FEASIBILITY OF ERADICATION AND SPREAD LIMITATION FOR SPECIES OF UNION CONCERN SENSU THE EU IAS REGULATION (EU 1143/2014) IN BELGIUM

Volume 2. Species of the 2nd and 3rd update of the Union list

Report prepared in support of the implementation of the IAS Regulation in Belgium

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Summary

The EU IAS Regulation (1143/2014) requires Member States to have in place effective management measures for IAS of the Union list that are present on their territory. While Member states are obligated to (try to) eradicate species that newly appear on their territory, accepted management goals for widespread species (sensu the EU IAS Regulation) range from eradication to containment and population control. The applied measures must be appropriate to the situation of the individual Member State, based on a cost-benefit analysis, have due regard to human health, animal welfare and the environment and be prioritized on cost-effectiveness. To support the decision-making process and to ensure robust evidence is used to decide on suitable management options, we organized for the second time a participatory approach involving scientists and species management experts. This second assessment focuses on species of the 2nd and 3rd update of the Union list.

First, we gathered all available information and data on the invasion, distribution and management of the Union List species in Belgium and used those to describe the invasion scenarios. For species that are not yet present on the Belgian territory but able to establish, the scenarios described are imaginary but theoretically realistic invasion scenarios considering pathways, entry points, habitat and detection threshold of the species. We then drafted realistic management strategies for eradication and spread limitation based on the literature on best management practices.

Second, a total of 31 Belgian experts with experience in species management used an adaptation of the UK Non-Native Risk Management scheme (NNRM) to score the feasibility of eradication and spread limitation. NNRM uses a semi-quantitative scoring system to assess key criteria linked with management feasibility: effectiveness, practicality, cost, impact, acceptability, window of opportunity and likelihood of re-invasion. Finally, based on the scores that were allocated by the experts, we agreed on a recommendation of a Belgian management strategy for every species under consideration.

The results are summarized in Table A below. In case expert scores did not converge, the differences between expert assessments were taken into account in that recommendation. For some species, additional requirements for successful implementation of the strategies were formulated as well as important comments on described management practices. We want to emphasize that for species that are currently still absent from the Belgian territory, the guiding principle according to the EU regulation is eradication. This assessment highlights for which species a derogation of this obligation might need to be considered. Out of the five species that are already established in Belgium, eradication is recommended for two, while spread limitation is advised for the three species that already exhibit a more widespread distribution.

The outcome of the full process supports the implementation of the EU Regulation in Belgium, notably for the identification of cost-effective management goals and techniques as required by Article 17 and 19 on IAS eradication and management, respectively. It provides an evidence base for Belgian management decisions through a transparent, standardized and repeatable process. The outcome of the current assessment can contribute to the development of management plans by the three Regions, as has been done with Volume 1 that fed into the regional prioritization of management of IAS, such as the PrIUS report in Flanders (D'hondt et al. 2022). Additionally, expert comments on management methods, feasibility and practicality can likewise feed into the development of more local management strategies or decision frameworks that take into account site specific criteria.

Besides reporting on the Belgian manageability assessment, we hope the management strategies developed for Belgium and the workflow followed to support decisions on the management of IAS can provide inspiration to practitioners and other Member States tackling invasive species of Union concern.

Table A. *Recommendations for management of the 19 species of the Union list (2nd and 3rd updates) that are considered in this assessment with their establishment status.* ***Consensus*** *means the three experts' assessments were in agreement* ***in favor of a strategy*** *that was therefore recommended by the core authors group.* ***Recommendation*** *means there was no full consensus between the three experts, but the core authors group agreed on a strategy based on experts' feedback.*

Species	Status in the wild in Belgium	Management recommendation
ANIMALS		
Acridotheres tristis	Casual	**Consensus on eradication strategy** as a guiding principle of the EU Regulation for species not yet established in Belgium.
Ameiurus melas	Absent	**Recommendation of eradication strategy** as a guiding principle of the EU Regulation for species not yet established in Belgium, though local factors could greatly decrease the probability of success. Conditions for derogations described in article 18 should be carefully checked within 2 months of species detection on the Belgian territory.
Arthurdendyus triangulatus	Absent	**No consensus on management strategy** to recommend. Conditions for derogations described in article 18 should be carefully checked within 2 months of species detection on the Belgian territory.
Axis axis	Absent	**Consensus on eradication strategy** as a guiding principle of the EU Regulation for species not yet established in Belgium.
Channa argus	Absent	**Consensus on eradication strategy** as a guiding principle of the EU Regulation for species not yet established in Belgium, though local factors could greatly decrease the probability of success. Conditions for derogations described in article 18 should be carefully checked within 2 months of species detection on the Belgian territory.
Faxonius rusticus	Absent	**Recommendation of eradication strategy** as a guiding principle of the EU Regulation for species not yet established in Belgium, though local factors could greatly decrease the probability of success. Conditions for derogations described in article 18 should be carefully checked within 2 months of species detection on the Belgian territory.
Fundulus heteroclitus	Absent	**No consensus on management strategy** to recommend. Long term **population control** is most realistic according to experts. Conditions for derogations described in article 18 should be carefully checked within 2 months of species detection on the Belgian territory.

Gambusia affinis	Absent	**Recommendation of eradication strategy** as a guiding principle of the EU Regulation for species not yet present in Belgium.
Gambusia holbrookii	Absent	**Recommendation of eradication strategy** as a guiding principle of the EU Regulation for species not yet present in Belgium.
Lepomis gibbosus	Established	**Consensus on spread limitation** scenario option 4 - *maintenance of pest free areas by preventing e.g. introduction and spread to uninvaded ponds of conservation concern*
Morone americana	Absent	**No consensus on management strategy** to recommend. Long term **population control** is most realistic according to experts. Conditions for derogations described in article 18 should be carefully checked within 2 months of species detection on the Belgian territory.
Xenopus laevis	Established	**Recommendation of eradication strategy**, though local factors could greatly decrease the probability of success. Conditions for derogations described in article 18 should be carefully checked within 2 months of species detection on the Belgian territory.
PLANTS		
Ailanthus altissima	Established	**Recommendation of spread limitation option 2** – *Stand-still principle with core area in the Atlantic and maintenance of pest-free areas in nature reserves within this bioregion*
Celastrus orbiculatus	Established	**Consensus on eradication strategy** as a management recommendation for Belgium.
Cortaderia jubata	Absent	**Recommendation of eradication strategy** as a guiding principle of the EU Regulation for species not yet established in Belgium.
Gymnocoronis spilanthoides	Absent	**Consensus on eradication strategy** as a guiding principle of the EU Regulation for species not yet established in Belgium.
Humulus scandens	Absent	**Consensus on eradication strategy** as a guiding principle of the EU Regulation for species not yet established in Belgium.
Koenigia polystachya	Established	**Consensus on spread limitation option 3** – *Elimination of the most dispersive populations* – with eradication of riparian populations
Lespedeza cuneata	Absent	**Consensus on eradication strategy** as a guiding principle of the EU Regulation for species not yet established in Belgium. Enhanced surveillance of the plant in the Vesdre valley is also advised due to recent detection in this area.

Table des matières

1. Introduction

To spend limited resources for invasive species control, managers, policy makers and scientists need to agree on achievable management goals. The supporting tools to achieve a robust decision must be objective and based on quantifiable criteria (Masunungure et al., 2023).

This report presents the results of the second structured evaluation of the management options for species of Union concern based on their distribution in Belgium, available control methods and expert scores of quantifiable criteria linked to the management feasibility of two predefined management scenarios. With this assessment, we aimed to compile best practices for species management and to inform decision makers on achievable national management goals. These outcomes can support management at different geographical scales: they support individual regions in defining priority species for management, inform on the need for interregional coordination of species management, and help to identify site specific characteristics to be taken into account when defining management methods for species and their populations at specific locations.

1.1. Context of the manageability assessment

Regulation (EU) 1143/2014 on IAS entered into force on 1 January 2015. It provides for a set of measures to be taken across the EU in relation to IAS included on a list of Invasive Alien Species of Union concern. The first list of invasive alien species of Union concern came into force on 3 August 2016 and comprised 37 species. A first update entered into force on the 12th of July and added 12 species to the Union list. A second update that entered into force on 25th July of 2019 added an additional 17 species to the Union list. The third and most recent update entered into force on 2 of August 2022 and added an extra 22 species to the list. In total, the list comprises 88 species at the time of writing – 41 plant and 47 animal species.

For species of EU concern, Member States have to take a decision on the management options. In principle, for species not yet present on the territory or with limited populations, rapid eradication is the rule (Art 17). Yet, Member States may decide, based on scientific evidence, not to apply eradication measures if there are technical limitations or if such interventions would incur disproportionate non-target effects (Art 18). Decisions not to rapidly eradicate should thus be formally based on robust evidence which Belgium addressed through structured feasibility assessment (Adriaens et al. 2019). Such an approach, where experts have to exchange opinions on management, has added value in terms of learning, the compilation of management practices and descriptions of alternative management strategies. For instance, for species that are considered widely spread in Belgium, effective management measures should be put in place to minimize their impacts on biodiversity, the related ecosystem services, and, where applicable, on human health or the economy. Here too, management measures need to be proportionate to the environmental impact (Art 19) and the feasibility assessment performed in this framework using the Booy et al. (2015, 2017) scheme provides justification for these decisions.

The discussions on the feasibility of different management strategies details the considerations on conflicting criteria which allows for policymakers to revisit the scores for individual criteria and weigh their relative importance depending on the objective or policy concern at hand (*e.g.* available budget, cost-effectiveness or public acceptability), as these can greatly influence the chosen scenario (Lafond et al., 2020). Additionally, it provides the necessary elements for risk communication to allow policymakers to explain decisions more easily. Such communication with stakeholders and end-users is paramount for public support of invasive species control and uptake of management objectives at different levels of society (Shackleton et al. 2019).

1.2. Objectives

The objective of the Belgian Manageability assessment is to **evaluate the feasibility of management for the species of EU concern** applying and adapting an existing risk management scheme, the Non-Native Risk Management scheme (NNRM) (Booy et al. 2015, 2017). This scheme was applied to the invasive species of Union concern (3rd and 4th batch) *sensu* the EU IAS Regulation 1143/2014.

The first manageability assessment was formalized at the joint thematic meeting of the Belgian IAS Scientific Council & Belgian IAS Committee (14th February 2017). The results were published and communicated to the expert community through a participative workshop (Adriaens et al. 2019). The current assessment, coordinated by the Belgian National Scientific Secretariat on IAS (NSSIAS), was formally acknowledged by the IAS Scientific Council and the Committee in September 2022. It was decided not to organize a participatory workshop for this second assessment because of practical reasons and since a large part of the species involved are not yet established, and hence poorly known by practitioners.

This assessment will:

- Support the implementation of EU Regulation 1134/2014 in Belgium;
- Provide an overview of current (best) management practices of IAS under consideration;
- Provide an evidence base for derogations on the rapid response obligation (Art 18) so this has not to be decided upon on a case-by-case basis;
- Provide a sound evidence base for decisions on IAS management through a transparent, repeatable process (Vanderhoeven et al. 2017);
- Provide a means of structured decision making (i.e. the collaborative and facilitated application of multiple objective decision making and group deliberation methods (Gregory et al. 2012)) for IAS management through a participatory approach of the Belgian expert community on IAS and their management.

As with many impact assessments *e.g.* using ISEIA (Branquart 2007; Vanderhoeven et al. 2015) or risk assessment schemes, the NNRM uses semi-quantitative response and confidence scores to assess seven key criteria linked with management feasibility of an invasive species: *Effectiveness*, *Practicality*, *Cost*, *Impact*, *Acceptability*, *Window of opportunity* and *Likelihood of re-invasion*. Though confidence scores of criteria given by reviewers were not directly analyzed, the justification for the high or low confidence by experts were taken into account and thus indirectly considered when formulating management goals.

The approach was adapted to fit the needs of the Belgian assessment (*e.g.* uncertainty framework in line with Harmonia+ (D'hondt et al. 2015).

1.3. Species considered

This second manageability assessment considers 19 Union list species (a subset of the 2nd and 3rd update of the Union list) *sensu* the EU IAS Regulation 1143/2014[1,2], including the species with a later entry into force date: *Xenopus laevis* (2 August 2024), *Pistia stratiotes* (2 August 2024), *Fundulus heteroclitus* (2 August 2024) and *Celastrus orbiculatus* (2 August 2027) (Table 1).

20 Union list species were not considered in this assessment because their establishment potential in Belgium was estimated to be very limited in the EU risk assessment that supported their listing. The status of these species in Belgium and their establishment potential under current and/or future climate can be found in Table 2.

***Table 1**. Union List species sensu the EU Regulation (2nd and 3rd updates) that are considered in this assessment with their establishment status at the time of the assessment and establishment potential according to the risk assessment for Europe (Current climate: can establish under current climatic conditions; Future climate: can establish under future climatic conditions, but not under current climatic conditions). *The species Humulus scandens has been retained in the assessment because it has been casually observed in Belgium.*

Scientific name	Common name (Dutch)	Common name (French)	Status (2023)	Establishment potential
ANIMALS				
Acridotheres tristis	Treurmaina	Martin triste	Casual	Current climate
Ameiurus melas	Zwarte dwergmeerval	Poisson-chat commun	Absent	Current climate
Arthurdendyus triangulatus	Nieuw-Zeelandse platworm	Ver plat de Nouvelle--Zélande	Absent	Current climate
Axis axis	Axishert	Cerf axis	Absent	Current climate
Channa argus	Noordelijke slangekopvis	Poisson à tête de serpent du Nord	Absent	Current climate
Faxonius rusticus	Roestbruine Amerikaanse rivierkreeft	Écrevisse à taches rouges	Absent	Current climate
Fundulus heteroclitus	Fundulus heteroclitus	Choquemort	Absent	Current climate
Gambusia affinis	Westelijk gambusia	Gambusie de l'Ouest	Absent	Current climate
Gambusia holbrookii	Oostelijk gambusia	Gambusie de l'Est	Absent	Current climate
Lepomis gibbosus	Zonnebaars	Perche soleil	Established	Current climate
Morone americana	Amerikaanse baars	Bar blanc d'Amérique	Absent	Current climate
Xenopus laevis	Afrikaanse klauwkikker	Xénope lisse	Established	Current climate

[1] Commission Implementing Regulation (EU) 2019/1262 of 25 July 2019 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern

[2] Commission Implementing Regulation (EU) 2022/1203 of 12 July 2022 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern

PLANTS				
Ailanthus altissima	Hemelboom	Ailante glanduleux	Established	Current climate
Celastrus orbiculatus	Aziatische boomwurger	Célastre asiatique	Established	Current climate
Cortaderia jubata	Hoog pampasgras	Herbe de la pampa pourpre	Absent	Current climate
Gymnocoronis spilanthoides	Smalle theeplant	Faux hygrophile	Absent	Current climate
Humulus scandens	Oosterse hop	Houblon du japon	Absent	Future climate*
Koenigia polystachya	Afghaanse duizendknoop	Renouée à nombreux épis	Established	Current climate
Lespedeza cuneata	Chinese struikklaver	Lespedeza soyeux	Casual	Current climate

Table 2. *Union List species sensu the EU Regulation (2nd and 3rd updates) excluded from the risk management assessment, their status in Belgium and establishment potential according to the risk assessment for Europe (Future climate: can establish under future climatic conditions, but not under current climatic conditions; / cannot establish under current nor future climatic conditions).*

Species	Common name (Dutch)	Common name (French)	Status (2023)	Establishment potential
ANIMALS				
Callosciurus finlaysonii	Thaise eekhoorn	Écureuil de Finlayson	Casual	Future climate
Lampropeltis getula	Koningsslang	Serpent roi de Californie	Casual	/
Limnoperna fortunei	Gouden mossel	Moule pygmée	Absent	Future climate
Plotosus lineatus	Gestreepte koraalmeerval	Poisson-chat rayé	Absent	/
Pycnonotus cafer	Roodbuikbuulbuul	Bulbul à ventre rouge	Casual	/
Solenopsis geminata	Tropische vuurmier	Fourmi de feu tropicale	Absent	/
Solenopsis invicta	Rode vuurmier	Grande fourmi de feu	Absent	/
Solenopsis richteri	Zwarte vuurmier	Fourmi de feu noire	Absent	/
Wasmannia auropunctata	Dwergvuurmier	Petite fourmi de feu	Absent	/
PLANTS				
Acacia saligna	Wilgacacia	Mimosa bleuâtre	Absent	Future climate
Andropogon virginicus	Amerikaans bezemgras	Barbon de virginie	Absent	Future climate
Cardiospermum grandiflorum	Ballonrank	Corinde à grandes fleurs	Absent	Future climate
Ehrharta calycina	Roze rimpelgras	Ehrharte calycinale	Absent	Future climate
Hakea sericea	Hakea	Hakéa soyeux	Absent	Future climate
Lygodium japonicum	Japanse klimvaren	Fougère grimpante du japon	Absent	/
Pistia stratiotes	Watersla	Laitue d'eau	Casual	Future climate
Prosopis juliflora	Mesquite	Bayahonde	Absent	/
Rugulopterix okamurae	Stomp gaffelwier	Algue brune du Japon	Absent	Future climate
Salvinia molesta	Grote vlotvaren	Salvinie géante	Casual	Future climate
Triadica sebifera	Talgboom	Arbre a suif	Absent	Future climate

2. Methodology

The assessment follows the methodology of the first manageability assessment as outlined by Adriaens et al. (2019). The main difference as compared to the first assessment is that the final management recommendation was formulated by the core expert group instead of a participatory workshop with practitioners. The main points of the methodology for this analysis are retaken below.

2.1. Invasion scenarios and management strategies

Invasion scenarios, factual descriptions of the species historic and current distributions and spread were drafted collectively by the NSSIAS and the core group for each species under consideration. For non-established species the scenario represents a probable invasion scenario that takes into account the probable pathway of introduction, a likely entry point in the wild and the most likely extent of the species in Belgium at the point detection based on existing surveillance. The scenario further describes the reliability of the distribution and the situation in neighboring countries.

The **distribution maps** accompanying the invasion scenarios are based on validated distribution data from different regions as officially reported by Belgium for the EASIN baseline (Magliozzi et al. 2023; Tsiamis et al. 2019). This distribution map used specific date cut-offs with reference period 2000-entry into force for the different species (Adriaens et al. 2023). Hence, the current distribution of the species can deviate from the map: the species can be underreported/underestimated (e.g. because of poor detectability, difficult identification of insufficient monitoring) or the distribution map can overestimate the actual distribution of a species, especially when it has been under management. In this case, this is clearly explained in the scenario. In addition, for some species, the distribution map can show gaps which are then also clearly mentioned.

To quantify **invasion extent** a table is presented containing the number of 10 km, 5km and 1km squares where the species was recorded in each bioregion (Atlantic/Continental) during the reference period. It also shows the percentage of 1 km square in Natura2000 areas (% 1km SAC) to provide an idea of its occurrence in protected areas. Management strategies were also drafted by the core team based on published information, such as the management annexes of the European risk assessment of listed IAS, the humane management manual for humane dispatch of vertebrates (Smith et al. 2022) and published literature on management methods and their effectiveness.

Two risk management strategies were considered for Belgium: eradication, the complete and permanent removal of a population, and spread limitation, which was described as one of four options linking to the degree of spread of an IAS

1. *Eradication*: the complete and permanent removal of a population of invasive alien species by lethal or nonlethal means (sensu EU Regulation 1143/2014).

2. *Spread limitation*: any management scenario aimed at halting/limiting the spread of an IAS, which was described as one of four options linking to the degree of spread of an IAS:

- **Option 1. Stand-still principle with a single or a few patches.** This strategy aims at limiting the presence of a species in Belgium to a single or a few patches where it is described in the invasion scenario. This is done primarily by implementing procedures to eradicate any new populations, measures to create dispersal barriers (*e.g.* fencing, making areas inaccessible to species or vectors) or management methods aimed at avoiding the production of propagules that might result in dispersion (e.g. mowing before seed setting, measures aimed at reducing the population density). This strategy also includes methods to rapidly eradicate any new patches discovered outside the known patches.
- **Option 2. Stand-still principle with core area(s).** This strategy aims at limiting a species within a given core area where it is more widely distributed by implementing management measures aimed at avoiding any further spread or establishment outside this area. This includes management measures aimed at avoiding the production of propagules that might result in dispersion (e.g. mowing before seed setting) as well as methods to rapidly eradicate any new patches discovered outside the known core area(s). As dispersal is often influenced by population density, the strategy can also include management measures aimed at reducing the population density within the core area.
- **Option 3. Progressive elimination of the most dispersive populations** (widespread species with uninvaded areas in the distribution). This strategy aims at eradicating the dispersive segment of the total population in order to reach a stand-still of its current distribution. For plant species, this includes differentiated management measures for patches that are the source of new propagules for dispersal and measures to limit propagule pressure in other places. For widely spread animal species, this can include the breeding part of the population.
- **Option 4. Maintenance of pest free areas** for widespread species. The spread limitation strategy aims at managing uninvaded areas as free areas. These areas are subjected to (i) dedicated biosecurity measures, (ii) management actions aiming to increase habitat resistance to invasion, (iii) an increased surveillance effort and (iv) rapid eradication actions after detection.

The time frame for eradication and spread limitation is important to assess the different risk management criteria. If a specific timeframe is envisaged, it is mentioned in the strategies. If no specific timeframe is mentioned in the strategies, eradication is considered to take as long as is necessary to achieve permanent removal during a time-limited campaign (Bomford and O'Brien 1995), whereas spread limitation should be considered an ongoing activity.

2.2. Assessment of management feasibility

These risk management strategies were then scored by experts using an adaptation of the UK Non-Native Risk Management scheme (NNRM) (Booy et al. 2017). The NNRM uses a semi-quantitative scoring protocol to assess seven key criteria linked with management feasibility (see Table 3 and Annex 1). The average feasibility of a certain strategy was calculated as the arithmetic mean of the seven criteria.

Assessors were selected for their expertise on the species or taxon at hand and were offered the possibility to request a remuneration. For every species, three assessors scored the eradication and spread limitation strategies via an online module developed by the Belgian Biodiversity platform (http://ias.biodiversity.be/harmoniaplus) (see Annex 2 for listing of experts). Upon scoring the management strategies, assessors had to assume the general provisions of the EU Regulation (trade bans, action plans on unintentional introduction) were in place.

Arithmetic means of experts scores were compared for each criterion between the two strategies. A principal component analysis was performed on the scores of both strategies to explore potential correlations between criteria and groups of species with similar patterns of scores.

The final **management recommendation** was then formulated by the core group of authors of this assessment report, based on the outcome of the average feasibility, with the following options:

- **Consensus** = individual expert feasibility scores consistently in favour of a strategy, with agreement of the core group of authors
- **Recommendation** = individual expert feasibility scores not consistently in favour of one strategy, but majority of experts in favour of one strategy, and agreement of the core group of authors
- **No consensus** = individual expert feasibility scores not consistently in favour of one strategy, and no agreement between the core group of authors on the most feasible strategy. An alternative third option, such as population control, is sometimes recommended.

Table 3. Seven criteria linked with management feasibility that were scored by assessors and interpretation of the score levels and average feasibility score

Criteria	Score				
	1	2	3	4	5
Effectiveness	Very ineffective	Ineffective	Moderate effectiveness	Effective	Very effective
Practicality	Very impractical	Impractical	Moderate practicality	Practical	Very practical
Cost	> € 10M	€ 1-10M	€ 200k - 1M	€ 50-200k	< €50k
Negative impact	Massive	Major	Moderate	Minor	Minimal
Acceptability	Very unacceptable	Unacceptable	Moderate acceptability	Acceptable	Very acceptable
Window of opportunity	< 2 months	2 months - 1 year	1 – 3 years	4-10 years	> 10 years
Likelihood of reintroduction	Very likely	Likely	Moderate likelihood	Unlikely	Very unlikely
Average feasibility of eradication	Very low	Low	Medium	High	Very high

3. Results

3.1. General Description

The two management scenarios – eradication and spread limitation – were scored for the 19 species on the seven feasibility criteria by three experts. With only a few blanks left by some assessors, this amounts to a total of 794 individual feasibility scores for Belgium. Although it is interesting to consider differences between species, **it should be noted that the methodology of this assessment was not specifically designed for this but rather the goal was to compare management scenarios within species. In this section, we only draw up a few general trends.**

The average feasibility of eradication or spread limitation – *i.e.* the arithmetic average of the 7 criteria – is shown in **Figures 1 and 2**. While some species scores show a large variability (*e.g. Gambusia* spp., *Ameiurus melas*), the average standard deviation between the three experts was rather low (0,3) indicating consistency across scores. Plants had a higher feasibility of spread limitation (3,5) than animals (3,1) (*t* test, p < 0,05), and they also tended to have a higher feasibility of eradication although this was not significant (3,7 vs 3,3, *t* test, p > 0,05). Two animal species – *Lepomis gibbosus* and *Arthurdendyus triangulatus* – have the lowest feasibility of eradication while the top 3 is made up of the plant species *Celastrus orbiculatus*, *Humulus scandens and Cortaderia jubata.*

Experts consider that local eradication of IAS with a feasibility index lower than 3.5 may be difficult to achieve, depending on site specificities. For example, the eradication objective of large populations or of populations established in watercourses could be difficult to reach. Derogations from the obligation of rapid eradication might need to be applied for them as described in article 18 of the Regulation in case of technical infeasibility, serious adverse impacts of eradication techniques or high and disproportionate eradication costs.

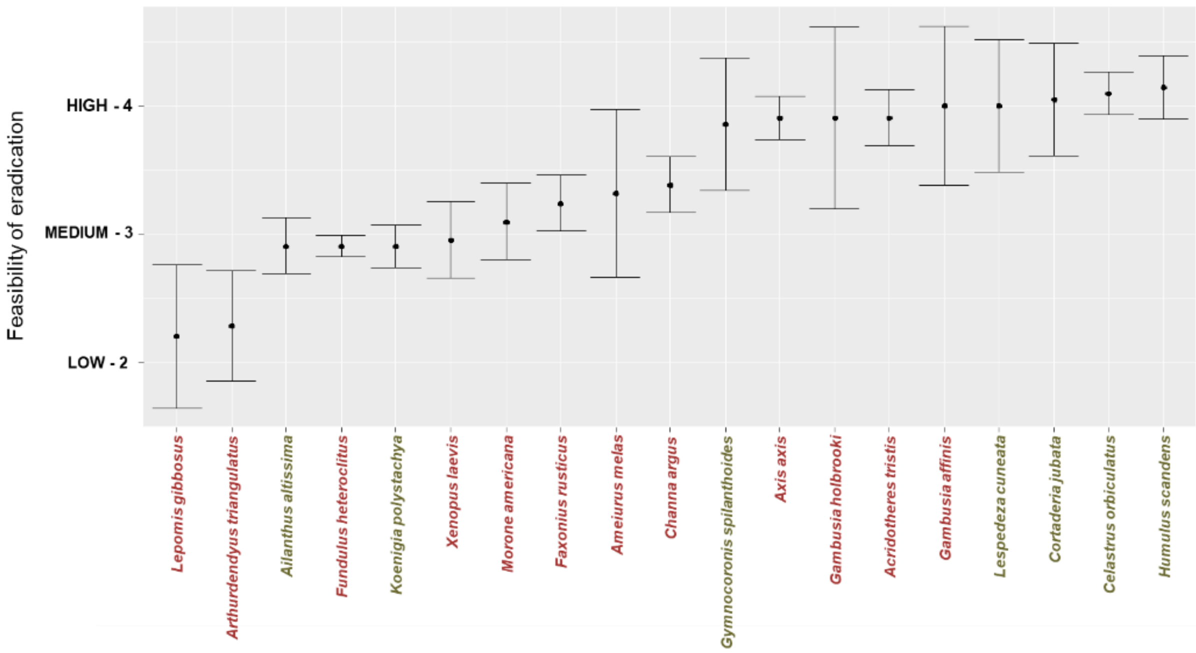


Figure 1. *Average feasibility of eradication of the 19 species assessed. Scores range from 1 (very low) to 5 (very high). Green: Plants are indicated in green and animals in red.*

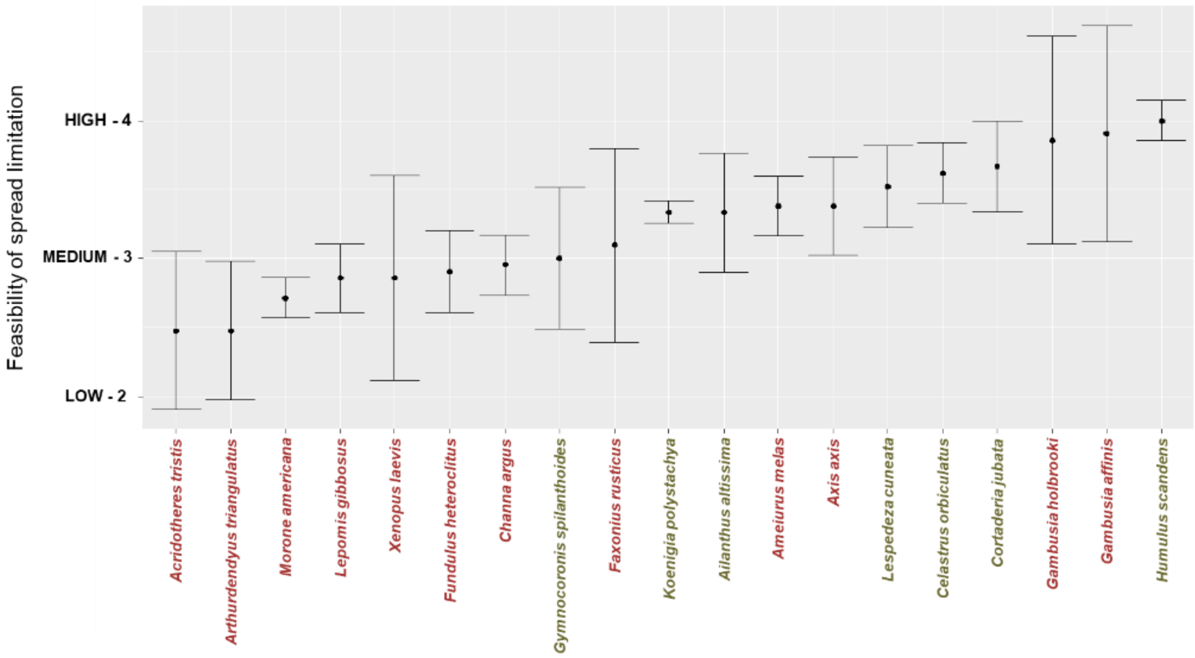


Figure 2. *Average feasibility of spread limitation of the 19 species assessed. Scores range from 1 (very low) to 5 (very high). Plants are indicated in green and animals in red.*

Eradication and spread limitation strategies were strongly correlated (**Fig. 3**), most species scored similarly on both scenarios: *e.g.* HIGH *H. scandens, C. jubata, C. orbiculatus, Gambusia spp.*; MEDIUM *Faxonius rusticus, Fundulus heteroclitus, Xenopus laevis*; LOW *A. triangulatus*. There are a few exceptions, with *Acridotheres tristis* – and *Gymnocoronis spilanthoides* to a lesser extent – scoring lower on the spread limitation strategy.

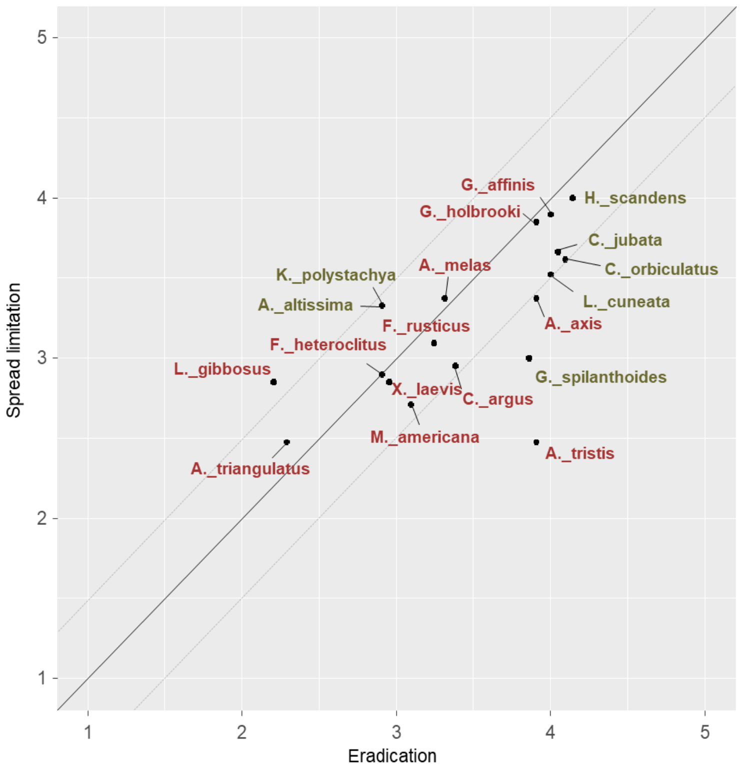


Figure 3. *Correlation between feasibility of spread limitation and eradication. Plants are indicated in green and animals in red.*

The **Principal Component Analysis** of the scoring results gives a synthetic overview of the correlations between the seven criteria. **For the eradication scenario**, the strongest correlations are between effectiveness, practicality and impact (Fig. 4). The ordination shows a first separation between species along the PC1 axis. The first group is made of species with high effectiveness, and limited cost and impacts of eradication, mostly composed of plants that are emerging, absent or eradicated (*H. scandens, C. jubata, C. orbiculatus, Lespedeza cuneata*) and vertebrates that are still absent (*A. tristis*, *Axis axis*, *Gambusia* spp.). The second group, with lower effectiveness and higher cost and impact, is made up of aquatic animals in all invasion stages (absent, emerging, or widespread - *e.g. Morone americana, X. laevis, L. gibbosus*) – and two plant species that are widespread (*Ailanthus altissima*, *Koenigia polystachya*). In the first group, three species are differentiated from the rest along the PC2 axis (*Gambusia affinis, G. holbrooki* and *L. cuneata*) mainly by having a shorter window of opportunity for any potential eradication. In the second group, three species stand out from the rest (*A. altissima*, *K. polystachya* and *X. laevis*) with higher costs and higher likelihood of reintroduction.

For the spread limitation scenario, correlations between criteria are less strong, although cost, impact, acceptability and practicality are moderately correlated (r : 0,42 – 0,54; Fig. 5). Differences between species are less clear than for the eradication scenario. It can be highlighted that for the two ***Gambusia*** species, together with the absent plant species (*H. scandens, C. jubata, C. orbiculatus, L. cuneata*), cost and non-target impact of the spread limitation strategy tended to be lower than for other species.

Although the manageability assessment only considered eradication and spread limitation as management strategies, species with low scores on the feasibility of eradication as well as a low score on spread limitation can be considered candidates for a long-term control program *sensu* Art 19.

