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Diet of the Round Goby *Neogobius melanostomus* (Pallas, 1811) (Gobiidae) in the Danube and Velika Morava Rivers in Serbia

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Abstract: Since the early 1970s the spread of the Ponto-Caspian gobiids along the Serbian part of the Danube River has been reported, mainly owing to the construction of dams and canals linking the larger rivers. The aim of our study was to analyse the diet of the round goby *Neogobius melanostomus* based on the fish intestinal contents and available food resources at selected sites in the Danube and Velika Morava rivers in Serbia. The fish samples were collected during October 2018, at three localities: Zemun and Stari Slankamen in the Danube River and Ljubičevski Most in the Velika Morava River. A total of 35 fish specimens were collected and examined. The analysis of the intestinal contents showed that *N. melanostomus* fed mainly on representatives of Gammaridae (*Dikerogammarus* sp.), insect larvae (Trichoptera, Chironomidae), Gastropoda, Bivalvia (*Dreissena* sp., *Corbicula* sp.), and Oligochaeta. The diet of fish from the Velika Morava River consisted mostly of Oligochaeta and Gammaridae, while the diet of fish from the Danube River consisted of larvae of Trichoptera and mollusks.

Key words: Food items, round goby, Danube River, Velika Morava River.

Introduction

Since the early 1970s the spread of the Ponto-Caspian gobiids (Gobiidae) from east to west along the Danube River has been reported, mainly owing to the construction of dams and canals linking the larger rivers (Lenhardt et al. 2011, Brandner 2014). The Ponto-Caspian gobies have shown relatively high invasive potential in the Balkan countries (Simonović et al. 2013). In Serbia, the gobiids are currently distributed within 11.3–14.2% of the total territory of the country, while other non-native fish species account for only few percents of the same area (Lenhardt et al. 2011). The colonisation success of the Ponto-Caspian invaders, including gobiids, can be attributed to several biological features, the most important of which are as follows: tolerance to wide temperature and salinity ranges, omnivorous opportunistic feeding, and rapid reproduction (e.g. high fecundity, fast growth, early maturity) (Bij de Vaate et al. 2002).

The round goby *Neogobius melanostomus* (Pallas, 1811) (Gobiidae) is a fairly small bottom-dwelling fish, living in brackish and freshwater environments. In rivers, *N. melanostomus* occurrs mainly along the banks in places with moderate water velocities and over sandy, sandy-gravelly or stony substratum (Kottelat & Freyhof 2007). *Neogobius*

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melanostomus are voracious feeders, eat mussels and other mollusks, with up to 60% of their diet made up of mussels in some places. They also eat aquatic insect larvae and eggs of other fish (Brandner et al. 2013). This fish mostly stays in one place with noticeably restricted movement. A patchy distribution and long distances between native regions of occurrence and newly settled areas are typical for the current world distribution of the species (Sapota 2004).

The expansion of *N. melanostomus* upstream of the Danube River appears to have started later than of the other Ponto-Caspian species (Harka & Bíró 2007). The species has been recorded in the Danube River in Serbia (Simonović et al. 1998), Austria (Wiesner 2000, 2005) Slovakia (Stranai & Andreji 2004, Adamek et al. 2007), Croatia (Mustafić 2005), and Hungary (Erős et al. 2005); in the Sava River in Croatia (Piria et al. 2011, 2016); in the Rhine River Basin in Belgium (Verreycken et al. 2011) and Switzerland (Kalchhauser et al. 2013); and in the Baltic Sea (Sapota 2004).

In Serbia, *N. melanostomus* was found for the first time in the waters of the Danube River downstream of the Djerdap II Reservoir (861 rkm), in the area of Prahovo Village, in 1997 (Simonović et al. 1998) (upstream distribution). Further upstream occurrence of this gobiid species has been recorded in the Djerdap I Reservoir in the area of Tekija Village (956 rkm), as well as at Banatska Palanka Village (1077 rkm) in 2001 (Smederevac et al. 2001). Simonović et al. (2001) have reported on the occurrence of different age and length classes in the sample. Currently, *N. melanostomus* has been considered to be naturalised invasive alien fish species in Serbia.

