Feeding ecology of invasive *Perccottus glenii* (*Perciformes*, *Odontobutidae*) in Slovakia

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ABSTRACT: Stomach contents of 331 specimens of *Perccottus glenii* (*Perciformes*: *Odontobutidae*) were analysed. Chironomids and ephemeropterans dominated the diet of all size classes of fish; however, the frequency of crustaceans was also high. Micro-crustaceans (ostracods, copepods and cladocerans) dominated in lower size classes (20–39 mm); macro-crustaceans (*Isopoda*, *Amphipoda*) dominated in higher size classes (up to 79 mm). The proportion of crustaceans decreased from the size class 80–89 mm. With the increasing size of fish the frequency of molluscs (*Gastropoda*) increased, the maximum was in size class 70–79 mm. Cannibalism occurred from 60 mm, and it was significant from 80 mm. The highly mobile invertebrates (*Coleoptera*, *Heteroptera*) were found in the largest size classes. In middle size classes (40–59 mm), the widest spectrum of prey units was documented; the food variability of small (<40 mm) and large (>90 mm) individuals was poor. Differences in the diet composition of small individuals were negligible; the diet of the largest ones differed significantly. According to diet, two feeding size class groups were recognised: the first <70 mm and the second ≥70 mm. Main differences between these groups were caused by feeding on molluscs, important was also the occurrence of cannibalism. Positive prey selection was shown for slowly moving invertebrates from the bottom or vegetation and negative prey selection for highly mobile invertebrates.

Keywords: fish; invasion; food; competitions; prey

Worldwide, species are transported by man out of their geographic area (Williamson, 1999). Successful invasion by non-native fish species may have important economic and ecological consequences, as they can affect the structure and functioning of native aquatic communities (Lodge, 1993). Predation and competition exerted by invading species may lead to changes in the relative abundance of indigenous prey species or competitors and may ultimately result in their local extinction (Zaret and Paine, 1973). Exotic species may also affect the functioning of communities by inducing changes in the trophic relationships within the indigenous biota (Adams, 1991; Meffe et al., 1997; Marchetti, 1999) or by altering structural aspects of the habitat (Bain, 1993).

Perccottus glenii (*Perciformes*: *Odontobutidae*) – the Amur sleeper, may be considered as one of the most successful invaders of aquatic communities in East Slovakian shallow water bodies (Koščo et al., 2003a). It occurs naturally in the far-east Asia, mainly in the Amur River basin. The species was introduced into European Russia twice: in 1916 (St. Petersburg) and in 1950 (Moscow), by amateur fish fanciers and has colonized large areas of East and Central Europe (Harka et al., 2001; Reshetnikov, 2003). It readily withstands low oxygen levels in water, including small frozen ponds in winter.

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In the region of East Slovakia, the Amur sleeper appeared in 1998 (Koščo et al., 1999). It became numerous by the year 2001, when its populations formed a dominant component of many fish communities, mainly in shallow stagnant waters and drainage canals (Koščo and Košuth, 2002).

The wide distribution and high abundance of the Amur sleeper in Europe suggests a potentially high impact on native communities of fish and other aquatic organisms. Nevertheless, there is a lack of information about the interaction of this species with indigenous biota. There are several studies on the ecology of the Amur sleeper, but most were carried out in the area of the original geographic distribution of the species (Kirpichnikov, 1945; Nikolski, 1956). The majority of ecological studies conducted in recently invaded areas have been mainly out-ecological (Spanovskaya et al., 1964; Litvinov and O'Gorman, 1996; Pronin et al., 1998; Koščo et al., 2003a); some of them focus on interactions with native biota (Reshetnikov and Manteifel, 1997; Reshetnikov, 2003; Manko et al., 2008). There are also some diet studies (Szitó and Harka, 2000; Koščo and Manko, 2003), but they describe the diet of only a few particular samples at a time.

The present study investigates the diet of specimens from six drainage canals in East Slovakia during various seasons within the years 2002–2005.

