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Rapid range expansion of the "whitefin" gudgeon *Romanogobio* cf. *belingi* (Teleostei: Cyprinidae) in a lowland tributary of the Vistula River (Southeastern Poland)

Michał Nowak[1]*, Artur Klaczak[1], Paweł Szczerbik[1], Jan Mendel[2] and Włodzimierz Popek[1]

[1] Department of Ichthyobiology and Fisheries, University of Agriculture in Kraków, Spiczakowa 6, 30-198 Kraków, Poland
[2] Department of Fish Ecology, Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, v.v.i., Květná 8, 603 65 Brno, Czech Republic

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Abstract – The "whitefin" gudgeon *Romanogobio* cf. *belingi* was recorded in the Nida River, a large lowland tributary of the upper Vistula (Southeastern Poland), for the first time in 2009. Since then, it has been caught during the periodical (three times per year) monitoring only sporadically. Conversely, in October and November 2012 *R.* cf. *belingi* was recorded frequently along an ~60-km lowermost stretch of the Nida River. The abundance of this fish gradually increased downstream. This paper provides details of that phenomenon and discusses it in the context of the currently known distribution of this species.

Key words: Faunistic / Gobioninae / ichthyofauna monitoring / population dynamics / rare species

Introduction

Rapid range expansions and colonizations are important ecological phenomena and in the case of biological invasions, have been extensively studied in recent years. This is because rapid colonizations are often coincident with introductions of non-native species that develop invasive populations. An example is the topmouth gudgeon (or stone moroko) *Pseudorasbora parva* (Temminck and Schlegel, 1846), an Asian cyprinid species that is closely related to European gudgeon species. Following its accidental introduction from China in to several European countries (Hungary, Lithuania, Romania and Ukraine) *via* the aquaculture industry in the early 1960s (Gozlan *et al.*, 2010 and citations therein) it has since colonized water bodies in most European countries and Middle East through natural and assisted means (Gozlan *et al.*, 2010). Downstream dispersal rates of over 30 km in 4 years have been recorded (Ahnelt and Tiefenbach, 1991), emphasizing the importance of natural dispersal and subsequent colonization in their invasion (Gavriloaie *et al.*, 2008; Gozlan *et al.*, 2010). While such range expansions are most often associated with biological invasions, they might also be important for native fishes that are, for example, responding to environmental change.

European gudgeons (genera: *Gobio* and *Romanogobio*) are among the most discussed groups of fishes. Their diversity, taxonomy, identification and distributions are still under debate (*e.g.*, Kottelat and Freyhof, 2007; Mendel *et al.*, 2008; Nowak *et al.*, 2008; Takács, 2012; Turan *et al.*, 2012). *Romanogobio belingi* (Slastenenko, 1934), usually referred to as the Dnieper whitefin gudgeon (*e.g.*, Kottelat and Freyhof, 2007) or the river gudgeon (Wolter, 2006), is a member of the *Romanogobio albipinnatus* species-group, known as the whitefin gudgeons. For a long time this group has remained unrecognized and confused either with the common gudgeon *Gobio gobio* (Linnaeus, 1758) or with the longbarbel (or stone) gudgeon *Romanogobio uranoscopus* (Agassiz, 1833). They were described in the 1930s and 1940s and the group consists of at least three more species formerly considered subspecies of *R. albipinnatus*: *Romanogobio albipinnatus* (Lukasch, 1933) occurring in the Volga and Don drainages, *Romanogobio tanaiticus* (Naseka, 2001a) from the Don drainage and *Romanogobio vladykovi* (Fang, 1943) from the Danube drainage (Naseka *et al.*, 1999; Naseka, 2001a, 2001b; Kottelat and Freyhof, 2007). The range of *R. belingi* is much wider and covers drainages of the Dniepr, Elbe, Rhine and Odra River (Naseka, 2001a, 2001b; Kottelat and Freyhof, 2007). The taxonomic position of the populations from the Dniestr (Dniester) and, especially, the Vistula drainage has been extensively discussed in the past (Naseka *et al.*, 1999).

