Ichthyol Res (2017) 64:155–158
DOI 10.1007/s10228-016-0537-4

NEWS AND COMMENTS

Invasion of round goby to the temperate salmonid streams in the Baltic Sea

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Received: 11 May 2016 / Revised: 10 June 2016 / Accepted: 12 June 2016 / Published online: 5 July 2016
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Round goby *Neogobius melanostomus*, initially originating from the Ponto-Caspian region, has become one of the most successful invasive species in the Northern Hemisphere. During the last three decades, this invasive fish has established numerous populations both in Eurasia and North America (reviewed in Kornis et al. 2012). In Europe, this species has invaded lakes, large rivers and also various marine environments. In Northern America, round goby has started to spread from lakes to several estuaries, marshes and smaller tributaries (Poos et al. 2010; Kornis et al. 2012).

High tolerance to various environmental factors, short generation time, opportunistic diet preferences and aggressive behaviour allows this species to colonize different biotopes (Corkum et al. 2004; Johnson et al. 2005; Brown and Stepien 2008; Kornis et al. 2014). Rapid invasion of round goby has proved to have impact on native fish populations in several invaded regions. Declines in abundance of some benthic fishes as stone loach *Barbatula barbatula*, bullhead *Cottus gobio* and white-finned gudgeon *Romanogobio albipinnatus* have been suggested in European freshwaters (Jurajda et al. 2005). In the Baltic Sea, the expansion of round goby has been suggested to affect flounder *Platichthys flesus*, eelpout *Zoarces viviparus* and native gobies (Balážová-L'avrincíková and Kovác 2007; Karlson et al. 2007). In North America, several percid and cottid species compete with round goby for food, territory and spawning grounds (Jude et al. 1995; Janssen and Jude 2001).

Round goby invasion to the Baltic Sea was confirmed in 1990, when several fish were caught from Puck Bay in Poland (Skóra and Stolarski 1993). In the Estonian coastal sea, round goby was found in 2002, from Pärnu Bay in the Gulf of Riga (Shpilev and Ojaveer 2003). However, first rapidly growing population occurred during the mid-2000s in Muuga Bay near Tallinn, in the southern coast of the Gulf of Finland (Ojaveer 2006). During the 2010s, round goby dispersed widely along the southern coast of Gulf of Finland and became particularly abundant in several small bays east of Tallinn.

Since 2011, the round gobies were found from six salmonid spawning streams along the North Estonian coast (Fig. 1). Fishes were caught during the national annual salmonid parr density survey, using backpack electrofishing gear. Study sites (two or three per stream) were located in rapid sections situated on the lower reaches of the streams which are accessible to anadromous salmonids. All sites were fished twice and the interval between sampling runs was at least 30 minutes. The abundance of salmonids and all other fish species were recorded, all caught fish were measured to the nearest mm (total length), kept in water buckets and released afterwards (except round gobies). Based on the maximum summer water temperatures, streams were classified as cool (13.1–17.0 °C; three locations) or temperate (17.1–21.0 °C; three locations) (Järvekülg 2001). The length of the streams varied between 25 and 85 km, catchment areas between 84–479 km^2 and mean discharges in lower reaches between 0.5–4.0 m^3/s (Loopmann 1979) [Electronic Supplementary Material (ESM) Table S1]. All the studied sites were located in freshwater, and distances along a stream from the sea varied from 0.5 to 2.6 km. In three streams, where round

Electronic supplementary material The online version of this article (doi:10.1007/s10228-016-0537-4) contains supplementary material, which is available to authorized users.

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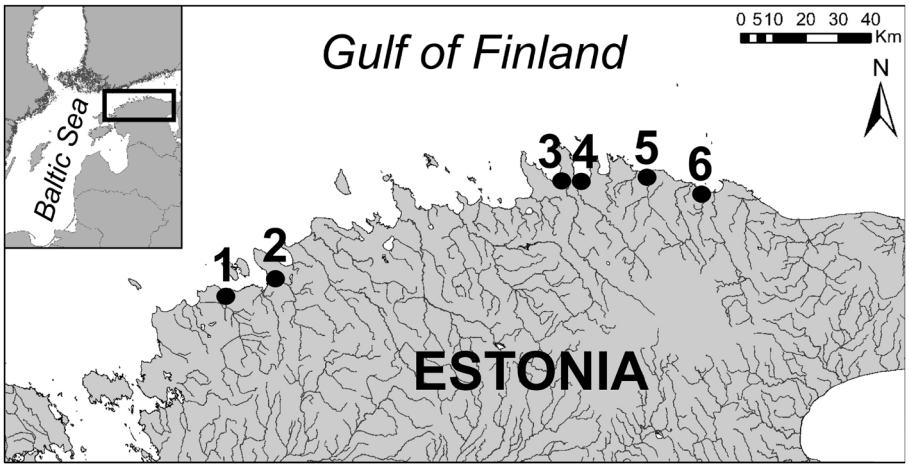

