

Research Article

Colonization of the Border Meuse area (The Netherlands and Belgium) by the non-native western tubenose goby *Proterorhinus semilunaris* (Heckel, 1837) (Teleostei, Gobiidae)

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Abstract

The western tubenose goby, *Proterorhinus semilunaris*, of Ponto-Caspian origin, already recorded in 2002 from the lowest course of the Dutch River Meuse, was caught upstream for the first time in 2008 in the Border Meuse, the river-stretch forming the border between Belgium and the Netherlands. In 2009 it reached the upstream extremity of the Border Meuse in Wallonia and in 2010 it was recorded in Flanders, in a canal connected to the Border Meuse. Discussion is provided about its migration pathway. Further upstream expansion of the western tubenose goby may be expected in less man-modified and lightly navigated sections of the River Meuse, e.g. those lined with macrophyte-rich habitats. Behavioural competition with the native bullhead *Cottus perifretum* is likely and might lead to a decline in the bullhead population.

Key words: non-native species, invasive, River Meuse, Zuid-Willems Canal, Gobiidae, *Proterorhinus semilunaris*, Cottidae, *Cottus perifretum*

Introduction

The western tubenose goby, *Proterorhinus semilunaris* (Heckel, 1837) is a freshwater fish native to the Black Sea (Dnieper, South Bug, Dniester and Danube rivers) and Aegean (River Maritza, its type-locality, and River Struma) basins. This small benthic species was previously known under the name *P. marmoratus* (Pallas, 1814), a taxon which has now been restricted to a marine relative that inhabits the Black Sea as evidenced by nuclear and mitochondrial DNA evidence and morphological divergence (Stepien and Tumeo 2006; Neilson and Stepien 2009a, b). Additional morphological criteria also supported recognition of *P. semilunaris* as a valid species (Freyhof and Naseka 2007).

The native range of *P. semilunaris* in the Danube basin remained practically unchanged from the 19th century until the beginning of the second half of the 20th century. Its native range included southern Romania, northern Bulgaria, northern Serbia, Hungary (Balaton Lake, Danube River and the lower reach of the Tisza River) and eastern Austria (Fertó Lake) (Harka and Bíró 2007). However, between 1960 and 1970, the western tubenose goby became invasive and spread throughout the Austrian Danube River, from Vienna to Linz. It reached the German reach of the Danube River in 1985 (first capture at Passau) and simultaneously expanded along Hungarian second order rivers (Harka and Bíró 2007).

In the Morava basin (Serbia) the species has been present at least since 1874, in the mouth of

the River Morava, which flows into the Danube. It was recorded more upstream for the first time in 1994, in one of the Nové Mlýny artificial water reservoirs (Czech Republic), on the River Dyje, a tributary of the River Morava, most likely as a result of its release as baitfish by anglers. Since then, it has expanded rapidly into the Morava and the Dyje Rivers (Prášek and Jurajda 2005). In the year 2000, it also expanded into the Yantra River, a Bulgarian tributary of the Danube River (Vassilev et al. 2008).

Following the completion of the Rhine-Main-Danube waterway in 1992, *P. semilunaris* dispersed further northwards, reaching the River Main near Eltmann in 1997 (Prášek and Jurajda 2005). It was first recorded in the middle reach of the German River Rhine in 2000 (von Landwüst 2006), in the Dutch Rhine in 2002 (Tien et al. 2003; van Kessel et al. 2009a), in the German part of the River Moselle in 2005 (von Landwüst 2006) and along the French bank of the canalized Rhine in 2007 (Manné and Poulet 2008).

In Belarus, the tubenose goby invaded the River Prypyat, a tributary of the Dnieper River, in 2007, perhaps due to inland water shipping. It was expected that it would subsequently invade the Bug and Vistula Rivers via the Pripyat-Bug Canal (Rivzevsky et al. 2007). In April 2008 *P. semilunaris* was observed in the River Vistula (Grabowska et al. 2008).

In the Baltic Sea area, the tubenose goby was recorded for the first time in August 2006, in the mouth of the Neva River, and in July 2007, in the nearby area of the Finland Gulf (Antsulevich 2007).