*Corresponding author: michal.nowak@ur.krakow.pl or mikhael.nowak@gmail.com

Recently, most authors considered that this region is inhabited by *R. belingi* (Naseka and Bogutskaya in: Naseka *et al.*, 1999; Naseka, 2001a, 2001b; Kottelat and Freyhof, 2007; but for the discussion, see: Bănărescu in: Naseka *et al.*, 1999). Conversely, molecular investigation suggests that *R. vladykovi* is involved as well (Mendel and Nowak, unpublished data; Nowak *et al.*, 2012). Therefore, in the present paper we apply the name "*Romanogobio* cf. *belingi*".

Presence of the "whitefin" gudgeon (initially identified as *G. albipinnatus*) in the Vistula drainage was recorded relatively late. Rolik (1965), when analysing museum specimens collected from the middle Vistula in 1933 and 1959, found among several dozens of specimens of *G. gobio* a few individuals of the "whitefin" gudgeon. Since then ~30 more localities of that species have been found (Nowak *et al.*, 2011, 2012). Thus, the "whitefin" gudgeon has been considered among the rarest freshwater fish species in Poland (Błachuta *et al.*, 1994), covered by national protection and marked as vulnerable (VU) on the territory of the whole country and as endangered (EN) in the Vistula drainage according to the Polish Red List (Witkowski *et al.*, 2009). Notwithstanding, since the 1990s there has been an increase in known localities of the "whitefin" gudgeon in both Odra (Oder) and Vistula drainages (Nowak *et al.*, 2011, 2012), with similar observations in other European regions (Freyhof *et al.*, 2000; Harka *et al.*, 2004; Soes *et al.*, 2005; Ruchin *et al.*, 2008; Sallai *et al.*, 2010). Such an increase in known distribution of the "whitefin" gudgeon was explained in the terms of either former misidentifications (Freyhof *et al.*, 2000; Ruchin *et al.*, 2008) or recent range expansion (Harka *et al.*, 2004; Sallai *et al.*, 2010).

Here, we describe changes in abundance of *R.* cf. *belingi* in the Nida River, a medium-size lowland tributary of the upper Vistula River. This fish was not recorded in this river until 2009 but has since become widespread and abundant along ~60-km-long lowermost stretch of the main river channel. In order to check if the observed changes in its abundance might reflect recent upstream invasion, we analysed catches obtained by two sampling strategies and data on specimens–length distribution.

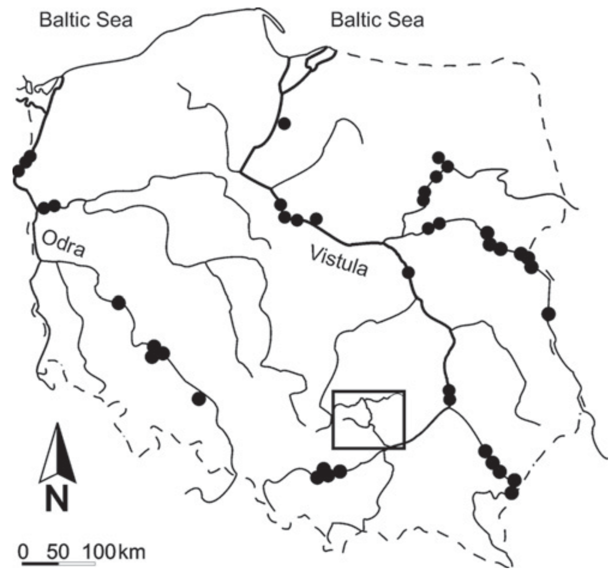

Fig. 1. Known occurrence of *Romanogobio* cf. *belingi* in Poland (filled circles; according to the sources cited in the text and unpublished data of the authors) and study area (box).

