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Risk analysis of the round goby, *Neogobius melanostomus*, risk analysis report of non-native organisms in Belgium

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Risk analysis report of non-native organisms in Belgium

Risk analysis of the round goby *Neogobius melanostomus*

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Risk analysis of the round goby *Neogobius melanostomus*

Developed by: Hugo Verreycken (INBO)

Reviewed by: Etienne Branquart (SPW)

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Contents

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Etienne Branquart (Cellule Espèces Invasives, Service Public de Wallonie) developed the risk analysis template that was used for this exercise.

The general process of drafting, reviewing and approval of the risk analysis for selected invasive alien species in Belgium was attended by a steering committee, chaired by the Federal Public Service Health, Food chain safety and Environment. RBINS/KBIN was contracted by the Federal Public Service Health, Food chain safety and Environment to perform PRA's for a batch of species. ULg was contracted by Service Public de Wallonie to perform PRA's for a selection of species. INBO and DEMNA performed risk analysis for a number of species as in-kind contribution. Steering committee members were:

Tim Adriaens	Research Institute for Nature and Forest (INBO)
Olivier Beck	Brussels Environment (BIM)
Roseline Beudels-Jamar	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Etienne Branquart	Département de l'Etude du Milieu Naturel et Agricole (DEMNA)
Jim Casaer	Research Institute for Nature and Forest (INBO)
Thibaut Delsinne	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Maud Istasse (chair)	Federal Public Service Health, Food chain safety and Environment
René-Marie Lafontaine	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Alice Lejeune	Federal Public Service Health, Food chain safety and Environment
Céline Prévot	Département de l'Etude du Milieu Naturel et Agricole (DEMNA)
Henri Robert	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Vinciane Schockert	Université de Liège (ULg)
Sonia Vanderhoeven	Belgian Biodiversity Platform (BBPF)
Hans Van Gossum	Agency for Nature and Forest (ANB)
Hugo Verreycken	Research Institute for Nature and Forest (INBO)

Rationale and scope of the Belgian risk analysis scheme

The Convention on Biological Diversity (CBD) emphasises the need for a precautionary approach towards non-native species. It strongly promotes the use of robust and good quality risk assessment to help underpin this approach (COP 6 Decision VI/23). More specifically, when considering trade restrictions for reducing the risk of introduction and spread of a non-native organisms, full and comprehensive risk assessment is required to demonstrate that the proposed measures are adequate and efficient to reduce the risk and that they do not create any disguised barriers to trade. This should be seen in the context of WTO and free trade as a principle in the EU (Baker et al. 2008, Shine et al. 2010, Shrader et al. 2010).

This risk analysis has the specific aim of evaluating whether or not to install trade restrictions for a selection of absent or emerging invasive alien species that may threaten biodiversity in Belgium as a preventive risk management option. It is conducted at the scale of Belgium but results and conclusions could also be relevant for neighbouring areas with similar eco-climatic conditions (e.g. areas included within the Atlantic and the continental biogeographic regions in Europe).

The risk analysis tool that was used here follows a simplified scheme elaborated on the basis of the recommendations provided by the international standard for pest risk analysis for organisms of quarantine concern[1] produced by the secretariat of the International Plant Protection Convention (FAO 2004). This logical scheme adopted in the plant health domain separates the assessment of entry, establishment, spread and impacts. As proposed in the GB non-native species risk assessment scheme, this IPPC standard can be adapted to assess the risk of intentional introductions of non-native species regardless the taxon that may or not be considered as detrimental (Andersen 2004, Baker et al. 2005, Baker et al. 2008, Schrader et al. 2010).

The risk analysis follows a process defined by three stages : (1) the <u>initiation process</u> which involves identifying the organism and its introduction pathways that should be considered for risk analysis in relation to Belgium, (2) <u>the risk assessment stage</u> which includes the categorization of emerging non-native species to determine whether the criteria for a quarantine organism are satisfied and an evaluation of the probability of organism entry, establishment, spread, and of their potential environmental, economic and social consequences and (3) <u>the risk management stage</u> which involves identifying management options for reducing the risks identified at stage 2 to an acceptable level. These are evaluated for efficacy, feasibility and impact in order to select the most appropriate. The risk management section in the current risk analysis should however not been regarded as a full-option management plan, which would require an extra feasibility study including legal, technical and financial considerations. Such thorough study is out of the scope of the produced documents, in which the management is largely limited to identifying needed actions separate from trade restrictions and, where possible, to comment on cost-benefit information if easily available in the literature.

This risk analysis is an advisory document and should be used to help support Belgian decision making. It does not in itself determine government policy, nor does it have any legal status. Neither

[1] A weed or a pest organism not yet present in the area under assessment, or present but not widely distributed, that is likely to cause economic damages and is proposed for official regulation and control (FAO 2010).

should it reflect stakeholder consensus. Although the document at hand is of public nature, it is important to realise that this risk assessments exercise is carried out by (an) independent expert(s) who produces knowledge-based risk assignments sensu Aven (2011). It was completed using a uniform template to ensure that the full range of issues recognised in international standards was addressed.

To address a number of common misconceptions about non-native species risk assessments, the following points should be noted (after Baker et al. 2008):

- Risk assessments are advisory and therefore part of the suite of information on which policy decisions are based;
- The risk assessment deals with potential negative (ecological, economic, social) impacts. It is not meant to consider positive impacts associated with the introduction or presence of a species, nor is the purpose of this assessment to perform a cost-benefit analysis in that respect. The latter elements though would be elements of consideration for any policy decision;
- Completed risk assessments are not final and absolute. New scientific evidence may prompt a re-evaluation of the risks and/or a change of policy.

Executive summary

PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)	
Entry in Belgium	It is very likely that round goby will continue entering Belgium in the near future because of its high abundance in neighbouring areas, where new arrivals can be expected through active migration via canals and additionally through ballast water transport by barges and international shipping. Illegal trade and use of this fish species as live bait (not confirmed in Belgium) can further disseminate round goby.
Establishment capacity	*Neogobius melanostomus* is already established in some canals and rivers in Belgium and its distribution is currently probably restricted to the more artificial habitats. However, from literature it is known that almost all habitats can be invaded by round goby. For the near future it is to be expected that not only big rivers and canals but also smaller tributaties will be invaded in Belgium.
Dispersion capacity	Human aided dispersal (mainly ballast water disposal) has helped round goby to invade large parts of North America and Eurasia. Also illegal (but often unintentional) release of round goby by anglers can be responsible for long-distance dispersal. Where already present, it can easily spread by natural dispersion towards neighbouring areas, expanding its range at a rate of 5-25 km/year.
EFFECT OF ESTABLISHMENT	
Environmental impacts	The environmental impacts of the presence of *N. melanostomus* in Belgium will be mainly through competition and predation but also possibly through pathogen pollution, disruption of trophic interactions and changes to nutrient/toxic substances cycling and availability. Mainly small benthic freshwater fish and freshwater mussels will be affected. A decline of bullhead *Cottus perifretum* (species from EU Habitat Directive) in rivers due to the presence of high densities of round goby is likely to be the most conspicuous impact to be expected in Belgium (cfr. The Netherlands).
RISK MANAGEMENT	
Ballast water disposal and natural spread of the species are identified as the most probable pathways of entry in Belgium. Mid-ocean ballast water exchange would dramatically reduce *N. melanostomus* survivorship in ballast tanks and may thus limit the number of new introductions. However, barges, that never enter sea water areas, also sometimes use ballast water for stability and may spread *N. melanostomus* further inland. The natural spread from high density populations from inter-connecting river systems cannot easily be managed. Only dams can prevent upstream (but not downstream) migration. Round goby may be involved in trade for two different purposes: aquarium trade and live bait for angling, which may ultimately lead to fish introduction into the wild and establishment of feral populations. Although no evidence of those specific uses could be found in Belgium, it is advisable to prohibit trade of *N. melanostomus* for any goals. Because of its benthic lifestyle, round goby is not easy to detect or observe at early stages of invasion and rapid eradication is therefore difficult. Piscicides may be useful in eradicating emerging round goby populations but only in confined areas and at a big cost. A reduction of population density may be achieved by commercial fishing but is probably not feasable in Belgium. Prohibition of the trade and use as live bait of round goby can diminish further impacts and will probably slow down its range expansion but, however, will not stop it.	

Samenvatting

<table>
<tr><td colspan="2">WAARSCHIJNLIJKHEID VAN VESTIGING EN VERSPREIDING (BLOOTSTELLING)</td></tr>
<tr><td>Introductie in België</td><td>Doordat ze nu al in groten getale in de buurlanden aanwezig zijn, is het erg waarschijnlijk dat nog meer zwartbekgrondels in de nabije toekomst hun weg naar België zullen vinden. Ook in de buurlanden wordt verwacht dat nieuwe exemplaren zullen toestromen door actieve migratie langs kanalen en bijkomend via het transport van ballastwater door binnenschepen en internationale scheepvaart. De illegale handel en het gebruik van deze vissoort als levend aas (niet bevestigd in België) kan een verdere verbreiding van de zwartbekgrondel in de hand werken.</td></tr>
<tr><td>Vestigingsvermogen</td><td>Neogobius melanostomus vestigde zich al in sommige kanalen en rivieren in België, hoewel zijn verspreiding zich momenteel wellicht beperkt tot de meer artificiële habitats. Uit de literatuur blijkt echter dat nagenoeg alle habitats ingenomen kunnen worden door de zwartbekgrondel. Voor de nabije toekomst wordt verwacht dat niet alleen de grote rivieren en kanalen, maar ook de kleinere zijrivieren in België door een invasie zullen worden aangetast.</td></tr>
<tr><td>Verspreidingsvermogen</td><td>De zwartbekgrondel werd voor zijn invasie van grote delen van Noord-Amerika en Eurazië een handje geholpen door de mens (hoofdzakelijk lozen van ballastwater). Eveneens kan ook het illegaal (maar vaak onopzettelijk) uitzetten van de zwartbekgrondel door hengelaars verantwoordelijk zijn voor de verspreiding over grote afstand. Waar deze soort aanwezig is, kan zij zich gemakkelijk tegen een snelheid van 5-25 km/jaar op natuurlijke wijze naar aangrenzende gebieden verspreiden.</td></tr>
<tr><td colspan="2">EFFECTEN VAN DE VESTIGING</td></tr>
<tr><td>Omgevingsimpact</td><td>De omgevingseffecten van de aanwezigheid van N. melanostomus in België zullen voornamelijk door voedsel- en habitatconcurrentie en predatie gebeuren, maar kunnen zich net zo goed uiten als pathogene verontreiniging, een inmenging in de trofische interacties en veranderde cycli en beschikbaarheid van nutriënten/toxische stoffen. Hoofdzakelijk bentische zoetwatervissen en zoetwatermosselen zullen hieronder te lijden krijgen. De meest opvallende impact die we in België (cf. Nederland) van de aanwezigheid van een hoge zwartbekgrondeldichtheid mogen verwachten, is een achteruitgang van de rivierdonderpad, Cottus perifretum (soort uit de EU-Habitatrichtlijn), in de rivieren.</td></tr>
<tr><td colspan="2">RISICOBEHEER</td></tr>
<tr><td colspan="2">Het lozen van ballastwater en de natuurlijke verspreiding van de soort worden beschouwd als de meest voor de hand liggende introductiewegen in België. Ballastwaterwisseling in de oceaan zou de overlevingskansen van N. melanostomus in de ballasttanks drastisch verminderen en dus nieuwe introducties kunnen beperken. Maar binnenschepen, die nooit in zeewatergebied komen, gebruiken soms ook ballastwater om stabiliteitsredenen en kunnen N. melanostomus verder landinwaarts verspreiden. De natuurlijke verspreiding van hele dichte populaties vanuit onderling verbonden rivierstelsels valt niet gemakkelijk te beheren. Alleen dammen kunnen de migratie stroomopwaarts (maar niet stroomafwaarts) voorkomen. De zwartbekgrondel kan om twee verschillende redenen in de handel worden aangeboden: voor de aquariumliefhebbers en als levend aas voor vissers; hierdoor zouden vissen in het wild kunnen worden geïntroduceerd en verwilderde populaties zich kunnen vestigen. Hoewel er in België geen aanwijzingen voor die specifieke doeleinden werden aangetroffen, is het raadzaam om de handel van N. melanostomus voor alle doeleinden te verbieden.</td></tr>
</table>

Door zijn bentische levensstijl is het niet evident om de zwartbekgrondel in een vroeg stadium van de invasie te detecteren of waar te nemen; een snelle uitroeiing is dan ook moeilijk. Hoewel pisciciden heel zeker nuttig kunnen zijn voor het uitroeien van de opduikende zwartbekgrondelpopulaties, lenen ze zich enkel voor afgebakende gebieden en zijn ze bijzonder duur. De dichtheid van de populatie zou kunnen worden teruggebracht door commerciële visvangst, maar dat is in België wellicht niet haalbaar. Een verbod op de handel in en het gebruik als levend aas van de zwartbekgrondel kan de impact verder terugdringen en zal de ruimtelijke expansie wellicht afremmen, maar niet volledig tot stilstand brengen.