Even outside Europe, the species has invaded new territories. In the Great Lakes region of North America, it was caught as early as 1990 in St. Clair River, which connects Lake St. Clair to Lake Huron (Jude et al. 1992). Although attributed to ballast water exchange from transoceanic shipping vessels, it is uncertain how it reached America (Leslie and Timmins 1998). Since then, it has spread in the shallow littoral waters of the western margins of some of the Great Lakes (Lake Erie, Lake St. Clair and Duluth-Superior harbour at the western extremity of Lake Superior), in their waterway interconnections (Detroit and St. Clair Rivers), dispersed as far as 30 km upriver in some small tributaries of these lakes and it has colonized the littoral waters of Bass Islands in the middle of Lake Erie (Kocovsky et al. 2011). The jump pattern of dispersal within the region is likely the

result of transport of ballast water by vessel traffic (Kocovsky et al. 2011). Transport of eggs attached to vegetation (Fuller et al. 2010) on the hull of boats (Moen 2002) was also suggested. In addition, expansion through open waters has been attributed to drift associated with night time vertical migration of larvae and juveniles (Kocovsky et al. 2011).

Since its arrival in the Dutch River Rhine in 2002, the western tubenose goby has continued to spread into Dutch water systems, including some lowland stretches of the River Meuse (Dorenbosch et al. 2009; Kranenbarg et al. 2009; van Kessel et al. 2009b). However, it was only in 2008 that it was first recorded in the Border Meuse, i.e. the part of the River Meuse common to Belgium and The Netherlands, and in 2009 it reached its more upstream section. In 2010 it was also found in the Flemish section of the Zuid-Willems Canal, a waterway connected to the Border Meuse.

The aim of the present work is to show the rapid range extension of *P. semilunaris* in the Meuse River area since 2008 and to discuss its likely further upstream expansion in the River Meuse as well as its possible threat to the native bullhead, *Cottus perifretum* (Freyhof, Kottelat and Nolte, 2005) (= *C. gobio* auct., pro parte: see Freyhof et al. 2005).

The term invasive in this paper is used for a species which spreads rapidly via its own dispersal means, through new territories outside its original area. Following Colautti and Richardson (2009), this definition excludes any subjective concept like impact, which strength still needs to be assessed.

Methods

The Border Meuse river section is here defined as extending along the international border, from ca 600 m downstream of the Belgian Lixhe weir till the border at the level of Kessenich-Stevensweert, near the Dutch village of Maasbracht (SPF Mobilité et Transports 2002), including also a short but entirely Dutch stretch between the Belgian localities of Petit-Lanaye and Smeermaas (Figure 1A, B). The Sand Meuse is the lowland course of the river immediately downstream of the Border Meuse section, flowing on a sandy bottom from Maasbracht up to the level of the town of Oss (which lies between the towns of 's-Hertogenbosch and Nijmegen, not in Figure 1).

