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First report on the importance of alien gobiids in the diet of native piscivorous fishes in the lower Vistula River (Poland)

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Abstract

We conducted a snapshot study to check the importance of non-native Ponto-Caspian gobies (monkey and racer goby) in the diet of native obligate (northern pike, pikeperch) and facultative (Eurasian perch) predators in the Vistula River 3-4 years after the appearance of aliens. In total 71 fish with non-empty stomachs, taken randomly from net catches from various parts of the river were analyzed, including 32 pike, 20 pikeperch and 19 perch specimens. We found that gobiids prevailed in the diet of smaller (<30 cm standard length, SL) individuals of pike and pikeperch, as well as larger (>15 cm SL) specimens of perch, although the effect of predator size on the presence of gobiids in the diet was not significant in the case of perch. Our results indicate that gobiids as a prey fish can stimulate considerable changes in local food webs, which require further studies.

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INTRODUCTION

In recent decades, spectacular expansion of Ponto-Caspian fish from the Gobiidae family has been noted in Laurentian Great Lakes in North America (Jude et al. 1992; Charlebois, Corkum 2001; Poos et al. 2009), in the Baltic Sea (Skóra, Stolarski 1993; Sapota 2004; Sapota, Skóra 2005) and in European rivers both in the Baltic (Copp et al. 2005) and the North Sea basins (van Beek 2006). In the lower Vistula River in Poland, which is a part of the central inland corridor used by Ponto-Caspian species to migrate in Europe (Bij de Vaate et al. 2002), two gobiids (the racer goby *Neogobius gymnotrachelus* and the monkey goby *Neogobius fluviatilis*) were recorded for the first time in the years 2000-2001 (Kostrzewa, Grabowski 2001, 2002). After 3-4 years (2004), they dispersed successfully in the river, becoming common species in its nearshore zone (Kakareko et al. 2009; Kakareko, Pawlikowska 2010). In 2008 another gobiid species, the tubenose goby *Proterorhinus marmoratus*, was reported in the Vistula for the first time (Grabowska et al. 2008).

The Ponto-Caspian gobiids can substantially alter food webs in novel environments (e.g. Johnson et al. 2005) due to their high abundance and specific ecological traits. They are small, bottom-dwelling, specialized benthivorous fish (Berg 1949) that may affect native benthic invertebrates (Dubs, Corkum 1996; Kuhns, Berg 1999; Janssen, Jude 2001; Barton et al. 2005) but at the same time become a substantial food resource for the top predators. Perhaps the latter phenomenon, contrary to the former, could be considered as a positive effect of the dispersion of the gobies in new areas. In the Great Lakes, the invasive round goby *N. melanostomus* is a common prey species for several predatory species, including yellow perch *Perca flavescens*, largemouth bass *Micropterus salmoides*, northern pike *Esox lucius* and

double-crested cormorants *Phalacrocorax auritas* (Johnson et al. 2005, 2010; Taraborelli et al. 2010). In Europe this species has also been found to constitute a major dietary item for some predators, such as cormorants *Phalacrocorax carbo* (Bzoma 1998), cod *Gadus morhua callarias* and turbot *Psetta maxima* (Sapota, Skóra 2005), in shallow waters of the Gulf of Gdańsk (Baltic Sea).

Little is known about the impact of other gobiid species, such as monkey and racer goby, on the trophic ecology of predators in newly invaded areas. We hypothesized that the alien fish could become an important dietary item of native predators due to their small body size (mostly up to ca. 10 cm) and oblong shape, which makes them relatively easy to take by gape-limited predators like piscivorous fish. However, no data on the role of these fish in the diet of predatory species in novel environments of European rivers have been published so far. Therefore, the aim of the present study was to assess the importance of the invaders as prey in the lower Vistula River shortly after their appearance. We ran a snapshot study on the diet of the most common predators (northern pike, pikeperch *Sander lucioperca* and Eurasian perch *Perca fluviatilis*) to check if the Ponto-Caspian gobiids became a common dietary item a few years (from 2000–2001 to 2004) after their appearance in the river. Our specific objective was to present the contribution of gobiids in the diet of predators in a standard manner to allow inter-population comparisons with past and future studies.

