UNIVERSITY OF GOTHENBURG

DEPARTMENT OF BIOLOGICAL AND ENVIRONMENTAL SCIENCES

INVASIVE PLANT SPECIES IN SOUTH WEST SWEDEN

Evaluating methods of removal by empirical study and literature review

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Lysichiton americanus in the field.

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Abstract

Invasive alien species (IAS), are one of the five biggest threats to biodiversity worldwide. An instrument for biodiversity protection in Sweden is the establishment and management of nature reserves. The goal of nature reserves is to protect valuable nature and rare species to preserve biodiversity. All over the planet, invasive alien species affect protected areas. Despite an abundance of studies on biological invasions, fairly little is known about which methods have been used to control these invasive plants. In this master thesis, three different studies were conducted to evaluate the most effective methods in removing invasive alien plants from nature reserves using a field experiment, literature review and survey. Two different removal methods were tested in the field to remove the study species *Lysichiton americanus*. In method 1 the root of the plants was destroyed. In method 2, the whole plant was removed with a spade. The literature review included research on the study species *Lupinus polyphyllus* & *Impatiens glandulifera* to find the most effective removal method for each species. The current situation of combating IAS in Sweden were reviewed by sending out a questionnaire to authorities and stakeholders, to understand what the incentives and motivations are for combating invasive alien species. The field experiment resulted in no significant difference between treatment methods. The results from the literature review show that there might not be one single most effective removal method for *I. glandulifera* and *L. polyphyllus*. The methods recommended to use are mechanical (cutting, mowing, hand-pulling and hot water). Combating invasive plants was deemed by the survey to be of high importance and that the work with invasive alien plants should be of an even higher priority than it currently is. Improved knowledge of effective removal methods of invasive alien species was needed in most municipalities in Västra Götaland.

Keywords

Invasive alien species, management, nature conservation, biodiversity

Abstract (SE)

Invasiva främmande arter (IAS) är ett av de fem största hoten mot biologisk mångfald i världen. Ett instrument för att skydda den biologiska mångfalden i Sverige är upprättande och skötsel av naturreservat. Målet med naturreservat är att skydda värdefull natur och sällsynta arter för att bevara den biologiska mångfalden. Över hela planeten påverkar invasiva främmande arter skyddade områden. Det finns ett överflöd av studier om biologiska invasioner. Trots detta vet man tämligen lite om vilka metoder som har använts för att kontrollera dessa invasiva växter. I denna masteruppsats har tre olika studier genomförts för att utvärdera de mest effektiva metoderna för att ta bort invasiva främmande växter från naturreservat med hjälp av ett fältexperiment, litteraturstudie och frågeformulär. Två olika borttagningsmetoder testades i fält för att avlägsna studiearten *Lysichiton americanus*. I metod 1 förstördes växtens pålrot och i metod 2 togs hela växten bort med en spade. Litteraturstudien inkluderade forskning om studiearterna *Lupinus polyphyllus & Impatiens glandulifera* för att hitta den mest effektiva borttagningsmetoden för varje art. Den nuvarande situationen för att bekämpa IAS i Sverige granskades genom att skicka ut ett frågeformulär till myndigheter och intressenter, för att förstå vilka incitament och motiv som finns för att bekämpa invasiva främmande arter. Fältexperimentet resulterade inte i någon statistisk skillnad mellan metoderna.
Resultaten från litteraturstudien visar att det kanske inte finns en metod som är effektivast för att avlägsna *I. glandulifera och L. polyphyllus*. De metoder som rekommenderas att använda är mekaniska (klippning, handdragning och varmvatten). Att bekämpa invasiva växter ansågs av frågeformuläret vara av stor betydelse och att arbetet med invasiva främmande växter borde ha

ännu högre prioritet. Förbättrad kunskap om effektiva borttagningsmetoder av invasiva främmande arter behövdes i de flesta kommuner i Västra Götaland.

Nyckelord

Invasiva främmande arter, skötsel, naturvård, biologisk mångfald

Introduction

Nature is changing at an ever-growing rate. Land and sea use alteration, direct exploitation of organisms, pollution, climate change and invasive alien species (IAS) are usually referred to as "the big five" drivers of biodiversity loss (Sala et al, 2000).
According to the United Nations (2022), native species abundance has on average declined by 20% since the 1900s.
The number of IAS and introductions has on the other hand increased by over a third, since the 1970s, On the global scale, the negative effects of invasive alien species may be as damaging to native species and ecosystems as is the loss and degradation of habitats, which is the biggest threat to biodiversity to date (IUCN, 2022).
Invasive alien species are found in all major taxonomic groups from viruses and fungi to plants and animals (IUCN, 2022). The cost, both ecologically and economically, of invasive alien species globally is massive due to the loss of biodiversity and direct impact on crop yields (IUCN, 2022). In 2009, the annual cost of invasive alien species in Sweden was estimated to be in the range of 1618-5077 million SEK y^{-1} (Gren et al, 2009).

Definitions

Artdatabanken (the Swedish Species Information Centre) was assigned to estimate potential risks from alien species concerning native biodiversity in Sweden. Strand et al, 2018 suggests that an alien species is a species, subspecies or lower taxon that has been introduced outside of its natural (historic or present) habitat. According to the definition, this also includes all parts of the species or organism that can reproduce and form a new organism such as gametes, eggs, seeds or propagules. Species spread by the help (directly or indirectly) by humans are also included (Strand et al, 2018).

"Alien species" (non-native, non-indigenous, foreign, exotic) means a species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce". This is the definition IUCN uses when classifying a species as invasive. (IUCN, 2000. IUCN guidelines for the prevention of biodiversity loss caused by alien invasive species.)

Invasive alien species

Animals and plants that have accidentally or intentionally been introduced into an environment where they are non-native and in the new environments have adverse negative effects on the ecosystem are called invasive alien species. The introduction and/or spread of the species not only threatens biodiversity but can also cause socioeconomic damages and damage to humans and other animal's health and well-being (Naturvårdsverket, 2022; European Commission, 2022).

According to IUCN (2000) "An alien species which becomes established in natural or semi-natural ecosystems or habitats, is an agent of change, and threatens native biological diversity". (IUCN, 2000. IUCN guidelines for the prevention of biodiversity loss caused by alien invasive species.)

The distribution of invasive alien species is influenced by other types of environmental change. Climate change, for example, is believed to play a big role in the expansion of invasive alien plants. Increasing temperatures cause these species to expand to higher latitudes, which were earlier too cold to be inhabited (IUCN, 2022). Increased leakage of nitrogen from agriculture and

households and atmospheric deposition of nitrogen pollutants to ecosystems are problematic since it aids the expansion of invasive plants (Tyler et al, 2015). Nitrogen (N) and phosphorus (P) are the most important nutrients for plants. N is mainly used for biosynthesis of amino acids, proteins and other bioactive materials and P for building nucleic acids and energy molecules such as ATP (Sharma et al, 2018). The invasions and invasiveness of alien plants are getting worse not only due to increased nutrient input from more severe over fertilization and eutrophication which in turn accelerates growth rate in plants. It is also getting worse due to increasing N deposition causing local communities to degrade, leading to these communities getting invaded easier than before since they are already weakened (Yessoufou et al, 2019). According to a large meta review from 2011, invasive plants have a higher degree of phenotypic plasticity during certain environmental conditions such as higher nutrient availability than non-invasive plants. This indicates that invasive plants can be very effective at reallocating recourses to growth to a higher degree than indigenous plants (Davidson et al, 2011).

The European Union has a list of invasive alien species called the "List of Invasive Alien Species of Union concern". This list is regulated by law. Any species that is found on the list has restrictions on keeping, importing, selling, breeding and growing (European Commission, 2022). An example of a plant species found on this list is the yellow skunk cabbage (*Lysichiton americanus,* Hultèn & H.ST. John, 1931).
However, not all invasive species are currently invasive in a certain country are on this list. In Sweden, several species, such as the Japanese knotweed (*Reynoutria japonica*) and the large-leaved lupine (*Lupinus polyphyllus)* are not on the EU list of invasive alien species but are in Sweden considered very invasive and problematic, e.g. for nature conservation (SLU Artdatabanken, 2022).

One of the instruments for biodiversity protection in Sweden is the establishment and management of nature reserves. The goal of nature reserves is to protect valuable nature and rare species to preserve biodiversity (Naturvårdsverket, 2022). Invasive alien species counteract the purpose of nature reserves by reducing biodiversity and outcompeting native flora (Foxcroft et al, 2013).

Why is invasive alien species a problem in nature reserves?

All over the planet, invasive alien species affect protected areas. Dramatic effects can already be seen and are expected to continue to grow in the future, especially since these effects are multiplied by climate and habitat change. If protected areas are to be the main tool and foundation for biodiversity conservation, then the management of invasive alien species in these areas must improve (Monaco and Genovesi, 2014).
Doing nothing or "letting nature run its course" is not a viable option and cannot be used as a strategy for managing IAS in protected areas (Monaco and Genovesi, 2014). Using the most effective methods for managing these species is a more suitable strategy.

There is an abundance of studies on biological invasions and the impact IAS may or may not have on ecosystems and native flora and fauna. Despite this, fairly little is known about which methods have been used to control these invasive plants (Weidlich et al, 2020).
The importance of studying different control methods and evaluating their effectiveness in Sweden is further increased by the fact that 8% of studies on invasive plant control was from Europe and only 34% of these studies researched mechanical removal methods (Kettenring & Adams, 2011).

Lysichiton americanus and its invasive nature explained

Biology and ecology

Lysichiton americanus also known as the yellow skunk cabbage or the American skunk cabbage (Figure 1) is a perennial herbaceous plant and is either a geophyte or a hydrophyte (Klingenstein & Alberternst, 2010). The plant grows up to 1.5 m in height, covering $1m^2$ of ground. The leaves of the plant can also grow up to 1.5m in length and has a light green sheen to them. The stem is commonly referred to as thick, fleshy rhizomes (up to 30 cm) which grows below ground (Klingenstein and Alberternst 2010). The plants usually have one too four inflorescences and are covered by a lively yellow spathe which grows up to 45 cm high. The spathe envelopes a big fleshy spadix, carrying numerous flowers at the bottom. The flowers are small, yellow and green, often with the female flowers below the male ones above. Usually flowering rakes place between March and May (Klingenstein and Alberternst 2010). Following flowering, fruits (150-350 berries) grow alongside the spadix. A berry contains 1-4 seeds which can remain viable in the ground for up to six years (Klingenstein & Alberternst, 2010).

The plants grow relatively slowly but can form old (over 80 years) and dense populations. In their native range, plants do not flower every year. When growing in shade, small plants are more likely to fail in flowering (Willson and Hennon, 1997). The common name, yellow skunk cabbage, is likely a result of the fact that the inflorescence has a unique odor of skunk, flesh and garlic. The smell attracts insects (Klingenstein & Alberternst, 2010).

Lysichiton americanus is native to western North America and dominates coastal marshes. The plant can grow in a variety of soils, light sand to heavy clay. The soil can be acid, basic or neutral. The plant can grow in running and standing water. Marshes, marshy woods, fens, bog woodlands, streams, riverbanks and generally wet areas is where the species is commonly found (Klingenstein & Alberternst, 2010).

Figure 1. *Lysichiton americanus* (Wikimedia commons, 2008).

Invasiveness, impacts and management

In Sweden, *Lysichiton americanus* was introduced after the 1800s as an ornamental plant in gardens and parks (Naturvårdsverket, 2022). It has since then spread either naturally or by man. The seeds can be transported by running water. Parts of the stem and rhizome can also be transported by vehicles and sprout a new plant in the new location it finds itself in. The most common method of spreading is however from planting in gardens. The plant can then spread by cloning (Klingenstein & Alberternst, 2010).

If *Lysichiton americanus* is introduced to an area, it can gradually form dense populations. This often leads to displacement and disappearance of the native species. The big leaves cover the vegetation below it, shading it from light, causing stress and eventually death of the vegetation below. Since the plants produce over a thousand seeds per plant/flowering season, a large seed bank is built in the soil, surviving for six to eight years (Naturvårdsverket, 2022).
L. americanus can also survive temperatures down to −15 °C.
Biodiversity is also negatively affected because of the plants ability to change its local environment by damming up the water, making it more stationary and shallower. This way even fish can be affected (Naturvårdsverket, 2022).
When one is to remove or manage this species, three main types of methods have been used:

Chemical control (spraying with glyphosate) is a method shrouded in debate as some studies have shown it to be effective (Chatters C, 2010) on the yellow skunk cabbage while others claim it to be unsatisfactory or even ineffective (EPPO platform on PRAs, 2022).
The use of chemical control should always be restrictive and only used in areas where it has been approved. Since *L. americanus* grows in wetlands it is not recommended to use chemicals since these can effective the rest of the ecosystem and get transported by water to other areas (Naturvårdsverket, 2022; Klingenstein & Alberternst, 2010).

Mechanical control consists of two main types: 1. Hand digging/pulling with the purpose of eradicating a stock, 2. digging the whole stock up with an excavator with the same purpose of eradicating the hole stock at once (Naturvårdsverket, 2022).
These methods are in many cases more favorable since the risk of contaminating the sensitive wetlands with chemicals is removed. The evidence in the case of mechanical control is clearer than for the chemical control methods. Several studies found that annual mechanical removal reduced the size and number of the stock and plants (Aldridge et al, 2018).
However, Fuchs et al (2003) showed that eradication by mechanical removal was ineffective since the plants build up a seed bank which lasts up to 8 years (Aldridge et al, 2018).

