Perccottus glenii *is currently the only known member of its genus.*
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The management of Amur sleeper (*Perccottus glenii*)

Measures and associated costs

Scientific name(s)	*Perccottus glenii*
Common names (in English)	Amur sleeper
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Common names

BG	Китайски поспаланко
HR	Rotan
CZ	Hlavačkovec Glenův
DA	Kinesisk sovekutling
NL	Amoergrondel
EN	Amur sleeper
ET	Kaugida unimudil
FI	Rohmutokko
FR	–
DE	Amurgrundel
EL	Goujon de l'amour
HU	Amurgéb
IE	–
IT	–
LV	Rotans
LT	Nuodėgulinis grundalas
MT	–
PL	Trawianka
PT	–
RO	Somn chinezesc
SK	Býčkovec amurský
SL	Kitajska sladkovodna dremavka
ES	Durmiente chino
SV	Amursömnfisk

Summary of the measures, emphasizing the most cost-effective options.

Perccottus glenii (Amur sleeper) is a small East Asian fish species with maximal total length of 25 cm, maximal weight of 250 g and maximal reported age of 7 years (Kottelat and Freyhof, 2007). Amur sleeper inhabits water bodies of different types and especially in standing, or slow flowing waters, it can reach high densities. It endures low oxygen content and poor chemical water composition well. Amur sleeper is a eurytherm fish that demonstrates normal vital activity within a very wide temperature range, from 1 to 37 °C. Its ability to freeze into ice and then “melt” is well known (several authors cfr Bogutskaya and Naseka, 2002) and it also survives in drying water bodies (Bogutskaya and Naseka, 2002). The species is known to have been intentionally introduced by aquarists, and accidently introduced into several regions as a stowaway in fish consignments and as escapees from infested fish farms (Reshetnikov, 2013). Adverse impacts have been reported through competition for food and predation, but also possibly through pathogen pollution and disruption of trophic interactions. Native freshwater fish and amphibians are the main affected groups, but (larvae of) large invertebrates are also heavily predated upon. Standing waters (oxbow lakes, ponds, etc.), where high densities of *P. glenii* can be expected, are the ecosystems especially at risk (Verreycken, 2013). Reshetnikov and Ficetola (2011) assessed the bioclimatic suitability for the Amur sleeper in Eurasia using MAXENT models and found much of the EU area with a temperate climate zone to be highly suitable for this species.

Prevention measures

Intentional introductions should be prevented by EU IAS Regulation 1143/2014, so the illegal disposal of aquarium fish is not dealt with in this management note. Nevertheless, it is important to note that awareness raising is probably more effective than law enforcement in avoiding these illegal fish disposals. As Amur sleeper is already present in several EU Member States (MS), measures to prevent unintentional introductions should be focused on non-invaded parts of the EU by (1) checking for stowaway specimens in fish farms and fish transports and (2) awareness raising campaigns, including education and training to reduce the risk of unintentional introductions. As Amur sleeper was unintentionally introduced as a contaminant of consignments of fish (such as common carp Cyprinus carpio) from Asia to Eastern Europe and the European part of Russia (Reshetnikov, 2013), it seems plausible that this may also be an important pathway for future introduction of the species in Western Europe (Verreycken, 2013). Fish consignments should, therefore, be subjected to increased inspections and control. Furthermore, awareness raising campaigns can be performed targeting anglers, fish farmers and local fisheries managers about the risk of accidentally transporting stowaway specimens of Amur sleeper (and other invasive species) when moving fish.

Secondary spread can be prevented through the control and maintenance of infested fish farms. Escapes from fish farms are known to be a major introduction pathway of Amur sleeper. At least 50% of the recent records of *P. glenii* outside the main area of its non-native distribution in East Europe are restricted to aquaculture facilities (Reshetnikov and Schliewen, 2013). Rigorous measures to prevent escapes from these facilities (for example, by applying fine mesh screens on outlet pipes of ponds, regular checking for Amur sleeper presence, and rigorous grading and sorting before transport) should be applied. Also, although escapes of Amur sleeper from garden ponds should be prevented by the EU IAS Regulation, awareness raising is also important and measures could be taken to remove all Amur sleepers from infested garden ponds.

Surveillance measures to support early detection

The species can be easily overlooked at early stages of invasion, which warrants the application of environmental DNA (eDNA), in complement of classic surveys, for early detection. Citizen-science initiatives can also enhance early detection. These measures should be applied by each MS, especially in areas close to known infestations of Amur sleeper. The eDNA technique is based on the amplification of DNA released by the species into the environment through mucus, faeces, urine and remains, and allows for species detection, even at very low Amur sleeper densities. Traditional fishing methods (electrofishing, fyke nets, seine nets, gill nets, etc) should preferably be combined with their use for other monitoring programmes (such as Water Framework Directive), in order to reduce costs and limit any negative impacts on non-target species.

Measures to achieve eradication

Newly detected Amur sleeper populations may be eradicated by application of chemical and mechanical removal techniques, but also by introducing native piscivorous fish. The latter method is environmentally friendly, cheap and very acceptable to stakeholders (Lemmens *et al.*, 2015), but may be less effective in conditions with low oxygen or poor water quality; Amur sleeper is a resilient fish species that can thrive in such circumstances, although pike or Eurasian perch much less so (Bogutskaya and Naseka, 2002). Mechanical removal is deemed possible in small, confined areas only, and therefore not effective if populations of Amur sleeper are detected in open waters (such as streams, rivers). Chemical removal (by applying rotenone) is possible in closed and (small) open waters (as has been shown for other invasive species), but this measure is the most controversial, as it has strong negative environmental side effects. The use of chemicals to eradicate fish is also legally constrained in the EU.

Methods to achieve control and mitigate impact

Integrated Pest Management (a combination of chemical and physical removal techniques) may be a way to control population densities of Amur sleeper. Efforts to control Amur sleeper should be focused on the current infestation sites, especially the most westerly invaded ponds in Bavaria (Germany), to avoid further spread of this invasive fish to Western Europe. General enhancing of the biotic resistance of lakes and rivers would be the most appropriate measure, although not feasible in a short period of time, due to its immense application scale and large associated costs.

Measures for preventing the species being introduced, intentionally and unintentionally.

This section assumes that the species is not currently present in a Member State, or part of a Member State's territory.

Measures for the prevention of intentional introductions do not need to be discussed further in this technical note.

MEASURE DESCRIPTION

As the species is listed as an invasive alien species of Union concern, the following measures will automatically apply, in accordance with Article 7 of the EU IAS Regulation 1143/2014:

Invasive alien species of Union concern shall not be intentionally:

(a) brought into the territory of the Union, including transit under customs supervision;
(b) kept, including in contained holding;
(c) bred, including in contained holding;
(d) transported to, from or within the Union, except for the transportation of species to facilities in the context of eradication;
(e) placed on the market;
(f) used or exchanged;
(g) permitted to reproduce, grown or cultivated, including in contained holding; or
(h) released into the environment

Also note that, in accordance with Article 15(1) – As of 2 January 2016, Member States should have in place fully functioning structures to carry out the official controls necessary to prevent the intentional introduction into the Union of invasive alien species of Union concern. Those official controls shall apply to the categories of goods falling within the Combined Nomenclature codes to which a reference is made in the Union list, pursuant to Article 4(5).]

Therefore measures for the prevention of intentional introductions do not need to be discussed further in this technical note.

Checking for stowaway specimens in fish farms and fish transports.

MEASURE DESCRIPTION

The contamination of fish consignments (for stocking or aquaculture) is a major pathway by which non-native organisms, including fish, are introduced to new areas. One of the best examples of this is the top mouth gudgeon *Pseudorasbora parva*, which was accidentally imported into Romania, and then introduced throughout Europe, in consignments of Asian carp species (Copp *et al.*, 2010). Checking for stowaway specimens of Amur sleeper (and other invasive species, for example, top mouth gudgeon) in fish farms and transports from within (and outside) the EU is therefore essential to prevent unwanted species being moved to regions where they do not occur yet.

The risk of introduction of Amur sleeper by human-mediated pathways (stowaway in fish transports) is estimated more important than natural colonisation from neighbouring areas. Amur sleeper was unintentionally introduced as a contaminant of consignments of fish (for example, common carp *Cyprinus carpio*) into Eastern Europe and the European part of Russia (Reshetnikov, 2013). Nowadays, many Western European aquaculturists buy fish in Eastern Europe and transport them to their own ponds. It is to be expected, since there are no border controls within the EU, that this will be the most important pathway for the introduction of Amur sleeper in Western Europe, as was the case in Poland (Copp *et al.*, 2005). In Germany, Amur sleeper was probably accidentally introduced via this pathway into managed fish ponds located in the integral nature reserve Charlottenhofener Weihergebiet in the upper Danube drainage (Bavaria, Germany; Reshetnikov and Schliewen, 2013). *Pseudorasbora parva* has also been introduced into Western Europe via the same vector (Verreycken *et al.*, 2007) and, within twenty years, many river basins have been invaded by this species (Gozlan *et al.*, 2010).