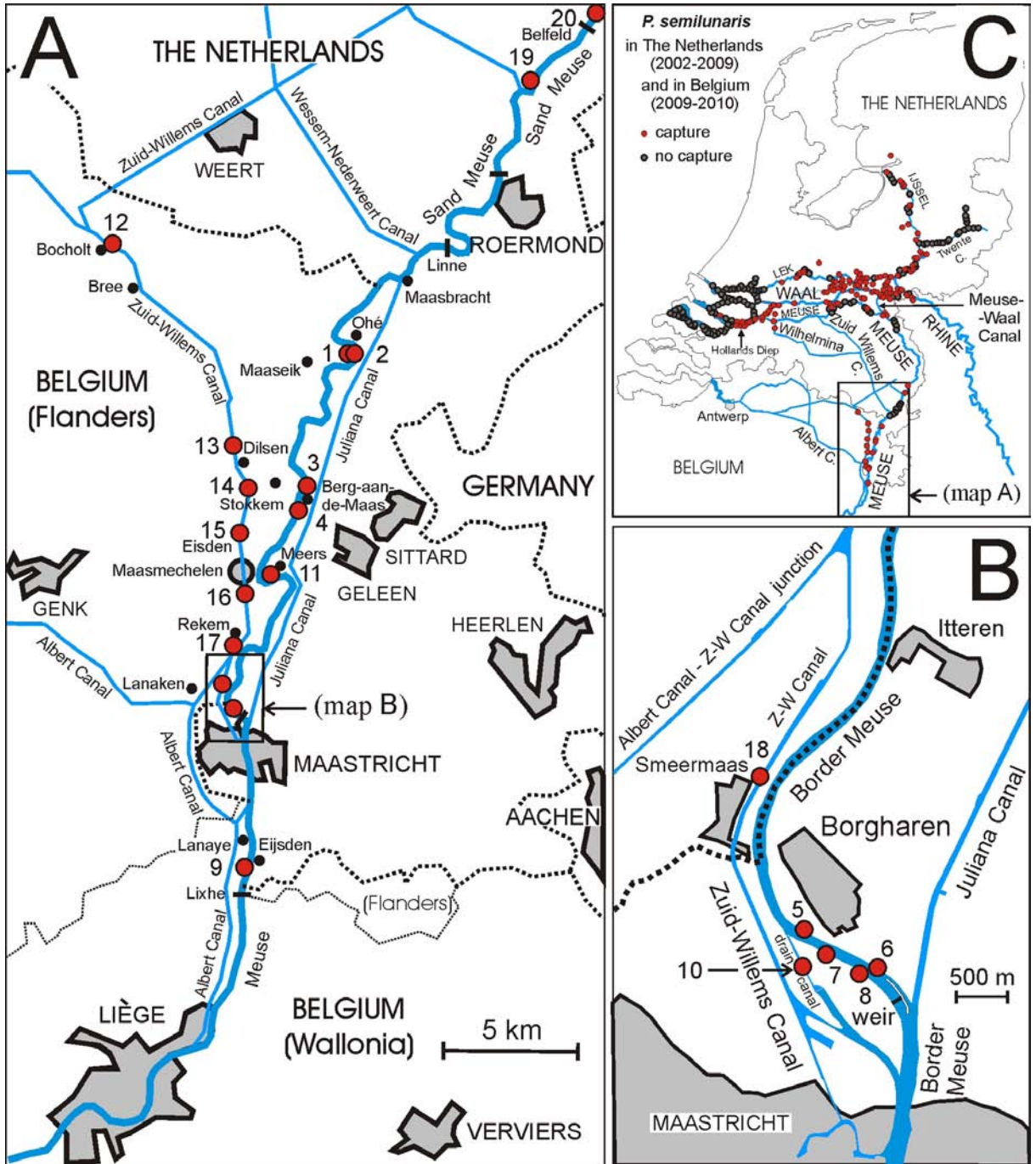


Figure 1. A: southernmost captures (red dots) of the fish *Proterorhinus semilunaris* in the River Meuse and connected waterways. Dotted lines represent terrestrial country borders. Weirs are symbolized by strokes across the river. B: details of the Borgharen area, corresponding to the inner small frame in the A map. Numbers associated to red dots in maps A and B refer to the sampling sites described in Appendix 1. C: sampled areas in The Netherlands and in Belgium, showing main waterways and distribution of *P. semilunaris* captures. The dark dots represent samples without capture. The lower frame in this map corresponds to the A map.

Western tubenose gobies were collected in the Border Meuse area during different fish or invertebrate surveys, each of them using methods corresponding to a particular aim. The location of the sampled sites is shown in Figure 1A, B and described in Appendix 1.

The most sustained survey is that of the Dutch 'Active Freshwater Fish Monitoring' programme for which sites 1–8 and 10 were covered each year since 1997, in May, by electrofishing (from a boat, continuous DC 2–10 A, 100–500 V or, if wading, pulsed DC 3A, 12 V) on permanent transects (their coordinates in Appendix 1 indicate the downstream starting point of the transect; on average 775 m of linear distance were covered within 45 minutes). Site 9 was monitored each year since 2007 for invertebrates by hand netting (five strokes, mesh size 0.5 mm) by the Walloon DEMNA. Site 11 was sampled in 2009 by seine netting (smallest mesh size 5 mm, in an area covering ca 500 m² at a depth of between 0.5 and 1.0 m) and sites 19–20 were sampled by electrofishing and hand netting in 2009 during the Dutch survey 'Chances for river fishes'. Sites 12–17 were sampled in 2010 and previously in 2000 and 2004 by electrofishing and fyke netting (two paired fyke nets immersed over a 48 h period, length 20 m, height funnel entrance 1 m, stretched mesh size 1 cm), by the Flemish INBO. Site 18 was sampled in 2010, but also annually from 2001 till 2006, for invertebrates by using artificial stony substrates (3 bags of 1 cm mesh size and 5 l capacity containing coarse stones, immersed on the bottom of the bank during 3–4 weeks) by the Flemish VMM.

