

## Article

# Prioritizing Management of Invasive Alien Species of EU Concern—A Northern Perspective

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**Abstract:** Invasive alien species (IAS) represent one of the major threats to biodiversity globally. Each member state in the EU is required to compile a management plan for IAS of Union concern. This requires risk assessments to prioritize management measures consistent with the requirements of each EU member state. Here, we review the management priorities for the 88 IAS of Union concern based on the risk assessment scheme developed for Finland. Of 88 species, 52 had not been detected in Finland and 51 species were categorized as species that fail to succeed in Finland. Climatic conditions can be regarded as a major factor limiting the success of those species. Five primary management categories were recognized. Monitoring was deemed the primary management option for 30 species, prevention of entry into Finland for 30 species, prevention of escape into nature for 17 species, prevention of further spread and/or the management of areas with high biodiversity value for 4 species and eradication for 7 species. It is concluded that national management plans should consider local environmental conditions and adjust management options according to national risk assessments.

**Keywords:** biodiversity; biological invasions; non-native species; risk assessment



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## 1. Introduction

Invasion of alien species represent one of the major threats to biodiversity globally. In Europe, the number of alien species is high for many taxonomic groups (e.g., [1]). While the invasion histories of alien species and their impacts are recognized in Europe, the legislation for preventing species invasions has only been enacted recently [2]. Each EU member state is required to implement measures for the species included in the list of invasive alien species of Union concern, with special focus on pathways, early detection and rapid eradication, as well as management of widely spread species. Compiling management plans requires risk assessments to prioritize management measures adjusted for the requirements of each EU member state.

Risk assessments of invasive alien species (IAS) included in the list of Union concern are conducted by following EPPO standard 5/5 (1) with a slight modification (see [3,4]). Fundamentally, the risk assessment can be based on any protocol if the detailed elements of the risk assessments are fulfilled [5]. The national-scale risk assessments utilize the information on IAS obtained from EU-scale risk assessments, which is complemented with more detailed information on the species distribution, invasion pathways and impacts (e.g., [6–9]). As a result, each country compiles adjusted management plans for IAS with prioritized management measures.

Finland is the most northern country in the EU (located between latitudes 60° and 70° north) and belongs mostly to the Dfc climate class with the southern coast in the Dfb climate class according to the Köppen–Geiger classification (e.g., [10]). Finland’s location and climate affect the introduction, spread and impacts of IAS and should be considered in the risk assessments. Natural pathways of the introduction of IAS are limited due to

Finland being bordered by the Baltic Sea in the south and west, and having a long, forested border in the east. Harsh climatic conditions act as a barrier for the range expansion of many IAS, preventing their establishment (e.g., [11,12]). For plants and insects, photoperiodic adaptation may also limit the range expansion for the species to northern latitudes since the variation in day length increases towards the poles [13]. The brackish low salinity water of the Baltic Sea limits the establishment of marine species. Large sparsely human populated areas limit the spread of IAS that benefit from rural habitats. Generally, human pressures on the environment, measured, e.g., as population density, the extent of built-up areas and transportation networks, are lower in the north compared to Central and Southern Europe [14]. Human pressures are strongly linked to biological invasions and the propagule and colonization pressure of IAS, and a lower human footprint may delay species invasions in the northern areas [15–17]. As climate change continues, the existing climatic barriers to the establishment of IAS will weaken and the range expansion of IAS towards the poles will increase (e.g., [12]). Growing international trade, intensified human activities and transportation promote species invasions [18,19]. These factors create the invasion level in the northern regions and may lead to the increased extinction of native species, biotic homogenization, altered ecosystem functioning and the hindering of ecosystem services, and consequently, may also constitute a threat to human health and livelihoods in the future (e.g., [18,20]). Overall, the number of potentially successful IAS is lower in northern than in southern regions in Europe and is limited by various factors (e.g., [21]). Assessment of the role of these factors represents the basis for prioritizing adjusted management measures for IAS.

Here, we review the management priorities for the 88 IAS of EU concern in Finland based on the risk assessment scheme developed for national evaluation. The results are discussed in the light of the goals of the EU IAS policy.

## 2. Materials and Methods

The Finnish national risk assessment scheme was developed for prioritizing management measures for IAS of EU concern in Finland [22]. It has been applied for prioritizing management measures in Finland for all 88 IAS of EU concern. The management plans were approved by the Ministry of Agriculture and Forestry [23]. We compiled a dataset based on the published risk assessment proposals [22,24,25] and an unpublished management plan draft for the species added to the updated list of IAS of EU concern in July 2022 [26,27].