Résumé

PROBABILITE D'ETABLISSEMENT ET DE DISSEMINATION (EXPOSITION)	
Introduction en Belgique	Il est très probable que le Gobie à taches noires continue dans un futur proche à entrer en Belgique en raison de sa grande abondance dans les régions voisines, où de nouvelles arrivées sont attendues, et via sa migration active le long des canaux ainsi que par le biais d'eaux de ballast transportées par les barges ou la navigation internationale. Le commerce illégal et l'utilisation de cette espèce de poisson comme appât vivant (usage non confirmé en Belgique) pourrait aussi faciliter la dissémination du Gobie à taches noires.
Capacité d'établissement	*Neogobius melanostomus* est déjà présent dans certains canaux et rivières en basse Belgique où sa distribution actuelle est probablement limitée à des habitats plutôt artificiels. Toutefois, la littérature nous apprend que pratiquement tous les habitats peuvent être envahis par le Gobie à taches noires. Dans un proche avenir, on doit donc s'attendre à ce qu'en Belgique non seulement les cours d'eau importants et les canaux mais aussi les plus petits cours d'eau soient envahis.
Capacité de dispersion	La dispersion assistée par l'homme (principalement par le déballastage des eaux des navires) a contribué à l'invasion par le Gobie à taches noires d'importantes zones d'Amérique du Nord et d'Eurasie. Le rejet illégal (souvent non intentionnel) de Gobies à taches noires par les pêcheurs peut aussi être la cause de sa dispersion sur d'importantes distances. Lorsqu'il est déjà présent, il peut facilement s'étendre par dissémination naturelle vers les zones voisines en élargissant son aire de 5 à 25 km/an.
EFFET DE L'ETABLISSEMENT	
Impacts environnementaux	Les impacts environnementaux liés à la présence de *N. melanostomus* en Belgique passeront surtout par une compétition et une prédation accrues mais aussi éventuellement par une pollution par des pathogènes, la rupture de chaînes trophiques et des modifications dans la disponibilité et les cycles de nutriments ou de substances toxiques. Ce sont surtout les petits poissons des zones benthiques et les moules d'eau douce qui seront affectés. Si des densités élevées de Gobies à taches noires sont atteintes, l'impact le plus important auquel on peut s'attendre dans les rivières de Belgique sera une diminution du nombre de Chabots fluviatiles *Cottus perifretum* (espèce de la directive UE « Habitats ») (cfr. situation aux Pays-Bas).
GESTION DES RISQUES	
Le rejet des eaux de ballast et la dissémination naturelle de l'espèce constituent les voies d' introduction les plus probables pour cette espèce en Belgique. L'échange des eaux de ballast en plein océan permettrait de réduire de manière draconienne la survie de *N. melanostomus* dans les ballasts et pourrait donc limiter le nombre des nouvelles introductions. Toutefois, les barges, qui ne naviguent jamais dans les eaux de mer, utilisent elles-aussi parfois de l'eau de ballast pour assurer leur stabilité et peuvent donc contribuer à la dissémination de *N. melanostomus* à l'intérieur des terres. La dissémination naturelle des	

populations en forte densité de l'espèce est difficile à gérer en raison de l'interconnexion entre les cours d'eau. Seuls des barrages peuvent empêcher la propagation vers l'amont (mais pas vers l'aval). Le Gobie à taches noires est commercialisé pour deux raisons : pour l'aquariophilie et comme appât vivant. Ces deux usages peuvent conduire finalement à l'introduction de l'espèce dans la nature et à l'établissement de populations férales. Bien qu'il n'y ait pas d'indications de ces utilisations spécifiques en Belgique, il est souhaitable d'interdire le commerce de *N. melanostomus* à n'importe quelle fin. Etant donné son mode de vie benthique, le Gobie à taches noires n'est pas facile à repérer ou à observer aux stades précoces d'invasion et son éradication rapide est dès lors difficile. L'utilisation de piscicides peut s'avérer utile dans l'éradication des populations émergentes du Gobie à taches noires mais uniquement dans les zones confinées et à un coût élevé. Une réduction de la densité de la population peut être obtenue par une pêche commerciale mais cette mesure n'est probablement pas faisable en Belgique. L'interdiction du commerce et de l'utilisation comme appât vivant du Gobie à taches noires pourrait diminuer les impacts et ralentir son expansion mais elle ne pourra cependant pas l'arrêter.

STAGE 1: INITIATION

Precise the identity of the invasive organism (scientific name, synonyms and common names in Dutch, English, French and German), its taxonomic position and a short morphological description. Present its distribution and pathways of quarantine concern that should be considered for risk analysis in Belgium. A short morphological description can be added if relevant. Specify also the reason(s) why a risk analysis is needed (the emergency of a new invasive organism in Belgium and neighboring areas, the reporting of higher damages caused by a non native organism in Belgium than in its area of origin, or request made to import a new non-native organism in the Belgium).

1.1 ORGANISM IDENTITY

Scientific name:	*Neogobius melanostomus* (Pallas, 1814)
Synonyms:	*Apollonia melanostoma, Gobius melanostomus, Gobius cephalarges*
Common names:	Round goby (EN), Gobie arrondie, Gobie à tache noire (FR), Zwartbekgrondel (NL), Schwarzmundgrundel (DE)
Taxonomic position:	Chordata (Phylum) > Actinopterygii (Class) > Perciformes (Order) > Gobiidae (Family).

1.2 SHORT DESCRIPTION

The round goby *Neogobiusmelanostomus* (Pallas, 1814) is a benthic, euryhaline species of the family Gobiidae. Maximum standard length is 25.0 cm but smaller sizes are attained in fresh waters (Pinchuk et al. 2003). Diagnostic characteristics of the round goby following Pinchuk et al. (2003) include a completely scaled nape with cycloid scales on the anterior and middle nape (also upper opercle, breast, pectoral fin lobes, and part of abdomen with cycloid scales while the rest of the body has weak ctenoid scales), head depth about equal to width, a lateral line typically with 49–55 scales, pelvic disc with weakly defined lateral lobes on anterior membrane usually not reaching anus, dorsal fins contiguous and second dorsal fin uniform in height. Most conspicuous is the prominent posterior black spot on the first dorsal fin. This spot does not occur in other Ponto-Caspian gobies except in *Neogobius caspius* (Eichwald, 1831). The latter species, however, can be easily distinguished from the round goby by e.g., anterior nostrils very close to the upper lip and a lateral line with 58–71 scales (Pinchuk and Miller, 2003). *Neogobius melanostomus* exhibit variable pigmentation with grey, brown or yellow–green bodies and large dark brown lateral spots. The head is usually darker than the rest of the body. Fins are generally dark grey, although a large oblong black spot is present on the posterior portion of the first dorsal fin, starting on the fifth ray. In breeding males, the body and fins may be almost completely black, with pectoral fins sometimes fringed with white or yellow (although body colour fades to tan when the breeding male is removed from other fish)(Kornis et al., 2012).
Both sexes can be externally distinguished from each other by their erectile urogenital papilla between the anus and the base of the anal fin (Figure 1). The female urogenital papilla is broad and blunt, 0.3-0.5 mm long and 0.2-0.4 mm wide. The male papillae are somewhat longer, with a length of 0.3-0.6 mm and a terminal slit (Miller, 1986).

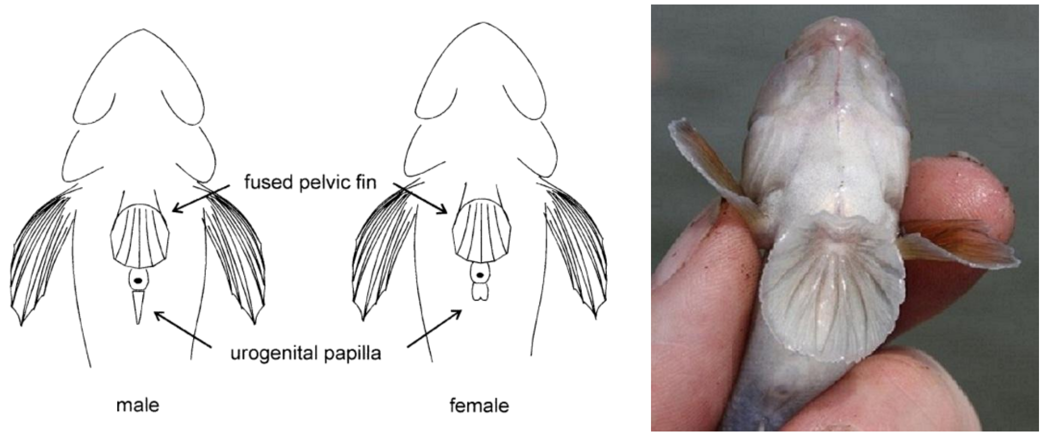

Figure 1: (a) Ventral view of male and female round gobies including urogenital papillae (Charlebois et al. 1997) and (b) photograph of pelvic fins fused to a pelvic disk (photo: oceana.org, 2013).

Figure 2: Lateral view of round goby with clear black spot on anterior dorsal fin (photograph: gallery.nanfa.org, 2013).

1.3 ORGANISM DISTRIBUTION

Native range

Native to central Eurasia including the Black-, Azov-, and Caspian seas (Verreycken et al., 2011)

Introduced range

Belgium:	River Scheldt, Albertcanal (Verreycken et al. 2011), Canal Gent-Terneuzen (Verreycken, unpublished data), River Meuse near Tihange (Sottiaux, 2013).
Rest of Europe:	The Netherlands (van Beek, 2006)(widespread and abundant in the Dutch Rhine and Meuse delta (Spikmans et al., 2010)), Germany (Danube and Baltic Sea) (Kottelat and Freyhof, 2007), Austria (Mühlegger et al., 2010), Poland (Grabowska et al., 2010), Czech Republic (Lusk et al., 2010), Hungary (Borza et al., 2009), Slovakia (Stráňai and Andreji, 2004), Bulgaria (Polacik et al., 2008), Serbia, Romania, Estonia, and Sweden (Froese and Pauly, 2010), France (G. Copp, pers.comm.), Luxembourg (Sottiaux 2013).

Other continents: USA and Canada (Corkum et al., 2004)

1.4 REASONS FOR PERFORMING RISK ANALYSIS

Currently the distribution area of the round goby in Belgium is probably restricted to downstream parts of the Scheldt and Meuse (large slow flowing rivers) and to canals despite the fact that the species is widely established in the Netherlands and different parts of Europe. Strong negative impacts on native biodiversity and economic impacts on fisheries and angling have been described for this species. This fish is in its initial phase of establishment in Belgium, fast spread and high densities are to be expected if no management actions are undertaken.

STAGE 2: RISK ASSESSMENT

2.1 PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

Evidence should be available to support the conclusion that the non-native organism could enter, become established in the wild and spread in Belgium and neighbouring areas. An analysis of each associated pathways from its origin to its establishment in Belgium is required. Organisms intentionally imported maybe maintained in a number of intended sites for an indeterminate period. In this specific case, the risk may arise because of the probability to spread and establish in unintended habitats nearby intended introduction sites.

2.1.1 Present status in Belgium

Specify if the species already occurs in Belgium and if it makes self-sustaining populations in the wild (establishment). Give detail about species abundance and distribution within Belgium when establishment is confirmed together with the size of area suitable for further spread within Belgium.