MATERIAL AND METHODS

Study site

The study was conducted in the East Slovakian Lowland, in the original floodplain of Latorica, Bodrog and Tisa Rivers (21°N, 48°E). The area contains a network of interconnected drainage canals which cover the whole territory. During floods, the water in the canals flows in the opposite direction and connects all canal networks. *Perccottus glenii* was numerous in microhabitats with aquatic vegetation, as demonstrated by earlier observations (Koščo et al., 2003a).

Field and laboratory methods

Fish were captured by electrofishing by means of pulse electric current 170–220 V, 0.5–3.5 A. Six drainage canals were sampled during the spring and summer seasons (April–August), 2002–2005. Fish were preserved in a 7% formalin solution im-

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                    Log of distance

      0.170       0.704        1.579        2.453        3.327
      |-------+-------+-------+-------+-------+-------+-------+-------+
20–29 -----------------|
                 |---------|
60–69 -----------------|       |
                     |--------|
30–39 |                 |       |
      |--------------------------|      |--------------------------|
50–59 |                          |                  |
                              |                  |
40–49 -----------------------------------|                  |
                                   |
70–79 -----------------------------------------|                |
                              |------|         |
80–89 -----------------------------------------|     |-------------|
                                     |
90–99 -----------------------------------------------|
(mm)          Percent chaining =  18.18
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Figure 1. Two functional feeding groups (20–69 mm and 70–99 mm) of *P. glenii* size classes, discriminated by cluster analysis (3.327) of food components

Table 1. The frequency of food components (%) in size classes of *P. glenii* (mm)

20–29	(%)	30–39	(%)	40–49	(%)	50–59	(%)	60–69	(%)	70–79	(%)	80–89	(%)	90–99	(%)
ChirL	36.84	ChirL	35.30	ChirL	35.21	ChirL	37.00	ChirL	44.53	ChirL	47.55	ChirL	64.36	ChirL	50.00
EphL	15.79	Ostr	21.57	EphL	15.36	EphL	23.67	EphL	24.38	Gast	12.59	Gast	7.46	ColL	14.29
Clad	13.37	EphL	19.61	Oligo	8.99	Ostr	7.32	Asell	6.89	EphL	8.74	EphL	4.79	OthDP	10.71
Ostr	12.15	Cope	10.97	Clad	8.61	Amph	5.67	Cope	4.03	ColI	6.99	Asell	3.72	Gast	10.71
Cope	10.53	ChirP	4.71	Asell	4.87	Asell	4.67	Gast	3.82	Asell	6.99	Perc	3.72	HetL	3.57
ChirP	3.64	OthDL	3.14	Ostr	4.12	HetI	3.67	TriL	2.97	ChirP	4.20	ColL	3.20	OthDL	3.57
OthDL	2.02	Gast	1.57	Cope	4.12	Gast	3.33	Oligo	2.15	Amph	2.80	ColI	3.20	ColI	3.57
Others	5.66	Others	3.13	Amph	3.75	TriL	3.00	OdoL	2.12	OthDP	2.45	Oligo	2.12	Perc	3.57
				ColI	3.37	Oligo	2.67	Others	9.12	ColL	1.75	OthDP	1.60		
				ChirP	2.62	ChirP	2.00			Clad	1.75	Others	5.83		
				Hiru	1.5	Cope	2.00			Others	4.20				
				Others	7.49	OdoL	1.33								
						Others	3.67								

ChirL – *Chironomidae* larvae; EphL – *Ephemeroptera* larvae; Clad – *Cladocera*; Ostr – *Ostracoda*; Cope – *Copepoda*; ChirP, *Chironomidae* pupae; OthDL – other *Diptera* larvae; Gast – *Gastropoda*; Oligo – *Oligochaeta*; Asell – *Asellus aquaticus*; Amph – *Amphipoda*; ColI – *Coleoptera* imago; Hiru – *Hirudinea*; HetL – *Heteroptera* larvae; TriL – *Trichoptera* larvae; OdoL – *Odonata* larvae; OthDP – other *Diptera* pupae; ColL – *Coleoptera* larvae; Perc – *Perccottus glenii*

