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The recent distribution and abundance of non-native *Neogobius* fishes in the Slovak section of the River Danube

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Summary

The distributions of invasive *Neogobius* species were investigated in the Slovak section of the River Danube from Bratislava downstream to the village of Chl'aba. During October 2004, the main channel of the Danube was sampled, including by-pass, head-race and tail-race canals of the Gabčíkovo dam, backwaters and the lower-most sections of the tributaries Malý Dunaj, Hron, Váh and Ipeľ. Three *Neogobius* species already documented in Slovakia were captured (monkey goby *Neogobius fluviatilis*, bighead goby *N. kessleri*, round goby *N. melanostomus*), with the latter two species being found in almost all stretches of the Slovak Danube. Monkey goby had a most limited distribution, and no racer goby *N. gymnotrachelus* were observed. The abundance of particular *Neogobius* species appeared to depend on the character of the shoreline habitat, and a possible association between larger towns and the abundance of bighead and round gobies requires further investigation.

Introduction

Four species of fish of the genus *Neogobius* (Pisces, Gobiidae) are known to have expanded upstream from their previous (native) distributions and invaded the middle sections of the River Danube. The Djerdap Gorge in Serbia (former Yugoslavia) was the previous upper boundary of bighead goby *Neogobius kessleri* (Günther, 1861) and monkey goby *N. fluviatilis* (Pallas, 1814), and this is thought to have been true for an extended period (Miller, 2003). The western most native distribution of *N. kessleri* in the Danube was delineated upstream by the mouths of the Velka Morava and Nera Rivers in Serbia (Ahnelt et al., 1998). The round goby *N. melanostomus* (Pallas 1814) originally inhabited the lower sections of the River Danube as far upstream as the town of Vidin, Bulgaria (Smirnov, 1986). The original distribution of the racer goby *N. gymnotrachelus* (Kessler, 1857) was either the town of Ruse in Bulgaria (Svetovidov, 1964; Georgiev, 1966) or Vidin (Smirnov, 1986).

Range expansion from a formerly static natural distribution of monkey goby in the Danube basin, i.e. downstream of the Djerdap Gorge (Serbia – Romania), was first observed during the 1960s (Bănărescu, 1970). At present, monkey goby occurs at several locations along the Serbian section of the Danube and some of its tributaries (Simonović et al., 2001). In 1970, a few specimens of monkey goby were caught in Lake Balaton (Biró, 1971), some distance from its original distribution; the species was subsequently confirmed in the Sió Channel (connecting Lake Balaton and the main Danube channel), and in the River Tisza and its tributary, the River Bodrog, both in Hungary (Ahnelt et al., 1998). More recently, monkey goby has been recorded in the Slovakian Danube near Hungary (Stráňai and Andreji, 2001) and a further upstream expansion of this species into the Slovakian part of the River Bodrog can be expected (Ahnelt et al., 1998; Kautman, 2001).

An upstream expansion of racer goby has also been reported in River Danube basin (summarized in Copp et al., 2005), although the sequence of reports appears almost contradictory. This species has been described as a new fish species for Serbia (Hegedis et al., 1991), but later listed, under *Mesogobius gymnotrachelus*, amongst the fish species found at Iron Gate I prior to dam construction on the Danube at that location (Janković, 1996). In contemporary reports, racer goby has been observed in the Danube in Serbia, about 130 km upstream of the Iron Gate I dam (Visnjic-Jeftic and Hegedis, 2004), in Slovakia near Bratislava (Kautman, 2001) and in Austria (Ahnelt et al., 2001) not been in the Hungarian stretch of the Danube (Erős et al., 2005; Erős, 2005). Wiesner (2005) attributes this patchy distribution to ship transport of *Neogobius* species, which he has found associated in the Danube with industrial harbours. In the case of bighead goby in the River Danube, upstream expansion from the Iron Gate I since 1992 (Simonović et al., 2001) includes reports in Austria near Vienna (Spindler and Chovanec, 1995; Zweimüller et al., 1996), in Hungary (Erős and Guti, 1997), Slovakia (Stráňai, 1997; Černý and Kvaszová, 1999; Černý et al., 2003) and Germany (Seifert and Hartmann, 2000), with migration over into the Rhine catchment reported to have been via the Rhine-Main-Danube Canal (Freyhof, 2003; Copp et al., 2005).