Several studies devoted to the diet of *N. melanostomus* populations present some basic information on the diet composition of this species (Simonović et al. 2001, Adámek et al. 2007, Copp et al. 2008, Polačik et al. 2009, Piria et al. 2016).

The aim of the present study was to analyse the diet spectrum of *N. melanostomus*, based on the fish intestinal contents and available food resources at selected sites in the Danube River and Velika Morava River in Serbia.

Materials and Methods

The fish samples were collected during the first half of October 2018, at three localities: two in the Danube River (Zemun and Stari Slankamen), and one locality in the Velika Morava River (Ljubičevski Most) (Fig. 1).

The fish were caught with electrofishing (HONDA 1.2kW, 6A) and measured in the field. The total length (TL), to the nearest 0.1 cm, and weight (W), to the nearest 0.1 g, of each specimen were recorded immediately following the capture. Then, the samples were transported to the laboratory, where the analysis

Fig. 1. Map of the sampling sites in the Danube River (Stari Slankamen and Zemun) and Velika Morava River (Ljubičevski Most), in October 2018.

of their intestines for food items was conducted. The intestines were examined under an Olympus binocular microscope and an Olympus stereomicroscope. The identification of intestinal contents of *N. melanostomus* was carried out to the lowest taxonomic level, using the appropriate identification keys.

In addition to fish, the sampling of benthic fauna was carried out at the same localities, from all available types of substrate: stones (6 cm), pebbles (2–64 mm), sand (0.06–2 mm), and mud (0.06 mm). The samples of benthic macroinvertebrates were collected by a benthic hand net (mesh size 500 μm) in shallow water (at depths up to 1.5 m) and by an Ekman dredge (225 cm^2) in deeper water (up to 10 m), according to the EN 27828 Standard. Part of the sampled material was examined on site and the rest was preserved in 70% ethanol and processed at the laboratory. The collected individuals were identified using the appropriate identification keys.

For the purposes of data analyses, the food items identified during the intestinal contents analyses were expressed as percentage frequency of occurrence (F) calculated by dividing the number of occurrences of a particular prey item by the total number of spraints × 100 (Hyslop 1980). The Ivlev's index (Ivlev 1961) was applied to assess the preferences of gobiids to available prey in the environment. The following equation was used: E=(ri–pi) / (ri+pi), where 'E' is the measure of selectivity for various prey items in the fish rations; 'ri' is the relative abundance of prey category 'i' in the digestive tract (as a proportion or percentage of all digestive tract contents); and 'pi' is the relative abundance of this prey in the environment. The values of this index range from −1 to +1, with negative values indicating rejection or inaccessibility of the prey, zero values – random feeding, and positive values – active selection.

Results

A total of 35 specimens of *N. melanostomus* were collected and examined, of them 17 in the Danube River and 18 in the Velika Morava River. The total length (TL) range was 7.0–11.0 cm, while the body weight (W) range was 4.6–19.26 g (Table 1). At the locality Ljubičevski Most (Velika Morava River) eight specimens had empty intestines, while at Zemun and Stari Slankamen (Danube River) one specimen at each locality was without food items (Table 1).

The examination of the intestinal contents revealed that in autumn 2018 *N. melanostomus* at the studied localities fed mainly on crustaceans belonging to the fammily Gammaridae, dominated by *Dikerogammarus* sp., and representatives of the insect taxon Trichoptera. In addition, representatives of the following taxa were also determined in the intestinal contents: Oligochaeta, Chironomidae, Gastropoda, and Bivalvia (*Dreissena* sp., *Corbicula* sp.) (Table 2). The diet of fish from the Velika Morava River consisted mostly of Oligochaeta and Gammaridae, while the diet of fish from the Danube River consisted of larvae of Trichoptera and mollusks (Table 2).