Results

The first specimens of *P. semilunaris* in the Border Meuse were collected in 2008 near the Dutch village of Ohé, and in a short Dutch section of the river just north of Maastricht, the later finding being only 15 km downstream the Belgian Lixhe weir (sites 1 and 5; Figure 1A, B and Appendix 1). The species was not found in the Border Meuse during previous surveys which were annually conducted since 1997 on the same transects, by electrofishing. Since 2008, however, the tubenose goby has been caught in some 17 sampling sites of the Border Meuse area (sites 2–18) as well as in two sites in the downstream nearby section of the Sand Meuse (sites 19 and 20) (Figure 1A, B and Appendix 1).

The increase in the number of catches of the species in each of the locations of the Border Meuse area covered by the same sampling effort from 2008 to 2010 is shown in Figure 2. The Dutch electrofishing survey caught only 5 tubenose gobies in 2008, the 2009 survey on the same transects caught 47, and captured 112 in 2010. This overall increase from 2009 to 2010 is significant (non-parametric Mann-Whitney U test, $P = 0.013$), some of the year to year differences were highly significant ($P < 0.001$, binomial test). The greatest increase was observed for the shallow Maastricht drain Canal (site 10).

Along the main channel of the Border Meuse, and beside the Maastricht drain Canal, the tubenose goby has been caught in a Dutch side arm, at Meers (site 11: Kranenbarg et al. 2009) and in a small creek of the Walloon reaches of the river, at Lanaye (site 9). The latter, located 2.8 km downstream of the Lixhe weir, is up to now, the most upstream known locality for this species in the Meuse area. It was not found there before 2009. The two sites are characterized by low flow velocity, that of Lanaye by abundance of shallow macrophyte-rich habitats. Sampling by hand (at Lanaye) or seine net (at Meers) yielded high values in comparison to electrofishing (160 and 216 specimens respectively per 1000 m bank versus a maximum of 61 per 1000 m for the Maastricht drain Canal).

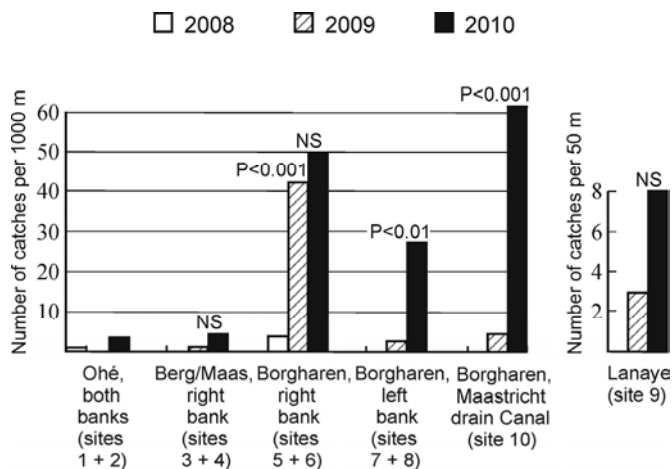
In the Zuid-Willems Canal, a substantial number of specimens (13) of *P. semilunaris* were collected in 2010 in artificial substrates in the Flemish village of Smeermaas (site 18, Figure 1B and Appendix 1), not far from where the canal branches off from the Border Meuse. In the same year, additional specimens were found at six other Flemish sites spread over this canal (sites 12–17, Figure 1A and Appendix 1).

Discussion

Colonization of the Border Meuse area

Before 2008, the western tubenose goby was not found in the Border Meuse during the annual surveys of permanent transects nor before 2009 in extensive invertebrate surveys (artificial substrates and hand netting) made in the Walloon reaches of the Meuse as well as in other Walloon waterways and rivers. It was only in 2010 that it was found in the Flemish section of the Zuid-Willems Canal, however its presence there had

Figure 2. Number of captures per unit effort of *P. semilunaris* in the Border Meuse locations successfully sampled from 2008 till 2010. Sampling along permanent transects by electrofishing or, for Lanaye, by hand net. Site numbers refer to sampling stations shown in Figure 1A and 1B and described in Appendix 1. Binomial tests (when applicable) between successive years and based on actual numbers. NS: non significant difference at the 0.05 level.



not been checked in the immediately preceding years.

