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Research article

Effective communications on invasive alien species: Identifying communication needs of Swedish domestic garden owners

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ABSTRACT

Invasive alien species threaten biodiversity with domestic gardens acting as a major pathway for the introduction of alien species. Even though the Nordic region is not currently a hotspot for biological invasions, the number of invasions in the Nordic area has been predicted to increase due to climate change. Given a time lag between introduction and invasion, many non-invasive horticultural alien species already introduced into gardens may become invasive in the future. This study aimed to identify the communication needs of Swedish garden owners regarding their management of invasive alien species. A survey among domestic garden owners, informed by topic specialists and local area experts, and interviews with garden owners were conducted in three different bio-climatic areas in a latitudinal gradient across Sweden. The questions targeted invasive alien species and their relations to biodiversity loss and climate change, as well as measures taken to control these species. Analysing the survey data collected in relation to measures taken to control invasive species, Bayesian Additive Regression Tree (BART) modelling was used to identify geographically varying communication needs of the domestic garden owners. In all study areas, the garden owners' measures taken to control invasive alien species were correlated with their strength of beliefs in having experienced local biodiversity loss. A majority of the garden owners were, moreover, uncertain about the impact of climate change on the invasiveness of alien species. In addition, the garden owners' capacity for identifying invasive alien species was often in need of improvement, in particular with respect to the species *Impatiens glandulifera*, *Reynoutria japonica* and *Rosa rugosa*. The results suggest that the evidence-based guidelines for effective communications we developed, have the potential to help communicators meet the local communication needs of garden owners across Sweden, in relation to the management of invasive alien garden species.

1. Introduction

Invasive alien species (IAS) pose a threat to biodiversity for several reasons such as competing for resources and as a major cause of ecosystem degradation (Pyšek and Richardson, 2010; Simberloff et al., 2013). According to Hulme et al. (2018), horticulture is the main pathway for the introduction of terrestrial invasive plant species. The range of horticultural species and varieties is large and increasing (Bradley et al., 2012; van Kleunen et al., 2018). Alien plants generally outnumber native plants in domestic gardens (Loram et al., 2008; Mayer et al., 2017) making domestic gardens a major pathway for introduction of alien species worldwide (Dehnen-Schmutz and Conroy, 2018).

Given a time-lag between the introduction of a species and the invasion phase (invasion debt) (Essl et al., 2011; Rouget et al., 2016), a large number of horticultural species already introduced, but currently not invasive, may become invasive in the future (Mayer et al., 2017; Haeuser et al., 2018).

In the Nordic region, which is not currently a hotspot for biological invasions, the number of invasions is predicted to increase due to climate change (Bellard et al., 2013; Dullinger et al., 2017; Gallardo et al., 2017). This is partly because of invasion debt but also because, with climate change, horticulture is predicted to assist alien species' migration (Van der Veken et al., 2008).

The Nordic country of Sweden is one of the largest countries in the

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EU, covering 41 million hectares (Statistics Sweden, 2022) and an extensive biogeographic range (Bevanger, 2021). In Sweden, 85% of the citizens live in urban areas and more than half (52%) of the population (10,5 million citizens) live in detached houses (Statistics Sweden, 2021). Norrland, in the north of Sweden, occupies more than half of the country's area but is inhibited by only 11% of the population. Most of the introduced alien species originate from Europe, Asia and North America (Weidema, 2000). To estimate how many plants are invasive in Sweden, 3175 alien plant species were screened for invasiveness (Strand et al., 2018) using the Environmental Impact Classification for Alien Taxa method (see Hawkins et al., 2015). Of these, the 585 most critical species were chosen for a more thorough risk assessment using the Generic Ecological Impact Assessment of Alien Species method (Version 3.3) (see Sandvik et al., 2017) of which 115 alien species were categorized as invasive (Strand et al., 2018). Notably, the majority of invasive plant species were observed in the southern part of the country, where the human population density is higher (Artportalen, 2023). The recorded costs for the control of IAS in Sweden between 1960 and 2021 was estimated to $1.45 billion (Kourantidou et al., 2022).