Zajicek *et al.* (2009) describe methods to prevent hitchhiking of non-native species in live shipments. Most problems with hitchhiking species occur when fish are harvested and loaded directly onto a hauling truck without passing through holding vats. Often a farmer first becomes aware of an unwanted species during harvest. It is essential for the farmer and the live hauler to place the fish in a holding tank first and inspect the fish in the net before loading. Unwanted fish will need to be carefully hand-sorted, a difficult task on commercial farms where thousands of pounds of fish are harvested at a time (Zajicek *et al.*, 2009).

As often this does not happen, fish transports should also be regularly checked for stowaway specimens of Amur sleeper (and other unwanted species). Import control of large trucks for fish transport has, however, proven to be very difficult. The checking of fish transport for stowaways can be done manually/visually or via new techniques, such as eDNA.

Manual and visual checking of fish transports for stowaways can be done with dip-net. Samples from the consignment can be visually checked for unwanted species; however, this is very difficult when the stowaway species is present in small quantities or when the container to be checked is very big, making unwanted species easily overlooked (pers. obs.). New tools like environmental DNA (eDNA) are promising. The eDNA is shed into the aquatic environment via faeces, skin, mucus and gametes, and can be used to detect the presence of a target species in a fish shipment, even at low densities (Minamoto *et al.*, 2012; Collins *et al.*, 2012). For specific detection needs, eDNA extraction and real-time PCR (qPCR) can be carried out within a few hours, making this technique a rapid, sensitive and specific method for the identification of an invasive species (Roy *et al.*, 2018). Depending on the technique used, one can test for the presence of one species, several unwanted species, or the whole array of fish present in the containment. Unfortunately, at the moment, these tests are not quick enough to be used as an instant tool to detect stowaways. As such, temporary quarantine of newly arrived fish consignments is necessary while waiting for the results (at least 48 h, R.Brys, pers. comm.). Thus, checking fish consignments at the fish farm before transport before they are loaded on a truck, would be much easier and probably more effective, although access to private grounds may be a problem in this case.

SCALE OF APPLICATION

As this measure is meant to prevent new introductions into the EU, especially into MS where the species is not present yet, it should be applied at fish transports entering the EU and moving between MS.

The Amur sleeper is present in many eastern MS since the mid-1900s. However, there is no available data on whether this measure has been applied (and at which scale) in Europe or anywhere else (author's statement). Most MS have some form of preventive measures to avoid unintentional introductions of stowaway species in consignments (for example, Live Fish Act in the UK), but it is unclear how and whether they are enforced.

EFFECTIVENESS OF MEASURE

Manually and visually checking fish transports for stowaways is very difficult, and unwanted species can be easily overlooked. Visual identification of fishes at the species level is also problematic, especially for very small specimens or early life stages (Roy *et al.*, 2018). Therefore, the screening of fish consignments is not fully efficient (Copp *et al.*, 2010).

New tools like eDNA are promising, but at the moment these tests are not quick enough to be used as an instant tool to detect stowaways. As such, testing for eDNA of unwanted species should be combined with temporary quarantine of newly arrived fish consignments. In the future, this measure may become more effective through the use of these new molecular techniques.

EFFORT REQUIRED

These measures should be taken any time fish transports are due to happen. On a yearly basis, for traditional aquaculture of cold-water fish, this would mainly occur in spring and autumn.

Only when a (law enforced) system where all fish transports are reported is developed, can these measures become more effective, still requiring flexible authorities to effectively check all transports.

RESOURCES REQUIRED

The resources needed for this preventive measure include: staff costs, costs for cars and material to check the consignments, costs of eDNA tests and costs of maintaining quarantine facilities. Costs can be reduced if samples of consignments are taken at the fish farm, rather than at the stocking sites (public, as well as private waters), because fish farms are less numerous than the stocking sites and, when quarantine is necessary, this can be done at the fish farm itself. Problems with access to private lands may hinder this last option, though.

No published information is available about the costs of this measure, but it can be expected that these are medium to high. If well organised, 300 to 500 people checking fish transports during four months per year is a rough estimate of the human resources needed for this measure (author's estimate).

SIDE EFFECTS

Environmental : Positive
Social: Negative
Economic: Negative

This measure would have very little side effects. A positive side effect is that other contaminant IAS could be identified. A small negative social effect could be that some fish consignments (those infested with Amur sleeper or other unwanted species) would not be stocked, or would be stocked at a later time. A small negative economic effect could occur for the fish farmer if an infested consignment was found. The effect could become bigger if the whole fish farm would be infested.

ACCEPTABILITY TO STAKEHOLDERS

Although most anglers and fish farmers will be glad that a new introduction of an invasive species will be prevented, some will certainly complain about non-stocked fish loads and more work to properly sort out the fish specimens. As the sorting out of the fish specimens will need to be more precise, it will take longer to undertake, which eventually may lead to higher mortalities in the stocked fish consignments.

ADDITIONAL COST INFORMATION

Preventing introductions should be considered as an initial step in the management of non-native species, as prevention is more feasible and cheaper than eradication. Inaction will lead to the introduction of Amur sleeper (and maybe other unwanted species) and, once the species is introduced, it will further spread and be hard to eradicate (Reshetnikov, 2013)

LEVEL OF CONFIDENCE[1]

Established but incomplete.

Very little information about the control of fish consignments is available, but most agree that stowaways in fish consignments are a major introduction pathway which should be controlled.

1 See Appendix

Awareness raising activities, including education and training.

MEASURE DESCRIPTION

Awareness of the threats posed by the introduction of invasive fish species (Amur sleeper and other unwanted fish species) by the public and key stakeholders is critical to reduce the risks of unintentional (and intentional) introductions. Three important sectors promote the species' introductions and spread: fish farmers, inland water fisheries (stocking practices) and the aquarium trade. Fish farmers, aquarium fish traders, fishery managers, governmental agencies and private fish pond owners should be informed about the risks of introducing Amur sleeper (and other unwanted invasive fish species) through escapes from ponds, fish farms and aquaria.

An awareness campaign and best practice guidance for key stakeholder groups is required. Scientifically robust information, awareness raising and training is needed for the stakeholder groups involved in aquaculture (better management practices in net cages, tanks, pond management, stocking), inland and recreational fisheries, and the aquarium trade. Media campaigns can also be useful to spread awareness faster and further.

Implementing a stock audit procedure (Davies and Britton, 2015) and employing trained and experienced fisheries officials may also reduce the extent of stock contamination by undesirable fish species, such as the Amur sleeper and other IAS (Tarkan *et al.*, 2015). Finally, an information campaign targeting anglers and other water body users on the threat caused by this invasive species should become widespread and be implemented for at least five years in each MS. The European Code of Conduct on Recreational Fishing and Invasive Alien Species could also be promoted at regional and national levels. Monitoring the effectiveness of such awareness programmes should be applied as well.

SCALE OF APPLICATION

Awareness raising should be applied in all MS of the EU.

Until now, this measure has not been very often applied in the EU, although recent campaigns have been developed, for example, in Ireland (www.invasivespeciesireland.com) and the UK (http://www.nonnativespecies.org).

Perccottus glenii *has a rounded snout and projecting lower jaw. © Maciej Bonk*

In the USA, awareness campaigns and outreach programmes are embedded in the non-native species programmes. One of the tasks of the Aquatic Nuisance Species Task Force is to "Educate and inform the general public and programme stakeholders about the prevention, management, and control of non-native species". Among others, they maintain a website and partner up with many different groups like fish clubs, state and federal agencies, several organisations, schools, companies, tribal and local governments, to increase education and outreach. One of the programmes implemented, Habit attitude focuses on the protection of the environment by preventing the release of unwanted fish and aquatic plants.

EFFECTIVENESS OF MEASURE

Unknown.

Although Amur sleeper is part of black lists in the USA, Canada and Europe, there is no information on awareness campaigns regarding *P. glenii* in Europe or elsewhere. Awareness raising campaigns and stakeholder specific guidelines are frequently used to reduce the risk of introduction or spread of invasive species, and seem to have been effective for other species, such as the northern snakeheads in the USA and Canada (Cudmore and Mandrak, 2006).

The effectiveness of this measure could be high if implemented strategically, especially involving careful awareness campaigns, advertising material and media work (such as Habitattitude campaign in the USA). However, other authors found that awareness (via Habitatattude) amongst hobbyists was low, and recommended that their behaviours may be improved by fostering hobbyist networks, creating materials that explain concrete, negative impacts and list prevention behaviours, and by disseminating these materials through trusted information sources (Seekamp *et al.*, 2016).

EFFORT REQUIRED

A drawback of public awareness and education programmes is that they need to be maintained over a long term period. Without active maintenance and creative advertising, the effects of awareness and education could quickly fade away.

RESOURCES REQUIRED

There is no information available about the costs, equipment or infrastructure that may be required to implement these measures, but it is widely accepted that prevention is more cost-effective than management of species such as the Amur sleeper.

SIDE EFFECTS

Environmental : Positive
Social: Positive
Economic: Neutral or mixed

Education and outreach will make the general public aware of the problems that invasive fishes cause, creating a greater awareness about IAS and the environment in general, thus having a positive environmental and social effect.

ACCEPTABILITY TO STAKEHOLDERS

As *P. glenii* is not important in the aquarium trade, very little opposition is expected against awareness campaigns on the dangers of introducing Amur sleeper.