Material and methods

The Nida River is a 152-km-long left-bank tributary of the upper Vistula River, itself flowing to the Baltic Sea (Fig. 1). Its drainage covers an area of ~3862 km^2. The ichthyofauna of this river was investigated for the first time in 1968–1969, when 35 fish species were recorded (Penczak, 1971). Surveys conducted in 1998–1999 sampled 30 fish species (Buras *et al.*, 2001). Neither Penczak (1971), nor Buras *et al.* (2001) recorded the whitefin gudgeon. In 2009, a small number of random sites (Fig. 2A) were sampled by wading electrofishing (using a battery-powered back-pack unit, Hans Grassl IG-600T) and from October 2010 the river was monitored three times per year (April, July and October) when boat electrofishing was used (Radomir Bednař BMA Plus generator-powered electroshocker, 3.5 kW, 350 V pulsed-DC, 50 Hz). This involved sampling 21 sites along a 100-km-long stretch of the river from the confluence with the Czarna Nida to the mouth to Vistula River (Fig. 2B–F). At each site continuous electrofishing was performed in downstream direction, along one bank, which was equivalent to 15 min of free flowing and covered an area of ~3500–4000 m^2. This was supported by samples taken during the 24-h seining (with a 7 × 3 m beach seine, mesh size of 6 mm knot-to-knot), undertaken three times per year on three additional sites (Fig. 2A–F). At all sampling events, fish were identified to species and standard length (SL) recorded (nearest mm). Voucher specimens were immediately overanaesthetized with chlorobutanol (1,1,1-trichloro-2-methyl-2-propanol) and fixed in buffered 4% formaldehyde. After transferring to 70% ethanol for storage they were deposited in the Department of Ichthyobiology and Fisheries of the University of Agriculture in Kraków.

To compare abundance of the whitefin gudgeon collected by beach seining in consecutive seasons the non-parametric Kruskal–Wallis test was performed. Differences in the mean SL of the specimens from beach seining and electrofishing samples were also tested using this test ($\alpha = 0.05$). All the computations were performed using the software R version 2.12.0 (R Development Core Team, 2010).

Results

Romanogobio cf. *belingi* was recorded for the first time in the Nida River during the preliminary expedition in May 2009. One specimen (61 mm SL) was caught by