Informed and motivated citizens can have an important role in IAS management (Marchante and Marchante, 2016) and several projects drawing on citizen science are active in Europe (Sweden: Artfakta, 2023a; Britain and Ireland: Plant alert, 2023). At present, studies targeting stakeholder involvement in the Nordic countries are underrepresented. However, examples from other parts of Europe provide valuable input to the development of country-specific guidelines for the Nordic countries. The general public's familiarity with the concept of IAS (Verbrugge 2013; Junge et al., 2019), the ability to correctly identify IAS morphologically (Lindemann-Matthies, 2016) and the knowledge of which plants are invasive (Shackleton and Shackleton, 2016), have been found to be important for the public's support for IAS control efforts. In addition, implementing a code of conduct can inform the public and limit the number of IAS available in the nursery trade (Heywood and Brunel, 2011). A need for communication with garden owners on the issue of the threat of IAS and the prevention of further dispersal has been acknowledged (Tyler et al., 2015; Dullinger et al., 2017). However, it has been emphasised that targeted campaigns aimed at specific groups are needed to reach the intended groups (Halford et al., 2014; Potgieter et al., 2019) and to be successful, a long-time perspective and commitment are necessary (Verbrugge et al., 2014). Whether the plants are considered beautiful and desirable or not can influence garden owners' willingness to remove the species from their gardens (Shackleton and Shackleton, 2016). This factor can complicate communications. Finding a plant beautiful can mean that detrimental aspects of the species may be accepted (Lindemann-Matthies, 2016) but diminishing sense of the beauty with new knowledge on the invasiveness of the species has also been reported (Cordeiro, 2020).

As a first step in a process to develop evidence-based guidelines for communications on IAS, what Swedish domestic garden owners need to know in relation to IAS was identified in consultations with a group of topic specialists. This mapping of causal relationships was supported by a literature overview and was followed by explorative interviews with garden owners in order to ensure that relevant aspects of garden owners' experience and knowledge relating to IAS were taken into account. Based on this preparatory work, the following hypotheses were formulated and tested.

H1: The strength by which garden owners believe that they have experienced local biodiversity loss due to invasive species correlates positively with measures taken to control invasive species in their gardens (cf. Niemiec et al., 2016)

H2: The strength by which garden owners believe in the impact of climate change on the invasiveness of invasive species correlates positively with measures taken to control invasive species in their gardens (cf. Bardsley and Edwards-Jones, 2007)

H3: The strength of appreciation of a specific plant species correlates negatively with measures taken to control invasive plant species (cf. Qvenild et al., 2014; Lindemann-Matthies, 2016)

The strength of Swedish garden owners' appreciation of the invasive alien species (3a) *Impatiens glandulifera*, (3 b) *Lupinus polyphyllus*, (3c) *Reynoutria japonica*, (3 d) *Rosa rugosa* and (3e) *Syringa vulgaris* correlates negatively with measures taken to control invasive alien plants in their gardens.

2. Method

2.1. Study areas

The three biosphere reserve areas Voxnadalen (in Norrland), Lake Vänern Archipelago and Mount Kinnekulle and Blekinge Archipelago (UNESCO, 2021), situated in a latitudinal gradient across Sweden and representing different bio-climatic conditions were used as study areas (Fig. 1). Complemented with a literature overview focusing on literature that is directly relevant to the study (e.g. communication needs and behaviour of garden owners), an expert group consisting of the managers of the three biosphere reserves, the national coordinator for the Swedish biosphere reserves, experts on IAS at the Swedish Environmental Protection Agency and the Swedish Species Information Centre (including the person responsible for the national risk assessment of invasive alien vascular plant species), were invited to share their knowledge and experiences of IAS in the designated biosphere reserves. The outcomes of the discussions were used to construct an influence diagram (see, Morgan et al., 2001) visualising the most important aspects and their causative relations to focus on in relation to invasive