ADDITIONAL COST INFORMATION

No specific costs are known for the implementation of this measure for *P. glennii*. In general, the cost of inaction is high, as it would probably lead to further introductions and spread of the species through aquaculture units, official or unofficial stocking, and uninformed anglers.

The cost-effectiveness is also high, as informed public and stakeholder groups support prevention of species introduction, and this is cheaper than eradication (Verbrugge *et al.*, 2014).

LEVEL OF CONFIDENCE[1]

Inconclusive.

There are no published papers on awareness campaigns for *P. glenii*; there are, however, several papers on awareness campaigns for invasive plants and other aquatic animals, but not all of them agree that these campaigns are successful in reaching the targeted stakeholders

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1 See Appendix

Measures to prevent the species spreading once they have been introduced.

Control and maintenance of fish farms to prevent escapes from infested aquaculture ponds.

MEASURE DESCRIPTION

In Germany, Amur sleeper unintentionally escaped into open waters from managed fish ponds located in the integral nature reserve “Charlottenhofener Weihergebiet” in the upper Danube drainage (NOBANIS, 2019). Typically, aquaculture water bodies are constructed on a natural water stream or canal. That water is used as a source for the fish ponds, while the surplus of water goes into the flood plain of the same stream. Reliable separation of larvae and small-sized young fish from departing water flow is a difficult task. Several multi-year studies in Eastern Europe showed that aquaculture ponds with populations of Amur sleeper became centres of secondary distribution in many regions of the current range of this invader (Reshetnikov, 2013). At least 50% of the recent introductions of *P. glenii* in Eastern and Central Europe outside of the main part of the Western Ukrainian subrange, are restricted to aquaculture facilities and, hence, may be consequences of local fish stocking activities of those farms (Reshetnikov and Schliewen, 2013). Beyer *et al.* (2007) also showed that specimens of top mouth gudgeon escaped from a fish farm to enter Tadburn Lake Stream via outflow waters, which discharge into the stream through a large, unscreened pipe at a rate of approximately 14 fish/1000 m^3, spreading downstream in significantly declining density.

Preventing escapes of specimens of Amur sleeper (and other invasive fish, such as top mouth gudgeon) from infested ponds is very difficult, as described above by Reshetnikov (2013). Fine mesh screens on the outlets of ponds can prevent some escapes, but are sometimes responsible for flooding of ponds when the screens get blocked by debris and green algae (pers. obs.). Therefore, screens should be regularly checked and cleaned. Special care should be taken when emptying ponds: aquaculture ponds are often emptied yearly, to harvest the cultured fish. The emptying is managed by a system of pipes that can be lowered so the water level drops, and the surplus water is guided to an adjacent canal, stream or river. Screen nets are used to prevent the escape of cultured fish, but often the meshes of these screens are not fine enough for stowaway specimens (especially larvae). Fine mesh screens should be used here, but this will tremendously slow the emptying, thus creating economic loss (higher fish mortality, higher predation possibility, longer working times; pers. obs.).

In theory, the excess water could be treated with fish larvae killing devices (for example UV-treatment, cfr. ballast water treatment) before flowing into adjacent waters, but in practice this is hardly realisable.

SCALE OF MEASUREMENT

Every fish farm should have a biosecurity plan and conduct regular inspections for diseases and nuisance species (Zajicek *et al.*, 2009). But in practice, the use of screens on outlets of aquaculture ponds is often the only measure applied to prevent escapes from the farm. No data are available about the scale at which these screens are used in pond aquaculture.

EFFECTIVENESS OF MEASURE

Effective.

Fine mesh screens will certainly diminish the number of specimens that escape from a fish farm to enter via outflow waters into open waters (Beyer *et al.*, 2007). However, reliable separation of larvae and small-sized individuals of Amur sleeper (and other invasive fish species, for example top mouth gudgeon) from departing water flows is a difficult task (Reshetnikov and Chibilev, 2009). Furthermore, often only coarse meshed screens are applied to aquaculture ponds to prevent the escape of farmed fish, which does not prevent small bodied fish (like Amur sleeper) and fish larvae escaping to adjacent waters.

EFFORT REQUIRED

Fine mesh screens should be applied year round, as larvae and small specimens drift from unscreened pipes at all times (Beyer, 2008). However, they are mostly necessary after reproduction and hatching (in Europe, in spring, for most fish species), and during the emptying of aquaculture ponds (often in autumn).

RESOURCES REQUIRED

No data are available on the resources needed to apply this measure, nor is any data available on how widely this measure is used, making it very difficult to estimate the required resources. Main expenses will be staff costs for applying the fine mesh screens, controlling and cleaning them. The costs of the material for the screens will be relatively low compared to labour costs.

SIDE EFFECTS

Environmental : Positive
Social: Neutral or mixed
Economic: Negative
Preventing specimens of Amur sleeper to escape from aquaculture facilities will also prevent other nuisance fish species to escape, which will diminish the pressure on the environment.

Applying fine mesh screens on pipe outlets of aquaculture ponds will slow down the draining of the ponds, and therefore create longer waiting times to empty the ponds. This can lead to higher predation by fish eating birds, general higher mortalities and increased time loss, obviously creating economic losses.

ACCEPTABILITY OF STAKEHOLDERS

Most aqua-culturists will not accept the potential economic losses associated with this measure.

ADDITIONAL COST INFORMATION

There will be no extra implementation costs for the MS. As Amur sleeper is on the EU list of invasive alien species of Union concern, fish farmers should already take all possible measures to prevent escapes of this species.

In general, cost of inaction is high, as it would probably lead to further spread of the species through aquaculture ponds, as was the case in several Eastern and Central European MS (Reshetnikov, 2013); the impacts and/or management of the species would eventually incur high costs.

The cost-effectiveness is medium to high; although placing of the screens will not stop the escape of specimens, it will certainly diminish the numbers that escape.

LEVEL OF CONFIDENCE[1]

Inconclusive.
Although dispersal of invasive fish species trough the overflows of aquaculture ponds is recognised as an important pathway by several authors (Beyer *et al.*, 2007;Zajicek *et al.*, 2009; Reshetnikov, 2013), very little information exists on the use and effectiveness of screens on outlet pipes to prevent fish escapes.

1 See Appendix

Measures for early detection of the species and to run an effective surveillance system for an early detection of a new occurrence.

Surveillance with traditional fish survey methods.

MEASURE DESCRIPTION

Electrofishing, fyke nets, gill nets, seine nets and traps are well-known and widely used methods for routine fish monitoring (for example via the EU Water Framework Directive(WFD)). They are also a measure to detect new fish species: round goby *Neogobius melanostomus* was first discovered in Flanders (Belgium) during WFD monitoring on the River Scheldt (Verreycken *et al.*, 2011) and again in 2019, naked goby *Gobiosoma bosc* was first found in the same river (Verreycken *et al.*, 2019). In Latvia, *P. glenii* was detected during research on the aquatic ecosystems of the amphibian *Bombina bombina* (Pupina *et al.*, 2015).

Surveillance sampling should target a variety of water bodies, as Amur sleeper could be introduced in a variety of waters, including oxbow lakes and artificial or natural standing and running waters. Electrofishing by wading or boat is the least intrusive fish-catching method for general surveying of a variety of rivers, wetlands and lakeshores. Also, fyke nets and traps are methods that allow to survey in a non-destructive way, when the nets are emptied at regular times (for example after 1 night). Gill-nets, however, may result in high mortalities of other non-target fishes, possibly including protected species (and other wildlife), and should only be used during routine survey work based on wider research/survey programmes (for example WFD fish monitoring in lakes). Efforts should be made to create synergies between routine monitoring programmes, such as application of the WFD, and the effort for early detection.

SCALE OF APPLICATION

This measure should be applied by each MS, especially in water bodies surrounding known infestation areas of Amur sleeper. In Eastern Europe, there are many waters where Amur sleeper is already present (Grabowska *et al.*, 2009; Lukina, 2011; Reshetnikov, 2013; Pupina *et al.*, 2015), but in Western Europe only one site in the Naab River, Bavaria (Germany), is known to have an Amur sleeper infestation. Monitoring of water bodies in the region of the expanding Bavarian subrange of *P. glenii* is needed (Reshetnikov and Karyagina, 2015). The Naab River is a Danube tributary and this population of *P. glenii* may already be, or may become, the source for downstream range expansion of this species, thereby threatening not yet invaded flood plain habitats along the upper and middle Danube in Germany, Austria, the western part of Slovakia and central Hungary (Reshetnikov and Schliewen, 2013).

Currently, no dedicated surveillance for Amur sleeper, or other invasive fish species, using traditional fish survey methods, is known to be ongoing on a wide scale. However, some MS and regions may have dedicated surveillance locally. Monitoring in the framework of other programmes (for example WFD) may, however, produce new data on occurrence of Amur sleeper and other invasive fish species.

EFFECTIVENESS OF MEASURE

Neutral.

Dedicated surveillance of Amur sleeper with traditional fish survey methods on a European scale will certainly provide new data on the distribution of this species and can be used as an early detection measure. Nonetheless, species at low densities in the early invasion stages, or in large water systems, may go unnoticed for long periods (Britton *et al.*, 2011b; Reshetnikov, 2013).