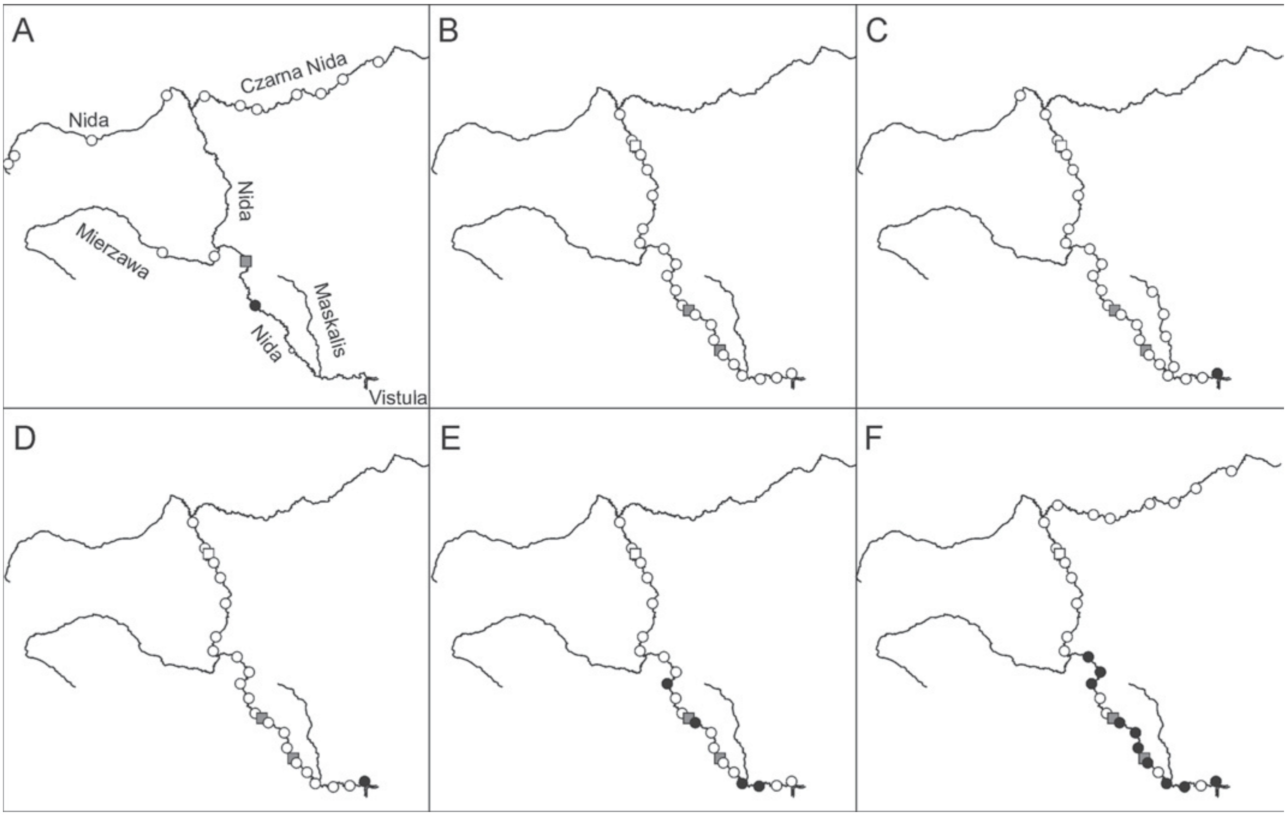

Fig. 2. Records of *Romanogobio* cf. *belingi* in the Nida River in: (A) 2009, (B) 2010 (seining in April, July and November, electrofishing in October only), (C) April, July and November 2011 (electrofishing and seining), (D) April 2012, (E) July 2012, (F) October 2012. Circles denote electrofishing sites, rectangles – seining sites, white background – lack of the species, filled – presence.

electrofishing in a fast-flowing, deep run of the main channel at Chroberz town (Fig. 2A; see Table 1 for the sites coordinates). In July 2009, another specimen (70 mm SL) was collected by seining on a sandy beach near Pasturka (Fig. 2A).

In 2010, despite increased effort in sampling, no specimens were caught from the 21 electrofishing sites (Fig. 2B). On the other hand, 32 specimens were collected by beach seining at two sandbanks near Stara Rudawa and Wiślica (Fig. 2B) with the majority of during the night hours. In 2011 (April, July and October, combined together), one specimen was recorded by electric fishing ~ 300 m upstream from the Nida and Vistula River confluence (Fig. 2C) and 37 individuals were found in beach seining samples (Fig. 2C). In April 2012, again, no specimens were caught by electrofishing and 12 specimens were recorded during beach seining (Fig. 2D). However, in July 2012 ten specimens of *R.* cf. *belingi* were sampled by electrofishing on four sites in the middle and lower stretch of the Nida River, with a further 49 specimens caught by beach seining on two sandbanks in Stara Rudawa and Wiślica (Fig. 2E). In addition, in October 2012, 100 specimens of *R.* cf. *belingi* were caught by electrofishing on ten sites in the middle and lower reaches of the Nida River (Fig. 2F), with a further 78 individuals recorded in beach seining on the two previously mentioned localities. Thus, between spring 2009 and autumn 2012, 321 specimens of *R.* cf. *belingi* were sampled including 112 individuals collected by the means of electrofishing and 209 by beach seining.