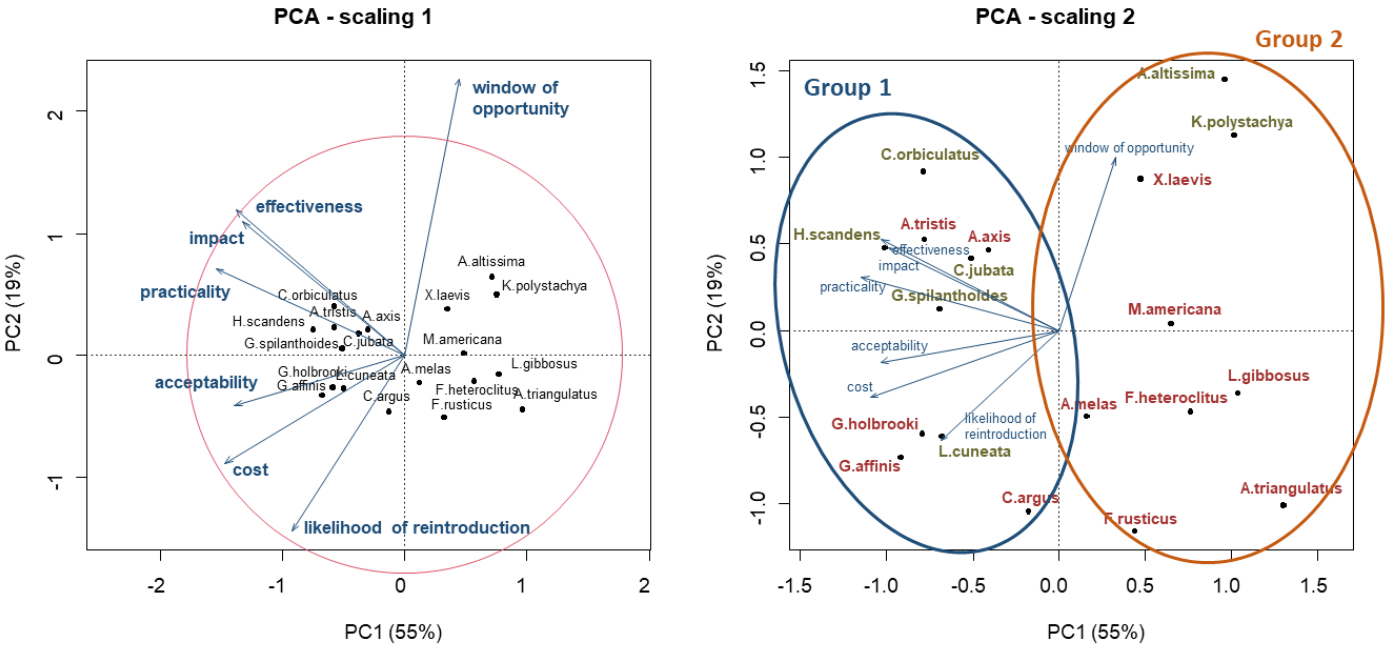


Figure 4. *Principal component analysis (scaling 1 and 2) of the species feasibility of* ***eradication***

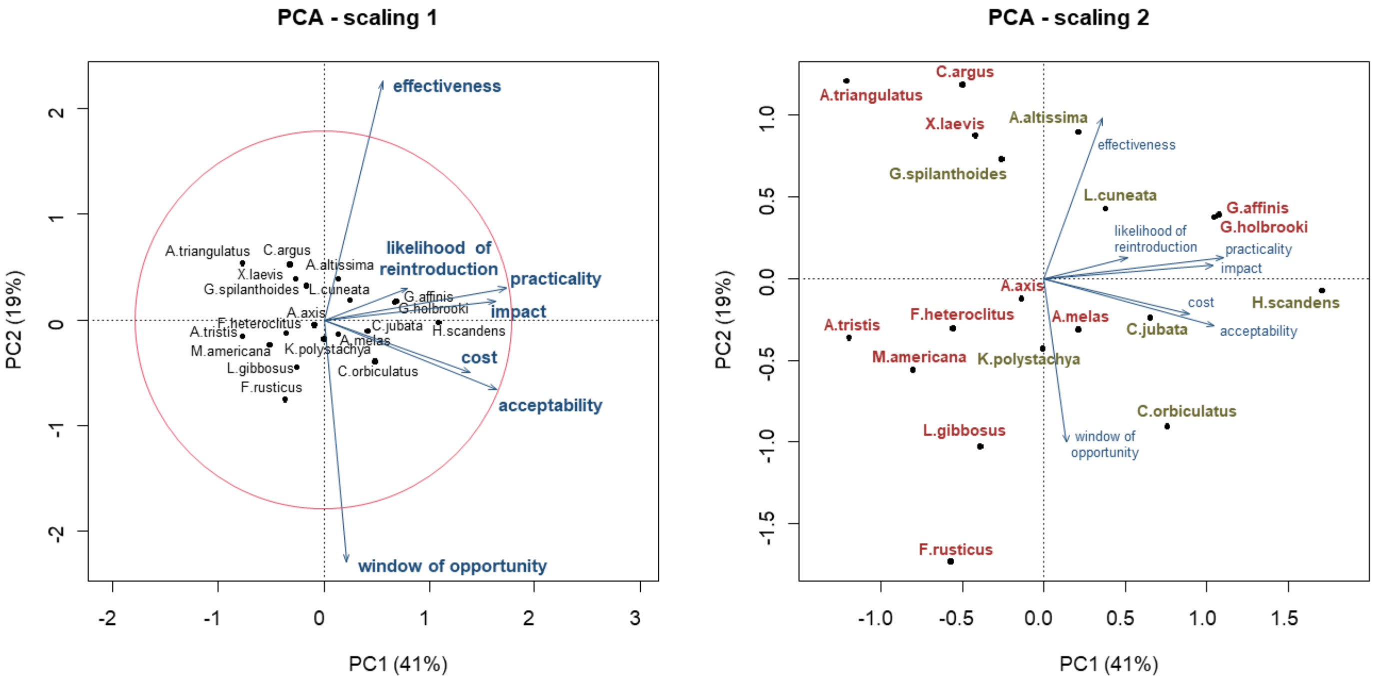


Figure 5. *Principal component analysis (scaling 1 and 2) of the species feasibility of* ***spread limitation***

3.2. Animals

3.2.1. Common myna, *Acridotheres tristis* (treurmaina, Martin triste)

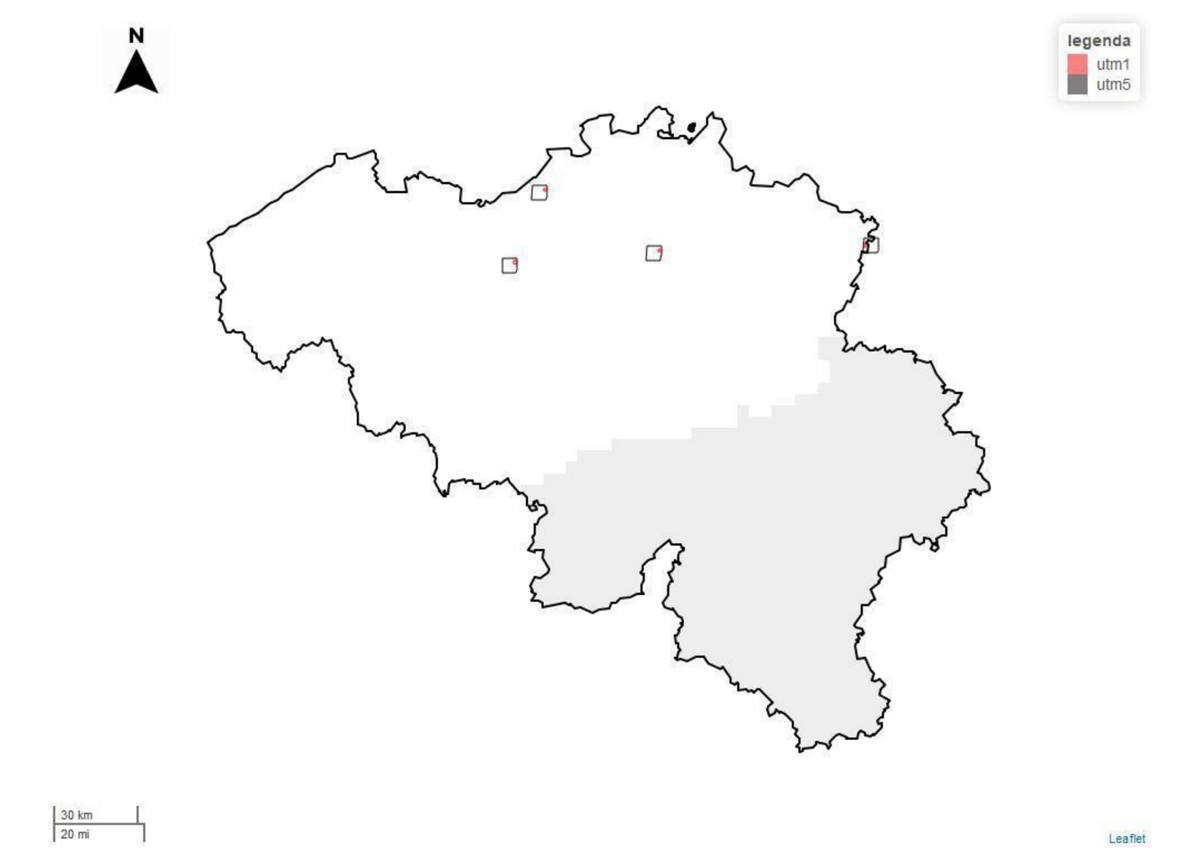
Credits: Shutterstock (Ethesam)

A. *Invasion scenario*

- Invasion situation and history in BE: The presence of the species was recorded in Belgium for at least four years, from 2005 to 2008 (Heist-Op-Den-Berg). Reproduction probably already occurred in 2005 with three birds present. In 2006, three breeding attempts were reported of which two were successful, all three in a breeding hole in a stand of poplars surrounded by agricultural land and meadows (Bosmans, 2009). Birds were observed foraging in short grassland, young corn fields or roadside verges. They regularly fed on cat food near houses, around compost heaps and were also observed feeding on ants and berries of rowan (*Sorbus aucuparia*) (Bosmans, 2009). By 2007, five birds were present in the same location. After the severe winter of 2008-2009, the mynas have not been sighted again and sparrows had taken over the breeding spot. Afterwards, there have been some sporadic sightings of the species (waarnemingen.be) scattered around the country, most probably linked to local escapes, the latest one comprising three birds observed by a local ornithologist in Beveren, a suburban area near Antwerpen. The current status of common myna in Belgium is casual, with casual observations of escaped birds reported by birders since 2000 (Scalera et al. 2018). The imaginary invasion scenario is a handful of birds recorded in a suburban environment. By the time they are reported, there has already been one year of breeding and the birds appear in a small family flock.

- Reliability of the BE distribution: Birds are easy to identify (though confusion with other mynas such as crested myna *A. cristatellus* or bank myna *A. ginginianus* is possible cf. Scalera et al. (2018), and coverage by birders is generally good, especially in more densely populated areas which are favoured by the species. Therefore, the distribution is considered to be reliable.

- <u>Invasion situation in neighbouring countries</u>: The species has been casually recorded in Germany, France (last observation in 2015 in Frontingan) and the Netherlands (1984 at the Veluwemeer, 2006 in Oss, 2008 in Rotterdam) in the past but despite some occasional breeding attempts (e.g. in France and the Netherlands) never truly established (Dubois *et al.* 2016, Lensink *et al.* 2015, NABU 2023, Smit 1985, Scalera et al. 2018). The species has not been recorded in Luxemburg.



	Atlantic	Continental
utm1	4	NA
utm2	4	NA
utm5	4	NA
utm10	4	NA
sac_perc	50	NA

B. Management strategy – eradication

- <u>Methods and techniques</u>:

  The strategy to eradicate this small population would involve either trapping, shooting by competent marksmen or a combination of both (Scalera et al., 2018; Saavedra et al., 2019).

- A variety of trap types can be used (Tindall or Tidemann traps or any traps that have a low base entrance as myna's walk rather than hop towards food sources). To be effective, the traps should contain decoy birds (which require daily check-ups for animal welfare reasons) and be placed around feeding areas. If live birds cannot be captured to serve as decoy, attractive food such as dry cat food or live insects can be used as bait (Linley et al. 2017).[3] Walk-in traps with decoys have been successful in rapidly eradicating this species from the Canary Islands in the early stages of establishment. Similarly, in Belgium, trapping was used to remove the first breeding pair of crested mynas (*A. cristatellus*) in 2011. Trapping can be performed by professional agents and/or trained volunteers. After capture, birds are humanely killed using carbon dioxide or carbon monoxide, anaesthesia or concussion (Tideman and King, 2009; Smith et al. 2022).
- Shooting is highly selective and, if performed by experienced personnel, is considered as a very humane measure (Smith et al. 2022). Though it is labour intensive, it has been used effectively to remove small numbers of birds during the early stages of establishment (Millet et al. 2005, Feare et al. 2017) or when trapping efficiency declines (Feare et al., 2021), since mynas are smart birds and can quickly become weary of traps and handlers. Shooting may be an effective method to use in complement with trapping to bring birds within range at sites where it is safe to shoot.

Netting and nest trapping are not part of the strategy since the population is still very small. Chemical methods such as avicides or chemical sterilants are not part of the strategy because they are not approved for use in the EU.

- Post-intervention verification:

  The area is being checked regularly by ornithologists during the two years after the eradication is completed. If more individuals are found, the eradication measures are repeated.

C. *Management strategy – spread limitation*

- Aim: *Option 1 stand-still principle with a single or a few patches.*

  The spread limitation strategy aims at limiting the presence of the small flock of common mynas to the suburban area where they started breeding and to maintain the current population level.

- Methods and techniques: The technique is to cull birds that occur outside the area using the method described in the eradication strategy (trapping and shooting, but mostly shooting individual birds). To maintain the current population level, repeated trapping actions are applied in the core area to remove a number of birds.[1] From the moment they start to breed, nest trapping in boxes should also be performed. Maintaining population levels requires continuous monitoring of the population which

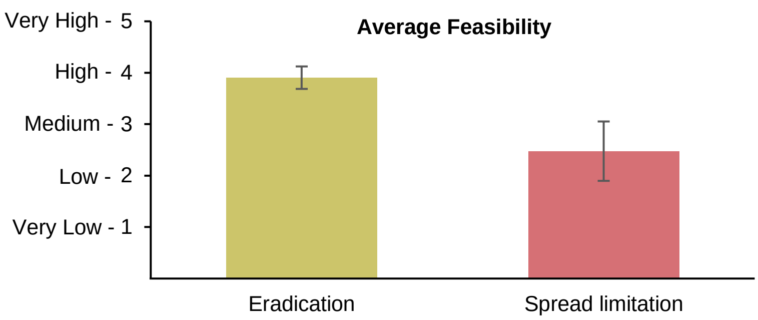
[3] These specifications were added after scoring of the scenarios following expert input

is performed by volunteer birders. In parallel, prevention is applied to limit anthropogenic food sources for birds and keep a low breeding success (e.g. compost heaps, cat food). Broader scale surveillance has to be set up in suitable areas around the core to detect any dispersing birds.

- <u>Post-intervention verification:</u> Detailed monitoring of the nest site, flock size and breeding success (at least the number of fledglings) is necessary. Where common mynas were removed outside the core breeding area, follow-up monitoring is performed for at least two years to ensure all birds were removed.

D. Assessment results

The **average feasibility score of the eradication strategy** given by experts was **high** (which is rather high compared to other animal species), **while the spread limitation was scored lower** – between low and medium. On average, 5 out of 7 criteria (effectiveness, practicality, cost, impact and acceptability) were scored 4 or higher for the eradication scenario, whereas only one of the 7 criteria of the spread limitation scenario scored better than 3 (cost). On average, effectiveness, practicality, acceptability and likelihood of reintroduction scored much lower for the spread limitation strategy than the eradication scenario.



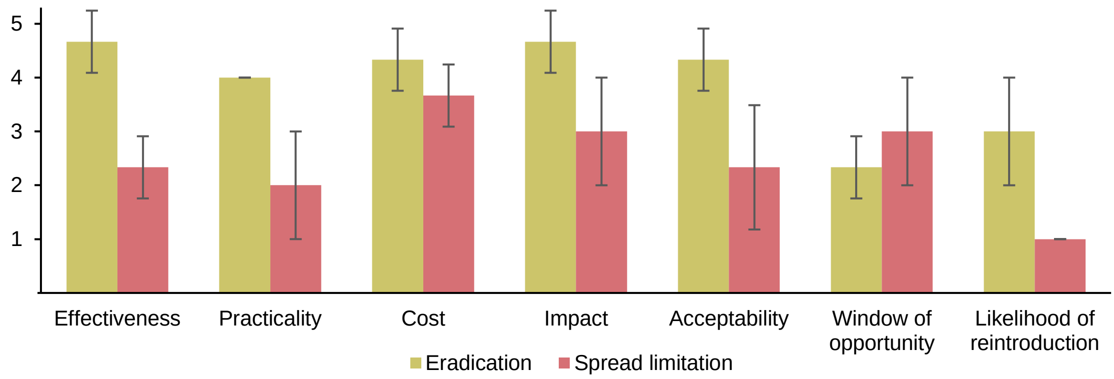


***Figure 6**. **Top**: Average feasibility scores for the eradication and spread limitation scenario of Acridotheres tristis; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of A. tristis*

E. Recommendations for management

The experts agree on the **eradication of all individuals on the Belgian territory as a management recommendation**, which is in line with the guiding principle of eradication for species of the EU Regulation not yet present in Belgium.

References

Bosmans (2009). Eerste broedgevallen van Treurmaina (*Acridotheres tristis*) voor België. natuur.aureolus 75(4), 123-124.

Dubois P.J., Maillard J.F. & J.M. Cugnasse (2016). Les populations d'oiseaux allochtones en France en 2015 (4e enquête nationale). Ornithos : 23-3 : 129-141. ORNITHOS. 23. 129-141.

Feare, C.J., van der Woude, J., Greenwell, P., Edwards, H.A., Taylor, J.A., Larose, C.S., Ahlen, P.A., West, J., Chadwick, W., Pandey, S. and Raines, K. (2017). Eradication of common mynas *Acridotheres tristis* from Denis Island, Seychelles. Pest Management Science, 73(2), pp.295-304.

Feare, C. J., Waters, J., Fenn, S. R., Larose, C. S., Retief, T., Havemann, C., ... & Accouche, W. (2021). Eradication of invasive common mynas Acridotheres tristis from North Island, Seychelles, with recommendations for planning eradication attempts elsewhere. Management of Biological Invasions, 12(3), 700.

Lensink, R., G. Ottens, T.M. van der Have (2013). Vreemde vogels in de Nederlandse vogelbevolking: een verhaal van vestiging en uitbreiding. Rapport 13-025, Bureau Waardenburg, Culemborg.

Linley, G.D., Paton, D.C. and Weston, M.A. (2017), A citizen-trapper effort to control Common Myna: Trap success, specificity and preferred bait type. Ecol Manag Restor, 18: 249-252. https://doi.org/10.1111/emr.12269

Millett J, Climo G, Shah NJ (2005). Eradication of Common Myna Acridotheres tristis populations in the granitic Seychelles: Successes, failures and lessons learned. Adv Vertebr Pest Manage 3: 169-183.

Nature And Biodiversity Conservation Union (2023). Die EU-Liste invasiver gebietsfremder Tier- und Pflanzenarten, https://www.nabu.de/tiere-und-pflanzen/artenschutz/invasive-arten/unionsliste.html

Saavedra, Susana & Reynolds, Silas. (2019). Eradication and control programmes for invasive mynas (*Acridotheres* spp.) and bulbuls (*Pycnonotus* spp.): Defining best practice in managing invasive bird populations on oceanic islands.

Scalera, R, Rabitsch, W, Genovesi, P, Adriaens, T, Robertson, P, Moore, N, Booy, O, Chapman, D & Kettunen, M (2018). Risk Assessment for Acridotheres tristis (Linnaeus, 1766): Risk assessment developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention" Contract No 07.0202/2016/740982/ETU/ENV.D.2 . in HE Roy, W Rabitsch & R Scalera (eds), Development of risk assessments to tackle priority species and enhance prevention : final report: Contract No 07.0202/2016/740982/ETU/ENV.D2. Publications Office of the European Union, Luxemburg, pp. 1-83. https://doi.org/10.2779/08867

Smit, A. (1985). Een nieuwe exoot in de vrije natuur. Het vogeljaar, vol 33 (1985) nr. 1 p. 20-21

Smith, K.G., Nunes, A.L., Aegerter, J., Baker, S.E., Di Silvestre, I., Ferreira, C.C., Griffith, M., Lane, J., Muir, A., Binding, S., Broadway, M., Robertson, P., Scalera, R., Adriaens, T., Åhlén, P-A., Aliaga, A., Baert, K., Bakaloudis, D.E., Bertolino, S., Briggs, L., Cartuyvels, E., Dahl, F., D'hondt, B., Eckert, M., Gethöffer, F., Gojdičová, E., Huysentruyt, F., Jelić, D., Lešová, A., Lužnik, M., Moreno, L., Nagy, G., Poledník, L., Preda, C., Skorupski, J., Telnov, D., Trichkova, T., Verreycken, H. and Vucić, M., 2022. A manual for the management of vertebrate invasive alien species of Union concern, incorporating animal welfare. 1st Edition. Technical report prepared for the European Commission within the framework of the contract no. 07.027746/2019/812504/SER/ENV.D.2.

Tidemann, Christopher & King, Daryl (2009). Practicality and humaneness of euthanasia of pest birds with compressed carbon dioxide (CO2) and carbon monoxide (CO) from petrol engine exhaust. Wildlife Research. 36. 522-527. 10.1071/WR09039.

3.2.2. Black bullhead, *Ameiurus melas* (zwarte Amerikaanse dwergmeerval, Barbotte noire)

Credits: Mathhew Zappa – CC BY 4.0 - https://www.inaturalist.org/observations/131134920

A. *Invasion scenario*

- Invasion situation and history in BE: The species is currently not present in Belgium. Although the species was released at some point in Belgium, genetic sampling revealed that all samples collected in the wild actually originated from specimens of *A. nebulosus* (Verreycken et al., 2010), which is morphologically very similar. Therefore, the imaginary invasion scenario is that the species is detected by professional personnel during fish monitoring electrofishing in a river/brook in the framework of a systematic monitoring along transects for the WFD and the discovery is later confirmed by DNA analysis. Introduction into Belgium likely happened via natural dispersal from neighbouring countries.

- Reliability of the BE distribution: The absence of the species from the Belgian territory in 2010 seems to be rather reliable since it was confirmed via genetic sampling. Nevertheless, we do not know what has happened in the last 10 years, especially since *A. melas* and *A. nebulosus* are rather difficult to distinguish morphologically.

- Invasion situation in neighbouring countries: The species is widespread in France, with a few records very close to the border, but all dating from before 2011 (openobs.mnhn.fr). The species also occurs in the Netherlands, with recent observations mainly from Limburg and the East of North Brabant, some of them very close to the border (ravon.nl, 2023). There are records of the species in Germany (Wolter and Rohr, 2010), with large populations mainly known from the area of the Saxon Elbe and the Black Elster, though there is discussion on the exact identification of the species (neobiota.bfn.de). A population is established in the Luxembourgian Moselle (Administration de la Gestion de l'Eau 2010).

B. Management strategy – eradication

The scenario considers eradication from both standing and running waters on the Belgian territory.

- Methods and techniques:

Eradication is extremely difficult once *A. nebulosus* is established, especially in larger and open aquatic systems. Measures that have proven to be successful consist of the application of chemicals such as rotenone. However, large-scale application of rotenone in water bodies cannot be part of the eradication strategy because the biocide is forbidden in most EU Member States, including Belgium, due to its non-target effects on other aquatic species. However, it could be an option in the future to eradicate the species from artificial - or low value - water bodies if a specific derogation on the use of biocides would be approved.

In ponds and other (small) standing waters, the first step is to determine where connectivity to other systems can be disrupted to avoid fish from spreading even further along the river system or into connected systems. Secondly, eDNA sampling should be performed to examine the presence of the species in adjoining aquatic habitats. When species presence has been confirmed in such neighbouring, closed systems, they should be dewatered and fish captured with seines – non target species should also be removed before drawdown. During the drawdown, care must be taken to avoid further dispersal through outlets of the pumping system. After dewatering, quicklime (Ca0) could be added since the fish can survive brief moments of drought in the sediment and are very tolerant to low oxygen conditions (Rechulicz and Plaska, 2018), but only for ponds of low ecological value due to the potential of non-target effects.

In rivers and larger standing waters, potential methods for eradication include the use of fyke nets[4], electrofishing and an increased angling effort promoted through dedicated communication campaigns with recreational anglers. It should be noted that while physical capture of catfish may lead to eradication in some very rare instances (*e.g.* Hill and Sowards, 2015), it is highly dependent on the context - such as the visibility under the water and the availability of a very dedicated network of people. Generally, eradication of *A. melas* is deemed not possible by mass capturing alone (Cucherousset et al., 2006).

- Post-intervention verification:

Sites where *Ameiurus* was eradicated should be monitored using e-DNA methodology (Clusa Questa et al., 2018) and trapping (funnels or electrofishing). Capturing of fish on rivers should be continued with the aid of anglers for multiple years.

C. Management strategy – spread limitation

- Aim: *Option 2. Containment of populations in core area*

The spread limitation strategy aims at containing the populations of black bullhead in the waterbody/watercourse where it has been observed and at avoiding any further spread

[4] This specification was added after scoring of the scenarios, following expert input

outside of this area. If populations are found outside of this initial system, they should be eradicated or contained if the former is not possible.

- Methods and techniques:

Firstly, connectivity of the system should be analysed, and action should be taken to avoid fish from spreading even further along the river system or into connected systems. Secondly, nearby aquatic systems should be monitored with e-DNA. If the species is detected in a small standing water, it should be dewatered where feasible. Before drawdown, non-target species should be removed. After dewatering, fish are captured with seines. During the drawdown, care must be taken to avoid further dispersal through outlets of the pumping system.

Lastly, where drawdown is not possible – such as on the rivers – other means of capture are employed. A combination of fyke or hoop nets and electrofishing are considered good forms of mechanical removal for ictalurid catfishes (Portt et al., 2006; Miranda and Boxrucker, 2009). Double fyke nets, consisting of two conically shaped fyke nets (mesh size of 8 mm) of which the mouth openings are connected with a vertically hanging net (length, 11 m; height, 0.9 m), have been previously used effectively in standing waters in Belgium (Louette and Declerck, 2006). Nevertheless, electrofishing is preferred because it has the least amount of by-catch to native fish populations (Mueller, 2005).

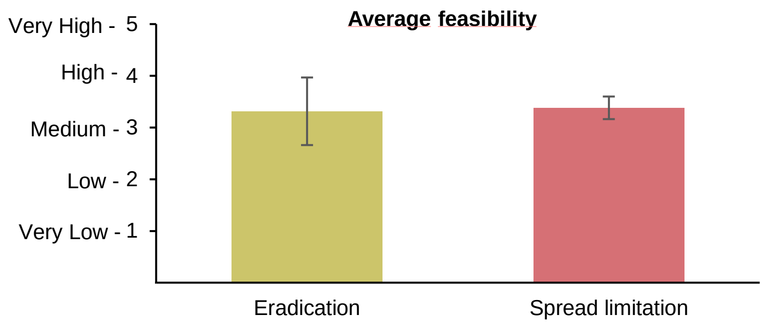
Angling and increased bagging effort by anglers could also help to control the population. Capture efforts should focus on the preferential habitat of the species which consists of slow flowing parts of the stream or reed beds in flood plains (Cucherousset et al., 2006).

- Post-intervention verification:

Clear information signs are installed along the colonised stretch of the river. Additionally, anglers are informed of the presence of the species and the harmful effects it can have on their hobby. Mass capture of specimens in the isolated stretch is repeated indefinitely. Monitoring of population size is also undertaken.

D. Assessment results

The average feasibility scores of the eradication and spread limitation scenario were (between) medium (and high). **There was no consensus between experts on the scenario that should be adopted.** Apart from a similar average feasibility score, scores of individual criteria were also very similar, though experts highlighted the context dependent nature of several criteria such as effectiveness, practicality and costs. The criterium with the lowest score was the window of opportunity for eradication, evaluated as short (2 months - 1 year).



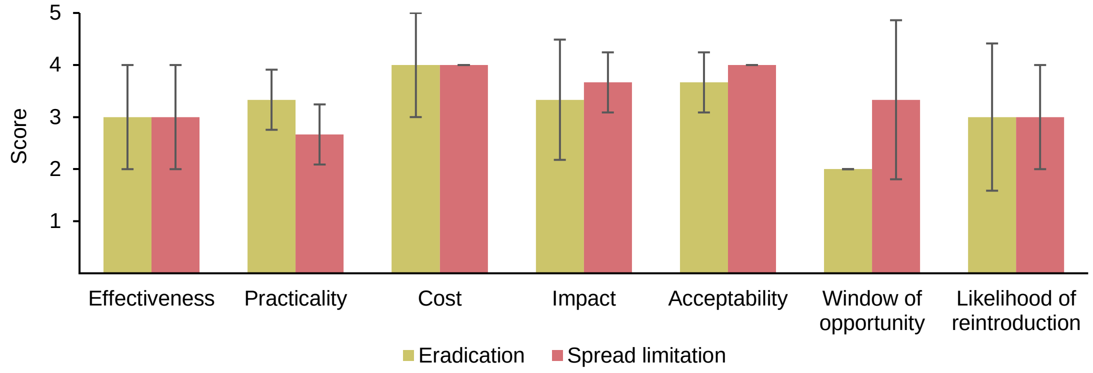


***Figure 7**. **Top**: Average feasibility scores for the eradication and spread limitation scenario of Ameiurus melas; **Bottom:** Breakdown of average feasibility scores into average scores of the seven key criteria for management of A. melas.*

E. Recommendations for management

No clear distinction could be made between the two scenarios – especially since the available management options are very context dependent. Therefore, **we suggest the default management option should be eradication**, in line with the guiding principle of eradication for species of the EU Regulation not yet present in Belgium, **though local factors could prevent such a management action to be successful**. The main issues are connectivity and the possibility of drawdown. In the invasion scenario under discussion in the current assessment the species was first detected in a river through which the species entered Belgium from neighboring countries, though the initial point of detection might not reflect reality since the species prefers large, standing waters. Derogations from the obligation of rapid eradication – *sensu* article 18 of the EU Regulation – might need to be sought for this aquatic species depending on local conditions.

References

Administration de la gestion de l'eau, 2010. Les poissons au Luxembourg : Cartographie des poissons, lamproies et écrevisses du grand-duché de Luxembourg. 2e éd., 213 pp.

Clusa Cuesta, L., & García Vázquez, E. (2018). A simple, rapid method for detecting seven common invasive fish species in Europe from environmental DNA. Aquatic Conservation: Marine and Freshwater Ecosystems, 28.

Cucherousset, J., Paillisson, J. M., & Carpentier, A. (2006). Is mass removal an efficient measure to regulate the North American catfish *Ameiurus melas* outside of its native range? Journal of Freshwater Ecology, 21(4), 699-704.

Hill, J. E., & Sowards, J. (2015). Successful eradication of the non-native loricariid catfish *Pterygoplichthys disjunctivus* from the Rainbow River, Florida. Management of Biological Invasions, 6(3), 311-317.

Louette G. and Declerck, S. (2006). Assessment and control of non- indigenous brown bullhead *Ameiurus nebulosus* populations using fyke nets in shallow ponds. *Journal of Fish Biology* 68, 522–531.

Miranda, L.E. and Boxrucker, J. (2009). Warmwater fish in large standing waters. pp. 29–42 In: S. A. Bonar, W. A. Hubert, and D. W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Mueller, G.A. (2005). Predatory fish removal and native fish recovery in the Colorado River main stem: what have we learned? *Fisheries* 30(9), 10–19.

Portt, C.B., Coker, G.A. Ming, D.L., and Randall R.G. (2006). A review of fish sampling methods commonly used in Canadian freshwater habitats. Canadian Technical Report of Fisheries and Aquatic Sciences. 2604 p.

Rechulicz, Jacek, and Wojciech Plaska (2018). The invasive *Ameiurus nebulosus* (Lesueur, 1819) as a permanent part of the fish fauna in selected reservoirs in Central Europe: long-term study of three shallow lakes. Turkish Journal of Zoology 42.4 : 464-474

Verreycken, H., Van Thuyne, G., & Belpaire, C. (2010). Non-indigenous freshwater fishes in Flanders: status, trends and risk assessment. In 2010). Science facing aliens: proceedings of a scientific meeting on invasive aliens species (pp. 71-75).

H. Verreycken, L.R. Aislabie, G.H. Copp. (2019). Information on measures and related costs in relation to species considered for inclusion on the Union list: *Ameiurus melas*. Technical note prepared by IUCN for the European Commission.

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.

3.2.3. New-Zealand flatworm, *Arthurdendyus triangulatus* (Nieuw-Zeelandse platworm, Ver plat de Nouvelle-Zélande)

Credits: S. Rae - CC by 2.0

A. Invasion scenario

- Invasion situation and history in BE: The species has not been observed in Belgium to date. The imaginary invasion scenario is that the species entered Belgium through contamination of potted plants and subsequently established in a private garden. After 15 years, the species is detected there and upon scrutiny even in multiple private gardens and an adjacent agricultural land (pasture).
- Reliability of the BE distribution: As the species is not well known, very inconspicuous, and flatworms are not popular among nature enthusiasts, the presence of this species might have been overlooked and underestimated.
- Invasion situation in neighbouring countries: There are no known populations of *A. triangulatus* in mainland Europe, but the species is established in the United Kingdom and Ireland. The species is more widespread in the North of the British Isles than in the South. Additionally, it is also present on the Faroe Islands. Eight other species of terrestrial flatworms are known from Belgium - of which five are restricted to greenhouses - and even more from neighboring countries (Soors et al., 2019; 2022). The three that have already been found in the wild in Belgium are *Caenoplana variegata*, *Obama nungara* and most recently *Marionfyfea adventor.*

B. Management strategy – eradication

- Methods and techniques:

No widespread eradication campaigns against *A. triangulatus* have been attempted so far, nor have potentially effective methods been described (Murchie, 2017). Confidence associated with the measures described below is therefore low.

Arthurdendyus triangulatus is susceptible to heat and physical damage so removal of refuges, scorching and turning the soil could eradicate the flatworm, but only at the very early stages of infestation - which have already passed in this scenario. Murchie and Harrison (2004) estimated from mark-release-recapture studies that 44% of the flatworm population was hidden in the soil, rather than at the soil surface. Once the flatworm has gotten into the soil, the only feasible means of eradication is to dig the soil up with mechanical diggers and heat it to temperatures above 30 °C (Murchie, 2017). Care must be taken to implement the proper biosecurity measures before moving any vehicle and other material or equipment off site (proper cleaning of machinery, hot water treatment). As high temperatures only kill the adult worms and not the eggs, the method will need to be repeated multiple times.

In the private gardens adjacent to the pasture lands, scorching combined with removal trapping of *A. triangulatus* using shelter traps on the soil surface (Cannon et al., 1999) can be considered, though this method is ineffective on a large, commercial scale (Blackshaw et al., 1996). A shelter trap can be a strong polythene bag filled with approximately 6 kg gravel, placed on bare soil (Boag at al., 2010; Murchie et al., 2013) or a ceramic tile with a coat of 5 mm polystyrene (Cannon et al., 1999). Traps should act as cool, dark and damp refuges under which the flatworms can hide during the day, but every potential refuge (rocks etc) should either be checked or removed. As high temperatures only kill the adult worms and not the eggs, the method will need to be repeated multiple times.

No chemical measures are available to target the flatworm in the soil (Murchie, 2017).

- <u>Post-intervention verification:</u>

Monitoring and surveillance of *A. triangulatus* by visual inspection underneath soil refugia such as stones, wood, and shelter traps on the soil surface as described in the methods and techniques can be utilised, preferably near the edges of the field as flatworm densities are higher due to increased shelter possibilities (Boag et al., 1999; Murchie et al., 2003). This type of monitoring is preferably undertaken in autumn as chances of detection vary spatio-temporally (Boag et al., 2005) and hot, dry conditions force the flatworms to bury deeper into the soil (Murchie et al., 2013).

C. Management strategy – spread limitation

- <u>Aim</u>: *Option 1 - Stand-still principle with a single or a few patches.*

In this scenario, flatworm numbers in the infected pastures and gardens are managed and effects mitigated, flatworms are discouraged from moving outside of the pasture and biosecurity measures are implemented to avoid secondary spread caused by human intervention.