The risk assessment scheme comprises four sections focusing on distribution, propagule pressure and likelihood of establishment, means of spread and pathways, and impact. Each section includes 2–5 multiple choice questions with 3–6 answer options depending on the question (see Figure S1 for details). Both primary and secondary options can be chosen. The fifth section focuses on suggested management measures, and it is based on the information obtained from the first four sections. Three aspects of management are addressed: establishment status of species in Finland, urgency of management measures and recommended primary management measures for species.

In the original risk assessments, multiple recommended primary management measures could have been assigned but here only primary options were considered. If two options were regarded as being equal in the assessment, an option with a more powerful management recommendation was chosen. The original classification of primary management recommendations (1 = monitoring distribution (outside Finland), 2 = prevention of entry, 3 = prevention of escape into nature, 4 = prevention of establishment, 5 = prevention of further spread, 6 = management of areas with high biodiversity value, 7 = eradication, 8 = no cost-effective eradication methods available) were reorganized as follows:

- (1) Monitoring species distribution: when monitoring species distribution is the primary management measure (value 1).
- (2) Prevention of entry: if given primary management measures were monitored together with prevention of entry (1 and 2) or prevention of entry alone (2).

- (3) Prevention of escape into nature (including escape from confinement and/or release in nature): if given management measures were prevention of entry and escape (2 and 3) or solely prevention of escape (3).
- (4) Prevention of spread: if prevention of further spread and management of areas with high biodiversity values (5 and 6) or solely management of areas with high biodiversity value were classified (6) as the primary management measure.
- (5) Eradication: if eradication was given as the only or one of the primary management measures (different combinations of given values: 7 or 1, 3, 7 or 2, 3, 7 or 5, 7).

The four impact categories (biodiversity, ecosystem, society and human impacts) of the risk assessment scheme were combined into an overall impact category by summing the answers of individual questions as follows: no impact (overall impact sum = 5), low impact (overall impact sum = 6–10), moderate impact (overall impact sum = 11–15), major impact (overall impact sum = 16–20), massive impact of widespread, established species (overall impact sum > 20).

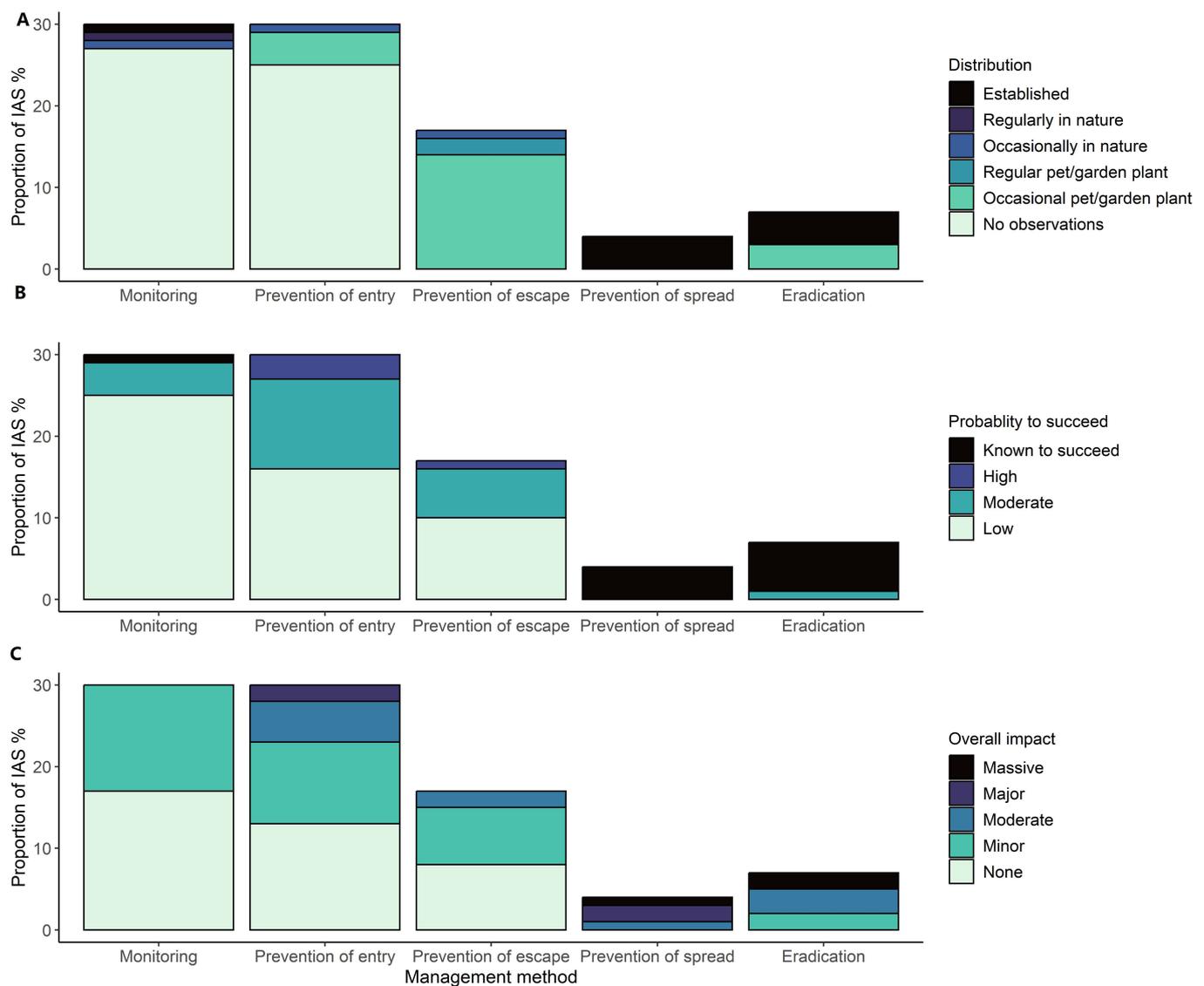
We recorded species counts and proportion of the total number of species for each risk assessment category. Furthermore, we calculated the values for each estimated category by primary management method.