EFFORT REQUIRED

The effort required for high probability early detection of aquatic non-native species is substantial. Hoffman *et al.* (2011) allocated sampling sites using (1) a spatially balanced random design and (2) a few targeted areas. The two designs did not have significantly different species accumulation curves, but the targeted area design samples had higher species richness and detected non-native species with a significantly higher probability. It was possible to reduce the effort required to detect established non-native species but, in contrast, the effort required to detect an ultra-rare, newly arrived species, remained large.

It may, therefore, be important to incorporate other wider survey methods, such as citizen support for early detection. Coordination of surveillance with other sampling schemes in

Europe (for example EU WFD fish sampling) and participation of anglers and professional fishers should be developed. The surveys and monitoring efforts will vary among MS, with a focus on the MS where Amur sleeper is already present.

RESOURCES REQUIRED

MS need to invest in electro-fishing equipment and fyke nets. Additionally, gill nets and beam trawls nets can be used. Many MS are already in possession of fishing gear for surveys in the framework of other monitoring programmes. This indicates that the resources required differ for different MS, making it very difficult to estimate costs.

Prices of electrofishing gear are estimated to range from €750 to €4,000 and more; fyke nets are between €500 and €1,500, while gill nets are cheaper, but different mesh sizes need to be applied and high mortalities to non-target fishes may occur. Large beam trawls can be used for large rivers, but must be operated from a ship, and cost ten thousands of euro's (author's estimation). The costs for operating these fishing gears are an important extra cost to consider, as they are very labour intensive.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Negative

Positive effects on the environment are that other invasive species can be discovered and removed from the water bodies. However, the use of some gear (especially gill nets) may incur high mortalities of non-target species and therefore have a negative environmental impact. The negative effects can be mitigated by emptying the nets at regular times, but mortalities due to the use of gillnets are unavoidable (pers.obs.).

No social effects are to be expected, except when high mortalities would occur, and anglers would oppose to potential catches disappearing.

By-catches in fykes and mortality in gillnets can cause a decrease in catches by commercial fishermen.

ACCEPTABILITY TO STAKEHOLDERS

Electrofishing, fyke and gill netting are commonly used as survey methods for monitoring fish populations in rivers, lakes and canals. Care should be taken, however, that by-catches and mortalities of non-target species are kept to a minimum. To this end, a grid should be placed at the entrance of fykes when otters, beavers or seals are known to be present. Electrofishing should only be performed by experienced staff, so that casualties are avoided. Gill nets have to be checked very regularly to avoid mass mortalities (author's own experience). Nevertheless, as mortality can happen, anglers and commercial fishermen might be against this measure.

ADDITIONAL COST INFORMATION

Intensity of detection measures will vary based on risk of introduction and potential for spread in each MS. Government fisheries and relevant research and academic institutes may already use this measure in the framework of existing monitoring programmes (for example for the implementation of the WFD), and thus there will be no substantial additional costs to those. In this case, cost-effectiveness will be high.

Early detection is extremely important in eradication and management actions. Inaction will lead to very high costs.

LEVEL OF CONFIDENCE[1]

Well established.

Many papers confirm that surveys using traditional fishing methods (electrofishing, fyke netting, etc.) were able to detect new non-native species. There are also papers describing the negative aspects of these methods, such as non-target mortalities, imperfect detection, etc.

1 See Appendix

Surveillance with molecular methods (eDNA).

MEASURE DESCRIPTION

Environmental DNA (eDNA) surveying is based on genetic material obtained directly from water samples; it is an efficient and non-invasive sampling approach (Thomsen and Willerslev, 2015). This method allows for surveying and monitoring without the need to collect living organisms and enables to survey organisms that are evasive and elusive. The content of an eDNA sample is usually analysed by amplification using polymerase chain reaction (PCR) and DNA sequencing. The amplification is done either by a single-species approach using specific primers, or by multiple species approach using generic primers for a given focal group of organisms. Especially the fast advancing next-generation sequencing (NGS) technologies have made comprehensive biodiversity surveys possible for limited effort and costs (Ficetola *et al.*, 2008). The technique is also applicable to other non-native aquatic species, such as crayfish, Chinese mitten crabs, American bullfrog and other non-native fish species. Because this approach can detect the existence of a few DNA molecules in the water, the presence of a species, even at very low densities, can be determined very accurately (Ficetola *et al.*, 2008; Dejean *et al.*, 2012).

SCALE OF APPLICATION

Molecular identification techniques hold the potential for rapid, accurate assessment of the presence of a species in a water body.

No standard eDNA surveillance/early detection programme for Amur sleeper is ongoing, but sampling should be focused in the surroundings of already established Amur sleeper populations, in order to early detect new species occurrences. As mentioned in the first *Prevention of unintentional introductions and spread* section, possibly infested fish farms, as well as areas around the infested ponds, should also be monitored very regularly.

EFFECTIVENESS OF MEASURE

Effective.

For instance, Blackman *et al.* (2017) reported the first record of *Gammarus fossarum* in the UK using eDNA, Dougherty *et al.* (2016) detected rusty crayfish *Faxonius (Orconectes) rusticus* at low abundances using this technique and Dejean *et al.* (2012) could improve the detection of American bullfrog *Lithobates catesbeianus* with eDNA.

Although the overall sensitivity of eDNA detection varies between studies and among species due to differences in methods, environmental conditions and the target species behaviour (Furlan *et al.*, 2016), detection successes of aquatic species with eDNA have been found higher than with standard fishing surveys, regardless of the population size and life stage of the target species. Other than lower detection rates, traditional surveys also cost at least 250% more in terms of expenditure and time. However, more research into the complementary use of different survey methods is required (Evans *et al.*, 2017).

The eDNA approach should be considered as a fast, cost-effective and standardised way to obtain information on absence/presence of the target species. New research on the use of eDNA has made this tool much stronger and even estimation of the relative abundance of the non-native species is now possible (R. Brys, pers. comm.).

EFFORT REQUIRED

Depending on its size, per pond, generally 1 to 2 hours of fieldwork are needed to obtain a full-covering spatial sampling, in order to appropriately test for the presence/absence of Amur sleeper (or other fish species) individuals via eDNA. For riverine systems, more efforts are required (Brys, pers. comm.).

Tests of the sensitivity of the technique at a spatial scale show that the detection probability was significantly affected by both the distance at which the samples were taken from the specimens and the density of specimens (Mauvisseau *et al.*, 2019). Because eDNA can occur very clustered in lentic waters, due to its limited dispersion capacity and relative fast decay rates, spatial sampling and merging of subsamples is needed to obtain efficient detection probabilities, especially if the target species occurs at low densities or shows a limited action radius within the water. Also, the type of technique applied is important: species-specific eDNA approaches, such as quantitative PCR (qPCR) and digital droplet PCR (ddPCR) methods, are far more sensitive in terms of detection probabilities and offer better insights in eDNA copy numbers per litre of water than the much more generalist eDNA meta-barcoding approaches (R. Brys, pers. comm.). The timing of sampling is equally important, since high turbidity of the water can inhibit amplification success, and thus detection efficiency. Water sampling is, consequently, preferred when the water is as clear as possible.

eDNA analyses need to be carried out in laboratories that are able to follow the general eDNA guidelines and protocol restrictions, in order to avoid false positive or false negative detections. Additionally, several control mechanisms need to be incorporated, such as the inclusion of field- and lab-blanks, and positive controls with eDNA from the target species (Harper *et al.*, 2018).

RESOURCES REQUIRED

The resources required for eDNA surveillance of Amur sleeper are not known.

General sampling and eDNA analysis are best performed with two staff members. The use of ddPCR analysis is preferred over traditional or quantitative PCR (qPCR) analysis. In comparison to qPCR, ddPCR is more sensitive to detect very low eDNA concentrations, is able to estimate exact concentrations, and is also less prone to inhibition at the stage of amplification, thus likely having more successful detections (Brys, pers. comm.). To avoid the risk of cross-contamination during the process of water filtering in the field or laboratory, but also at the stage of eDNA extraction, the use of enclosed capsule filters is generally recommended.

A rough estimation of the costs associated with one eDNA analysis for an 'average-sized' pond, is between €80 and €90 (Brys, pers.comm.). It is clear that handling costs significantly depend on the size of the pond, expertise of the scientists/lab technicians who are conducting the work and protocol available. If a larger number of ponds/samples needs to be investigated, additional costs for negative blanks and positive controls (one or two per 20-25 samples) need to be taken into account (Brys, pers.comm.).

SIDE EFFECTS

Environmental: Positive
Social: Neutral or mixed
Economic: Neutral or mixed

A positive environmental effect is that generic tests can be used to detect other invasive aquatic species than those targeted. No social or economic effects are to be expected.

ACCEPTABILITY TO STAKEHOLDERS

eDNA sampling is rapid and non-invasive (Harper *et al.*, 2018), being generally acceptable to stakeholders

ADDITIONAL COST INFORMATION

All MS should start an eDNA surveillance system for Amur sleeper, as this is a rapid, non-invasive, cost-efficient biodiversity monitoring tool (Harper *et al.*, 2018). Early detection is very important, and Amur sleeper and other invasive fish species can be easily overlooked with traditional fishing methods, when occurring at low densities (Britton *et al.*, 2011b). Cost of inaction will be high and will reduce the effectiveness of future eradication or management measures.