Fig. 1 Map of the Estonian coast of the Gulf of Finland with black dots showing sampling sites. *1* Vihterpalu; *2* Vasalemma; *3* Valgejõgi; *4* Loobu; *5* Mustoja; *6* Toolse

Table 1 Date of samplings, number of round gobies caught and their average total length

Location	Date of sampling	Number of fish caught	Total length (mm)
Vihterpalu	29 August 2014	1	85
Vihterpalu	16 September 2015	8	83 (61-120)
Vasalemma	6 September 2011	3	92 (80-105)
Vasalemma	8 September 2012	1	67
Vasalemma	3 September 2013	4	78 (72-84)
Vasalemma	12 September 2014	11	77 (59-121)
Vasalemma	7 September 2015	17	67 (51-102)
Valgejõgi	4 September 2013	1	70
Loobu	4 September 2013	1	87
Mustoja	19 September 2014	2	79 (69-89)
Mustoja	22 September 2015	3	82 (78-87)
Toolse	27 August 2015	1	62

Ranges are in parentheses

gobies were caught repeatedly, their abundances increased during consecutive sampling years (Table 1). In Vihterpalu River, the number increased from 0.45 individuals/100 m^2 in 2014 to 3.83 individuals/100 m^2 in 2015; in Vasalemma River, from 1.94 individuals/100 m^2 in 2011 to 8.64 individuals/100 m^2 in 2015; and in Mustoja River, from 0.76 individuals/100 m^2 in 2014 to 1.36 individuals/100 m^2 in 2015. Fish communities were dominated by salmonids: Atlantic salmon *Salmo salar* and anadromous brown trout *Salmo trutta* (species densities 0–17.2 and 3.4–48.4 individuals/100 m^2, respectively). Additionally, species from Petromyzontidae; Cyprinidae; Cobitidae; Nemacheilidae; Esocidae; Gasterosteidae; Percidae and Cottidae families were recorded (Table 2).

Over recent decades, Ponto-Caspian round goby has expanded its range northward and westward into several major European watersheds and into the Baltic and North seas. So far, the invasion of round goby into European flowing waters has been confined to larger rivers such as the Danube, Oder, Rhine and Vistula (Jurajda et al. 2005; Roche et al. 2015). However, in North American Laurentian Great Lakes, round goby has started to spread to estuary, marsh and tributary areas and already established several abundant tributary populations (Kornis et al. 2012). To our knowledge, this study is the first report of round goby invasion into European temperate salmonid streams. It is known that round goby can predate on salmonid (e.g. lake trout (*Salvelinus namaycush*)) eggs (Chotkowski and Marsden 1999, Corkum et al. 2004). It has also been suggested in several areas that round goby can negatively affect other fish species characteristic to salmonid rivers, e.g. bullhead and stone loach (Jurajda et al. 2005). Thus, it is likely that round goby invasions to freshwater salmonid streams may negatively affect those ecosystems and should

Table 2 Fish densities (individuals/100 m^2) in the studied stream locations

Species	Vihterpalu 2014-15	Vasalemma 2011-15	Valgejõgi 2013	Loobu 2013	Mustoja 2014-15	Toolse 2015
Lampetra fluviatilis		*			*	*
Salmo salar		14.62	15.36	11.88	17.18	
Salmo trutta	48.37	11.45	3.37	15.36	31.88	13.97
Thymallus thymallus					*	
Esox lucius	*	*				
Rutilus rutilus		*				
Leuciscus leuciscus	**					
Phoxinus phoxinus	***	**	*	***	***	*
Gobio gobio	**	**	*	**	*	
Alburnus alburnus	*	*				
Alburnoides bipunctatus	*			***		
Carassius gibelio	*	*			*	
Cobitis taenia	*	*		**		
Barbatula barbatula	**		**	**	***	***
Gasterosteus aculeatus		*		*		**
Pungitius pungitius		*				*
Perca fluviatilis		*				
Cottus gobio		**	**			
Neogobius melanostomus	2.09	3.68	0.37	0.31	1.04	0.56

* rare (<0.1 individuals/100 m^2)

** common (1–10 individuals/100 m^2)

*** abundant (>10 individuals/100 m^2)

be taken into consideration in future management and/or conservation activities.

Acknowledgements We thank all the people who helped us during the fieldwork.

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