### 3. Results

Based on the management plans conducted in Finland, most of the 88 IAS of Union concern (52 species, 59.1% of all species) have not been detected in Finland (Figure 1A, Table S1). Over a quarter of the species (23 species, 26.1%) are kept as pets, aquarium species or garden plants in Finland. Four species were detected casually or regularly in Finland, while nine (10.2%) of the 88 species were established in Finnish nature. The established species included two mammals (*Ondatra zibethicus* and *Nyctereutes procyonoides*), one fish (*Lepomis gibbosus*), one invertebrate (*Pacifastacus leniusculus*) and five plant species (*Heracleum mantegazzianum*, *Heracleum persicum*, *Heracleum sosnowskyi*, *Impatiens glandulifera*, *Lysichiton americanus*). All of the established species in Finland also had established populations in neighboring areas (Sweden, Norway, Estonia, Russia (close to Finnish border), the Baltic Sea). Two of the established species, *L. gibbosus* and *L. americanus*, were regarded as locally distributed in Finland, while the remaining established species were considered as already widespread species.

Over half of the IAS of Union concern (51 species, 58.0%) were categorized as species that fail to establish in Finland (Figure 1B, Table S1). One quarter of the IAS of Union concern (22 species, 25.0%) had a moderate probability to succeed in Finland (Figure 1B). Eight of these species were casual pets, garden or aquarium species. Most of the IAS of Union concern (38 species, 43.2%) were regarded as harmless, and 32 species (36.4%) were considered to cause only minor negative impacts on biodiversity, ecosystems, society or human health (Figure 1C, Table S1). Eleven species (12.5%) had moderate probability to cause harm, and four species (4.5%) were considered to cause harm with major probability: *I. glandulifera*, *P. leniusculus*, *Elodea nuttallii* and *Microstegium vimineum*. Three (3.4%) species, *H. mantegazzianum*, *H. persicum* and *H. sosnowskyi*, were known to cause severe negative impacts.

Based on the distribution, likelihood of establishment, means of spread and impacts, the primary management measures were addressed for each IAS of EU concern. Subsequently, we present the detailed results for the IAS in five different management groups.



**Figure 1.** The proportion of invasive alien species (IAS) of EU concern for each primary management method: (A) distribution of species in Finland, (B) probability to thrive in Finland and (C) the overall impact.