It appears logical that the specimens collected in the Border Meuse are the result of upstream migration. The species was first recorded in the Netherlands in 2002, near the northern entrance of the Meuse-Waal Canal (Figure 1C) in the River Waal, which is a distributary of the Dutch Rhine, from where the goby appears to have penetrated the Dutch waterways. This canal may have been used as a corridor for the upstream migration of the goby into the Meuse. However, it was not until 2008 that it was found near the southern entrance of the Meuse-Waal Canal, in the Sand Meuse (51°45'10" N, 5°51'32" E).

In 2002 the western tubenose goby was also found in the lowest course of the River Meuse, the Hollands Diep. It thus could likely have migrated from the lowest reaches of the Meuse to the Belgian course of the Zuid-Willems Canal, through the Wilhelmina Canal or the Dutch section of the Zuid-Willems Canal (Figure 1C), which are connected to the lowland River Meuse at the cities of Breda and 's-Hertogenbosch respectively. However, tubenose goby has not yet been found in the latter canals, except in the joint branch of the Wilhelmina and Mark Canals which opens in the Amer, a section of the Meuse just upstream of the Hollands Diep.

The western tubenose goby was not found in the Juliana Canal, which was sampled for the first time in 2010 (electrofishing, 6 different transects of 150 to 500 m length). This highly navigated riprap-walled canal which short-cuts the Border Meuse nearly all along its length seems not to have been used as a southwards

migration corridor for the goby. Also, the species has not yet been found in the highly navigated concrete-walled Albert Canal which connects the Rivers Meuse and Scheldt, although this canal also opens into the Border Meuse through the lock of Lanaye as well as into the Zuid-Willems Canal through the locks of Lanaken and Neerharen and connects via other waterways to the Zuid-Willems Canal (Figure 1). Contrary to the western tubenose goby, another non-native fish, the round goby *Neogobius melanostomus* (Pallas, 1811), was discovered in the Albert Canal in June 2010 (Verreycken et al. 2011). However, it most likely ascended from the River Scheldt where the first occurrence of that species in Belgium was noted near the Antwerp harbour.

Future expansion of the western tubenose goby

It may be expected that the tubenose goby will further invade Belgian waters along with other goby species in the near future, as is already the case in The Netherlands. Further expansion in waterways with weir and lock regulating systems may be expected, but not every part of the canalized waterways, especially the Walloon River Meuse and the Albert Canal, will provide suitable habitat for the western tubenose goby. In The Netherlands, where the species has been captured in fair numbers (e.g. 569 specimens in 2009), there are long river stretches interspersed between known populations, where it was not caught, despite sustained fish sampling (Figure 1C). Gaps of tens of km in the distribution of invading tubenose gobies also exist in Bulgaria (Vassilev et al. 2008) and in Poland (Grabowska

et al. 2008). One of the reasons of discontinuity in distribution of the western tubenose goby could be its inability to withstand heavy ship's backwash, a situation prevailing in canalized sections of the Sand Meuse as well as in the Albert and Juliana Canals. Indeed, in the Lake Erie, the species is typically present in areas protected from wave action, and absent from wave-lashed shores (Kocovsky et al. 2011). In the Border Meuse, no commercial navigation takes place in the sections where the western tubenose goby was caught, i.e. between Borgharen and Maasbracht and in the section forming the border between Wallonia and The Netherlands.

Moreover, Kocovsky et al. (2011) showed that the presence of the western tubenose goby is primarily related to macrophyte-rich habitats, the species' maximum density being found in areas with 25–30% macrophyte cover. Additional optimal conditions are a diverse, mostly rocky, bottom and a maximum of 1.5 m water depth. This is exactly what occurs at the Walloon Lanaye site and in the Maastricht drain Canal, where tubenose gobies are easily found.