- <u>Methods and techniques:</u>

Controlling flatworm numbers can be achieved through a number of methods as described in the methods for eradication such as frequent soil turning and burning, and removal trapping for smaller areas. On the farmland, mitigation measures preferencing the earthworms can also by applied:

  - Frequent tillage with intervals that allow the earthworm population to recover;
  - Increased fertilization such as farmland manure to support the population;
  - Habitat manipulation to encourage predation by predatory beetles and/or other natural enemies or discourage flatworm colonization by increasing the possibility of drying out.

Additionally, as the species can move up to 17 meter per hour under laboratory conditions (EU PRA) and populations can move 1 meter per day once established in a field (Boag and Neilson, 2014), inhospitable barriers are set up around the infected perimeter (such as regular turning of the soil and thermal treatment to prevent further dispersal. Surveillance is set up in surrounding fields by visual inspection underneath soil refugia and strategically placed shelters at the edges of fields.

Care is taken to prevent further dispersal of the species due to human intervention by avoiding the transfer of topsoil between sites and by thoroughly cleaning machinery.
On the private premises (gardens), regular removal trapping should be practiced, as described above.

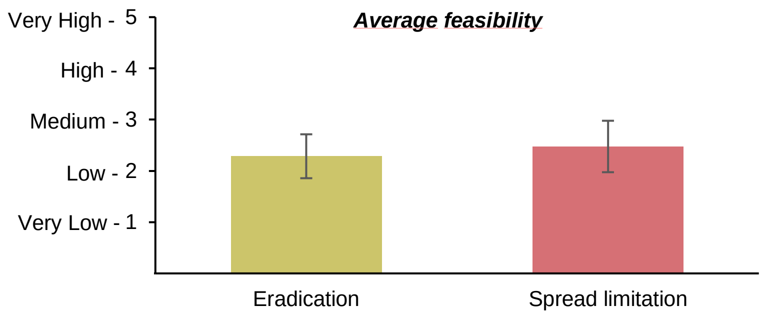
- <u>Post-intervention verification:</u>

The methods described above need to be applied indefinitely.

D. Assessment results

The average feasibility scores of the eradication and spread limitation scenario were between low and medium. Two experts scored the feasibility of spread limitation slightly higher than eradication, while the third expert scored in the opposite sense. It is the lowest eradication feasibility score reached amongst emerging IAS included in this report, due *e.g.* to low species detectability in the field and low effectiveness of available management techniques.

On average, the spread limitation scenario scored better on effectiveness while there were no other major differences between scenarios. The lowest scores for the eradication scenario were for effectiveness, practicality and window of opportunity.



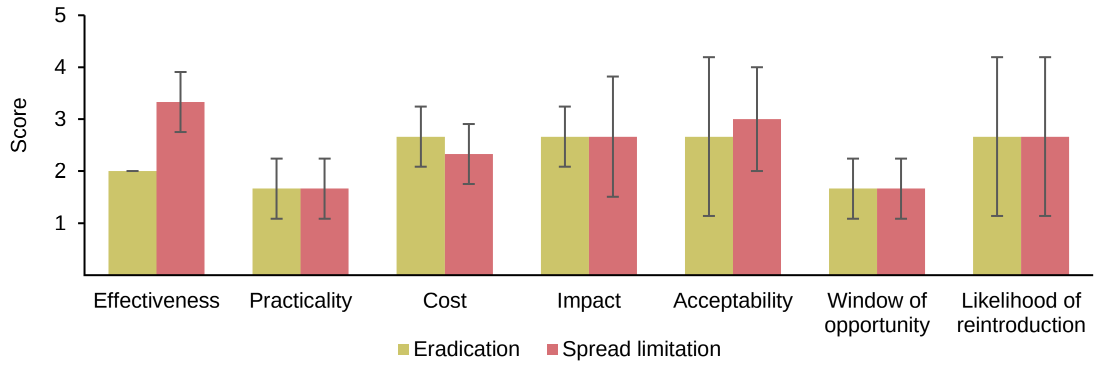


***Figure 8**. **Top:** Average feasibility scores for the eradication and spread limitation scenario of Arthurdendyus triangulatus; **Bottom:** Breakdown of average feasibility scores into average scores of the seven key criteria for management of A. triangulatus*

E. Recommendations for management

Since the species is not yet present in Belgium, the default management option stipulated by the European Regulation is eradication. However, **since feasibility of eradication is scored as low – with both low effectiveness and practicality – we estimate that the probability of success is very limited.** The spread limitation strategy could be more effective, but only if the species is rapidly detected (even earlier than described in the invasion scenario under discussion) and the population is still very small and localized (short window of opportunity, 2 months – 1 year). Prevention of transfer of soil from contaminated areas is crucial for this.

Derogations from the obligation of rapid eradication – *sensu* article 18 of the EU Regulation – might need to be sought for *A. triangulatus* depending on local conditions.

References

Blackshaw RP (1996) Control options for the New Zealand flatworm. Brighton Crop Protection Conference, Pests and Diseases, Brighton, UK, 18–21 November 1996. vol 3. BCPC, p 1089–1094.

Blackshaw RP, Moore JP, Alston R (1996) Removal trapping to control *Artioposthia triangulata*. Annals of Applied Biology 129(2):355–360.

Boag, B., et al. (1999) Spatial distribution and relationship between the New Zealand flatworm *Arthurdendyus triangulatus* and earthworms in a grass field in Scotland. *Pedobiologia* 43.4 : 340-344.

Boag, B., Deeks, L., Orr, A., & Neilson, R. (2005). A spatio-temporal analysis of a New Zealand flatworm (*Arthurdendyus triangulatus*) population in western Scotland. *Annals of applied biology*, *147*(1), 81-88.

Boag, B., Mackenzie, K., McNicol, J. W., & Neilson, R. (2010). Sampling for the New Zealand flatworm. *Crop Protection in Northern Britain 2010*, 45-50.

Boag, B., & Neilson, R. (2014). The spread and movement of the New Zealand flatworm (*Arthurdendyus triangulatus*) in Scotland. Proceedings of Crop Protection in Northern Britain 2014, 55-59.

Cannon, R. J. C., Baker, R. H. A., Taylor, M. C., & Moore, J. P. (1999). A review of the status of the New Zealand flatworm in the UK. *Annals of Applied Biology*, *135*(3), 597-614.

Hugh D. Jones & Ronald Sluys (2016) A new terrestrial planarian species of the genus *Marionfyfea* (Platyhelminthes: Tricladida) found in Europe, Journal of Natural History, 50:41-42, 2673-2690, DOI: 10.1080/00222933.2016.1208907

Murchie, A. (2017). Technical note: The management of New Zealand flatworm (A*rthurdendyus triangulatus*) measures and associated costs.

Murchie, A. K., Moore, J. P., Walters, K. F., & Blackshaw, R. P. (2003). Invasion of agricultural land by the earthworm predator, *Arthurdendyus triangulatus* (Dendy): The 7th international symposium on earthworm ecology· Cardiff· Wales· 2002. *Pedobiologia*, *47*(5-6), 920-923.

Murchie, Archie & Harrison, A.J. (2004). Mark-recapture of 'New Zealand flatworms' in grassland in Northern Ireland. Proc. Crop Protection in Northern Britain 2004. 63-67.

Murchie, Archie K., and Alan W. Gordon (2013). The impact of the 'New Zealand flatworm', *Arthurdendyus triangulatus*, on earthworm populations in the field. Biological Invasions 15 : 569-586.

Soors, J, Van den Neucker, T, Halfmaerten, D, Neyrinck, S & De Baere, M (2019). On the presence of the invasive planarian *Obama nungara* (Carbayo, Alvarez-Presas, Jones & Riutort, 2016) (Platyhelminthes: Geoplanidae) in an urban area in Belgium', *BELGIAN JOURNAL OF ZOOLOGY*, vol. 149, no. 1, pp. 43-47.

Soors J., Mees J., Sevrin D. & Van den Neucker T. (2022). *Marionfyfea adventor* Jones & Sluys (2016), a non- native land planarian new for Belgium (Platyhelminthes: Tricladida: Geoplanidae). Belgian Journal of Zoology 152: 113–116. https://doi.org/10.26496/bjz.2022.102

3.2.4. Axis deer, *Axis axis* (chital, Cerf axis)

Credits: Shutterstock

A. Invasion scenario

- Invasion situation and history in BE: The species is absent from the wild in Belgium. Considering the species has been included on the positive list of mammals since 2001 (which was regionalized in 2009), we can assume that some legally acquired captive specimens are still present in Belgium. The imaginary invasion scenario is that six individuals that escaped an enclosure are reported and correctly identified by a nature enthusiast in a forest in the Campine region (more specifically "Limburgse Kempen").

- Reliability of the BE distribution: Since the species is quite easily distinguished from native roe deer, we can expect the distribution to be reliable. The species might be confused with the non-native fallow deer *Dama dama*, which has been observed in the wild throughout Belgium with several bigger population nuclei (*e.g.* Drongengoed). Confusion might also arise with red deer *Cervus elaphus*, and more probably, with sika deer *C. nippon*. A small reproductive nucleus of the latter Union list species is present locally in the Campine region (Zonhoven) but is under removal management as of 2023.

- Invasion situation in neighbouring countries: The species is absent from our neighboring countries.

B. Management strategy – eradication

- Methods and techniques:

A network of camera traps (state-of-the-art model, with infrared camera) is set up in the forest to confirm the presence and pattern of activity (locations, diurnal behaviour) of *Axis axis* individuals. Ground shooting, which is the most successful control strategy for axis deer (Côté et al. 2004 ; Gurtler et al., 2018), is performed during the day, at dawn (from one hour before sunrise) and at dusk (up to one hour after sunset), since Axis deer has a bimodal activity pattern, with activity peaking in the morning (between 7:00 and 9:00 am) and in the evening (between 5:00 and 11:00 pm), which is a typical behavioral pattern of cervids (Centore et al. 2018). If considered necessary, an exemption is requested to allow for shooting at night. Nightly shooting involves additional safety hazards and requires necessary care to avoid causing inconvenience or disturbance to local residents. The local police and municipal authorities are informed to help alleviate any concerns from residents and visitors. Nightly hunting is performed by professionals in the field and under coordination of the regional agency.

Since these animals escaped from captivity and are probably not as trap shy as wild game, traps could also be considered. This not only ensures the animals are not disturbed and reduces the chances of them moving on, but it also ensures citizens will keep notifying the correct services when large IAS herbivores are observed. Trapping can also be considered when shooting is difficult. For large herbivores, a clover trap, a Stephenson trap or a corral trap could be used (Mitchel, 2016; Smith 2022) The traps used are equipped with cameras that have integrated SIM card and send images to the coordinator/trappers smartphone/ipad to reduce the number of hours spent in the field. Bycatch (e.g. roe deer) is released on site. Caught animals are humanely killed (Smith et al. 2022). In the case of chital deer, cameras or traps are (pre)baited with lucerne and mineral salt, to increase the chances of detection (The Deer Initiative, 2008; Waring et al., 1998; Mitchell, 2016). However, relatively high winter temperature and corresponding increased food availability prevent successful trapping of high numbers using corrals/enclosures (Lammertsma et al., 2012).

Once the spread of chital is too advanced, eradication of the population might not be effective, as was the case in Scotland and Germany (Perez-Espona et al., 2009; Elliger et al., 2011) for the sika deer.

- Post-intervention verification:

Camera trapping has to be maintained in the area and suitable habitat nearby for at least 3 years after removal of the animals. The first year this is achieved by a professional, the next two years surveillance will rely on volunteers and locals. Additionally, efforts are undertaken to enhance enforcement of the restrictions regarding captive chital.

C. Management strategy – spread limitation

- Aim: *Option 1. Stand-still principle with **a single or a few patches***

The spread limitation strategy aims at containing the populations of axis deer in the forest domain and at avoiding any further spread outside of this area.

- Methods and techniques:

Any new free-roaming chital (populations) outside the area are eradicated using the methods described in the eradication strategy.

Culling can prevent range expansion (Bartos, 2009; Pérez-Espona et al., 2009; Swanson & Putman, 2009) and hybridisation with other deer species. However, many deer species are usually considered hard to cull because of their high alertness and propensity to change their behaviour in response to regular hunting (Kamei et al., 2010; Dvorak et al., 2014). Therefore, it should be considered to organise a well-coordinated campaign that is informed by camera trapping and documenting deer habits, but only spans a short timeframe in which shooting is practiced. To keep densities low, chital deer could also be trapped in the wintertime using the traps mentioned in the eradication strategy.

If other efforts prove unsuccessful, the population could be fenced with fences of minimum 2 meters high, a full hunting ban is instated inside the fenced area and the habitat kept as-is in order to keep providing chital habitat (food and shelter) and not to induce natural dispersal to other areas.

- Post-intervention verification:

The fence needs to be maintained and inspected regularly. A network of cameras should be set up around the borders of the fenced forest (when fencing was applied), in neighbouring suitable habitat and in other locations where specimens have been removed.

D. Assessment results

The average feasibility scores appointed by experts range from medium to high for both the eradication and the spread limitation scenario, which is rather high compared to other animal species. **All experts ended up with a higher feasibility score for the eradication scenario than for the spread limitation scenario**. When looking at individual criteria, effectiveness, practicality, cost and likelihood of reintroduction were scored between 5 and 4 for the eradication scenario. The worst scores were found in the spread limitation scenario, most notably for practicality and impact.

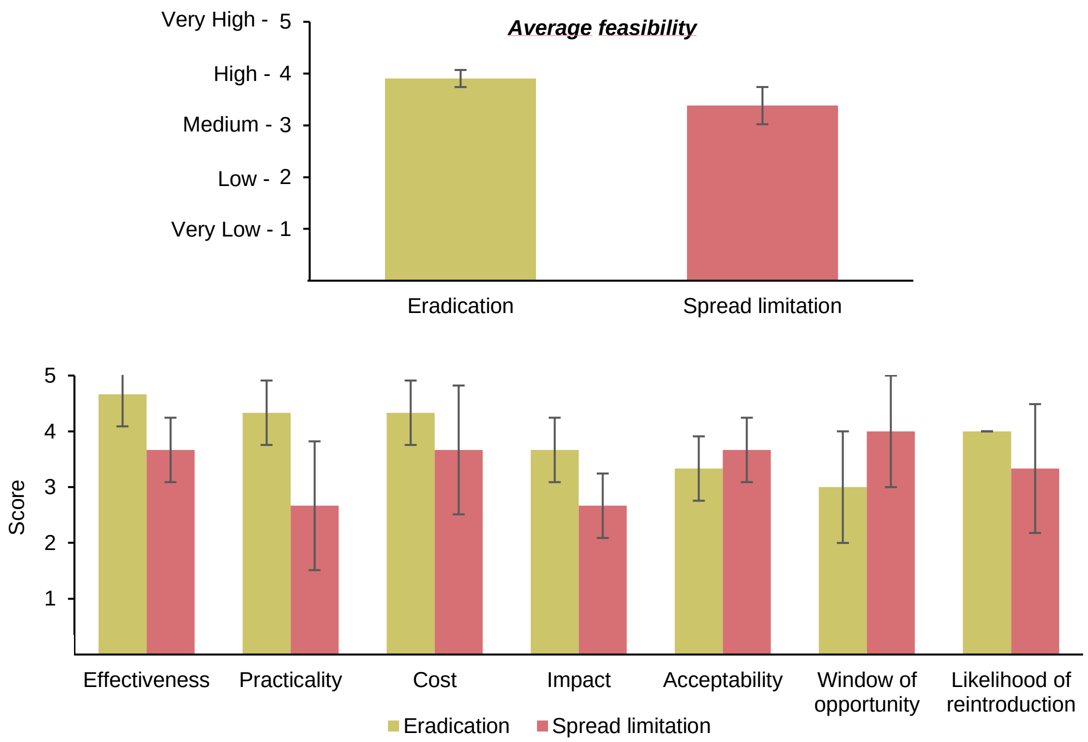


***Figure 9. Top:** Average feasibility scores for the eradication and spread limitation scenario of Axis axis; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of A. axis*

E. Recommendations for management

The experts agree on the **eradication of all individuals on the Belgian territory as a management recommendation**, which is in line with the guiding principle of eradication for species of the EU Regulation not yet present in Belgium.

References

Bartos, L. (2009) Sika deer in continental Europe. In: McCullough et al. (Eds), Sika deer: biology and management of native and introduced populations, Springer Japan: 573-594.

Côté, S. D., Rooney, T. P., Tremblay, J., Dussault, C., & Waller, D. M. (2004). Ecological Impacts of Deer Overabundance. Annual Review of Ecology, Evolution & Systematics, 35 (1), 113-147.

Elliger, A., M. Pegel and P. Linderoth (2011). Jagdbericht Baden-Württemberg 2010/2011. LAZBW, Aulendorf.

Dvořák, S., Barták, V., Macháček, Z., & Matějů, J. (2014). Home range size and spatio-temporal dynamics of male sika deer (Cervus nippon; Cervidae, Artiodactyla) in an introduced population. Folia zoologica, 63(2), 103-115.

Gürtler, R.E., Rodríguez-Planes, L.I., Gil, G., Izquierdo, V.M., Cavicchia, M. and Maranta, A. (2018). Differential long-term impacts of a management control program of axis deer and wild boar in a protected area of north-eastern Argentina. *Biological invasions*, *20*(6), pp.1431-1447.

Lammertsma, D. R., Bruinderink, G. G., & Griffioen, A. J. (2012). Risk assessment of Sika deer Cervus nippon in the Netherlands(No. 2295). Alterra, Wageningen-UR.

The Deer Initiative (2008). Corporate strategy 2008-2015.

Kamei, T., Takeda, K. I., Izumiyama, S., & Ohshima, K. (2010). The effect of hunting on the behavior and habitat utilization of sika deer (Cervus nippon). Mammal study, 35(4), 235-241.

Smith, K.G., Nunes, A.L., Aegerter, J., Baker, S.E., Di Silvestre, I., Ferreira, C.C., Griffith, M., Lane, J., Muir, A., Binding, S., Broadway, M., Robertson, P., Scalera, R., Adriaens, T., Åhlén, P-A., Aliaga, A., Baert, K., Bakaloudis, D.E., Bertolino, S., Briggs, L., Cartuyvels, E., Dahl, F., D'hondt, B., Eckert, M., Gethöffer, F., Gojdičová, E., Huysentruyt, F., Jelić, D., Lešová, A., Lužnik, M., Moreno, L., Nagy, G., Poledník, L., Preda, C., Skorupski, J., Telnov, D., Trichkova, T., Verreycken, H. and Vucić, M. (2022). A manual for the management of vertebrate invasive alien species of Union concern, incorporating animal welfare. 1st Edition. Technical report prepared for the European Commission within the framework of the contract no. 07.027746/2019/812504/SER/ENV.D.2.

Swanson, G.M. & Putman, R. (2009) Sika deer in the British Isles. In: McCullough DR, Takatsuki S, Kaji K (eds) Sika Deer: Biology and Management of Native and Introduced Populations, 595–614. Springer, Tokyo, Japan.

Mitchell, J. (2016) Final Report, Chital Deer Trapping. Unpublished report. https://www.researchgate.net/publication/321403198_Final_Report_Chital_Deer_Trapping

Pérez-Espona, S., Pemberton, J.M. & Putman, R. (2009) Red and sika deer in the British Isles, current management issues and management policy. Mamm. biol. 74: 247–262.

Robertson, P. (2019). Information on measures and related costs in relation to species considered for inclusion on the Union list: *Axis axis*. Technical note prepared by IUCN for the European Commission.

Waring, George H. "Preliminary study of the behavior and ecology of axis deer on Maui, Hawaii." *Department of Zoology, Southern Illinois University, Carbondale, IL, USA. Available at:(accessed 20 December 2006)* (1996).

3.2.5. Northern snakehead, *Channa argus* (noordelijke slangenkopvis, Poisson à tête de serpent du Nord)

Credits: Andshel - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=25142635

A. Invasion scenario

- Invasion situation and history in BE: *Channa argus* is currently not present in Belgium. The imaginary invasion scenario is that at the point of detection a few individuals were reported in Lake Cherapont in Gouvy by local fishermen. The introductions likely result from the dumping of the content of an aquarium by a member of the public, because the fish were getting too large.

- Reliability of the BE distribution: Since the species is quite conspicuous, absent from our neighboring countries, and not a very popular aquarium fish – though now export of snakehead fish from India is on the rise (Harrington et al., 2022)- we estimate that the distribution is reliable. However, other established populations may be undetected in standing waters since dedicated fish monitoring is mostly confined to rivers and streams in Belgium.

- Invasion situation in neighbouring countries: The species is absent from our neighbouring countries and the rest of the Union.

B. Management strategy – eradication

- Methods and techniques:

Firstly, the system should be isolated from other flowing or standing waters. In large systems, mechanical removal (overharvesting) seems the only way of potentially eradicating the species since drawdown is nearly impossible to achieve. Moreover, the dry state would need to be continued for several months since the species could burrow (for this species of *Channa* mostly in response to temperature) and survive temporary droughts, implying large side-effects on the entire ecosystem. Protocols for mechanical removal have been developed for a wide variety of fishes including predatory fishes similar to *Channa* species (such as West et al., 2007). A few mechanical removal methods are combined to increase harvest:

- Local anglers and recreational anglers are asked to bag every *Channa argus* they catch (cfr Agarwal et al., 2016) and increase effort on fishing this species. Along with this request, information on the impact of the local fish population is distributed to ensure there is no interest to spread this large species to other sites (Agarwal et al., 2016).

- Protocols for removal are well developed for a wide variety of fishes including predatory fishes similar to *Channa* species (e.g West et al., 2007) but electrofishing is preferred because it has the least amount of by-catch and damage to native fish populations (Mueller, 2005). Large scale removal should be easier during the (spring) spawning season, before juvenile dispersal, as *C. argus* is least mobile (Lapointe et al., 2010) and fish congregate in suitable habitats.

The use of 'rotenone' piscicide cannot be considered as a main option due to the legal restrictions in Belgium, yet it could be an option to eradicate the species in some conditions (artificial or low value water bodies) under a specific derogation on the use of biocides.

- Post-intervention verification:

Other waterbodies in the immediate vicinity could be monitored with eDNA since these fish can migrate over land for short distances at a slow pace – especially in response to drought. However, this behavior appears to be rare. Eradication measures should be applied if a positive sample is confirmed. For smaller systems, this implies draining the system and capturing the individuals with seines. Care must be taken to avoid further dispersal through outlets of the pumping system and a barrier should be installed along the pond to prevent specimens from escaping over land (Bressman et al., 2019). The drainage should last long enough (at least two years) since the species can burrow in response to drought (Courtenay and Williams, 2004; Landis, et al., 2011). A multi-year drought will ensure freezing in winter or desiccation in summer if the specimens try to escape the dry pond but are stopped by a barrier. In practice, it is complicated by partial fill of the lake/pond when there is a lot of rain which allows the snakehead to survive.

C. Management strategy – spread limitation

- Aim: *Option 1 - Stand-still principle with a single or a few patches.*

The spread limitation strategy aims at limiting the presence of this species in Belgium to the lake, pond or river basin.

- Methods and techniques:

Firstly, connectivity of the system should be analysed, and action should be taken to avoid fish from spreading even further into connected systems.

Secondly, nearby aquatic systems should be monitored with eDNA. If the species is detected in a small standing water, where feasible, it should be dewatered and fish captured - non target species should also be removed before drawdown. During the drawdown, care must be taken to avoid further dispersal through outlets of the pumping system. A barrier should be installed along the pond to prevent specimens from escaping over land (Bressman et al., 2019). The drainage should last long enough (at least two years) since the species can burrow in response to drought (Courtenay and Williams, 2004; Landis, et al., 2011). A multi-year drought will lead to freezing in winter or desiccation in summer if the specimens try to escape the dry pond but are stopped by a barrier.

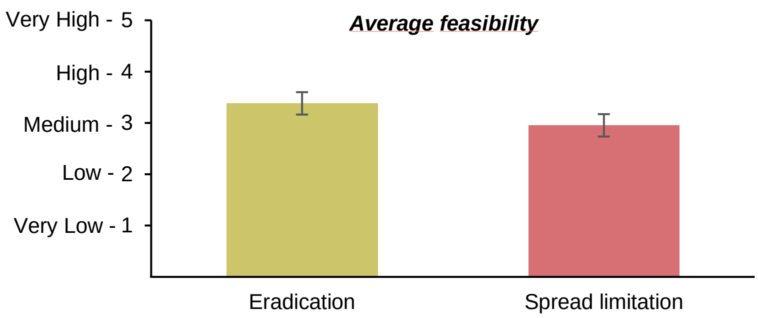
After drainage, quicklime (CaO) could be added since the fish can survive brief moments of drought in the sediment and are very tolerant to low oxygen conditions in any water that may remain and can even switch to air breathing (Duan et al., 2018;). However, this should only be considered for ponds of low ecological value due to the potential of non-target effects.

- Post-intervention verification:

Clear information signs are put up in the infected stretch of river. Additionally, anglers are informed of the presence of the species and the harmful effects it can have on their hobby. Mass capture of specimens in the isolated stretch is repeated indefinitely, and population size is monitored.

D. Assessment results

The average feasibility scores appointed by experts ranged from a little over medium to a little under medium for the eradication and the spread limitation scenario respectively. Though the difference in average feasibility score between both scenarios is not very large, **all three experts scored the eradication scenario as most feasible**. It must be noted however, that while 6 out of 7 criteria were consistently scored higher by all experts for the eradication scenario, the "effectiveness" criterion was scored consistently lower for the eradication scenario than the spread limitation scenario by all experts. The main limiting factor for both scenarios is the window of opportunity evaluated as short (2 months - 1 year).



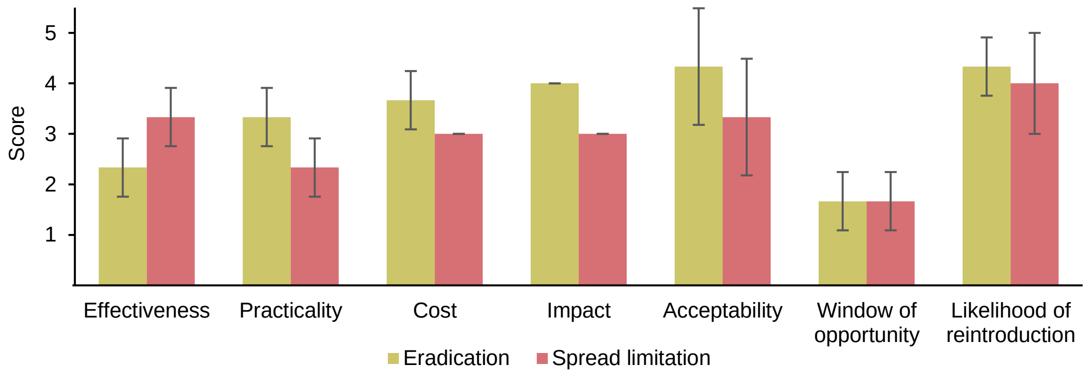


Figure 10*. **Top***: *Average feasibility scores for the eradication and spread limitation scenario of Channa argus;* ***Bottom***: *Breakdown of average feasibility scores into average scores of the seven key criteria for management of C. argus.*

E. Recommendations for management

The invasion scenario that was proposed was a worst-case scenario, in which the species was located in a system that is large and has a river flowing through. Even with these limitations for hydrological isolation (inundation, beaver activity), the eradication scenario was consistently scored higher by assessors – except on the effectiveness criterion. It is estimated that electrofishing and drawdown are not effective for this burrowing species which is also adapted to aerial respiration for several days. Therefore, it is suggested to combine drawdown with CaO application.

Therefore, **we suggest the eradication strategy as management recommendation**, in line with the guiding principle of eradication for species of the EU Regulation not yet present in Belgium, **though local factors could prevent such a management action to be successful**. The main influencing factors are connectivity and the possibility of drawdown.

Experts stipulated that since breeding activity of this species is not limited to spring, eradication should take place as soon as possible after detection. Furthermore, an addition to the current strategy could be to develop a rehoming strategy in partnership with the zoos to encourage all anglers – also those that would not want to kill a captured specimen – to be supportive of the efforts.

Derogations from the obligation of rapid eradication – *sensu* article 18 of the EU Regulation – might need to be applied for this aquatic species depending on local conditions.

References

Agarwal, I., Amrhein, L., Fitzgerald, B., Golt, S., Gonzalez, Z., Hentati, Y., ... & Watts, N. (2016). Angler Perception and Population Dynamics of the Northern Snakehead (*Channa argus*) in the Potomac River & Tributaries (Doctoral dissertation).

Bressman, N. R., Love, J. W., King, T. W., Horne, C. G., & Ashley-Ross, M. A. (2019). Emersion and terrestrial locomotion of the northern snakehead (*Channa argus*) on multiple substrates. Integrative Organismal Biology, 1(1), obz026.

Courtenay, W., J. Williams (2004). Snakeheads (Pices, Channidae)- a biological synopsis and risk assessment.

Duan, T., Shi, C., Zhou, J., Lv, X., Li, Y., & Luo, Y. (2018). How does the snakehead Channa argus survive in air? The combined roles of the suprabranchial chamber and physiological regulations during aerial respiration. Biology Open, 7(2), bio029223.

Harrington, L. A., Mookerjee, A., Kalita, M., Saikia, A., Macdonald, D. W., & D'Cruze, N. (2022). Risks associated with the global demand for novel exotic pets: A new and emerging trade in snakehead fish (Channa spp.) from India. Biological Conservation, 265, 109377.

Landis, A., N. Lapointe, P. Angermeier (2011). Individual growth and reproductive behavior in a newly established population of northern snakehead (*Channa argus*), Potomac River, USA. Hydrobiologia, 661: 123-131.

Lapointe, N. & Thorson, James & Angermeier, P. (2010). Seasonal meso-and microhabitat selection by the Northern snakehead (*Channa argus*) in the Potomac river system. Ecology of Freshwater Fish - ECOL FRESHW FISH. 19. 10.1111/j.1600-0633.2010.00437.x.

Mueller, G.A. (2005). Predatory fish removal and native fish recovery in the Colorado River main stem: what have we learned? *Fisheries* 30(9), 10–19.

H. Verreycken, L.R. Aislabie, G.H. Copp (2019). Information on measures and related costs in relation to species considered for inclusion on the Union list: *Channa argus*. Technical note prepared by IUCN for the European Commission.

West, P., Brown, A. and Hall, K. (2007). Review of alien fish monitoring techniques, indicators and protocols: Implications for national monitoring of Australia's inland river systems. Invasive Animals Cooperative Research Centre, Canberra, Australia.

3.2.6. Rusty crayfish, *Faxonius rusticus* (roestbruine Amerikaanse rivierkreeft, Ecrevisse à taches rouges)

Credits: Emilio Concari, CC BY-NC - https://www.inaturalist.org/photos/123275116?size=original

A. Invasion scenario

- Invasion situation and history in BE: Not currently established in the wild in Belgium. The imaginary invasion scenario is that at the point of detection there will be several individuals reported in the Dijle (Dyle) and some adjacent closed meanders. This introduction is the result of the release of unwanted animals from an aquarium.
- Reliability of the BE distribution: The species is widely present and considered to be popular in the aquarium culture (Chucholl et al., 2013 but not in Pakota et al. 2015) yet has never been reported in the wild in Belgium. Since the species has only been observed in France, the distribution is thought to be reliable.
- Invasion situation in neighbouring countries: The species has only been reported in France in 2019 in the Aveyron department.

B. Management strategy – eradication

- Methods and techniques:

In the context of closed systems, the best method is a combination of pond drawdown, liming and fencing (Basilico et al 2013). Firstly, a barrier is installed around the ponds before drainage to avoid crayfish emigration and facilitate hand capture. Secondly, the closed systems are maximally drained by allowing water to pour out naturally or by active pumping. Care should be taken that the individuals are not spread by the displacement of water. After drawdown, there are two options:

- Though burrowing behavior is not well described for this species in Europe (Gherardi et al. 2011; Tricarico & Aquiloni 2016; Stebbing and Tricario, 2017), maximal drawdown should be maintained during at least 2 successive years in order to kill potentially burrowed animals by drought, but especially frost during the wintertime.
- Alternatively, quicklime could be added immediately after drawdown and hand capture, to quickly render the habitat inhospitable.

Finally, no matter the option chosen, restoration measures should be taken after drawdown[5].

In the river system, connectivity to other systems should be interrupted and fencing could be considered at some strategic sites where crayfish are more likely to crawl out. The crayfish populations are targeted using a combination of predation by eel, pike or perch (Müller & Frütiger 2001, Frütiger & Müller 2002) and intensive trapping. Both approaches are complementary (Hein et al. 2006) since predators usually target juveniles or small sized crayfish, while trapping targets larger individuals. A combination of baited traps of various designs (Swedish traps, Evo-traps, collapsible traps, fyke nets, seine nets, etc.) should be used in combination with artificial refuge traps which are more efficient at catching subadult stages and ovigerous females (Green et al., 2018) and are supposed to limit bycatch (Curti et al., 2021). Trapping should be conducted for extensive periods with high trap density, high emptying frequency (at least every two days) and attractive baits such as fish (Gherardi et al., 2011; Stebbing et al., 2014; Stebbing et al., 2016).

The use of sexual pheromones, sterile male release, pesticides (e.g Pyblast), electrofishing and crayfish pathogens (e.g. white spot syndrome virus and bacteria *Spiroplasma*) as biocontrol agents are not part of the strategy because of limited efficiency and/or legal limitations and/or strong non-target effects in the Belgian context (see e.g. Aldridge et al. 2015).

- Post-intervention verification:

Once the species has been removed from the closed systems and the river system, they are monitored by a dedicated team to ensure *F. rusticus* does not recolonize the sites. This is done using trapping systems and eDNA.

C. Management strategy – spread limitation

- Aim: *Option 2 - Stand-still principle with core areas.*

The spread limitation strategy aims at limiting the presence of this species in Belgium to the stretch of river where it has first been reported and to eliminate all occurrences outside of this stretch of river.

- Methods and techniques:

In the closed systems (closed meander/ponds), eradication is achieved using the methods outlined in the eradication strategy.

In the river system, the population is controlled using trapping, but with a lower intensity than in the eradication scenario.

[5] This specification was added after scoring of the scenarios, thanks to expert's input

- Post-intervention verification:

The closed meanders where the species has been removed are monitored using a combination of traps and eDNA by a dedicated team to ensure *F. rusticus* does not recolonize the sites. Additionally, ponds more downstream and upstream are also monitored with these techniques to ensure the population does not expand.

D. Assessment results

The average feasibility score of the eradication and spread limitation scenario were a little bit higher than medium for both scenarios. **There was no consensus between experts on the scenario that should be adopted.** While the first expert favoured the spread limitation scenario, the second favoured the eradication scenario and the third ranked them as equal. Average scores of 4 out of 7 criteria were identical for both scenarios (practicality, impact, acceptability, likelihood of reintroduction).

The effectiveness of the eradication scenario scored on average below medium effectiveness while the spread limitation effectiveness scored even lower - a little below ineffective. Variability on effectiveness scoring was rather high, with one assessor scoring both scenarios as very ineffective and both other experts scoring the eradication scenario higher than the spread limitation scenario. The largest difference between scenarios was the window of opportunity, which was larger for the spread limitation scenario.