N. melanostomus occurs in the Lower Scheldt, Canal Gent-Terneuzen, Albertcanal and Lower Meuse (Sottiaux, 2013). Recently (Oct. 2012) very small (young) specimens of the round goby were discovered in the Albertcanal near Hasselt and in the River Meuse near Tihange (Verreycken, unpublished data and Sottiaux 2013) strongly suggesting natural reproduction in Belgian waters. Also mature males and females were caught in the same canal. Abundance and distribution of this species is not well known due to the inability of traditional scientific fish monitoring methods (electrofishing and fyke netting) to sample round gobies. Most distribution data are gathered from anglers' catches; recently a questionnaire was sent to anglers associations in order to collect more data on distribution and abundances of *N. melanostomus*. The few results from this questionnaire only indicated occurrence in Canal Gent-Terneuzen and Albertcanal. Additional distribution records were found on 'waarnemingen.be' (1 record in 2010 and 58 in 2012).

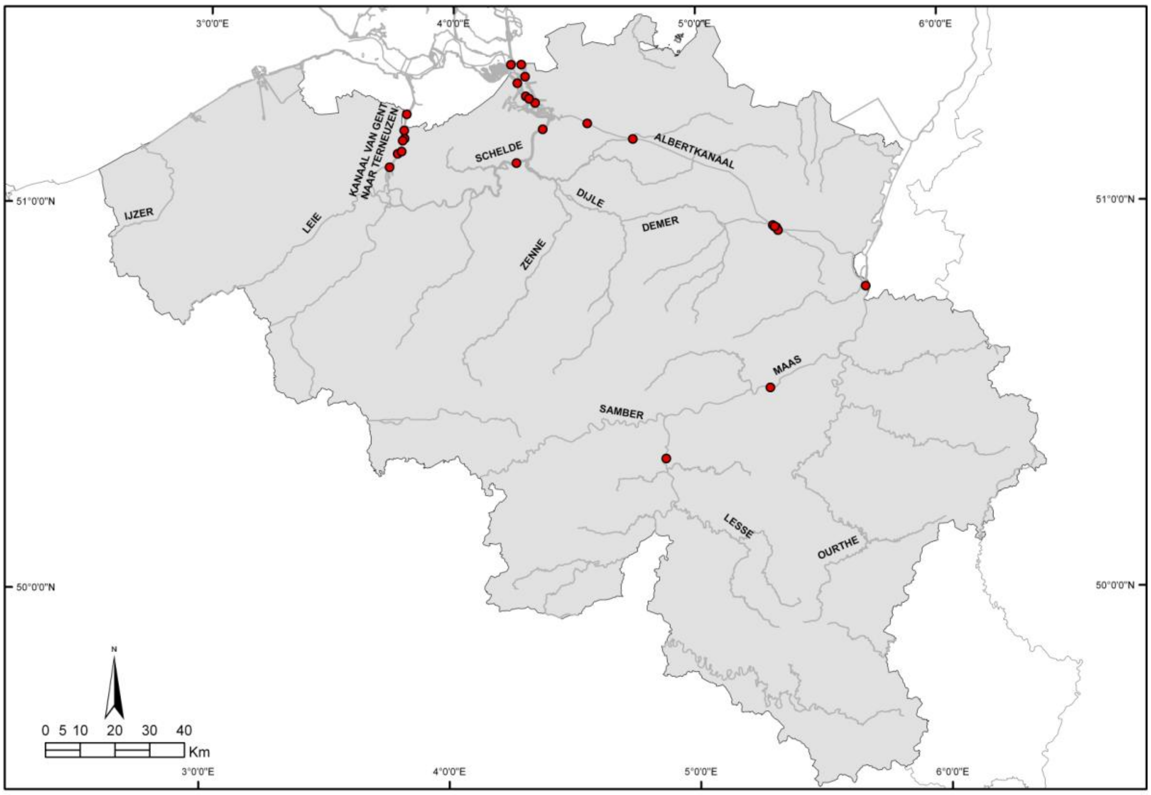

Figure 3: Distribution of *Neogobius melanostomus* in Belgium (map by INBO, 2013)

2.1.2 Present status in neighbouring countries

Mention here the status of the non-native organism in the neighbouring countries.

The Netherlands: established, widespread and high abundances (Spikmans et al., 2010) , France: established (G. Copp, pers.comm.), Germany: established (Wolter & Röhr, 2010), Luxembourg (Moselle): established (Sottiaux, 2013).

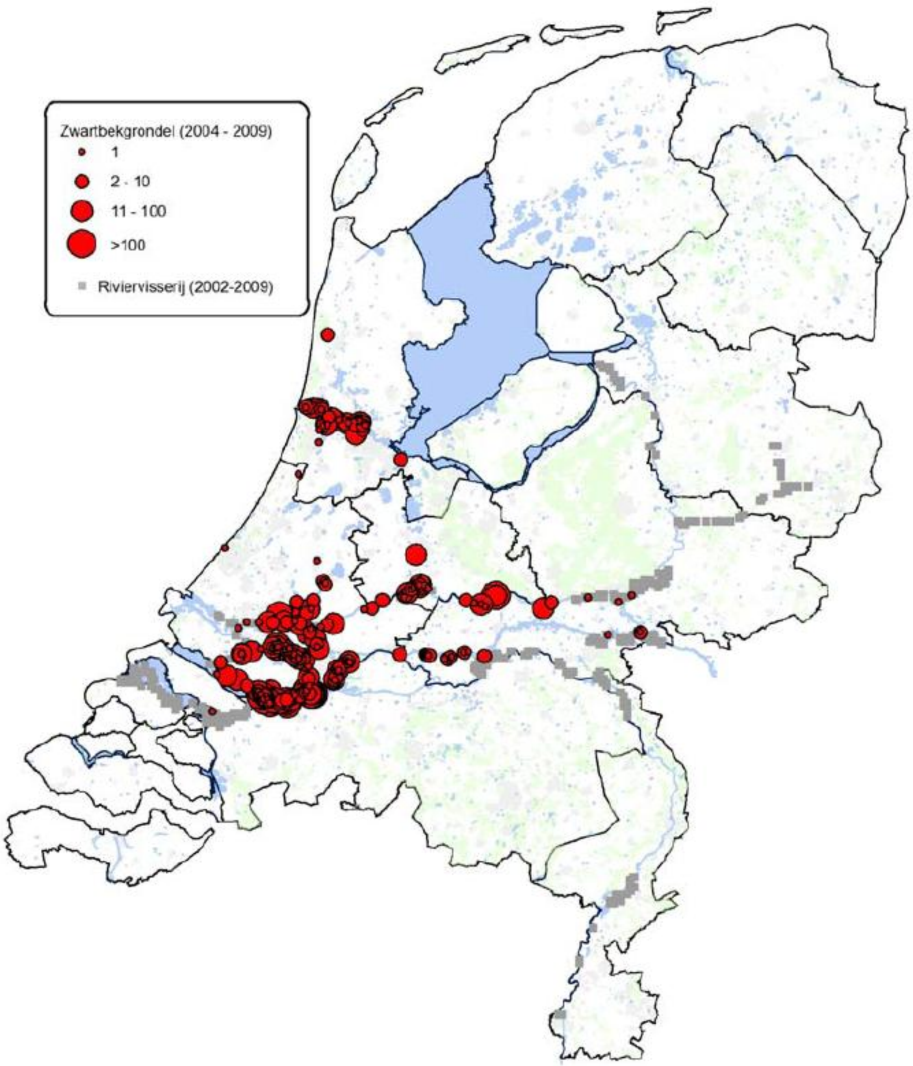

Figure 4: Distribution and abundances of *N. melanostomus* (red circles) in The Netherlands. Grey squares indicate sampled locations without round goby records (Spikmans et al, 2010).

2.1.3 Introduction in Belgium

Specify what are the potential international introduction pathways mediated by human, the frequency of introduction and the number of individuals that are likely to be released in Europe and in Belgium. Consider potential for natural colonisation from neighbouring areas where the species is established and compare with the risk of introduction by the human-mediated pathways. In case of plant or animal species kept in captivity, assess risk for organism escape to the wild (unintended habitats).

The Ponto-Caspian round goby was transported with ballast water to different parts of Europe and North America (Corkum et al., 2004). While ballast water transport was an important vector for the rapid spreading of the round goby over long distances, also active migration was suggested as a colonization route. This was facilitated by the opening of the Main-Danube Canal in 1992 which connected the Rhine and Danube river systems and thus enabling Ponto-Caspian species to move actively to West-Europe (Copp et al. 2005a). It is likely that, in Belgium, round gobies were released in the lower part of the River Scheldt (within the proximity of the international harbour of Antwerp) with ballast water disposal. It cannot be ruled out, however, that also active migration of specimens from the dense populations in the Dutch Rhine delta through the Rhine– Scheldt Canal has taken place (Verreycken et al., 2011).

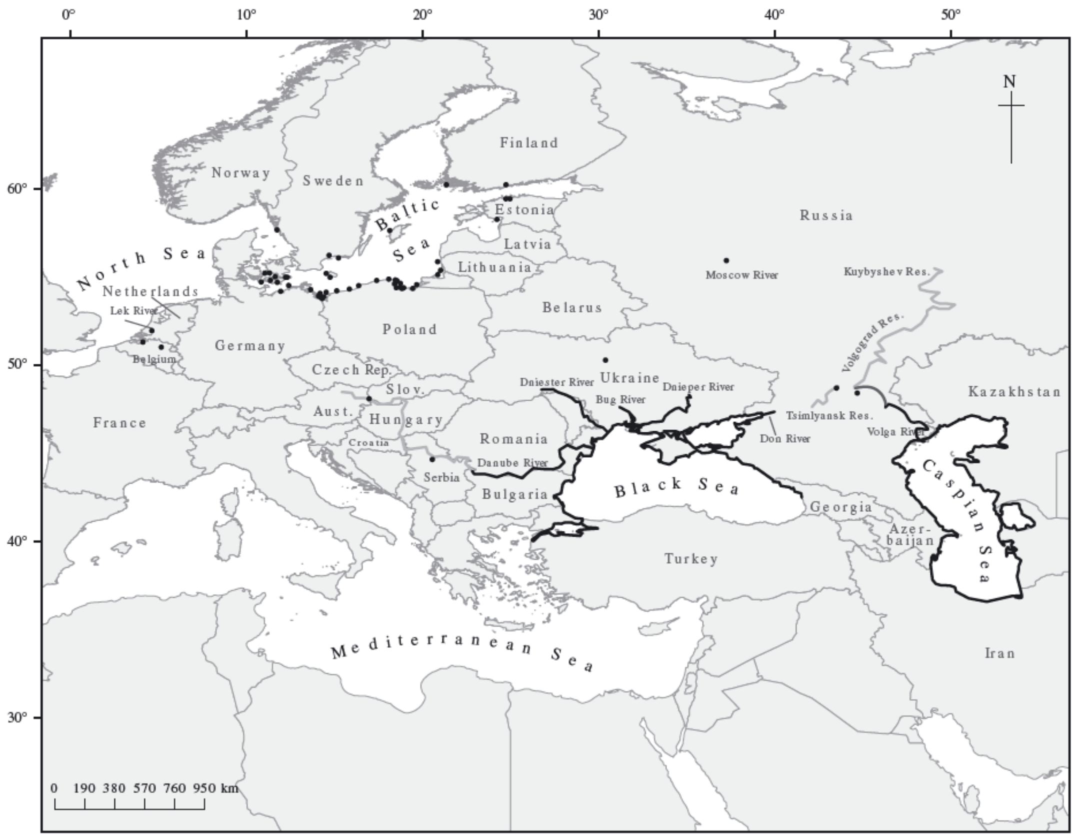

Figure 5: Distribution of *Neogobius melanostomus* in Eurasia, including records of captured *N. melanostomus* outside its native range (black dot), rivers reported as invaded from the literature (grey line) and the native range as defined by Miller (1986) (black line)(Kornis et al., 2012)

ENTRY IN BELGIUM

It is very likely that round goby will continue entering Belgium in the near future because of its high abundance in neighbouring areas, where new arrivals can be expected through active migration via canals and additionally through ballast water transport by barges and international shipping. Illegal trade and use of this fish species as live bait (not confirmed in Belgium) can further disseminate round goby.