Expansion of round goby upstream of Vidin, Bulgaria (Smirnov, 1986), has long been anticipated (Simonović et al., 1998). Since the first record of this species in 1997 in the lower Serbian Danube (Simonović et al., 1998), upstream migrations in the Danube (see map in Copp et al., 2005) have been reported for Serbia (Visnjic-Jeftic and Hegedis, 2004), Austria (Wiesner et al., 2000), and then Slovakia (Stráňai and Andreji, 2004) and Hungary (Guti et al., 2003; Erős et al., 2005).

Since the initial records of *Neogobius* spp. in Slovakia, research on these species has been site specific investigation of their environmental biology (e.g. Kováč and Siryová, 2005; L'avrinčíková et al., 2005). To address the dearth of information about the distribution of non-native *Neogobius* spp. in Slovakia, the aim of the present study was to assess the recent

distribution and relative abundance of *Neogobius* spp. in the Middle Danube, Slovakia.

Study area, material and methods

Two surveys of goby abundance, one preliminary (20–22 April 2004) and one comprehensive (4–8 October 2004), were undertaken along the longitudinal profile of the Danube's main channel, its by-pass in the Gabčíkovo dam, its side-channels and the lower parts of its tributaries (Fig. 1). All types of available shoreline were examined, and the length of each survey site (mean length = 110.7 m; Table 1) was delimited by the length of homogenous shoreline substratum, which was categorized as: sand (< 0.5 cm), gravel (0.5–2.0 cm), pebbles (2–10 cm), stones (11–20 cm), rocks (21–50 cm), boulders (> 50 cm). Water velocity at the mid-point of each site was determined semi-quantitatively using a dip net according Copp (1992): gentle ballooning of the net indicated a slow water velocity (> 0 but ≤5 cm s^{-1}), moderately rapid ballooning of the net represented a medium velocity (5–10 cm s^{-1}), and rapid ballooning of the net corresponded to a high velocity (≥10 cm s^{-1}).

Using the same methods and sampling team throughout (described below), the preliminary survey (April 2004) was undertaken at five sites (Fig. 1: 10, 11, 15, 16 and 17) along the Slovak stretch of the Middle Danube, and the comprehensive survey (October 2004) encompassed the Danube between Bratislava and Chl'aba (river km 1708–1880) and the downstream most parts of its tributaries (rivers Malý Dunaj, Váh, Hron, Ipel'). Sampling was undertaken during daylight hours under uniform hydrological and climatic conditions using continuous, single depletion catch-per-unit-effort (CPUE = number of fish per 100 m of shoreline) electrofishing (Zalewski, 1985) with portable backpack units (maximum output 225/300 V, frequency: 75–85 Hz; fitted with a 40 × 20 cm, elliptical, anode of stainless-steel with netting of 4 mm mesh size). Because electrofishing along boulder and rock banks captures only about 50% of gobiid fishes present (C. Wiesner, pers. comm.), the CPUE estimates of relative density were made with the same sampling team to minimize between operator bias (Bain and Finn, 1990). Fish were identified to species on the bank and returned to the river. Differences in the relative (CPUE) of fish among the types of shoreline habitat were tested using the Kruskall–Wallis test. Associations between fish presence and shoreline habitat types were tested for using the Fisher Exact test (because of expected values < 5).