LEVEL OF CONFIDENCE[1]

Well established.

Extensive information on the use of eDNA as a surveillance measure for invasive species is available. It has proven to be a well-developed method that is very reliable and cost-effective for species detection in aquatic environments.

1 See Appendix

Citizen-science.

MEASURE DESCRIPTION

Early detection of aquatic non-native species such as Amur sleeper is important in order to act rapidly. Involvement of citizens (for example anglers and fisheries managers) can contribute to initiatives for the early detection of species undertaken by governments. Recreational fishers and fisheries managers should be quickly aware of a new species in their water systems. Given proper training, citizen scientists should be able to participate in the detection of invasive fishes in their local area, and with a validation system in place, the data they collect can be used with confidence by professional scientists to track and respond to early detection (Gallo and Waitt, 2011). As such, citizen involvement in early detection can be very useful.

SCALE OF APPLICATION

Citizen-science initiatives should be expanded in all MS. Surveillance using citizen scientists can be applied at any desired geographic scale. It is useful to implement general, large scale surveillance to train volunteers in identifying the species and to intercept any solitary escaped or translocated individuals in uninvaded areas.

Around existing populations, more dedicated citizen-science surveys can be organised. For plants and birds, such initiatives are used successfully in the whole of Europe (for example observations.be and observations.nl). For aquatic animals like fishes, mainly initiatives to report anglers' catches are used extensively and sometimes by-catches of new non-native fishes are reported (for example the app MijnVismaat.nl in the Netherlands). An application called 'Invasive Alien Species Europe' , developed by the Joint Research Centre of the European Commission, can be used by the general public to acquire and upload information on the IAS of Union concern, which is the case of the Amur sleeper.

EFFECTIVENESS OF MEASURE

Neutral.

Trained citizen scientists can easily recognise a species like Amur sleeper and can report first catches of this species. Although no data are available for Amur sleeper, other non-native invasive species were reported for the first (or nearly first) time by anglers, for example bighead goby *Ponticola kessleri* in Belgium (Jacobs and Hoedemakers, 2013) and

*Amur sleeper (*Perccottus glenii*) – detail of the head, freshwater fish of Odontobutidae family. © Petrtyl. CC BY-SA 3.0*

naked goby *Gobiosoma bosc* in the Netherlands (van Emmerik and Beelen, 2018). On the other hand, (solitary) anglers often do not want to be disturbed while fishing and do not report their catches (pers. obs.).

EFFORT REQUIRED

Surveys are best performed continuously, but anglers often do not go out fishing in winter time.

RESOURCES REQUIRED

Citizen-science platforms may have relatively high organisational costs and need careful planning and start-up. The amount of resources required depends on the area of potential spread in each MS. Each MS must create a strategy for specific and measurable monitored citizen-science involvement. At the very least, each MS should organise a programme that trains citizen scientists to detect the arrival and dispersal of invasive freshwater fishes in their local areas and to report them into an online database, with scientific coordination. The data need to be validated by a scientific coordinator. The cost of this kind of set-up and coordination is roughly estimated at least at 100,000 Euro per year (one coordinator, training, meetings, website development and maintenance) (pers. obs.).

SIDE EFFECTS

Environmental: Positive
Social: Positive
Economic: Neutral or mixed

Citizen-science initiatives build wider awareness and understanding among the public and specific stakeholder groups; this is positive for the environment, as more non-native species will be reported. Citizen scientists will maybe get in contact with each other to survey together, which enhances social contacts.

ACCEPTABILITY TO STAKEHOLDERS

Generally, citizen-science initiatives are non-destructive and they build wider awareness and understanding among the public and specific stakeholder groups.

ADDITIONAL COST INFORMATION

All MS should start citizen-science surveillance for Amur sleeper, as this is a non-invasive and low cost tool to monitor invasive fishes. Early detection is very important, and Amur sleeper and other invasive fish species can be easily missed during traditional fishing surveys, especially when occurring at low densities (Britton *et al.*, 2011b). Cost of inaction will be high and will reduce the effectiveness of future eradication or management measures.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

Citizen-science for IAS reporting, in general, is well established, but the use of volunteers for invasive fishes surveillance is much less common. Also information on the effectiveness of citizen-science compared to other methods (for example eDNA) is mostly lacking.

1 See Appendix

Stocking with native predators.

MEASURE DESCRIPTION

Eradication of *P. glenii* populations after stocking with native predators (for example pike *Esox lucius*) may be possible in small closed systems (like aquaculture ponds and oxbows), if action is taken soon after detection of the species. Amur sleeper, however, can withstand very harsh conditions like low oxygen contents and high alkaline concentrations, freezing in, drying out, etc. Most of the predators will not be able to withstand these harsh conditions; therefore, if present under these environments, it will be difficult to eradicate all specimens (Verreycken, 2013).

Many authors (for example, Bogutskaya and Naseka, 2002; Reshetnikov, 2013; Telcean and Cicort-Lucaciu, 2016) describe how Amur sleeper populations are suppressed by the presence of large fish predators. In natural waters with high biotic resistance where native predators are common, populations of Amur sleeper are non-existing or densities are extremely low. Also for other invasive species, for example top mouth gudgeon, it was demonstrated that native predators can reduce, and even eradicate, the invader (Lemmens *et al.*, 2015).

This measure can also be used to efficiently manage and contain invasive fish species (for example top mouth gudgeon, Amur sleeper) in ponds and other small closed water systems (Britton *et al.*, 2011a).

SCALE OF APPLICATION

Only newly detected invasions in small closed systems could benefit from this eradication measure. In larger open waters, stocking with pike and other predators may well be an effective strategy for limiting the size of Amur sleeper populations (Bogutskaya and Naseka, 2002).

EFFECTIVENESS OF MEASURE

Unknown.

Although eradication of Amur sleeper by native predators may well be possible in small closed systems, this measure is more likely to be effective as a management measure for limiting the size of Amur sleeper populations. In a review paper, Rytwinski *et al.* (2018) found no evidence for the effective removal of invasive fishes through the use of predatory fish only.

EFFORT REQUIRED

Stocking of native predators has to be maintained during several years (Lemmens *et al.*, 2015). The native predators should best be of different sizes, so that all length stages of Amur sleeper are eaten. One could also choose to stock different species of predators for example pike for larger sleepers and Eurasian perch (*Perca fluviatilis*) for smaller specimens, for better effectiveness.

RESOURCES REQUIRED

Although stocking of natural predators for eradication of invasive species is a recent phenomenon, there is the longstanding tradition of pike stocking in the restoration of shallow ponds and lakes (Lemmens *et al.*, 2015). However, no quantitative data on the resources required are available. Costs will be limited, compared to the use of chemical removal techniques.

SIDE EFFECTS

Environmental: Negative
Social: Neutral or mixed
Economic: Neutral or mixed

Stocking of pike and/or perch can restore the ecological resistance of fish communities against invasion by non-native species (Lemmens *et al.*, 2015), but it can also promote increased predation pressure on non-target species. No social or economic effects are expected.

ACCEPTABILITY TO STAKEHOLDERS

While in comparison with eradication programmes using rotenone, the introduction of pike fingerlings is more feasible, cost-effective, and sustainable (Lemmens *et al.*, 2015), the manipulation of numbers of predatory fish might be considered not acceptable, especially in aquaculture ponds.

ADDITIONAL COST INFORMATION

All MS where new Amur sleeper infested water bodies are detected should take immediate measures. The cost for stocking predatory fish in these ponds will be rather low, compared to other measures for eradication. Costs of inaction could be very large, if the invasive fish escapes (for example during flooding) from the infested ponds and drifts into open waters. No data are available on socio-economic aspects of this measure, but one can assume that stocking of predatory species in aquaculture ponds will cause lower productivity due to predation of cultivated fish and, therefore, be controversial.

LEVEL OF CONFIDENCE[1]

Well established.

Although several papers exist on the use of predatory fish as a management tool to control invasive fish, most of them offer no conclusive evidence that it also works for eradication.

1 See Appendix

Dewatering and physical control.

MEASURE DESCRIPTION

Eradication of *P. glenii* populations through dewatering and physical removal is only possible in small closed systems (like aquaculture ponds and oxbows). The water level of infested ponds can be lowered, or the pond can be completely emptied, and then physical removal with electrofishing and netting (fykes, traps, seine nets) can be done. Physical removal with seine nets in shallow waters, without lowering the water level, was also effective in the case of top mouth gudgeon (Britton *et al.*, 2010). However, as Amur sleeper can withstand low oxygen contents, freezing in and drying out, it will be difficult to eradicate all specimens like this (Verreycken, 2013). Non-target species should be stocked elsewhere until eradication is complete. Care should be taken that no specimens of Amur sleeper escape with the out flowing water (see *Control and maintenance of fish farms to prevent escapes from aquaculture ponds* section for more details).