2.1.4 Establishment capacity and endangered area

Provide a short description of life-history and reproduction traits of the organism that should be compared with those of their closest native relatives (A). Specify which are the optimal and limiting climatic (B), habitat (C) and food (D) requirements for organism survival, growth and reproduction both in its native and introduced ranges. When present in Belgium, specify agents (predators, parasites, diseases, etc.) that are likely to control population development (E). For species absent from Belgium, identify the probability for future establishment (F) and the area most suitable for species establishment (endangered area) (G) depending if climatic, habitat and food conditions found in Belgium are considered as optimal, suboptimal or inadequate for the establishment of a *reproductively viable population. The endangered area may be the whole country or part of it where ecological factors favour the establishment of the organism (consider the spatial distribution of preferred habitats). For non-native species already established, mention if they are well adapted to the eco-climatic conditions found in Belgium (F), where they easily form self-sustaining populations, and which areas in Belgium are still available for future colonisation (G).*

A/ Life-cycle and reproduction

Nests are generally under stones, under logs, or in cavities. Gobies also will use artificial substrata, such as beer cans, for nesting. Artificial reefs constructed in the Sea of Azov were colonized rapidly by gobies, thus enhancing local population levels. A male attracts females to his nest by producing a call. A receptive female responds with a quieter call. The male goby then prepares a nest site by coating the substrate with exudate from the "cement gland" (Charlebois et al, 1997). *Neogobius melanostomus* are multiple spawners, typically spawning every 3 - 4 weeks from April through to September in its native range (Charlebois et al., 1997). Spawning is cued by water temperature (9–26◦ C) and both gravid females and breeding-coloured males have been captured as late as November in the Detroit River (MacInnis & Corkum, 2000) due to prolonged warm water temperatures. The male guards the nest from predators and fans the eggs to maintain oxygenation, reduce fungal infection, and reduce siltation (Charlebois et al, 1997). Males mature at age 3 or 4 years and females at age 2 or 3 years in its native range (Miller, 1986), but both sexes may mature up to a year earlier in the Great Lakes based on findings from the upper Detroit River (MacInnis & Corkum, 2000). Males guard nests and may not feed during spawning, suggesting most males die after one spawning season (Charlebois et al., 1997), although this has yet to be confirmed (Kornis et al., 2012). Up to 10 000 eggs from four to six females may be present in a nest, and fertilization and hatching rates are as high as 95% (Charlebois et al., 1997). Eggs and larvae are relatively large (3.2 mm diameter) compared to other gobiid species; as a result, a single female produces relatively few eggs (328 - 5221 in native range) (Kovtun, 1978). Fecundity was lower in the Detroit River than in the native range (mean 198 eggs per female with a positive linear relationship between number of eggs and standard length), but greater than most native competitor species (MacInnis & Corkum, 2000). *Neogobius melanostomus* hatch at *ca.* 5 mm total length, with black eyes, flexed urostyle and well-developed fins and digestive system; the characteristic black spot on the posterior of the spinous dorsal fin is also visible at hatching (Leslie & Timmins, 2004).

B/ Climatic requirements[2]

N. melanostomus occurs in the temperate and continental climate zones (Köppen-Geiger classification), especially in subzones 'Maritime Temperate climates' and 'Warm Summer Continental climates'. Current distribution area in North America is limited between 39° – 49° N and 75° – 92° W while for Eurasia this is defined between approx. 35° - 60° N and 4° - 54° E (see figure 5). *Neogobius melanostomus* has a wide thermal tolerance, ranging from −1 to 30◦ C (Moskal'kova, 1996), but prefer warmer water; energetic optimum temperature is estimated to be 26◦ C (Lee & Johnson, 2005). This may partially explain the disparity in *N. melanostomus* success across the Great Lakes, as the species is most widespread and at its greatest densities in the warmest lake (Erie) and has the smallest range and lowest densities in the coldest (Superior). Water temperature was also significantly higher at stream sites invaded by *N. melanostomus* versus sites where the species was

[2] Organism's capacity to establish a self-sustaining population under Atlantic temperate conditions (Cfb Köppen-Geiger climate type) should be considered, with a focus on its potential to survive cold periods during the wintertime (e.g. plant hardiness) and to reproduce taking into account the limited amount of heat available during the summertime.

absent (Kornis & Vander Zanden, 2010). The ultimate distribution and effect of *N. melanostomus* will be influenced by anthropogenic climate change. Increased water temperatures will allow the geographic range of *N. melanostomus* to shift northwards and should benefit *N. melanostomus* throughout much of its invasive range, as temperatures will approach energetically optimal temperatures reported by Lee & Johnson (2005) (Kornis et al., 2012).

C/ Habitat preferences[3]

Neogobius melanostomus spawn, feed and hide in hard substrata and are typically most abundant in rocky habitats. Nonetheless, soft substrata are also utilized by *N. melanostomus* and abundance may be similar on soft and hard substrata in some areas (Johnson et al., 2005a; Taraborelli et al., 2009). Thus, mud and sand habitat are not resistant to invasion and the lack of a hard substratum will not prevent colonization, although *N. melanostomus* will probably colonize hard before soft substrata. In Lakes Michigan and Erie, adults were more abundant on rock while juveniles were more abundant on sand, leading to the hypothesis that adults displace juveniles to sub-optimal habitats (Charlebois et al., 1997; Ray & Corkum, 2001).

Neogobius melanostomus abundance may correlate with depth and density of aquatic vegetation. Along the shorelines of Lakes Michigan and Huron, it was more abundant in deeper habitat (0.65 m) than shallow (0.38 m) (Cooper & Ruetz, 2009), while in the Bay of Quinte (Lake Ontario) *N. melanostomus* was more abundant at depths of 1.5 - 3 m relative to 3 - 5 and 5 - 7 m (Taraborelli et al., 2009). Thus, *N. melanostomus* appears to avoid the shallow surf zone, but ultimately prefers shallower water (0.7 - 3 m) over deeper depths during the summer spawning season (Kornis et al., 2012). *Neogobius melanostomus* migrates offshore during winter and has been recorded as deep as 130 m during April sampling in Lake Ontario (Walsh et al., 2007). Abundance was positively correlated with submerged aquatic vegetation in coastal lakes and drowned river mouths (Cooper & Ruetz, 2009), but no correlation was found between sparse and moderately vegetated habitats in the Bay of Quinte (Taraborelli et al., 2009).

Neogobius melanostomus tolerate a wide range of habitat conditions, potentially contributing to its widespread success. They exhibit a wide salinity tolerance, inhabiting fresh, brackish and marine waters with a reported salinity tolerance of 40.5 pro mille (Moskal'kova, 1996). Nonetheless, there are no known populations in a full ocean habitat (Charlebois *et al*., 1997). Oceanic salinities (*c.* 35 pro mille) appear suitable since *N. melanostomus* are present in high saline (40.5 pro mille) areas of the Caspian Sea, but salts in these habitats are from two distinct molecules (CaSO4 in the Caspian and Aral Seas and NaCl in the ocean). The fact that no ocean populations are known, *N. melanostomus* probably has a salinity tolerance < 30 pro mille in oceanic (NaCl) waters (Kornis et al., 2012).

Neogobius melanostomus also has a wide thermal tolerance, ranging from −1 to 30 °C (Moskal'kova, 1996), but prefer warmer water; energetic optimum temperature is estimated to be 26 °C (Lee & Johnson, 2005). *Neogobius melanostomus* are tolerant of very low dissolved oxygen levels, but may attempt to escape hypoxic conditions. Critical lethal threshold values range from 0.4 to 1.3 mg l^{-1} (Charlebois et al., 1997).

[3] Including host plant, soil conditions and other abiotic factors where appropriate.

D/ Food habits[4]

Neogobius melanostomus feeds on many taxa including zooplankton (as juveniles), benthic invertebrates, small fishes and the eggs and larvae of large fishes (Kornis et al, 2012). Diets are influenced by habitat, time of day and year and body size.

In lakes and seas (lentic habitats), molluscs are usually the primary diet component (mean of 57·0 and 64·5% by mass in the Laurentian Great Lakes and Eurasia, respectively). Laboratory studies, however, suggest dreissenids may be primarily consumed when more profitable prey e.g. chironomids are rare or difficult to capture (Coulter et al., 2011). *Neogobius melanostomus* can crush mollusc prey with the pharyngeal teeth (Ghedotti et al., 1995) with field studies indicating c. 50 % of mussels consumed by *N. melanostomus* are crushed v. 50 % swallowed whole (Andraso et al., 2011). In at least one lentic habitat, however, decapods (shrimp, *Palaemon* spp.) comprised the greatest percentage by mass of the diets of *N. melanostomus* > 10.3 cm total length. In streams (lotic habitats), diets are typically dominated by non-mollusc benthic invertebrates. Such diet diversity among populations demonstrates *N. melanostomus* is capable of adapting to locally abundant food sources, facilitating the species' invasion potential (Kornis et al, 2012).

While adult *N. melanostomus* feed heavily on dreissenids in the Great Lakes, dreissenids are not required for *N. melanostomus* populations to thrive. Carman et al. (2006) documented abundant *N. melanostomus* populations at river sites lacking dreissenids.

Several species targeted by conservation efforts may suffer reduced recruitment as a result of egg depredation by *N. melanostomus*. They significantly reduced lake trout *Salvelinus namaycush* (Walbaum 1792) fry emergence success in aquaria experiments by consuming both eggs and fry (Chotkowski & Marsden, 1999; Fitzsimons et al., 2009), suggesting the potential for depredation in the natural setting (Walsh et al., 2007). *Neogobius melanostomus* also prey on the eggs of lake sturgeon *Acipenser fulvescens* Rafinesque 1817, a species listed as threatened in North America. In addition to *A. fulvescens* and *S. namaycush*, other desirable fish species vulnerable to egg depredation from *N. melanostomus* include *Micropterus dolomieu* (Steinhart et al., 2004), walleye *Sander vitreus* (Mitchill 1818) (Roseman et al., 2006) and probably any species with benthic eggs (Kornis et al., 2012).

E/ Control agents

Due to its widespread success and abundance, *N. melanostomus* has become an important forage item for many species in both the Great Lakes and the Baltic Sea. Kornis et al. (2012) give an overview of species which directly predate on *N. melanostomus*. Predators with heavy reliance on *N. melanostomus* in the Great Lakes include burbot *Lota lota* (L. 1758), double-crested cormorants *Nerodia sipedon*, watersnakes, yellow perch *Perca flavescens* (Mitchill 1814) and smallmouth bass *Micropterus dolomieu*. In the Baltic Sea, main predators include perch *Perca fluviatilis* L. 1758, cod *Gadus morhua* L. 1758, great cormorants *Phalacrocorax carbo* and grey herons *Ardea cinerea*. There is some evidence that high predation levels contribute to control of *N. melanostomus* abundance. Abundance declined from 2004 to 2008 in Lake Erie, coinciding with increased importance of *N. melanostomus* in *L. lota* diets (Madenjian et al., 2011). Increased predation may therefore contribute to recent stabilizing trends in *N. melanostomus* populations.

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[4] For animal species only.

F/ Establishment capacity in Belgium

N. melanostomus was first found in Belgium in the Lower Scheldt in 2010. It now occurs at several locations in the Lower Scheldt, Canal Gent-Terneuzen, Albertcanal and Lower Meuse (see figure 3). Recent observations of very small (young) specimens of the round goby in the Albertcanal near Hasselt (Verreycken, unpublished data, Oct. 2012) and in Lower Meuse near Tihange (Sottiaux, March 2013) suggest natural reproduction in Belgian waters and thereby confirm its establishment. Also, from most locations, mature males and females were sampled. In The Netherlands, round goby occurs in the Netherlands especially in slow-flowing rivers (62% of observations). In addition, the species is also observed in canals and brakish waters. In the Dutch rivers with riprap substrate, round goby is recorded in the highest densities (Spikmans et al., 2010).