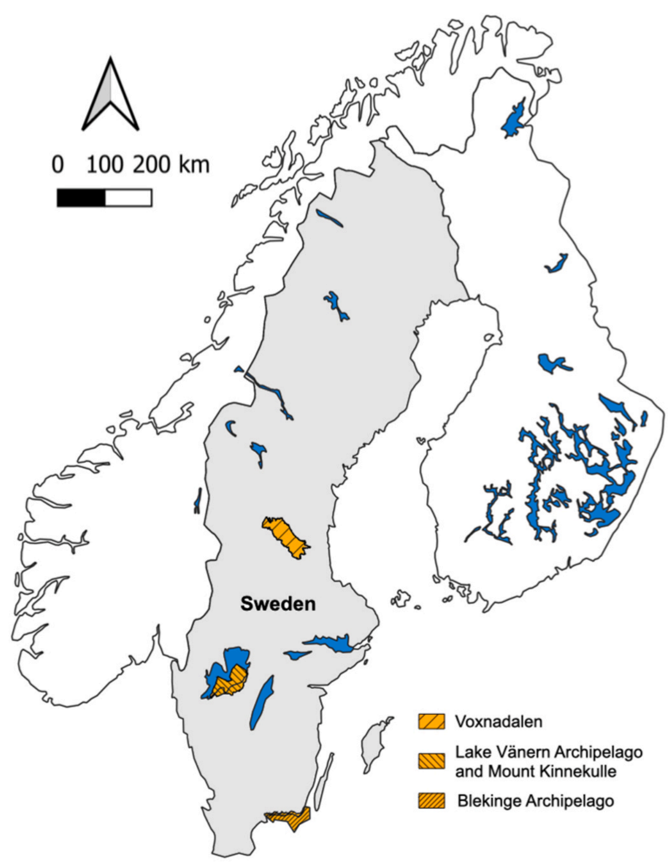

Fig. 1. Location of the study areas Voxnadalen, Lake Vänern Archipelago and Mount Kinnekulle and Blekinge Archipelago, in Sweden. Made with Natural Earth.

garden plant species that threaten the local biodiversity in the study areas (cf. Fischhoff, 2013). Semi-structured interviews with four to five garden owners in each study area were conducted to complement the influence diagrams with aspects that are important to garden owners but were unknown, or not prioritised, by the professional invasive species experts.

2.2. Survey

The influence diagram was used to formulate questions for a survey of domestic garden owners in the three study areas. The interviews helped to focus the survey as well as providing input concerning which species to focus on. The purpose of the interviews was also to make sure that the terminology to be used in the survey was comprehensible to the receivers (see de Bruin and Morgan 2019). Approximately 6000 randomly sampled domestic garden owners (approximately 2000 in each study area) were invited to participate in the survey which used postal invitations to a web-based questionnaire (Fig. S1) using the survey tool Netigate (2021). A cover letter (Fig. S2) informed the respondents of the objectives and the purpose of the study. Participation in the survey was voluntary and none of the questions included were compulsory to answer. All questions in the questionnaire and the information in the cover letter were formulated in Swedish. The survey was open for access from October 22 to December 7 in 2020 and resulted in 990 responses (Text S1).

The questionnaire included 24 questions on IAS, their relation to biodiversity, and climate change. Questions in the questionnaire asked about five plant species for this study, Himalayan balsam, *Impatiens glandulifera* Royle, Garden lupin, *Lupinus polyphyllus* Lindl., Japanese knotweed, *Reynoutria japonica* Houtt., Rugosa rose *Rosa rugosa* Thunb., and Lilac *Syringa vulgaris* L., all of which had been selected from the Swedish risk assessment on IAS, category "Severe Impact" (see Strand et al., 2018). All five species were originally introduced as ornamentals and are common garden species, grown in all the three study areas (Artfakta 2023). Henceforth, the species included in the study will be called "set of species" when referred to as a group. The species in the questionnaire were presented to the respondents in random order.