Only beach seining provided sufficient data on abundance of *R.* cf. *belingi* to perform season-by-season comparisons of number of individuals collected. In spite of noticeable increase in abundance of *R.* cf. *belingi* from year to year, the Kruskal–Wallis test did not reveal significant differences neither among consecutive 3 years of the research ($H = 3.012$, $df = 2$, $P = 0.222$), nor among consecutive seasons ($H = 7.654$, $df = 8$, $P = 0.468$). The individuals of *R.* cf. *belingi* captured by beach seining were of 41–94 mm SL (mean $\pm$ S.D. $= 64.65 \pm 13.99$ mm SL) in 2010, 44–92 mm SL (63.65 ± 13.51 mm SL) in 2011 and 38–96 mm SL (63.37 ± 12.60 mm SL) in 2012. The differences among years were not significant (Kruskal–Wallis test: $H = 0.109$, $df = 2$, $P = 0.947$). When comparing mean SL among consecutive seasons, the significant differences were found on both sites in Stara Rudawa (Kruskal–Wallis test: $H = 73.470$, $df = 7$, $P < 0.001$) and Wiślica (Kruskal–Wallis test: $H = 19.632$, $df = 6$, $P < 0.05$; Fig. 3). The specimens collected by electrofishing in October 2012 were of 24–84 mm SL (57.59 ± 14.18 mm SL). The differences among consecutive sampling sites were significant (Kruskal–Wallis test: $H = 27.439$, $df = 9$, $P < 0.01$); however no noticeable trend, either decreasing or increasing, was found.

Table 1. Total numbers of *Romanogobio* cf. *belingi* specimens recorded at 21 monitoring sites in the consecutive samplings during the period of 2010–2012.

				2010	2011			2012		
No.	Locality name	Latitude	Longitude	October	April	July	October	April	June	October
1	Brzegi	50°44'43"N	20°24'46"E	0	0	0	0	0	0	0
2	Sobków	50°42'28"N	20°26'26"E	0	0	0	0	0	0	0
3	Staniowice	50°40'34"N	20°27'48"E	0	0	0	0	0	0	0
4	Korytnica	50°39'15"N	20°28'48"E	0	0	0	0	0	0	0
5	Motkowice	50°36'37"N	20°29'47"E	0	0	0	0	0	0	0
6	Skowronno	50°33'44"N	20°29'04"E	0	0	0	0	0	0	0
7	Kopernia	50°31'19"N	20°28'25"E	0	0	0	0	0	0	0
8	Pińczów	50°31'09"N	20°30'33"E	0	0	0	0	0	0	1
9	Pasturka	50°29'58"N	20°32'47"E	0	0	0	0	0	0	1
10	Kowala	50°28'51"N	20°32'43"E	0	0	0	0	0	3	10
11	Krzyżanowice	50°27'01"N	20°32'47"E	0	0	0	0	0	0	0
12	Chroberz	50°25'43"N	20°33'31"E	0	0	0	0	0	0	0
13	Nieprowice	50°24'34"N	20°35'22"E	0	0	0	0	0	2	1
14	Kobylniki	50°23'10"N	20°38'35"E	0	0	0	0	0	0	1
15	Jurków	50°21'55"N	20°38'31"E	0	0	0	0	0	0	1
16	Wiślica	50°20'33"N	20°39'55"E	0	0	0	0	0	0	1
17	Szczytniki	50°19'25"N	20°41'59"E	0	0	0	0	0	0	0
18	Czarkowy	50°18'20"N	20°43'06"E	0	0	0	0	0	1	7
19	Stary Korczyn	50°17'47"N	20°45'25"E	0	0	0	0	0	4	9
20	Nowy Korczyn	50°17'47"N	20°48'02"E	0	0	0	0	0	0	0
21	mouth to Vistula	50°18'16"N	20°50'48"E	0	0	0	1	0	0	68
	Total number			0	0	0	1	0	10	100