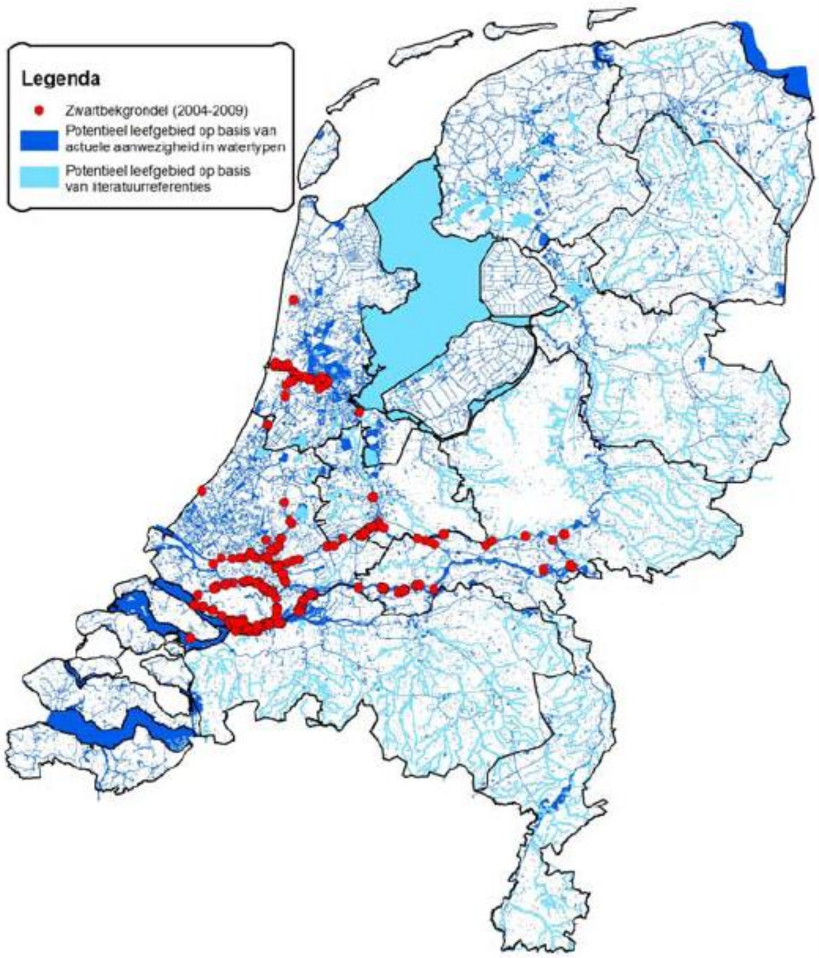

Figure 6: Potentially suitable habitats of round goby in The Netherlands based on current records of *N. melanostomus* in different water habitat types (dark blue) and on literature data (pale blue)(Spikmans et al., 2010).

Based on the observations and potentially suitable habitats in The Netherlands (figure 6), also for Belgium, it can be expected that round goby will spread further in large slow-flowing rivers and canals. Especially since most of these rivers and canals often harbour the favourite habitats (rip rap and cobble stones) of *N. melanostomus*.

G/ Endangered areas in Belgium

The distribution of *N. melanostomus* in Belgium is currently probably restricted to the more artificial habitats of big rivers and canals. From literature, however, we know that almost all habitats can be invaded by round goby (Kornis et al, 2012). In the Netherlands also some lakes and other standing waters are infested with round goby (Spikmans et al., 2010) suggesting that pools and lakes (e.g. in nature reserves) in Belgium are not immune to invasion by (self-supporting) populations of round goby. The higher parts of Belgium (e.g. the Ardenne) will be less vulnerable because of higher water velocities and the more natural state of the rivers.

Establishment capacity in the Belgian geographic districts:

Districts in Belgium	**Environmental conditions for species establishment**[5]
Maritime	Optimal
Flandrian	Optimal
Brabant	Optimal
Kempen	Optimal
Meuse	Optimal
Ardenne	Suboptimal
Lorraine	Suboptimal

ESTABLISHMENT CAPACITY AND ENDANGERED AREAS IN BELGIUM

***Neogobius melanostomus* is already established in some canals and rivers in low Belgium and its distribution is currently probably restricted to the more artificial habitats. However, from literature it is known that almost all habitats can be invaded by round goby. For the near future it is to be expected that not only big rivers and canals but also smaller tributaties will be invaded in Belgium.**

2.1.5 Dispersion capacity

Specify what is the rate of dispersal once the species is released or disperses into a new area. When available, data on mean expansion rate in introduced territories can be specified. For natural dispersion, provide information about frequency and range of long-distance movements (i.e. species capacity to colonise remote areas) and potential barriers for spread, both in native and in introduced areas, and specify if the species is considered as rather sedentary or mobile. For human-assisted dispersion, specify the likelihood and the frequency of intentional and accidental movements, considering especially the transport to areas from which the species may easily colonise unintended habitats with a high conservation value.

A/ Natural spread

While ballast water transport was an important vector for the rapid spreading of the round goby over long distances, also active migration was suggested as a colonization route. This was facilitated by the opening of the Main-Danube Canal in 1992 which connected the Rhine and Danube river systems and thus enabling Ponto-Caspian species to move actively to West-Europe (Copp et al, 2005a). Following its initial introduction, *N. melanostomus* has spread both through natural dispersal and through commercial shipping within invaded ecosystems. They are typically

[5] For each district, choose one of the following options : optimal, suboptimal or inadequate.

sedentary with limited home ranges (estimated at 5 m^2 by Ray & Corkum (2001), but individuals occasionally move long distances (Kornis et al, 2012). In a tagging experiment, 18 of 19 recaptured fish were caught within 67 m of the tagging site, but one fish was caught 218 days after tagging 2 km from the tagging site (Wolfe & Marsden, 1998). River colonization appears to be driven by 'stratified dispersal', a combination of diffusion over short distances by most individuals and long-distance colonization by migrant individuals (Bronnenhuber et al., 2011). A relatively high proportion of migrants in streams probably facilitates fast spread rates, with estimates ranging from 500 m $year^{-1}$ on average (Bronnenhuber et al., 2011) to **up to 1 - 4 km $year^{-1}$ in select areas** (Kornis & Vander Zanden, 2010). Where high quality habitats are present, higher range expansion rates are even predicted to occur, up to 5-25 km/year (Brownscombe et al., 2012). Evidence of high intraspecific competition between *N. melanostomus* at high densities in streams suggests that density-dependent factors probably contribute to range expansion. Migration barriers (e.g. dams) may prevent upstream (but not downstream) migration of round goby (Kornis et al., 2012).

B/ Human assistance

Evidence strongly suggests that *N. melanostomus* was transported to the Laurentian Great Lakes and the Baltic Sea via ballast water from transoceanic vessels. *Neogobius melanostomus* larvae are nocturnally pelagic, feeding on zooplankton at or near the water surface (0 - 9 m depth) (Hensler & Jude, 2007; Hayden & Miner, 2009). Nocturnal ballasting could therefore easily result in the transport of thousands of juveniles at a time, and night-time foraging suggests that *N. melanostomus* would be able to survive in dark ballast tanks for extended periods (Hayden & Miner, 2009). Also in Belgium (Verreycken et al, 2011) and The Netherlands (van Beek, 2004), ballast water transport was put forward as an important vector in the long distance spread of round goby.

Some anglers in Belgium probably use round goby as live bait to fish on predatory fish like pikeperch *Sander lucioperca* (see discussion on Roofvisforum.nl, accessed 28 January 2013). In Canada, it is believed that the initial introduction in the Trent River system was the result of one or more bait bucket releases by anglers that brought round goby from the infested waters of Lake Ontario (Gutowsky & Fox, 2011)

DISPERSAL CAPACITY

Human aided dispersal (mainly ballast water disposal) has helped round goby to invade large parts of North America and Eurasia. Also illegal (but often unintentional) release of round goby by anglers can be responsible for long-distance dispersal. Where already present, it can easily spread by natural dispersion towards neighbouring areas, expanding its range at a rate of 5-25 km/year.

2.2 EFFECTS OF ESTABLISHMENT

Consider the potential of the non-native organism to cause direct and indirect environmental, economic and social damages as a result of establishment. Information should be obtained from areas where the pest occurs naturally or has been introduced, preferably within Belgium and neighbouring areas or in other areas with similar eco-climatic conditions. Compare this information with the situation in the risk analysis area. Invasion histories concerning comparable organisms can usefully be considered. The magnitude of those effects should be also compared with those caused by their closest native relatives.

2.2.1 Environmental impacts

Specify if competition, predation (or herbivory), pathogen pollution and genetic effects is likely to cause a strong, widespread and persistent decline of the populations of native species and if those mechanisms are likely to *affect common or threatened species. Document also the effects (intensity, frequency and persistency) the non-native species may have on habitat peculiarities and ecosystem functions, including physical modification of the habitat, change to nutrient cycling and availability, alteration of natural successions and disruption of trophic and mutualistic interactions. Specify what kind of ecosystems are especially at risk.*

A/ Competition [HIGH]

Neogobius melanostomus competes with many species through resource competition, spawning interference and displacement of native species to sub-optimal habitat. Kornis et al. (2012) list the species directly affected from competition with by *N. melanostomus*. Round goby dominated food resources in laboratory experiments with three native species of fishes, suggesting native species suffer from resource competition (Bergstrom & Mensinger, 2009). Spawning interference is illustrated by laboratory experiments in which *N. melanostomus* attacked nestguarding mottled sculpins *Cottus bairdii* Girard 1850, occupied their nest, changed to black spawning colouration and caused loss of nearly all *C. bairdii* eggs (Janssen & Jude, 2001). Displacement of native species is also supported by laboratory experiments in which aggressive *N. melanostomus* oust resident *C. bairdii* (Dubs & Corkum, 1996) and logperch *Percina caprodes* (Rafinesque 1818) (Balshine et al., 2005) from shelters, running counter to the common behavioural finding that residents typically defeat challengers in territory disputes (Balshine et al., 2005).

Van Kessel et al. (2011) concluded that competition for shelter induced by invasive non-native gobiids may be a realistic threat to small native benthic fish species in the Rhine and Meuse system in The Netherlands. They demonstrated in laboratory experiments a shift to less favourable habitats for *C. perifretum* in competition with western tubenose goby *P. semilunaris* and bighead goby *N. kessleri*. No habitat shift was induced by *N. melanostomus* during the experiments held outside the breeding season. Van Kessel et al. (2011), however, state that the negative impact of *N. melanostomus* on native benthic fish species may be underestimated by the absence of aggressive behavioural interactions of the species that only occur during the spawning season and subsequent brood care. Data from long-term fish monitoring in large(r) rivers in the Netherlands show a **strong decline (even disappearance) of bullhead *Cottus perifretum*** due to the settlement of round and western tubenose goby in these rivers (M. Dorenbosch, pers.comm.). For Belgium no data of competition are available.

B/ Predation/herbivory [HIGH]

Neogobius melanostomus feeds on many taxa including zooplankton (as juveniles), benthic invertebrates, small fishes and the eggs and larvae of large fishes. Kornis et al. (2012) give an extensive overview of species directly affected from predation by *N. melanostomus*. This list includes zooplankton, molluscs (bivalves and gastropods), crustaceans (amphipods, isopods, barnacles and decapods), other benthos (Diptera, Ephemeroptera, Trichoptera and Polychaeta) and fishes. Diets are influenced by habitat, time of day and year and body size. In lakes and seas (lentic habitats), molluscs are usually the primary diet component (mean of 57·0 and 64·5% by mass in the Laurentian Great Lakes and Eurasia, respectively). In streams (lotic habitats), diets are typically dominated by non-mollusc benthic invertebrates (mean of 71·3% by mass in Laurentian Great Lakes tributaries) (Kornis et al., 2012).