Study species (literature review)

Lupinus polyphyllus (Figure 2) also known as the large-leaved lupine or the garden lupine is a perennial herb native to western North America. In Australia, New Zeeland and Europe it has been introduced intentionally as a common garden plant for ornamental purposes. The plants are 50-150 cm tall and has numerous flowers (up to 80) per plant in colors ranging from blue, pink to white (Fremstad, 2010). In Sweden, the species was first found in 1870 as a garden escapee. Today the species is widespread in most parts of Sweden and grows mainly along roads but can also be found in other habitats. *L. polyphyllus* lives in symbiosis with nitrogen fixating bacteria which enables the plants to grow faster than many native plants and, in turn, outcompeting them. Due to the plant´s ability to fix nitrogen, it changes the soil dynamics, increasing the available nitrogen in the soil. Given enough time, the species composition in the habitats this species invades changes and biodiversity is reduced (SLU Artdatabanken, 2022).

L. polyphyllus is classified as SE (severe impact) in the assessment of invasive plants SLU Artdatabanken. This is the highest level a species can be given and states that the species has great or potentially great ecological effect and ability to spread over large areas (Strand et al, 2018). *L. polyphyllus* is not on EUs "List of Invasive Alien Species of Union concern".

Figure 2. *Lupinus polyphyllus.* Wikimedia commons (2015).

Impatiens glandulifera (Figure 3), commonly referred to as the Himalayan balsam, is an annual plant which can grow up to 3 m in height. It is easily recognized by its numerous flowers which vary in color from pink to white. It is native to the western Himalayas. There it grows from 1800 m to 4000 m above sea level (Helmisaari, 2010). In Europe *I. glandulifera* was introduced as an ornamental garden plant and has since then spread to other habitats and ecosystems. In Sweden, it was first found in the 1920s. And is nowadays very widespread in major parts of the country. *I. glandulifera* forms thick stands on moist and nutrient rich grounds along watercourses, lakes, ditches and in damp forests (SLU Artdatabanken, 2022).
The plant expands its range via seeds. The seeds are catapulted by the bursting seed capsules and travel up to 5 m. The seeds are however mainly transported by running water.
In Germany, up to 32 thousand seeds per square meter have been reported (Koenis & Glavac 1979).
Like many invasive alien plants, *I. glandulifera* outcompetes native plants by growing taller and shading them. According to (Hulme & Bremner 2006), *I. glandulifera* can reduce the biodiversity in the habitats they invade by up to 25%. There is also evidence indicating that *I. glandulifera* attract pollinators which would otherwise pollinate native plants (Helmisaari, 2010). Increased concentrations of CO_2 and temperature has a positive effect on the species and it is therefore believed that its invasiveness will get worse as global warming increases (Helmisaari, 2010).

Figure. 3. *Impatiens glandulifera*. Wikimedia commons (2007).

Aim and scope

This paper aims are to evaluate the most effective methods in removing invasive alien plants from nature reserves using a field experiment. This is made by comparing two different removal methods used to remove the study species *Lysichiton americanus.* A second scope of the paper is to review existing literature on removal methods on different invasive alien species in nature reserves in Sweden and to review the current situation of combating IAS is Sweden by sending out a questionnaire to authorities and stakeholders, to understand what the incentives and motivations are for combating invasive alien species.

Research questions

Field study:
Which method is more effective in removing *Lysichiton americanus*? Is it sufficient to destroy only the main root or does the main root and vertical growing roots also need to be removed?

Survey:
Are the incentives for combating invasive alien plants different in different counties and does the motivations and priorities differ between counties or stakeholders?

Literature study:
Which method is the most effective at removing *Impatiens glandulifera* & *Lupinus polyphyllus* according to the literature?

Methods

Field experiment

Ten sites in Vitsippsdalen (57°40'52.1"N 11°57'26.7"E) were selected for their potential used in the experiment. The criteria used for the selection of the sites was the number of plants. Five sites were required for the experiment. An online random number generator was used to retrieve a number between 1-10. If the same number between 1-10 was generated twice, the randomizer was run again. Figure 4. Illustrates how the experiment was set up in the field. At each site both methods were implemented along with a control plot. Figure 4 and 5 shows were on the west coast of Sweden the field experiment took place.

In the field a checklist was followed as to ensure that all locals were treated in the same way.

- Take the coordinates of the site with a phone and save them so that you can find your way back after the winter even if the markings are gone.
- Mark out the area with poles and warning tape (Figure 7), mark out the areas that will act as treatments and control.
- Count the number of plants in the marked area.
- Take pictures of the fence in area before and after the experiment.
- Take the before and after photos from roughly the same location in order to compare the pictures more easily later.

Methods of removal and why they were chosen

Lysichiton americanus has a large deep contractile root-system that it uses to stabilize its growth in fluctuating water-levels (Klingenstein & Alberternst, 2010). The roots of plants are the organ that absorbs nutrients and water for the plant to survive and grow. Damaging the roots of a plant

will therefore cause substantial damage to the plant, which, if sufficient, will cause the plant to die (University of Maryland, 2022).

Method 1:
Cut the plant with a spade about 5-10cm below the ground. Then use a" spear" to hack the remaining root (Figure 6).

Method 2:
Remove the main root by digging (usually 30 cm deep). *Lysichiton americanus* have as mentioned, contractile roots which activity results in a movement of the lateral buds away from the mother plant. This type of vegetative spreading extends only a few centimeters from the mother bulb. It is therefore important to remove these roots, as well as an area of around 10 cm of soil around the plant to remove possible shoots (Figure 7) (Waisel et al, 1991).

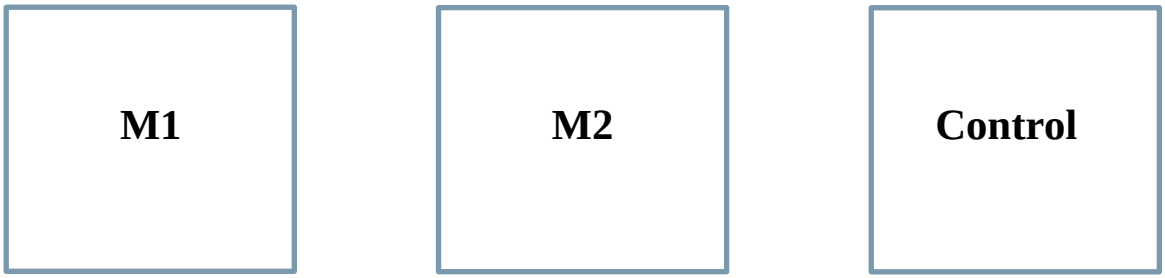


Figure 4. The experimental design for the field experiment. In each of the five sites, 2 methods to remove *Lysichiton americanus* and 1 control was used.

Five sites were selected after random selection among ten possible sites in the field experiment. Sites 3 and 2 are close in proximity to each other and therefore shown as one circle (Figure 5).

Figure 5. Red circles represent the sites which were selected. The numbers correspond to the site.

The five sites were located in Änggårdsbergen, a nature reserve managed by Västkuststiftelsen (Figure 6).

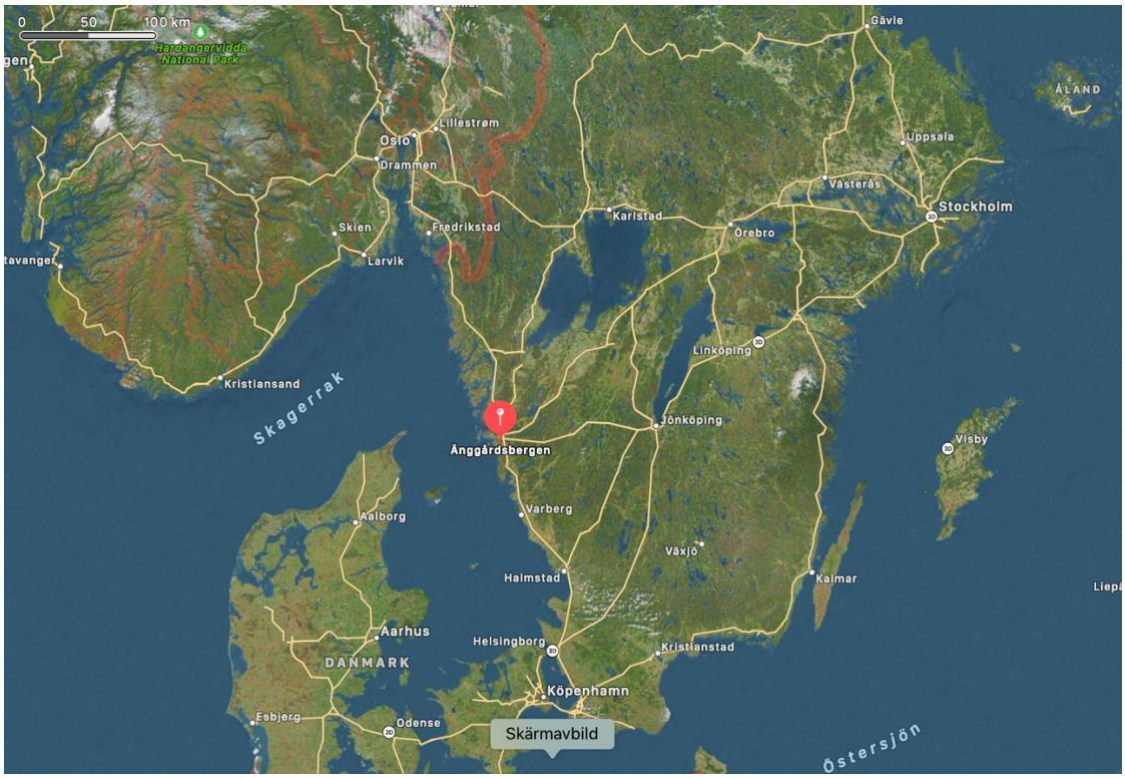


Figure 6. Map of the west coast of Sweden. The pin specifies were the five sites are located.

Figure 7 shows Site 7 in the field. The experimental sites were fenced in by using poles and warning tape.

Figure 7. Shows site 7 in the field.

When the main root is cut, the remaining root should be visible. This ensures that the root was not failed to be hit. There should be no visible root remaining. Hack around the root to ensure all of it is gone (Figure 8).

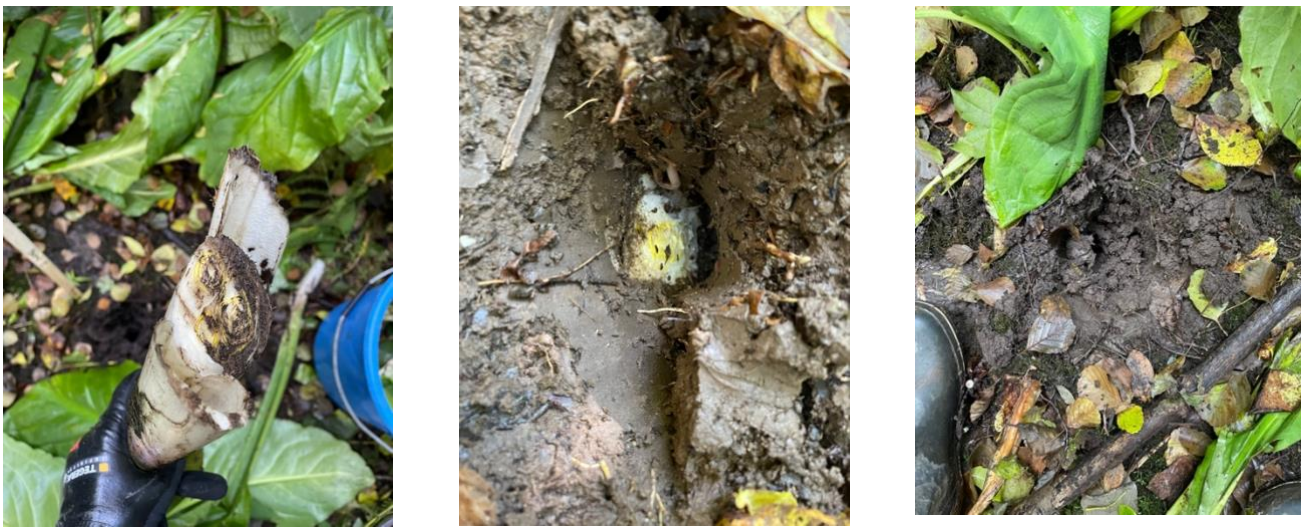


Figure 8. Method 1 in practice. The main root was severed with a spade and then hacked with a spear until the root.

When digging, the whole main needs to be removed. Remove any bits that might have fallen of the main root. The soil is water saturated and therefore heavy, take several scoops if necessary (Figure 9).

Figure 9. Method 2 in practice. The main root as well as an area of 10 cm in all directions around the plant was dug up with a spade.

Statistics

In September 2022, the number of *Lysichiton americanus* plants were counted in each site before removal started. 13 plants were removed with each method in all sites. The plants in the controls were untouched. The number of excluded plats was also counted for each treatment and site respectively. 26 plants in each site in total were removed. In late April 2023, the number of plants was again counted in all treatments and sites.

The statistics program SPSS was used to analyze the data from the field experiment. A statistical analysis was made to see if there was a difference between the removal methods. No test was made to test the difference between years. According to the Shapiro-Wilk test, data were normally distributed for all treatments ($p > 0.05$). To increase the power of the test the same number of plants were removed in each site. The data had one extreme outlier. Therefore, the non-parametric Kruskal-Wallis test was used since it is less affected by outliers than an ANOVA.

Survey

For the questionnaire,16 questions about invasive alien plants were identified. The purpose of the questionnaire was to investigate how different agencies work with invasive alien plants as well as the incentives for combating them and what methods were used when doing so. The questions were formulated by myself and then adjusted by the supervisors. The questionnaire was sent out to all municipalities in Västra Götalands län and was specifically sent to people who work with removing and controlling invasive alien plants. The survey was made in Microsoft Forms. Both an English version and a Swedish version was made. Only the Swedish version was sent to the counties on the 2022-11-21. Three weeks was given to answer the questions. After two weeks, a reminder was sent out to the municipalities. In appendix B, answers which had detailed written answers have been categorized. Both questions and answers are in Swedish.