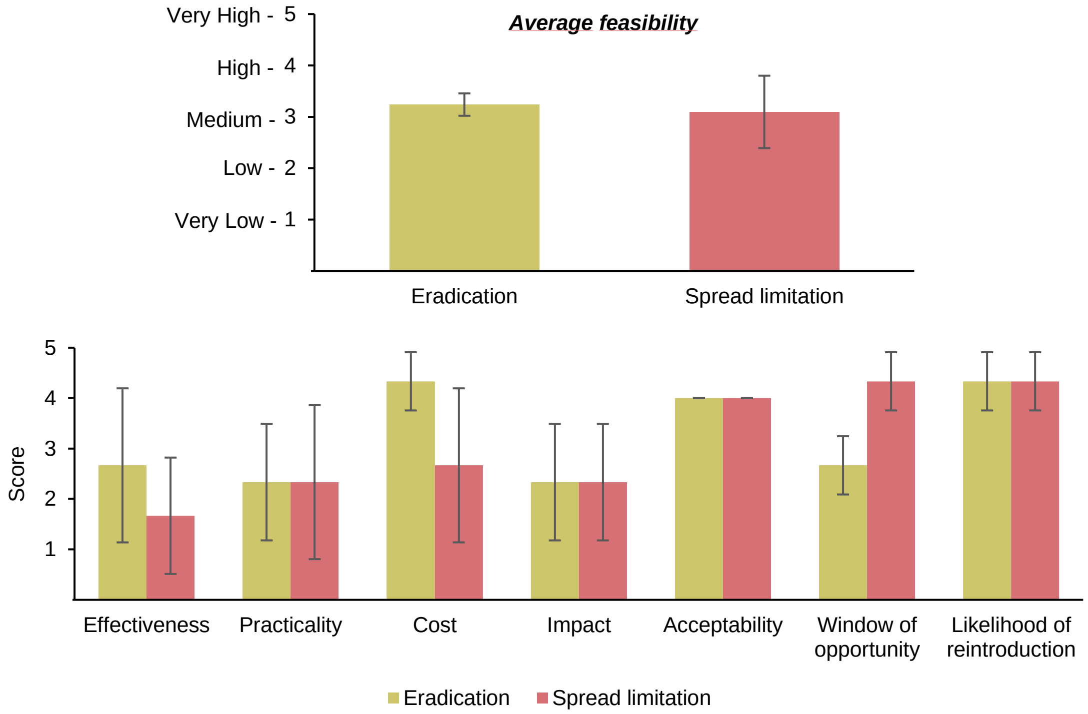


***Figure 11. Top**: Average feasibility scores for the eradication and spread limitation scenario of Faxonius rusticus; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of F. rusticus*

E. Recommendations for management

No clear distinction could be made between the two scenarios – especially since the management methods that can be deployed – and consequently also practicality, effectiveness, costs - are very context dependent. The main influencing factors are connectivity and the possibility of drawdown with subsequent liming and removal of bank substrate. Therefore, **we suggest the default management option should be eradication**, in line with the guiding principle of eradication for species of the EU Regulation not yet present in Belgium, **though local factors could prevent such a management action to be successful**. Experts agree that eradication can most likely only be successful for small and isolated ponds at an early invasion stage.

Derogations from the obligation of rapid eradication – *sensu* article 18 of the EU Regulation – might need to be applied for this aquatic species depending on local conditions.

References

Aldridge D. C. et al. (2015). Control of freshwater invasive species: global evidence for the effects of selected interventions. The University of Cambridge, UK.

Basilico L. et al. (2013). Les invasions d'écrevisses exotiques : impacts écologiques et pistes pour la gestion. Les rencontres de l'ONEMA, 76 pp.

Chucholl, Christoph (2013). Invaders for sale: trade and determinants of introduction of ornamental freshwater crayfish. Biological invasions 15 : 125-141.

Curti, J. N., Fergus, C. E., & Palma-Dow, A. A. D. (2021). State of the ART: Using artificial refuge traps to control invasive crayfish in southern California streams. Freshwater Science, 40(3), 494-507.

Gherardi, F., Aquiloni, L., Diéguez-Uribeondo, J., & Tricarico, E. (2011). Managing invasive crayfish: is there a hope?. Aquatic Sciences, 73, 185-200.

Green, N., Bentley, M., Stebbing, P., Andreou, D., & Britton, R. (2018). Trapping for invasive crayfish: comparisons of efficacy and selectivity of baited traps versus novel artificial refuge traps. Knowledge & Management of Aquatic Ecosystems, (419), 15.

Patoka, J., Kalous, L., & Kopecký, O. (2014). Risk assessment of the crayfish pet trade based on data from the Czech Republic. Biological Invasions, 16, 2489-2494.

Stebbing, P., Longshaw, M., & Scott, A. (2014). Review of methods for the management of non-indigenous crayfish, with particular reference to Great Britain. Ethology Ecology & Evolution, 26(2-3), 204-231.

Stebbing, P. (2016). The management of invasive crayfish. Biology and ecology of crayfish, 337-357.

Stebbing, P., Tricario, E. (2017). Information on measures and related costs in relation to species considered for inclusion on the Union list: *Orconectes rusticus*. Technical note prepared by IUCN for the European Commission.

Tricarico E., Aquiloni L., (2016). How behaviour helped invasive crayfish to conquer the freshwater ecosystems. In: Weis J, Sol D (eds) Biological Invasions and Animal Behaviour, Cambridge University Press, Chapter 16: 291-308.

3.2.7. Mummichog, *Fundulus heteroclitus* (mummichog, Choquemort)

Credits: Alex R. - CCBYNC - https://www.inaturalist.org/photos/21705657

A. Invasion scenario

- Invasion situation and history in BE: The species is currently not established in the wild in Belgium. The imaginary scenario is that, at the point of detection, a population is discovered by an employee of Ghent University in the brackish part of the Scheldt estuary (Zeeschelde). The introduction was probably the result of the dumping of the content of an aquarium or alternatively, resulted from the release of contaminated ballast water.
- Reliability of the BE distribution: While we consider the distribution to be quite reliable, established populations may be underdetected in tidal creeks and saltmarshes since dedicated fish monitoring is mostly confined to rivers and streams in Belgium. For the Scheldt estuary, the monitoring of estuaries fits into the framework of the Water Framework Directive.
- Invasion situation in neighbouring countries: The species is currently absent from our neigbouring countries.

B. Management strategy – eradication

- Methods and techniques:

Since this species has a "fast" life-history strategy (i.e. small-sized, early maturation, and ability for populations to rapidly increase), and lives in large, open habitats (estuaries, coastal lagoons, and saltmarshes), it will easily have formed a population before being detected.

Currently, there is no method for eradication described unless it is in a very small, closed habitat - which is not typical for the mummichog (García-Berthou and Alcaraz-Hernández, 2019). Early detection is essential to avoid establishment and reproduction in the open habitats (coastal lagoons and estuaries) typical of this species. If mummichog arrived in an enclosed or isolated water body such as a ditch, channel or a small pond, complete drainage of the small waterbody would be a possible eradication measure (García-Berthou and Alcaraz-Hernández, 2019) - taking into account proper measures to ensure no further spread by dewatering of the system. Furthermore, it needs to be taken into account that the eggs are deposited on the high intertidal and can withstand prolonged air exposure.

For the Zeeschelde and its saltmarshes, the eradication strategy relies on the use of electrofishing, although its effectiveness is expected to be limited in a large open and intertidal system (H. Verreycken, personal communication, 2023). An increased angling effort could also be promoted through dedicated communication campaigns with recreational anglers, even though the species is unlikely to be targeted by anglers due to its small size and would require changes in the legislation in terms of the amount of specimens anglers are allowed to take. This strategy would require intensive effort and multiple treatments over a number of years.

- Post-intervention verification:

Sites where *Fundulus* was eradicated should be monitored using eDNA methodology (Davison et al. 2017) and trapping (funnels or electrofishing) for multiple years.

C. Management strategy – spread limitation

- Aim: *Option 2 - Stand-still principle with a core area.*

The spread limitation strategy aims at limiting the presence of this species in Belgium to the brackish part of Scheldt estuary and avoiding dispersal to the Yser estuary and to standing waters.

- Methods and techniques:

Population numbers in the Zeeschelde are managed through trapping efforts (trawl nets, fyke nets, traps) and electrofishing – with the limitations mentioned above.

Upstream parts of the Scheldt (freshwater) are monitored with electrofishing. If necessary, capture should be performed in these stretches of the river via increased angling efforts – with the limitations mentioned above.

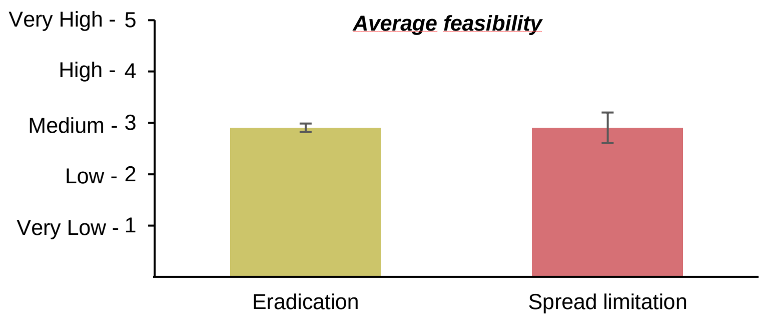
The Yser estuary and protected habitats of interest (e.g. Zwin, Nieuwpoort) are also monitored via increased efforts of trapping – even though such dispersal events would probably be very rare due to the lack of suitable habitat in between[6]. If the species is detected, eradication should be achieved using the methods outlined in the eradication strategy.

- Post-intervention verification:

Sites where *Fundulus* was eradicated should be monitored using e-DNA methodology (Davison et al., 2017) and trapping (funnels or electrofishing) for multiple years.

D. Assessment results

Average feasibility score of both scenarios was identical – slightly below medium - though assessors did not agree on relative feasibility of scenarios. One assessor scored the eradication scenario as most feasible, while another scored the spread limitation as most feasible. The third assessor scored them as equal. Average scores of 4 out of 7 criteria were identical for both scenarios (effectiveness, practicality, cost, impact). While assessors sometimes assigned different scores for these criteria, not a single one changed their appreciation between both scenarios indicating they do agree that there is no clear difference between these scenarios in terms of effectiveness, practicality, cost and impact. Of these 4 criteria, only costs was estimated to be a little over 3 (and thus better than medium). Differences in appreciation between scenarios were very small for the other 3 criteria. Practicality of the methods was the most limiting factor for both scenarios, which was seen as impractical.



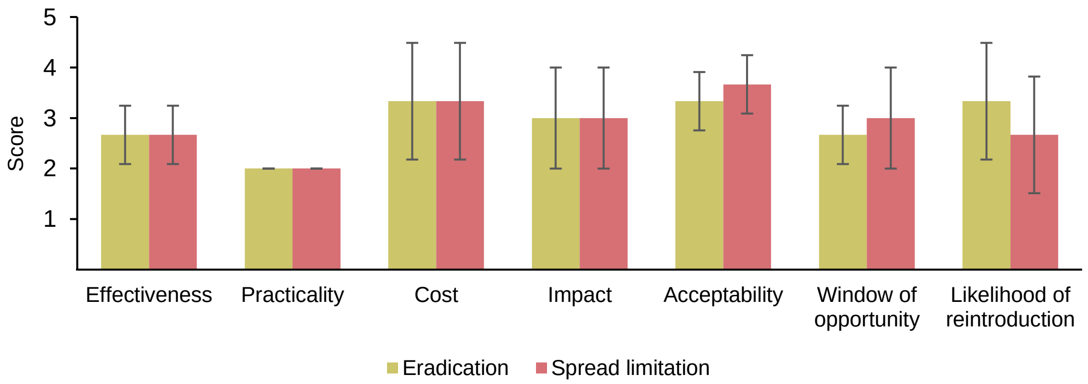


Figure 12. Top: Average feasibility scores for the eradication and spread limitation scenario of *Fundulus heteroclitus*; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of *F. heteroclitus*.

[6] This specification was added after scoring of the scenarios, following expert's input

E. Recommendations for management

No clear distinction could be made between the two scenarios, mainly because experts do not deem either scenarios feasible or realistic due to the lack of effective and practically deployed measures. **Though eradication is the default option foreseen by the EU Regulation for species not yet present in Belgium, we do not deem this feasible, unless the species would be discovered in a small and closed system.** A choice for a **population control strategy** would be most realistic, given the fact that spread limitation also has a low feasibility. Experts also stress the greater efficiency of implementing preventive measures to avoid the introduction of marine and brackish water species.

Derogations from the obligation of rapid eradication – *sensu* article 18 of the EU Regulation – will probably need to be applied for this aquatic species depending on local conditions.

References

Davison P.I., Copp G.H., Créach V., Vilizzi L., Britton J. (2017). Application of environmental DNA analysis to inform invasive fish eradication operations. *The Science of Nature* 104(3-4):35.

García-Berthou, E. and J.D. Alcaraz-Hernández 2019. Information on measures and related costs in relation to species considered for inclusion on the Union list: *Fundulus heteroclitus*. Technical note prepared by IUCN for the European Commission.

3.2.8. Western gambusia, *Gambusia affinis* (Westelijk gambusia, Gambusie de l'ouest)

Credits: Nozo

A. Invasion scenario

- Invasion situation and history in BE: The species is currently not present in the wild in Belgium. The likely invasion scenario is that at the point of detection a population is detected in an isolated pond, probably resulting from the dumping of the content of an aquarium or an illegal introduction for mosquito control.
- Reliability of the BE distribution: While we consider the distribution to be quite reliable, established populations may be underdetected in standing waters since dedicated fish monitoring is mostly confined to rivers and streams in Belgium.
- Invasion situation in neighbouring countries: The species is currently not present in any of our neighbouring countries.

B. Management strategy – eradication

- Methods and techniques:

The methods under consideration below are adapted from Reynolds and Smith, 2022.

Effective eradication is most likely to be successful when the invasion is at a very early stage and limited to a relatively small and closed system. Successful eradications in large open bodies of water are very rare.

The most successful method would combine drainage, with potential quicklime treatment (which might not be needed since the species is pelagic[7]), and biomanipulation. Before drainage, mechanical capture methods such as electrofishing, seine nets, minnow traps, and fyke nets could be used. Seine nets, traps and dip nets are the most efficient for capturing

[7] This specification was added after scoring of the scenarios, following expert inputs

Gambusia. However, as small mosquitofish easily get stuck in the nets, biosecurity measures should be applied to the equipment that was used in the management actions. Native species should be removed and quarantined before management actions start. After refilling of the pond – and conditions turning back to normal pH conditions if quicklime (CaO) was applied – they can be released again (Britton and Brazier, 2006). In ponds with native amphibians present, drainage should be performed between September and January.

After management actions, it could be considered to increase the resilience of the waterbody to new invasions of mosquitofish trough biomanipulation with juvenile northern pike (*Esox lucius*) or large Eurasian perch (*Perca fluviatilis*) (Davison et al. 2017) .

The use of 'rotenone' piscicide is not considered in this scenario due to the legal restrictions in Belgium, yet it could be an option to eradicate the species from urban artificial water bodies under a specific derogation on the use of biocides (e.g. fountains or other).

- Post-intervention verification:

Sites where *Gambusia* was eradicated should be monitored using eDNA methodology (Davison et al. 2017) and trapping (funnels or electrofishing) for at least two years.

C. Management strategy – spread limitation

- Aim: *Option 1 - Stand-still principle with a single or a few patches.*

The spread limitation strategy aims at limiting the presence of the *Gambusia* in Belgium to the few ponds, where it has been observed.

- Methods and techniques:

The ponds where the species was observed are left unmanaged, but measures to avoid fish from spreading further into connected systems should be implemented.

Secondly, nearby aquatic systems should be monitored with eDNA. If the species is detected in a small standing water, it should be eradicated using the methods outlined in the eradication strategy. If the species is detected in open waters, rapid eradication could be attempted with electrofishing and an increased angling effort, though the chances of success are deemed very low.

- Post-intervention verification:

Clear information signs are put up near the infected ponds. Other sites in the vicinity are monitored using eDNA methodology and trapping (funnels or electrofishing) for multiple years.

D. Assessment results

The average feasibility scores of both the eradication and spread limitation scenario were high. However, **there was no consensus between experts on which scenario was most feasible** since one assessor deemed the eradication scenario as most feasible and the other two indicated the spread limitation scenario as most feasible.

Average scoring of all criteria except window of opportunity was 4 or higher for the eradication scenario and above 3 for the spread limitation scenario. Window of opportunity was the criterion that was scored the lowest – in both scenarios. It scored between very low and low for the eradication scenario and between low and medium for the spread limitation scenario. On average, only cost and window of opportunity scored a little bit better in the spread limitation scenario, the other average scores were higher for the eradication scenario.

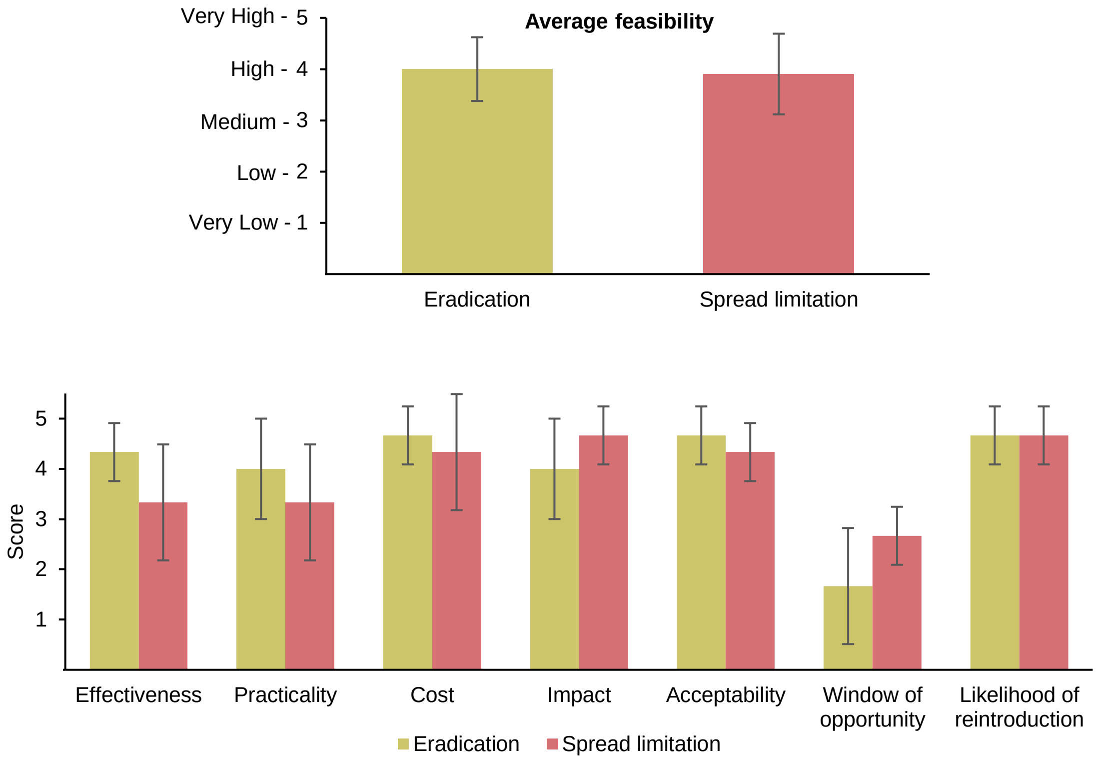


***Figure 13**. **Top:** Average feasibility scores for the eradication and spread limitation scenario of Gambusia affinis;*
***Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of G. affinis*

E. Recommendations for management

Because there was no real consensus between assessors and average scores given by experts were 4 or higher for the eradication scenario, **we recommend the eradication scenario**, in line with the guiding principle of eradication for species of the EU Regulation not yet present in Belgium, **though local factors could prevent such a management action to be successful**. The main influencing factors are connectivity and the possibility of drawdown. It has to be noted that, while the scenario is a detection in an isolated pond, the species can also thrive in riverbanks, flood plains and marshes, where eradication would be much harder.

In all instances, rapid action – within the year of detection – would also be required. Experts stress the need to perform eDNA monitoring quickly after detection to inform on the best management strategy.

References

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

Davison P.I., Copp G.H., Créach V., Vilizzi L., Britton J. (2017). Application of environmental DNA analysis to inform invasive fish eradication operations. *The Science of Nature* 104(3-4):35.

Reynolds R., Smith K. (2022). The management of *Gambusia holbrooki* and *Gambusia affinis*. Information on measures and related costs in relation to species on the Union list.

Verreycken, H. and G.H. Copp (2019). Risk Assessment for *Gambusia affinis.* Annex V with evidence on measures and their implementation cost and cost effectiveness*.*

3.2.10. Eastern gambusia, *Gambusia holbrooki* (Oostelijk gambusia, Gambusie de l'est)

Credits: MarshBunny CC BY-SA 4.0

A. Invasion scenario

- Invasion situation and history in BE: The species is currently not present in the wild in Belgium. The likely invasion scenario is that at the point of detection a population is detected in an isolated pond, probably resulting from the content of an aquarium or an illegal introduction for mosquito control.
- Reliability of the BE distribution: While we consider the distribution to be quite reliable, established populations may be undetected in standing waters since dedicated fish monitoring is mostly confined to rivers and streams in Belgium.
- Invasion situation in neighbouring countries: The species is established in France, but the closest location is almost 500 km from the Belgian border (inpn.mnhn.fr). There have been some isolated sightings in Germany, but the species is not considered to be established. The species is absent from the Netherlands and Luxembourg.

B. Management strategy – eradication

- Methods and techniques:

The following methods are taken from Reynolds and Smith, 2022.

Effective eradication is most likely to be successful when the invasion is at a very early stage and limited to a relatively small pond. Successful eradications in large open bodies of water are very rare.

The most successful method would combine drainage, with potential quicklime treatment (which might not be needed since the species is pelagic[8]), and biomanipulation. Before drainage, mechanical capture methods such as electrofishing, seine nets, minnow traps, and fyke nets could be used. Seine nets, traps and dip nets are the most efficient for *Gambusia.*

[8] This specification was added after scoring of the scenarios, following expert inputs

However, as small mosquitofish easily get stuck in the nets, biosecurity measures should be applied to the gear that was used. Native species should be caught and quarantined before management actions start. After refilling of the pond -and conditions turning back to normal pH conditions if quicklime (CaO) was applied - the native species can be released again (Britton and Brazier, 2006). In ponds with native amphibians present, drainage should be performed between September and January.

After management actions, increasing the resilience of the waterbody to new invasions of mosquitofish trough biomanipulation with juvenile northern pike (*Esox lucius*) or large Eurasian perch (*Perca fluviatilis*) (Davison et al., 2017) could be considered.

The use of 'rotenone' piscicide is not considered due to the legal restrictions in Belgium, yet it could be an option to eradicate the species from urban artificial water bodies under a specific derogation on the use of biocides (e.g. fountains or other).

- Post-intervention verification:

Sites where *Gambusia* was eradicated should be monitored using eDNA methodology (Davison et al. 2017) and trapping (funnels or electrofishing) for at least two years.

C. Management strategy – spread limitation

- Aim: *Option 1 - Stand-still principle with a single or a few patches.*

The spread limitation strategy aims at limiting the presence of the *Gambusia* in Belgium to the few ponds, where it has been observed.

- Methods and techniques:

The ponds where the species was observed are left unmanaged, but measures to avoid fish from spreading further into connected systems should be implemented.

Secondly, nearby aquatic systems should be monitored with eDNA. If the species is detected in a small standing water it should be eradicated using the methods outlined in the eradication strategy, where feasible. If the species is detected in open waters, rapid eradication could be attempted with electrofishing and an increased angling effort, though the chances of success are deemed very low.

- Post-intervention verification:

Clear information signs are put up near the infected ponds. Other sites in the vicinity are monitored using eDNA methodology and trapping (funnels or electrofishing) for multiple years.

D. Assessment results

Average feasibility scores of both eradication and spread limitation scenarios were high. However, **there was no consensus between experts on which scenario was most feasible** since one assessor deemed the eradication scenario as most feasible and the other two indicated the spread limitation scenario as most feasible.

Average scoring of all criteria except window of opportunity was 4 or higher for the eradication scenario and above 3 for the spread limitation scenario. Window of opportunity was the criterion that was scored the lowest – in both scenarios. It scored between very low and low for the eradication scenario and between low and medium for the spread limitation scenario. On average, only cost and window of opportunity scored a little bit better in the spread limitation scenario, the other average scores were higher (better) for the eradication scenario.

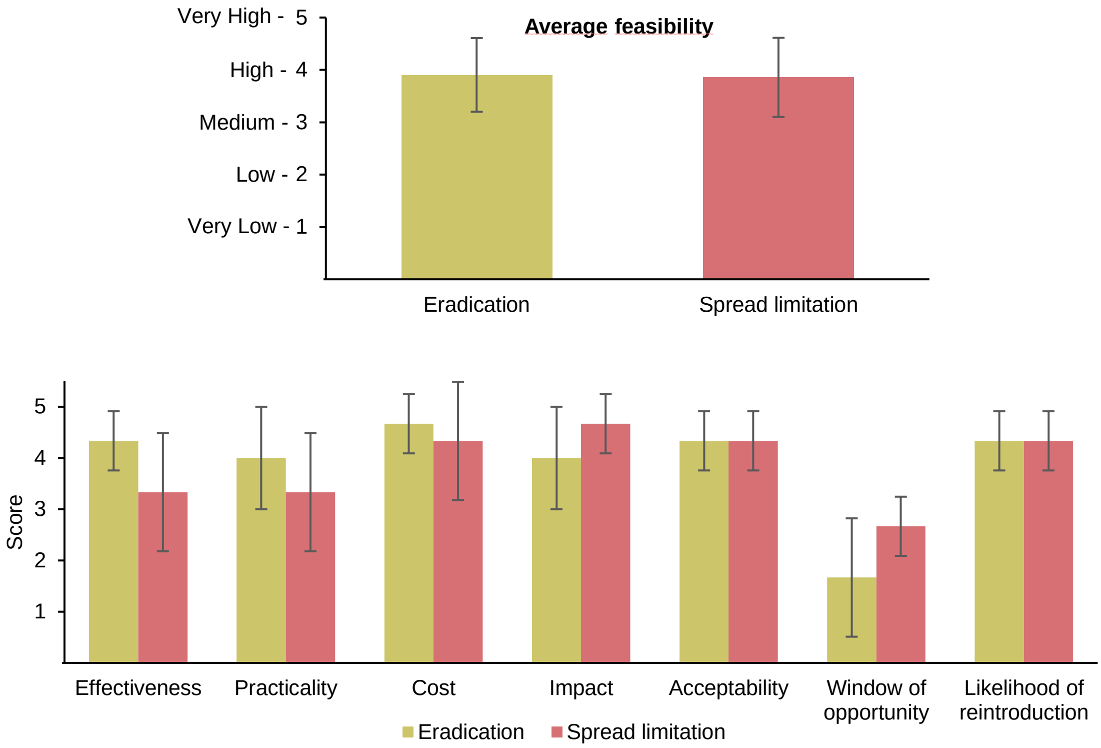


***Figure 14**. **Top**: Average feasibility scores for the eradication and spread limitation scenario of Gambusia holbrooki; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of G. holbrooki.*

E. Recommendations for management

Because there was no real consensus between assessors and average scores given by experts were above "high" in the eradication scenario, **we recommend the eradication scenario**, in line with the guiding principle of eradication for species of the EU Regulation not yet present in Belgium, **though local factors could prevent such a management action to be successful**. The main influencing factors are connectivity and the possibility of drawdown. It has to be noted that, while the scenario is a detection in an isolated pond, the species can also thrive in riverbanks, flood plains and marshes, where eradication would be much harder.

In all instances, rapid action – within the year of detection – would also be required. Experts stress the need to perform eDNA monitoring quickly after detection to inform on the best management strategy.

References

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

Davison P.I., Copp G.H., Créach V., Vilizzi L., Britton J. (2017). Application of environmental DNA analysis to inform invasive fish eradication operations. *The Science of Nature* 104(3-4):35.

Reynolds R., Smith K. (2022). The management of *Gambusia holbrooki* and *Gambusia affinis*. Information on measures and related costs in relation to species on the Union list.

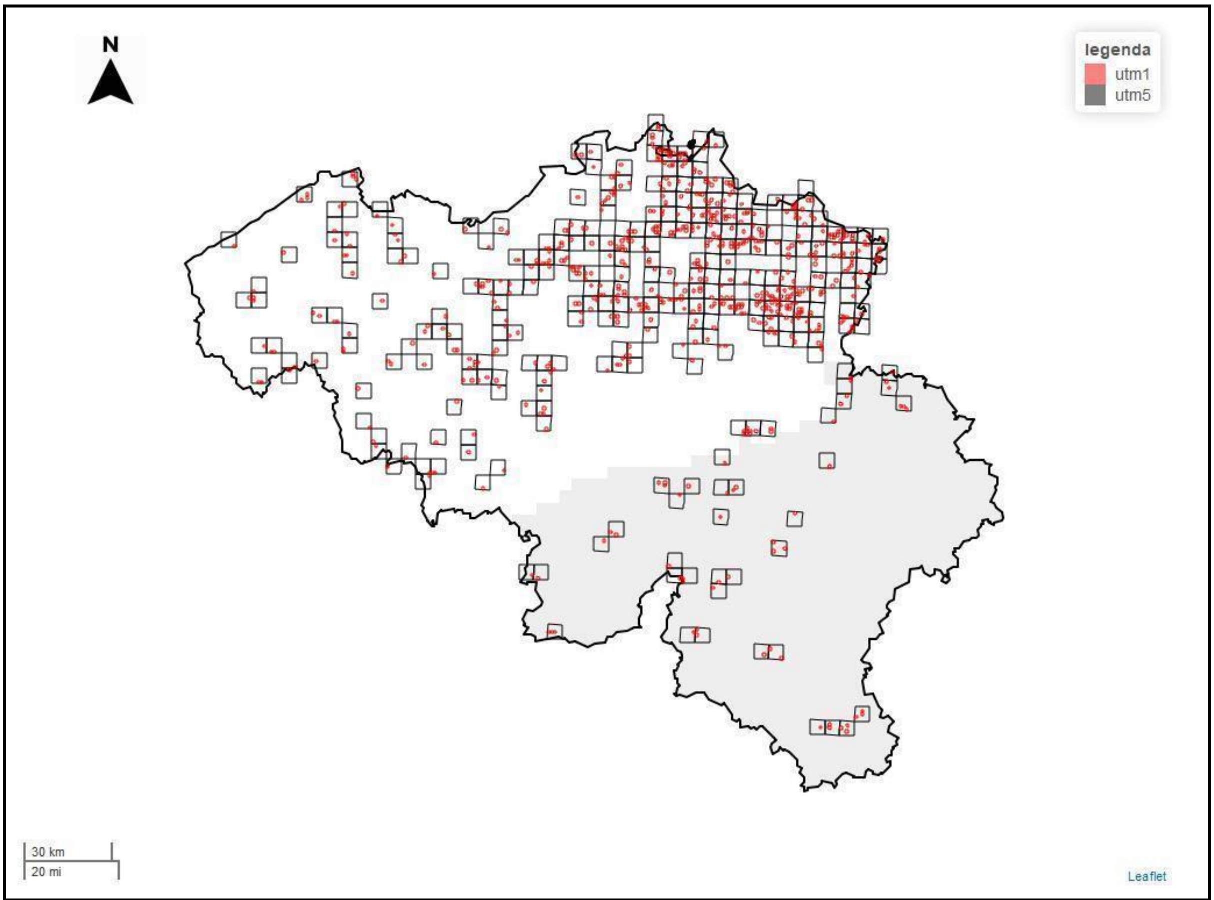
Verreycken, H. and G.H. Copp (2019). Risk Assessment for *Gambusia affinis.* Annex V with evidence on measures and their implementation cost and cost effectiveness

3.2.11. Pumpkinseed, *Lepomis gibbosus* (zonnebaars, Perche soleil)

Credits: Smithsonian Environmental Research Center - https://www.flickr.com/photos/serc_biodiversity/50599396317/ - CCBY2.0

A. Invasion scenario

- Invasion situation and history in BE: The species was imported into Belgium in the beginning of the 19th century as an ornamental fish for ponds and aquaria (Verreycken et al., 2007). Subsequently, specimens were dumped or they escaped and in 1884 the first sighting of a pumpkinseed fish in the wild in Belgium was reported. At first, the species was confined to the East of the country (basins of the Demer, Nete and Meuse) – where the largest populations can still be found – but it is now also expanding to the west. At present, the species is relatively common North of Samber and Maas and rather rare South of Samber and Maas. In the Atlantic bioregion, the species occurs in rivers, brooks, canals, fens, puddles and isolated ponds. In the continental bioregion, the species can mostly be found in river systems (e.g. Bocq, Lesse, Meuse, Ourthe, Sambre and Viroin), but also occurs in ponds, such as the protected water body étang de l'Illé in Etalle.
- Reliability of the BE distribution: The current distribution is probably underestimated in standing waters since dedicated fish monitoring is mostly confined to rivers and streams in Belgium, which means that the preferred habitats - slow moving or standing (artificial) waters - are not surveyed.
- Invasion situation in neighbouring countries: The species is widespread in Luxemburg, the Netherlands, Germany, and France (inaturalist.org, openobs.mnhn.fr). In the Netherlands, the species can be found in isolated and connected waters along the whole of the Belgian border. In Germany the species is mainly found in the Southwest, and observations of the species near Bonn, Neffenbachtal, Trier etc have been reported. In France, populations can be found close to the Belgian border in Hauts-de-France and Grand Est.



	Atlantic	Continental
utm1	622	59
utm2	490	53
utm5	267	37
utm10	131	28
sac_perc	57.07	62.71

B. Management strategy – eradication

- Methods and techniques:

The scenario considers eradication from both standing and running waters on the Belgian territory.

Eradication is extremely difficult once *Lepomis* species are established, especially in open larger river basin areas. Centrarchid sunfishes have been successfully eradicated from small and isolated water bodies only (using chemical treatments), but not in larger or connected hydrosystems (Britton et al, 2010; Zogaris, 2017).

In ponds or other standing waters with *Lepomis* presence fish should be captured with seines, electrofishing or gill netting, though the latter can cause serious damage to other species of fish[9]. Afterwards, ponds should be dewatered. while taking care to avoid further dispersal

[9] This specification was added after scoring of the scenarios, following expert inputs

through outlets of the pumping system. Deeper sections of the aquatic system can be filled up with sand to eliminate the remaining fish (Van Kleef et al., 2008). Additionally, by filling up the deeper sections (reprofiling the pond bottom), the drying frequency of the waterbody is increased, causing fish to die. Quickliming after drainage is not considered in this scenario due to the large potential of non-target effects in high value lentic habitats where *Lepomis* can occur.

In lotic environments (rivers), methods for eradication are based on overharvesting by electrofishing and an increased angling effort promoted through dedicated communication campaigns with recreational anglers.

Large-scale application of chemicals such as rotenone in water bodies (Zogaris, 2017) is potentially the most successful eradication method but the use of that biocide is forbidden in most EU countries including Belgium due to its non-target effects on other fish species. Yet it could be an option to eradicate the species from artificial water bodies under a specific derogation on the use of biocides.

- <u>Post-intervention verification:</u>

Sites where *Lepomis* was eradicated should be monitored via e-DNA (Davison et al. 2017) and trapping (funnels or electrofishing). This should ideally be done in April-May: before the breeding season, and outside of the natural dry phase of the aquatic system (Sarat et al., 2015).

C. Management strategy – spread limitation

- <u>Aim</u>: *Option 4 - maintenance of pest free areas*

The spread limitation strategy aims at keeping the population in check to avoid further dispersion of this widespread species. More specifically, the continental bioregion - especially Ardenne and Lorraine districts - is maintained free of pumpkinseed. Additionally, selected sites such as ecologically valuable small lakes or ponds or fen and bog areas where endangered amphibians such as *Pelobates fuscus, Hyla arborea*, *Triturus cristatus* or where threatened invertebrates (e.g. damselflies such as *Coenagrion lunulatum, C. hastulatum*) are present (i.e. Natura 2000 areas) should also be treated as pest free zones in the Atlantic bioregion. When eradication in these sites is not possible, population control actions can be implemented.