Neogobius melanostomus predation has contributed to community shifts at lower trophic levels. Invertebrates in invaded Lake Erie tributaries had e.g. a reduced Shannon diversity relative to streams without *N. melanostomus* (Krakowiak & Pennuto, 2008). In Green Bay, Lake Michigan, several macroinvertebrate species (dreissenids, isopods, amphipods, trichopterans and gastropods) significantly decreased in abundance from 2003 (when *N. melanostomus* was absent) to 2006 (when

N. melanostomus was present) (Lederer et al., 2008). In similar fashion, a 94 % decline in quagga mussels *Dreissena bugensis* and a 85 % decline in amphipods (*Gammarus fasciatus* and *Echinogammarus ischnus*) correlated with an increase in *N. melanostomus* density from 6.5 to 14 m^{-2} from 2001 to 2004 in eastern Lake Erie (Barton et al., 2005). *Neogobius melanostomus* consumption of dreissenids may lead to localized declines in dreissenid abundance, but consumption rates are not high enough to effect dreissenid populations on a system-wide scale (Kornis et al., 2012).

C/ Genetic effects and hybridization [UNLIKELY]

No native species of the genus *Neogobius* (or hypothesised closely related genera *Mesogobius* or *Proterorhinus*) exist is Belgium (Kottelat & Freyhof, 2007) so the risk of hybridization and/or other genetic effects is extremely small.

D/ Pathogen pollution [LIKELY]

The parasite fauna of *N. melanostomus* has received close attention in both its native and invaded range. At least 94 species of parasites are known for *N. melanostomus* (Kvach & Stepien, 2008), but new parasite records emerge as the species increases its range (Kosuthova et al., 2009; Francová et al., 2011). In the introduced Eurasian and North American populations, *N. melanostomus* has often acquired local parasites; thus far it has not been reported to harbour invasive parasites into invaded areas (Kvach & Stepien, 2008; Francová et al., 2011).

Neogobius melanostomus is also a known host of viral haemorrhagic septicaemia virus (VHSV) in the Great Lakes (Al-Hussinee et al., 2011). While there is no evidence linking consumption of *N. melanostomus* to VHSV occurrence in predatory fishes, VHSV can be transmitted to predators through the gut following ingestion of an infected prey item (Meyers & Winton, 1995). Given the growing importance of *N. melanostomus* as prey for piscivorous fishes, further research into the incidence of VHSV in *N. melanostomus* is warranted (Kornis et al., 2012).

The combination of *N. melanostomus* abundance at shallow depths, vulnerability to low-level neurotoxin exposure, erratic swimming behaviour when infected and higher infection rates compared to other species strongly suggest that *N. melanostomus* is a primary vector for botulism neurotoxin to fish-eating birds. Affected birds are often found with *N. melanostomus* in their guts (Hannett et al., 2011).

E/ Effects on ecosystem functions [HIGH]

Neogobius melanostomus has become an important component of the Laurentian Great Lakes and Baltic Sea food webs by virtue of its high abundance and widespread distribution. The species has had both positive and negative effects on various species through competition, predation and providing forage. Such trophic linkages, particularly with invasive dreissenids (zebra mussel *Dreissena polymorpha* and quagga mussel *Dreissena rostriformis bugensis*), have resulted in several indirect effects, potentially altering nutrient and contaminant pathways (Hogan et al., 2007; Ng et al., 2008) and leading to increased outbreaks of avian botulism (Yule et al., 2006).

In the Baltic Sea, *N. melanostomus* primarily competes with the commercially important flounder *Platichthys flesus*, evidenced by strong similarities in diet and a negative correlation between *P. flesus* and *N. melanostomus* abundance (Karlson et al., 2007).

Benthic-oriented piscivorous fishes show substantial reliance on *N. melanostomus* as prey in the Laurentian Great Lakes where dreissenids constitute the majority of adult *N. melanostomus* diets. *N. melanostomus* thus facilitates the transfer of previously unavailable energy (from dreissenids) up to higher trophic levels (Johnson et al., 2005b). While predators vary in their reliance on *N. melanostomus* as forage, its invasion has undoubtedly altered the flow of energy through Laurentian Great Lakes and Baltic Sea food webs (Kornis et al., 2012).

Great Lakes *N. melanostomus* may facilitate bioaccumulation of toxic substances [mercury, polychlorinated biphenyls (PCB) and polychlorinated naphthalenes (PCN)] to upper levels of the food web. A pre and post-*N. melanostomus* study found that *Micropterus dolomieu* continued to accumulate mercury (Hg) at pre-invasion levels (1993) in 2003 despite declines in sediment Hg concentrations over that decade, presumably due to a *N. melanostomus*-rich diet (Hogan et al., 2007). These findings are pertinent to fish consumption advisories for anglers, as Hg concentrations were highest in skinless boneless fillets and rate of Hg concentration increase was greatest in *S. vitreus*, a popular eating species (Azim et al., 2011).

Evidence also suggests increased PCB accumulation related to the *N. melanostomus* invasion. One study found PCB contamination increased three to five-fold at each successive trophic level (e.g. dreissenids → *N. melanostomus*; *N. melanostomus* → *M. dolomieu*) and that PCB levels in *M. dolomieu* and *N. melanostomus* were relatively constant across a gradient of PCB sediment concentration, concluding that exotic species (dreissenids and *N. melanostomus*) contribute to contaminant recycling (Kwon et al., 2006). On the basis of these findings, *N. melanostomus* probably results in increased heavy metal (Hg) recycling compared to historical levels, but recycling and trophic-level bioaccumulation of PCBs and PCNs is widely variable and more dependent on ambient levels of sediment contamination (Kornis et al, 2012).

ENVIRONMENTAL IMPACTS

The environmental impacts of the presence of *N. melanostomus* in Belgium will be mainly through competition and predation but also possibly through pathogen pollution, disruption of trophic interactions and changes to nutrient/toxic substances cycling and availability. Mainly small benthic freshwater fish and freshwater mussels will be affected. A decline of bullhead *Cottus perifretum* (species from EU Habitat Directive) in rivers due to the presence of high densities of round goby is likely to be the most conspicuous impact to be expected in Belgium (cfr. The Netherlands).

2.2.2 Other impacts

A/ Economic impacts

Describe the expected or observed direct costs of the introduced species on sectorial activities (e.g. damages to crops, forests, livestock, aquaculture, tourism or infrastructures).

There is no definitive study on the economic costs of *N. melanostomus* in the Great Lakes, largely because this species degrades indirect-use values that are moderately difficult to measure. The most direct economic effect of *N. melanostomus* is associated with recreational angling. Depending on the target species, *N. melanostomus* either deters anglers from fishing due to frequent capture as by-catch, or encourages anglers to fish due to perceived increases in the frequency of above-average-sized fish (Kornis et al., 2012). In Belgium, no economically important freshwater fishery exist so in the worst case its presence may affect angling activities (see B/Social impacts) which can have an indirect effect on the sales of angling material and fishing licences.

B/ Social impacts

Describe the expected or observed effects of the introduced species on human health and well-being, recreation activities and aesthetic values.

In Belgium, some anglers report certain sites at the Albertcanal and the Canal Ghent - Terneuzen as unsuitable for angling due to very frequent captures of the unwanted round goby (Verreycken, unpublished data). This may negatively affect the number of anglers and/or angling activities on certain canals (and other waters) where *N. melanostomus* is abundant.

2.2.3 Summary of the environmental risk assessment

Fill in the following table with the conclusions provided at the end of the different sections of the risk assessment.

PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)	
Entry in Belgium	It is very likely that round goby will continue entering Belgium in the near future because of its high abundance in neighbouring areas, where new arrivals can be expected through active migration via canals and additionally through ballast water transport by barges and international shipping. Illegal trade and use of this fish species as live bait (not confirmed in Belgium) can further disseminate round goby.
Establishment capacity	*Neogobius melanostomus* is already established in some canals and rivers in low Belgium and its distribution is currently probably restricted to the more artificial habitats. However, from literature it is known that almost all habitats can be invaded by round goby. For the near future it is to be expected that not only big rivers and canals but also smaller tributaties will be invaded in Belgium.
Dispersion capacity	Human aided dispersal (mainly ballast water disposal) has helped round goby to invade large parts of North America and Eurasia. Also illegal (but often unintentional) release of round goby by anglers can be responsible for long-distance dispersal. Where already present, it can easily spread by natural dispersion towards neighbouring areas, expanding its range at a rate of 5-25 km/year.
EFFECT OF ESTABLISHMENT	
Environmental impacts	The environmental impacts of the presence of N. melanostomus in Belgium will be mainly through competition and predation but also possibly through pathogen pollution, disruption of trophic interactions and changes to nutrient/toxic substances cycling and availability. Mainly small benthic freshwater fish and freshwater mussels will be affected. A decline of bullhead *Cottus perifretum* (species from EU Habitat Directive) in rivers due to the presence of high densities of round goby is likely to be the most conspicuous impact to be expected in Belgium (cfr. The Netherlands).

STAGE 3: RISK MANAGEMENT

The decision to be made in the risk management process will be based on the information collected during the two preceding stages, e.g. reason for initiating the process, estimation of probability of introduction and evaluation of potential consequences of introduction in Belgium. If the risk is found to be unacceptable, then possible preventive and control actions should be identified to mitigate the impact of the non-native organism and reduce the risk below an acceptable level. Specify the efficiency of potential measures for risk reduction.

3.1 RELATIVE IMPORTANCE OF PATHWAYS FOR INVASIVE SPECIES ENTRY IN BELGIUM

The relative importance of intentional and unintentional introduction pathways mediated by human activities should be compared with the natural spread of the organism. Make use e.g. of information used to answer to question 2.1.3.

Unintentional introduction was probably the most important pathway for the rapid spread of the round goby. The opening of the Main – Danube canal, however, has facilitated the natural dispersal. Initial introduction in West-Europe probably happened through ballast water disposal. Also in Belgium, it is likely that this vector was responsible for long-distance dispersal. Natural spread through highly infested canals and large rivers in The Netherlands connected with Belgian waters is also believed to be a possible introduction route for round goby. Ongoing genetic research can maybe elucidate the origin of the Belgian round goby populations (Verreycken, unpublished data).

3.2 PREVENTIVE ACTIONS

Which preventive measures have been identified to reduce the risk of introduction of the organism? Do they reduce the risk to an acceptable level and are they considered as cost-effective? Specify if the proposed measures have undesirable social or environmental consequences. Consider especially (i) the restrictions on importation and trade and (ii) the use of specific holding conditions and effect of prohibition of organism introduction into the wild.

(i) Prohibition of organism importation, trade and holding

Oceanic ballast water exchange may help limit further spread of *N. melanostomus* (Ellis & MacIsaac, 2009), but many vessels are exempt from ballast water exchange regulations (Duggan et al., 2005). Round goby may be involved in trade for two different purposes: aquarium trade and live bait for angling, which may ultimately lead to fish introduction into the wild and establishment of feral populations (cfr. Trent river in Canada) (Copp et al. 2005b, Gutowsky & Fox, 2011). Although no evidence of those specific uses could be found in Belgium, it is advisable to prohibit trade of *N. melanostomus* for any goals.

(ii) Use of specific holding conditions and effect of prohibition of organism introduction into the wild

In accordance with Council Regulation no 708/2007, any introduction of round goby to an aquaculture facility is subjected to the issue of a permit by the receiving Member State, which may be only obtained when the risk of environmental impact is considered as negligible due to adequate holding conditions.

Belgian regional nature conservation and fishery acts strictly prohibit intentional release of most exotic fish species into the wild (incl. round goby) and their use as live bait for angling. In spite of those legal instruments, such practices cannot be completely prevented, e.g. because control actions in the field are time and resource consuming and demand a good knowledge of all fish species.

3.3 CONTROL AND ERADICATION ACTIONS

Which management measures have been identified to reduce the risk of introduction of the organism? Do they reduce the risk to an acceptable level and are they considered as cost-effective? Specify if the proposed measures have undesirable social or environmental consequences. Consider especially the following questions.

(i) Can the species be easily detected at early stages of invasion (early detection)?

Detection of scarce, previously unknown, aquatic species is very difficult. This results in an unavoidable time difference (up to several years) between the actual introduction of a fish species into a water body and its recording (Reshetnikov, 2013). Even if an invasive fish species is known from interconnected river and canal systems, it may take years before a new species is recorded (e.g. round goby in The Netherlands since 2004 while first record in Belgium in 2010) (Verreycken et al., 2011).

(ii) Are they some best practices available for organism local eradication?