Upstream of the Lixhe weir, the River Meuse is in a much less natural state than is the Border Meuse. Its shorelines are canalized, being stone pitched or concrete walled for most of ~ 80 km till Namur, as are those of its navigated shortcut, the Albert Canal which opens in the town of Liège (Figure 1A). This highly modified ecosystem, regulated by weirs and locks, seems not to offer suitable habitat for the western tubenose goby, although a few isolated riprap shorelines exist. The Lixhe weir itself presents a barrier for fish migration being devoid of any lock and its fish-ladder appears not to be suitable for benthic fish (Philippart et al. 2005). Nevertheless, in Hungary, the first invasive specimens of Ponto-Caspian goby species - including *P. semilunaris* - were usually found in highly modified water bodies where, moreover, the water temperature was higher than those of the tributaries in their native range (Harka and Bíró 2007). Upstream of Namur, the more natural state of the River Meuse may again be suitable for the western tubenose goby. A possibility which cannot be excluded is the downstream colonization of the French upper course of the River Meuse from its canalized junction with the Rivers Moselle and Rhine, as suggested in Manné and Poulet (2008).

Possible threat for the native bullheads

Bullhead *Cottus perifretum* is present in the Border Meuse till downstream of the base of the Walloon hydroelectric Lixhe weir (Philippart et al. 2005) and is also recorded well beyond, in the upstream Belgian course of the River Meuse (Sonny 2006; DEMNA original data).

The question is whether the western tubenose goby may have a negative impact on the native bullhead populations. A decline of the bullhead population density was recorded in the Slovak reach of the River Danube invaded by *P. semilunaris*, in the early-to-mid-1990s (Jurajda et al. 2005) and the absence of bullhead in the headwater of a weir populated by the tubenose goby on the River Moselle, at Koblenz, was mentioned as a first indication of negative impacts of increasing numbers of the species on a native benthic species (von Landwüst 2006). In the Dutch River Rhine, bullhead populations have declined since the arrival of alien gobiids (Dorenbosch 2009).

Indeed, the increase of the western tubenose goby population in the Border Meuse is likely to increase competition with the bullhead as they share the same ecological niche. Both species feed mainly on benthic invertebrates (Tomlinson and Perrow 2003; Adámek et al. 2010) and seem to have a similar reproduction strategy, with the males guarding the eggs. *P. semilunaris* may spawn at the age of one year, from April to August, up to three times per season, a total of 185–1045 eggs being deposited under or between stones, in natural or artificial cavities or attached to vegetation (Pinchuk et al. 2004; Freyhof and Kottelat 2008). According to Mills and Mann (1983), *C. perifretum* also spawns at the age of one year in lowland rivers, three or four times per season and is able to lay down a similar number of eggs, which are glued under stones (Tomlinson and Perrow 2003).

However, taking into account what is known from behavioural interactions between native bullhead and alien gobiids in North America (Dubs and Corkum 1996; Janssen and Jude 2001; Lauer et al. 2004) and in The Netherlands (van Kessel et al. 2011), the greatest threat for the Meuse bullhead population lies perhaps in a negative consequence of competition for shelter or interference with spawning. *Ex situ* habitat experiments conducted with *C. perifretum*, stone loach *Barbatula barbatula* (Linnaeus, 1758) and four non-native gobiid species, showed a significant shift in habitat choice of

C. perifretum when placed in co-occurrence with *P. semilunaris* and *Neogobius kessleri* (Günther, 1861). The bullhead was outcompeted to less preferred habitat types (van Kessel et al. 2011). The increase of western tubenose goby in the Border Meuse might thus lead to a decline in the bullhead population.

Until now, the bullhead still remains a common fish in the Border Meuse, with, in 2009, a total of 122 bullheads caught versus 44 specimens of tubenose goby (van Kessel et al. 2009b). Future data can reveal if competition or behavioural interactions with the tubenose goby might indeed lead to a decline of the bullhead population.

Addendum

A western tubenose goby was recently (19 April, 2011) found by an angler 400 m downstream of the foot of the Lixhe weir. Although it has colonized the Border Meuse along its entire length, the species is still not yet recorded upstream of this weir.

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Supplementary material

The following supplementary material is available for this article.

Appendix 1. *Proterorhinus semilunaris* catches in the Border Meuse and connected waterways or side arms.

This material is available as part of online article from:

http://www.aquaticinvasions.net/2012/Supplements/AI_2012_2_Cammaerts_et_al_Supplement.pdf