Table 2. The frequency of food components (%) of *P. glenii* in months

Taxon	Month			
	April	May	July	August
Oligochaeta	–	5.14	–	2.47
Gastropoda	–	2.94	7.49	2.39
Cladocera	6.82	1.96	3.63	–
Copepoda	–	6.36	4.33	–
Ostracoda	19.48	6.12	1.29	–
Asellus aquaticus	21.10	1.22	1.17	3.29
Amphipoda	12.66	–	–	–
Ephemeroptera larvae	–	22.77	10.75	**57.51**
Odonata larvae	–	1.47	–	1.61
Heteroptera imago	–	–	1.29	5.59
Coleoptera larvae	–	–	2.57	–
Coleoptera imago	–	4.9	2.46	–
Trichoptera larvae	–		–	11.97
Chironomidae larvae	**34.09**	**34.39**	**57.65**	11.18
Chironomidae pupae	2.93	5.52	–	–
Culicidae larvae	1.30	–	–	–
Other *Diptera* larvae	–	1.71	–	–
Other *Diptera* pupae	–	–	2.11	–
Perccottus glenii	–	1.71	–	–
Others	1.62	3.79	5.26	3.99

mediately after sampling. In the laboratory, 331 fish were measured for standard length (Sl) and eviscerated. Sl of specimens ranged between 18.0 and 103.8 mm.

The stomach and intestine were removed and the gut content was examined under the stereo- and binocular microscopes. Prey items were identified to the genus or species level, but in results we presented only higher taxa. Kicking and sweeping to estimate the food availability of the habitats collected semiquantitative samples of invertebrates. The samples were preserved immediately in a 4% formalin solution.

Data analysis

The frequency of the particular prey type occurrence is defined and expressed as the frequency of the total number of stomachs in which prey is present. Prey selection was analysed using Ivlev´s index of electivity (Ivlev, 1955) based on a comparison of diet composition and benthic invertebrate presence in the canals.

Cluster analysis (methods: single linkage clustering, distance measure, Euclidean distances, average method, Statgraphics 4.0) was employed to explore systematic differences in the diet frequency composition between groups of size classes, between sampling sites and between seasons. Analyses were performed using PC-Ord System Package (McCune, 1987).

RESULTS

Food composition of the Amur sleeper was highly size-dependent. The cluster analyses yielded functional groups of size classes with distinct diet compositions. Based on the frequency of food components, two functional groups could be distinguished in the populations: < 70 mm Sl and ≥ 70 mm Sl (Figure 1). The diet of all size classes was characterized by the prevalence of chironomids (larvae, pupae) and ephemeropterans (Table 1). The frequency of crustaceans was also high. With the increasing body size, the share of micro-crustaceans (copepods, cladocerans and ostracods)

Table 3. Ivlev electivity index of individual food components of *Perccottus glenii* in Slovakia

Site/date	Size		Gast	Bival	Oligo	Hiru	Asell	EphL	OdoL	HetL	HetI	MegL	ColL	ColI	TriL	LepL	CulL	ChirL	ChirP	OthDL	OthDP
	Component (relative abundance in %)																				
SM/120504	S	A	44.3	0.76	42.8	1.53	2.29	1.53	1.53				3.82	0.76						0.76	
		U			44.3		1.64	32.8										13.1			
																				6.56	
		E	−1	−1	0.02	−1	−0.2	0.91	−1				−1	−1				1		0.792	
	L	A	44.3	0.76	42.8	1.53	2.29	1.53	1.53				3.82	0.76						0.76	
		U	50					25										12.5		12.5	
		E	0.06	−1	−1	−1	−1	0.88	−1				−1	−1				1		0.885	
SM/140704	S	A	25.2		0.84		10.1	0.84			7.56		2.52	5.88			21.9	23.5		0.84	0.84
		U											4.69		1.56		1.56	50			
		E	−1		−1		−1	−1			−1		0.3	−1	1		−0.9	0.36		**−1**	**−1**
	L	A	25.2		0.84		10.1	0.84			7.56		2.52	5.88			21.9	23.5		0.84	0.84
		U	4.58		1.41			0.7	0.35	1.76	0.7		6.34	2.82				75.4		0.7	2.82
		E	−0.7		0.25		−1	−0.1	1	1	−0.8		0.43	−0.4			−1	0.52		**−0.09**	**0.541**
PC/120504	S	A	67.3		4.68	0.58			3.51		8.19						0.58	14.6		0.58	
		U	1.82		7.27	2.42	1.21	0.61	2.42					0.61		1.82		69.1		2.42	2.42
		E	−0.9		0.22	0.61	1	1	−0.2		−1			1		1	−1	0.65		**0.613**	**1**
	L	A	67.3		4.68	0.58			3.51		8.19						0.58	14.6		0.58	
		U	8.06		1.61				1.61					66.1		1.61		8.06			11.29
		E	−0.8		−0.5	−1			−0.4		−1			1		1	−1	−0.3		**−1**	**1**
PC/140704	S	A	38.9		0.96			43.3			2.88			0.96		0.48	0.96	8.17			0.48
		U	11.6					15.7		0.51	0.51		0.51	4.04				33.3		3.54	2.53
		E	−0.5		−1			−0.5		1	−0.7		1	0.62		−1	−1	0.61		**1**	**0.681**
	L	A																			
		U	31.4						2.33					5.81	2.33	1.16		31.4			5.81
		E	1						1					1	1	1		1			**1**