Results

The pilot study in April 2004 revealed that the shoreline from Bratislava downstream to Komárno consisted mainly of boulders, and predominantly gently sloping gravel from Komárno downstream to Štúrovo, the end of the Slovak stretch. Round goby was recorded immediately downstream of the Gabčíkovo dam (site 15) and at the beginning of headrace canal (upstream of the dam) near village of Dobrohošt' (1 km upstream of site 11, sampled in October). Round goby was not observed at the two sites further downstream (16 and 17), nor at the site (11) upstream of the dam (Table 1). In October 2004, a total of 1582 fish, representing 25 species, were captured at the 36 sampling sites (i.e. 3984.5 m of river shoreline). At two sites (Table 1), no fish of any species were recorded. In total, 1096 specimens of three *Neogobius* species were collected (69.3% of total catch): bighead goby (492 specimens), round goby (575 specimens) and monkey goby (29 specimens). Racer goby was not observed. The most abundant of the other species were roach *Rutilus rutilus* (9.9% of catch), tubenose goby *Proterorhinus marmoratus* (5.9% of catch) and perch *Perca fluviatilis* (3.9% of catch). In frequency of occurrence, bleak *Alburnus alburnus* was the most frequently encountered

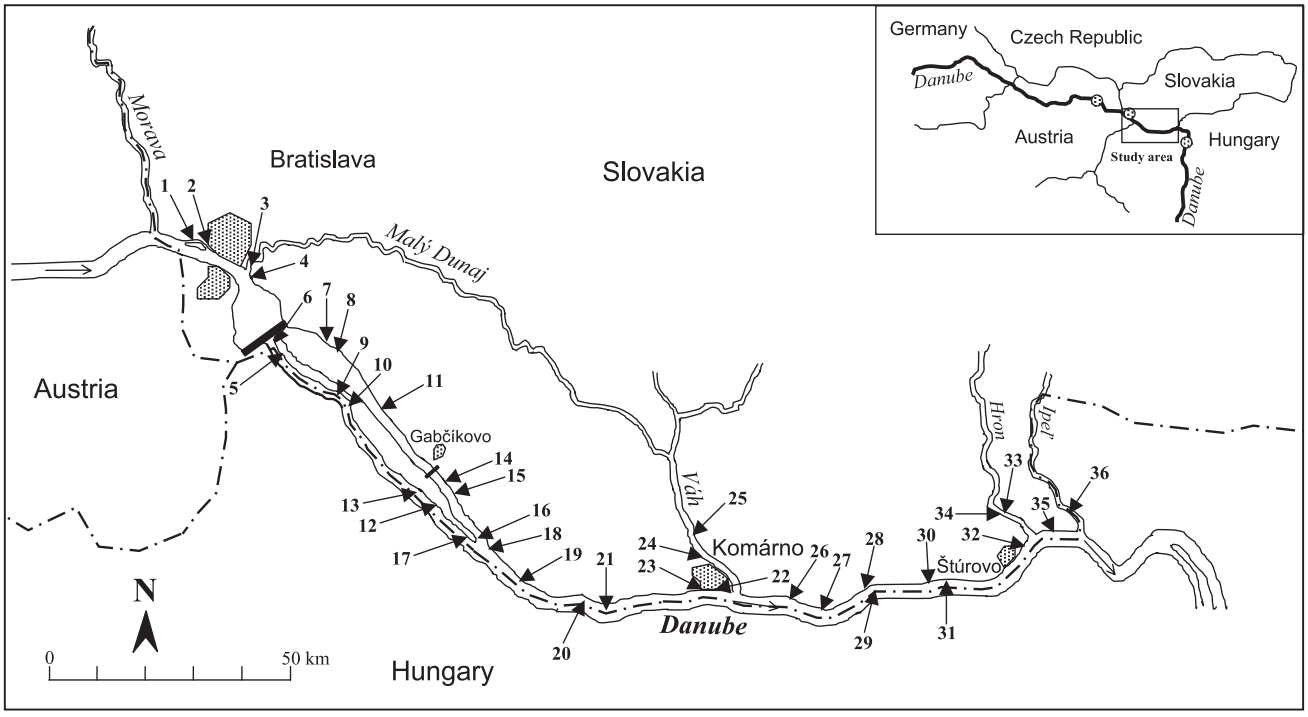

Fig. 1. Map of the Slovak stretch of the River Danube surveyed in October 2004 with the study sites indicated