- <u>Methods and techniques:</u>

Uninvaded areas are managed as pest free areas; they are subjected to (i) increased surveillance effort complemented with a survey of fishermen's catches (Zogaris, 2017) and (ii) rapid eradication actions after *Lepomis* detection using the methods described in the eradication strategy. Widespread Installation of barriers on rivers and streams is considered unrealistic because it counteracts measures for fish migration, but this might be considered in local situations to prevent further movement from reservoir and weir impoundments (Zogaris, 2017). Additionally, structures or mechanisms preventing the movement of sunfishes and other predatory fishes from the contaminated waters to uninvaded water bodies could be considered in specific cases (Tyus and Saunders, 2000).

In selected areas where the species is established but where eradication is not feasible, control of the population should be based on increasing resilience of the system that breaks the dominance of the exotic pumpkinseed:

- Removal of the Pumpkinseed fish on a yearly or bi-yearly basis. Mechanical removal of centrarchid sunfishes can be done by gill netting, seine netting and electrofishing or with funnel traps. Protocols for removal are well developed but electrofishing is preferred because it has the least amount of bycatch and non-target effects on the native fish populations or other non-target species. Funnel traps are effective in catching age 2 and older pumpkinseed specimens (Fox and Keast, 1990; Fox, 1994). Removal is preferably done before the reproductive period, but if temperatures are still too cold to ensure high fish activity, trapping can be done later in the year.
- Secondly, natural enemies such as pike (*Esox lucius*) should be introduced. Introduced pikes should be old enough so that they will not feed on endangered amphibians or libella (LIFE RESILIAS project). Since large pikes will also prey on small pikes, this will result in an equilibrium where predation on non-target species is limited. Note that this ecosystem resilience response will not lead to ecological gain when the invasive species *Umbra pygmaea* is present as pike do not prefer this species and *Umbra* can be expected to increase in numbers in the absence of *Lepomis*.

- Post-intervention verification:

Sites where *Lepomis* was eradicated should be monitored using e-DNA methodology (Davison et al. 2017) and trapping (funnels or electrofishing). This should ideally be done in April-May: before the breeding season, and outside of the natural dry phase of the aquatic system (Sarat et al., 2015). Sites where resilience was increased should also be monitored via electrofishing. These measures need to be applied indefinitely.

D. Assessment results

Average feasibility score of the spread limitation strategy was higher than that of the eradication strategy – this was also true for the individual feasibility scores of all three experts. Though the spread limitation scenario was considered to be more feasible, the feasibility score was between low and medium.

On average, the spread limitation scenario scored better on five criteria. Only effectiveness and likelihood of reintroduction scored lower for the spread limitation scenario in comparison to the eradication scenario, though that difference was only one score unit by one assessor. Apart from a very limited effectiveness and practicality, the likelihood of reintroduction was also evaluated as likely to very likely.

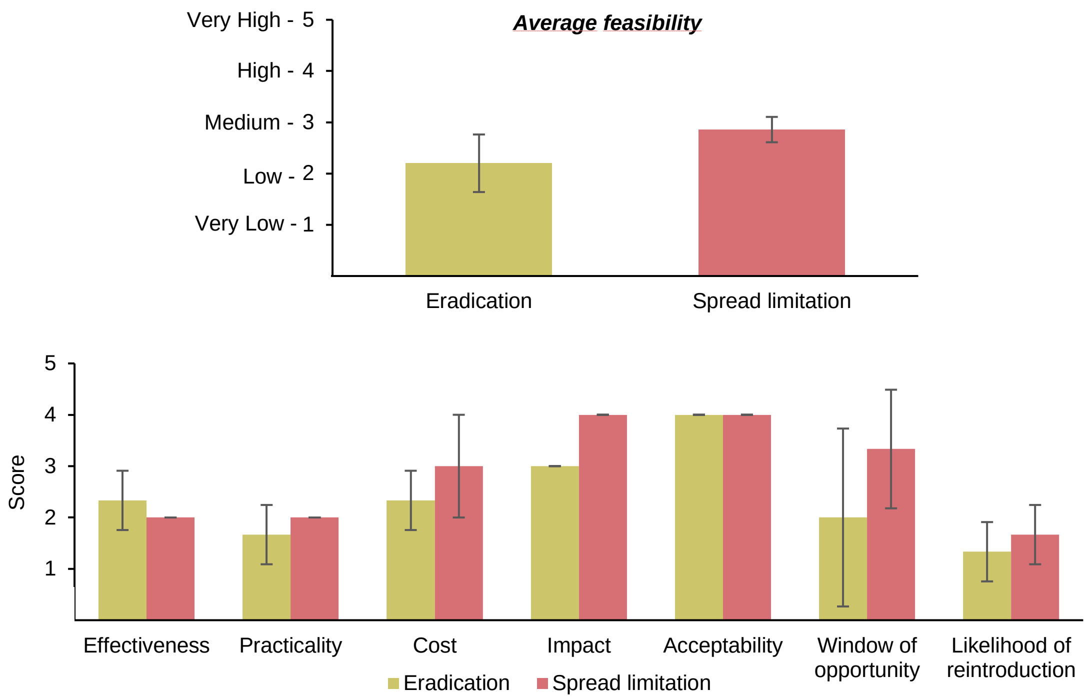


Figure 15. Top*: Average feasibility scores for the eradication and spread limitation scenario of Lepomis gibbosus;* ***Bottom****: Breakdown of average feasibility scores into average scores of the seven key criteria for management of L. gibbosus*

E. Recommendations for management

Because there was a consensus between assessors on the lower feasibility of eradication, **we recommend the spread limitation scenario (option 4 - maintenance of pest free areas).** However, scores were also low for spread limitation, which indicates that the chances of success are limited. It should be considered to reduce the ambition and size of the pest free area – defined as the continental bioregion in the scenario – by preventing spread only to new ponds, especially ecologically valuable small lakes or ponds. Furthermore, the strategy should include dedicated awareness raising stressing the prohibition of release and transport, and the need of biosecurity measures in aquaculture to avoid contaminants.

References

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

Cucherousset, J., Copp, G.H., Fox, M.G. *et al.* (2009). Life-history traits and potential invasiveness of introduced pumpkinseed *Lepomis gibbosus* populations in northwestern Europe. *Biol Invasions* 11, 2171. https://doi.org/10.1007/s10530-009-9493-5

Davison P.I., Copp G.H., Créach V., Vilizzi L., Britton J. (2017). Application of environmental DNA analysis to inform invasive fish eradication operations. *The Science of Nature* 104(3-4):35.

Fox, Michael G., and Allen Keast (1990). Effects of winterkill on population structure, body size, and prey consumption patterns of pumpkinseed in isolated beaver ponds." Canadian journal of zoology 68.12: 2489-2498.

Fox, M. G. (1994). Growth, density, and interspecific influences on pumpkinseed sunfish life histories. Ecology, 75(4), 1157-1171.

Harold M. Tyus & James F. Saunders III (2000) Nonnative Fish Control and Endangered Fish Recovery: Lessons from the Colorado River, Fisheries, 25:9, 17-24

van Kleef, H., van der Velde, G., Leuven, R.S.E.W. & Esselink, H. (2008) *Pumpkinseed sunfish (Lepomis gibbosus) invasions facilitated by introductions and nature management strongly reduce macroinvertebrate abundance in isolated water bodies.* Biological Invasions. DOI 10.1007/s10530-008-9220-7

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

Sarat E., Mazaubert E., Dutartre A., Poulet N. et Soubeyran Y. (2015). Les espèces exotiques envahissantes dans les milieux aquatiques : connaissances pratiques et expériences de gestion. Volume 2 – Expériences de gestion. Onema. Collection comprendre pour agir. 240 pp.

Soes, D.M., S.J. Cooke, H.H. van Kleef, P.B. Broeckx & P. Veenvliet (2011). A risk analysis of sunfishes (*Centrarchidae*) and pygmy sunfishes (*Elassomatidae*) in the Netherlands. Bureau Waardenburg, Culemborg; Volume 11-042

van Delft J., van Kleef H., van der Burg R., Bosman W., Bouwman J., de Kort N. (2013). De zonnebaars: levenswijze, problematiek en beheer. Stichting RAVON, Stichting Bargerveen, Bosgroep Zuid Nederland in opdracht van Provincie Noord-Brabant.

Zogaris, S. (2017). Information on measures and related costs in relation to species included on the Union list: *Lepomis gibbosus*. Technical note prepared by IUCN for the European Commission.

3.2.12. White perch, *Morone americana* (Amerikaanse zeebaars, Bar blanc d'Amerique)

Credits: Jesse Bissette

A. Invasion scenario

- Invasion situation and history in BE: *Morone americana* is currently not established in Belgium. A possible invasion scenario is that at the point of detection, a few dozen individuals were reported in het Zwin, in the tidal estuary. These could be resulting from an aquaculture facility that was infected through contamination of a hybrid morone fish consignment, via ballast water or even the intentional release of some specimens.
- Reliability of the BE distribution: The distribution is considered to be reliable as the species is rather conspicuous, although it might be underdetected in estuaries because of the lack of dedicated fish monitoring.
- Invasion situation in neighbouring countries: The species is not established in our neighbouring countries.

B. Management strategy – eradication

The management strategy is adapted from Verreycken et al. 2019.

- Methods and techniques:

Eradication would involve the combined use of mechanical removal by trapping (trawl nets, fyke nets, traps) and electrofishing. Drainage of the system is not possible in this scenario.

Eradication effectiveness may be enhanced by using deterrents, e.g. strobe lights (Sager et al., 2000) to keep *M. americana* restricted in the location where the trapping is implemented.

The use of rotenone piscicide is not considered in this scenario due to the legal restrictions in Belgium and to the high value of the habitat in het Zwin. Yet it could have been an option to eradicate the species if it had been detected in an artificial water body under a specific derogation on the use of biocides.

- Post-intervention verification:

Sites where *Morone* was eradicated should be monitored using eDNA methodology (Davison et al. 2017) and trapping (funnels or electrofishing) for at least two years.

C. Management strategy – spread limitation

- Aim: *Option 2 - Stand-still principle with a core area.*

The aim of this strategy is to contain the species to het Zwin and prevent establishment in the Yser and Scheldt brackish environments.

- Methods and techniques:

Population numbers in het Zwin are managed through trapping efforts (trawl nets, fyke nets, traps) and electrofishing. Key connection points are also monitored with traps and eDNA.

The Scheldt and Yser estuaries are monitored with electrofishing. If necessary, electrofishing and angling efforts should be increased to capture specimens, although electrofishing effectiveness is expected to be limited in open intertidal systems (H. Verreycken, personal communication, 2023).

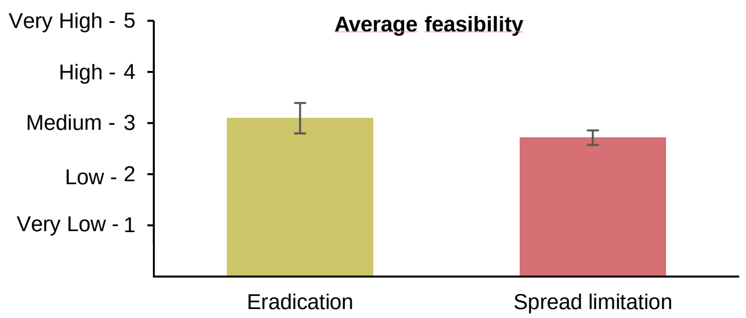
Other protected habitats should also be monitored via increased trapping efforts. If the species is detected, eradication should be achieved using the methods outlined in the eradication strategy.

- Post-intervention verification:

Clear information signs are put up to inform visitors. Other sites in the vicinity are monitored using eDNA methodology and trapping (funnels or electrofishing) for multiple years.

D. Assessment results

The average feasibility score was higher for the eradication scenario than for the spread limitation scenario and was assessed a little bit higher and lower than medium respectively. Limited differences between the two scenarios are observed for the criteria practicality (moderately practical *vs* impractical) and likelihood of reintroduction (moderately likely *vs* likely). Both strategies were considered equally ineffective by all assessors so effectiveness can be considered as one of the main limitations.



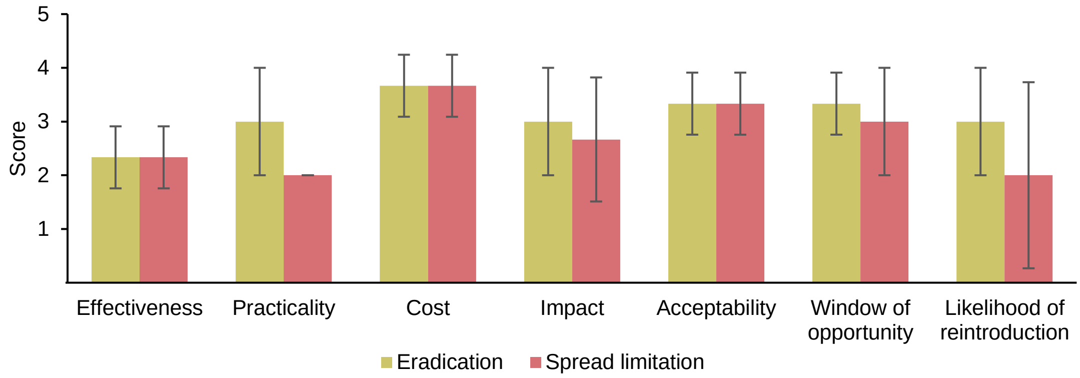


***Figure 16**. **Top**: Average feasibility scores for the eradication and spread limitation scenario of Morone americana; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of M. americana.*

E. Recommendations for management

No clear distinction could be made between the two scenarios, mainly because the experts noted a lack of effective management measures for this species in its preferred habitat. Furthermore, it can be expected that the species might show seasonal migration and will not stay in one place (Kerr and Secor 2012). **Though eradication is the default option foreseen by the EU Regulation for species not yet present in Belgium, we do not deem this realistic, unless the species would be discovered in a small and closed water system.** Instead, we advise that a **control strategy** would be most realistic, given the fact that spread limitation also has a low feasibility. Experts also stress the greater efficiency of implementing preventive measures to avoid the introduction of marine and brackish water species.

Derogations from the obligation of rapid eradication – *sensu* article 18 of the EU Regulation – will probably need to be applied for this aquatic species depending on local conditions.

References

Davison P.I., Copp G.H., Créach V., Vilizzi L., Britton J. (2017). Application of environmental DNA analysis to inform invasive fish eradication operations. The Science of Nature 104(3-4)-35.

Kerr, L. A., & Secor, D. H. (2012). Partial migration across populations of white perch (*Morone americana*): a flexible life history strategy in a variable estuarine environment. Estuaries and Coasts, 35, 227-236.

Sager, D.R., Hocutt, C.H. & Stauffer Jr, J.R. (2000). Avoidance behavior of *Morone americana, Leiostomus xanthurus* and *Brevoortia tyrannus* to strobe light as a method of impingement mitigation. Environmental Science & Policy 3, 393–403.

Verreyken, H., Aislabie L. and G.H. Copp (2019). Risk Assessment for *Morone americana.* Annex V with evidence on measures and their implementation cost and cost effectiveness.

3.2.13. African clawed frog, *Xenopus laevis* (Afrikaanse klauwkikker, Xénope lisse)

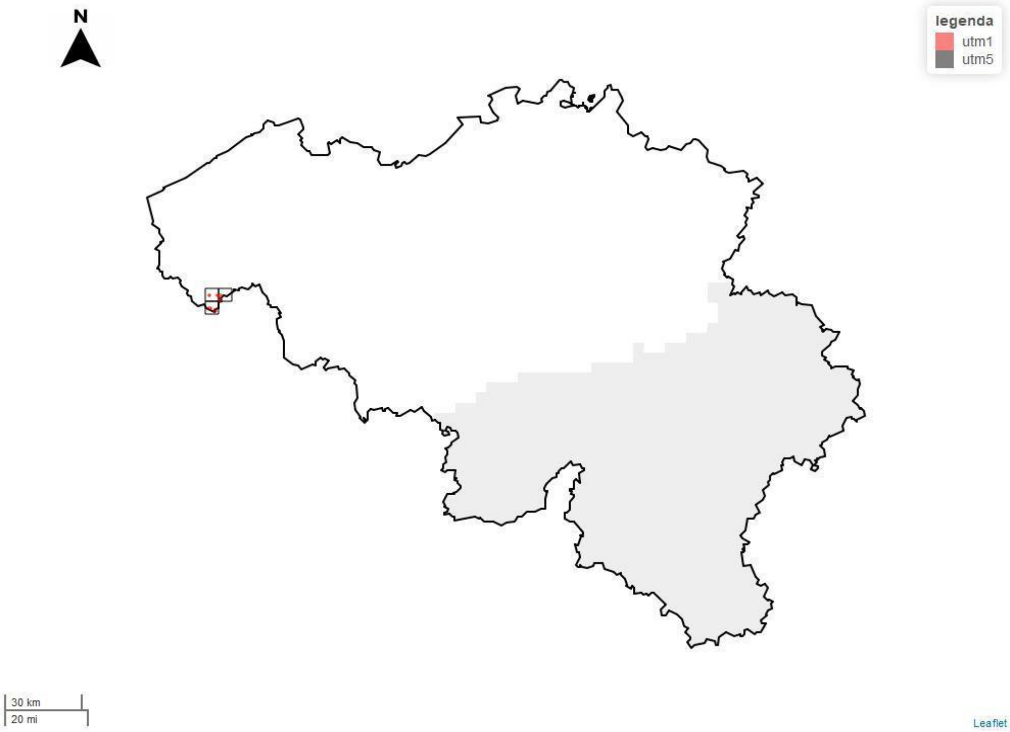
Credits: Tim Adriaens

A. Invasion scenario

- Invasion situation and history in BE: In 2008, 30 *Xenopus laevis* larvae were observed in a pond on the premises of Antwerp University and reported to Hyla (amphibian and reptile working group of Natuurpunt). Presumably this population disappeared. Two other individuals were also found in Comines-Warneton (Wallonia) as reported on observations.be - one in 2006 (an albino specimen) and one in 2016. Finally, multiple observations were reported in Comines - Warneton in June 2022, both in ponds and in a dead branch of the Lys river indicating establishment of the species. The species presence has been confirmed by eDNA analysis. While an eDNA study in 2020 confirmed that no population was present on the Flemish side of the border in 2020 (Van Doorn et al. 2022), numerous tadpoles have been recently observed in three cattle drinking ponds along the Douvebeek on the Flemish side, a tributary of the Lys river. In the winter of 2023, the ponds were temporarily fenced, drained and treated with quicklime (CaO). Although this resulted in many frogs dying, the effectiveness of this action is hitherto unknown. At least two of the treated ponds were again recolonized, presumably by dispersing frogs that used the brook, as the fence was not kept intact long enough (Adriaens et al. 2023). Repeat treatment is ongoing at the site as well as more extensive eDNA surveillance both on Flemish and Walloon territory.
- Reliability of the BE distribution: The species is probably underreported given the early stage of invasion and the absence of systematic monitoring. At the Flemish side of the border the extent of the distribution is considered relatively reliable as the entire area has been screened with eDNA in 2021 and 2022. In Wallonia, such screening is

underway but there are probably gaps in the currently known distribution. One known unknown is whether *Xenopus* uses the Douvebeek, the Lys or other rivers as reproductive habitat or merely as a dispersal corridor.

- Invasion situation in neighbouring countries: The species has been reported since 2018 in France in La Chapelle d'Armentières in an urban pond in a park area (Parc Courtembus), just across the border near Comines-Warneton. It has not been reported elsewhere near Belgian borders but species presence is likely elsewhere in the Armentières-Deûlémont area. In Germany, a population was reported in 2013, but at more than 100 km of the border.



B. Management strategy – eradication

- Methods and techniques:

The eradication strategy consists of a combination of methods, including amphibian fencing, traps, fyke-nets, hand dipping, electro-fishing and drainage of the water, potentially in combination with quickliming, the latter depending on the type of site.

Prior to any action, ponds should be fenced to prevent further dispersion of individuals since they can easily disperse over land (De Viliers and Measey, 2017), especially in the face of deteriorating conditions. Traps should be added on the inside of the fence to capture the individuals getting out of the pool.

After fencing, individuals remaining in the water should be trapped using the following means:

- The use of (single and double) **funnel traps and fyke nets** is the most widespread method to study and support the control of the species (Robertson and Scalera, 2018). They can be used for tadpoles and adults alike. Baiting the traps increases effectiveness; liver, cat or dog food can be used. Traps could also be baited with females as this not only outperforms other baits such as food or calling lures, but also increases the capture of males and females alike (Lorain-Solignon et al., 2021). A specific vertical trap has been developed in France by the LIFE CROAA project which shows good results for deep or large water bodies (Merlet et al. 2022). When deploying funnel traps and fyke nets, proper placement is very important to guarantee the correct functioning.

- **Electrofishing** is a practical and effective method for accessible waterbodies (Rebelo et al., 2011; Sousa et al., 2017; Sousa et al., 2018).
- **Hand capture, dip-netting and seine netting** of adults or larvae can be used to reduce the number of individuals from a water body, mostly if it is a small pond (Robertson and Scalera, 2018; Rebelo et al., 2011; Sousa et al., 2017; Sousa et al., 2018).

Afterwards, ponds should be drained (after fencing), which has proven to be successful in eradicating several populations (Measey et al., 2012; Tinsley and McCoid, 1996; Pascual et al., 2007). Biosecurity measures should be put into place to avoid dispersion through pumping outlets. When the system has been dewatered, quicklime (calcium oxide) should be added to increase pH (>12) of the system for a minimum of 24 hours, preferably 48. Generally, this takes at least 0,6 to 3,1 kg/m3. Derogations allowing for the use of this substance should be requested at the relevant service. Note that the use of calcium dioxide which is much more readily available as a compound is known to be ineffective.

Since lotic systems are generally thought to favour *X. laevis* dispersion (Fouquet and Measey 2006; Faraone et al. 2008; Measey, 2016) and not to support breeding (but see Moreira et al., 2017), specific traps designed for rivers are deployed before and after the breeding season. This is supplemented with regular electrofishing to intercept and remove dispersing (sub)adults.

Other chemical methods, such as using rotenone, have not proven to be very effective for this species and would be difficult to apply in Belgium because of regulations regarding the use of biocides in aquatic environments. The release of sterile males could be effective in the future, but it has not yet been developed for *X. laevis.*

- Post-intervention verification:

After eradication, follow-up is needed to assess whether frogs have effectively been removed. This is performed with eDNA yet there are knowledge gaps as to the decay function after eradication. In case of drainage, the ponds should be monitored yearly for at least two breeding seasons after control. This can be done by performing captures using fykes or by using eDNA from water samples.

C. Management strategy – spread limitation

- Aim: *Option 2. Stand-still principle with **a core area***

The spread limitation strategy aims at containing the populations of African clawed frog in the upper Lys (Southwestern Flanders and Wallonia) and avoiding any further spread outside of this area.

- Methods and techniques:

Enhanced surveillance through e-DNA samplings in freshwater ecosystems of the Scheldt river basin to detect new populations. Priority sites could be determined by looking at habitat characteristics of the aquatic sites, but also terrestrial features that determine resistance maps should be taken into account (Fouquet & Measey, 2006; Vimercati et al., 2018; Ginal et al., 2021). Eradication of newly detected populations outside the containment area is achieved using the methods described in the eradication strategy (capture, electrofishing, drainage). Additionally, fishermen and garden pond owners are informed about the risk of accidentally transposing larvae when moving fish. Invaded ponds at the edge of the metapopulation can also be fenced to prevent dispersal.

- Post-intervention verification:

After eradication of new populations, follow-up is needed to assess whether African clawed frogs have effectively been removed. In case of drainage (after fencing), the ponds should be monitored for at least two breeding seasons after control using fyke nets or eDNA. This is supplemented with regular repeated sampling of suitable habitat in priority zones for population expansion using e-DNA. Priority zones could be determined by looking at habitat characteristics of the aquatic sites, but also terrestrial features that determine resistance maps should be taken into account (Fouquet & Measey, 2006; Vimercati et al., 2018; Ginal et al., 2021).

D. Assessment results

Average feasibility scores of both scenarios were similar – a little below medium. There was no consensus between assessors, with one assessor preferring the eradication scenario, another the spread limitation scenario and the third showing no preference.

Average scores of five out of seven criteria were identical for both scenarios. Only cost and impact were different between scenarios, with average costs and environmental impact being more advantageous in the eradication scenario. Out of all criteria, likelihood of reintroduction was scored the lowest and was assessed as very likely under both scenarios.

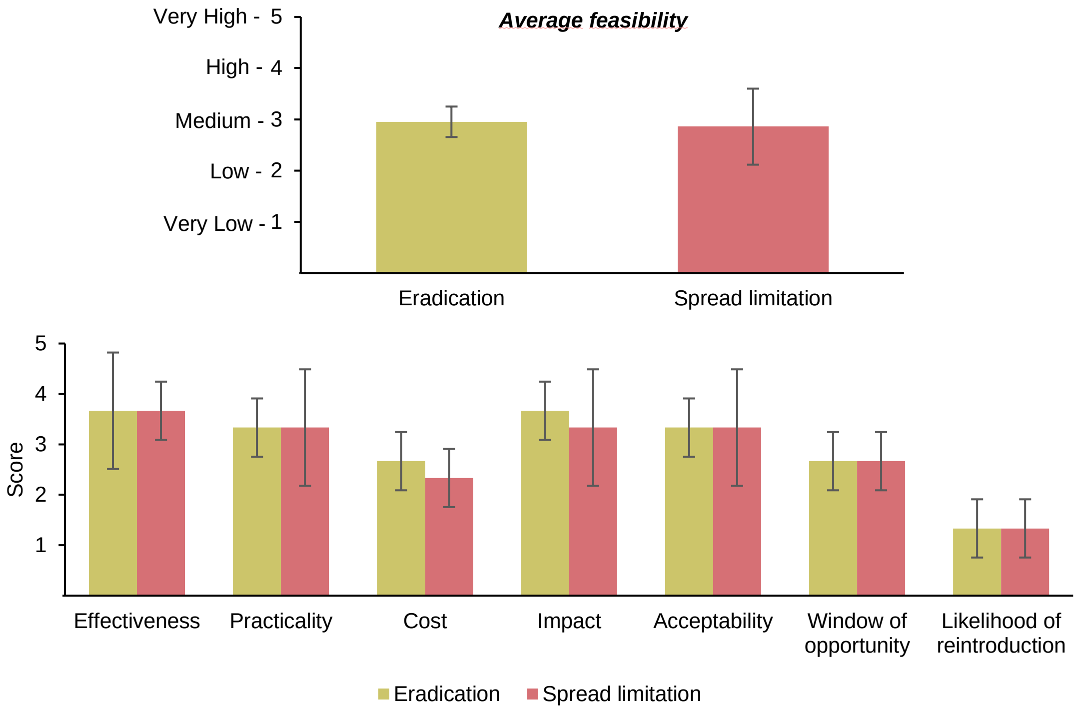


*Figure 17. **Top**: Average feasibility scores for the eradication and spread limitation scenario of Xenopus laevis; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of X. laevis*

E. Recommendations for management

Although there was no marked difference between scenarios with a medium feasibility, **we recommend the eradication scenario for this emerging species.** It must be noted however that the likelihood of reintroduction is very high and that a geographically more comprehensive plan is required to be able to eradicate *X. laevis* permanently (cooperation between Flanders, Wallonia and France). Additionally, while methods are intrinsically highly effective, their execution is very challenging and also depends on the local setting with access to private property (agricultural area in use for livestock grazing) presenting a clear bottleneck. Experts also point to the necessity of at least 10 years of cross border monitoring after eradication is achieved.

Derogations from the obligation of rapid eradication – *sensu* article 18 of the EU Regulation – might need to be sought for this species depending on local conditions.

References

Adriaens, T., Morbidelli, M., Brys, R., Devisscher, S., Everts, T., Pardon, N., Speybroeck, J., & van Doorn, L. (2023). A rapid eradication attempt of emerging African clawed frog, Xenopus laevis, using quicklime. Poster presentation 13th European Vertebrate Pest Management Conference (EVPMC), 28/08/23 → 1/09/23, Florence, Italy.

De Villiers FA, Measey J. (2017) Overland movement in African clawed frogs (*Xenopus laevis*): empirical dispersal data from within their native range. PeerJ. Nov 10;5:e4039.

Faraone FP, Lillo F, Giacalone G, Lo Valvo M (2008) The large invasive population of *Xenopus laevis* in Sicily (Italy). Amphib-Reptil 29:405–412

Fouquet, A., & Measey, G. J. (2006) Plotting the course of an African clawed frog invasion in western France. Animal Biology, 56, 95–102.

Ginal, P., Moreira, F. D., Marques, R., Rebelo, R., & Rödder, D. (2021). Predicting terrestrial dispersal corridors of the invasive African clawed frog Xenopus laevis in Portugal. NeoBiota, 64, 103-118.

Lafferty, K. D. and Page, C. J. (1997) Predation on the endangered tidewater goby, *Eucyclogobius newberryi*, by the introduced African clawed frog, *Xenopus laevis*, with notes on the frog's parasites. Copeia 1997: 589-592.

Lorrain-Soligon, Léa, et al. (2021) Effects of conspecific lures, call playbacks, and moonlight on the capture rate of *Xenopus laevis*, a major invasive amphibian. Management of Biological Invasions 12.3 : 716.

Measey, J. (2016). Overland movement in African clawed frogs (Xenopus laevis): a systematic review. PeerJ, 4, e2474.

Measey, G.J., Rödder, D., Green, S.L., Kobayashi, R., Lillo, F., Lobos, G., Rebelo, R. and Thirion, J.M. (2012) Ongoing invasions of the African clawed frog, *Xenopus laevis*: a global review. Biological Invasions, 14(11), pp.2255–2270.

Merlet A. (coord.) (2022) Guide technique pour la gestion de la Grenouille taureau et du Xénope lisse. Projet européen LIFE CROAA (LIFE15 NAT/FR/000864), Société Herpétologique de France (Ed.), 136 pp.

Merlet A., Labadesse M., Ladislas M., Martin A., Martin B., Trochet A., & Barthe L. (2022) Technical sheet, African clawed frog capture techniques, Société Herpétologique de France. 27 pages.

Moreira, F. D., Marques, R., Sousa, M., & Rebelo, R. (2017) Breeding in both lotic and lentic habitats explains the invasive potential of the African clawed frog *(Xenopus laevis*) in Portugal. Aquatic Invasions, 12(4), 565–574.

Pascual, G., Llorente, G.A. and Richter-Boix, A.M.A. (2007) Primera localización de *Xenopus laevis* en libertad en España. Boletín de la Asociación Herpetológica Española 18:42–43.

Rebelo, R., Carreira, B. and Sousa, M. (2011) Plano de controlo de *Xenopus laevis* nas ribeiras do concelho de Oeiras. Relatório Ano II (2011). Centro de Biologia Ambiental da Faculdade de Ciências da Universidade de Lisboa e Instituto da Conservação da Natureza e da Biodiversidade.

Robertson, P., Scalera, R. (2018) The management of African clawed frog (*Xenopus laevis*). Measures and associated costs. Technical note, EU Commission.

Sousa, M., Moreira, F., Maurício, A., Castro, L. and Rebelo, R. (2017) Plano de erradicação de *Xenopus laevis* nas ribeiras do concelho de Oeiras. Relatório Ano VIII (2017). cE3C/CMO/ICNF. 19 pp.

Sousa, M., Maurício, A. and Rebelo, R. (2018) The *Xenopus laevis* Invasion in Portugal: An Improbable Connection of Science, Mediterranean Climate and River Neglect. Histories of Bioinvasions in the Mediterranean (ed. by A.I. Queiroz and S. Pooley), pp. 133–148. Springer International Publishing, Cham.

Tinsley, R.C. and McCoid, M.J. (1996) Feral populations of *Xenopus* outside Africa. pp 81–94, In: Tinsley RC, Kobel HR (eds) The biology of *Xenopus*. Oxford University Press, Oxford.

van Doorn, L., Speybroeck, J., Adriaens, T. & Brys, R. (2022) Environmental DNA sampling for African clawed frog in Flanders, Wallonia and France in 2020. Reports of the Research Institute for Nature and Forest 2022 (6). Research Institute for Nature and Forest , Brussels.

Vimercati, Giovanni & Labadesse, Myriam & Dejean, Tony & Secondi, Jean. (2019) Assessing the effect of landscape features on pond colonisation by an elusive amphibian invader using environmental DNA. Freshwater Biology. 65. 1-12. 10.1111/fwb.13446.

3.3. Plants

3.3.1. Tree of heaven, *Ailanthus altissima* (hemelboom, Ailante glanduleux)

Credits: Cbaile19 – CC0 – https://commonswikimedia.org/w/index.php?curid=41318151

A. Invasion scenario

- Invasion situation and history in BE:

Ailanthus altissima has been used as an ornamental tree in public parks and private gardens and estates for well over 100 years (Verloove, 2020). Establishment in natural habitats was first observed in river valleys in Wallonia such as sun-exposed rocky slopes in the valley of river Meuse near Huy, and of the river Ourthe near Embourg where the species was reported as naturalised in 1952 and in 1973 respectively. It is a light-demanding, thermophilic species that occurs on well-drained soils. Its winged seeds spread easily by wind and water. From the 1980's onward, the species increasingly spread from urban habitats in both Flanders and Wallonia, first appearing in larger cities (Antwerpen, Brussels, Gent, La Louvière and Liège where *A. altissima* now has its most dense concentrations (Van Landuyt, 2006, DEMNA, 2020) but soon also appeared in smaller cities (Brugge, Kortrijk, Leuven, Mechelen, Roeselare,…). The spread of *A. altissima* in Flanders is a relatively recent phenomenon, with most records dating post-1990 (Van Landuyt, 2006). It is still increasingly reported in urban areas, where it is adapted to cope with the urban heat effect and is expected that these urban pockets will serve as refuges to invade more natural areas (Géron et al. 2022).

At present, the species is a locally common urban tree in various man-made habitats such as urban wasteland, mining heaps, railway yards and tracks, old walls, along motorways and on canal banks. The species is quite widespread and produces large and dense populations in the Brussels capital region, in Flanders - where it is mostly confined to urban (thermophilous) habitat-, and in Wallonia around the Sambre and Meuse rivers, including both urban areas and semi-natural dry grasslands, cliffs and rocky slopes. Some isolated populations are also reported elsewhere, mainly in urbanised areas. In Flanders, outside ruderal and urban settings, the species has colonized dunes and invaded almost 10% of protected dune reserves over a surface area of about 2000 m^2 (Adriaens et al., 2022). A bigger *A. altissima* forest in Calmeynbos (De Panne) has meanwhile been removed (pers. comm. Johan Lamaire). While the species is not specific to protected areas, 26% of protected areas are already colonised by *A. altissima* (D'hondt et al. 2022). In the continental area there is potential for further spread, for example in the Fagne-Famenne and the Gaume, where the species is currently not yet established.