Literature review

A literature search was conducted using the databases PubMed and Web of Science. As many articles as possible was identified to answer the research question. Only peer reviewed scientific literature was used in the review.
Key words used in PubMed and Web of Science were "*Lupinus polyphyllus* " and "removal" OR "eradication" OR "control" OR "nature conservation".
"Impatiens glandulifera" and "removal" OR "eradication" OR "control" OR "nature conservation".
Articles were selected for further data extraction if a method of removal was stated to have been researched. The key word protected area and nature reserve were excluded since an initial literature search resulted in no articles.

Results

Field experiment

The number of plants differed greatly between the years 2022 and 2023. In all sites and treatments, the number of plants increased from 2022 to 2023 (Figure 10).

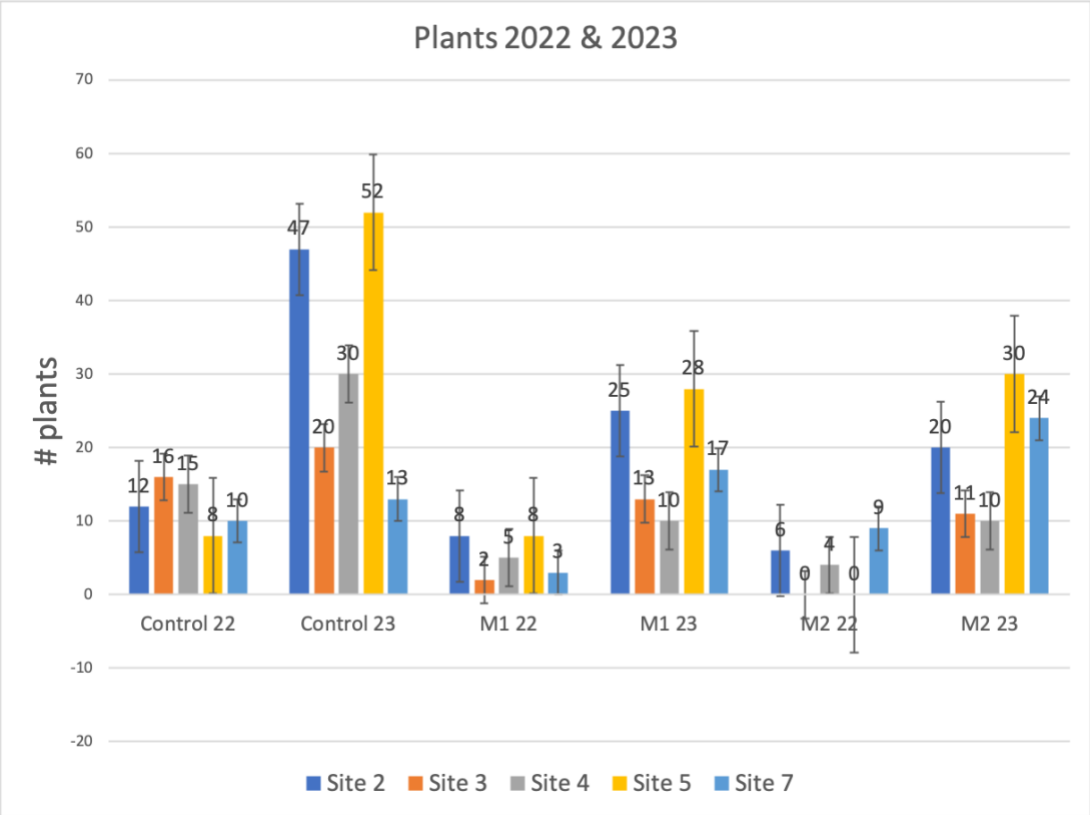


Figure 10. Shows the number of plants after removal in all treatments and sites the year 2022 and number of new plants in 2023. The x-axis shows the treatment and sites. The y-axis shows the number of plants.

The difference between the number of plants in each treatment and site between the years 2022 and 2023. The largest difference in plants in the controls are in sites 2, 4 and 5. The site with the biggest increase in plants overall is site 5. The lowest increase in plants were in site 3 (Figure 11).

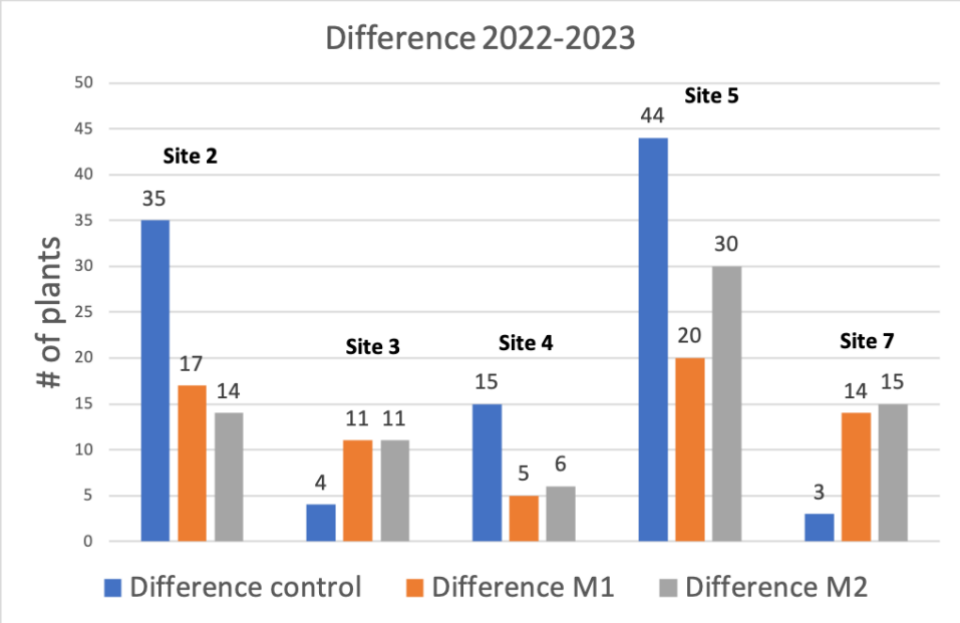


Figure 11. X-axis shows the treatments. Y-axis shows the increase in plants. Above the bars is the corresponding site.

The number of new plants were higher in the controls than in the treatments. 4/5 controls had a higher number of plants (Figure 12), which is an indication that the treatments influenced the occurrence of new plants.

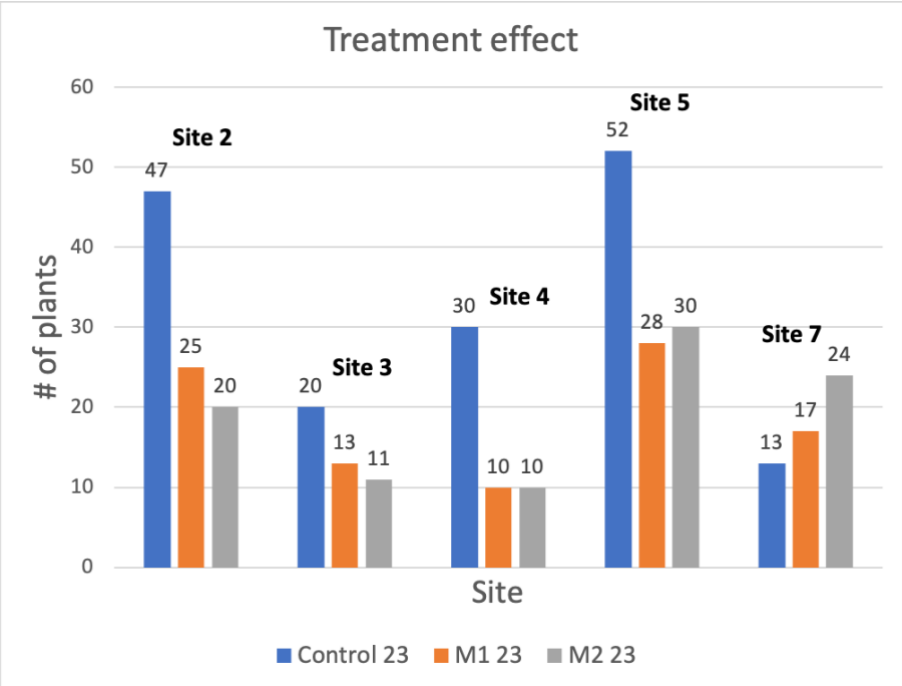


Figure 12. X-axis shows the sites. Y-axis shows the number of plants that increased from 2022-2023. The blue bars are the control, orange is method 1 and grey is method 2.

The Kruskal- Wallis H test, however, resulted in a non-significant result (Table 1). The mean rank of CWWS scores (effectiveness of the method) was not statistically significantly different between groups, $X^2(2) = 0.035$, $p = 0.983$.

Table 1. Shows the result of the Kruskal-Wallis test. Test was not significant.

Independent-Samples Kruskal-Wallis Test Summary

Total N	15
Test Statistic	.035[a]
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	.983

a. The test statistic is adjusted for ties.

Survey

The questionnaire was sent out to 49 municipalities in Västra Götaland. In total, the questionnaire amounted to 36 answers. There were 16 questions to answer. 9 out of 16 got less than 36 answers. 13 out of 16 questions were summarized in the result since the last two questions were unrelated to the topic and question 8 was misinterpreted.

Question 1. Do you think combating and managing invasive alien plants is important?
75% answered that it is very important (blue) to manage invasive alien plants, while 25% answered that it is important (orange) to manage invasive alien plants (Figure 13).

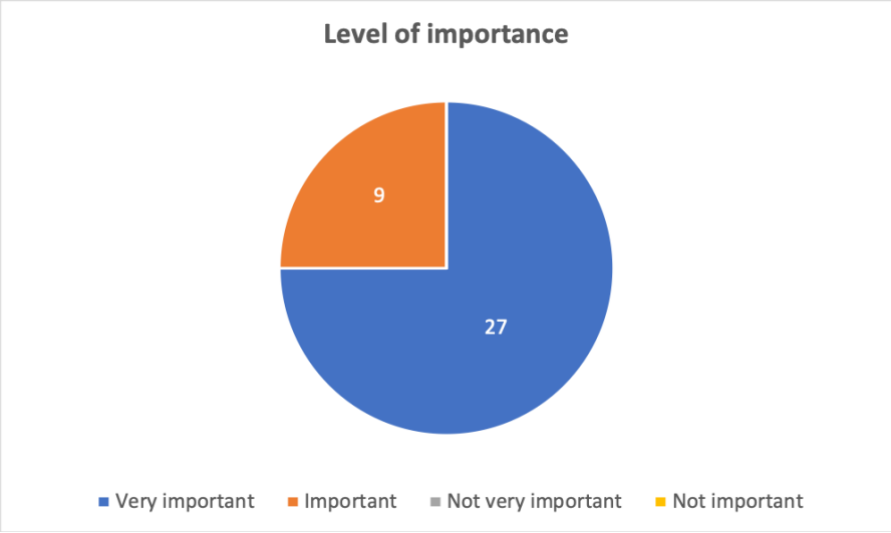


Figure 13. Colors corresponds to the answer given by participants. Blue matches "Very importand" and red matches "Important".

Question 2. What are the main drivers for working with invasive alien plants?
The most important driver for working with invasive alien plants was by the respondents considered to be to preserve biodiversity, followed by stopping the spread and minimizing the negative effects on ecosystems and human health (Figure 14).

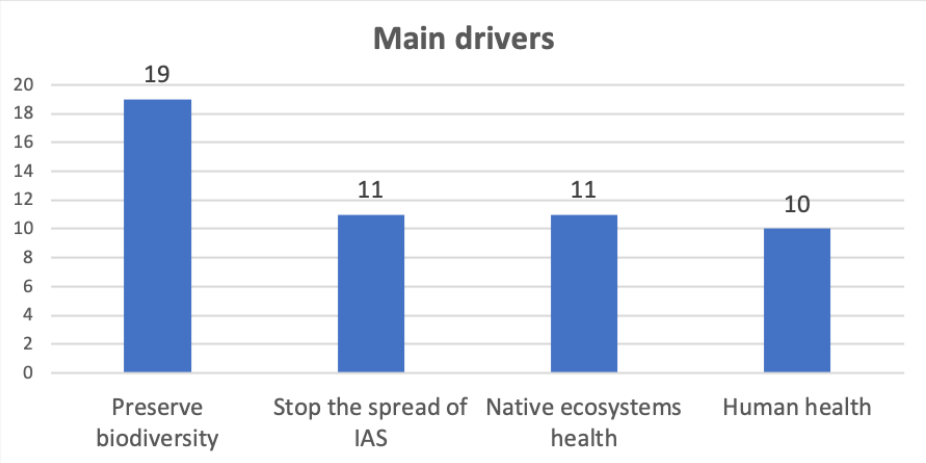


Figure 14. The x-axis shows the main driver to preserve biodiversity category. y-axis shows the number of answers. Bars show how many participants answered each category.

Question 3. Do you think your agency should have a higher priority in working with invasive alien species? If so why?