### 3.1. Monitoring as Primary Management

Monitoring was regarded as the primary management option for 30 (34.1%) invasive alien species of Union concern (Figure 1). Of these species, 27 (30.7%) had not yet appeared in Finland (Figure 1A), while three species had been detected in Finland. *Ondatra zibethicus* was classified as an established species, known to succeed in Finland (Figure 1; Table S1). *Oxyura jamaicensis* had been detected occasionally and *Eriocheir sinensis* had regularly been detected in Finland but did not exist as reproducing populations. *Eriocheir sinensis* had low and *O. jamaicensis* had moderate probability to succeed in Finland. Most of the species with monitoring as the primary management measure (25 species, 28.4%) fail to establish and thrive in Finland (Figure 1B). In addition to *O. zibethicus* and *O. jamaicensis*, it is possible for three other species to establish in Finland: *Baccharis halimifolia*, *Herpestes javanicus* and *Pueraria montana* (Table S1).

Only four species, with monitoring as the primary management option, were regarded as species with any primary means of spread (Table S1). *Ondatra zibethicus* was considered to spread naturally in Finland, *E. sinensis* was introduced into Finland unintentionally by humans and *O. jamaicensis* may arrive in Finland unaided from neighboring countries.

*Ludwigia grandiflora* is not yet present in Finland, but it may be introduced to Finland deliberately as an ornamental water plant.

Species with monitoring as the primary management option did not have any (17 species, 19.3%) or only minor (13 species, 14.8%) impacts (Figure 1C). Except for the three above-mentioned species already occurring in Finland, control methods are not topical.

### 3.2. Prevention of Entry as Primary Management

Prevention of entry into Finland was the main management option for 30 species (34.1% of all species). Most of these species (25 species, 28.4%) had not been detected in Finland (Figure 1A). Four species in this management group, *Pseudorasbora parva*, *Gymnocoronis spilanthoides*, *Plotosus lineatus* and *Percottus glenii* were considered to be casual aquarium species in Finland, and *Acridotheris tristis* had occasionally been detected in Finnish nature (Table S1).

Most species had low (16 species, 18.2%) or moderate probability (11 species, 12.5%) to thrive in Finland (Figure 1B). *Percottus glenii*, *E. nuttallii* and *Sciurus carolinensis* had major probability to establish and thrive in Finland. Largely, the species did not have any means of spread into Finland (19 species, 21.6%) (Table S1). However, most of the fish species in this management group were categorized as species that had been deliberately introduced, e.g., as aquarium species. *Pseudorasbora parva* may have been unintentionally introduced by humans into Finland, whereas *E. nuttallii* may have arrived unaided.

Most of these species had no (13 species, 14.8%) or minor (10 species 11.4%) impacts (Figure 1C). The impacts of *E. nuttallii* and *M. vimineum* were considered to be major, and five species may have moderate impacts.

### 3.3. Prevention of Escape into Nature

Prevention of escape into nature was regarded as the primary management option for 17 species (19.3% of the total number of species). Most of these species (14 species, 15.9%) were casual pets, aquarium or garden species, whereas two species, *Pistia stratiotes* and *Cabomba caroliniana*, were categorized as common aquarium species (Figure 1A). One species, *Trachemys scripta*, had been occasionally detected in nature. *Trachemys scripta* is a pet that was considered to have entered Finnish nature both intentionally and unintentionally.

Most species in this management group had low (10 species, 11.3%) or moderate probability (6 species, 6.8%) to succeed in Finland. *Tamias sibiricus* was the only species with high probability to succeed in Finland (Figure 1B). If *T. sibiricus* and *Procyon lotor* escaped into nature, they could have moderate impacts. For other species in this management group, no or minor impacts were identified. Most species (13 species, 14.8%) were categorized as species that had spread outside and within Finland after deliberate introduction.

### 3.4. Prevent Further Spread and/or the Management of Areas with High Biodiversity Values as Primary Management Option

The prevention of further spread and/or the management of areas with high biodiversity values was identified as the primary management option for four established species: *H. mantegazzianum*, *I. glandulifera*, *P. leniusculus* and *N. procyonoides* (Figure 1A, Table S1). All of these species are already widespread and require immediate management measures.

*Pacifastacus leniusculus* may have been intentionally introduced in Finland, whereas the three others mainly spread after unintentional introduction by humans or naturally. The impacts were categorized as moderate for *N. procyonoides*, major for *I. glandulifera* and *P. leniusculus*, and massive for *H. mantegazzianum*.

### 3.5. Eradication as Primary Management Option

Eradication was considered as the primary management measure for seven species (8.0% of the total number of species) (Figure 1). Three of them were casual garden plants: *Ailanthus altissima*, *Asclepias syriaca* and *Celastrus orbiculatus*. *Ailanthus altissima*

and *C. orbiculatus* were categorized as having minor impacts, but *A. syriaca* had moderate impacts following its escape into nature.