Table 1
List of study sites on the Slovak stretch of the River Danube, their location by name and river km, the type of location, the substratum type, the site length, the water velocity category (0, none; 1, 0.0–0.1 m s^{-1}; 2, 0.1–0.6 m s^{-1}; 3, >0.6 m s^{-1}), the abundance (CPUE) of *Neogobius* spp. surveyed in October 2004 (in parentheses data from April 2004)

Site no.	River	Site location	River km	Habitat	Substrate	Length of site (m)	Velocity (0–3)	Bighead goby	Round goby	Monkey goby
1	Dunaj	Bratislava – Karlova Ves	1873	Side arms	Rocks	39	0		79.5	
2	Dunaj	Bratislava	1872	Main channel	Rocks, boulders	84	2	7.1	7.1	
3	Malý Dunaj	Bratislava	0	Backwater	Gravel, rocks	35	0	28.6	34.3	
4	Dunaj	Bratislava	1866	Main channel	Rocks	100	2	14.0	12.0	
5	Dunaj	Čuňovo	1851	Bypass	Boulders	55	0	14.5	18.2	
6	Dunaj	Čuňovo	1851	Bypass	Gravel	30	1	36.1	59.0	
7	Dunaj	Šamorín	1847	Headrace reservoir	Gravel	100	0			
8	Dunaj	Šamorín	1846	Headrace reservoir	Rocks	150	0	13.0	13.0	
9	Dunaj	Dobrohošť	1843	Bypass	Boulders	50	1	26.0		
10	Dunaj	Dobrohošť	1842	Bypass	Rocks	63	1	(7.8) 19.0	(0) 22.2	
11	Dunaj	Vojka	1838	Headrace canal	Rocks	344	0	(30.3) 26.5	(0) 6.7	
12	Dunaj	Gabčíkovo	1819	Bypass	Rocks	191	0	35.6	25.6	
13	Dunaj	Gabčíkovo	1819	Bypass	Rocks	111	0	26.1	52.3	
14	Dunaj	Gabčíkovo	1818	Tailrace	Rocks	182	1	.	0.5	
15	Dunaj	Gabčíkovo	1818	Tailrace	Rocks	106	1	(35.0) 10.4	(7.0) 7.5	
16	Dunaj	Sap	1811	Tailrace	Boulders	250	2	(4.0) 2.0	(0) 5.6	
17	Dunaj	Sap	1811	Main channel	Rocks	90	2	(0)	(0) 1.1	
18	Dunaj	Sap	1810	Main channel	Boulders	149	2	2.7		
19	Dunaj	Číčov	1798	Main channel	Boulders	143	2	2.8		
20	Dunaj	Vel'ké Kosiny	1790	Main channel	Rocks	100	2	6.0		
21	Dunaj	Zlatná na Ostrove	1779	Main channel	Rocks	100	2	9.0	3.0	
22	Dunaj	Komárno	1767	Main channel	Gravel, rocks	155	0	12.3	18.7	
23	Dunaj	Komárno	1769	Backwater	Rocks	100	0	25.0		
24	Váh	Komárno	3	Tributary	Gravel, rocks	150	1	30.7	96.0	1.3
25	Váh	Kava	8	Tributary	Rocks, boulders	85	2	12.9	68.2	
26	Dunaj	Iža	1759	Main channel	Gravel, rocks	100	0	6.0	14.0	1.0
27	Dunaj	Patince	1754	Main channel	Gravel	150	1	0.7		0.7
28	Dunaj	Radvaň nad Dunajom	1748	Main channel	Rocks	73	2	30.1	43.8	
29	Dunaj	Radvaň nad Dunajom	1748	Main channel	Gravel	96	2		1.0	1.0
30	Dunaj	Kravany nad Dunajom	1740	Main channel	Gravel, rocks	150	1	1.3	2.0	0.7
31	Dunaj	Kravany nad Dunajom	1740	Main channel	Gravel	100	0			
32	Dunaj	Štúrovo	1718	Main channel	Gravel, rocks	50	0	52.0	30.0	
33	Hron	Kamenice nad Hronom	6	Tributary	Boulders	53	2	7.5	11.3	
34	Hron	Kamenice nad Hronom	6	Tributary	Gravel	50	3			2.0
35	Dunaj	Chľaba	1706	Main channel	Rocks	100	0	15.0		
36	Ipeľ	Chľaba	3	Tributary	Rocks	100	2	1.0		22.0

(44% of sites), followed by chub *Leuciscus cephalus* (36%), tubenose goby *P. marmoratus* (36%), perch (30%) and roach (17%). Single specimens of bullhead *Cottus gobio* and white-finned gudgeon *Gobio albipinnatus* were captured.