Figure 15, shows that the overwhelming majority of respondents answered that combating IAS needs a higher priority than it currently has. 34 answers in total. 22 (65%) answered that their work place should prioritize working with IAS more. 4 (12%) said NO and 8 (27%) said MAYBE

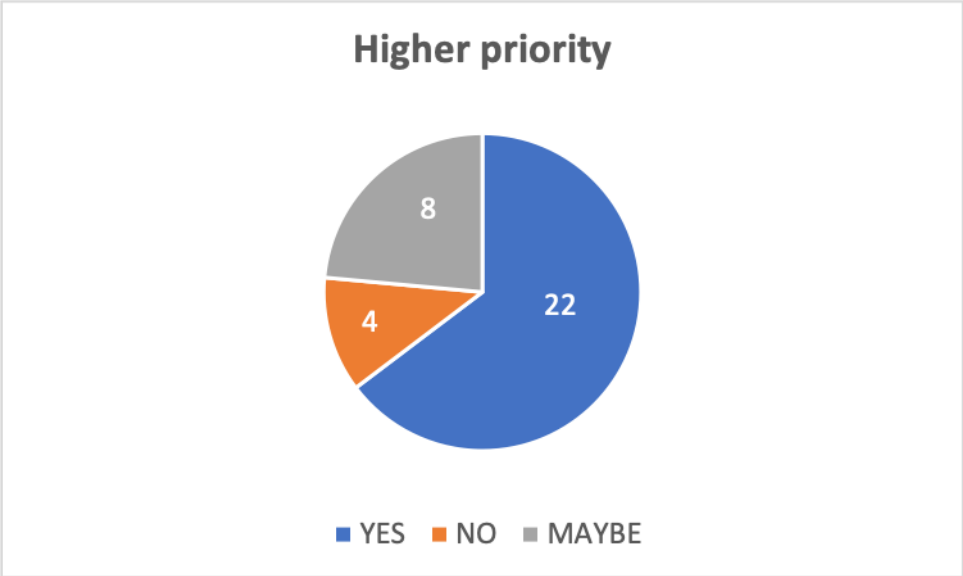


Figure 15. The color corresponds to the answers. Blue = "YES", orange = "NO" and grey = "MAYBE".

Question 4. What are the main invasive species (plants) you work with managing/controlling? The main invasive plants controlled/managed was Japanese knotweed (22), giant hogweed (18) and Himalayan balsam (19), (Figure 16).

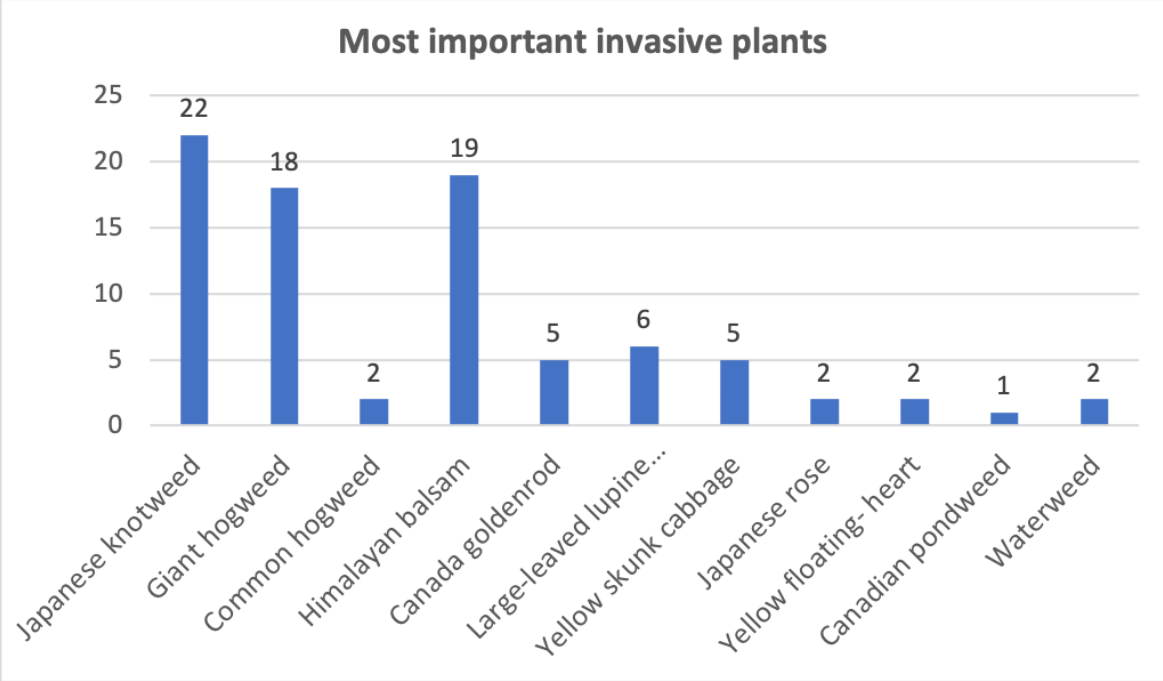


Figure 16. X-axis shows the species common name. Latin names for most common plants controlled: *Reynoutria japonica* (japanese knotweed), *Impatiens glandulifera* (Himalayan

balsam), *Heracleum mantegazzianum* (giant hogweed). Y-axis shows number of answers (many answers had multiple species chosen).

Question 5. What is your current knowledge on IAS and their impacts?
Most respondents rated their current knowledge on IAS and their impacts as "good knowledge". 22% and 20% rated themselves as "informed" and "very informed" (Figure 17). 58% estimated that they had good knowledge on IAS. 22% had very high knowledge and 20% stated that they were informed.

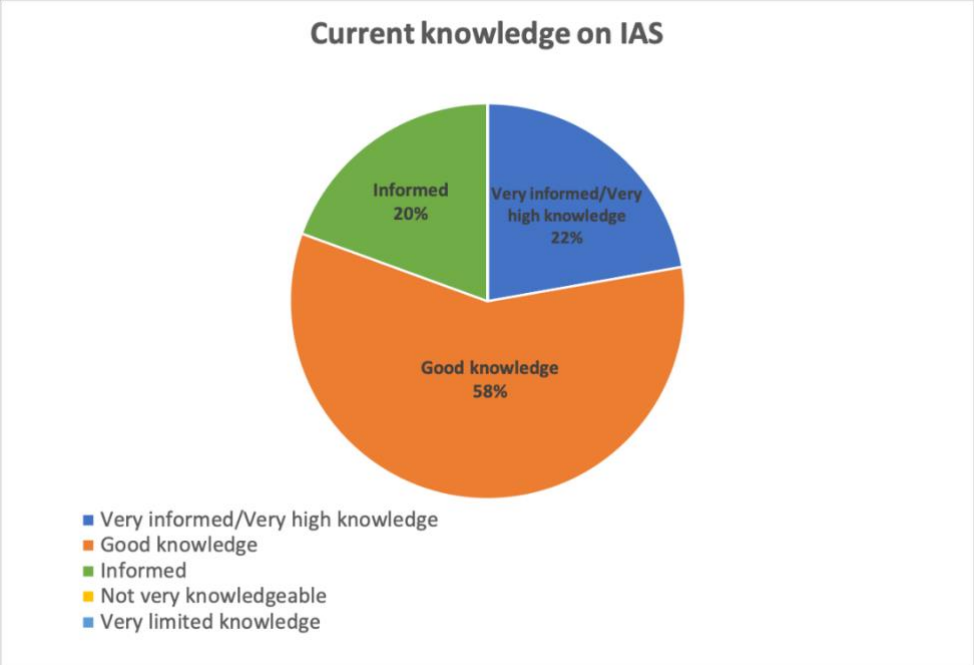


Figure 17. The color corresponds to the answers. Blue = Vey informed", orange = "Good knowledge" and green = "Informed".

Question 6. If you lack knowledge, what kind of knowledge is that?
Out of the 36 respondents, 20 chose to answer question 6. The respondents most commonly wanted to know what the most effective removal method is for a specific species (figure 18). 13 wanted to know which method is most effective for the specific species they work with.

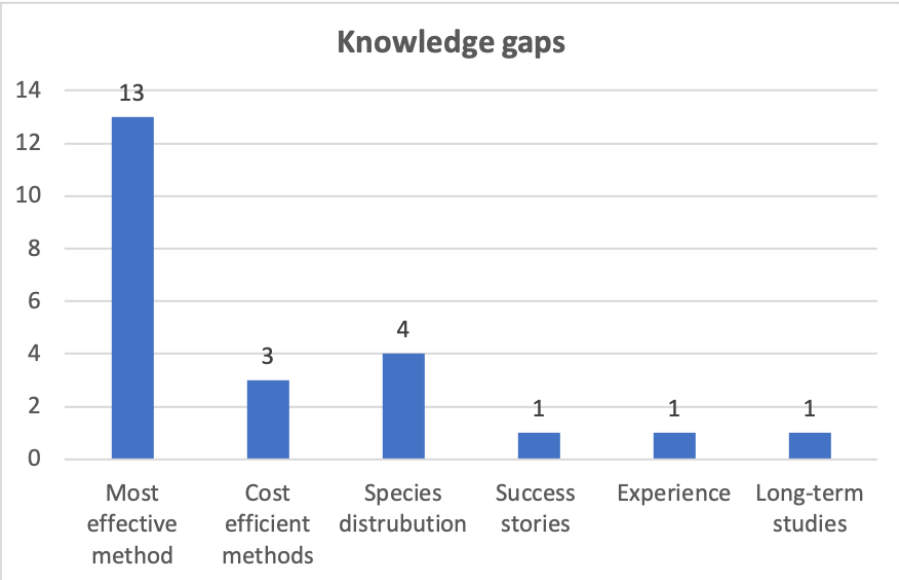


Figure 18. X-axis shows the knowledge gap stated by participants. Y-axis shows the number of answers. Bars show how many participants answered each category.

Question 7. What does your agency do if an invasive species is not on the EUs list of invasive species? Are such species also considered for management? Do you act in regard to managing it?
Even if a species was not on EUs list of invasive alien species, respondents answered that they still manage these species since they are also a threat to indigenous species and biodiversity (Figure 19). The majority (18) did work with species that are not on EU´s list. 5 did not, 5 did it sometimes. See appendix B for individual answers.

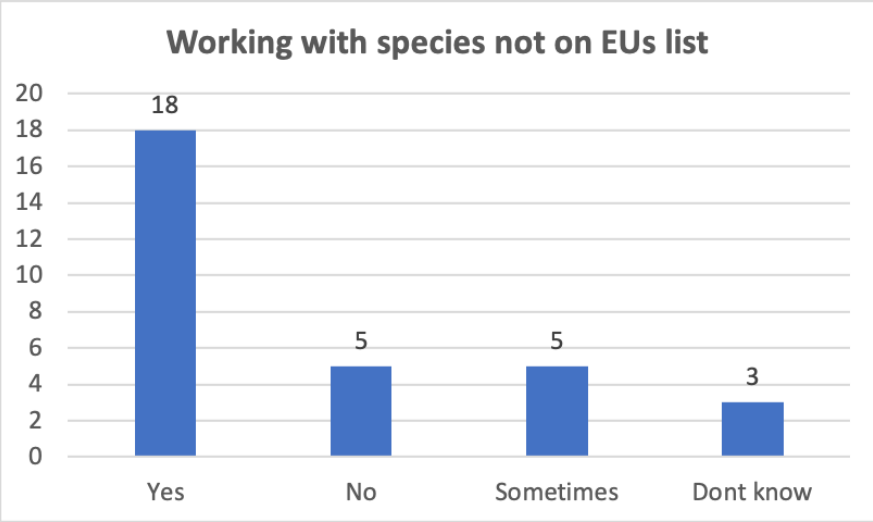


Figure 19. X-axis shows how many stated "Yes, No, Sometimes and Don't know". Y-axis shows the number of answers. Bars show how many participants answered each category.

Question 8 does not have a result due to misinterpretation by the respondents. The misunderstanding arose by the question being wrongly formulated by myself. Many responses did not state a species or removal method to match with a species and so it was difficult to summarize the answers.

Question (9) 8 Does your agency provide you with the latest research on management methods?
Two thirds of respondents were not given the latest research on IAS and their removal methods by their employer (Figure 20). 66% (23 answers) are not provided with the latest research on removal methods by their agency.

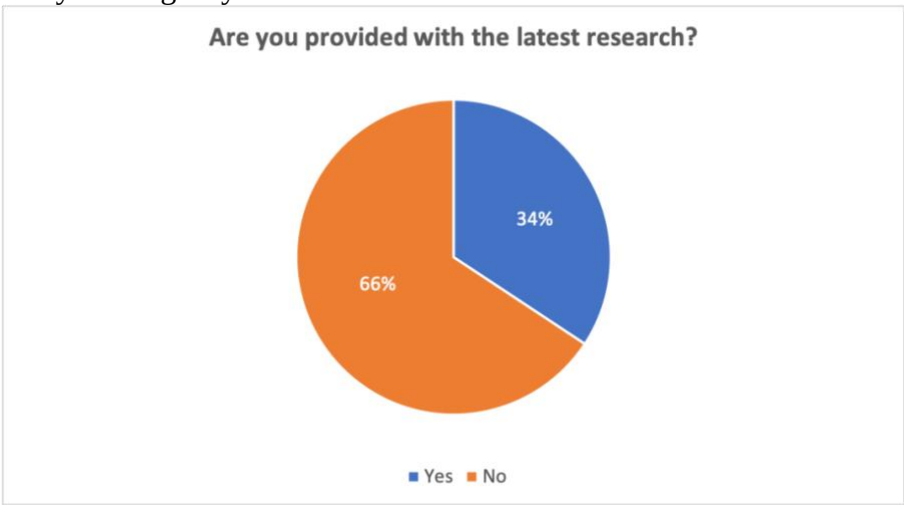


Figure 20. Shows how many % of participants answered “Yes” (blue) and “No” (orange).

Question (10) 9 Where do you go for information about invasive alien plants?
35 answers in total. 15 uses the internet for information. 3 answered books and 17 (48%) answered “other”. The internet and “other” were stated to be used the most to gather information about IAS. “Other”, was multiple choice answers (Figure 21).