Table 3 to be continued

Site/date	Size		Gast	Bival	Oligo	Hiru	Asell	EphL	OdoL	HetL	HetI	MegL	ColL	ColI	TriL	LepL	CulL	ChirL	ChirP	OthDL	OthDP
			Component (relative abundance in %)																		
KM/050703	S	A	5				2	2	55	7		18			4	2	1		4		
		U	8				0	0	33	0		58			0	0	0		0		
		E	0.23				–1	–1	–0.3	–1		0.53			–1	–1	–1		–1		

S < 70 mm, L ≥ 70 mm; A – available, U – utilization, E – electivity index; SM – Svätá Mária, PC – panel canal, KM – Kamenná moľva canal

Gast = *Gastropoda*; Bival = *Bivalvia*; Oligo = *Oligochaeta*; Hiru = *Hirudinea*; Asell = *Asellus aquaticus*; EphL = *Ephemeroptera* larvae; OdoL = *Odonata* larvae; HetL = *Heteroptera* larvae; MegL = *Megaloptera* larvae; ColL = *Coleoptera* larvae; ColI = *Coleoptera* imago; TriL = *Trichoptera* larvae; LepL = *Lepidoptera* larvae; CulL = *Culicidae* larvae; CulP = *Culicidae* pupae; ChirL = *Chironomidae* larvae; ChirP = *Chironomidae* pupae; OthDL = other *Diptera* larvae; OthDP = other *Diptera* pupae; InsI = *Insecta* imago – terrestric; Clad = *Cladocera*; Cope = *Copepoda*; Ostr = *Ostracoda*; Clbl = *Colembola*; PeGl = *Perccottus glenii*

decreased, while the frequency of macro-crustaceans – *Isopoda* (*Asellus aquaticus*), *Amphipoda* (*Synurella ambulans, Niphargus* sp.) increased. Fish with Sl > 80 mm had a decreasing share of crustaceans at all.

The frequency of molluscs (*Gastropoda*) also increased with the body size. It was negligible in the size classes < 70 mm, while the gut content of the largest size classes (≥ 70 mm) was characterized by a higher frequency of molluscs (Table 1). Cannibalism was observed in the size class 60 to 69 mm for the first time and it increased with the body size, mainly in the largest size classes (> 80 mm). The frequency of highly mobile components (*Coleoptera*, *Heteroptera*) increased with the body length (≥ 70 mm). The diet of specimens from the intermediate size group (40–70 mm) was characterized by a large variety of prey. The gut contents of the smallest (< 40 mm) and especially of the largest (≥ 70 mm) size classes were characterized by a small variety of prey. The diet of fish in the first functional group was similar, but the similarity of gut contents in the second functional group was low. The variability of prey was the smallest in April and the highest in May, with a decreasing tendency in subsequent months.