Four species were identified as established species that required immediate management measures: *H. persicum*, *H. sosnowskyi*, *L. gibbosus* and *L. americanus* (Table S1). The *Heracleum* species were regarded as widespread species that spread naturally in Finland or following unintentional introduction and have severe impacts. *L. gibbosus* and *L. americanus* were locally distributed, may have been introduced intentionally and have moderate impacts.

## 4. Discussion

### 4.1. Challenges of Risk Assessment of IAS

Over half of the IAS of Union concern were not found in Finland, which is less than the average in the EU [28]. Furthermore, over half of the species were categorized as species that fail to succeed in Finland. This suggests that climatic conditions are a major factor limiting the success of IAS of Union concern in northern regions, which was earlier suggested regarding alien species in agricultural environments [11,29]. However, a small probability remained that several of the IAS might establish in Finland, especially as the climate is changing, although prognoses vary. This may also take place due to niche shifts of species in their introduced range [30,31], although most invasive species conserve their climatic niches [32]. These uncertainties underline the importance of evaluating the establishment risk in the changing climate for the species at their northern range [12] and the importance of updating risk assessments. In addition to climate, the success of IAS in northern regions can be limited by species' opportunities to enter and the availability of suitable habitats due to a low human footprint [15,17], other environmental constraints (e.g., [13,33]) and competition with other species [34]. In the future, these factors should be considered further by taxa in risk assessments in northern areas.

Risk assessments are based on expert opinion, and therefore, there is always a risk that evaluations vary among experts. The variables used in the assessment to decide on management measures also bear some uncertainties, such as insufficient information on species occurrence. Of the evaluated species, an invasive alien fish, *L. gibbosus*, was found in a pond for the first time in Finland in 2014 [35]. In six years, the number increased up to 19 ponds [36]. We do not know when exactly the introductions occurred, but in most cases, the species was already well established in those ponds. There is no systematic mapping for this species, and it is very likely that the number of waterbodies invaded by *L. gibbosus* is much greater.

The majority of the IAS of EU concern have not been detected in Finland or are kept as pets, aquarium species or garden plants. After the publication of the management plans [22,24,25], one aquarium fish and plant species, *P. glenii*, and *E. nuttallii*, were recently found in Finland [37,38]. For both species, the prevention of entry, their primary management measure, failed, or failed to reveal that the species already existed in aquariums or ponds. Both species were already known to occur in nature in neighboring countries. *Elodea nuttallii* occurs in Sweden along the Gulf of Bothnia up to Haparanda in Norrbotten, close to the Finnish border [39]. Thus, it was expected that *E. nuttallii* would spread naturally along the coast, e.g., with waterfowl, to Finland [24]. *Percottus glenii* occurs in the Neva estuary in the easternmost part of the Gulf of Finland [40]. Surprisingly, both species were detected in small ponds in southwestern Finland, and these introductions may have been deliberate [37,38]. Human activity is increasingly recognized as a strong predictor of non-native fish introductions [41]. Despite the border control, and information about transport and a holding ban for IAS of Union concern, it needs only one individual to ignore or be unaware of the regulations.

The identification and the mapping of the distribution area of IAS may be challenging and may even require DNA diagnostics (e.g., [42,43]). Based on the management plans for the *Heracleum* plant species included in the EU list, *H. mantegazzianum*, *H. persicum* and *H. sosnowskyi* are established and widespread in Finland [22,24]. Although several

observations of *H. sosnowskyi* have been reported in Finland [44], none of the records have been confirmed by experts. According to Piirainen and Saarinen 2018, there are no verified observations of *H. sosnowskyi* in Finland [45]. In this regard, the establishment status of *H. sosnowskyi*, and consequently recommendations for primary management measures, may have been overestimated. *Heracleum sosnowskyi* occurs in the Republic of Karelia in Russia, not far from the Finnish border [46]; thus, it has a high likelihood of future introduction into Finland. Additionally, *H. sosnowskyi* may already exist in Finland but has not yet been detected or recorded. The identification of invasive *Heracleum* species is difficult (e.g., [47]) and *H. sosnowskyi* may have been misidentified as *H. mantegazzianum* or *H. persicum*. Regardless of the species in question, all three invasive *Heracleum* species have similar, severe impacts and control methods [48], and therefore, eradication as the primary management option for *H. sosnowskyi* is still justified.