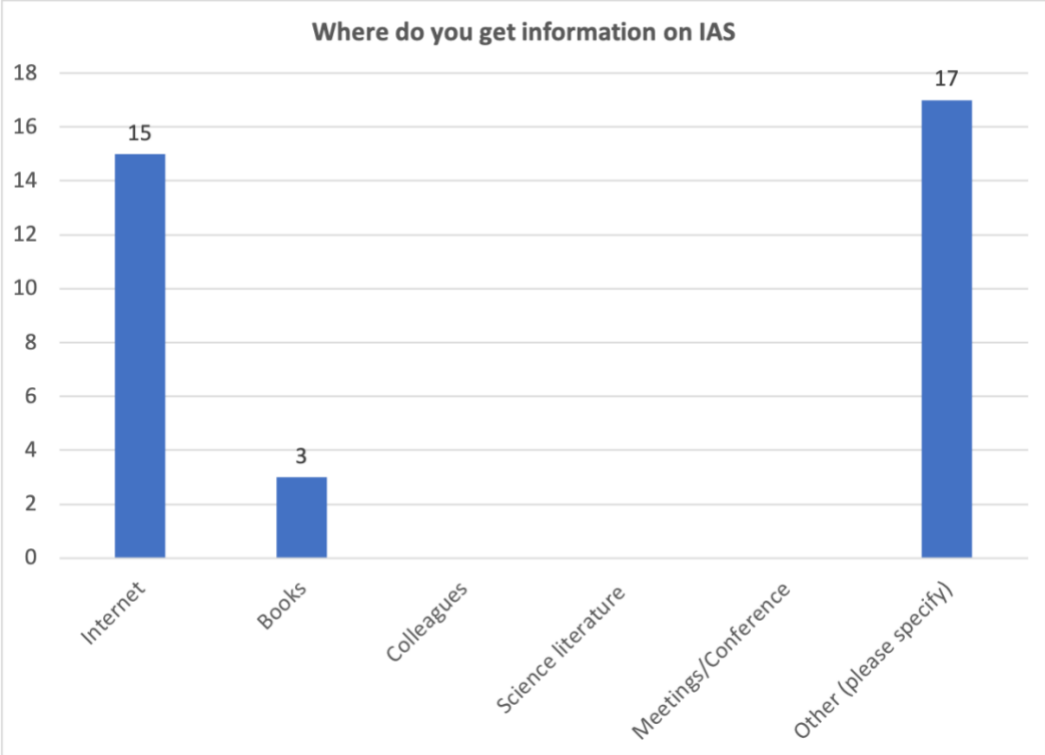


Figure 21. X-axis shows how participants stated to retrieve information on IAS. Y-axis shows the number of answers. Bars show how many participants answered each category

Question (11) 10 Where do you get the information on which methods (mechanical, chemical) to use when removing invasive alien plants?
83% (30 answers) used websites of agencies (Länstyrlesen, Naturvårdsverket) to get information on which removal method to use. 11% and 6% respectively used colleagues and consultants as an information source (Figure 22).

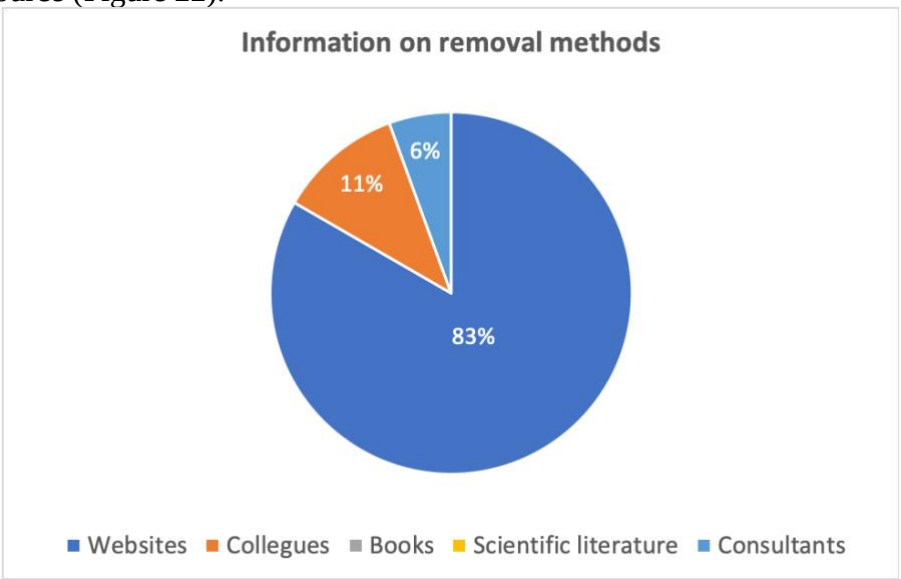


Figure 22. The color corresponds to the answers. Blue = “Websites”, orange = “Colleagues” and light blue = “Consultants”.

Question (12) 11 Does your agency manage IAS inside nature reserves?
51% answered that their agency did manage invasive species inside nature reserves and 49% answered “No”, they did not manage IAS inside nature reserves (Figure 23).

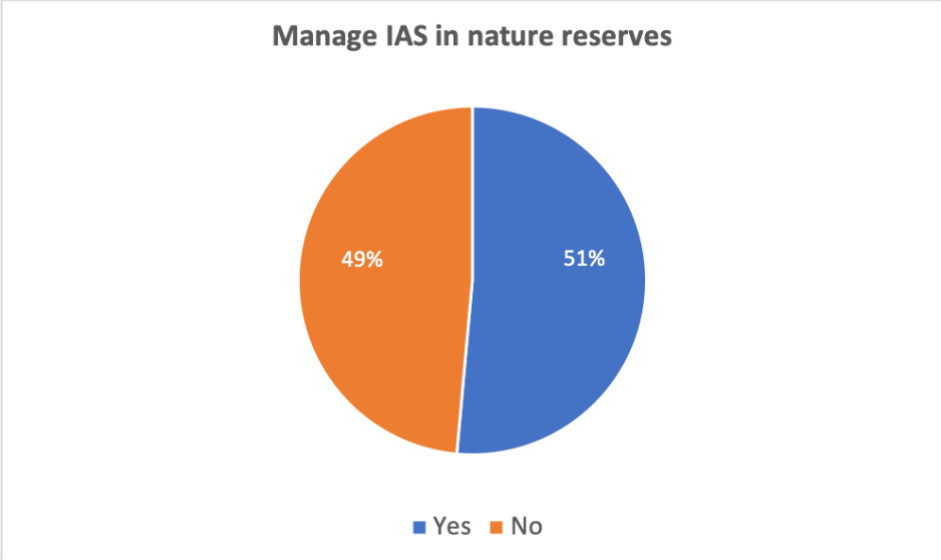


Figure 23. Shows how many % of participants answered “Yes” (blue) and “No” (orange).

Question (13) 12 Is the removal of invasive alien plants inside nature reserves given enough priority?
Close to 60% answered that the removal of IAS inside nature reserves is not prioritized enough while the rest said it had enough priority as is (Figure 24).

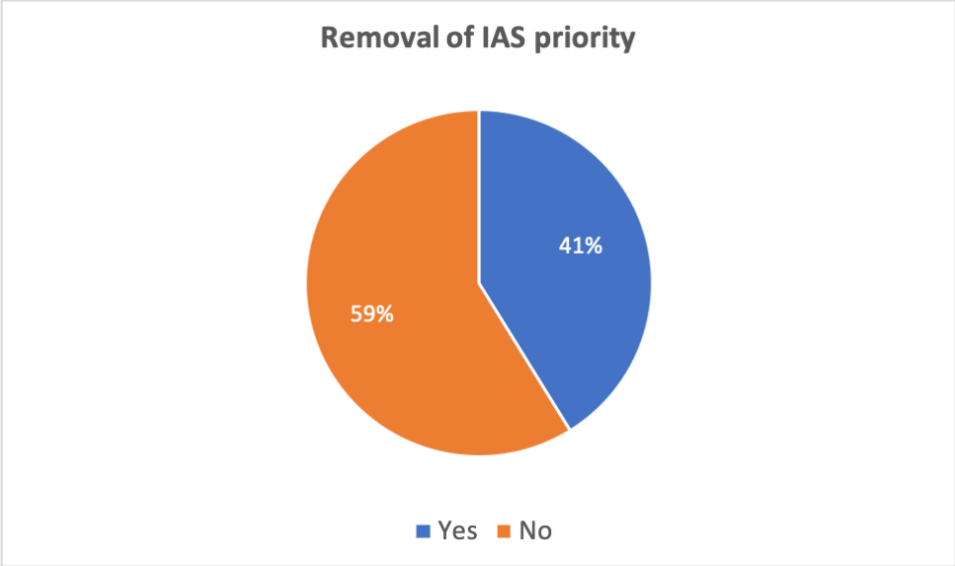


Figure 24. Shows how many % of participants answered “Yes” (blue) and “No” (orange).

Question (14) 13 Which of these species have you found inside nature reserves?
The most common species found in nature reserves were the Himalayan balsam (*Impatiens glandilifera*, Japanese knotweed (*Reynoutria japonica)* Large-leaved lupine (*Lupinus polyphyllus)* and Japanese rose (*Rosa rugosa)* (Figure 25).

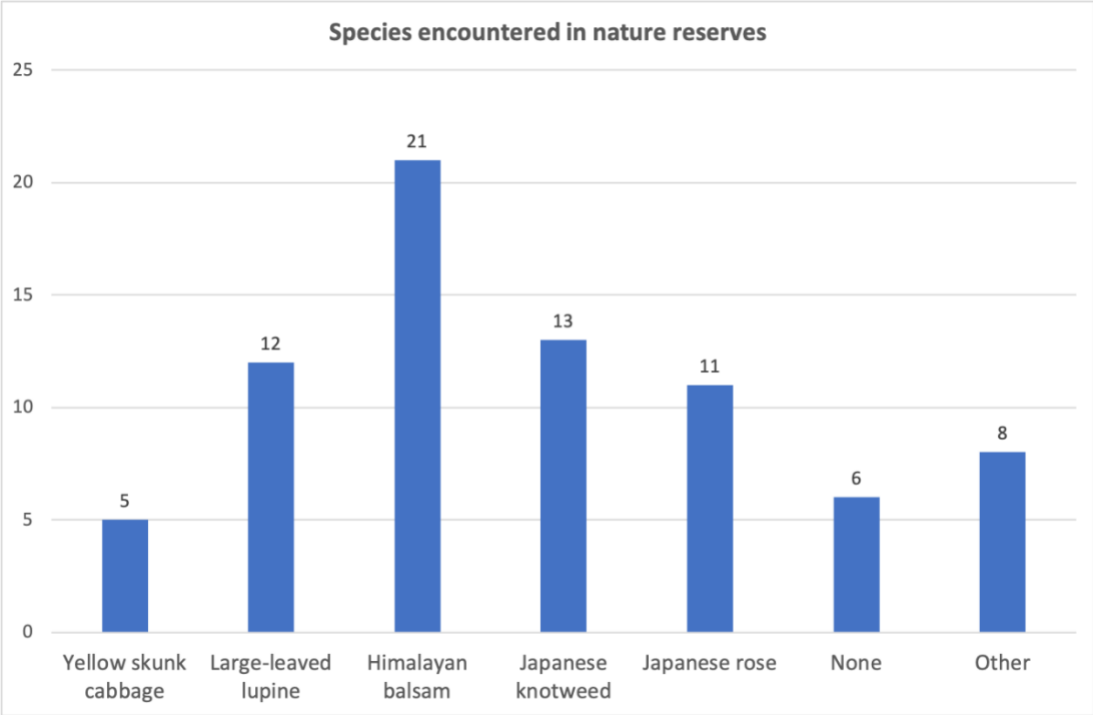
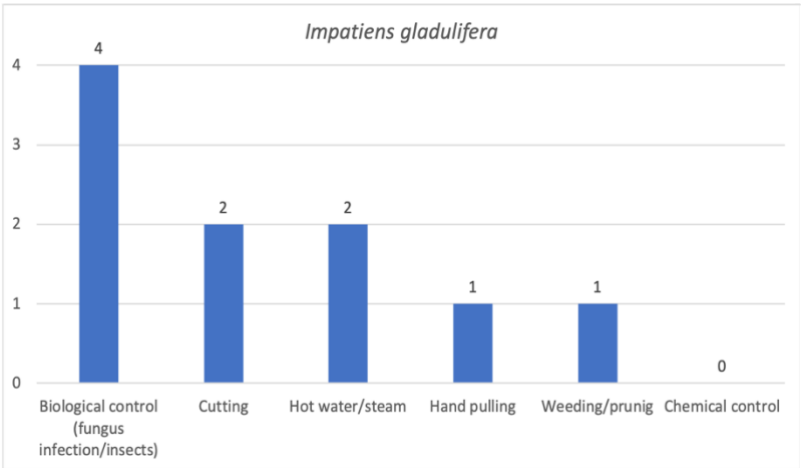


Figure 25. X-axis shows the species stated to have been encountered in nature reserves by participants. Y-axis shows the number of answers.

Literature review

The literature search on different removal methods and their effect on the species *Impatiens glandulifera* and *Lupinus polyphyllus* resulted in 137 articles and 92 articles, respectively. Out of the 137 articles, 9 were selected for further data analyses, the rest were considered irrelevant since they did not study the correct species, did not research removal methods directly or were in the wrong field of research. Of the 92 articles, 7 were selected. Figure 26 shows the number of articles that researched the categorized removal methods. The most common method for *I. glanulifera* was biological control and for *L. polyphyllus* the most common method was cutting/mowing.