MATERIALS AND METHODS

The study area and sampling procedure

The Vistula River is the major river flowing through Poland. It is 1068 km long and has a catchment area of about 194,300 km^2 (Mikulski 1963). The lower course of the river (lower Vistula), runs for 391 km. The transit depth is 1.9 m and the width of the navigable channel is 375 m (Kloze 1983, after Głogowska 2000). The mean annual water discharges are from 900 m^3 s^{-1} at the upper part (downstream from the Narew River's mouth) to ca. 1050 m^3 s^{-1} at the mouth (Głogowska 2000). Its hydrology is modified by a dam reservoir (Włocławek Reservoir), the largest (75 km^2) in Poland and the only one along this river course (Giziński et al. 1989).

The sampling was conducted in the lower Vistula between the 744th and 772th km of the river course (near the city of Bydgoszcz, ca. 70 km below the dam of the reservoir), successively from 8 July and 22 October 2004, using two fishing techniques depending on the size of collected fish. Smaller individuals (<15 cm standard length, SL) of predatory fish were collected between the 758th and 772th km of the river course with a special pouch-style seine net (length: 19 m, width in the end of wings: 0.6 m, width in the pouch: 2.5 m), with stretched mesh size of 2 × 5 mm. The catches were carried out in the daytime at various hours, in shallow (below 1 m in depth) and deeper (up to 2 m) nearshore areas with soft bottom and slow or moderate flow. Such habitats are most common along the shores of the lower Vistula River. The details of the sampling procedure have been described by Kakareko et al. (2009). Larger fish (>15 cm SL) were captured between the 744th and 748th km of the river course using gillnetting by a commercial fisherman. They were sampled at night by 100-150 m long, drifting or standing trammel nets with 30, 60 and 80 mm mesh sizes.

Stomach content analysis

In total, the diet of 71 fish with non-empty stomachs was analyzed, including 32 pike, 20 pikeperch and 19 perch specimens. Means, standard deviations and ranges of the standard length (SL) of the fish studied (in cm) were as follows: pike 26.8, 17.7, 8.9-68.0; pikeperch 38.0, 21.0, 63.0-72.0; perch 16.4, 7.2, 8.5-35.0. Immediately after capture, the fish were killed and their total and standard length was measured to the nearest 1 cm. Then their alimentary tracts were extracted by dissection and stored in 4% formalin for the later stomach content analysis. In the laboratory, stomach contents were removed and analyzed under a stereomicroscope. All recognizable prey remains were separated and identified. Invertebrate prey items were divided into nine categories: Gastropoda, Lumbricidae, Amphipoda, Copepoda, *Asellus aquaticus,* Decapoda, Coleoptera, Chironomidae larvae and Zygoptera larvae. Fish prey species were identified on the basis of scales and bones (e.g. pharyngeal teeth, opercula) and measured to the nearest 1 mm. Size (height or width) of pharyngeal teeth was used for the reconstruction of the standard length of partially digested fish prey according to Radke et al. (2000).

The by-volume (%V) composition and frequency of occurrences (%FO) were determined for all identified prey species to quantify their contribution

in the diet, according to Hyslop (1980). %V is the contribution of a given species in the total volume of stomach contents, while %FO is its frequency of occurrence, expressed as the percentage of all analyzed stomachs (with empty stomachs excluded). The diet of the collected fish was illustrated by Costello's (1990) graphical method. The values of %V were plotted against the %FO values on a graph. Thus, the most important prey species are located near the top right corner of the graph, whereas the prey items closer to the top left corner are those with a low occurrence but high percentage by volume of the overall food and correspond to some sort of specialization.

Statistics

To determine the effect of predator size on the presence of gobiids in the diet, we used a logistic regression with the standard length of a predator (pike, pikeperch or perch in consecutive analyses) as an independent variable and the presence/absence of gobies in predator stomachs as a dependent binary variable. To measure the strength of association between the size of particular predators and the size of their prey fish (all species combined), we calculated Pearson linear correlations for each predator species. The analyses were made with the statistical program IBM® SPSS® Statistics 19.0.0.