- Reliability of the BE distribution:

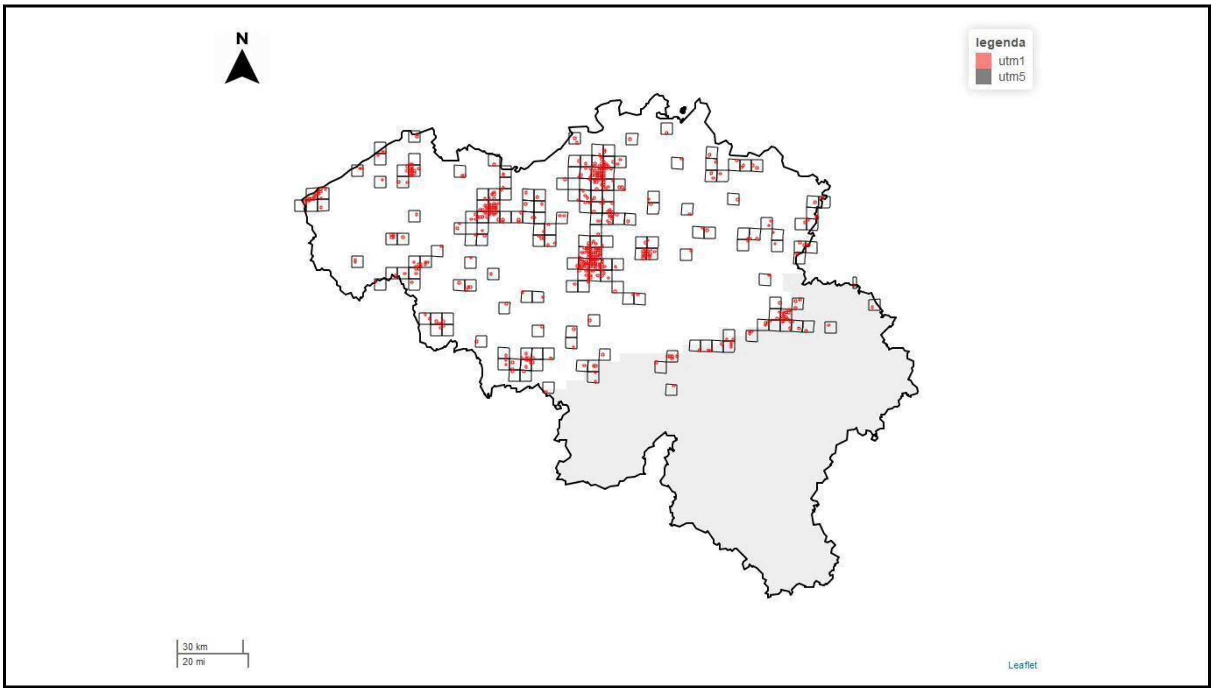
Although the distribution is probably quite reliable, the species might be underreported as people pay less attention to urban wasteland habitats. The distribution in de Middenkust is badly known because of limited survey intensity. There could be some confusion with non-native *Rhus typhina* which is sometimes also considered problematic locally.

- Invasion situation in neighbouring countries:

The species has only been established relatively recently (1996) in the Netherlands, despite the tree being used as an ornamental from the 1800's. Today the species is rather widespread in the Southern part of the country and mainly found in urbanized regions along quay walls, wastelands, roads and railways (Boer, 2012; waarnemingen.nl) but has also colonised natural areas such as along the river Waal. In France, the species is extremely widespread in the Mediterranean area, but is also abundant around Lyon and Paris; it occurs both in urbanised areas and in natural habitats (Collin & Dumas 2009, FCBN 2016). In the vicinity of the Belgian border, the plant can be found in the dunes and urbanised areas in the region around Lille-Lens-Douai (, FCBN 2016). In Germany, the species is considered naturalized and occurs mainly in urban areas and cities, and in warmer areas such as the Ruhr area, Rhine-Main area, the dry East German areas, the Northern upper-Rhine and Middle-Rhine area (floraweb.de, 2020). In Luxemburg, the species is mostly confined to Luxemburg city and surroundings (Ries & Pfeiffenschneider 2020).

- Climate change considerations:

Ailanthus altissima is likely to be strongly favoured by climate change and its geographic range and occurrence in Belgium are likely to increase a lot during the coming decades unless strong measures are put in place to control it rapidly.



	Atlantic	Continental
utm1	442	53
utm2	299	40
utm5	171	22
utm10	105	16
sac_perc	18.78	33.96

“b”.

Source: Trias brain annual report, 2019

B. Management strategy – eradication

- <u>Methods and techniques:</u>

The eradication strategy consists of removing all patches of *A. altissima*, including the ones found in urban areas and along infrastructures, as well as all the ones growing in semi-natural habitats such as quarries, cliffs and dry grasslands. This requires good surveillance and mapping of all known occurrences. It should be noted that *A. altissima* is a difficult species to control and an integrated management approach is advised as re-sprouting is very common. Such an integrated approach consists of using chemical and manual control options together (Kowarik & Saumel, 2007), in combination with habitat management (Brundu, 2017).

Staff in charge of the control of the plants should avoid touching the plant with bare skin (Bennett et al., 2013) and should wear protective, synthetic, water-resistant clothing, and gloves with long sleeves, as well as protective glasses when cutting trees (EPPO, 2020). Proper biosecurity measures should be implemented to avoid transporting samaras and seeds off-site.

Eradication is achieved by tackling adult trees, saplings and seedlings. Since the species is dioecious, female trees that are a source of seeds in the population should be tackled first. Seedlings should be destroyed as soon as possible and before they develop a tapered root. Depending on the lifestage different techniques should be used (EPPO, 2020; Adriaens et al. 2022).

1. **Tackling trees:**

Due to rapid regeneration, **cutting trees** or wounding roots usually causes the species to form root shoots, even up to 50 meters away from the mother plant (Radtke et al., 2013). It does not kill the tree but rather stimulates vigorous resprouting from the remaining trunk and roots (Burch, 2003; CABI, 2019), even a "double-cut stump treatment (no herbicides used)" performed each year for 5 consecutive years failed to significantly reduce the ability to resprout (Constán-Nava S, 2010). Therefore, **this method should not be considered** (de Groot and Oldenburger, 2011).

Girdling or ring barking causes fewer root shoots to be formed than with cutting and has been shown to be effective (Brundu, 2017 and EPPO, 2020). It should be noted the tree must not be removed or cut before it is dead. It can therefore only be foreseen on sites where standing dead trees are acceptable and pose no danger. The technique is a good solution when herbicides are not available, but still leads to the formation of root shoots (Hunter, 2000) and sprouts below the ring (Liess and Dresher, 2008). The method needs to be applied at an adequate height and needs a certain level of expertise, so it should only be performed by trained individuals.

The **application of herbicides** combined with physical treatment has effectively controlled regrowth of trees after cutting and significantly reduced the presence of *A. altissima* in invaded areas (Burch 2003; Meloche, 2006) and is regarded as most effective (de Groot and Oldenburger, 2011). A derogation on the prohibition of the use of herbicides in areas of public service or along watercourses is requested when necessary, with competent authorities. Different types of herbicides and their utilisation are referenced in literature, we describe here the **three main techniques** which are stem injection, basal bark application and cut stump treatment:

- ➔ Stem injection: Stem injection followed by the sealing of the drilled holes is the safest technique to be used, especially in natural habitats or in areas to be preserved. However, as the trees can remain viable and standing for a long time and then suddenly fall, it should not be considered in residential or urban areas. Technical specifications of the technique are described in detail by Badalamenti (2013) and needs to be performed late in the vegetative growth of the species, mid-summer being the best time. Additionally, EPPO (2020), DiTomasio and Keyser (2007), and Dufour-Dror (2013) provide some information on effective herbicides and methodology of drilling.
- ➔ Basal bark application: Basal bark application does not require any cutting and should be applied when the tree is fully leafed. Systemic herbicides should be used for this application and sprayed in a continuous band around the tree, the width depending on the diameter of the tree (Boer, 2013; Fogliatto et al., 2016; Milan et al., 2018). As it is very labor intensive, this method is best applied to smaller infestations or isolated

trees. Follow-up foliar herbicide application to basal sprouts and root suckers may be necessary (Swearingen & Panhill, 2009).

➔ <u>Cut stump treatment:</u> Cut stump treatment implies cutting the tree down and directly applying systemic herbicides to the cambial regions of the cutting surface (Dufour-Dror, 2013). This can be done with a paintbrush directly on the stump of the tree. This should be done during the growing season and preferably in late summer. Description of tested herbicides and their effect on the reduction of re-sprouts can be found in EPPO (2020). It should be noted that glyphosate has proven little effective in this context (Swearingen & Panhill, 2009).

2. **Tackling saplings:**

<u>Foliar spray method:</u> To limit the risk of unintentionally spraying other trees and shrubs or herbaceous vegetation growing in the proximity of plants to be treated, foliar spraying should be avoided for plants taller than 2 m. Foliar spray using the non-selective glyphosate for large thickets of seedlings has proven to be effective and could be used if the risk to non-target species is minimal (SE-EPPC, 2002). This treatment has also been described for seedlings and saplings by Miller (2003). It is recommended that chemical application to the foliage is applied in the active growth season of the plant.

<u>Frilling</u>: For saplings where bark is easily destroyed, frilling can be practiced: cutting of the bark followed by systemic herbicide application (Dufour-Dror, 2013). A knife is used to debark a section of the stem and the herbicide (such as triclopyr or glyphosate) is applied using a small paintbrush.

3. **Tackling seedlings:**

<u>Foliar spray method:</u> see above in the "saplings" section.

<u>Hand pulling of very young seedlings:</u> Young seedlings can be removed along with their root system by hand (Q-bank, 2019; CABI, 2019) as early as possible and before the appearance of the taproot. Hand pulling can be done at any time of the year but is best done when the soil is moist and loose to ensure the whole root system is removed. This is very important since broken fragments will resprout (SEPPC, 2012).

Additionally, establishing a thick cover of trees (non-invasive and preferably native) or grass cover will help shade out and discourage establishment of *Ailanthus* seedlings.

- <u>Post-intervention verification:</u>

Aftercare is needed on all treated sites, regardless of the chosen method. Sites should be monitored one or more times a year, and new suckers or seedlings should be dealt with as soon as possible during at least 5 years (EPPO, 2020).
Cut stump without herbicide application and the application of fire are not considered for this strategy as they have proven to be ineffective (Constan-Nava et al., 2010; Rebbeck and Hutchinson, 2019). Biological control measures such as fungi are not considered as the tested fungi can cause diseases to native trees.

C. Management strategy – spread limitation

- Aim: *Option 2. Stand-still principle with core area(s).*

In this strategy, the whole of the Atlantic zone is considered as the core area. This is supplemented with maintenance of small pest-free areas within the core area. Pest free areas would include thermophilic habitats, oligotrophic habitats like coastal and inland dunes, heartlands, quarries and calcareous grasslands. The most dispersive populations along water courses should also be eradicated.

- Methods and techniques:

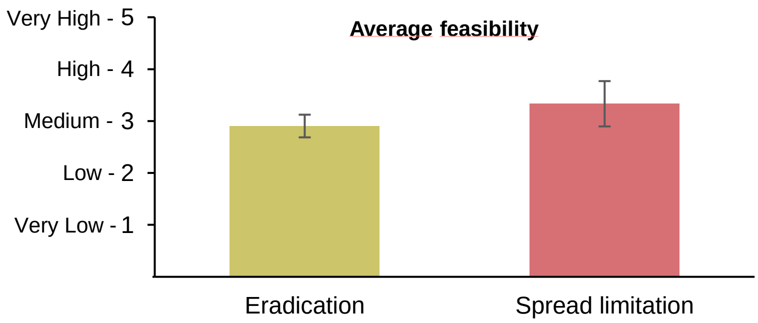
In pest free areas, the species is eradicated using the methods described in the eradication scenario above. The most dispersive populations along watercourses are also tackled using these methods.

- Post-intervention verification:

Aftercare is needed on all treated sites, regardless of the methods used. Sites should be monitored one or more times a year, and new suckers or seedlings handled appropriately as soon as possible during at least 5 years (EPPO, 2020).

D. Assessment results

The **average feasibility of the spread limitation scenario was higher than the eradication scenario** (a little above medium feasibility and a little below medium feasibility respectively). **There was no consensus between assessors**, with one assessor judging them equally feasible and two assessors deeming spread limitation more feasible. The largest average differences between the two scenarios were found in the criteria cost and acceptability – which were both more advantageous in the spread limitation strategy (a little less than major *vs* massive and acceptable *vs* moderately acceptable, for spread limitation and eradication respectively).
Cost and likelihood of reintroduction were the main limiting factors in both scenarios, and were scored as likely. Experts highlight the high risk of reintroduction from private gardens or public greenery where the tree was commonly planted in the past, a practice which should phase out.



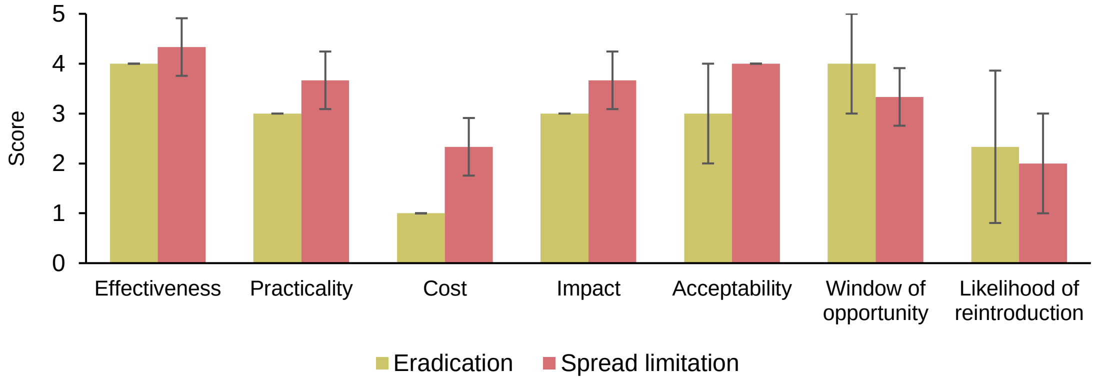


***Figure 18**. **Top**: Average feasibility scores for the eradication and spread limitation scenario of Ailanthus altissima; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of A. altissima.*

E. Recommendations for management

Although there was no full consensus between experts on the most feasible strategy, none of the experts deemed the eradication scenario more feasible than the spread limitation scenario. Additionally, **since the average feasibility score of the eradication scenario was below medium feasibility we recommend the spread limitation scenario (Option 2. Stand-still principle with core area).** However, feasibility scores were also low for spread limitation, mainly due to the high cost and high likelihood of introduction from private gardens, public greenery or the many populations along transport infrastructure (e.g. railways, motorways). Enhanced surveillance effort deserves to be provided in the continental bioregion and within protected areas in the Atlantic bioregion so that eradication at early invasion stage can be applied in case of species detection.

Also, excluding ornamental trees with exceptional value, municipalities and cities with *Ailanthus* trees should seek to remove and replace those gradually. Experts noted that large ornamental trees should not be cut down as they will resprout vigorously, but one should rather wait until their natural death.

References

Adriaens, T., P. Verschelde, E. Cartuyvels, B. D'hondt, E. Vercruysse, W. van Gompel, E. Dewulf, and S. Provoost (2019). A preliminary field trial to compare control techniques for invasive *Berberis aquifolium* in Belgian coastal dunes. NeoBiota 53:41. doi: 10.3897/neobiota.53.38183

Adriaens T., D'hondt B., Carael S., Deconinck D., Devisscher S., Hillaert J., Jacobs I., Janssen J., Oosterlynck P., Strubbe R., Van Gompel W., Van Landuyt W., Vercruysse E., Paredis R., Westra T., Provoost S. (2022). Assessment of current and future invasive plants in protected dune habitats of the Atlantic coastal region - Including management accounts of selected species for the LIFE DUNIAS project (LIFE20 NAT/BE/001442). Reports of the Research Institute for Nature and Forest 2022 (29). Research Institute for Nature and Forest, Brussels. DOI: doi.org/10.21436/inbor.86703335

Badalamenti E, Mantia TLa (2013). Stem-injection of herbicide for control of *Ailanthus altissima* (Mill.) Swingle: a practical source of power for drilling holes in stems. iForest. http://www.sisef.it/iforest/contents?id=ifor0693-006

Bennett, Warren O., James T. Paget, and Duncan Mackenzie. "Surgery for a tree surgeon? Acute presentation of contact dermatitis due to *Ailanthus altissima*." Journal of Plastic, Reconstructive & Aesthetic Surgery 66.3 (2013): e79-e80.

Boer, E. (2013). Risk assessment *Ailanthus altissima* (Mill.) Swingle. Naturalis Biodiversity Center, Leiden.

Burch PL, Zedaker SM (2003). Removing the invasive tree *Ailanthus altissima* and restoring natural cover. Journal of Arboriculture, 29(1):18-24.

Brundu G. (2017) Information on measures and related costs in relation to species considered for inclusion on the Union list: Ailanthus altissima. Technical note prepared by IUCN for the European Commission.

Collin, P. & Dumas, Y. (2009) Que savons-nous de l'Ailante (*Ailanthus altissima* (Miller) Swingle)? Revue forestière française LXI: 117-130.

Constán-Nava S, Bonet A, Pastor E, Lledo M (2010). Long-term control of the invasive tree *Ailanthus altissima*: insights from Mediterranean protected forests. Forest Ecology and Management 260: 1058-1064.

D'hondt B, Hillaert J, Devisscher S, Adriaens T (2022). Een kader voor de aanpak van invasieve uitheemse soorten in Vlaanderen: een prioritering voor het natuurbeleid (PrIUS). Rapporten van het Instituut voor Natuur- en Bosonderzoek 2022 (36). Instituut voor Natuur- en Bosonderzoek, Brussel. DOI: doi.org/10.21436/inbor.88096226

de Groot, C., & Oldenburger, J. (2011). De bestrijding van invasieve uitheemse plantensoorten. Probos.

Dufour-Dror, J. M. (2013). Guide for the control of invasive trees in natural areas in Cyprus: Strategies and technical aspects. Department of Forests, Republic of Cyprus.

DiTomaso JM, Kyser GB (2007). Control of *Ailanthus altissima* using stem herbicide application techniques. Arboriculture & Urban Forestry, 33(1):55-63.

EPPO (2020) National Regulatory Control Systems: PM 9/29 *Ailanthus altissima*. Bulletin OEPP/EPPO Bulletin 50(1): 148–155.

Fogliatto, S., Milan, M., & Vidotto, F. (2020). Control of *Ailanthus altissima* using cut stump and basal bark herbicide applications in an eighteenth-century fortress. Weed Research, 60(6), 425-434.

Géron C., Lembrechts J., Nijs I., & Monty A. (2022). Woody invaders from contrasted climatic origins istribute differently across the urban-to-rural gradient in oceanic Europe – Is it trait-related? Urban Forestry & Urban Greening 75, https://doi.org/10.1016/j.ufug.2022.127694

FCBN, 2016. SI Observation flore. *Ailanthus altissima.* https://siflore.fcbn.fr/

Hunter, J. (2000). *Ailanthus altissima* (Miller) Swingle. *Invasive Plants of California's Wildlands. University of California Press, Berkeley*, 32-36.

Kowarik, Ingo (2003). Biologische Invasionen – Neophyten und Neozoen in Mitteleuropa (in German). Stuttgart: Verlag Eugen Ulmer. ISBN 978-3-8001-3924-8.

Kowarik, I. & Saumel, I. (2007) Biological flora of Central Europe: *Ailanthus altissima* (Mill.) Swingle. Perspectives in Plant Ecology, Evolution and Systematics 8: 207-237.

Kowarik, I. & Säumel, I. (2008) Water dispersal as an additional pathway to invasions by the primarily wind-dispersed tree *Ailanthus altissima*. Plant Ecology 198: 241-252.

Landenberger, R. E., Kota, N. L., & McGraw, J. B. (2007). Seed dispersal of the non-native invasive tree *Ailanthus altissima* into contrasting environments. *Plant Ecology*, *192*(1), 55-70.

Ließ, Nicole, and Anton Drescher (2008). "*Ailanthus altissima* spreading in the Danube National Park–possibilities of control." Neobiota 7 : 84-95.

Meloche C, Murphy SD (2006). Managing tree-of-heaven (*Ailanthus altissima*) in parks and protected areas: a case study of Rondeau Provincial Park (Ontario, Canada). Environmental Management, 37(6):764-772.

Milan, M., Fogliatto, S., De Palo, F., Ferrero, A., & Vidotto, F. (2018). Strategies to eradicate Ailanthus altissima (Mill.) Swingle in a forested area. In 18th European Weed Research Society Symposium-EWRS 2018 (pp. 97-97). Kmetijski inštitut Slovenije

Miller, James H. (2003). Nonnative invasive plants of southern forests: a field guide for identification and control. Gen. Tech. Rep. SRS–62. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 93 p.

Radtke, A., Ambraß, S., Zerbe, S., Tonon, G., Fontana, V., & Ammer, C. (2013). Traditional coppice forest management drives the invasion of *Ailanthus altissima* and *Robinia pseudoacacia* into deciduous forests. Forest Ecology and Management, 291, 308-317.

Rebbeck, J., Hutchinson, T. F., & Iverson, L. R. (2019). Effects of prescribed fire and stem-injection herbicide on *Ailanthus altissima* demographics and survival. Forest Ecology and Management, 439, 122-131.

Ries, C. & M. Pfeiffenschneider (Eds.) (2020). *Ailanthus altissima* (Mill.) Swingle. In: neobiota.lu - Invasive Alien Species in Luxembourg. National Museum of Natural History, Luxembourg. URL: https://neobiota.lu/ailanthus-altissima/ [Accessed 2020-08-28].

Schmeil, Otto; Fitschen, Jost; Seybold, Siegmund (2006). Flora von Deutschland, 93. Auflage (in German). Wiebelsheim: Quelle & Meyer Verlag. p. 42. ISBN 978-3-494-01413-5.

Swearingen, J. M., & Pannill, P. D. (2009). Tree of Heaven: *Ailanthus Altissima*. Plant Conservation Alliance, Alien Plant Working Group.

Southeast Exotic Pest Plant Council (SEPPC) (2012). Southeast Exotic Pest Plant Council Invasive Plant Manual: Tree-of-Heaven. https://www.se-eppc.org/manual/ailanthus.html [Accessed: 4th of june 2020]

Van Landuyt W. (2006) *Ailanthus altissima*. In: Van Landuyt W., Hoste I., Vanhecke L., Van den Bremt P., Vercruysse W. & De Beer D., Atlas van de flora van Vlaanderen en het Brussels gewest. Instituut voor Natuur- en Bosonderzoek, Nationale Plantentuin van België en Flo.Wer: 116.

Verloove F. (2002) Ingeburgerde plantensoorten in Vlaanderen. Mededeling van het Instituut voor Natuurbehoud n° 20: 227 p.

Verloove F. (2020) *Ailanthus altissima*. On: Manual of the Alien Plants of Belgium. Botanic Garden Meise, Belgium. At: http://alienplantsbelgium.be/content/ailanthus-altissima, accessed 15/04/2020.

3.3.2. Staff vine, *Celastrus orbiculatus* (Aziatische boomwurger, Célastre asiatique)

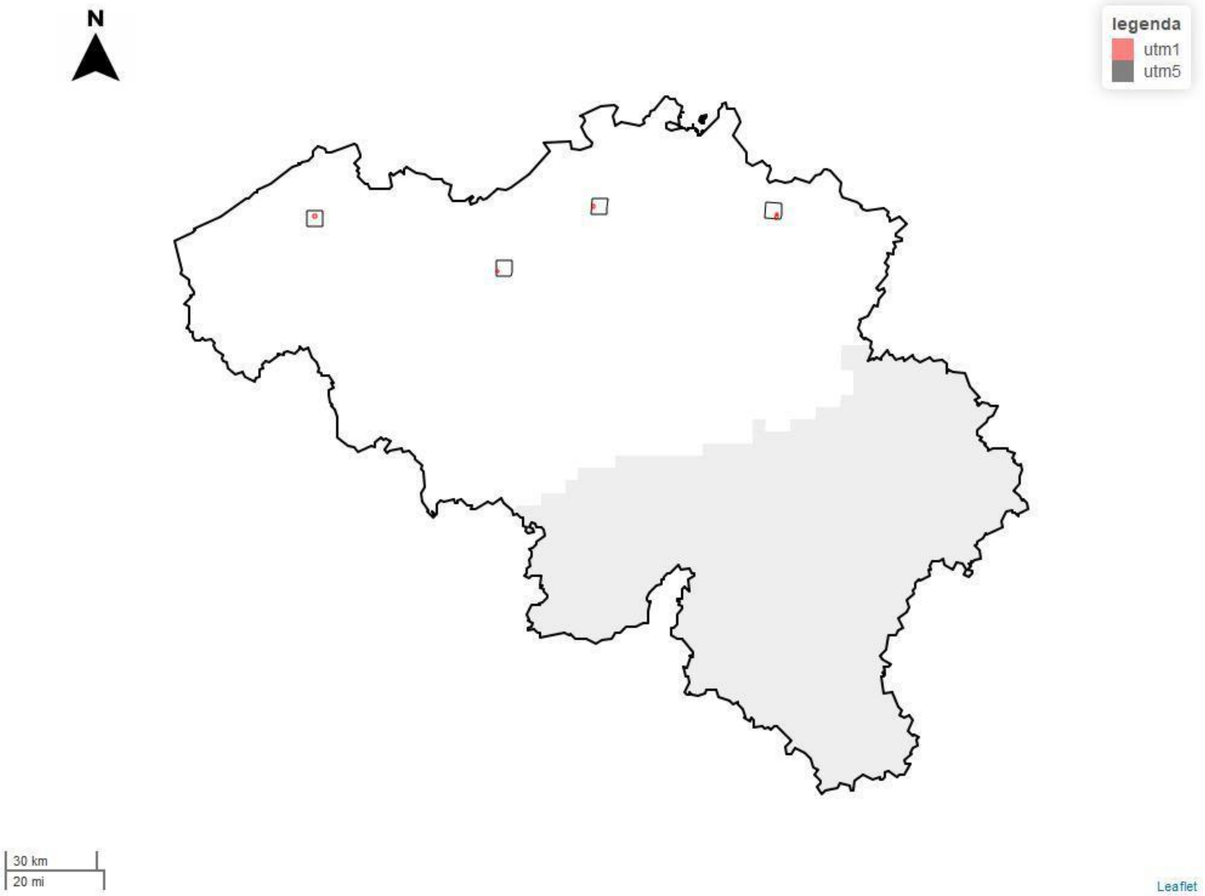
Credits: A. Purcel

A. Invasion scenario

- Invasion situation and history in BE: In Belgium, *Celastrus orbiculatus* is present in a few locations in Flanders only, as a result of escapes from cultivation (Verloove, 2022). It was first observed in 2004 on the edge of a nature reserve in Berchem-Antwerpen (Wolvenberg), where it appears very persistent (pers. comm. F. Rylant). In 2005, it was also recorded in the valley of the river Scheldt in Berlare (Oost-Vlaanderen) and in 2013 in an old arboretum in Lommel (Limburg) and in Loppem (West-Vlaanderen) (Verloove, 2022). All the records are considered separate introductions. The species has not been reported from the Continental bioregion (observations.be).

- Reliability of the BE distribution: The distribution is considered to be reliable, as there is no confusion with other species in Belgium. However, given that it could be confused with other cultivated *Celastrus* species and that the species does not exhibit its most striking characteristic (its yellow fruit that turns to red) since it hardly flowers in Belgium, it might be underreported.

- Invasion situation in neighbouring countries: A few escaped individuals have been reported in the Netherlands and in Germany but not close to the Belgian border.



B. Management strategy – eradication

- Methods and techniques:

Celastrus orbiculatus is a vine that can spread via dispersal of seed by birds and mammals. Seedlings mainly emerge directly from seed rain and recruitment of seeds to the seed bank is thought to be rather low (Ellsworth et al., 2004). There are a few methods that can be considered:

- For smaller infestations eradication through mechanical removal is a good option. For small plants, this can be achieved by hand pulling. Care must be taken that the entire plant is removed including the entire root system, as the species will vigorously resprout from root suckers, especially when the main vine is cut. For larger climbing vines, besides removing the entire root system, the stem should also be cut to relieve the host tree canopy.
- For larger infestations, mowing the larger plants close to ground level could be considered as an option. However, patches should be mowed at least once a month to control the vigorous regrowth and exhaust the plant (Dreyer, 2003; Lynch, 2009). Only mowing 3 times during the season will not suffice and only leads to regrowth. Such regular cutting, when applied with high frequency, appeared to be more than 90% effective for plants of large stem diameter in the second year of management (Van Valkenburg, 2021). All plant material that is extracted needs to be removed from

the site following management since it can give rise to new growth (Lynch, 2009; IPSAWG, 2019). This method is expected to work only with sustained effort of several years.

- The most effective method of eradication is the cut-stump technique: a combination of cutting or mowing the stem tissue (approximately 5 cm above the ground) and immediate application of a systemic herbicide on the cut stumps. This technique should be applied wherever possible.

- Post-intervention verification:

Several years of monitoring is required to be sure no resprouting from the roots occurs, and any regrowth is eradicated (Van Valkenburg, 2021). As the species is cultivated in private gardens, dedicated communication actions convincing private owners to remove the species from their garden since cutting all the flowering heads is almost impossible are performed in the vicinity of the site. After chemical application to the cut stumps, subsequent foliar application may be needed to control new seedlings (IPSAWG, 2019).

C. Management strategy – spread limitation

- Aim: *Option 1 - Stand-still principle with a single or a few patches.*

The spread limitation strategy aims at limiting the presence of this species in Belgium to the few records already documented.

- Methods and techniques:

The surroundings of the patches are regularly and continuously monitored in the long term in order to react as quickly as possible if the small populations start expanding. In case this happens, the strategy is to eradicate the new small plants by hand pulling and uprooting the plant, or when possible, by the cut-stump technique. Collected material is safely taken off site taking biosecurity measures into account (UICN Comité français, Suez Recyclage, Valorisation France 2022). As the species is cultivated in private gardens, dedicated communication actions are done close to the escape locations in order to convince private owners to remove the species from their garden to avoid further spread of the species in the environment.

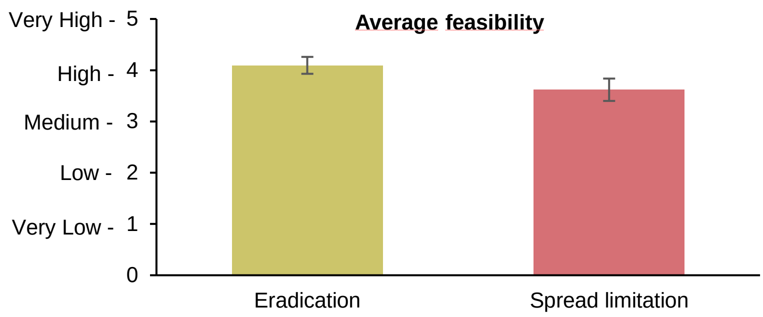
- Post-intervention verification:

For the main population, measures will need to be repeated indefinitely. New locations where individuals were eradicated, and the surroundings, are monitored for several years (Van Valkenburg, 2021) and any new seedlings are eradicated.

D. Assessment results

The average feasibility of the eradication scenario was considered to be high - with all assessors scoring it at least as high. **Average feasibility of the spread limitation scenario was considered to be between medium and high**, with assessors all scoring below high. There was consensus between assessors to favor the eradication scenario over the spread limitation scenario.

On average, five out of seven criteria were scored higher for the eradication scenario. Only average scores of impact and window of opportunity were considered as more advantageous in the spread limitation scenario. For impact, this was only the result of one assessor that increased the score of that criterion in the spread limitation scenario – this opinion was not shared between all assessors. For the criteria 'window of opportunity' two assessors agreed that it was more advantageous in the spread limitation scenario. The most limiting factor for both scenarios was the likelihood of reintroduction, scoring the lowest for the spread limitation scenario.



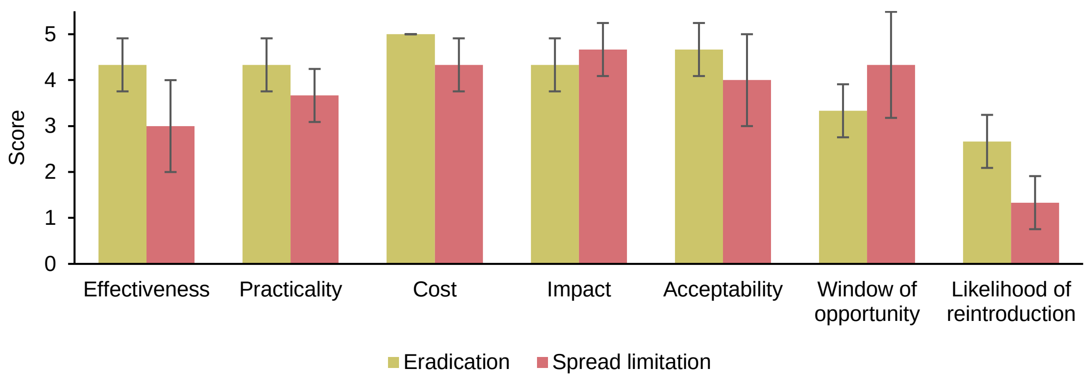


Figure 19. ***Top****: Average feasibility scores for the eradication and spread limitation scenario of Celastrus orbiculatus;* ***Bottom****: Breakdown of average feasibility scores into average scores of the seven key criteria for management of C. orbiculatus*

E. Recommendations for management

There is a consensus on **eradication as the management strategy for the entire Belgian territory** for this emerging species. While there are no restrictions or bottlenecks identified in terms of cost, practicality or acceptability, the problem of access to private property will need to be considered for this ornamental species.

References

Dreyer, G. D. (2003). Element Stewardship Abstract for *Celastrus orbiculatus* Asiatic Bittersweet. The Nature Conservancy. 11 p.

Ellsworth, J. W., Harrington, R. A., & Fownes, J. H. (2004). Survival, growth and gas exchange of *Celastrus orbiculatus* seedlings in sun and shade. The American midland naturalist, 151(2), 233-240.

Hutchison, M. (1992). Vegetation management guideline: round-leaved bittersweet (*Celastrus orbiculatus* Thunb.). Natural Areas Journal, 12, 161.

IPSAWG (2019). Oriental bittersweet *Celastrus orbiculatus*. Invasive plant species fact sheet. Available at: https://www.in.gov/dnr/files/Oriental_Bittersweet.pdf

Lynch, A. (2009). Investigating distribution and treatments for effective mechanical and herbicide application for controlling oriental bittersweet (Celastrus orbiculatus Thunb.) vines in an Appalachian hardwood forest. MS Thesis, Davis College of Agriculture, Natural Resources and Design, USA.

UICN Comité français, Suez Recyclage, Valorisation France (2022). Accompagner le traitement des déchets de plantes exotiques envahissantes issus d'interventions de gestion. Guide technique. Centre de ressources Espèces exotiques envahissantes. UICN Comité français & Office français de la biodiversité. 136 pages.

Van Valkenburg, J. (2021). Information on measures and related costs in relation to species considered for inclusion on the Union list – *Celastrus orbiculatus*. Technical note prepared by IUCN for the European Commission.

Verloove F. (2022). *Celastrus orbiculatus*. On: Manual of the Alien Plants of Belgium. Botanic Garden of Meise, Belgium. At: alienplantsbelgium.be, accessed 28/07/2022.

3.3.3. Purple pampas grass, *Cortaderia jubata* (hoog pampasgras, Herbe de la pampa pourpre)

Credits - by Jon Sullivan - CC BY-NC 2.0

A. Invasion scenario

- Invasion situation and history in BE: The species is not established in the wild in Belgium nor in the rest of Europe. A probable invasion scenario is that at the point of detection the species is present as a small population of 10 square meters and is producing fertile seeds. The species was probably introduced via wind dispersed seeds from a private garden, and then further expanded. Since the species sets seeds only after two to three years and can be confounded with other species such as *C. selloana*, it is likely that the population has already been thriving for a few years. It is unclear whether *C. jubata* was also grown in Belgium.
- Invasion situation in neighbouring countries: No established populations in the wild have been reported in neighboring countries nor in the rest of Europe.
- Reliability of the BE distribution: The distribution is considered to be potentially underestimated as the species bears strong similarity with *C. selloana* which is commonly found in gardens and horticulture, as well as with other Cortaderia species such as toetoe Grass *C. richardii* which is known to be much more recorded across Britain and Ireland - Stroh et al. 2020). In the most recent taxonomic revision, *C. jubata* is even recognised as a subspecies of *C. selloana* (Testoni & Linder, 2017). *Cortaderia selloana* is bred more frequently in our neighbouring countries (greenity.nl) and has been recorded in the wild in multiple locations in the Netherlands.