Seasonal shifts in the diet of the Amur sleeper. Chironomids were dominant in April, May and mainly in July, ephemeropterans in August. The ephemeropterans were absent in April, the first peak in their higher frequency in the diet was in May (the first generation of larvae). The proportion of ephemeropterans decreased sharply in July (after emergence of the first generation). The second peak frequency of ephemeropterans was in August, when with a decreasing variety of prey, their frequency increased sharply (the second generation of larvae). The ephemeropterans mainly belonged to bivoltine species from the families *Baetidae* and *Caenidae*.

Amur sleeper consumed crustaceans (the third most important fraction of diet) mainly in spring. The frequency of crustaceans decreased during the year, only macro-crustaceans (mainly *Asellus aquaticus*) were consumed in August. Thus, crustaceans were dominant in April, ephemeropterans and many other components in May, chironomids in July and ephemeropterans in August (Table 2).

Depending on the food availability, *Perccottus glenii* selected positively chironomids, ephemeropterans and crustaceans (small specimens mainly micro-crustaceans, larger specimens macro-crustaceans). Gastropods were also eaten by large specimens. Amur sleeper was found to choose preferably the less mobile prey, which had a preference for the bottom or vegetation. Highly mobile organisms and organisms inhabiting pelagial or surface waters were negatively selected by the fish (Table 3). Feeding strategy analyses suggest a high individual specialisation and the Amur sleeper has an opportunistic feeding strategy, mainly in the adult stage. Such a life-history trait is typical of successful invaders.

DISCUSSION

Given that various prey is available to fish in a particular ecosystem, by default fish feed selectively (Link, 2004). The diet of the Amur sleeper in drainage canals includes a variety of animal food, of the accessible size, including its own young. A similar diet composition was described in the areas of its origin (Kirpichnikov, 1945; Nikolski, 1956) and in the new, invaded areas (Litvinov and O'Gorman, 1996; Pronin et al., 1998; Szitó and Harka, 2000). Generally, a good agreement between the studies was found, although some aspects were different.

In Kirpichnikov (1945) and Nikolski (1956), the variety of food components was lower, although in the area of origin the trophic webs are quite stable. Furthermore, specimens from Slovakia showed a higher diversity of prey items, allowing them to survive in the new environment. According to Kirpichnikov (1945), in the area of origin (Amur River basin) *Perccottus glenii* is a predacious fish and feeds on Entomostraca, larvae of the insects (*Odonata*, *Hemiptera*, *Chironomidae*), worms and small fish (cannibalism is rather usual). In contrast, in the present study, fishes, except its own young, were negligible prey items. This was probably caused by the lack of other fish species in the sampling localities. Spanovskaya et al. (1964) also stated that the Amur sleeper fed more on benthos than fishes. However, if the feeding conditions are not suitable, the cannibalism was observed from 45 mm Sl. Litvinov and O'Gorman (1996) and Pronin et al. (1998) also defined two feeding groups, although based on age (≤ age 2 and > age 2). Standard lengths at these ages are confirmed by previous results (Koščo et al., 2003b). According to Reshetnikov and Manteifel (1997) and Reshetnikov (2003), the Amur sleeper displaces the newts (*Triturus* sp.) from their localities and preys for them. In the present study, newts were absent in its diet because of their absence in investigated localities. Szitó and Harka (2000) also confirmed the negative selectivity of animal food living on the surface (*Culicidae*) by laboratory experiments.

In all above studies, zooplankton (micro-crustaceans) is the main prey component of young fish, the intermediate size classes fed on macro-invertebrates (larvae of insects, molluscs) and the bigger (older) fish consumed amphibian larvae or fish.

Amur sleeper has successfully adapted itself to the environmental conditions in the drainage canals of East Slovakia. Its success in colonizing this type of habitat suggests that it will be able to establish populations in other similar areas of Slovakia, mainly in the lowland areas of South Slovakia.

Chironomids and ephemeropterans were an important part of the Amur sleeper diet and they were also an important part of diet of the endemic *Umbra krameri* (Libosvárský and Kux, 1958) and other native rare fishes like *Leucaspius delineatus* and *Carassius carassius* (Koščo et al., 2003a). These fishes must now share space and food resources with the invader. Some species of native fishes (mainly phytophilous) spawn in canals and potential consumption of eggs and young fish by the Amur sleeper is perhaps a serious threat to them.

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