Eradication or control of *N. melanostomus* populations may be possible in smaller systems if action is taken soon after detection of the species. *Neogobius melanostomus* is susceptible to piscicides such as rotenone, but such toxicants do not discriminate between *N. melanostomus* and native species and thus are not ideal (Schreier *et al*., 2008). In some cases, chemicals such as rotenone may be the only appropriate management tool and unwanted side effects (killing native fishes) may be acceptable if *N. melanostomus* is eradicated (Kornis et al., 2012).

(iii) Do eradication and control actions cause undesirable consequences on non-target species and on ecosystem services ?

See *(ii)*

(iv) Could the species be effectively eradicated at early stage of invasion?

Probably not, active migration from neighbouring, inter-connected water catchments will form new centers of invasion. E.g. in 2004, *N. melanostomus* was discovered in Pefferlaw Brook, a tributary to Lake Simcoe, Ontario. It was deemed a serious threat to Simcoe's angling industry (Kurji et al., 2006) and in 2005, rotenone was applied to a 5 km stretch of Pefferlaw Brook with the sole goal of eradicating *N. melanostomus* (Borwick & Brownson, 2006; Corkum et al., 2008). Unfortunately, in this instance several *N. melanostomus* were captured a few months after treatment and despite an intense seining effort to remove the remaining *N. melanostomus*, individuals have since been captured in Lake Simcoe (Kornis et al., 2012).

(v) If widely widespread, can the species be easily contained in a given area or limited under an acceptable population level?

In larger systems, commercial exploitation of *N. melanostomus* might reduce local abundance (Kornis et al, 2012). *Neogobius melanostomus* is commercially harvested in its native range, where they are canned for human consumption (Jude et al., 1992). Its distribution is limited by salinity but even coastal salt marshes and estuaries, where salinities often mirror those of the Baltic Sea, can be invaded by round goby (Stepien & Tumeo, 2006). It is expected that its range will expand to include virtually all littoral hard substrata of the Laurentian Great Lakes, perhaps with the exception of northern sections of Lake Superior and Lake Huron, where they will be limited by cold temperatures. Upstream expansion into Great Lakes tributaries will be hindered by the presence of dams, but *N. melanostomus* can make its way over dams with the assistance of humans and will continue to move upstream within the Great Lakes basin (Kornis et al, 2012). Kornis et al. (2012) conclude that the ultimate distribution and effect of *N. melanostomus* will be influenced by anthropogenic climate change. Increased water temperatures will allow the geographic range of *N. melanostomus* to shift northwards and should benefit *N. melanostomus* throughout much of its invasive range, as temperatures will approach energetically optimal temperatures reported by Lee & Johnson (2005).

CONCLUSION OF THE RISK MANAGEMENT SECTION

Ballast water disposal and natural spread of the species are identified as the most probable pathways of entry in Belgium. Mid-ocean ballast water exchange would dramatically reduce *N. melanostomus* survivorship in ballast tanks and may thus limit the number of new introductions. However, barges, that never enter sea water areas, also sometimes use ballast water for stability and may spread *N. melanostomus* further inland. The natural spread from high density populations from inter-connecting river systems cannot easily be managed. Only dams can prevent upstream (but not downstream) migration. Round goby may be involved in trade for two different purposes: aquarium trade and live bait for angling, which may ultimately lead to fish introduction into the wild and establishment of feral populations. Although no evidence of those specific uses could be found in Belgium, it is advisable to prohibit trade of *N. melanostomus* for any goals.

Because of its benthic lifestyle, round goby is not easy to detect or observe at early stages of invasion and rapid eradication is therefore difficult. Piscicides may be useful in eradicating emerging round goby populations but only in confined areas and at a big cost. A reduction of population density may be achieved by commercial fishing but is probably not feasable in Belgium. Prohibition of the trade and use as live bait of round goby can diminish further impacts and will probably slow down its range expansion but, however, will not stop it.

LIST OF REFERENCES

Andersen M.C., Adams H., Hope B., Powell M. (2004). Risk assessment for invasive species. *Risk analysis* 24(4):787-793.

Andraso, G. M., Ganger, M. T. & Adamczyk, J. (2011). Size-selective predation by round gobies (*Neogobius melanostomus*) on dreissenid mussels in the field. *Journal of Great Lakes Research* **37,** 298–304.

Aven, T. (2011). Misconceptions of risk: Wiley.

Azim, M. E., Kumarappah, A., Bhavsar, S. P., Backus, S. M. & Arhonditsis, G. (2011). Detection of the spatiotemporal trends of mercury in Lake Erie fish communities: a Bayesian approach. *Environmental Science and Technology* **45,** 2217–2226.

Baker, R., Black R., Copp G., Haysom K., Hulme P., Thomas M., Brown A., Brown M., Cannon R., Ellis J. (2008). The UK risk assessment scheme for all non-native species.

Baker, R. et al. (2005) Novel strategies for assessing and managing the risks posed by invasive alien species to global crop production and biodiversity. *Ann. Appl. Biol.* 146: 177-191.

Balshine, S., Verma, A., Chant, V. & Theysmeyer, T. (2005). Competitive interactions between round gobies and logperch. *Journal of Great Lakes Research* **31,** 68–77.

Barton, D. R., Johnson, R. A., Campbell, L., Petruniak, J., & Patterson, M. (2005). Effects of round gobies (*Neogobius melanostomus*) on dreissenid mussels and other invertebrates in eastern Lake Erie, 2002-2004. *Journal of Great Lakes Research* **31** (Suppl. 2), 252–261.

Bergstrom, M. A. & Mensinger, A. F. (2009). Interspecific resource competition between the invasive round goby and three native species: logperch, slimy sculpin, and spoonhead sculpin. *Transactions of the American Fisheries Society* **138,** 1009–1017.

Bergstrom, M. A., Evrard, L. M. & Mensinger, A. F. (2008). Distribution, abundance, and range of the round goby, *Apollonia melanostoma*, in the Duluth-Superior Harbor and St. Louis River Estuary, 1998-2004. *Journal of Great Lakes Research* **34,** 535–543.

Borwick, J. A. & Brownson, B. (2006). Rotenone – an option to control the spread of round goby (*Neogobius melanostomus*). *Annual Conference on Great Lakes Research* **49**.

Borza, P., Erös, T. & Oertel, N. (2009). Food resource partitioning between two invasive gobiid species (Pisces, Gobiidae) in the littoral zone of the River Danube, Hungary. *International Review of Hydrobiology* **94,** 609–621.

Bronnenhuber, J. E., Dufour, B. A., Higgs, D. M. & Heath, D. D. (2011). Dispersal strategies, secondary range expansion and invasion genetics of the nonindigenous round goby, *Neogobius melanostomus*, in Great Lakes tributaries. *Molecular Ecology* **20,** 1845–1859.

Brownscombe, J.W., Masson, L., Beresford, D.V. & Fox, M.G. (2012). Modeling round goby *Neogobius melanostomus* range expansion in a Canadian river system. *Aquatic Invasions* **7**(4): 537-545.

Carman, S. M., Janssen, J., Jude, D. J. & Berg, M. B. (2006). Diel interactions between prey behaviour and feeding in an invasive fish, the round goby, in a North American river. *Freshwater Biology* **51,** 742–755.

Charlebois, P. M., Marsden, J. E., Goettel, R. G., Wolfe, R. K., Jude, D. J. & Rudnika, S. (1997). *The Round Goby, Neogobius melanostomus (Pallas), a Review of European and North American Literature.* Zion, IL: Illinois-Indiana Sea Grant Program and Illinois Natural History Survey.

Chotkowski, M. A. & Marsden, J. E. (1999). Round goby and mottled sculpin predation on lake trout eggs and fry: field predictions from laboratory experiments. *Journal of Great Lakes Research* **25,** 26–35.

Cooper, M. J. & Ruetz, C. R. III. (2009). Habitat use and diet of the round goby (*Neogobius melanostomus*) in coastal areas of Lake Michigan and Lake Huron. *Journal of Freshwater Ecology* **24,** 477–488.

Copp, G. H., Bianco, P. G., Bogutskaya, N., Erös, T., Falka, I., Ferreira, M. T., Fox, M. G., Freyhof, J., Gozlan, R. E., Grabowska, J., Kováč, V., Moreno-Amich, R., Naseka, A. M., Peňáz, M., Povž, M., Przbylski, M., Robillard, M., Russell, I. C., Stakėnas, S., Šumer, S., Vila-Gispert, A. & Wiesner, C. (2005a). To be, or not to be, a non-native freshwater fish? *Journal of Applied Ichthyology* **21,** 242–262.

Copp, G. H., Wesley, K. J. & Vilizzi, L. (2005b). Pathways of ornamental and aquarium fish introductions into urban ponds of Epping Forest (London, England): the human vector'. *Journal of Applied Ichthyology* **21**, 263-274.

Corkum, L. D., Meunier, B., Moscicki, M., Zielinski, B. S. & Scott, A. P. (2008). Behavioural responses of female round gobies (*Neogobius melanostomus*) to putative steroidal pheromones. *Behaviour* **145,** 1347–1365.

Corkum, L. D., Sapota, M. R. & Skóra, K. E. (2004). The round goby, *Neogobius melanostomus*, a fish invader on both sides of the Atlantic Ocean. *Biological Invasions* **6,** 173–181.

Coulter, D. P., Murry, B. A., Webster, W. C. & Uzarski, D. G. (2011). Effects of dreissenid mussels, chironomids, fishes, and zooplankton on growth of round goby in experimental aquaria. *Journal of Freshwater Ecology* **26,** 155–162.

Dubs, D. O. L. & Corkum, L. D. (1996). Behavioural interactions between round gobies (*Neogobius melanostomus*) and mottled sculpins (*Cottus bairdi*). *Journal of Great Lakes Research* **22,** 838–844.

Duggan, I. C., van Overdijk, C. D. A., Bailey, S. A., Jenkins, P. T., Limén, H. & MacIsaac, H. J. (2005). Invertebrates associated with residual ballast water and sediments of cargo-carrying ships entering the Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences* **62,** 2463–2474.

Ellis, S. & MacIsaac, H. J. (2009). Salinity tolerance of Great Lakes invaders. *Freshwater Biology* **54,** 77–89.

FAO (2004) International Standard for Phytosanitary Measures No.11: *Pest risk analysis for pests, including analysis of environmental risks and living modified organismsmodified organisms*.

FAO (2010) International Standard for Phytosanitary Measures No. 5: *Glossary of phytosanitary terms*.

Fitzsimons, J. D., Brown, S. B., Williston, B., Williston, G., Brown, L. R., Moore, K., Honeyfield, D. C. & Tillitt, D. E. (2009*a*). Influence of thiamine deficiency on lake trout larval growth, foraging, and predator avoidance. *Journal of Aquatic Animal Health* **21,** 302–314.

Francová, K., Ondračková, M., Polačik, M. & Jurajda, P. (2011). Parasite fauna of native and non-native populations of *Neogobius melanostomus* (Pallas, 1814) (Gobiidae) in the longitudinal profile of the Danube River. *Journal of Applied Icthyology* **27,** 879–886.

Froese, R. & Pauly, D. (eds.) (2013). FishBase. [version 02/2013] http://www.fishbase.org.

Genovesi P., Scalera R., Brunel S., Roy D., Solarz W. (2010). Towards an early warning and information system for invasive alien species (IAS) threatening biodiversity in Europe. European Environment Agency, Copenhagen.

Ghedotti, M. J., Smihula, J. C. & Smith, G. R. (1995). Zebra mussel predation by round gobies in the laboratory. *Journal of Great Lakes Research* **21,** 665–669.

Grabowska, J., Kotusz, J.,Witkowski, A. **(**2010). Alien invasive fish species in Polish waters: an overview. *Folia Zoologica* **59** (1): 73–85.

Gutowsky, L. F. G. & Fox, M. G. (2011). Occupation, body size and sex ration of round goby (*Neogobius melanostomus*) in established and newly invaded areas of an Ontario river. *Hydrobiologia* **671,** 27–37.

Hannett, G. E., Stone,W. B., Davis, S. W. &Wroblewski, D. (2011). Biodiversity of *Clostridium botulinum* type E associated with a large outbreak of botulism in wildlife from Lake Erie and Lake Ontario. *Applied and Environmental Microbiology* **77,** 1061–1068.