The qualitative and quantitative composition of the diet of *N. melanostomus* and bottom macroinvertebrate fauna at the sampling localities were compared and the results presented in Table 3 and Fig. 2. The results show that *Neogobius melanostomus* exhibited strong dietary preferences for Gammaridae and Trichoptera. Gammaridae, Oligochaeta, insect groups and Mollusca were identified in bottom fauna in the environment, and the Ivlev's index of prey selectivity indicated the different preference for those items (Table 3).

Discussion

Feeding ecology of an invasive species can influence community interactions including distribution and abundance of a species (Shea & Chesson 2002, Carmen et al. 2006). The round goby *N. melanostomus* is a species with broad and flexible diet (Diggins et al. 2002, Copp et al. 2008, Polačik et al. 2009), aggressive behaviour, tolerance to a wide range of environmental factors, and early

Table 1. Total length (TL) and body weight (W) of the examined *Neogobius melanostomus* in the Danube River and Velika Morava River, in October 2018. The parameters are presented with a mean value, standard deviation (±SD), and a range of the values (in parentheses).

Locality	Number of examined specimens	Number of specimens without intestinal contents	TL (cm)	W (with intestinal contents) (g)
Velika Morava River (Ljubičevski Most)	18	8	9.52±1.14 (7.6–11.0)	12.05±4.44 (5.2–19.26)
Danube River (Stari Slankamen)	7	1	9.17±1.17 (7.0–10.4)	9.96±3.35 (4.6–13.9)
Danube River (Zemun)	10	1	8.76±1.18 (7.2–11.0)	8.81±3.46 (4.7–15.7)

Table 2. Identified food items in the intestinal contents of the studied *Neogobius melanostomus* and the corresponding percentage frequency of occurrence.

Locality	Food items	Percentage frequency of occurrence
Velika Morava River (Ljubičevski Most)	Oligochaeta	20.00
	Gammaridae (*Dikerogammarus* sp.)	26.67
	Gammaridae	53.33
Danube River (Stari Slankamen)	Oligochaeta	6.67
	Gammaridae (*Dikerogammarus* sp.)	13.33
	Gammaridae	20.00
	Trichoptera	20.00
	Chironomidae	6.67
Danube River (Zemun)	Gammaridae	13.33
	Trichoptera	46.67
	Chironomidae	6.67
	Gastropoda	26.67
	Bivalvia	6.67

Table 3. Comparison of the food items of *Neogobius melanostomus* and the bottom fauna based on relative abundance (%) of the identified taxonomic groups and the Ivlev's index of prey selectivity (E).

Locality/ Taxonomic group	Relative abundance in intestinal contents (%)	Relative abundance in bottom fauna (%)	Ivlev's index (E)
Velika Morava River (Ljubičevski Most)			
Oligochaeta	10.7		
Gammaridae	89.3	38.9	-0.39
Ephemeroptera		9.1	
Trichoptera		10.9	
Hemiptera		4.5	
Diptera (Chironomidae)		34.8	
Bivalvia		1.8	
Danube River (Stari Slankamen)			
Oligochaeta	7.7	8.7	0.06
Gammaridae	46.2	28.3	-0.24
Mysidae		2.4	
Odonata		0.8	
Trichoptera	30.8		
Chironomidae (Diptera)	7.7		
Gastropoda		57.5	
Bivalvia	7.7	2.4	-0.52
Danube River (Zemun)			
Oligochaeta		24.1	
Gammaridae	11.1		
Trichoptera	66.7		
Chironomidae (Diptera)	3.7	27.6	0.76
Gastropoda	18.5	3.4	-0.69
Bivalvia		44.8	