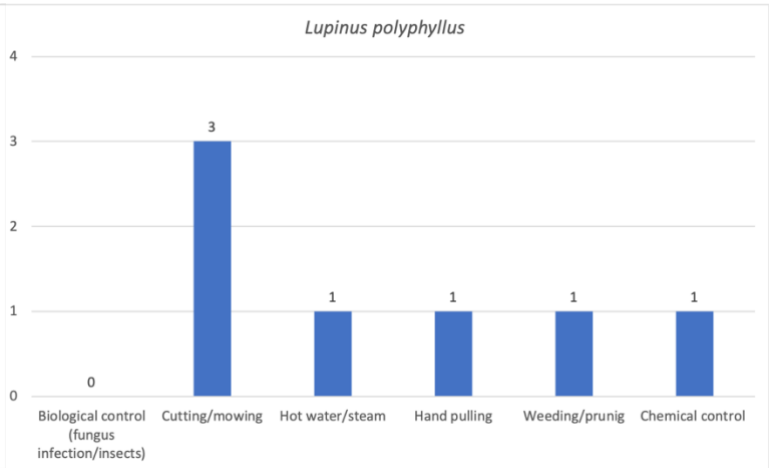


Figure 26. The X-axis shows the different removal methods researched. The Y-axis shows number of articles.

Geographical location

Most articles published (87.5%), were from Europe and Scandinavia. The rest (12.5% or 2 articles) were from Canada and New Zeeland. Figure 27 shows the number of articles published for the specific species per country.

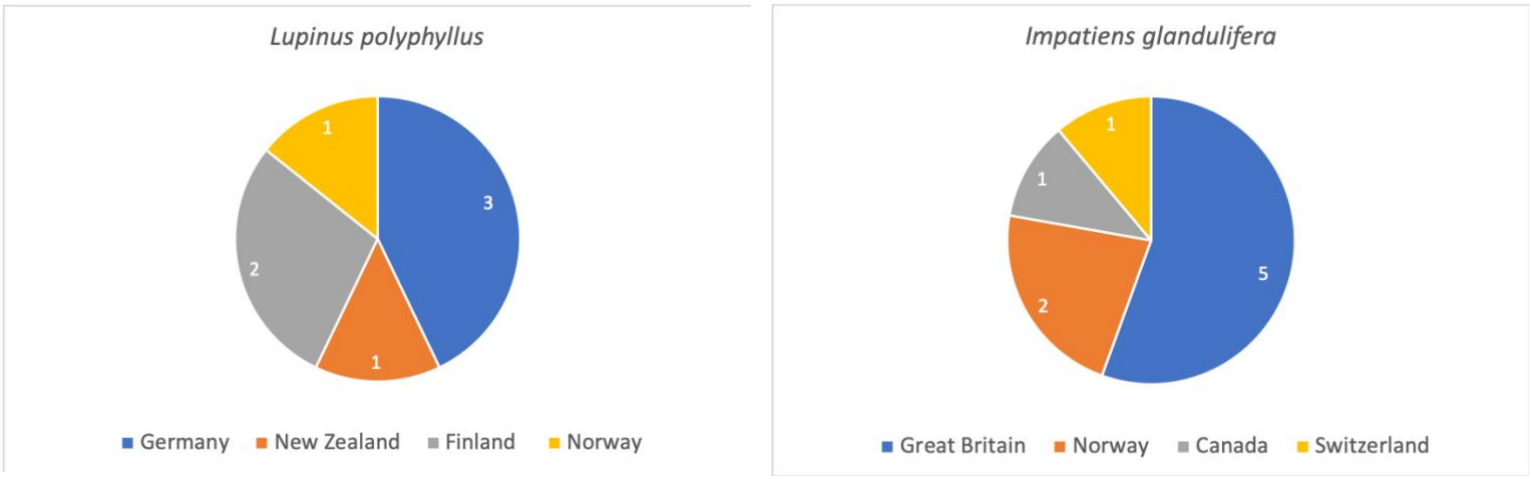


Figure 27. The color corresponds to the country in which the article where written. Blue = "Germany", orange = "New Zeeland/Norway", Grey = "Finland/Canada" and yellow = "Norway/Switzerland".

Result of removal method

Many articles showed good results for the removal method they investigated. 13 of 16 articles showed good results while 2 showed poor result and 1 showed mixed result of both good and poor. Table 2 shows the result of the removal method for each article for each species of plant.

Table 2. The articles found describing the effect of different methods to reduce *Impatiens glandulifera* and *Lupinus polyphyllus* and their stated result of the method used. 14 of 16 articles stated a good result of the removal method studied.

Impatiens glandulifera	Ellison et al, 2020	Hulme & Bremmer 2006	Oliver et al, 2020	Tanner et al, 2015	Bitarafan, 2021	Leblanc & Lavoie, 2017	Cockel et al, 2014	Burkhart & Nentwig 2008	Pollard et al, 2021
Removal method	Fungus	Cutting	Hot water/ cutting	Fungus	Steam	Hand pulling	Weeding/pruning	Moths	Fungus
Result of removal	Good	Good	Good	Good	Good	Good	Good	Bad	Mixed

Lupinus polyphyllus	Hansen et al, 2022	Anderson et al, 2014	Klinger et al, 2020	Ramula, 2020	Bitarafan, 2021	Jauni & Ramula 2016	Westerman & Von Oheimb 2021		
Removal method	Mowing	Herbicide	Mowing	Mowing	Steam	Weeding (Digging)	Pulling		
Result of removal	Good	Good	Good	Good	Good	Bad	Good		

Discussion

Field experiment

In this thesis, I have performed three different studies. The first was a field experiment, testing two different removal methods on the invasive alien plant *Lysichiton americanus*. Results from the statistical data analysis show that there was no significant difference between the two removal methods and the controls in any site. The reason for the non-significance result could be due to a small sample size. If the sample size were greater than perhaps the result would look different. Judging from the *p*- value of 0.983 the sample size might not have made a big difference.
A limitation of the study design was the proximity of the control and methods too each other. Ideally, the sites would have been larger and treatments further apart from each other. Due to *L .americanus* ability to regrow from parts of its rhizome, the close proximity of the control to the removal sites could have affected the amount of new plants in these areas. According to Fremstad (2010), the best time to remove the species is in early summer since this weakens the remaining rhizomes. My experiment was carried out in late summer/early fall 2022 due to time limitations. Also, due to time limitations, the plants in 2023 were counted in late April. This might also have influenced the results.

Even though the statistical test was not significant, a difference between the control of 2023 and M1 and M2 2023 can be seen (Figure 10 & Figure 12). This might be an indication that removing the plants irrespective of the method results in fewer plants the following year.
The controls had a large variability in the number of plants between the sites and within the same site while the plots where *L. ameircanus* was removed in 2022 (methods M1 and M2) had a smaller variability in the number of plants between the years and sites (Figure 11).
Site 2 and 5 had a big difference in the number plants between 2022 and 2023 in all treatments. In the field these sites had similar appearance. The sites had running water next to where the plants grew and the soil was muddy and yet firm at several places. Site 3, 4 and 7 had smaller difference in the number of plants between the years. Site 7 had an increase in plants in all sites in both the control and where a method was carried out. There is a bigger increase in plants in the methods than the control. The reason is difficult to discern, maybe these plants had a bigger root system or more seeds. Sites 3,4 and 7 had running water further away from where the plants grew. It is unclear whether the abiotic or biotic factors is what caused the difference in the number of plants.
In site 5, where the whole plants had been removed with a spade (M2), had a value of +30 and was therefore an outlier in the data since there were no plants left in 2022 and 30 new ones in 2023. This is the reason why a non-parametric test was used.
An ANOVA was also conducted but resulted in the same non-significant result. Hence, due to the higher sensitivity to outliers of the ANOVA and the non-significant result, these results were not included in the final thesis.

Survey

The second study was a survey of how different municipalities in Västra Götaland work with invasive alien plants. There were 16 questions in the questionnaire. 13 questions were summarized in this thesis. Questions 15 and 16 were not included since they were not directly related to the research questions. In the following the answers to the remaining questions are discussed and analyzed.

Question 8 *(What are the methods you use when removing invasive alien plants, please give up to three examples of method and species that you work the most with?)* was also not included in the analysis since I was unable to summarize it in a clear way. Many respondents misinterpreted the question and did not mention a species on which the three methods they mentioned was used. The answer itself was therefore not useful. Since all the other answers to the other questions were clear and concise, I conclude that question 8 itself must have been asked in a wrongful way. This means that the formulation of the question was not clear and this question will not be further discussed.

Question 1. Do you think combating and managing invasive alien plants is important?
75% of people thought that it is very important to manage and combat IAS and 25% said that it is important. This is positive news for the field of conservation biology since the people who work with one of the big five drivers of biodiversity loss thinks that it is very important to do so since the rate of invasions and emersions of new invasive species are not appearing to slow down (Pyšek et al, 2020).

Question 2. (What are the main drivers for working with invasive alien plants?) and
Question 3. (Do you think your agency should have a higher priority in working with invasive alien species? If so why?)
Also, received promising answers in that the most important driver for working with invasive alien plants is to preserve biodiversity. 65% of the respondents also thought that their workplace should prioritize IAS more than they currently do.
When asked to elaborate on question 3, the "maybe" answerers mentioned that their workplace should prioritize the work with IAS in certain cases. Often this included specific species that were particularly abundant in their municipality. The main reason people answered "no" was because they were already ambitious in their work with IAS.
Many respondents also mentioned that the will to manage IAS is there but they lack resources in the form of funding, time and people which is consistent with the findings of Weidlich et al (2020).

Question 4. What are the main invasive species (plants) you work with managing/controlling?
According to the survey the main species that were actively managed were Japanese knotweed, giant hogweed and Himalayan balsam. Japanese knotweed is known to be almost impossible to get rid of if it becomes sufficiently established, having a rhizome network that goes three meters below ground. It is therefore important to manage it early in its invasion (Dusz et al, 2021). Similar arguments can be given for the giant hogweed and Himalayan balsam. The giant hogweed can be directly harmful to humans due to its phototoxicity and is therefore important to manage and remove as quickly as possible as stated by Naturvårdsverket (Naturvårdsverket, 2023). An important thing to note however, is that there are two species of hogweed in Sweden. The giant hogweed and the common hogweed. Some answers did not specify which of them they referred to. I therefore in a few cases had to guess which species was referred to. The tricky thing is that the common hogweed isn't invasive and is native to Sweden while the giant hogweed is

introduced and invasive. The reason behind the confusion might be that the systematics of the genus *Heracleum* is not so clearly understood. Since only one answer explicitly mentioned common hogweed (björnloka), this does most likely not influence the results in a significant way.

The Himalayan balsam is not harmful to humans, nor is it especially difficult to remove. Why is it then the third most managed species? One explanation could be that it is very common on the west coast of Sweden (SLU Artdatabanken, 2023), and is therefore, due to its sheer number of plants/stands targeted for management more than other plants on the questionnaire. Japanese knotweed and the giant hogweed are also very common on the west coast. Most likely this is an important reason why it is managed to a higher degree than other plants on the list in the study area of this thesis.
All three species are also classified as SE (severe impact) by SLU Artdatabanken, which is another reason to why these species are managed to a higher degree.

Question 5. What is your current knowledge on IAS and their impacts? and *Question 6. If you lack knowledge, what kind of knowledge is that?* are closely related and will therefore be discussed together.
58% of the respondents of the questionnaire had good knowledge on invasive alien plants, 22% had very high knowledge and 20% stated that they were informed. These results are in line with what I hypothesized they would be since the questionnaire was sent to people who actively work with IAS and their knowledge of these species can be expected to be high. Overall, the results are show that the overwhelming majority had a high knowledge of invasive alien plants and their impacts.
20% stated that they were "only" informed. Having no knowledge of the work experience or background of the participants in the survey, I am unable to say why the remaining 20% answered the way they did. Maybe they were new to work on managing IAS?
Only 20 out of 36 respondents answered question number 6. This could be because the rest did not know what to write or that they simply did not lack any knowledge. Of the 20, 13 wanted to know which method is most effective for the specific species with which they work. This suggests that investigations like this thesis and similar studies, are needed since more knowledge on effective removal methods are requested.

Question 7. What does your agency do if an invasive species is not on the EUs list of invasive species? Are such species also considered for management) Do you act in regard to managing it?
18 answers (53%) did work with species that are not on EUs list. 5 did not and 5 sometimes worked with these species.
Not surprisingly, many municipalities do work with species that are not on EUs list on invasive alien species. Even though a species is not on the list and therefore not required by law to be managed, these species still cause harm and is a threat to biodiversity and management is therefore needed as stated by many of the answers. Depending on where the species grow and how big the municipality's budget is, the work with species not on the list gets prioritized higher.

Question (9) 8 Does your agency provide you with the latest research on management methods?
Question (10) 9 Where do you go for information about invasive alien plants?
Question (11) 10 Where do you get the information on which methods (mechanical, chemical) to use when removing invasive alien plants?
These three questions are linked and will be discussed together. 66% of respondents working with removing invasive alien plants answered that they did not get the latest research on removal methods. However, 83% used websites of agencies´ (Länsstyrelsen, Naturvårdsverket) to get information on which removal method to use. This could be the reason why they do not use scientific articles since these authorities (Länsstyrelsen, Naturvårdsverket) are based mostly on

scientific literature. As to why the workplace does not provide the latest research on removal methods, it could be that there isn't much literature on removal methods to begin with. This is further shown by the result of the literature review below.
43% used the internet for information on invasive alien plants. 48% answered "other". When this result was analyzed I noticed that the 48% that answered "other" did so because they selected more than one answer. In hindsight, I realize that when making the questionnaire I forgot to include the possibility to select multiple answers. Many of the "other" answers mentioned websites such as those of Länsstyrlesen and Naturvårdsverket. These were not considered "Internet (e.g. google search)" by the participants and therefore the majority selected the reply "Other". If I had used the same options as question (11) the result of question (10) would probably look similar.