RESULTS

The examination of stomach contents revealed that non-native gobiids constituted an important dietary item of predatory fish in the lower Vistula River, however, their percentage share in the diet of pike and pikeperch clearly decreased with the increasing predator size (Table 1, Fig. 1, 2). The logistic regression revealed that these relationships were significant for both species (pike: $\chi^2_1 = 5.33$, $p = 0.021$; pikeperch: $\chi^2_1 = 17.05$, $p < 0.001$). The gobiids constituted on average 48% of the total food volume (%V) and 53% frequency of occurrence (%FO) in the diet of smaller pike (<30 cm SL). For the pikeperch of the corresponding size these values were 80% and 80%, respectively (Table 1). The role of gobiids in the diet of larger individuals of these species (>30 cm SL) was substantially less important as they fed mainly on cyprinids (especially roach and white bream). The gobiids constituted 17.8%V and 17.8%FO of the diet of larger pike and 2.1 and 4.2 in the diet of larger individuals of pikeperch,

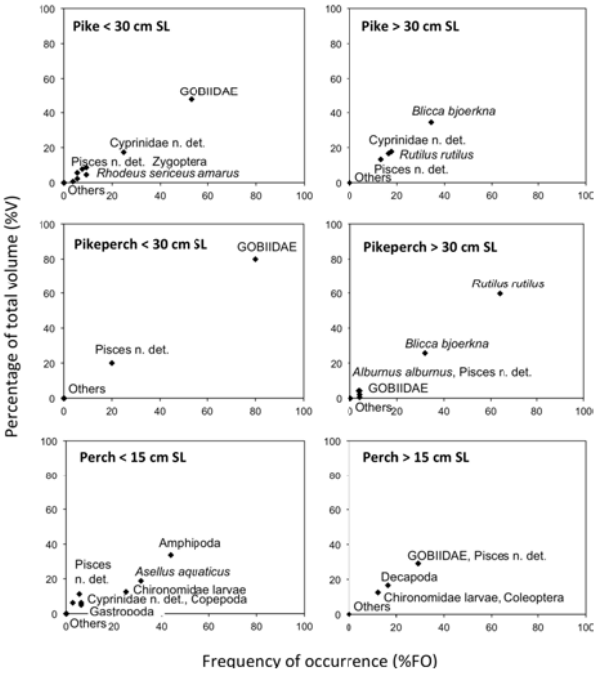

Fig. 1. Diet composition of the predatory fish from the lower Vistula River plotted according to Costello (1990).

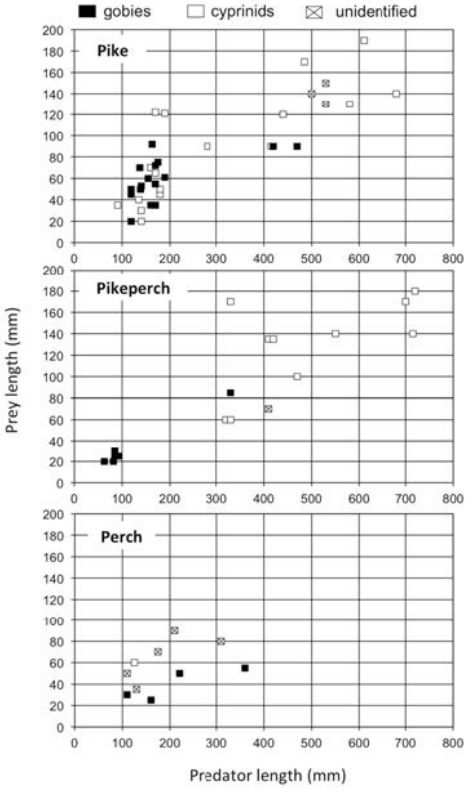

Fig. 2. Relationship between the size predators and their fish prey.

Table 1

Percentage of the total volume (%V) and frequency of occurrence (FO%) of the particular components in the diet of the predatory fish collected in the lower Vistula River.