B. Management strategy – eradication

- Methods and techniques:

For smaller invasions as described in the scenario, eradication can be achieved by physical removal (Ditomaso et al., 2010; Gosling et al., 2000). For very small plants this implies hand pulling, for larger plants other tools such as spades can be used. For very large plants, a chain is wrapped around the stalk and pulled with an excavator (depending on the surroundings as an excavator does a lot of damage to the surrounding vegetation). This action should be undertaken before flowering (which lasts from August to October) as the plants can be very fertile (although the germination capacity in Belgium is unknown) and seeds can disperse widely. Pulling up the majority of roots to prevent resprouting from rootstock increases effectiveness of the method (Ditomaso et al., 2010). Plant material should be safely taken off site, taking biosecurity measures into account (UICN Comité français, 2022).

Since the population was probably already thriving for a few years, seeds may have dispersed in the surroundings by wind along the ditch where the population developed. Seeds may also have been transported by animals. Therefore, the surrounding area should be scrutinized for several kilometers where possible (New Zealand Plant Conservation Network, 2018).

Biocontrol and chemical measures are not part of the strategy because of limited research and legal limitations in the Belgian context respectively and the availability of an effective mechanical alternative (99% effective – Ditomaso et al., 2008).

- Post intervention verification:

If all the stalks are removed, 3 years of post-care should suffice (Visser, 2017; LIFE STOP Cortaderia, 2020), although some sources indicate 7 years of post-intervention surveillance is necessary (Penniman et al., 2011). During this period, potential regrowth should be removed with the means described above. Since seeds have short viability of only 4 months when buried (Drewitz and Ditomaso, 2004), we suggest performing a first site visit to check for seedlings and regrowth 6 months after the initial management intervention, and then every year before seed set.

As the species is cultivated in private gardens in the area, private owners in the vicinity are notified that they need to eradicate the species in their garden.

C. Management strategy – spread limitation

- Aim : *option 1 – limiting species presence to a single or a few patches*

The spread limitation strategy aims at limiting the presence of *C. jubata* in Belgium this single patch, avoid the production of any propagule that might result in further dispersion, and rapidly eradicate any new patch discovered in the field.

- Methods and techniques:

Every year, flowering heads (originating from August through October) are removed to avoid seed set, starting with the largest plants. Additionally, seedlings are pulled by hand or removed with a spade when encountered. Plant material should be safely taken off site, taking biosecurity measures into account (UICN Comité français, Suez Recyclage, Valorisation France 2022).

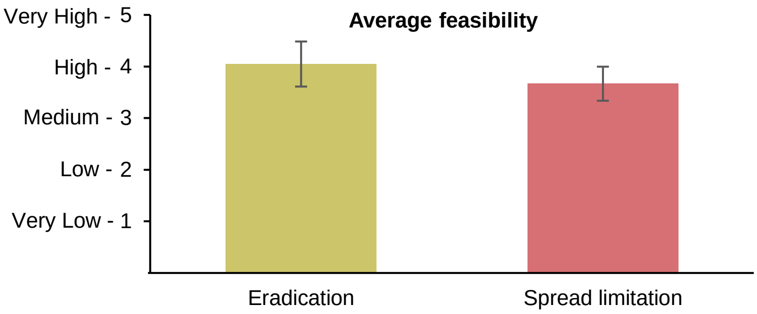
- Post intervention verification:

The surroundings are regularly monitored. In case new patches were found and eradicated, follow-up monitoring must be undertaken for a period of 1 year to avoid seed set as seeds buried under natural conditions only remain viable for a period of 6 months (Drewitz and DiTomaso, 2004). This could be done by hand pulling the seedlings that still emerge after physical removal.

As the species is cultivated in private gardens in the area, dedicated communication actions are initiated close to the escape locations, targeting private owners in order to convince them to eradicate the species in their garden or at a minimum, cut the inflorescence before seed maturation.

D. Assessment results

The average feasibility scores of the eradication and the spread limitation strategy were a little bit over "high" and a little bit under "high" respectively. **There was no consensus between reviewers on which is the most feasible strategy** with 2 assessors reaching a higher average feasibility score for the eradication scenario and the other for the spread limitation scenario, though the latter difference was minimal (0,3 points). Average scores of six out of seven criteria were very similar between scenarios. The biggest difference could be found for effectiveness, which was scored between effective and very effective in the eradication scenario while it was scored as ineffective or moderately effective for the spread limitation scenario. Two out of three reviewers considered effectiveness to be a lot higher for the eradication scenario while one reviewer stated effectiveness would be identical.



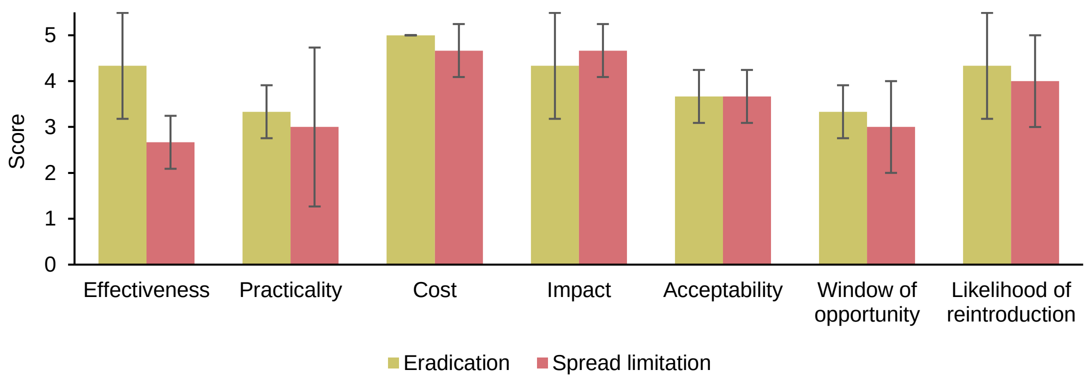


***Figure 20. Top**: Average feasibility scores for the eradication and spread limitation scenario of Cortaderia jubata; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of C. jubata.*

E. Recommendations for management

There was no full consensus on a preferred strategy, although average feasibility of both scenarios was around high and effectiveness was above 4. Therefore, **we suggest the default management option should be eradication**, in line with the guiding principle of eradication for species of the EU Regulation not yet present in Belgium. A main impediment that was identified by assessors was access to the local population.

It should also be noted that there are doubts about the species capacity for heavy seed set and germinating capacity under the prevailing climatic conditions. If the species would show such capacity, eradication feasibility should be reevaluated.

References

Drewitz, J., & DiTomaso, J. (2004). Seed biology of jubatagrass (*Cortaderia jubata*). Weed Science, 52(4), 525-530.

DiTomaso, J. M., Drewitz, J. J., and Kyser, G. B. (2008). Jubatagrass (*Cortaderia jubata*) control using chemical and mechanical methods. Invasive Plant Science and Management, 1(1), 82-90. Retrieved from https://doi. org/10.1614/IPSM-07-028.

Gosling, D. S., Shaw, W. B., Beadel, S.M., (2000). Review of control methods for pampas grasses in New Zealand. Department of Conservation.

LIFE STOP Cortaderia (2020). Guide des bonnes pratiques pour le contrôle de *Cortaderia selloana*. Cantabria, Espagne, 77 pp. via https://www.calameo.com/read/0032989852bb709a6d3a8

New Zealand Plant Conservation Network. (2018). New Zealand's Flora: *Cortaderia jubata*.

Penniman, T. M., Buchanan, L., and Loope, L. L. (2011). Recent plant eradications on the islands of Maui County, Hawaii. In C. R. Veitch, M. N. Clout, and D. R. Towns (Eds.), Island invasives: eradication and management (pp.325-331). Gland: IUCN.

Popay, I. (2020). *Cortaderia jubata* (purple pampas grass). In: CABI Compendium. Wallingford, UK: CAB International. https://doi.org/10.1079/cabicompendium.113484

UICN Comité français, Suez Recyclage, Valorisation France (2022). Accompagner le traitement des déchets de plantes exotiques envahissantes issus d'interventions de gestion. Guide technique. Centre de ressources Espèces exotiques envahissantes. UICN Comité français & Office français de la biodiversité. 136 pages.

Stroh, P.A., Humphrey, T. A., Burkmar, R.J., Pescott, O.L., Roy, D.B., Walker, K.J. (2020). *Cortaderia richardii* (Endl.) Zotov in BSBI Online Plant Atlas 2020, eds https://plantatlas2020.org/atlas/2cd4p9h.y1e [Accessed 06/11/2023]

Testoni, D., & Linder, H. P. (2017). Synoptic taxonomy of *Cortaderia* Stapf (Danthonioideae, Poaceae). PhytoKeys, (76), 39–69. https://doi.org/10.3897/phytokeys.76.10808

Visser, V. (2017). Technical note: The management of purple pampas grass (*Cortaderia jubata*) measures and associated costs.

3.3.4. Senegal tea plant, *Gymnocoronis spilanthoides* (smalle theeplant, Faux hygrophile)

Credits: Tim Adriaens

A. Invasion scenario

- Invasion situation and history in BE: The species does not occur in the wild in Belgium, but has been sold for use in garden ponds and aquaria. There are no exact numbers for the trade in Belgium, but *G. spilanthoides* is a plant that is present in many aquaria and private ponds.

  A probable invasion scenario is that at the point of detection, a large patch of plants stretching over 30m along a smaller water course is reported. It is believed that the population originated from an aquarium dump. Since the vegetation on the ditch bank has been mowed for two years by the municipality, plant fragments have dispersed 100 m downstream, where a second population spanning 10 m was also found.

- Reliability of the BE distribution: The distribution is considered to be reliable because the species is fairly easy to identify based on its conspicuous, white flowers. Confusion has occurred with aberrant flower colours of *Centaurea jacea* yet this is a terrestrial species with a very different leaf.

- Invasion situation in neighbouring countries: The species did appear in 2019 in an artificial, rainwater-fed, ex-polder urban water system in Vleuten (province of Utrecht) in the Netherlands where it exhibited vigorous flower production and vegetative spread. The plants have since been eradicated (Van Valkenburg and Odé, 2020). In France, *G. spilanthoides* was first reported in 2022 with numerous populations found along a 20 km stretch of the Sarthe river near the city of Le Mans (Centre North west) (Centre de ressources EEE, 2022).

B. Management strategy – eradication

- Methods and techniques:

Firstly, the population needs to be isolated from the watercourse with gauze mats or mesh with a mesh width of 5 mm to prevent fragments from spreading. Secondly, one should remove a 30 cm thick layer of the shore (in which the species roots) and transport it offsite with the necessary biosecurity measures. As excavation is not always possible, an alternative is to hand pull or rake the plants. The drawback of these mechanical options is that some roots could remain from which the plant can regenerate (GISD, 2023). It is therefore recommended to wash away the soil (with a water pump and nozzle) around the root system of the plants to reduce root breakage (Van Valkenburg and Odé, 2020). The method has been proven successful in reducing small infestations (Parsons & Cuthbertson, 2001; Van Valkenburg and Odé, 2020). Management actions should be performed before seed set. All cut plant material is removed and should be disposed of at a certified composting facility.

Management actions should take into account that buried seeds have 5 times longer longevity than exposed ones (Panetta, 2010). It could be envisioned to maximally disturb the seed bank to remove more plants in the aftercare and favor population decline. However, this would require a better understanding of the appropriate methods and close monitoring would be needed.

Herbicides effective in controlling *G. spilanthoides* such as the selective broad-leaf herbicide metsulfuron-methyl which provides good control are not part of the strategy due to the legal limitations of their use in aquatic systems in Belgium (Champion et al., 2002; Champion & Clayton, 2003; Sainty & Jacobs, 2003; Van Oosterhout, 2010).

- Post-intervention verification:

The sites and potential downstream areas remain under close surveillance over a 5-year period in order to detect any resurgence of the species or any resprouting from the seed bank. As soon as the population recovers or downstream infestation is observed, the method described above is applied again.

C. Management strategy – spread limitation

- Aim: O*ption 1 - Stand-still principle with a single or a few patches.*

The spread limitation strategy aims at limiting the presence of *G. spilanthoides* in Belgium to this single population.

- Methods and techniques:

The population is permanently isolated from the downstream watercourse with gauzemats or mesh with a mesh width of 5 mm in order to prevent spread of vegetative fragments. The mats/mesh are then regularly maintained to remove any debris building up at the upstream side to secure water flow within the ditch. To avoid seed set, flowers are cut preferably manually. Alternatively, plants can be mowed multiple times per season. To avoid cut fragments from being spread, additional barriers should be added at the time of mowing.

Individuals found further downstream or outside of this ditch are eradicated using the same physical methods described above. Machinery hygiene and biosecurity actions are implemented to avoid secondary spread of vegetative fragments when leaving the site.

- Post-intervention verification:

An accurate surveillance is implemented in the immediate vicinity of existing populations to be able to detect any further spread originating from these populations. Verification of the success of control actions is achieved in the same way as for the eradication strategy.

D. Assessment results

The average feasibility of the eradication scenario is considered to be a little below high, while average feasibility of the spread limitation scenario is considered to be medium. There is consensus among experts that the eradication scenario is more feasible.

Average scores of 6 out of 7 criteria were higher in the eradication scenario. Only the criterium impact was considered to be a little bit higher in the eradication scenario, though 2 out of three experts scored non-target impact as identical in both scenarios. One assessor made the remark however, that he would consider the spread limitation scenario to have a more noticeable non-target impact (lower score) if the screen would encompass the entire width of the stream. The criterion with the lowest score was the window of opportunity, evaluated as short (2 months - 1 year) for both scenarios.

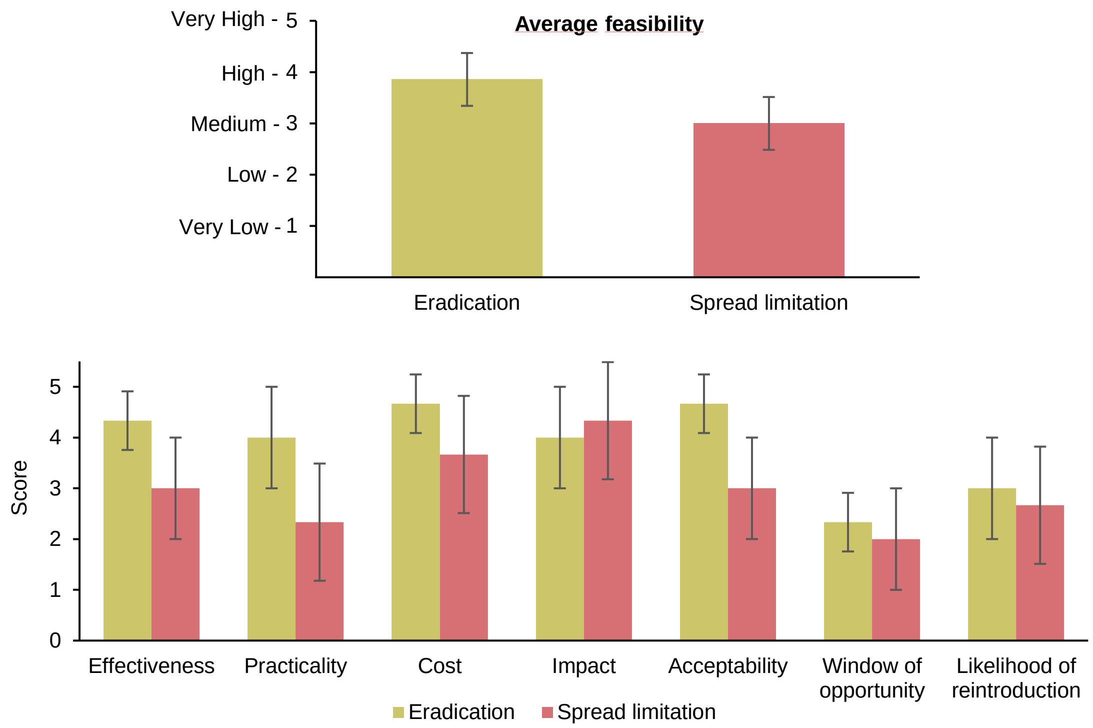


*Figure 21. Top: Average feasibility scores for the eradication and spread limitation scenario of Gymnocoronis spilanthoides; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of G. spilanthoides*

E. Recommendations for management

Since the eradication scenario has a higher average feasibility and scores consistently better on 6 out of 7 criteria, **we recommend the eradication option, in line with the guiding principle of the EU Regulation for species not yet present in Belgium.** To ensure success, rapid action – within the year of detection – would be required. Aftercare would be of outmost importance to achieve success.

References

CABI (2022). '*Gymnocoronis spilanthoides* (Senegal tea plant)' . In: CABI Compendium. Wallingford, UK: CAB International. https://doi.org/10.1079/cabicompendium.26246

Champion, P.D., Rowe D. & Clayton, J.S. (2002). Lake Manager Handbook: Alien Invaders. https://environment.govt.nz/assets/Publications/Files/lm-alien-invaders-jun02.pdf

Champion PD & Clayton JS (2003). The evaluation and management of aquatic weeds in New Zealand. In *Plant Invasions: Ecological Threats and Management Solutions* (Eds L Child, JH Brock, G Brundu, K Prach, P Pysek, PM Wade & M Williamson), pp. 429– 434. Backhuys Publishing, Leiden (NL).

Global Invasive Species Database (GISD) (2023). Species profile Gymnocoronis spilanthoides. Available from: http://www.iucngisd.org/gisd/species.php?sc=863

Panetta, F. (2010). Seed persistence of the invasive aquatic plant, *Gymnocoronis spilanthoides* (Asteraceae). Australian Journal of Botany. 57. https://doi.org/10.1071/BT09187.

Parsons, W.W.T. and Cuthbertson, E.E.G. (2001). Noxious Weeds of Australia. Csiro Publishing, Canberra, 534-536.

Sainty, G.R. & Jacobs, S.W.L. (2003). *Waterplants in Australia*, 4th edn, 416 pp. Sainty & Associates Pty Ltd, Potts Point, NSW (AU).

Van Oosterhout, E. (2010). Senegal tea. Primefact 993. Industry & Investment NSW.

Van Valkenburg, J. (2017). Technical note: The management of Senegal tea plant (*Gymnocoronis spilanthoides*) Measures and associated costs

Van Valkenburg, J. L. C. H., & Odé, B. (2020). Smalle theeplant (*Gymnocoronis spilanthoides* (D. Don ex Hook. & Arn.) DC., Asteraceae), een onverwachte eerste vondst voor Nederland. *Gorteria Dutch Botanical Archives*, *42*(1), 39-45.

3.3.5. Japanese hop, *Humulus scandens* (Oosterse hop, Houblon du Japon)

Credits: Tim Adriaens

A. Invasion scenario

- Invasion situation and history in BE: The species was reported in the fifties in a hedge in Schaarbeek and on a dump in Mechelen (Verloove, 2018), but is - as of yet - not established in Belgium. The invasion scenario is that the species is observed by a botanist on a large non-riparian rubbish dump in the Brussels region. The species was not detected at the early invasion stage because of confusion with *H. lupulus* and already extends over an area of more than 100 m² along a hedge adjacent to the plot.

  H. scandens is an annual vine and reproduces exclusively by seeds which are primarily dispersed by gravity. The seeds can form a seed bank with ca. 3 years viability (Balogh and Dancza, 2008; EPPO, 2018).

- Reliability of the BE distribution: The distribution is thought to be relatively reliable, although the species could be confused with our native hop (*Humulus lupulus*). Taking this into consideration, it is not unlikely that the distribution of *H. scandens* is underestimated, especially near gardens, dumps or on dynamic river banks.

- Invasion situation in neighboring countries: The species was first reported from the wild in France in 2004 and is now considered to be established and invasive in riparian habitats in the South of France. The species is absent from the rest of our neighboring countries.

B. Management strategy – eradication

- Methods and techniques:

The eradication technique consists of uprooting the plants. This can be done mechanically or physically, before seed formation. Uprooting should be done when the soil is moist (Pannill et al., 2009) which will decrease fracture of roots which causes regrowth. The most favorable period is the end of spring (April – May) while the roots are still small and before the vines become tangled with other vegetation (Pannill et al., 2009). At that stage, intra-specific competition should also have reduced the number of individuals (Fried, 2018). The management should be repeated again later in the season to control regrowth, additional flowering and new seedlings (Tassus et al., 2018).

For small infestations (up to 100m²) that are not too dense, uprooting can be achieved by hand pulling. This method ensures as little damage as possible to other plants. Since the hooked hairs on the stem may cause injuries and blisters to hands it is recommended to wear protective gloves during weeding (Balogh and Danca, 2006).

For larger infested areas (100 to 1000 m²), mechanical uprooting will be more cost-effective. The plant reproduces predominantly by seeds which can be dispersed by water or be incorporated in the seed bank, though vegetative growth from fragments cannot be entirely excluded (Panke and Renz, 2013). All biomass should be treated in an industrial composting facility. Uprooting and transportation of biomass after seed set should be avoided to prevent seeds dispersing in the natural environment.

Chemical control, although effective in some cases (Guyon and Cosgriff, 2022), is not part of any strategy due to the legal limitations of herbicide use in Belgium.

- Post-intervention verification:

Since seeds can remain viable for three years, aftercare (uprooting) should be done for three consecutive years (Krauss, 1931).

C. Management strategy – spread limitation

- Aim: *Option 1: Stand-still principle with a single or a few patches.*

The spread limitation strategy aims at limiting the presence of this species in Belgium to the newly discovered population in the hedge.

- Methods and techniques:

The strategy aims to limit the seed production and suppress the existing population. In order to do so, the whole population needs to be hand pulled, or mowed as close to the ground as possible multiple times a year and before seed maturation. The mowing should start early in the season (late spring) and should last until fall. Cut material should be bagged and properly disposed of to avoid seed incorporation in the seedbank or further dispersal. This method is able to suppress the population in three years time (Balogh and Dancza, 2008).

The surrounding area is regularly monitored. Mechanical or manual uprooting will be performed for any new individual recorded in the neighboring area as a result of seed establishment from the source population.

- Post-intervention verification:

In case new patches are found, eradication and follow-up monitoring must be undertaken for a period of at least three years to avoid seed establishment.

D. Assessment results

Average feasibility of both the eradication scenario and the spread limitation scenario were scored as high. The main difference between both scenarios was found in the assessment of effectiveness of the proposed measures. One reviewer in particular deemed effectiveness to be a lot lower in the spread limitation scenario as he argued it is impossible to eliminate all seeds and thus it cannot be guaranteed that the species would not have spread further.

Four out of seven criteria (cost, acceptability, window of opportunity, likelihood of reintroduction) were assigned identical average scores. Two (practicality and impact) were scored similarly in both scenarios: between practical and very practical and between minimal and minor impact. The criterion with the lowest score was the window of opportunity, evaluated as short to moderate (between a few months and a few years) for both scenarios.

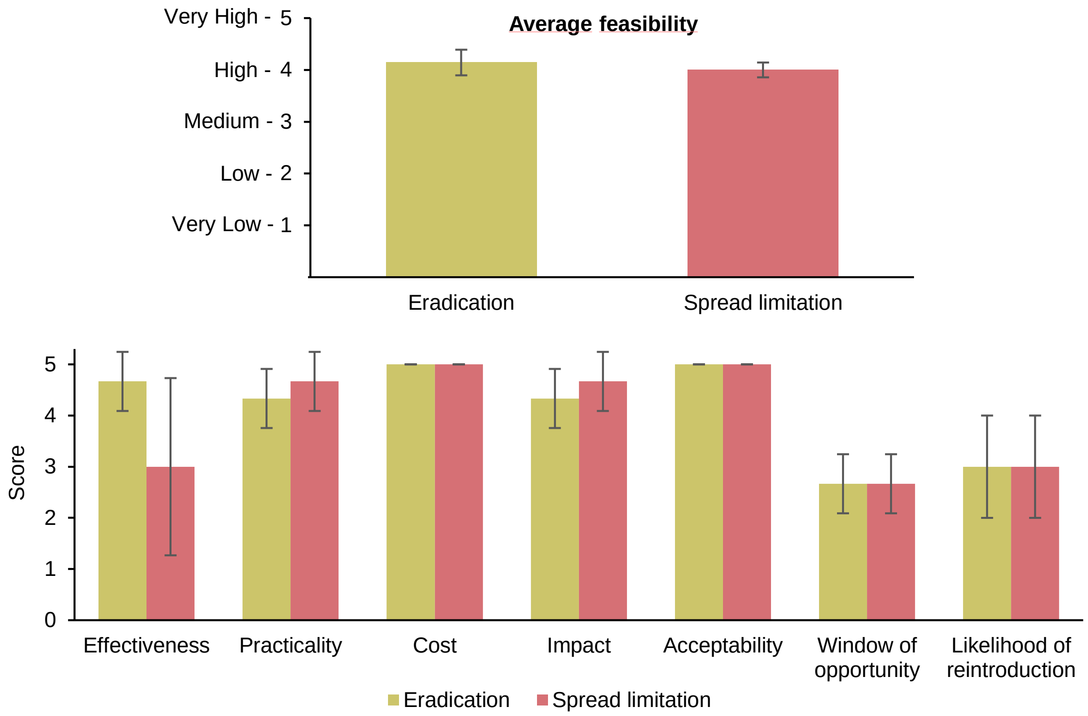


***Figure 22**. **Top**: Average feasibility scores for the eradication and spread limitation scenario of Humulus scandens; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of H. scandens.*

E. Recommendations for management

Since there are no big differences between the strategies for six of the seven criteria, and effectiveness is seen as high in the eradication scenario, **we recommend the eradication option, in line with the guiding principle of the EU Regulation for species not yet present in Belgium.**

Experts indicate that if the species was found in riparian habitat instead of next to a dump, it would change practicality as well as impact. Additionally, upstream sections would need to be managed first since the species produces a lot of seed and could easily reinfect cleared stretches. A riparian invasion is equally probable and would also yield a lower score for the criteria 'window of opportunity' as seeds are easily spread by water. The reality of plant removal in a dynamic, entropic riparian system would make such a scenario much less feasible and warrant immediate action.

References

Balogh, L., & Dancza, I. (2008). *Humulus japonicus*, an emerging invader in Hungary. Plant invasions: human perceptions, ecological impacts and management. Backhuys Publishers, Leiden, 73-91.

EPPO (2018). Pest risk analysis for *Humulus scandens*. EPPO, Paris.

Fried, G. (2018). Information on measures and related costs in relation to species included on the Union list: *Humulus scandens*. Technical note prepared by IUCN for the European Commission.

Krauss, O. (1931). Humulus L., Hopfen. In: Bonstedt, C. (ed.), Pareys Blumengärtnerei. Erster Band, pp. 498-499. Verlag Paul Parey, Berlin.

Lyle J Guyon, Robert J Cosgriff (2022). Japanese Hops (*Humulus japonicus*) Control and Management Strategies in Large River Floodplains, Journal of Forestry, Volume 120, Issue 2, Pages 156–169, https://doi.org/10.1093/jofore/fvab055

Panke, B., & Renz, M. J. (2013). Japanese hop (*Humulus japonicus*). University of Wisconsin--Extension, Cooperative Extension.

Pannill, P.D., Cook, A Hairston-Strang, and J.M. Swearingen. 2009, Fact sheet: Japanese hop. Plant Conservation Alliance's Alien Plant Working Group. Available online at https://www.invasive.org/alien/fact/pdf/huja1.pdf

Sarat, E., Fried, G. & Reygrobellet, J-P. (2015) Houblon du Japon (*Humulus japonicus*): expérimentation des méthodes de gestion du houblon du Japon dans le bassin versant des Gardons. Espèces exotiques envahissantes en milieux aquatiques : connaissances pratiques et expériences de gestion. Onema, IUCN France

Tassus, X., Monty, A., Albert, A., Fried, G., Silvie, P., Balesdent, M. H., ... & Wetzel, T. (2018). Réalisation d'une analyse de risques relative au houblon du Japon et élaboration de recommandations de gestion.

F. Verloove, 2018, Manual of the invasive plants of Belgium. (http://alienplantsbelgium.be/content/humulus-japonicus) - accessed June 2020.

3.3.6. Himalayan knotweed, Koenigia polystachya (Afghaanse duizendknoop, Renouée à épis nombreux)

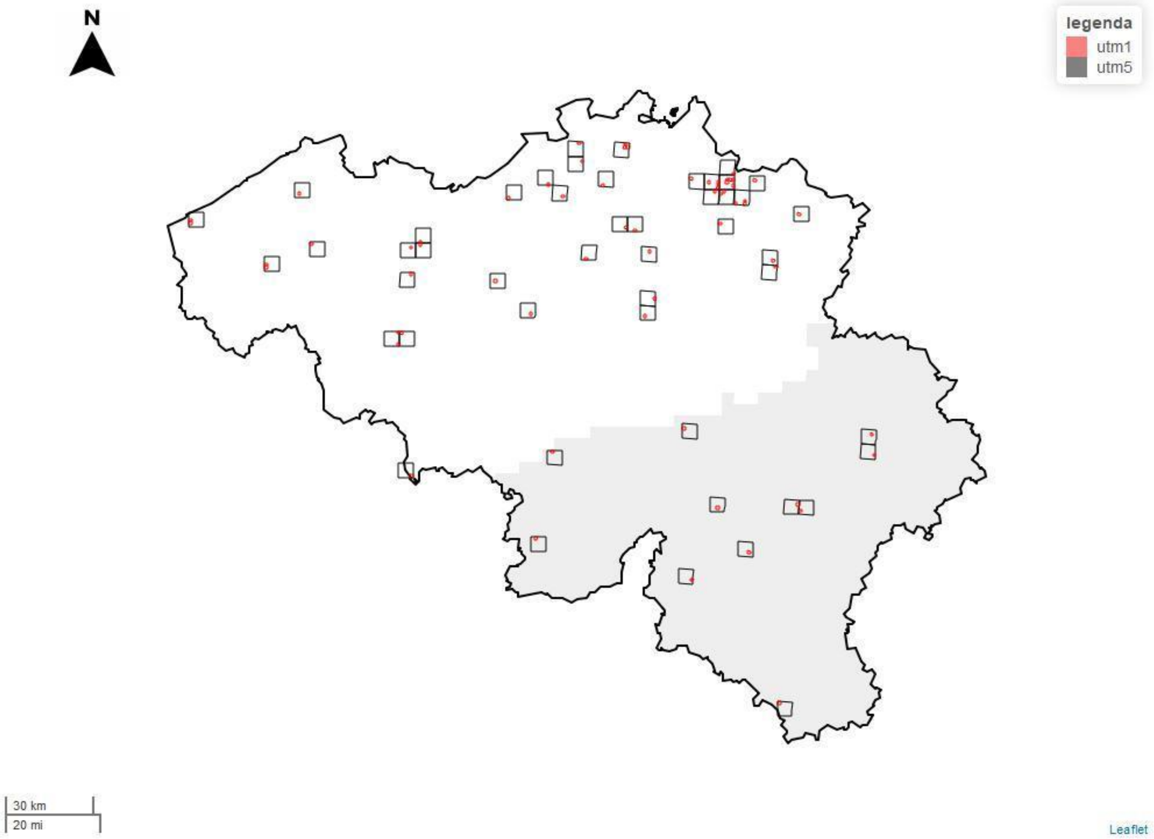
Credits: Tim Adriaens

A. Invasion scenario

- Invasion situation and history in BE: *Koenigia polystachya* is widely present in Belgium but in rather isolated populations locally being naturalized from garden escapes. The species is considered to be well-established and can form large, dense and persistent populations. It was first recorded in 1898 in Oostende, and was then observed in numerous locations throughout Belgium, though it is more abundant in Flanders. The species is locally very abundant in the Kempen and persistent in Mirwart, Wijnegem, Petite-Chapelle etc. (Verloove, 2022). The plant is mostly found on canal and riverbanks, along roads, railbanks and on wastelands (Verloove, 2022).

  Koenigia polystachya reproduces mainly by vegetative fragmentation of rhizomes (Soll, 2004) and can also regenerate from internodes on stems or root buds. Rhizome fragments could be transported by water but this is not considered as an important dispersal route (DiTomaso & Healy, 2007; Tanner, 2018; Tanner & Branquart, 2019). The plant's dispersal capacity by natural means is estimated to be low but is very poorly studied (Willeput et al. *unpublished*).

- In Poland, long-distance expansion from established populations has not yet been observed (Bacieczko et al., 2015). In the UK the species has been shown to spread rapidly (NNSS, 2019), despite showing a decrease in distribution since the year 2000 in lowland England suggesting it does not persist well (Abraham et al. 2018). It has not shown similar high spread in other EU Member States despite ancient introduction (1898 in Belgium). In general, most populations seem to originate from plant or garden waste introductions and have low population expansion rates (see e.g. Beringen et al., 2019, Tanner & Branquart, 2019) so they do not actively spread in the natural environment.
- Reliability of the BE distribution: Reliable. The species could however be confused with other species of knotweed in Belgium.
- Invasion situation in neighbouring countries: In the Netherlands, the species is widespread, with multiple observations in North Brabant and Limburg, at less than 20km from the Belgian border. These observations include populations of a few hundred individuals. In France, the species is mostly abundant in Brittany and Normandy, but some populations are located close to the Belgian border, such as in the Meuse valley. In Germany, the species is considered to be established, but shows a restricted distribution not close to the Belgian border. In Luxemburg there are no records of the species (Beringen et al., 2019).



B. Management strategy – eradication

- Methods and techniques:

Himalayan knotweed is best controlled at landscape level due to its high ability to resprout and produce rhizomes (Soll, 2004). For the moment, it is thought that *K. polystachya* does not produce fertile seeds yet (Beringen, 2017). A few methods inspired from techniques promoted to control Japanese knotweed can be used, preferably in combination – though it is stated that those are probably only effective in achieving eradication when infestations are smaller than 20 to 50 m^2 (Branquart et al., 2018; Thoonen and Willems, 2018) :

- **Control by manual or mechanical removal**: cutting with handheld tools or motorized machinery, every 2-3 weeks in the growing season and at least four times per year (Beringen et al., 2019). This should be sustained for at least 2-3 years (CABI, 2022), but sometimes the infestation is still not eradicated after 4 years (Beringen et al., 2019). All cut material is collected and disposed adequately (see below). This is very important because the risk of secondary spread due to mowing is very high as stem fragments and rhizome fragments can sprout. This type of management is best combined with chemical control.
- **Repeated uprooting:** repeated uprooting (and removal) of superficial rhizomes can be applied to small stands and is more effective than stem cutting.
- **Covering:** heavy geotextile should be applied over the infestation and extend beyond the plant zone for at least 2 extra meters (but preferably more). The textile should be applied before the growing season or after a few cuttings in the spring and left in place during the whole season. The bands of textile should widely overlap (and are preferably stitched together) and are preferably covered with 30 to 50 cm of soil to avoid damage to the geotextile (e.g. by birds). While some sources state it is not successful when applied on its own (CABI, 2022), others state that root structures are exhausted in 4 years of time (Beringen et al, 2019). A drawback to this method is that it cannot be used under tree cover or when obstacles are present.
- **Excavating:** Removing the root system along with the soil. While the bulk of the root system is generally in the upper layers, the soil is excavated to a depth of 1 up to 3 meters depending on the case (Hallword and Sellentin, 2011). The excavated soil can be carefully transported to a landfill for deep burial or reused on site at a depth of at least 5 meter (2 if coated in geotextile) - GOV.UK 2019. Excavated locations should be planted with native vegetation and monitored for regrowth and all new growth should be hand pulled or treated with chemical products.
- **Chemical control:** when applying chemical control, systemic herbicides - products that transfer efficiently to the roots – should be used (CABI, 2022). Chemical control should best be combined with mowing and only when there is no other alternative. A combination of mowing and one time injection of the stems led to eradication of knotweed within three years (Böhmer et al., 2006). Jones et al., 2018 tested 19 different methods of combinations of chemical control.