Question (12) 11 Does your agency manage IAS inside nature reserves?
Question (13) 12 Is the removal of invasive alien plants inside nature reserves given enough priority?
Almost equal numbers of respondents combated invasive alien plants inside nature reserves as did not. The reason for this is unclear. Maybe some municipalities have fewer nature reserves than others and perhaps these reserves were not governed by the municipality itself but by some other third party such as Länsstyrelsen or Västkuststiftelsen (Länsstyrelsen, 2023; Västkuststiftelsen, 2023).
59% of the respondents thought that the removal of invasive alien plants inside nature reserves was not given enough priority, while 41% thought that it was prioritized enough. Since the purpose of nature reserves is to preserve valuable nature and biodiversity, it is a good sign that almost 60% of survey participants thought that this issue needed to be prioritized more than it currently is as management, policy and research on IAS in protected areas are insufficient. The impacts of IAS in protected areas are increasing worldwide, particularly invasive alien plants (Shackleton et al, 2020).

Question (14) 13 Which of these species have you found inside nature reserves?
The most common species found in nature reserves were the Himalayan balsam, Japanese knotweed, large-leaved lupine and Japanese rose. These species are highly common in Västra Götaland and it is therefore not a surprise that these species were the most commonly found in nature reserves. Japanese knotweed and Japanese rose are notoriously difficult to completely remove and it is therefore a serious observation that these species are commonly found in nature reserves (Alberternst & Böhmer, 2011; Bruun, 2005).
However, the question did not include how many stands or individuals of the species that were found in nature reserves. The fact that these species were common does not mean they were the most numerous. The Himalayan balsam was by the respondents suggested to be the most commonly found species in nature reserves and an explanation could the biology of the species and its reproductive strategy. It grows fast and catapults its seeds by the bursting seed capsules. The seeds can travel up to 5 m. The seeds are also incredibly numerous: 6 to over 30 thousand/m^2 have been observed (Koenis & Glavac 1979).
Overall, the answers from the survey indicate that there is great variation between municipalities in Västra Götaland when it comes to which species are being removed and why and how informed the participants are. Some trends that can be seen across all municipalities are that the majority have the same drive for combating IAS, what the current knowledge gap is, if they work with species that is not on EUs list and where they get information on removal methods and on species. Some topics had an almost equal distribution of answers, if participants removed IAS in nature reserves and if they got the latest research on IAS.

Literature review

The third study of this thesis was a literature review of removal methods on the study species *Impatiens glandulifera* and *Lupinus polyphyllus*. The results revealed that there were 9 relevant articles published on *I. glandulifera* and 7 relevant articles published on *L. polyphyllus.* A surprisingly low number of articles researched the effect of a removal method on the growth and vitality of these two species.
These species were chosen because they are both very common in South-West Sweden and because one (*I. glandulifera*) is on EU´s list of invasive alien plants and one (*L. polyphyllus*) is not. Since the difference in the number of published articles was only two, it is most likely not due to *I. glandulifera* being on EUs list.

The most common removal method researched for *I. glanulifera* was biological control.
The result of the biological control experiments was mixed. Two articles reported good results while one was mixed and one had bad results. The good result came from articles researching the effects of the rust fungus *Puccinia komarovii var. glanduliferae*. The fungus reduced growth rate and vitality in infected plants. According to Tanner et al, 2015, this control method has promise because it attacks its host twice during the growing season. In the spring, the rust infects young seedlings, frequently causing early mortality and thus no seed set. Later, in the summer, the fungus covers leaf surfaces reducing the area available for photosynthesis. Infected plants quickly lost their early season height advantage, appearing significantly smaller and less healthy than nearby uninfected plants.
Burkhart & Nentwig (2008) had a poor result and researched the tortricid moth *Pristerognatha fuligana.* The results showed that *P. fuligana* had no effect on the Himalayan balsam. It did not harm the plant and is therefore unlikely to be an effective control agent.

The most researched removal method for *L. polyphyllus* was cutting/mowing. Cutting is a common practice for removing lupines and is considered effective. It does have to be repeated regularly for years however to eradicate the plants entirely (Januten et al, 2007). Table 2 illustrates this further, the result of all articles researching cutting/mowing had a good result on removing the plants. Hansen et al (2022) removed the plants by up weeding them with weeding forks. Major parts of the root system were therefore removed, and this had a good result.
Klinger et al (2020) researched whether the timing of cutting influenced seed germination in lupines. They concluded that lupines should be cut before seed set, if possible. If not, they recommend cutting the plants when the seeds are still green and soft.
The third article researching cutting was Ramula (2020). That study found that cutting twice a year for two years, greatly reduced plant vitality due to the plants having to use much of their stored energy to grow the following year.
According to Weidlich et al (2020), economic realities play a role in the control method chosen to study. Cutting/mowing are both time- and cost-effective methods. There is a pressing demand to come up with easy and inexpensive solutions to implement in restoration and management IAS (Weidlich et al, 2020).

Jauni & Ramula (2016), researching weeding (digging) as a removal method for *L. polyphyllus* had a poor result. The mild soil disturbance method (breaking the soil with a spade) increased the number of plants by 5% compared to the control and the intense soil disturbance method (removing all plants and soil 5 cm down) had no effect on the number or reemerging plants. When comparing seedling survival between the methods and control they found that the intense disturbance method increased seedling survival by 15% the following summer but not the year

after that. Thompson et al (2001), also suggest that invasive plant control can enhance invasiveness through released resources and decreased competition.
Digging is a common removal method used in management and is recommended by Naturvårdsverket and the method catalog for removing IAS which is produced by several government agencies such as Naturvårdsverket, Havs- och vattenmyndigheten and Jordbruksverket (Metodkatalog, 2022). It could be that digging as a practice (often with big machines) is a time effective way of removing many plants over large areas and is therefore often used in management but that does not mean that it is the best method for management IAS. Jauni & Ramula (2016) highlight that more research is needed, not only on soil removal as a method but for other methods used in management of IAS today as well.

Limitations

The field experiment could be improved by a more strongly developed sampling technique. It was difficult to remove all the roots when using method 2 of the study. Some sites had a high flow of water and were very muddy. This could have affected method 2 since I needed a sufficiently stable surface to stand on when digging and were sometimes not 100% satisfied with the way I dug. In all the controls, plants were left untouched. These plants might have been able to spread and affect the result of the removal method sites since they were close to each other. Ideally, controls and method 1 and 2 would have been further away from each other in some sites they had good distance and in some it could have been better but due to the distribution of the plants, this was not possible.
As shown by question 8 of the survey, it is difficult to formulate questions so that everyone understands them as intended. It was my first time making a questionnaire and I therefore found it to be difficult to formulate each question in a way that all can understand. Luckily, I had my supervisors help to guide me. Next time, I would go through the survey extra carefully and check the grammar and answer options available so the participants would have it easier.
The literature review resulted in relatively few articles, and this could be because of the keywords used and the databases used. If the search criteria would have been broader, I might have been able to find more articles but at the same time these articles might to a large extent not have been relevant to the present study. As I only wanted scientific literature, I did not use google scholar which is prone to include both grey literature and scientific literature.

Future research

The field experiment resulted in a non-significant difference between the removal methods and the controls. Despite these results, prior research has shown good results from mechanical removal if it is repeated for several years. For this reason, it should still be researched further but with a longer time scale than my study since it is shown to take several years to fully remove *L. americanus (*Aldridge et al, 2018).
As shown in the survey, almost all respondents wanted to know what the most effective removal method is for a specific species. This highlights the need for more research on this topic and more efficient ways to distribute the state-of-the-art knowledge about methods to remove IAS. The literature review also showed a lack of research on this topic by the modest number of articles found by the literature search. Weidlich et al (2020), claims that there is a communication gap between researchers and managers. This can be seen by the high number of articles researching biological control methods. These are not very applicable in the field since they are time consuming, labor intensive and economically costly.
Future research should also continue to be innovative in the search for effective control methods since the most effective methods is determined by many factors such as the place of the invasion,

severity of the invasion and the economic reality of the removal method chosen (Weidlich et al, 2020).
When selecting new control methods to study, one should always have the biology of the plant in mind since its imperative for effective removal of invasive plants. Longer studies and follow up studies are also needed since many studies have time frame which is to short and is seldom followed up a year or several years later (Blossey, 1999).
All studies researching the effects of rust fungus on *I. glandulifera* did so in a lab. It would be interesting to see how well this removal method works in the field. Future research should consider field experiments and follow up studies to see what the status of the infected population is and research the effects on the native plants to make sure the fungus hasn't spread to them.
No articles in the literature search were found regarding protected areas and control of the study species. This is also an area needing more research since protected areas are one of the most important tools for biodiversity management (Baldwin & Beazley, 2019).

Conclusion

This thesis studied the effects of different removal methods on the invasive alien plant *Lysichiton americanus* via a field experiment. Since the results were negative (no difference between the treatments) the research question for the field experiment is answered. Still, mechanical removal methods have been shown in multiple studies to be effective and is therefore still recommended to be used. A survey and a literature review was also conducted and showed that the incentives for working with invasive alien plants were largely the same in the different municipalities of Västra Götaland. Combating invasive plants was deemed by the survey to be of high importance and that the work with invasive alien plants should be of an even higher priority than it currently is.
The following list are recommendations based on the literature study, survey and field experiment on how to most effectively deal with invasive alien plants in nature reserves.

- There might not be one single most effective removal method for *I. glandulifera* and *L. polyphyllus*. The methods recommended to use are mechanical such as cutting, mowing,

hand-pulling and hot water. Preferably performing these methods by hand and minimizing the use of heavy machinery.

- Chemical removal methods (although effective), are not recommended to be used when removing *I. glandulifera* and *L. polyphyllus* in nature reserves due to the negative impact these chemicals can have on native plants and animals.

- Biological removal methods (rust fungus) are also not recommended since more research is needed on how the fungus effects native plants and if native plants are susceptible to infection.

- Since *L. americanus* grows in wetlands it is not recommended to use chemicals since these can affect the rest of the ecosystem and get transported by water to other areas and cause damage.

- Although labor intensive, removing *L. americanus* by hand is preferred due to it being the easiest to implement both small and large scale. This also minimizes the damage to native flora and fauna.

- The most effective method is the one that suits the specific situation the best and is the one that can be carried out realistically.

- The intention to improve management of IAS exist in all Västra Götaland. Knowledge of the most effective removal methods are needed. A way to increase this knowledge is to provide the latest research on removal methods to the people who work with management.

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Appendix A

Popular science summary

Invasion of the alien plants

Did you know that since the 1970s, the number of invasive alien species has increased by 70%? On the global scale, the negative effects of invasive alien species are the second largest threat to biodiversity, causing damage to native species, ecosystems and in some cases even directly to humans. Invasive alien species are found in all major groups of organisms from plants and animals to fungi.

What an invasive alien species?

Animals and plants that have accidentally or intentionally been introduced into an environment where they are non-native. In the new environments, they have adverse negative effects on the ecosystem. The introduction and/or spread of the species not only threatens biodiversity but can also cause socioeconomic damages and damage to humans and other animal's health and well-being.

Definition
Invasive alien species- "An alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity

So, the difference is basically that an invasive alien species causes harm to the environment it ends up in. clarify a bit

Why is this important and what is the point of this thesis you might ask?

If you are not yet convinced about the importance of this topic, here are some reasons too why you might want to consider it a bit more.

- All over the planet, invasive alien species affect ecosystems and the most sensitive of these are protected areas which have the sole purpose of conserving the native plant and animal wildlife.

- Dramatic effects can already be seen and are expected to continue to grow in the future, especially since these effects are multiplied by climate and habitat change.

- In 2009, the annual cost of invasive alien species in Sweden was estimated to be in the range of 1618-5077 million SEK/year.
  Now imagine that number worldwide!

- The European Union has a list of invasive alien species called the "List of Invasive Alien Species of Union concern". Any species that is found on the list has restrictions on keeping, importing, selling, breeding and growing. However, not all invasive species currently invading a certain country is on this list.

With my thesis, I aim to evaluate the most effective methods in removing invasive alien plants from nature reserves using field experiments. I will be comparing two different removal methods on the study species *Lysichiton americanus* or American skunk cabbage as it is usually called. *Lysichiton americanus* is native to western North America. In Sweden, the species was introduced after the 1800s as an ornamental plant in gardens and parks. It has since then spread either naturally or by man and is now common in many parts in southern Sweden. The big leaves cover the vegetation below it, shading it from light, causing stress and eventually death of the vegetation below reducing native plants and biodiversity.

One method involves cutting the plant (which looks like a huge cabbage) by the root and then destroying the remaining root with a spear. The second method is more straight forward, you simply dig the whole plant up with the main root and all.
By doing this type of comparison, one method might turn out to be more effective in removing this species. This finding would save money and manual labor for the people who work with this species. There is, of course a chance that there is no difference between the methods. If that is the case then that is fine because that's how science works.

Currently there is little research on removal methods and control of several invasive plants. Therefore, I am also doing a literature review and a survey on how people work with invasive alien plants. The literature review will focus on two invasive plants which are very common in Sweden, Himalayan balsam and the large-leaved lupine.
The survey, which is a form with a bunch of questions, is sent to all counties in Västra Götaland.

Apendix B

Survey

Questions with detailed answers

In the results, several questions which were written answers, were categorized for ease of understanding and to not be too long in the text. Only answers which were catogerized and contained more detailed answers will be included in this appendix. Both questions and answers are in Swedish.

Question 2. What are the main drivers for working with invasive alien plants?