The present study draws upon seven of the questions included in the questionnaire. These concerned knowledge level, management against IAS, species-identification skills, presence of IAS in the respondents' gardens, experience of biodiversity loss, and expectations of climate change impacts on the invasiveness of invasive species. Four additional questions on socio-demographics targeting age, gender, municipality, and gardening interest were also used in the study. Five hundred and sixty-six responses from respondents having responded to all the questions used for variable construction were analysed.

Arguably, only respondents familiar with the concept of IAS and respondents who have at least one IAS in their garden can be expected to take measures to control IAS. Garden owners with at least one of the species in the set of species were thus selected for use in the subsequent analysis (Q1 and Q3 in Table 1). To know if a certain species is growing in a garden, moreover, requires the skill to identify the species. The self-stated identification skills of the respondents varied greatly depending on the target species. In addition to variation in identification skills between species, geographical variation in identification skills between the three biodiversity reserves were found (Table S1).

2.3. Variable construction

The dichotomous response variable *control* was constructed from the question relating to measures for control of IAS taken in the respondent's garden with the response alternatives yes = 1 and no = 0 (Q4 in Table 1). A Bayesian Additive Regression Tree (BART) model modified to handle classification for dichotomous response variables (Kapelner and Bleich, 2016) was fitted to the data to predict the probability of *control* (cf. Blennow et al., 2020).

Table 1
Questions analysed in the present study.

Number	Question	Response option
Q1	Do you know the meaning of the term 'invasive species'?	Yes No
Q2	Do you know the species: Applied to 5 invasive species[a],[b]	Yes No [c]
Q3	Does this species grow in your garden? Applied to 5 invasive species[a],[b]	Yes No Do not know
Q4	Have you or anyone else taken measures to control invasive species in your garden?	Yes No
Q5	Have you experienced biodiversity loss in your local environment due to invasive alien species	No, I have definitely not experienced that (-3)- 2 −1 Do not know 1 2 Yes, I have definitely experienced that (3)
Q6	How much do you appreciate the following species? Applied to 5 invasive species[a],[b]	Not at all (0) 1 2 3 Much (4) Do not know
Q7	Do you believe climate change leads to changes in invasive alien species?[d]	Definitely not (-3)- 2 −1 Do not know 1 2 Yes, definitely (3)
Socio-demographic variables		
Q8	In what municipality do you live?	A list of 21 municipalities within the three study areas
Q9	How old are you?	<21 years old 21–30 years old 31–40 years old 41–51 years old 51–60 years old >60 years old
Q10	Gender	Woman Man Other or do not want to disclose
Q11	How interested in gardening are you?	Scale from Not interested (0) to Very interested (4)

[a] *Impatiens glandulifera*, *Lupinus polyphyllus*, *Rosa rugosa*, *Reynoutria japonica*, *Syringa vulgaris*. Only the Swedish common names were presented in the survey, see Text S1.
[b] Order of species randomised.
[c] Answer options reformulated from the original survey. For original formulation see Fig. S1.
[d] Question reformulated from the original survey. Here, the strength of belief in the effects of climate change was taken as the inverse of the responses to the question. For original formulation of the question, see Fig. S1.

Six questions asked in the survey were used to construct the 25 variables that were tested as predictors in the model and these were subsequently used to test empirical consequences of the hypotheses H1–H3. The variables *identification Impatiens, identification Reynoutria, identification Rosa, identification Lupinus* and *identification Syringa* were constructed to reflect the self-stated ability to identify each of the five plant species and was based on Q2 (Table 1). The variable*s garden presence Impatiens, garden presence Reynoutria, garden presence Rosa, garden presence Lupinus and garden presence Syringa* were constructed to reflect whether each of the species were growing in the respondent's garden and were based on question Q3 (Table 1). The variable *biodiversity loss* was constructed to reflect whether the respondents had experienced biodiversity loss in their surrounding environment due to

