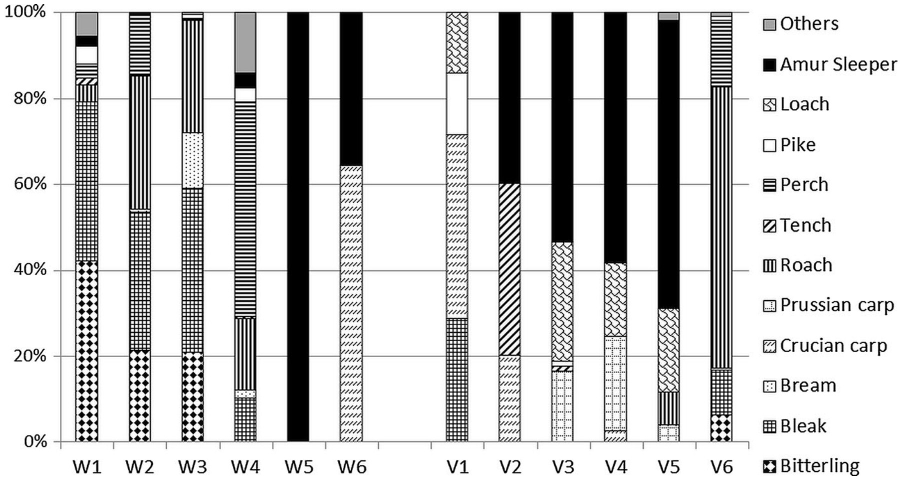

Fig. 2 Fish composition in oxbow lakes in Vistula (V1–V6) and Wieprz (W1–W6) rivers, others—fish species *n*% > 10: Chub, Gudgeon, Pikeperch, Pikeperch, Rudd, Stone loach, Sunbleak, White bream

to five families. Species richness ranged from 1 to 9 species, depending on the oxbow lake, with a slightly higher mean value in the oxbow lakes of the Vistula ($p > 0.05$, not significant). Comparison between oxbows by presence/absence of Amur sleeper (irrespective of location) revealed lower species richness where Amur sleeper was present. However, the estimated number of species was higher in habitats where Amur sleeper was present (Table 3). The average number of fish was more than three times higher in the oxbow lakes of the Vistula River (0.95 CPUE) than in those of the Wieprz (0.28 CPUE) (statistically not significant) (Table 3). The relative abundance of Amur sleeper in the oxbow lakes ranged from 0.002 CPUE to 1.60 CPUE in the basin of the Vistula River and from 0.04 CPUE to 0.36 CPUE in the basin of the Wieprz ($p > 0.05$, not significant) (Table 3). The percentage of Amur sleeper ranged from 2.42 to 100 % in the oxbow lakes of the Vistula River valley and from 40 % to more than 67 % in the oxbow lakes of the Wieprz River (Fig. 2).

The diversity indices for the fish communities of the oxbow lakes of the two rivers were not statistically different (ANOVA, $p > 0.05$), but were slightly higher for fish from the River Vistula. At the same time the values for most parameters, with the exception of the estimated number of species (eS) and overall density of fish (total CPUE), were higher in the

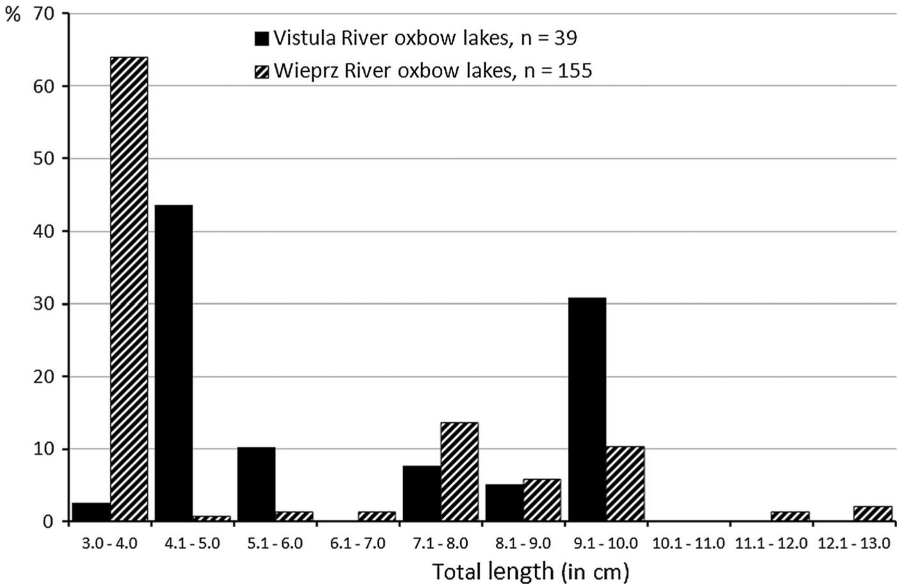

Fig. 3 Frequency of total length (Tl) of Amur sleeper caught in oxbow lakes in Vistula and Wieprz rivers