In terms of distribution, bighead goby was found along the entire longitudinal profile of the Slovak Danube, from Bratislava to Chľaba and in all study tributaries, occurring at 80.6% at all sampling sites, compared with 69.4% for round goby. Both bighead and round gobies seemed to occur more often along shorelines composed of rocks than other types of shoreline (Fig. 2), but the frequencies did not deviate from expected (Fisher Exact test, $P > 0.05$). The relative densities (Table 2) of bighead and round gobies also did not differ (Kruskal–Wallis tests) between shoreline types (Table 2).

In relative density (Table 1), round goby was the most abundant species (mean CPUE = 17.6), followed by bighead goby (mean CPUE = 13.2) and monkey goby (mean CPUE = 2.21; calculated only for the sites downstream the town of Komárno). The highest relative densities of monkey and round gobies were observed in the Danube tributaries (Ipeľ' and Váh), whereas those of *N. kessleri* were in the Danube main channel (Table 1).

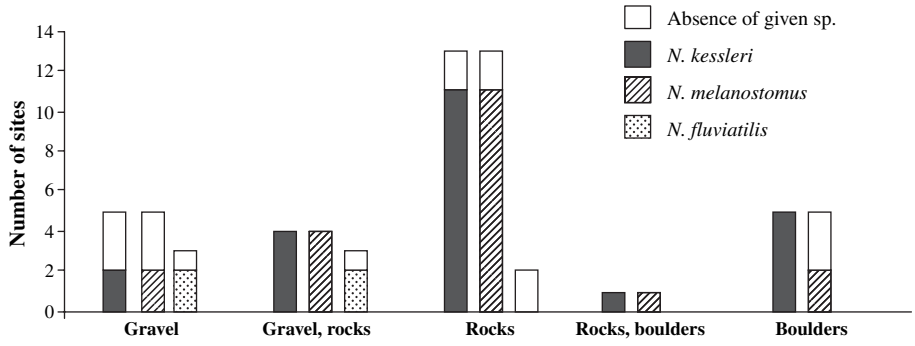

Fig. 2. Number of sites along the Slovak stretch of the River Danube at which bighead goby *Neogobius kessleri*, round goby *N. melanostomus* and monkey goby *N. fluviatilis* where observed in October 2004 according to shoreline habitat type (backwater sites excluded; in the case monkey goby, only sites downstream town of Komárno are included)

Table 2
Substratum type, number of sites (n) and mean abundance (CPUE, with SE) of *Neogobius* spp. (bighead, round, monkey goby) along shoreline habitats (backwater sites excluded) of the Danube River, Slovakia, with probability (P) from Kruskal–Wallis comparisons of CPUE among particular habitats (excluding 'rocks, boulders' category because of low sample size)

	Bighead goby*			Round goby**			Monkey goby[a]		
Substratum	n	Mean	SE	n	Mean	SE	n	Mean	SE
Gravel	5	7.35	16.06	5	12.01	26.28	3	0.57	0.43
Gravel, rocks	4	17.90	23.17	4	16.18	11.59	3	0.56	0.42
Rocks	13	15.75	11.22	13	14.88	16.79	2	0	–
Rocks, boulders	1	7.14	–	1	7.14	–	–	–	–
Boulders	5	9.61	10.55	5	3.64	8.13	–	–	–

*P = 0.282; **P = 0.059; [a]P = not tested.