Fish species	Pike				Pikeperch				Perch			
Size classes SL in cm	<30 (n = 22)		>30 (n = 10)		<30 (n = 5)		>30 (n = 15)		<15 (n = 10)		>15 (n = 9)	
Diet composition	%V	%FO	%V	%FO	%V	%FO	%V	%FO	%V	%FO	%V	%FO
GOBIIDAE	47.6	53.0	17.8	17.8	80	80	2.1	4.2	6.3	2.8	29.2	29.2
Abramis brama	-	-	-	-	-	-	4.2	3.8	-	-	-	-
Alburnus alburnus	2.2	5.6	-	-	-	-	4.2	4.2	-	-	-	-
Blicca bjoerkna	-	-	34.4	34.4	-	-	25.7	31.9	-	-	-	-
Rhodeus sericeus amarus	4.5	9.4	-	-	-	-	-	-	-	-	-	-
Rutilus rutilus	5.6	5.6	16.7	16.7	-	-	59.7	63.9	-	-	-	-
Cyprinidae n.det.	17.5	24.8	17.8	17.8	-	-	-	-	6.3	6.3	-	-
Pisces n. det.	7.7	7.7	13.3	13.3	20	20	4.2	4.2	11.3	5.6	29.2	29.2
Total Pisces	85.1	88.9	100	100	100	100	100	100	23.8	14.6	58.4	58.4
Gastropoda	-	-	-	-	-	-	0.4	4.2	5.0	6.3	-	-
Lumbricidae	5.6	5.6	-	-	-	-	-	-	-	-	-	-
Amphipoda	-	-	-	-	-	-	-	-	33.8	43.8	-	-
Copepoda	-	-	-	-	-	-	-	-	6.3	6.3	-	-
Asellus aquaticus	0.8	3.9	-	-	-	-	-	-	18.8	31.3	-	-
Decapoda	-	-	-	-	-	-	-	-	-	-	16.7	16.7
Coleoptera	-	-	-	-	-	-	-	-	-	-	12.5	12.5
Chironomidae larvae	-	-	-	-	-	-	-	-	12.5	25.0	12.5	12.5
Zygoptera larvae	8.7	9.4	-	-	-	-	-	-	-	-	-	-
Total invertebrates	15.0	18.8	-	-	-	-	0.4	4.2	76.3	87.5	41.7	41.7

respectively. About a half of the total volume of fish found in the stomachs of perch studied were identified as gobiids. Most of them were taken by perch individuals larger than 15 cm SL (Table 1). Smaller perch ate mainly invertebrates (73.6%V and 87.5%FO). However, the presence of gobiids in the perch diet was not significantly related to the size of this predator ($\chi^2_1 = 3.58$, $p < 0.058$). Among the invertebrates taken by perch, the most important dietary category included Amphipoda (33.8%V, 43.8%FO) and *Asellus aquaticus* (18.3%V, 31.3%FO). The number of taxa and quantity of invertebrates found in the stomachs of pike and pikeperch individuals were considerably lower than those observed in the stomachs of perch specimens.

The size of fish prey was highly correlated with the size of predators for pike ($r = 0.84$, $p < 0.001$) and (pikeperch: $r = 0.86$, $p < 0.001$) but not for perch ($r = 0.46$, $p = 0.185$).

DISCUSSION

Our study shows that the Ponto-Caspian gobiids, which within 3-4 years had colonized the lower Vistula River (Kakareko et al. 2009), became an important dietary component of common predatory fishes, such as northern pike, pikeperch and larger specimens of Eurasian perch. The aforementioned predatory fishes are considered as typical opportunists, very flexible in their feeding habits, capable of changing their diet spectra rapidly in response to changes in the abundance and vulnerability of available prey (Mann 1982; Chapman, Mackay 1984; Adams 1991; Beaudoin et al. 1999; Brylińska 2000). They usually focus their feeding effort on the most abundant and easy to catch prey available in the environment, according to the optimal foraging theory (Werner, Hall 1974). This implies that the gobiids were taken in substantial amounts by such piscivorous fish most probably because they were numerous in the environment and commonly available for the predators. This is supported by the results of the previous study (Kakareko et. al 2009) on the relative abundance of Ponto-Caspian gobiids in the lower Vistula, conducted in the same area and season as the present research (2004). The monkey goby turned out to be one of the subdominant species (18.1% of the total number of fish captured; 64.3% frequency of occurrence in catches) together with bleak *Alburnus alburnus*, roach and three-spined stickleback *Gasterosteus aculeatus*. The racer goby was much less abundant, though also quite common (2.5 and 32.9%, respectively) (Kakareko et. al 2009). Thus, probably most of the gobiids found in the stomachs of predatory fish in our study were the individuals of