#### 4.2. Primary Management Measures

Monitoring and prevention of entry was regarded as the primary management option for most of the IAS of EU concern (60 species, 68.2%) in Finland. Generally, species in these management groups are not present in Finland and the Finnish climate is too harsh for the establishment of these species. Furthermore, these species do not pose a major threat and do not have any known means of spread into Finland. However, there are some exceptions to these general rules. Monitoring of the occurrence and distribution area was considered to be the primary management measure for one widespread established mammal species, *O. zibethicus*. Based on the risk assessment, *O. zibethicus* does not cause harm and the populations are small, local and naturally decreasing in Finland [49]. Similarly, due to the lack of negative impacts, monitoring was considered to be a sufficient management measure for an invasive bird, *O. jamaicensis*, although it has been occasionally detected in Finland and may fly here. Sometimes the impacts of IAS are species-specific, and in the case of *O. jamaicensis*, the negative impacts are primarily on endangered *Oxyura leucocephala*, a species that does not exist in Finland [50,51]. The final decision on which primary management group a species is assigned to is always made based on expert estimation, and universal rules are difficult to make.

Two species with prevention of entry as their primary management option, *E. nuttallii* and *M. vimineum*, were estimated to cause major impacts. *E. nuttallii* is one of the most common alien aquatic species in Europe with wide tolerance of environmental conditions, substantial growth capacity and severe ecological and economic impact [52,53], while *M. vimineum* is an invasive grass that forms dense mats and reduces diversity [54]. In addition to *E. nuttallii*, *P. glenii*, and *S. carolinensis* can establish and thrive in Finland. For *E. nuttallii* and *P. glenii*, the prevention of entry has failed as both species have recently been detected in Finnish nature [37,38].

Prevention of escape into nature was the main management measure for 17 species (19.3%). All these species are pet, garden or aquarium species that are mainly spread intentionally. Of these species, *T. scripta* was the only one that has been occasionally detected in Finnish nature. *T. scripta* can establish and reproduce in Central Europe [55,56], and due to climate change, its establishment may be possible in Baltic countries in the future [57]. The possibilities to thrive in a Nordic climate remain low. To prevent the escape of *T. scripta* and other pets, and garden and aquarium species into nature calls for increased public education and an awareness-raising campaign for owners of exotic pets, and aquarium and garden species [22].

Prevention of further spread and/or the management of areas of high biodiversity value was regarded as the primary management option for four species. These species are widespread, established species with moderate or major impacts and require immediate action. For seven IAS of Union concern, eradication was regarded as the primary management option. Most of these species were local or widespread, established or occasional garden plants. Drawing the line between different primary management options is sometimes difficult. In the management plans for *H. mantegazzianum*, *H. persicum* and *H. sosnowskyi*,

all were regarded as being widespread species. It would have been logical that the primary management option would be the same for all *Heracleum* species. However, eradication was regarded as the main management method only for *H. persicum* and *H. sosnowskyi*, although the goal is that all *Heracleum* species will be eradicated from Finland within 20 years [23]. The overall feasibility of the eradication has not been thoroughly evaluated. Booy et al. [58,59] point out that a structured assessment of management feasibility enhances the prioritization of management efforts of the IAS. The Finnish national scheme to prioritize IAS management covers only the possibility that the management is not feasible if no cost-effective eradication methods are available. None of the IAS of Union concern were regarded as IAS lacking cost-effective management methods in Finland.

It is still too early to say how the established management plans decrease impacts. We understand that in some cases, as shown above, we cannot yet stop all introductions into nature. There are still some anglers, aquarium keepers and gardeners who may release listed species, being unaware of regulations or ignoring them without appreciation of the consequences. However, increased awareness of IAS and co-operation with people in hobby groups has already increased the numbers of public observations of listed species and efforts to manage IAS populations.

## 5. Conclusions

All EU-listed IAS have been evaluated using an EU risk assessment protocol designed to expose species risks to EU member states. However, the risks in different member states vary because species' ability to disperse, survive and establish in different parts of Europe differ substantially. In northern regions, the key issues are entry and the establishment risk of IAS. National management plans should consider local environmental conditions and adjust management options according to national risk assessments. Management plans of IAS may require updates and re-evaluation if new information on the risks of the species are obtained.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/d15050585/s1>, Figure S1: The structure of the risk assessment scheme; Table S1: Risk assessment data of the 88 IAS of EU concern in Finland.

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