This measure can also be used to efficiently manage and contain invasive fish species (for example top mouth gudgeon, Amur sleeper) in ponds and other small closed water systems (Britton *et al.*, 2011a).

SCALE OF APPLICATION

Only newly detected invasions in small closed systems could benefit from this eradication measure. In larger open waters, new infestations of Amur sleeper cannot be eradicated using this measure.

EFFECTIVENESS OF MEASURE

Ineffective.

The effectiveness of the combination of dewatering and physical removal was not covered in Rytwinski *et al.* (2018) – the authors only found one study where dewatering was used and it was classified as an ineffective measure for eradication. Also, the combined use of different physical removal techniques was found to be ineffective for eradication.

Environmental DNA can be used to test whether a complete eradication was performed, as DNA fades quickly after removal of the targeted species.

This measure will be more effective to manage and contain invasive fish populations.

EFFORT REQUIRED

Repeated removal attempts will result in higher efficiency. This measure should be repeated every year until eradication is found complete.

RESOURCES REQUIRED

No publications are available about the sources required for the combination of dewatering and physical removal. Aquaculture ponds are commonly equipped with draining pipes, so emptying/lowering water level in those is not a problem. The tools for physical removal (electrofishing apparatus, fyke and seine nets) have to be purchased. Also, staff costs can be high, because this measure is labour intensive. When not available at the site, ponds to stock the non-target fish species can be temporarily rented.

Britton *et al.* (2010) estimated the cost for a near eradication of top mouth gudgeon (15 specimens left after 5 biomanipulation exercises) in a small (0.3 ha) and shallow (<1.5 m) lake to be £2,100.

SIDE EFFECTS

Environmental: Negative
Social: Negative
Economic: Negative

Emptying ponds or lowering the water level to a minimum can be destructive for other aquatic life (fish, as well as invertebrates; Britton *et al.*, 2010), so care should be taken to move all non-target species to other ponds prior to applying this measure. Nevertheless, this operation will definitely impact non-target aquatic animals.

Removal of valuable fish species and a possible prohibition for angling in the infested ponds will have negative social and economic impacts.

ACCEPTABILITY TO STAKEHOLDERS

Emptying ponds, removing valuable fish species and prohibiting angling in infested ponds will negatively impact social and economic aspects and certainly face opposition from some stakeholders.

ADDITIONAL COST INFORMATION

The cost for draining and subsequent removal of the invasive fish will be much lower than eradication with chemicals (Britton *et al.*,2010). Cost-effectiveness is estimated medium to high. Costs of inaction could be very large if the invasive fish escape (for example during flooding) from the infested ponds and drift into open waters. No data are available on socio-economic aspects of this measure, but there will be temporarily less revenue for fisheries and fish farms with infested ponds.

LEVEL OF CONFIDENCE[1]

Inconclusive.

Several studies exist on the use of combinations of physical removals for eradication, but many are rated with a low study validity (Rytwinski *et al.*, 2018) and none refer to the combination of those with dewatering.

1 See Appendix

Measures to achieve rapid eradication after an early detection of a new occurrence.

Chemical control.

MEASURE DESCRIPTION

Eradication of *P. glenii* populations using chemicals, such as rotenone is probably possible in small closed systems (like aquaculture ponds and oxbows).

This measure was successfully used for eradicating the invasive top mouth gudgeon *Pseudorasbora parva* in the UK (Britton and Brazier, 2006; Britton *et al.*, 2008).There, an established population of top mouth gudgeon was discovered in a recreational fishery in Northwest England in 2002. Eradication involved the fishery being treated twice with a rotenone-based piscicide. *P. parva* density was high prior to rotenone application and, following application, no specimens were recorded. Non-target species in the fishery were removed prior to rotenone application; following rotenone degradation (rate of decomposition depends upon several factors, including temperature, pH, water hardness and sunlight), they were re-introduced and subsequently spawned, with young-of-the-year recorded (Britton and Brazier, 2006). Subsequently, several other lakes in England and Wales were also successfully treated with rotenone to eradicate top mouth gudgeon (Britton *et al.*, 2010).

Rotenone was also successfully applied to eradicate the invasive smallmouth bass *Micropterus dolomieu* in a 4 km reach of the Rondegat river in South Africa (Weyl *et al.*, 2013, 2014). Rotenone was applied to the river using a series of drip cans sited at seven locations spaced approximately at 1-h water travel time intervals to maintain the recommended treatment concentration of 1 mg/l CFT Legumine (5 % active rotenone) during a 6-h treatment (Jordaanand Weyl, 2013). Rotenone can be deactivated by applying potassium permanganate (in granular form or as a 2.5% solution) at the downstream end of the reach where eradication is not necessary (Finlayson *et al.*,2000). Deactivation activity increases directly with increase in temperature, and applicators should take in account that chemical reactions slow by 50% for each 10 °C reduction in temperature and increase by twofold for each 10 °C increase.

Eradication of Amur sleeper with chemicals may be more difficult than for the abovementioned invasive fish species. Experiments have shown that, of all species of ‘weed fishes’, Amur sleeper is the most resistant to lime chloride and ammonia water (Bogutskaya and Naseka, 2002). However, 100% death occurs at concentrations of 0.3 g lime chloride/l water at more than 6-h exposure. As such, Bogutskaya and Naseka (2002) conclude that this measure can only be applied in small pools. Ammonia was used to eradicate Amur sleeper in a catchment canal; at water temperatures of 7–8 °C and pH 9.0, 100% death of Amur sleeper occurred in 1 hour and 5 minutes, after1 ml of ammonia water was diluted in one pool (Bogutskaya and Naseka, 2002).

This measure can also be used to efficiently manage and contain invasive fish species (for example top mouth gudgeon, Amur sleeper) in ponds and other small closed water systems (Britton *et al.*, 2011a).

The use of piscicides has EU/national/local legal restrictions. Rotenone was withdrawn from use in the European Union in 2007 (Schapira, 2010), but derogations are probably possible in some MS (for example Britton *et al.*, 2010).

SCALE OF APPLICATION

Newly detected invasions of Amur sleeper in small closed systems can be eradicated with chemicals (Bogutskaya and Naseka, 2002; Britton *et al.*, 2010). In larger open waters, the use of chemicals may be less effective. However, small streams (width 5 m, length 4 km) have been treated successfully with rotenone to eradicate smallmouth bass (Weyl *et al.*, 2013).

EFFECTIVENESS OF MEASURE

Neutral.

Chemicals have been used successfully to eradicate a range of fish species (also Amur sleeper, see above). Rytwinski *et al.* (2018), however, found several studies where chemical eradication was thought to be ineffective. Rotenone was reported effective in eradicating a non-native fish in 75% of the datasets, while antimycin A was reported effective in 89% of the data sets.

EFFORT REQUIRED

Application of multiple treatments is more effective than single treatments (Rytwinski *et al.*, 2018). In a river, rotenone was applied using a series of drip cans sited at seven locations spaced approximately at 1-h water travel time intervals to maintain the recommended treatment concentration of 1 mg/l CFT Legumine (5% active rotenone) during a 6-h treatment (Weyl *at al.*, 2013).

RESOURCES REQUIRED

It is recommended to undertake an effective risk-based, decision-making framework concerning the control, mitigation and eradication of invasive fauna previous to applying this measure (Britton *et al.*, 2010).

The costs of applying rotenone are high and were calculated for six ponds and lakes in the UK (for the eradication of top mouth gudgeon) as ranging from £6,600 (€7,500) for a small pond to £61,000 (€70,000) for a larger lake (Britton *et al.*, 2010).

SIDE EFFECTS

Environmental: Negative
Social: Negative
Economic: Negative

Although eradication using piscicides is acknowledged as a key option for impact mitigation and remediation, and has been used successfully across the world, it is rarely used in Europe. In Europe, it is viewed as a controversial and almost impossible goal due to its high expenses, difficulty of success and the likelihood of imposing substantial collateral damage on native species (Britton *et al.*, 2008). Since the application of most chemicals is not species specific, high collateral damage can occur (despite efforts to remove ecologically and economically important fish species prior to the use of the chemical), which leads to negative environmental, social and economic effects.

ACCEPTABILITY TO STAKEHOLDERS

Over the past years, the use of rotenone (and other chemicals) has become a concern to a variety of interests, including environmental and animal rights groups. As a result, its use in the USA has been challenged, halted, or discouraged (American Fisheries Society). Also, in the UK, where it was applied to eradicate top mouth gudgeon in lakes some years ago, it was viewed as controversial (Britton *et al.*, 2010). In addition, there is very little public support for the use of chemicals (Witmer *et al.*, 2015).

Good communication with stakeholders about why and how chemicals could and should be used, could make this measure more acceptable (author's perception).

ADDITIONAL COST INFORMATION

Although the application of chemicals is expensive, especially on a MS level, this method can be seen as being cost-effective (Witmer *et al.*, 2015).

LEVEL OF CONFIDENCE[1]

Well established.

Many papers are available about the use of chemicals (and their effectiveness) for eradication purposes of invasive fish species.

1 See Appendix

Measures for the species' management.

Integrated Pest Management.