monkey goby, as this species clearly prevailed over racer goby in the river. On the other hand, the racer goby has been found to prevail over the monkey goby in the nearshore fish assemblages in the Włocławek Dam Reservoir (Kakareko, Pawlikowska 2010) located upstream from the area of the present study. Thus, in the reservoir, the racer goby probably constitutes a more important food source for piscivorous fish the than monkey goby, contrary to the situation in the river below the dam.

The percentage share of alien gobiids in the diet of piscivorous fish changed with the increasing predator size. The gobiids were eaten mostly by smaller individuals of pike and pikeperch as well as larger individuals of Eurasian perch, though the effect of predator size on the presence of gobies in the diet was not significant in the case of perch. It is worth to point out that as much as 50% of the fish individuals found in the stomachs of perch were highly damaged and rated as unidentified prey taxa for the analysis. A similar pattern of trophic relationships between native predators and the invasive round goby has been found in Lake St. Pierre (St. Lawrence River, Canada) by Reyjol et al. (2010). They demonstrated that the probability of the round goby occurrence in predator stomachs decreased with the increasing length of large predator species (northern pike and walleye *Sander vitreus*). The opposite situation was observed for a smaller predator, the smallmouth bass *Micropterus dolomieu*, the occurrence of round gobies increased with the bass size. The cited authors hypothesized that these patterns might reflect differences in the energetic return, as large predators seek larger prey as they grow (Breck 1993; Mittelbach, Persson 1998). Otherwise, it might reflect changes in habitat selection as a function of size for walleye and northern pike. Similarly, we hypothesize that in the Vistula River young (age 0+) and small (below ca. 3 cm of total length) gobiids were highly vulnerable and profitable especially for young specimens of large predators, like northern pike and pikeperch, and probably adult specimens of small predators like Eurasian perch. Most probably this pattern is or can be accounted for by the gape limitation of these piscivores and/or their utilization of habitats with high gobiid densities (e.g. shallow nearshore waters in the river). As suggested by Kangur et al. (2007), especially small pikeperch individuals are known to be gape-limited (Salonen et al. 1996, Smith et al. 1998). Thus, they are unable to eat large individuals of deep-bodied prey (species such as common bream), but they can forage on more elongated species like smelt (Smith et al. 1998). Therefore, small and oblong shaped alien gobiids seem to be an attractive source of energy for them, as well as for small pike contrary to the feeding preferences of larger individuals of these predator species. This could be an important phenomenon that accompanied the invasions by Ponto-Caspian gobies. However, further, more comprehensive research on predator-prey interactions between native piscivores and invaders is highly needed to understand their role in the local food webs in newly invaded areas of large European rivers. There are some indications that native piscivores feeding on non-native fish species could considerably contribute to the ecosystem resistance against their invasion (Robinson, Wellborn 1988; Baltz, Moyle 1993), although the contrary evidence also exists, showing that predators do not provide adequate predation pressure to mediate sufficient biological resistance when the propagule pressure of alien prey is too great (Beyer 2008). The fact that the gobiids constitute a major dietary item of younger individuals of pike and pikeperch in the Vistula River suggests that the predation pressure from these native predators against aliens could be greater than towards native fishes. However, the real predation intensity on various fish species in the river has not been assessed yet. This and other aspects of the role of the gobiids as prey in local fish communities are yet to be assessed in the future studies.

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