Table 4 Canonical correspondence analysis: inter-set correlations of environmental variables with the first three axes of the CCA for oxbow lake habitats of Wieprz and Vistula Rivers

Correlations			
Variables	Axis 1	Axis 2	Axis 3
pH	0.3449	0.1302	−0.4768
Temperature	−0.0625	0.8242	0.0060
Conductivity	−0.0526	−0.3025	0.6600
TDS	−0.0577	−0.2903	0.6813
Oxygen	0.4489	−0.4272	−0.1844
ORP	−0.3465	0.4410	0.3503
Pl_pl	−0.6347	−0.3815	−0.1070
Em_pl	−0.7676	−0.3025	0.0341

oxbow lakes where Amur sleeper was not present, but these differences were also not statistically significant (ANOVA, $p > 0.05$) (Table 3).

Analysis of the size structure, and thus the age of the fish caught, showed a clear dominance of juvenile forms (Tl < 50 mm) (Fig. 3). In the oxbow lakes of the Vistula River there was a slightly larger percentage, approximately 30 %, of specimens ranging in length from 91 to 100 mm. In the population of the oxbow lakes of the Wieprz River, only 2–3 % of individuals had the largest body size, Tl < 120 mm (Fig. 3).

In general the CCA explained 79.4 % of cumulative variability in the study; the first three axes accounted for 35.4, 18.2 and 13.3 % of the species variability. From the correlations (Table 4), we concluded that the canonical axes representing environmental variables were explained by a multivariate space determined by axes 1 and 2 (Fig. 4), because axis 1 and axis 2 were most strongly correlated with environmental variables. The CCA analysis did not show a clear distinction between the oxbows of the Vistula and Wieprz rivers. The Monte Carlo permutation test showed that the factor determining species composition, independently of which oxbow lake was analysed, was the degree of bottom coverage by submerged plants ($\lambda = 0.66$; $F = 2.98$; $p = 0.002$). This was also the most important factor determining the occurrence of Amur sleeper. When the two locations were analysed as separate habitats, the test showed that the species composition in the Wieprz River oxbow lakes was most influenced by temperature ($\lambda = 0.51$; $F = 3.37$; $p = 0.068$) and dissolved oxygen ($\lambda = 0.69$; $F = 2.54$; $p = 0.046$), while in the oxbow lakes of the Vistula species composition was determined to the greatest extent by coverage by pleustonic plants ($\lambda = 0.95$; $F = 3.93$; $p = 0.002$) and pH ($\lambda = 0.22$; $F = 7.4$; $p = 0.068$). The occurrence of Amur sleeper was most strongly correlated with coverage of the water surface by pleustonic plants and coverage of the bottom by submerged plants (Fig. 4).