Discussion

From the late 1990s a rapid increase in known distribution of the whitefin gudgeon in Central Europe occurred. It was recorded in the Odra (Oder), Elbe, German and Netherland parts of Rhine, and Austrian and German parts of Danube (Freyhof *et al*., 2000; Soes *et al*., 2005; Wolter, 2006; Kottelat and Freyhof, 2007). According to the recent research, majority of these findings regard *R. belingi* (Kottelat and Freyhof, 2007). Simultaneously, the known range of *R. albipinnatus* in the Volga and Don drainages was greatly contributed by Ruchin *et al*. (2008). In the Vistula River drainage, the whitefin gudgeon was recorded for the first time in the 1960s (Rolik, 1965). Till the end of the 20th century, it was considered one of the rarest species in Poland (Błachuta *et al*., 1994; Witkowski *et al*., 1999). Irrespective, in recent years the number of known sites of the whitefin gudgeon in Poland has been doubled (review in: Nowak *et al*., 2011, 2012; Nowak, unpublished data). Following the increase in known distribution of that species in both Vistula and Odra (Oder) River drainage, the conservation status of the whitefin gudgeon was changed from "data deficiency" (Witkowski *et al*., 1999) to "vulnerable" (Witkowski *et al*., 2009). Both Freyhof *et al*. (2000) and Ruchin *et al*. (2008) concluded that such a rapid increase of known distribution of the whitefin gudgeon could be most probably attributed to former ignorance and misidentification with other species, especially with the common and widely distributed *G. gobio*. According to these authors, such a rapid invasion seems improbable. We agree with Freyhof *et al*. (2000) and Ruchin *et al*. (2008) in that the majority of these "new" records are artefacts of former overlook of the whitefin gudgeon. However, the results here for the Nida River system does appear to be evidence of recent and rapid colonization of the main channel of that river by the whitefin gudgeon. Although the temporal increases were not significant between 2010 and 2012, a total of 32 individuals were captured in 2010, 37 in 2011 and 139 in 2012 (Table 2). Even more obvious are the data obtained during electrofishing: no specimens in 2010, one in 2011 and 110 in 2012 (at constant sampling effort; Table 1). The size structure of the individuals captured by electrofishing differed significantly among the sites but no clear, either decreasing or increasing pattern was found (Fig. 4). However, interesting is that at the lowermost site (mouth to the Vistula) the proportion of the juvenile (<50 mm SL) specimens was twofold higher ($\sim 40\%$ of all the specimens) than on all other sites ($<20\%$). Variation in size structure of the captured specimens of *R*. cf. *belingi* reflects recruitment in each year. Mean standard length on both sites sampled by beach seining was significantly lower in summer 2011 and 2012 than in spring of the respective year. It was most probably due to appearance in our samples of young-of-the-year specimens, recruited in late spring (Bless and Riehl, 2007).

Additional support to our opinion is that the uppermost known occurrence of *R*. cf. *belingi* is localized at Pińczów town. It is the uppermost stretch of the Nida River retaining the full connectivity with the Vistula River [in which *R*. cf. *belingi* is one of the most dominant fish species (Nowak and Klaczak, unpublished data)]. At 62.6–80.4 km from the mouth of the river, there is a first (0.5 m high) of a series of weirs (0.35–2.25 m high) which successfully prevent most upstream fish migrations. Despite extensive sampling undertaken in the main