De invasiva arterna behöver tryckas tillbaka och i bästa fall elimineras som ett sätt att värna den inhemska floran och faunan. Som en del i det övriga arbetet med att bevara den biologiska mångfalden.
Att förhindra förlusten av biologisk mångfald på bekostnad av invasvia arter
Förhindra spridning så att IAS tar över växligheten och bevarande av biologisk mångfald.
Bevarande av biologisk mångfald. Men kan även vara risk för skada på egendom.
Att värna den inhemska floran och faunan.
Minimera oönskad spridning och negativ påverkan på inhemska arter.
Biologiskt mångfald. Vill fortsätta se en variation av växter och djur i naturen. Värna om den Svenska blomsterängen
Invasiva växter riskerar breda ut sig i naturen i så stor omfattning att det påverkar den biologiska mångfalden på ett mycket negativt sätt. Vissa invasiva växter skapar också stora problem för människan direkt, till exempel Parkslide på fastigheter och Jätteloka som har en kemisk substans som vid beröring och hantering kan skapa brännskador på mänslig hud.
Ur mitt perspektiv är det viktigaste att de stör naturliga ekosystem samt riskerar att påverka naturligt förekommande växter och djur samt övrig biologisk mångfald negativt. Även att de påverkar rekreationsvärden, kan vara skadliga för människan (loka) osv.
Biologisk mångfald
hindra spridning och se till att ingen skadar sig , tänker på jätte lokan.
Hejdad förlust av biologisk mångfald.
kvalitet och följa riktlinjer/lagstiftning
Att främja den biologiska mångfalden
Att de konkurrerar ut inhemsk flora, vissa är hälsofarliga och kan påverka byggnader negativt.
Förlust av biologisk mångfald
Att dom inte sprids. Och att dom kommer in i våra VA ledningingar eller i innvånarnas hus
Begränsa spridning
Att problemen blir värre ju längre man låter det fortgå.
Skydda den biologiska mångfalden hos de inhemska arterna
För att fortsätta arbetet med att begränsa och ta bort invasiva växter som hotar många andra arter.
Biologisk mångfald, risker, kostnader
För att minska/begränsa utbredningen av monokulturer och för att istället få en större biologisk mångfald och därmed en bättre resiliens.
Att inte sprida den vidare. Då vissa av dem är svår bekämpade
Gynna biologisk mångfald. Skydda privata tomter. Skydda naturreservat. Värna kommunens gröna värden.

Bekämpning: Minska negativa effekter av inhemska arters utbredning, samt motverka ytterligare spridning genom kunskapsökning och skapa förebyggande rutiner och arbetssätt för arbeten i miljöer där de kan förekomma. (undvika oavsiktlig spridning)
- Främja den biologiska mångfalden - Minimera kostnader för samhälle och enskilda vid skada som invasiva arter kan orsaka
Att förhindra spridning och förhindra att inhemska arter utkonkurreras. Även att arter som jätteloka kan medföra risk för skada på människor t ex vid lekplatser eller andra platser där barn vistas.
reducera hotet som de främmande invasiva arterna utgör för inhemska arter
Minska skadorna i miljön/på naturen nu, arbeta långsiktigt för att förebygga skador på miljö, ekonomi och människors hälsa framåt.
för att motverka minskad biologisk mångfald
minska hotet från IAS på biologisk mångfald
Biologisk mångfald.
Att invasiva växter förstör naturliga ekosystem samt att det blir väldigt kostsamt att åtgärda om vi väntar.
Naturvårdsrelaterade aspekter samt olägenhet för allmänhet.

Question 3. Do you think your agency should have a higher priority in working with invasive alien species? If so why?

Ja, men resurserna är små och det är svårt att mobilisera för att kunna utföra en vettig bekämpning som ofta kräver långsiktighet och att man kan utföra den vid rätt tillfälle, inte sällan under sommaren och semestertider.
Åtgärdstakten är för långsam
Ja alla bör arbeta mer med att bekämpa IAS.
Ja. Vi utför ingen systematisk bekämpning idag. Har tex parkslide och vresros som vi skulle behöva jobba mer med. Tyvärr räcker inte resurserna till. Kommer troligen att få söka LONA-bidrag för att kunna göra större insatser. Om dessa arter kommer upp på EU-listan är vi ju skyldiga att bekämpa dem och ju längre vi väntar desto dyrare blir det eftersom risken är stor att bestånden ökar.
Ja, det behövs ett större fokus på hantering av exempelvis parkslide. Denna skapar stora problem runt om ikommunen för våra fastighetsägare.
Eventuellt.
Vi arbetar så gott vi kan med de resurser vi har. Sen skulle vi givet vis kunna arbeta mer med de. Liten kommun små resurser.
Vi arbetar så mycket vi kan idag med att inventera och bekämpa invasiva växter. Givetvis skulle mer kunna göras med en högre ekonomisk budget och mer personal till detta arbete.
Nej, vi är ambitiösa i dagsläget
Vi prioriterar arbetet med invasiva arter relativt högt och har tagit fram en plan för hur vi ska arbeta med både förebyggande arbete och bekämpningsinsatser.
Ja, fast nästa år kommer vi arbeta mer med detta
nej tycker vi har en bra nivå
Ja, bekämpningen är omfattande men brister ibland i noggrannhet, vilket innebär att den inte alltid är effektiv.
nej inte just nu.
Avsätta mer resurser i form av både mer arbetstid och ekonomiska resurser
Ja, absolut. Vi har ingen bra samordning mellan förvaltare i frågan. men det är på gång.
Ja, Tanums kommun har inte kommit långt i detta. Jag, i form av nyanställd kommunekolog, ska be om ansvaret att få utforma en handlingsplan för bekämpning av invasiva främmande arter, så förhoppningsvis kommer vårt arbete vara mer strukturerat och utvecklat inom ett år ungefär.

Ja har gjorts väldigt lite innan
Ja. Mest tycker jag att kommunerna borde ha ansvaret och inte (som idag) Länsstyrelsen. Kommunerna har bättre koll på lokala bestånd och har bättre förutsättningar att kontakta markägare inför åtgärder.
Ja, men vi håller på att ta fram en strategi som jag hoppas kommer ta arbetet en god bit framåt. Kunskapen om risklistan har varit obefintlig så därför är det inte så konstigt. Tex har SE-arter planterats fram tills nyligen men det ska förhoppningsvis bli ändring på.
i vissa fall ja! T.ex. jättebaslamin som är förhållandevis lätt att begränsa ytterligare spridning.
Ja, kostnaderna ökar i framtiden när spridningen ökar, hot mot den biologiska mångfalden och våra inhemska arter, kan innebära risker för människor och djur.
Ja det tycker jag, åtminstone med de arter som är EU-listade. Idag är det gul skunkkalla som vi har en handlingsplan för att bekämpa och har påbörjat bekämpning. Jätteloka bekämpas med punktinsatser, det finns inte riktigt ett utstakat, strategiskt arbete med jätteloka eller jättebalsamin.
Vi gör redan tillräckligt och dt skulle bli för stor börda om vi gjorde mer.
Ja delvis. Själva bekämpningen är ofta kostsam och komplicerad och det kräver en stor budget. Jag tror dock att detta är ett problem som blir mer och mer känt och förhoppningsvis kommer vi i framtiden att ha en avsatt årlig budget för detta.
se ovan.
Ja, det finns en stor vilja men saknas tillräckligt med resurser både för planering och utförande av bekämpning. Vi avvaktar godkännande av kemisk bekämpning med glyfosat under särskilda villkor även för platser avsedda för allmänheten att vistas.
Vi borde prata mer om det, dock har vi inte jätte många platser med invasiva växter på kommunens mark.
Ja, idag finns mycket stora behov men begränsad budget. Kostnaderna och de ekologiska effekterna kommer att bli mycket större om några år om vi inte lyckas stoppa, begränsa eller utrota växterna idag. Idag hanteras frågan också som huvudsakligen en naturvårdsfråga, och fler områden behöver involveras i arbetet framåt (exempelvis inom samhällsbyggnad).
Min arbetsplats har regeringsuppdrag om invasiva arter och vi har en bra organisation kring detta och det börja sätta sig i organisationen att det är många som behöver jobba med IAS i sina befintliga arbetsuppgifter där de kommer in.
ja. svårt att få gehör för IAS bekämpning och problematik i utförardelen i kommunen
Vi kommer att lägga tid och pengar på detta enligt nästa års budget men det är lite svårt att hitta personer som kan åta sig detta.
Ja, det behövs mer resurser till bekämpning.
Ja. Förekomsten av invasiva arter är högre och risken för spridning större än de resurser som läggs på bekämpning.

Question 6. If you lack knowledge, what kind of knowledge is that?

Hade önskat mer kunskap om vilka metoder som förespråkas vad gäller parkslide. Men försöker hålla mig uppdaterad vad myndigheter anger och vad andra kommuner testar. Men ingen verkar ha hittat en bra lösning för just parkslide än. Är själv med och testar metoder för bekämpning av sjögull men det är dyrt och svårt. Vi hoppas bättre metoder kommer snart.
Bättre kunskap om bekämpning
Bra kostnadseffektiva bekämpningsmetoder för alla IAS skulle man vilja ha bättre kunskap om.
Vilka arter som finns och vilken utbredning de har i kommunen. Vilka metoder som är bäst för bekämpning .
Mer i detalj hur man bör hantera invasiva arter (skillnader etc.)
Vill kunna känna mej trygg med att jag har det senaste och bästa metoderna för bekämpning.

Som alla andra saknar jag kunskap om vilka bekämpningsinsatser som är de mest effektiva för parkslide. När det kommer forskningsresultat kring detta kommer det underlätta vårt arbete mycket.
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något som fungerar till 100 % på parkslide.
det går alltid bli bättre, all information är bra information
Konkreta fall där bekämpningen varit lyckad.
Saknar kunskap om hur det ser ut i just vår kommun pga finns ingen samlad inventering.
Erfarenhet
Bekämpningsmetoder för fler arter än de "vanligaste" på NVs hemsida
Längre studier av vissa metoder.
Bekämpningsmetoder
tex bra metod för slidesbekämpning, kommunen arbetar bla med hetvatten, men skulle naturligtvis vilja ha beprövade, giftfria (gärna billiga) metoder att sätta in för bekämpning.
Detaljkunskap om arterna samt hur det ser ut i andra länder och deras åtgärder.
Det saknas generellt kunskap om vilka bekämpningsmetoder som är de mest effektiva.
Arternas förekomst i landskapet.

Question 7. What does your agency do if an invasive species is not on the EUs list of invasive species? Are such species also considered for management. Do you act in regard to managing it?

Vi gör vad vi kan exempelvis med sjögull där vi sökt LONA-pengar för bekämpningen. I övrigt finns inte så mycket resurser för att jobba med EU-arterna. Vi kanske ska komma igång med bekämpning av jättebalsamin men det kräver att man kan utföra det vid rätt tidpunkt på sommaren.
I första hand arbetar vi med arter som är med på listan
Ja visst det är inte bara arterna på EUs lista som är invasiva och skadliga för våra ekosystem och mångfalden.
Inte i nuläget.
Vet ej
Vi sköter allt arbete med grönytor i egen regi och upplever att det är lättare att styra resurserna där vi behöver de.
Vi försöker bekämpa Parkslide som jag nämnt tidigare och Blomsterlupin.

Ja exempelvis Parkslide
Ja, vi prioriterar även andra växtarter, både i det förebyggande arbetet och i bekämpning. Framförallt när det gäller parkslide.
Nej
vet ej
Viljan finns, men kunskap och resurser saknas på verkställande förvaltning (lupiner).

Tyvärr inte på grund av resursbrist
De skulle kunna prioriteras, men det görs inte i dagsläget.
Vet ej
Har inte hänt än
Ja i mån av budget
Vi lägger in de fynd vi hittar i artdataportalen, även vissa som inte är med på EUs lista (t.ex. Parkslide).
Förhoppningsvis börjar det arbetet under sommaren som jag nämnt ovan. Men det kommer bli en fördel med nationella listan när den kommer. Jag tror det kan vara svårt att argumentera för allt för många arter samtidigt, tror att folk tappar hoppet isf, så därför viktigt att fokusera på några och faktiskt märka att det gör skillnad där.
samlar in data/information om plats och omfattning.
Ja
I dagsläget är det i stort sett bara parkslide som har bekämpats, men enbart då det har varit ett måste, tex när vi skulle dra om en väg. Vi har dock tagit fram en strategi med de 3 EU-listade arterna + 4 till som inte är med på EU-listan. Viljan är att kunna bekämpa alla 7 arter i framtiden. Vid bekämpning ska det ses till platsen och vilka arter som finns där. Växer det tex både jätteloka och vresros på en plats är det mest effektivt att bekämpa båda på samma gång. Tanken är även att kunna samarbeta med andra förvaltningar/markägare om en art växer på båda markägares mark.
Ibland, beror på var de växer.
Ja. Om de upptäcks inom ett exploateringsområde följer vi riktlinjer för hantering av invasiva arter och förhindrar spridning.
Bedömning av behov samt prioritering utefter resurser.
De tas också med i arbetet men tilldelas lägre prioritet. För att de ska få högre eller likvärdig prioritet behöver nationell förteckning över invasiva främmande arter tas fram där dessa arter omfattas av reglerna.
Vi har bekämpning av parkslide - även om den är lägre för närvarande pga kemikalieförordningen. Det är allra mest tryck på bekämpning av denna art från allmänheten och boende.
inom vår egen organisation kan vi även prioritera dessa arter
Ja, de kan prioriteras inom skyddade områden och i informationsinsatser.
I vårt uppdrag står att vi bör prioritera dessa arter och eftersom vi inte har bra bekämpningsmetoder för tex den EU-listade arten smal vattenpest håller vi på och gör åtgärder för sjögull som är spridd men ej EU-listad. Vi prioriterar även utifrån skyddade områden eller risken för spridning till skyddade områden.
Skulle säga att det som avgör om kommunen agerar är hur problematisk arten. Att Länsstyrelsen skickar ut informationsbrev är ganslka tandlöst då det inte händer något om man inte bekämpar IAS arter på EU listan. i princip prioriteras de inte om de inte utgör ett problem
Även arter som inte är med på EU:s lista är aktuella att arbeta med.
Ja, t ex parkslide prioriteras ändå.
Det beror på om området är utpekat skyddsvärt där hypotetisk invasiv art förekommer.