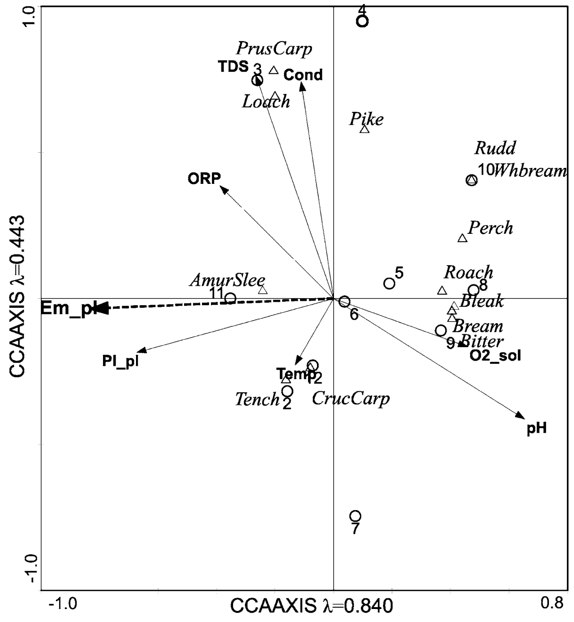

Fig. 4 Canonical correspondence analysis triplots for collected fish species and environmental variables in studied oxbow lakes. *Dashed line* indicates significant parameters in Monte Carlo permutation test at $p < 0.01$. Samples collected in studied habitats are marked with an Arabic numeral: *1–6* Wieprz, *7–12* Vistula. Temp., water temperature; Cond., conductivity; O2_sol, dissolved oxygen; pH; TDS, total dissolved solids; ORP, oxidation–reduction potential; Pl_pl, pleustonic plant; Em_pl, emergent plant (Bitter *Rhodeus sericeus*, Bleak *Alburnus alburnus*, Bream *Abramis brama*, CrucCarp *Carassius carassius*, Chub *Leuciscus cephalus*, Gudgeon *Gobio gobio*, PrusCarp *Carassius gibelio*, Roach *Rutilus rutilus*, Rudd *Scardinius erythrophthalmus*, Sunbleak *Leucaspius delineates*, Tench *Tinca tinca*, Whbream *Blicca bjoerkna*, Perch *Perca fluviatilis*, Pikeper *Sander lucioperca*, Pike *Esox lucius*, Loach *Misgurnus fossilis*, Stloach *Cobitis taenia*, AmurSlee *Perccottus glenii*)

Discussion

The present study is the first record of the presence of Amur sleeper in the oxbow lakes of the Wieprz River, a tributary of the Vistula River. This region is located between two rivers, the Bug and the San, which were the main channels by which the species entered Polish territory (Reshetnikov 2013). The study sites described in this paper are located in the Wieprz River valley, approximately 160 km upstream from the sites where *P. glenii* was first found (Terlecki and Pałka 1999). Control fishing in the two rivers (see Table 2) and the available literature data indicate that the species is a poor swimmer which does not do well in swift water currents (Koščo et al. 2003). If it moves, it usually moves with the current. Hence the question arises of how this species reached the new, distant floodplain if not by way of the Wieprz River, against the current. Or perhaps it was there earlier, before it was noted in the Vistula River? These are questions that we cannot answer. According to Bogutskaya and Naseka (2002), spring floods are conducive to this species, allowing it to spread from known places of occurrence to new local small streams and water bodies. Another important factor in dispersion is waterfowl (documented cases are lacking) and human activity, such as accidental introduction by anglers or, while less likely, together with stocking material. An important fact is that recently single individuals of this species have also been reported in the Główna River (a tributary of the Warta), belonging to the Oder River basin (Andrzejewski et al. 2011). Until now the Vistula River has been the western boundary of occurrence of this species, and this indicates that the direction of its spread is to the west of Europe (Reshetnikov 2013).

In the current observations the Amur sleeper was recorded in four of the six oxbow lakes studied in each river basin. Variation in the occurrence of this pest fish in water bodies located in one river basin was also observed by Reshetnikov and Chibilev (2009), who investigated isolated water bodies in the Irtysh River Basin and noted the presence of Amur sleeper only in 59 of the 77 study sites.

The study showed varied relative abundance of Amur sleeper in the oxbow lakes depending on the river valley, as well as in the oxbow lakes within the main channel of one river. Its abundance in the oxbow lakes of the Vistula River ranged from 0.002 CPUE (V1) to 1.60 CPUE (V5). Generally, in the oxbow lakes of the Vistula *P. glenii* did not represent a large share of the fish fauna, but in some sites (V5) its percentage share was 100 %. In contrast, in the oxbow lakes of the Wieprz valley in which it was found, it accounted for a significant proportion of the ichthyofauna (>40 % of the total number of fish). A similar, significant percentage share of *P. glenii* was observed by Orlova et al. (2006) in the eastern Gulf of Finland (Baltic Sea), where the proportion of this pest fish in the littoral zone was as high as 85 %, and its density was up to 1500 individuals per ha. In addition, these authors observed that the significant proportion of Amur sleeper was accompanied by a decrease in the number of fish species. This was confirmed by our observations, where in one of the oxbow lakes near the Vistula River (V5) only *P. glenii* was caught, and in oxbow lakes in the Wieprz valley (W3 and W4), only two or three fish species were noted together with Amur sleeper, usually Prussian carp and loach (Fig. 2). Coexistence of Amur sleeper and selected species of the genus Carassius was also noted by Reshetnikov (2003) and Reshetnikov and Petlina (2007). According to these authors, adult *Carassius carassius* individuals can occur together with Amur sleeper even for several years.