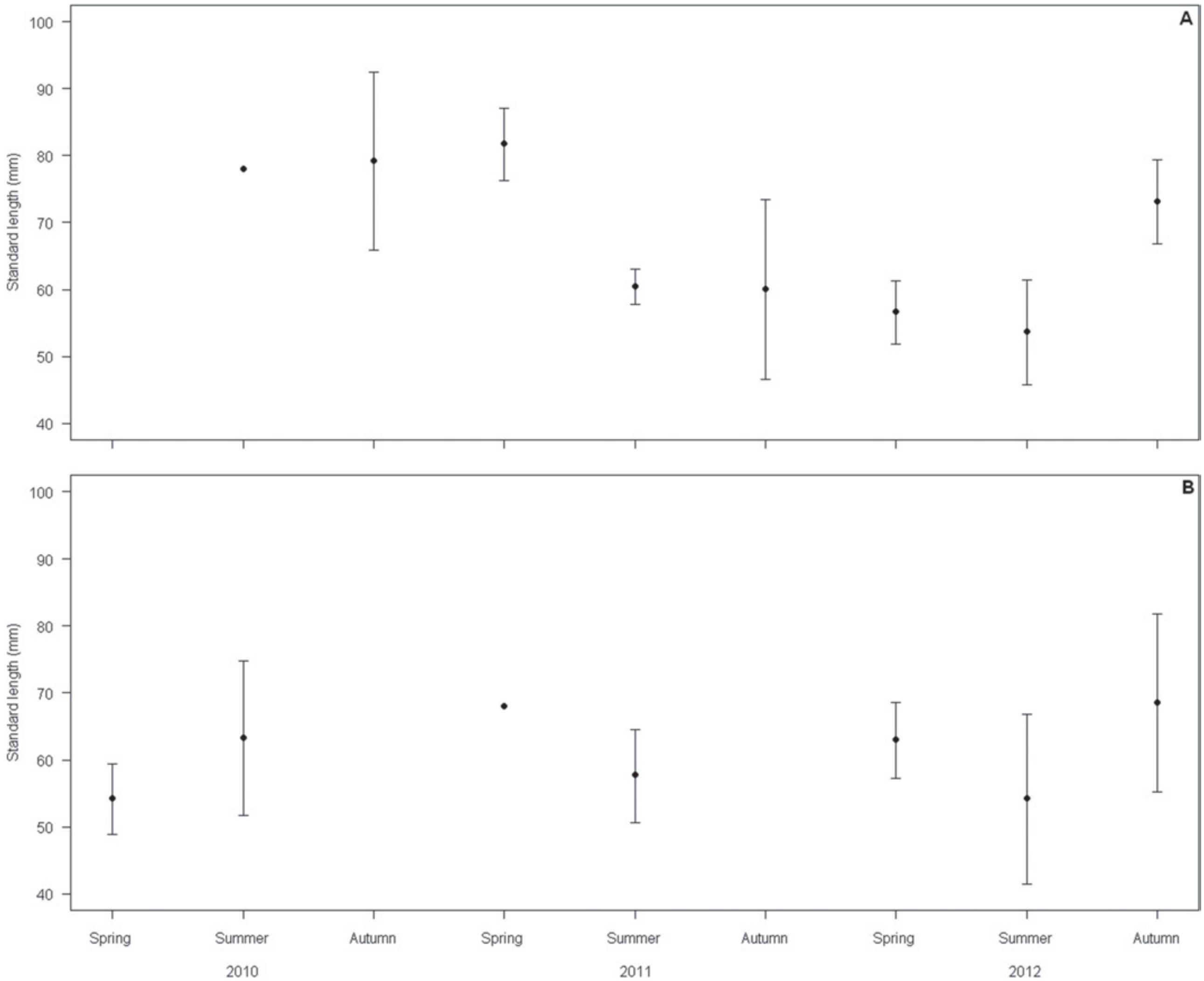

Fig. 3. Mean (±S.D.) standard length (mm) of specimens of *Romanogobio* cf. *belingi* collected by beach seining on sites in (A) Stara Rudawa and (B) Wiślica in consecutive seasons.

channel upriver from the weir in Pińczów, as well as in the Czarna Nida River system, we did not record *R*. cf. *belingi* elsewhere, which seems to contribute to our opinion about recent colonization. In several other tributaries of the upper Vistula sampled in the period of 2010–2012 (Nowak *et al*., 2011, 2012; Nowak, Klaczak and Szczerbik, unpublished data) the whitefin gudgeon was always recorded only in the lowermost stretches, usually up to the lowermost weir (or other transverse barrier). Such a pattern of distribution is a strong support for the recent colonization of those rivers by this species. Additionally, our data are in agreement with observations made in several Hungarian tributaries of the Danube, in which recent range expansion of *R. vladykovi* was documented (Harka *et al*., 2004; Sallai *et al*., 2010). First, Harka (personal communication) noticed that in the mid-1980s *G. gobio* has disappeared from the Kisköre Reservoir (known also as the Tisza Lake) and simultaneously the abundance of *R. vladykovi* has greatly increased. Later, similar phenomenon was observed on the Zagyva and Tarna Rivers within the Tisza River system (Harka *et al*., 2004). Finally, Sallai *et al*. (2010) found that since the last fish faunistic survey performed on the Hungarian stretch of the Maros (Mures) River (Nalbant, 1995) *G. gobio* has nearly completely disappeared, whereas *R. vladykovi* has become very abundant. The upriver invasion hypothesis was also proposed as a plausible explanation for frequent occurrence of *R. vladykovi* in the Slovak part of the upper Danube (Balon *et al*., 1987).