MEASURE DESCRIPTION

Integrated Pest Management using biocontrol (introducing native predators) and biomanipulation (intensive fish removals) can significantly reduce abundances of lentic populations of small invasive fishes (for example top mouth gudgeon). Removals provide short-term population suppression, but high effort is needed to overcome compensatory responses, as after each reproductive season, the remaining fish compensate through increased reproductive output. Biocontrol can provide longer-term suppression, but could invoke unintended ecological consequences via 'stocking-up' food webs (Davies and Britton, 2015).

SCALE OF APPLICATION

Everywhere where possible in parts of the EU with widespread populations of Amur sleeper. No data are available about scales and successes of this measure.

EFFECTIVENESS OF MEASURE

Unknown.

Davies and Britton (2015) report successful management of top mouth gudgeon through this type of measure in a closed water. Population density in an invaded pond over two reproductive seasons reduced from > 60 to < 0.1 individuals per square meter. In open, connected waters, this measure

*Amur sleeper (*Perccottus glenii*) from the Danube Delta in Vylkove, South-Western Ukraine. © Yuriy Kvach. CC BY-SA 3.0*

will not be feasible (pers. obs.). No publications are available for Amur sleeper.

EFFORT REQUIRED

Repeated removal attempts will result in higher efficiency: Davies and Britton (2015) carried out mass removal at approximately 6-month intervals for two years. Also, stocking of native predators has to be maintained during several years (Lemmens *et al.*, 2015).

RESOURCES REQUIRED

The tools for physical removal (electrofishing apparatus, fyke and (micro-mesh) seine nets) have to be purchased. Also, staff costs can be high, because this measure is labour intensive. When not available at the site, ponds to stock the non-target fish species can be temporarily rented.

Britton *et al.* (2010) estimated the cost for a near eradication of top mouth gudgeon (15 specimens left after 5 biomanipulation exercises) in a small (0.3 ha) and shallow (<1.5 m) lake to be £2,100. Also, the native piscivorous fishes have to be purchased (pike 20–40 cm approx. €5/piece, perch 10–15 cm €11/kg) (www.aquafarm.be, accessed 02/08/2019).

SIDE EFFECTS

Environmental: Negative
Social: Negative
Economic: Negative

Removal of invasive fishes can be destructive for other aquatic life (fish, as well as invertebrates) (Britton *et al.*, 2010), so care should be taken to move all non-target species to other ponds prior to applying this measure. Nevertheless, this operation will definitely impact non-target aquatic animals. Also will the removal of valuable fish species, and a possible prohibition for angling in the infested ponds will have negative social and economic impacts.

ACCEPTABILITY TO STAKEHOLDERS

The introduced predators may expand their prey range to non-target native species, leading to irreversible effects (Davies and Britton, 2015). Also removal of invasive fishes by netting can injure other valued species. Especially in aquaculture ponds, biomanipulation and biocontrol might be considered not acceptable.

ADDITIONAL COST INFORMATION

Costs of inaction could be very large, if the invasive fish escape (for example during flooding) from the infested ponds and drift into open waters. No data are available on socio-economic aspects of this measure, but there will be temporarily less revenue for fisheries and fish farms with infested ponds.

LEVEL OF CONFIDENCE[1]

Inconclusive.

Only one study was found that rigorously tested the combined use of biocontrol and biomanipulation as a management measure for invasive fish species.

1 See Appendix

Bibliography

Beyer, K. (2008). Ecological implications of introducing *Leucaspius delineatus* (Heckel, 1843) and *Pseudorasbora parva* (Temminck and Schlegel, 1842) into inland waters in England. *PhD Thesis, University of Hull*, 445 pp.

Beyer, K., Copp, G.H.,and Gozlan, R.E. (2007). Microbabitat use and interspecific associations of introduced top mouth gudgeon *Pseudorasbora parva* and native fishes in a small stream. *Journal of Fish Biology*, 71, 224–238.

Blackman, R.C., Constable, D., Hahn, C., Sheard, A.M., Durkota, J., Hänfling, B. and Lawson Handley, L. (2017).Detection of a new non-native freshwater species by DNA metabarcoding of environmental samples – first record of *Gammarus fossarum* in the UK. *Aquatic Invasions*, 12(2), 177–189.

Bogutskaya, N.G. and Naseka, A.M. (2002). *Perccottus glenii* Dybowski, 1877. Freshwater Fishes of Russia, Zoological Institute RAS. http://www.zin.ru/Animalia/Pisces/eng/taxbase_e/species_e/perccottus/perccottus_glenii_eng.pdf.

Britton, J.R.,and Brazier, M. (2006). Eradicating the invasive top mouth gudgeon *Pseudorasbora parva* from a recreational fishery in Northern England. *Fisheries Management and Ecology*, 13, 329–335.

Britton, J.R., Davies, G.D.,and Brazier, M. (2010). Towards the successful control of the invasive *Pseudorasbora parva* in the UK. *Biological Invasions*, 12(1), 125–131.

Britton, J.R., Davies, G.D., Brazier, M.,and Chare, S. (2008). Case studies on eradicating the Asiatic cyprinid Pseudorasbora parva from fishing lakes in England to prevent their riverine dispersal. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 18, 867–876.

Britton, J.R., Gozlan, R.E. and Copp, G.H. (2011a). Managing non-native fish in the environment. *Fish and Fisheries*, 12(3), 256–274.

Britton, J.R., Pegg, J. and Gozlan, R.E. (2011b). Quantifying imperfect detection in an invasive pest fish and the implications for conservation management. *Biological Conservation*, 144 (9), 2177–2181.

Collins, R.A., Armstrong, K.F., Meier, R.,Yi, Y., Brown, S. D. J., Cruickshank, R. H., Keeling, S., and Johnston, C. (2012) Barcoding and border biosecurity: identifying cyprinid fishes in the aquarium trade. PLoS ONE, 7, e28381.

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. and Wiesner, C. (2005). To be, or not to be, a non-native freshwater fish? *Journal of Applied Ichthyology*, 21, 242–262.

Copp, G.H., Vilizzi, L. and Gozlan, R.E. (2010). Fish movements: the introduction pathway for top mouth gudgeon *Pseudorasbora parva* and other non-native fishes in the UK. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 20, 269–273.

Cudmore, B. and Mandrak, N.E. (2006). Risk assessment for northern snakehead (*Channa argus*) in Canada. Canadian Science Advisory Secretariat, Department of Fisheries and Oceans, Ottawa, ON, Canada.

Davies, G.D. and Britton, J.R. (2015). Assessing the efficacy and ecology of biocontrol and biomanipulation for managing invasive pest fish. *Journal of Applied Ecology*, 52, 1264–1273.

Dejean, T., Valentini, A., Miquel, C., Taberlet, P., Bellemain, E. and Miaud, C. (2012). Improved detection of an alien invasive species through environmental DNA barcoding: the example of the American bullfrog *Lithobates catesbeianus*. *Journal of Applied Ecology*, 49(4), 953–959.

Dougherty, M.M., Larson, E.R., Renshaw, M.A., Gantz, C.A., Egan, S.P., Erickson, D.M., and Lodge, D.M. (2016). Environmental DNA (eDNA) detects the invasive rusty crayfish *Orconectes rusticus* at low abundances. *Journal of Applied Ecology*, 53, 722–732.

Evans, N.T., Shirey, P.D., Wieringa, J.G., Mahon, A.R.,and Lamberti, G.A. (2017). Comparative cost and effort of fish distribution detection via environmental DNA analysis and electrofishing. *Fisheries*, 42(2), 90–99.

Ficetola, G.F., Miaud, C., Pompanon, F. and Taberlet, P.(2008). Species detection using environmental DNA from water samples. *Biology Letters*,4, 423–425.

Finlayson, B.R., Schnick, R., Cailteux, L., Demong, L., Horton, W., McClay, W., Thompson, C. and Tichacek, G. (2000). Rotenone use in fisheries management. Administrative and technical guidelines manual. Bethesda, Maryland: American Fisheries Society.

Furlan, E.M., Gleeson, D., Hardy, C.M. and Duncan, R.P. (2016). A framework for estimating the sensitivity of eDNA surveys. Molecular Ecology Resources, 16(3), 641–654.

Gallo, T. and Waitt, D. (2011). Creating a successful citizen-science model to detect and report invasive species. *BioScience*, 61(6), 459–465.

Gozlan, R.E., Andreou, D., Asaeda, T., Beyer, K., Bouhadad, R., Burnard, D., Caiola, N., Cakic, P., Djikanovic, V., Esmaeili, H.R., Falka, I., Golicher, D., Harka, A., Jeney, G., Kovac, V., Musil, J., Nocita, A., Povz, M., Poulet, N., Virbickas, T., Wolter, C., Tarkan, A.S., Tricarico, E., Trichkova, T., Verreycken, H., Witkowski, A., Zhang, C.G., Zweimueller, I. and Britton, J. R. (2010). Pan-continental invasion of *Pseudorasbora parva*: towards a better understanding of freshwater fish invasions. *Fish and Fisheries*, 11, 315–340.

Grabowska, J., Grabowski, M., Pietraszewski,D. and Gmur J.(2009). Non-selective predator-versatile diet of Amur sleeper (*Perccottus glenii* Dybowski, 1877) in the Vistula River (Poland), a newly invaded ecosystem. *Journal of Applied Ichthyology*, 25, 451–459.