The presence of invasive species in mass numbers has a significant impact on aquatic ecosystems. In addition to occupying habitats and competing for food, it can significantly affect the composition of fish fauna. Amur sleeper in small water bodies are predators that significantly restrict the occurrence of young cyprinids, eating macrozoobenthos and the eggs of fish and amphibians, thus affecting other aquatic organisms, including amphibians (Reshetnikov 2001; Reshetnikov and Chibilev 2009). In natural ecosystems a defence against invasive species is the presence of predators, which may effectively limit their dispersal ability (Bogutskaya and Naseka 2002). In the water bodies investigated in the present study there were no large fish predators. For this reason Amur sleeper may dominate, and due to its predispositions, assume the role of a non-selective top predator (Koščo et al. 2008; Grabowska et al. 2009).

Evaluation of the impact of invasive species on ecosystems is extremely difficult and often requires knowledge of the ecosystem existing before the occurrence of the invasive species and a long observation period after its appearance (Lorenzoni et al. 2006; Gaygusuz et al. 2007). Assessments can be made by monitoring the ecosystem and estimating biodiversity parameters. In our research, the analysis of species diversity indices showed that *P. glenii* had no statistical impact on these indices (Table 3), but indices were slightly lower in the oxbow lakes where this species was noted. While it is true that some invasive species can disrupt ecosystems and eliminate native species, the same processes may also lead to an increase in ecological diversity (Thomas 2013). Any increase in local biodiversity resulting from the introduction of new species will be offset by a decline in global biodiversity (Simerloff and Genovesi 2013). Therefore, the most rational action is to assess the risk posed by invasive species and to observe whether a given species causes the disappearance of native species or finds its own place in the habitat.

It should be noted that the oxbow lakes in both locations where the research was conducted are situated in areas protected under the Nature 2000 Network (PLB140006 and PLH060030). Any presence of this pest fish can pose a threat and cause changes in species composition. Due to traits such as high resistance, broad habitat requirements, voracity, ease of reproduction and a number of others, the Amur sleeper can directly affect other species, particularly those under protection.

Analysis of the body size of *P. glenii* showed that the populations from both locations had a similar size structure, with dominance of juvenile individuals with a Tl < 6 cm (Fig. 3). In addition, the reproductive potential of the species is evidenced by a significant percentage of individuals that have just reached sexual maturity, which according to Grabowska et al. (2011) is already attained in this species at a size of about 6 cm. These data indicate that both of the populations studied are in the expansion phase and confirm that this is the first stage of the invasion of Amur sleeper in this region (Krebs 2009).

Jurajda et al. (2006) describe *P. glenii* as a typical limnophilic species, inhabiting freshwater canals, oxbow lakes and gravel pits with dense aquatic vegetation and a mud substrate. Oxbow lakes are characteristic water bodies with significant variations in temperature often accompanied by oxygen deficits. Reshetnikov and Chibilev (2009) suggest that isolated water bodies with abundant macrophytes are the optimal habitat for this species. This was confirmed by our observations. The occurrence of *P. glenii* was most strongly correlated with the presence of macrophytes and was not affected by poor oxygen conditions (Fig. 4). At the same time, according to Orlova et al. (2006) and Grabowska et al. (2011), habitat conditions, especially temperature, strongly influence the increase in the number of individuals and the development of the population of this invasive species.

To sum up, Amur sleeper was recorded in significant numbers in a new location on the border areas of its current range (the Wieprz River basin). This confirms the strong dispersion of the species into areas of central and (presumably in the future) Western Europe, which are not yet dominated by this invasive species. Significant numbers of *P. glenii* affect aquatic ecosystems by reducing the number of species and the occurrence of small native fish. At the same time, the habitat characteristics of oxbow lakes (presence of macrophytes, high temperature amplitude) as well as traits of the species (predation, resistance to oxygen deficiency and a suitable size structure) allow these populations in new areas to exhibit characteristics of expansion, creating a real threat that its range of distribution will increase.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All applicable international, national and/or institutional guidelines for the care and use of animals were followed. All procedures performed in studies involving animals were in accordance with the ethical standards of the institution or practice at which the studies were conducted. The current study focused on invasive fish species, which, according to the existing national legislation, should be removed from the ecosystem.

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