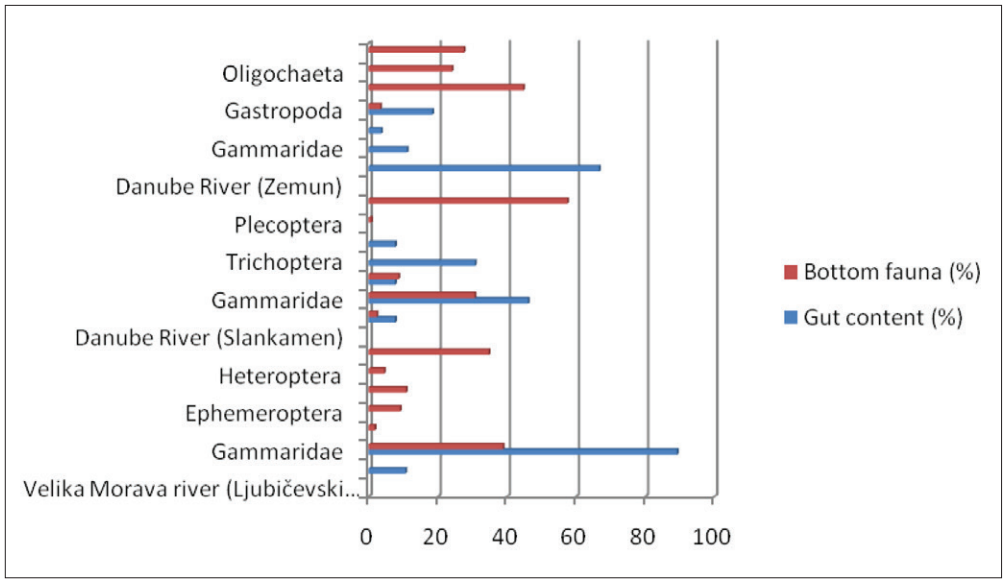

Fig. 2. Relative abundance of the food items identified in the intestinal contents of the studied *Neogobius melanostomus* specimens and the bottom fauna taxonomic groups.

sexual maturation (L'avrinčíková & Kováč 2007). *Neogobius melanostomus* is a voracious feeder, eat mussels and other mollusks, aquatic insect larvae and eggs of other fish (Brandner et al. 2013). When reaching a certain body size, it feeds mainly on mollusks and freshwater amphipods (Adámek et al. 2007, Kornis et al. 2012). The species quickly adapts to new surroundings, for example, by changing its feeding habits depending on the sources and the season. Native species are often easier prey as they have not developed defense strategies against the newcomers. And this benefits the non-native species (Polačik et al. 2009, Brandner et al. 2013).

In the Slovak part of the Danube River, seasonal changes influence the diet composition of *N. melanostomus*. The seasonal variations suggest that the species is a more flexible feeder, taking the advantage of energy rich sources during season when available (Ševove & Kováč 2013). According to this study, the most predominant food types in *N. melanostomus* are the chironomid larvae, *Corophium* sp., bryozoans, and Cladocera, while in the bighead goby *Ponticola kessleri* (Günther, 1861) those are: *Dikerogammarus* sp. and the chironomid larvae (Ševove & Kováč 2013). In our study, the analysis of the diet of *N. melanostomus* revealed the significant predominance of Gammaridae and participation of Trichoptera representatives.

The comparison of the intestinal contents and the prey available in the environment based on the Ivlev's selectivity index show that *N. melanostomus* exhibit dietary preference for Diptera (Chironomidae) and Oligochaeta (E = 0.76, 0.06, respectively), even though Gammaridae and Trichoptera are the most abundant items in the environment. Similar phenomenon has been previously reported by Polačik et al. (2009), who hypothesise that Mollusca are an unavoidable alternative, rather than the most preferred prey.

In a previous investigation, in the Serbian stretches of the Danube River, *N. melanostomus* prefers in its diet mollusks, as well as gammarids, due to their presence (Simonović et al. 1998). According to Simonović et al. (2001), *N. melanostomus* feeds mainly on mollusks, gammarids, Oligochaeta, and insects (Diptera and Plecoptera). The selectivity for mussels of the species in the Danube River confirms the findings of Svetovidov (1964). Another analysis of intestinal contents indicates that Gastropoda are highly important prey items for *N. melanostomus* in the Croatian part of the Danube River Basin (Piria et al. 2016).

Our results have shown that *N. melanostomus* has adapted to local food resources, consuming diverse food from small to large items, both with soft and/or hard body, which enhances the capability of this invasive species to spread successfully. The data obtained may serve as an estimation of its impact on the native benthic-feeding fish species.

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