Harper, L.R., Buxton, A.S., Rees, H.C., Bruce, K., Brys, R., Halfmaerten, D., Read, D.S., Watson, H.V., Sayer, C.D., Jones, E.P., Priestley, V., Mächler, E., Múria, C.,Garcés-Pastor, S., Medupin, C., Burgess, K. Benson, G., Boonham, N., Griffiths, R.A., Lawson Handley, L. and Hänfling, B. (2018). Prospects and challenges of environmental DNA (eDNA) monitoring in freshwater ponds. *Hydrobiologia*, 826 (1), 25–41.

Hoffman, J.C., Kelly, J.R., Trebitz, A.S., Peterson, G.S., and West, C.W. (2011). Effort and potential efficiencies for aquatic non-native species early detection. *Canadian Journal of Fisheries and Aquatic Sciences*, 68(12), 2064–2079.

Jacobs, P. and Hoedemakers, K. (2013). The round goby *Neogobius melanostomus* (Pallas, 1814) (Perciformes: Gobiidae), an invasive species in the Albert Canal (Belgium). *Belgian Journal of Zoology*, 143(2), 148–153.

Jordaan, M. S.,and Weyl O.L.F. (2013). Determining the minimum effective dose of rotenone for eradication of alien smallmouth bass *Micropterus dolomieu* from a South African river. *African Journal of Aquatic Science*, 38, 91–95.

Kottelat, M. and Freyhof, J. (2007). Handbook of European freshwater fishes. *Publications Kottelat, Cornol, Switzerland.* 646 pp.

Lemmens, P., Mergeay, J., Vanhove, T., De Meester, L., and Declerck, S.A.J. (2015). Suppression of invasive top mouth gudgeon *Pseudorasbora parva* by native pike *Esoxlucius* in ponds. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 25(1), 41–48.

Lukina, I. (2011). Distribution of the Amur Sleeper (*Perccottus glenii* Dybowski, 1877) in Belarus. *Russian Journal of Biological Invasions*, 2(2–3), 209–212.

Mauvisseau, Q., Burian, A., Gibson, C., Brys, R., Ramsey, A. and Sweet, M. (2019). Influence of accuracy, repeatability and detection probability in the reliability of species-specific eDNA based approaches. *Scientific Reports*, 9, 580.

Minamoto, T., Yamanaka, H., Takahara, T., Honjo, M. N., and Kawabata, Z. (2012). Surveillance of fish species composition using environmental DNA. *Limnology*, 13, 193–197.

NOBANIS (2019).www.nobanis.org/species-alerts/perccottus-glenii/,Date of access: 08/05/2019.

Pupina, A., Pupins, M., Skute, A., Pupina, A.,and Karklins, A. (2015). The distribution of the invasive fish amur sleeper, rotan *Perccottus glenii* Dybowski, 1877 (Osteichthyes, Odontobutidae), in Latvia. *Acta Biologica Universitatis Daugavpiliensis*, 15(2), 329–341.

Reshetnikov, A.N. (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.

Reshetnikov, A.N. and Chibilev, E.A. (2009). Distribution of the fish rotan (*Perccottus glenii* Dybowski, 1877) in the Irtysh River basin and analysis of possible consequences for environment and people. *Contemporary Problems of Ecology*,2(3), 224–228.

Reshetnikov, A.N.,andFicetola, G.F. (2011). Potential range of the invasive fish rotan (*Perccottus glenii*) in the Holarctic. *Biological Invasions*, 13(12), 2967–2980.

Reshetnikov, A.N. and Karyagina, A.S. (2015). Further Evidence of Naturalisation of the Invasive Fish *Perccottus glenii* Dybowski, 1877 (Perciformes: Odontobutidae) in Germany and Necessity of Urgent Management Response. *Acta Zoologica Bulgarica*, 67(4), 553–556.

Reshetnikov, A.N. and Schliewen, U.K. (2013). First record of the invasive alien fish rotan *Perccottus glenii* Dybowski, 1877 (Odontobutidae) in the Upper Danube drainage (Bavaria, Germany). *Journal of Applied Ichthyology*, 29, 1367–1369.

Roy, M., Belliveau, V., Mandrak, N. E. and Gagné, N. (2018). Development of environmental DNA (eDNA) methods for detecting high-risk freshwater fishes in live trade in Canada. *Biological Invasions*, 20(2), 299–314.

Rytwinski, T., Taylor, J.J., Donaldson, L.A., Britton, J.R., Browne, D.R., Gresswell, R.E., Lintermans, M., Prior, K.A., Pellatt, M.G., Vis, C. and Cooke, S.J. (2018). The effectiveness of non-native fish removal techniques in freshwater ecosystems: a systematic review. *Environmental Reviews*, 27(1), 71–94.

Schapira, A.H. (2010). Complex I: inhibitors, inhibition and neurodegeneration. *Experimental Neurology*, 224, 331–335.

Seekamp, E., Mayer, J.E., Charlebois, P. and Hitzroth, G. (2016). Effects of Outreach on the Prevention of Aquatic Invasive Species Spread among Organism-in-Trade Hobbyists. *Environmental Management*, 58(5), 797–809.

Tarkan, A.S., Marr, S.M. and Ekmekçi, F.G. (2015). Non-native and translocated freshwater fish species in Turkey. *FISHMED Fishes in Mediterranean Environments*, 3, 28.

Telcean, I., and Cicort-Lucaciu, A. (2016). Messages of invasive *Perccottus glenii* individuals eaten by an *Esoxlucius* from the Danube Delta. *Journal of Fisheries*, 4(3), 435–438.

Thomsen, P.F. and Willerslev, E. (2015). Environmental DNA–An emerging tool in conservation for monitoring past and present biodiversity. *Biological Conservation*, 183, 4–18.

van Emmerik, W.,and Beelen, P. (2018). Eerste hengelvangst naakte grondel. *Kijk op exoten*, 25, 11 [in Dutch].

Verbrugge, L.N.H., Leuven, R.S., van Valkenburg, J.L., and van den Born, R.J. (2014) Evaluating stakeholder awareness and involvement in risk prevention of aquatic invasive plant species by a national code of conduct. *Aquatic Invasions*, 9(3), 369–381.

Verreycken, H. (2013) Risk analysis of the Amur sleeper *Perccottus glenii*, Risk analysis report of non-native organisms in Belgium. Rapporten van het Instituut voor Natuur- en Bosonderzoek, INBO.R.2013.40, Instituut voor Natuur- en Bosonderzoek, 29 pp.

Verreycken, H., Anseeuw, D., van Thuyne, G., Quataert, P.,andBelpaire, C. (2007). The non-indigenous freshwater fishes of Flanders (Belgium): review, status and trends over the last decade. *Journal of Fish Biology*, 71 (Supplement D), 160–172.

Verreycken, H., Breine, J., Snoeks, J. and Belpaire, C.(2011). First record of the round goby, *Neogobius melanostomus* (Actinopterygii: Perciformes: Gobiidae) in Belgium. Acta Ichthyologica et Piscatoria, 41(2), 137–140.

Verreycken, H., Galle, L., Lambeens, L., Maes, Y., Terrie, T., van den Bergh, E. and Breine, J.J. (2019). First record of the naked goby, *Gobiosoma bosc* (Actenopterygii: Perciformes: Gobiidae) from the Zeeschelde (Belgium). Acta Ichthyologia et Piscatoria, in press.

Weyl, O.L.F.,Ellender, B.R., Woodford, D.J. and Jordaan, M.S. (2013). Fish distributions in the Rondegat River, Cape Floristic Region, South Africa, and the immediate impact of rotenone treatment in an invaded reach. *African Journal of Aquatic Science*, 38(2), 201–209.

Weyl, O.L.F., Finlayson, B., Impson, N.D., Woodford, D.J. and Steinkjer, J. (2014). *Threatened Endemic Fishes in South Africa's Cape Floristic Region: A New Beginning for the Rondegat River. Fisheries*, 39(6), 270–279.

Witmer, G.W., Snow, N.P. and Moulton, R.S. (2015). Efficacy of potential chemical control compounds for removing invasive American bullfrogs (*Rana catesbeiana*). *Springerplus*, 4, 497.

Zajicek, P.W., Hill, J.E., Stone, N., Thomforde, H., Ohs, C., Cooper, D., Flimlin, G., McLane, B. and Anderson W.D. (2009). Preventing Hitchhiking Nonindigenous Species in Live Shipments. Southern Regional Aquaculture Center, SRAC Publication No. 3902.

Appendix

Level of confidence provides an overall assessment of the confidence that can be applied to the information provided for the measure.

- **Well established:** comprehensive meta-analysis or other synthesis or multiple independent studies that agree.[1]
- **Established but incomplete:** general agreement although only a limited number of studies exist but no comprehensive synthesis and/or the studies that exist imprecisely address the question.
- **Unresolved:** multiple independent studies exist but conclusions do not agree.
- **Inconclusive:** limited evidence, recognising major knowledge gaps.

1 A statistical method for combining results from different studies which aims to identify patterns among study results, sources of disagreement among those results, or other relationships that may come to light in the context of multiple studies.

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