Management of Himalayan knotweed should be hygienic. Care should be taken that plant material is not transported off site by water, dirty machinery or tools. Therefore, nets should be placed in aquatic systems before tackling the plants so plant fragments cannot be transported by the water. It is advised to use a mowing-sucking combination to avoid fragments from being spread (Oldenburger et al., 2017). Additionally, increased biosecurity measures are needed during management and before leaving the site – described thoroughly in Thoonen and Willems, 2018. In short: all used machinery and other tools should be cleaned thoroughly and care must be taken with soil and machinery placement. Lastly, all plant material should be bagged and treated at an industrial compost facility since temperatures in open compost heaps do not have sufficient temperature to kill the plant fragments (Fuchs, 2017) .

The use of electricity in managing infestations of *K. polystachya* is not considered in this document since field and laboratory tests have proven not to be effective against the underground root structures in other knotweed species (van Dijck and de Visser, 2019).

- Post-intervention verification:

The patch is monitored for at least three years and any regrowth or seedlings are eradicated. While population growth can be very prolific through vegetative spread, the species seldom spread over longer distances (Conolly 1977 and Bacieczko et al. 2015 in Beringen, 2017) implying time and effort should not be spent on thoroughly monitoring the surrounding landscape.

C. Management strategy – spread limitation

- Aim: *Option 3. Elimination of the most dispersive populations*

The spread limitation strategy aims at eliminating the riparian populations to limit the dispersal of the species.

- Methods and techniques:

Riparian populations are eradicated using similar techniques as those proposed in the eradication strategy. Other populations are not managed as long as they do not threaten areas of conservation value. If populations are accessible to the public, information posts are put up.

- Post-intervention verification:

An accurate surveillance is implemented in the immediate vicinity of the core area to be able to detect any further spread from it. Any regrowth or new seedlings are eradicated.

D. Assessment results

The average feasibility score of the eradication and the spread limitation scenario were a bit lower than medium and a bit higher than medium respectively. **There was consensus between experts that the spread limitation scenario was slightly more feasible.** Six out of seven criteria were scored higher in the spread limitation scenario. Cost, effectiveness, practicality and likelihood of introduction were the most limiting factors, although a high variability demonstrates the scarcity of information on adequate management practices for this species.

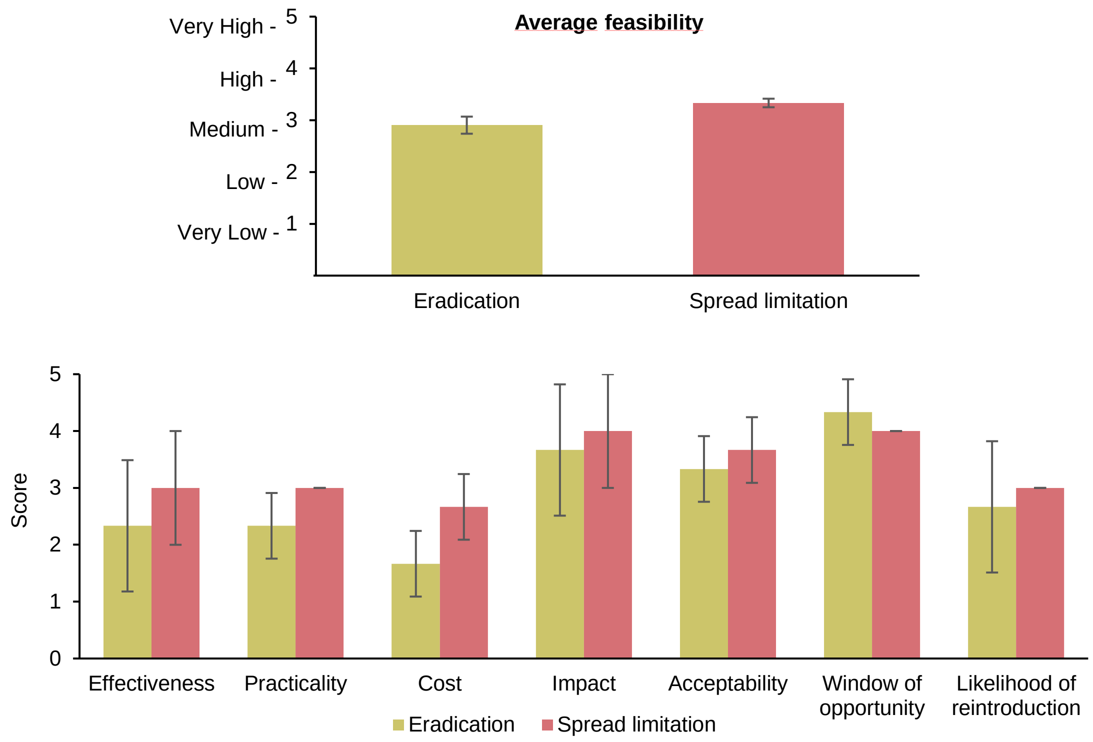


***Figure 23. Top**: Average feasibility scores for the eradication and spread limitation scenario of Koenigia polystachya; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of K. polystachya.*

E. Recommendations for management

Based on expert assessments, the eradication strategy has a relatively low effectiveness and a high cost. **We therefore recommend the spread limitation as a management strategy, with the aim of eliminating the dispersive riparian populations.** Tackling only riparian populations also ensures access.

Little information is available on the effectiveness of the management of this species and it is very likely that methods need to be adapted according to the locality at hand. Much of what is known is extrapolated from knowledge of other exotic congeners, which are notoriously difficult to manage. However, as the species is still relatively limited in Belgium, chances of eradication cannot be completely ruled out. Hand pulling with aftercare would probably be the best way.

Experts note that the species could be underdetected and that by only eliminating known riparian populations, the objective might be missed. They point to the **need for enhancing surveillance effort.** Also size and other peculiarities of existing populations should be measured in the field to better assess management feasibility.

References

Abraham, F., Briggs, M., Harmes, P., Hoare, A., Knapp, A., Lording, T., Scott, B., Shaw, M., Streeter, D. & Sturt, N. (eds) (2018). The Flora of Sussex. Sussex Botanical Recording Society. Pisces Publications, Newbury.

Adriaens T., Vandegehuchte M., Casaer J. (2015). Basisdocument voor het opmaken van een code van goede praktijk (best practice) voor invasieve exoten. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2015 (INBO.R.2015.7041776). Instituut voor Natuur- en Bosonderzoek, Brussel.

Bacieczko, W., Borcz, A., & Kaszycka, E. (2015). Ecological characteristics of *Polygonum polystachyum* population in north-western Poland. Polish Journal of Natural Sciences, 30(1), 35-46.

Beringen, R., R.S.E.W. Leuven, B. Odé, M. Verhofstad & J.L.C.H. van Valkenburg (2019). Risicobeoordeling van vier Aziatische duizendknopen in Europa. FLORON-rapport: 2018.049.e1

Böhmer, H.J., T. Heger, B. Alberternst & B. Walser (2006). Ökologie, Ausbreitung und Bekämpfung des Japanischen Staudenknöterichs (*Fallopia japonica*) in Deutschland. Anliegen Natur 30: 29-34.

Branquart, E., Vanparys, V., Trojan, M. (2018). Les renouées asiatiques en Wallonie: 10 techniques pour mieux les combattre. Service Public de Wallonie, Cellule interdépartementale Espèces invasives.

DiTomaso, J. M., & Healy, E. A. (2007). Weeds of California and other western states (Vol. 3488). UCANR Publications.

Fuchs, J.G. (2017). Studie zur Persistenz von Erdmandelgras (*Cyperus esculentus*) und Japanknöterich (*Reynoutria japonica*) in Kompostierungs- und Vergärungsprozessen. Forschungsinstitut für Biologischen Landbau (FiBL, Schweiz).

GOV.UK (2019). Guidance Treatment and disposal of invasive non-native plants: RPS 178. Environment Agency (https://www.gov.uk/government/publications/treatment-and-disposal-of-invasive-non-native-plants-rps-178/treatment-and-disposal-of-invasive-non-native-plants-rps-178, Updated 9 April 2019).

Hallworth, J., and Sellentin, E. (2011). Understanding and Controlling Invasive Knotweeds in BC. BC Ministry of Forests, Lands and Natural Resource Operations: Victoria, BC, Canada.

Jones, D., G. Bruce, M.S. Fowler, R. Law-Cooper, I. Graham, A. Abel, F.A. Street-Perrott & D. Eastwood, (2018). Optimising physiochemical control of invasive Japanese knotweed. Biological Invasions 20(8): 2091–2105.

NNSS (2019). Non native species information portal. *Persicaria wallichii.* https://www.nonnativespecies.org/non-native-species/information-portal/view/2603

Oldenburger, J., J. Penninkhof, C. de Groot & F. Voncken (2017). Praktijkproef bestrijding duizendknoop. Probos, Wageningen.

Soll, J. (2004). Controlling knotweed (*Polygonum cuspidatum, P. sachalinense, P. polystachyum* and hybrids) in the Pacific Northwest. Portland, Oregon, USA: Nature Conservancy, Oregon Field Office.

Tanner, R. (2018). Study on Invasive Alien Species – Development of Risk Assessments: Final Report. Annex with evidence on measures and their implementation cost and cost-effectiveness – *Koenigia polystachya*.

Tanner, R. and Branquart E., (2018). Risk assessment on *Koenigia polystachya* developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention" Contract No 07.0202/2017/763379/ETU/ENV.D.21

Thoonen M., Willems S. (2018). Invasieve duizendknoop in Vlaanderen. Een kader voor goed beheer. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2018 (62). Instituut voor Natuur- en Bosonderzoek, Brussel. DOI: doi.org/10.21436/inbor.14708391

Thoonen M., Willems S. (2018). Invasieve duizendknoop in Vlaanderen. Beslishulp voor beheerders. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2018 (63). Instituut voor Natuur- en Bosonderzoek, Brussel. doi.org/10.21436/inbor.14745748

van de Witte, Y. (2022) '*Persicaria wallichii* (Himalayan knotweed)'. In: CABI Compendium. Wallingford, UK: CAB International. https://doi.org/10.1079/cabicompendium.120210

van Dijck and de Visser (2019). Effectiviteit elektrificatie technologie voor bestrijding Japanse duizendknoop. Wageningen Research, Rapport WPR-922. 14 blz.

Verloove, F. (2022) *Rubrivena polystachya*. On: Manual of the Alien Plants of Belgium. Botanic Garden of Meise, Belgium. At: alienplantsbelgium.be, accessed 03/08/2022

3.3.7. Chinese bushclover, *Lespedeza cuneata* (Chinese struikklaver, Lespédèze soyeuse)

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A. Invasion scenario

- Invasion situation and history in BE: In 2022 the species was discovered - for the first time in Europe - during a post-inundation plant survey on the banks of the Vesdre river in Goffontaine in the easternmost part of Belgium and was subsequently removed (Verloove et al. 2023). The species is probably to be considered a wool adventive as many aliens in that valley. The combination of extreme floods (and the subsequent removal of dispersed *Reynoutria japonica*) and an exceptionally warm summer and autumn of 2022 might have favored the germination and further development (Verloove et al. 2023). Considering this the invasion scenario is one small dense stand of about 10m^2 spotted in a field, where it probably arrived as a seed contaminant.
- Reliability of the BE distribution: Since the species looks quite typical at mature stage and should not remain unnoticed for very long, the distribution is considered relatively reliable. It should be noted that the presence of the species might be overlooked at early stages as the species could be confused with other legumes.
- Invasion situation in neighbouring countries: The species is not known to occur in the wild anymore in Europe.

B. Management strategy – eradication

- Methods and techniques:

The eradication strategy combines mechanical and chemical methods, as suggested by Stevens (2002). The strategy aims at limiting seed production and juvenile recruitment in the patch through mowing and increasing adult and juvenile mortality by the use of herbicides (Emry, 2008). This integrated approach consists of mowing plants at the flower bud stage (early to mid-summer, when plants are about 30-40 cm high), followed by herbicide treatment. Mowing should not be undertaken too soon in the season since early mowing can increase ramet production. In contrast, mowing late in the season inflicts most damage since plants are trying to build root reserves (Ohlenbusch and Bidwell, 2001). The herbicides can be applied after mowing using broad cover spraying or spot spraying – with spot spraying having lesser non-target impact. Triclopyr and fluroxypyr have provided the most consistent control of the species across different life stages, including seedlings and adult plants (Altom et al., 1992; Koger et al., 2002; Farris and Murray, 2009 – in Flory, 2018), though glyphosate has also proven to be effective for tackling *Lespedeza* invasions (Farris and Murray, 2009; Brooke and Harper, 2017). Authorized herbicide active ingredients in Belgium should be confirmed via fytoweb. A derogation on the prohibition of use of herbicides in areas of public service or along watercourses should be requested with competent authorities. The combination method of mowing and chemical application has to be undertaken for several years as seeds are expected to remain viable in the soil for multiple years (Ohlenbusch and Bidwell, 2001). During management actions, proper biosecurity procedures should be followed to avoid seed dispersal (machinery hygiene, limited foot traffic, limited soil disturbance…).

If livestock were kept on the field, the contaminated plot should be fenced to avoid animals accessing the contaminated patch. Not only can seeds stick to their fur and spread, but grazing early in the growing season can also promote the production of more ramets.

Hand pulling is not part of the strategy due to the extensive perennial root system of the plant and the fact that soil disturbance increases germination of seeds. Burning is not part of the strategy since burning can stimulate resprouting and encourages seed germination in the field (Gucker, 2010, Wong et al., 2012). Biological control with *Lespedeza* webworms that decrease seed production is also not considered in this strategy (Eddy and Moore, 1998).

- Post-intervention verification:

The patch area and its surroundings, especially disturbed areas, are being monitored and any regrowth or seedling is eradicated. As *L. cuneata* is a prolific seed producer (one ramet can produce 900 seeds- Wood et al., 2009) and seeds can remain viable for many years, large numbers of viable seeds can remain in the seed bank for several years. Special care is taken to avoid seed dispersal during post intervention actions (cleaning up of the machinery, limited foot traffic, limited soil disturbance…). Follow-up monitoring must be undertaken for at least 4 years.

C. Management strategy – spread limitation

- Aim: *Option 1 - Stand-still principle with a single or a few patches.*

The spread limitation strategy aims at limiting the presence of *L. cuneata* in Belgium to this single patch.

- Methods and techniques:

Once established, it is very difficult to remove *L. cuneata* due to the seed bank which may remain viable for decades. The patch is therefore mowed at the early flower bud stage to avoid seed set and further spread through seed dispersal, but not too early in the growing season so as to not increase ramet production (Ohlenbusch and Bidwell, 2001). The surroundings of the patch, and especially disturbed sites are regularly monitored in order to react as quickly as possible if the small stand starts expanding. In case new seedlings are reported outside the original patch, they are quickly treated by mowing them at the flower bud stage (early to mid-summer), followed by herbicide treatment. This effort should be sustained for three consecutive years. Since seedlings are very poor competitors, it might also be considered to increase native vegetation cover to increase competition. During management actions, proper biosecurity procedures are followed to avoid the seed dispersal due to management actions (machinery hygiene, limited foot traffic, limited soil disturbance…).

- Post-intervention verification:

The patch area and its surroundings, especially disturbed areas, are being monitored and any regrowth or seedling is eradicated. As *L. cuneata* is a prolific seed producer (one ramet can produce 900 seeds- Wood et al., 2009) and seeds can remain viable for many years, large numbers of viable seeds can remain in the seed bank for several years. Special care is taken to avoid seed dispersal during post intervention actions (cleaning up of the machinery, limited foot traffic, limited soil disturbance…). Follow-up monitoring during at least 4 years must be undertaken.

D. Assessment results

The average feasibility scores of the eradication and spread limitation scenario were high and between medium and high respectively. **Experts agreed that the eradication scenario was more feasible than the spread limitation scenario**. Four out of seven criteria (effectiveness, practicality, cost, acceptability) were - on average - assessed as more favorable in the eradication scenario. The other three criteria (impact, window of opportunity, likelihood of reintroduction) were scored almost identically between scenarios by the assessors. The criterium with the lowest score was the window of opportunity, evaluated as short to moderate (2 months – 1 year) for both scenarios.

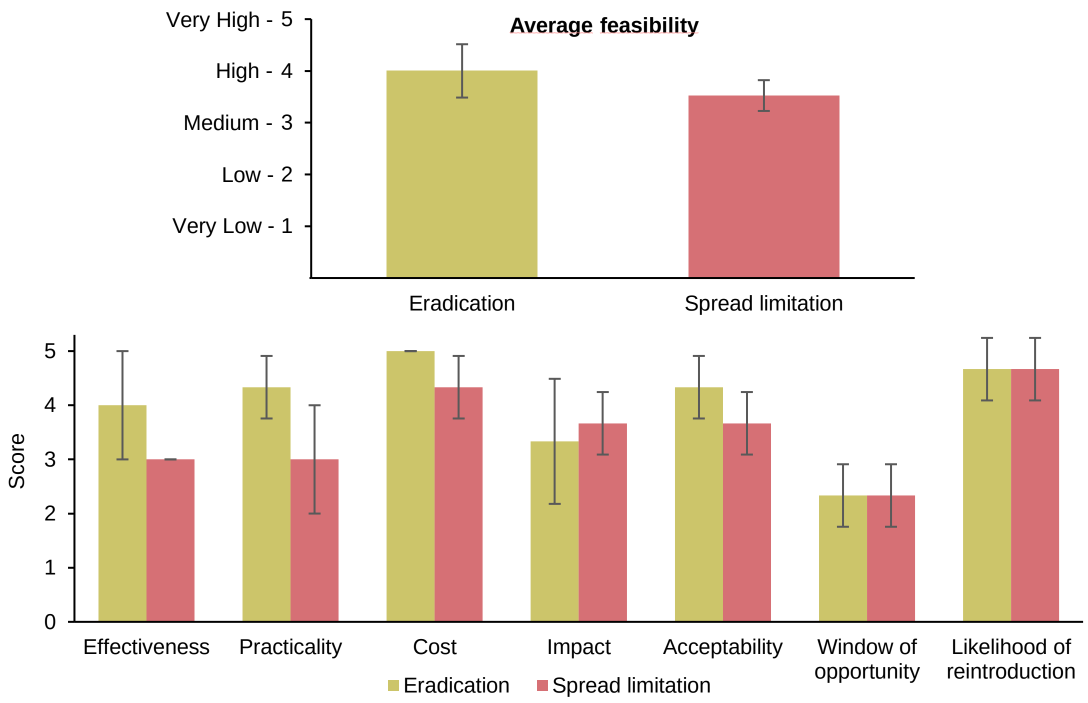

***Figure 24**. **Top**: Average feasibility scores for the eradication and spread limitation scenario of Lespedeza cuneata; **Bottom**: Breakdown of average feasibility scores into average scores of the seven key criteria for management of L. cuneata.*

E. Recommendations for management

There is agreement on eradication of *L. cuneata* as management recommendation for Belgium, which is in line with the guiding principle of eradication for species of the EU Regulation not yet present in Belgium. Rapid action – within the year of detection – would be required. Increased surveillance followed by rapid eradication is advised in case of any new plant detection in the Vesdre valley.

References

Altom, J. V., Stritzke, J. F., and Weeks, D. L. (1992). *Sericea lespedeza (Lespedeza cuneata)* control with selected postemergence herbicides. Weed Technology, 6(3), 573-576.

Brooke, Jarred M., and Craig A. Harper (2016). "Herbicides are effective for reducing dense native warm-season grass and controlling a common invasive species, *Sericea Lespedeza*." J. Southeastern Assoc. Fish Wildlife Agencies 3 : 178-184.

Cullen, J. (1995). Lespedeza. European Garden Flora Vol IV. pp. 494-495.

Eddy, T., & Moore, C. (1998). Effects of *Sericea lespedeza* [*Lespedeza cuneata* Dumont (G. Don)] Invasion on Oak Savannas in Kansas. *Transactions Wisconsin Academy Science, Arts and Letters*, *86*, 57–62.

Emry, D. J. (2008). Population ecology and management of the invasive plant, Lespedeza cuneata (Doctoral dissertation, University of Kansas).

EPPO (2018) *Pest risk analysis for Lespedeza cuneata* EPPO, Paris. (accessed on CIRCAB, Sept 2018)

Farris, R. L., and Murray, D. S. (2009). Control of seedling *Sericea lespedeza* (*Lespedeza cuneata*) with herbicides. Invasive Plant Science and Management, 2(4), 337-344.

Flory, S.L. (2018). Information on measures and related costs in relation to species considered for inclusion on the Union list: *Lespedeza cuneata*. Technical note prepared by IUCN for the European Commission.

Global Invasive Species Database (2020) Species profile: *Lespedeza cuneata*. Downloaded from http://www.iucngisd.org/gisd/species.php?sc=270 on 20-03-2020.

Gucker, C. (2010). *Lespedeza Cuneata*. In: Fire Effects Information System, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory Retrieved from http://www.fs.fed.us/database/feis/plants/forb/lescun/all.html

Koger, C. H., Stritzke, J. F., and Cummings, D. C. (2002). Control of *Sericea lespedeza (Lespedeza cuneata)* with triclopyr, fluroxypyr, and metsulfuron. Weed Technology, 16(4), 893-900.

Ohlenbusch, P.D. and T. Bidwell (2001). *Sericea lespedeza*: history, characteristics, and identification. MF-2408. Kanas State University. Agricultural Experimental Station and Cooperative Extension Service.

Remaley T. (1997). *Lespedeza cuneata* (Dumont) G. Don . National Park Service, Plant Conservation Alliance, Alien Plant Working Group.

Stevens S. (2002). Element Stewardship Abstract for *Lespedeza cuneata* (Dumont-Cours.) G. Don. The Nature Conservancy.

Verloove F., Gonggrijp S., Valentini S. and Dana, E.D. (2023). The first European record of Lespedeza cuneata (Fabaceae), an invasive alien species of Union concern. BioInvasions Records 12, in press

Woods, M. T., Hartnett, C. D., & Ferguson, J. C. (2009). High propagule production and reproductive fitness homeostasis contribute to the invasiveness of Lespedeza cuneata (Fabaceae). *Biological Invasions*, *11*, 1913–1927.

Wong, B. M., Houseman, G. R., Hinman, S. E., & Foster, B. L. (2012). Targeting vulnerable life-stages of *Sericea lespedeza* (*Lespedeza cuneata*) with prescribed burns. Invasive Plant Science and Management, 5(4), 487-493.

4. Limitations and application of the manageability assessment

The outcome of this manageability exercise aims to provide support to the decision-making process on the management of the Union concern species (3rd and 4th batch) in Belgium. However, the exercise has clear limitations and for several reasons the manageability scores do not directly translate into a decision on management objectives for Belgium (Adriaens et al. 2019). The decision making process may find a lot of value in the drafted management strategies, the accounts of species invasion and distribution, as well as the consideration of the various criteria considered and the species specific feasibility scores. However, only a limited number of experts, often without actual management expertise (*e.g.* because the species are absent from Belgium and have never been under management, or because management expertise on a species is simply not available), have assessed the feasibility, therefore caution is warranted when comparing between species and/or strategies. Also, the reality of management is complex and management objectives are sometimes more dynamic especially when principles of adaptive management (Gregory et al. 2012) are applied. For instance, the strategy could quickly change from spread limitation to long term control, or from rapid eradication to limiting further spread.

Despite these limitations, the outcomes of this multi-criteria, multi-expert assessment of management feasibility can be used in the decision making in various ways:

- **Management prioritisation workflows**. For example, D'hondt et al. (2022) have used the manageability scores to prioritize species for management at regional level in Flanders. Likewise, in Wallonia, the manageability scores were combined with distribution data to determine cut-off levels for long term control programmes (Branquart et al., unpublished).
- The drafting of **management plans** and management regulations which include good management practices.
- The drafting of **contingency plans** for new species (Adriaens et al. 2015) that can be expected and would need an immediate response.

Regardless of the outcome of the management feasibility assessment presented here, management planning, budgets, monitoring and methods have to be addressed when drafting a management strategy (cf. the checklist of Dana et al. 2019).

5. References

Adriaens, T., Branquart, E., Gosse, D., Reniers, J., Vanderhoeven, S. (2019). Feasibility of eradication and spread limitation for species of Union concern *sensu* the EU IAS Regulation (EU 1143/2014) in Belgium. Report prepared in support of implementing the IAS Regulation in Belgium. Institute for Nature and Forest Research, Service Public de Wallonie, National Scientific Secretariat on Invasive Alien Species, Belgian Biodiversity Platform. https://doi.org/10.21436/17033333.

Adriaens, T., Vandegehuchte, M., Casaer, J. (2015). Guidance for drafting best management practices for invasive alien species. Report of the Research Institute for Nature and Forest INBO.R.2015.7041776, Brussels.

Adriaens T., D'hondt B., Carael S., Deconinck D., Devisscher S., Hillaert J., Jacobs I., Janssen J., Oosterlynck P., Strubbe R., Van Gompel W., Van Landuyt W., Vercruysse E., Paredis R., Westra T., Provoost S. (2022). Assessment of current and future invasive plants in protected dune habitats of the Atlantic coastal region - Including management accounts of selected species for the LIFE DUNIAS project (LIFE20 NAT/BE/001442). Reports of the Research Institute for Nature and Forest 2022 (29). Research Institute for Nature and Forest, Brussels. https://doi.org/10.21436/inbor.86703335

Adriaens, T., Barbier, Y., Branquart, E., Coupremanne, M., Desmet, P., Devisscher, S., Jacobs, A., Prevot, C., Reniers, J., Van Hoey, S., Vanderhoeven, S., & Verreycken, H. (2023). Belgian baseline distribution of invasive alien species of Union concern (Regulation (EU) 1143/2014) [Data set] https://doi.org/10.5281/zenodo.7708520

Booy, O. (2015). Risk management and prioritisation in GB. GB Non-native Species Secretariat.

Booy, O., A.C. Mill, H.E. Roy, A. Hiley, N. Moore, P. Robertson, S. Baker, M. Brazier, M. Bue, R. Bullock, S. Campbell, D. Eyre, J. Foster, M.H.-E., J. Long, C. Macadam, C. Morrison-Bell, J. Mumford, J. Newman, D. Parrott, R. Payne, T. Renals, E. Rodgers, M. Spencer, P. Stebbing, M.S.-C. ., K.J. Walker, A. Ward, S. Whittaker, G. Wyn. (2017). Risk management to prioritise the eradication of new and emerging invasive non-native species. Biol Invasions 19(8): 2401–2417.

D'hondt, B., Vanderhoeven, S., Roelandt, S., Mayer, F., Versteirt, V., Adriaens, T., Ducheyne, E., San Martin, G., Grégoire, J., Stiers, I., Quoilin, S., Cigar, J., Heughebaert, A., Branquart, E. (2015). Harmonia+ and Pandora+: risk screening tools for potentially invasive plants, animals and their pathogens. Biol Invasions 17:1869–1883.

D'hondt, B., Hillaert, J., Devisscher, S., & Adriaens, T. (2022). Een kader voor de aanpak van invasieve uitheemse soorten in Vlaanderen: Een prioritering voor het natuurbeleid (PrIUS). (Rapporten van het Instituut voor Natuur- en Bosonderzoek; Nr. 36). Instituut voor Natuur- en Bosonderzoek. https://doi.org/10.21436/inbor.88096226

Dana, E.D., García-de-Lomas, J., Verloove, F., & Vilà, M. (2019). Common deficiencies of actions for managing invasive alien species: a decision-support checklist. NeoBiota 48: 97-112. https://doi.org/10.3897/neobiota.48.35118

Gregory, R., Failing, K., Harstione, M., Long, G., McDaniels, T., Ohlson, D. (2012). Structured Decision Making: A Practical Guide to Environmental Management Choices. Wiley-Blackwell

Lafond, V., Lingua, F., Lumnitz, S., Paradis, G., Srivastava, V., & Griess, V. C. (2020). Challenges and opportunities in developing decision support systems for risk assessment and management of forest invasive alien species. *Environmental Reviews*, *28*(3), 218-245.

Magliozzi, C., Deriu, I., Gervasini, E., Melone, B., D`amico, F., Akuma, G. and Cardoso, A.C. (2023). Baseline distribution of invasive alien species added to the Union list by Comm. Impl. Reg. (EU) 2022/1203, EUR 31530 EN, Publications Office of the European Union, Luxembourg, 2023, ISBN 978-92-68-04019-5, doi:10.2760/34258, JRC133398.

Masunungure, C., Manyani, A., Dalu, M.T.B., Ngorima, A., Dalu, T. (2023). Decision support tools for invasive alien species management should better consider principles of robust decision making, Science of The Total Environment, 899: 165606. https://doi.org/10.1016/j.scitotenv.2023.165606

Reyns, N., Casaer, J., De Smet, L., Devos, K., Huysentruyt, F., Robertson, P. A., Verbeke, T. & Adriaens, T. (2018). Cost-benefit analysis for invasive species control: the case of greater Canada goose Branta canadensis in Flanders (northern Belgium). PeerJ, 6, e4283.

Shackleton, R. T., Adriaens, T., Brundu, G., Dehnen-Schmutz, K., Estévez, R. A., Fried, J., Larson, B.M.H., Liu, S., Marchante, E, Marchante, H., Moshobane, M.C., Novoa, A., Reed, M., Richardson, D. M. (2019). Stakeholder engagement in the study and management of invasive alien species. Journal of environmental management, 229, 88-101. https://doi.org/10.1016/j.jenvman.2018.04.044

Smith, K.G., Nunes, A.L., Aegerter, J., Baker, S.E., Di Silvestre, I., Ferreira, C.C., Griffith, M., Lane, J., Muir, A., Binding, S., Broadway, M., Robertson, P., Scalera, R., Adriaens, T., Åhlén, P-A., Aliaga, A., Baert, K., Bakaloudis, D.E., Bertolino, S., Briggs, L., Cartuyvels, E., Dahl, F., D'hondt, B., Eckert, M., Gethöffer, F., Gojdičová, E., Huysentruyt, F., Jelić, D., Lešová, A., Lužnik, M., Moreno, L., Nagy, G., Poledník, L., Preda, C., Skorupski, J., Telnov, D., Trichkova, T., Verreycken, H. and Vucić, M. (2022). A manual for the management of vertebrate invasive alien species of Union concern, incorporating animal welfare. 1st Edition. Technical report prepared for the European Commission within the framework of the contract no. 07.027746/2019/812504/SER/ENV.D.2.

Tsiamis, K., Deriu, I., Gervasini, E., D`amico, F., Katsanevakis, S. and De Jesus Cardoso, A. (2019). Baseline distribution of invasive alien species added to the Union list in 2019, EUR 30631 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-32135-4, doi:10.2760/68915, JRC124283.

Vanderhoeven, S., Adriaens, T., D'hondt, B., Van Gossum, H., Vandegehuchte, M., Verreycken, H., Cigar, J., Branquart, E. (2015). A science-based approach to tackle invasive alien species in Belgium–the role of the ISEIA protocol and the Harmonia information system as decision support tools. Management of Biological Invasions 6, 197–208.

Vanderhoeven, S., Branquart, E., Casaer, J., D'hondt, B., Hulme, PE, Shwartz, A., Strubbe, D., Turbe, A., Verreycken, H., Adriaens, T. (2017). Beyond protocols: improving the reliability of expert-based risk analysis underpinning invasive species policies. Biol Invasions 19(9):2507–2517.

Annex 1 - Criteria used for scoring the eradication strategy

Adapted from Booy et al. 2017

Effectiveness

This part of the assessment scores how effective the defined strategy would be regardless of other issues, such as the practicality of deploying methods, costs, acceptability of methods, etc. Which are taken into account elsewhere. For example, the eradication strategy for a non-native fish in a river could be to flood it with the pesticide rotenone – this would likely score 'very effective' despite low scores associated with practicality, impact and acceptability.

Points to consider:

- How effective has this approach proven to be in the past or in an analogous situation?
- How effective is the approach despite the biology / behaviour of the target organism?

Practicality

How practical is it to deploy the described strategy? In particular, consider barriers that might prevent the use of the strategy such as issues gaining access to relevant areas, obtaining appropriate equipment, skilled staff, chemicals, etc. If there are any legal barriers to undertaking the work these should be assessed here.

Points to consider:

- How available are the methods in the EU?
- How accessible are the areas required to deploy the strategy?
- How easy would it be to obtain relevant licences or other approvals / permissions (e.g. access permission) to undertake the approach?
- How easy would it be to overcome legal barriers?
- How safe are the methods used in this approach (are there health and safety barriers)?

Cost

Cost relates to the total direct cost of the strategy. Total cost includes the cost of staff, resources, materials, etc. over the entire time period involved in the eradication and any required post surveillance and follow-up. Note indirect costs (e.g. loss of business) are considered an impact and not recorded here.

In your comment, indicate the period over which costs would be occurred (i.e. number of years) and, if possible, indicate whether the cost would be evenly spread, frontloaded or back loaded.

Impact

Impact relates to the impact of the strategy itself. It is important to note that any indirect economic impacts (i.e. economic consequences of the eradication strategy rather than the cost of the strategy itself) are recorded here and not under 'cost'.

Points to consider:

- How significant is the environmental harm caused by this approach?
- How significant is the economic harm caused by this approach? Examples of economic harm might include: reduction in the ability to trade or do business as a result of the management method; loss of earnings; reduction in tourism; reduction in house prices; etc.
- How significant is the social harm, including to human health, caused by this approach (note that this is different from acceptability below)? Examples of social harm might be a reduction in a person's use or enjoyment (e.g. preventing them walking in a woodland or fishing in a river), disruptions of communities, etc.

Acceptability

Acceptability relates to significant issues that could arise as a result of disapproval or resistance from individuals, groups or sectors. This does not include regulatory or legislative barriers which are considered under practicality.

Points to consider:

- How acceptable is the approach likely to be based on environmental / animal welfare grounds? Note this question relates to likely criticism / resistance that the approach would meet based on environmental / animal welfare grounds.
- How acceptable is the approach likely to be to the general public?
- How acceptable is the approach likely to be to other stakeholders?

Assessing the window of opportunity

The window of opportunity relates to how quickly the species will spread beyond the point that the defined strategy would be effective. It is linked to the mechanism and rate of spread, which is considered during the risk assessment.

Assessing the likelihood of reintroduction

Assuming the strategy is successful, how likely is it that reintroduction will occur?

Annex 2 – Names of experts who provided assessments

Species	Assessors
ANIMALS	
Acridotheres tristis	Jane Reniers, Koen Leysen, Niels Luyten
Ameiurus melas	Hugo Verreycken, Pieter Boets, Thierry Demol
Axis axis	Bram D'hondt, Jane Reniers, Laura Abraham
Arthurdendyus triangulatus	Jan Soors, Sytske de Waart, Tom van den Neucker
Channa argus	Jane Reniers, Maarten Van Steenberge, Tim Adriaens
Faxonius rusticus	Kevin Scheers, Pieter Boets, Xavier Vermeersch
Fundulus heteroclitus	Jos Snoeks, Pascal Hablützel, Thomas Verleye
Gambusia affinis	Hugo Verreycken, Jane Reniers, Maarten Van Steenberge
Gambusia holbrookii	Hugo Verreycken, Jane Reniers, Maarten Van Steenberge
Lepomis gibbosus	Hugo Verreycken, Pieter Boets, Thierry Demol
Morone americana	Jos Snoeks, Pascal Hablützel, Thomas Verleye
Xenopus laevis	Jeroen Speybroeck, Loïc van Doorn, Sarah Descamps
PLANTS	
Ailanthus altissima	Arnaud Monty, Sonia Vanderhoeven, Wouter van Landuyt
Celastrus orbiculatus	Arnaud Monty, Frédérique Steen, Wouter van Landuyt
Cortaderia jubata	Etienne Branquart, Quentin Groom, Sonia Vanderhoeven
Gymnocoronis spilanthoides	Dido Gosse, Jérémie Guyon, Kevin Scheers
Humulus scandens	Arnaud Jacobs, Frédérique Steen, Wouter van Landuyt
Koenigia polystachya	Arnaud Monty, Dido Gosse, Sonia Vanderhoeven
Lespedeza cuneata	Arnaud Jacobs, Etienne Branquart, Frédérique Steen