Discussion

As in the Hungarian section of the Danube during autumn of 2004 (Erős et al., 2005), only three of the four goby species (round, bighead, monkey) were observed in the Slovak section, and the fourth (racer goby) was not captured. Nonetheless, racer goby has been repeatedly documented (Kautman, 2001; M. L'avrinčíková, pers. comm.) in a side arm of the Danube at Bratislava (Fig. 1, site 1). The absence of racer goby in both the Slovak and Hungarian sections of the Danube suggests very low and localized abundance and may indicate that this species is just beginning its establishment in the Middle Danube. In Austria, the recent occurrence of racer goby is documented mainly in the backwaters near Vienna (Ahnelt et al., 2001; Wiesner, 2005) without notable evidence of its expansion. Whereas, in the River Vistula (Poland), which racer goby invaded via the River Bug (a tributary) and the Pripyat-Bug Canal, the species is becoming increasingly abundant (Grabowska, 2005).

Bighead goby was the first of the *Negobius* species to be recorded in the Slovak Danube, in 1996 (Stráňai, 1997; Černý et al., 2003), and correspondingly it has amongst the widest distribution of the three *Neogobius* species. Whereas, the round goby was reported for the first time relatively recently, in August 2003 (Stráňai and Andreji, 2004). Then in spring 2003, seven specimens were caught downstream of the Gabčíkovo dam (river km ≈1820), followed by a few specimens again in April 2004. By October 2004, round goby had become one of the two most abundant and the second-most frequently encountered *Neogobius* species in the Slovak Danube (Table 1). In contrast to the other two *Neogobius* species, monkey goby has not been found in the Slovak Danube upstream of the town of Komárno, where it was observed in the relatively low density (Table 1). This may be because of the specific environmental requirements and different behaviour of the monkey goby relative to the bighead and round gobies (Holčík et al., 2003), which occurred together at 58.3% of the sites examined. This pattern of co-occurrence by bighead and round goby has been documented before (e.g. Simonović et al., 1998; Kautman, 2001; Holčík et al., 2003).

The temporal pattern of *Neogobius* expansion to date suggests that bighead goby has already achieved its peak of abundance in the Middle Danube (Table 1), with round goby increasing rapidly towards its peak abundance (Wiesner, 2005). Because round goby expansion has been unusually rapid, especially close to industrial areas (i.e. Bratislava, sites 2 and 4 in Fig. 1 and Table 1) and large towns (i.e. Komárno, Štúrovo), its dispersal does not appear to have been entirely natural, with freight vessels probably being the vector of introduction into the middle Danube (Biró, 1971; Ahnelt et al., 1998; Wiesner, 2005). But, the relatively high densities of both bighead and round gobies in the Danube main channel that by-passes the Gabčíkovo dam, indicate that natural dispersal is also functioning, similar to reports in the lower Danube (Vassilev, 1994). This stretch of the Slovak Danube has not supported the traffic of any vessels since at least August 1992, and one of the first reports of bighead goby in the Slovak Danube was just downstream of the Gabčíkovo tail-race, the Palkovičovo side arm (site 47, Fig. 1 of Černý et al., 2003).

The high frequency and abundance of non-native *Neogobius* fishes in shoreline habitats suggests a potential impact on the native fish assemblage. Several native fish species (mainly bullhead, white-finned gudgeon, stone loach *Barbatula barbatula*) were known to inhabit the shorelines now exploited by *Neogobius* spp. (Černý and Kvaszová, 1999; Černý, 1999). Stone loach was not collected during the study, and only single specimens of bullhead and white-finned gudgeon were captured. Bullhead and white-finned gudgeon may have already been on the decline in the early-to-mid-1990s, when tubenose goby was on the increase (in both relative density and abundance; see Table 1 in Černý et al., 2003). Bullhead were not found in the Slovak stretch of the Danube during a study to assess the impact of the Gabčíkovo hydroscheme on 0+ fishes, and despite a virtual doubling of sampling effort at the sites compared between 1992 and 1996, the number of white-finned gudgeon captured dropped from 18 in 1992 to one specimen in 1996 (Černý et al., 2003). The invasion of *Neogobius* species has coincided with a progressive decline in native benthic fishes, and the ecological interactions behind these changes in fish assemblage composition warrant further study.

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