Hayden, T. A. & Miner, J. G. (2009). Rapid dispersal and establishment of a benthic Ponto- Caspian goby in Lake Erie: diel vertical migration of early juvenile round goby. *Biological Invasions* **11,** 1767–1776.

Hensler, S. R. & Jude, D. J. (2007). Diel vertical migration of round goby larvae in the Great Lakes. *Journal of Great Lakes Research* **33,** 295–302.

Hogan, L. S., Marschall, E., Folt, C. & Stein, R. A. (2007). How non-native species in Lake Erie influence trophic transfer of mercury and lead to top predators. *Journal of Great Lakes Research* **33,** 46–61.

Janssen, J. & Jude, D. J. (2001). Recruitment failure of mottled sculpin *Cottus bairdi* in Calumet Harbor, southern Lake Michigan, induced by the newly introduced round goby *Neogobius melanostomus*. *Journal of Great Lakes Research* **27,** 319–328.

Johnson, T. B., Allen, M., Corkum, L. D. & Lee, V. A. (2005a). Comparison of methods needed to estimate population size of round gobies (*Neogobius melanostomus*) in western Lake Erie. *Journal of Great Lakes Research* **31,** 78–86.

Johnson, T. B., Bunnell, D. B. & Knight, C. T. (2005b). A potential new energy pathway in Central Lake Erie: the round goby connection. *Journal of Great Lakes Research* **31** (Suppl. 2), 238–225.

Jude D.J., Reider, R.H. & Smith G.R. (1992). Establishment of Gobiidae in the Great Lakes basin. *Canadian Journal of Fisheries and Aquatic Sciences* **49**:416-421.

Karlson, A. M. L., Almqvist, G., Skóra, K. E. & Appelberg, M. (2007). Indications of competition between non indigenous round goby and native flounder in the Baltic Sea. *ICES Journal of Marine Science* **64,** 479–486.

Kornis M. S., Mercado-Silva N. & Vander Zanden M. J. (2012). Twenty years of invasion: a review of round goby *Neogobius melanostomus* biology, spread and ecological implications. *Journal of Fish Biology* **80**, 235–285.

Kornis, M. S. & Vander Zanden, M. J. (2010). Forecasting the distribution of the invasive round goby (*Neogobius melanostomus*) in Wisconsin tributaries to Lake Michigan. *Canadian Journal of Fisheries and Aquatic Sciences* **67,** 553–562.

Kosuthova, L., Kosco, J., Letkova, V., Kosuth, P. & Manko, P. (2009). New records of endoparasitic helminths in alien invasive fishes from the Carpathian region. *Biologia* **64,** 776–780.

Kottelat, M. & Freyhof, J. **(**2007). Handbook of European freshwater fishes. Kottelat and Freyhof, Cornol, Switzerland, Berlin, Germany.

Kovtun, I. F. (1978). On the fecundity of the round goby, *Gobius melanostomus*, from the Sea of Azov. *Journal of Ichthyology* **17,** 566–573.

Krakowiak, P. J. & Pennuto, C. M. (2008). Fish and macroinvertebrate communities in tributary streams of eastern Lake Erie with and without round gobies (*Neogobius melanostomus*, Pallas 1814). *Journal of Great Lakes Research* **24,** 675–689.

Kurji, K., Payne, M., Doyle, H. & LaMarca, J. (2006). The lesser evils of battling round goby infiltration. *Canadian Medical Association Journal* **174,** 1557.

Kvach, Y. & Stepien, C. A. (2008). The invasive round goby *Apollonia melanostoma* (Actinopterygii: Gobiidae) – a new intermediate host of the trematode *Neochasmus umbellus* (Trematoda: Cryptogonimidae) in Lake Erie, Ohio, USA. *Journal of Applied Ichthyology* **24,** 103–105.

Kwon, T. D., Fisher, S. W., Kim, G. W., Hwang, H. & Kim, J. E. (2006). Trophic transfer and biotransformation of polychlorinated biphenyls in zebra mussel, round goby, and smallmouth bass in Lake Erie, USA. *Environmental Toxicology and Chemistry* **25,** 1068–1078.

Lederer, A. M., Janssen, J., Reed, T. & Wolf, A. (2008). Impacts of the introduced round goby (*Apollonia melanostoma*) on Dreissenids (*Dreissena polymorpha* and *bugensis*) and on macroinvertebrate community between 2003 and 2006 in the littoral zone of Green Bay, Lake Michigan. *Journal of Great Lakes Research* **34,** 690–697.

Lee, V. A. & Johnson, T. B. (2005). Development of a bioenergetics model for the round goby (*Neogobius melanostomus*). *Journal of Great Lakes Research* **31,** 125–134.

Leslie, J. K. & Timmins, C. A. (2004). Description of age-0 round goby, *Neogobius melanostomus* Pallas (Gobiidae), and ecotone utilization in St. Clair lowland waters, Ontario. *Canadian Field Naturalist* **118,** 318–325.

Lusk, S., Lusková, V. & Hanel, L. (2010). Alien fish species in the Czech Republic and their impact on the native fish fauna. *Folia Zoologica* **59** (1), 57–72.

MacInnis, A. J. & Corkum, L. D. (2000). Fecundity and reproductive season of the round goby *Neogobius melanostomus* in the upper Detroit River. *Transactions of the American Fisheries Society* **129,** 136–144.

Madenjian, C. P., Tapanian, M. A., Witzel, L. D., Einhouse, D. W., Pothoven, S. A. & Whitford, H. L. (2011). Evidence for predatory control of the invasive round goby. *Biological Invasions* **13,** 987–1002.

Meyers, T. R. & Winton, J. R. (1995). Viral hemorrhagic septicemia virus in North America. *Annual Review of Fish Diseases* **5,** 3–24.

Miller, P. J. (1986). Gobiidae. In *Fishes of the North-East Atlantic and the Mediterranean* (Whitehead, P. J. P., Bauchot, M. L., Hureau, J. C., Nielsen, J. & Tortonese, E., eds), pp. 1019–1095. Paris: UNESCO.

Moskal'kova, K. I. (1996). Ecological and morphophysiological prerequisites to range extension in the round goby Neogobius melanostomus under conditions of anthropogenic pollution. *Journal of Ichthyology* **36**: 584–590.

Mühlegger, J.M., Jirsa, F., Konecny, R. & Frank, C. (2010). Parasites of *Apollonia melanostoma* (Pallas 1814) and *Neogobius kessleri* (Guenther 1861) (Osteichthyes, Gobiidae) from the Danube River in Austria. *Journal of Helminthology* **84** (1): 87–92.

Ng, C., Berg, M., Jude, D., Janssen, J., Charlebois, P., Amara, L. & Gray, K. (2008). Chemical amplification in an invaded food web: seasonality and ontogeny in a high biomass, low diversity ecosystem. *Environmental Toxicology and Chemistry* **27,** 2186–2195.

Pinchuk, V.I. & Miller, P.J. (2003). *Neogobius caspius* (Eichwald, 1831). Pp. 173–180. *In*: Miller P.J. (ed.) The freshwater fishes of Europe. V. 8/I. Mugilidae, Atherinidae, Atherinopsidae, Blenniidae, Odontobutidae, Gobiidae 1.AULA-Verlag, Wiebelsheim, Germany.

Pinchuk, V.I., Vasil'eva, E.D., Vasil'ev, V.P. & Miller, P.J. (2003). *Neogobius melanostomus* (Pallas, 1814). Pp. 293–345. *In*: Miller P.J. (ed.) The freshwater fishes of Europe. V. 8/I. Mugilidae, Atherinidae, Atherinopsidae, Blenniidae,Odontobutidae, Gobiidae 1. AULA-Verlag, Wiebelsheim, Germany.

Ray, W. J. & Corkum, L. D. (2001). Habitat and site affinity of the round goby. *Journal of Great Lakes Research* **27,** 329–334.

Reshetnikov, A. (2013). Spatio-temporal dynamics of the West-Ukrainian centre of invasion of the fish *Perccottus glenii* and consequences for European freshwater ecosystems. *Aquatic Invasions* **8**: 193–206.

Roseman, E. F., Taylor, W. W., Hayes, D. B., Jones, A. L. & Francis, J. T. (2006). Predation on walleye eggs by fish on reefs in western Lake Erie. *Journal of Great Lakes Research* **32,** 415–423.

Schrader, G., Unger, J.G. & Starfinger, U. (2010) Invasive alien plants in plant health: a review of the past ten years. Bulletin OEPP/EPPO Bulletin 40, 239–247.

Schreier, T. M., Dawson, V. K. & Larson, W. (2008). Effectiveness of piscicides for controlling round gobies (*Neogobius melanostomus*). *Journal of Great Lakes Research* **34,** 253–264.

Shine, C., Kettunen, M., Genovesi, P., Essl, F., Gollash, F., Rabitsch, W., Scalera, R., Starfinger, U. & ten Brink, P. (2010) Assessment to support continued development of the EU strategy to combat invasive alien species. Final report for the European Commission. Institute for European Environmental Policy (IEEP), Brussels, Belgium.

Sottiaux, B. (2013). Il envahit la Meuse: le gobie à taches noires ! Le Pêcheur belge. Available at http://www.pecheurbelge.be/.

Spikmans, F., van Kessel, N., Dorenbosch, M., Kranenbarg, J., Bosveld, J. & Leuven, R. (2010). Plaag Risico Analyses van tien exotische vissoorten in Nederland. Nederlands Centrum voor Natuuronderzoek: Stichting RAVON, Radboud Universiteit Nijmegen, Stichting Bargerveen & Natuurbalans – Limes Divergens, Nijmegen (in Dutch)

Steinhart, G. B., Marschall, E. A. & Stein, R. A. (2004). Round goby predation on smallmouth bass offspring in nests during simulated catch-and-release angling. *Transactions of the American Fisheries Society* **133,** 121–131.

Stepien, C. A. & Tumeo, M. A. (2006). Invasion genetics of Ponto-Caspian gobies in the Great Lakes: a 'cryptic' species, absence of founder effects, and comparative risk analysis. *Biological Invasions* **8,** 61–78.

Stráňai, I. & Andreji, J. (2004). The first report of round goby, *Neogobius melanostomus* (Pisces, Gobiidae) in the waters of Slovakia. *Folia Zoologica* **53,** 335–338.

Taraborelli, A. C., Fox, M. G., Schaner, T. & Johnson, T. B. (2009). Density and habitat use by the round goby (*Apollonia melanostoma*) in the Bay of Quinte, Lake Ontario. *Journal of Great Lakes Research* **35,** 266–271.

van Beek, G. C. W. (2006). The round goby *Neogobius melanostomus* first recorded in the Netherlands. *Aquatic Invasions* **1,** 42–43.

van Kessel, N., Dorenbosch, M., De Boer, M.R.M., Leuven, R.S.E.W., Van der Velde G. (2011). Competition for shelter between four non-native gobiid and two native small benthic fish species. *Current Zoology* **57**, 844 – 851.

Verreycken, H., Breine, J. J., Snoeks, J. & Belpaire, C. (2011). First record of the round goby, *Neogobius melanostomus* (Actinopterygii: Perciformes: Gobiidae) in Belgium. *Acta Ichthyologica et Piscatoria* **41**, 137–140.

Walsh, M. G., Dittman, D. E. & O'Gorman, R. (2007). Occurrence and food habits of the round goby in the profundal zone of southwestern Lake Ontario. *Journal of Great Lakes Research* **33,** 83–92.

Wolfe, R. K. & Marsden, J. E. (1998). Tagging methods for the round goby (*Neogobius melanostomus*). *Journal of Great Lakes Research* **24,** 731–735.

Wolter, C. & Röhr, F. (2010). Distribution history of non-native freshwater fish species in Germany: how invasive are they? *Journal of Applied Ichthyology* **26**, 19–27.

Yule, A. M., Barker, I. K., Austin, J. W. & Moccia, R. D. (2006). Toxicity of *Clostridium botulinum* type E neurotoxin to Great Lakes fish: implications for avian botulism. *Journal of Wildlife Diseases* **42,** 479–493.