Another question is why *R*. cf. *belingi* increased its abundance during last three years. The period of time and extent of this study do not allow formulation of any reliable explanation. However, it is worth mentioning that observed increase in abundance of that species coincided with the consecutive decreasing of water level in the Nida River system during the period of 2010–2012. In late summer and autumn 2012 extensive draught caused that the water level in that catchment was the lowest ever recorded. On the other hand, the phenomenon described in the present paper might be seen in the context of recent

Table 2. Total number of *Romanogobio* cf. *belingi* specimens collected from the Nida River by beach seining in consecutive samplings. NA indicates that particular sampling was not performed.

No.	Locality name	Latitude	Longitude	2009	2010			2011			2012		
				Summer	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
1	Mokrsko	50°41'51"N	26°26'46"E	NA	0	0	0	0	0	0	0	0	0
2	Pasturka (sandbank)	50°29'40"N	20°33'03"E	1	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	Stara Rudawa	50°24'47"N	20°34'45"E	NA	NA	1	8	6	4	22	10	45	31
4	Wiślica (sandbank)	50°20'59"N	20°39'27"E	NA	11	12	NA	1	4	0	2	4	47
	Total number			1	11	13	8	7	8	22	12	49	78

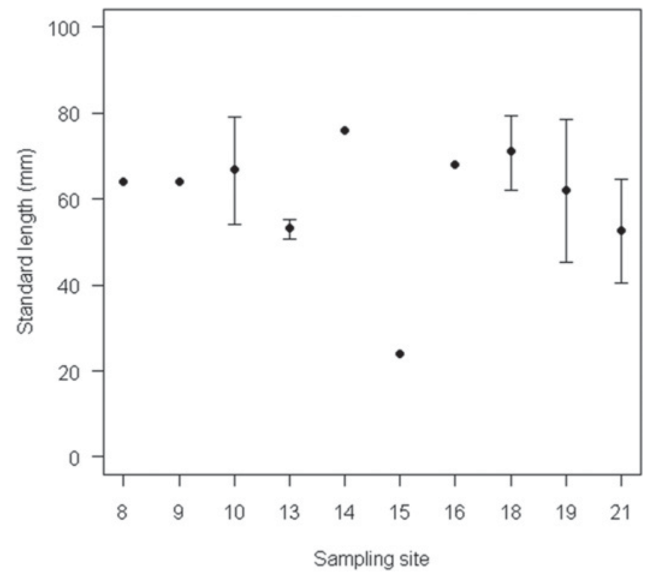

Fig. 4. Mean (±S.D.) standard length (mm) of specimens of *Romanogobio* cf. *belingi* collected by electrofishing on consecutive sites in October 2012. Site numbers as in Table 1.

range expansions of several other Ponto-Caspian fish species. Probably the most spectacular and discussed examples are gobies: the racer goby *Babka gymnotrachelus* (Kessler, 1857), the monkey goby *Neogobius fluviatilis* (Pallas, 1814), the round goby *Neogobius melanostomus* (Pallas, 1814), and the Western tubenose goby *Proterorhinus semilunaris* (Heckel, 1837) (*e.g.*, Copp *et al*., 2005). All four species were found in the Vistula drainage for the first time in 1990s and 2000s and their spreading in the last years along the Vistula River was recorded (Grabowska *et al*., 2008, 2010). Simultaneously with invasion into new areas, an upriver expansion of these species was observed within their native range (Vasil'eva, 2003; Copp *et al*., 2005; Polačik *et al*., 2008).

Obviously, the time scale of this study prevents establishing whether this is a random peak in abundance of *R*. cf. *belingi* or represents a something more sustainable. If the former explanation is true, certain shifts in morphology or life-history traits might be expected (Smith and Skulason, 1996; Záhorská and Kováč, 2009; Polačik *et al*., 2012). Therefore, in the future years the monitoring will be continued and supported with research on several life-history traits, which might provide better understanding of the phenomenon described in the present paper. We expect that further data would clarify the status of *R*. cf. *belingi* population in the Nida River system.

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