IAS and was based on Q5 (Table 1). The variable *appreciation of species* was constructed to reflect the self-stated appreciation of each of the five IAS species in the set of species, and was based on Q6 (Table 1). The variable *climate change impacts* was constructed to reflect how strongly the respondent believed in climate change impacts on the invasiveness of IAS and was constructed from Q7 (Table 1). Two compound variables were constructed. The variable *garden presence* was constructed by counting the number of plants stated to be present in each of the garden owner's garden, and the variable *Study area* was constructed by aggregating the respondents based on municipality of residence in the three study areas included in the study. The variable *Study area* was not included in the BART model but was used for the Bayesian proportion tests.

2.4. Statistical analysis

The most important variables were identified and statistically tested for their importance as covariates following Kapelner and Bleich (2016). Variables not significantly contributing to the model were dropped in a backwards stepwise manner, and only variables with a significant effect were retained in the final model. To test if the difference in proportions (probabilities of success) between groups of respondents was significant, a single-sided Bayesian proportion test was used, applying a uniform prior distribution (Bååth, 2014). All tests were conducted at $\alpha = 0.05$. Descriptive statistics of the responses to the survey questions used in this paper are found in Table S2 in the supplementary material.

The open-source software R Project for Statistical Computing v 3.6.2 was used to analyse the data (R Core Team, 2019). The packages Bayesian first aid (Bååth, 2014) and BART-Machine (Bayesian Additive Regression Trees) v 1.2.6 were used (Kapelner and Bleich, 2016) for all analyses.

3. Results

3.1. Beliefs and values

H1: The strength by which garden owners believe that they have experienced local biodiversity loss due to invasive species correlates positively with measures taken to control invasive species in their gardens (*cf.* Niemiec et al., 2016)

We found that the answer "Yes, definitely" to the question "Have you experienced biodiversity loss in your local environment due to invasive species" (variable *biodiversity loss)* was positively correlated with measures taken to control IAS in the BART model (Fig. S3).

A correlation between the strength of belief in having experienced local biodiversity loss due to IAS and reporting to have taken measures to control IAS was found for all three study areas. Moreover, 21–28% of the respondents in each study area reported being uncertain whether they had experienced biodiversity loss due to IAS (Table S3, test 2–4).

A geographical variation in the proportion of garden owners who had taken measures to control IAS between the study areas was also found, with two thirds of the respondents in the Voxnadalen study area, and one third of the respondents in each of the study areas Lake Vänern Archipelago and Mount Kinnekulle and Blekinge Archipelago (Table S4).

H2: The strength by which garden owners believe in the impact of climate change on the invasiveness of invasive species correlates positively with measures taken to control invasive species in their gardens (cf. Bardsley and Edwards-Jones, 2007)

The respondents' strengths of belief in climate change impacts on the invasiveness of species did not correlate with measures taken to control IAS in their gardens in the BART model. However, when using Bayesian proportion tests for individual study areas, measures taken to control IAS correlated negatively with a determinate belief that climate change does not impact on the invasiveness of alien species for respondents in the Voxnadalen study area, although the test was based on only six responses (Table S3, test 5–8). Moreover, 52% (Voxnadalen), 64% (Lake Vänern Archipelago and Mount Kinnekulle) and 59% (Blekinge Archipelago) of the respondents in each study area, respectively, reported to not knowing if they expect climate change to lead to changes in the invasiveness of alien species.

H3: The strength of appreciation of a specific plant species correlates negatively with measures taken to control invasive plant species (cf. Qvenild et al., 2014; Lindemann-Matthies, 2016)

The following five empirical consequences were tested: the strength of garden owners' appreciation of the invasive alien species (3a) *Impatiens glandulifera*, (3 b) *Lupinus polyphyllus*, (3c) *Reynoutria japonica,* (3 d) *Rosa rugosa* and (3e) *Syringa vulgaris,* correlate negatively with measures taken to control invasive alien plants taken in their own gardens. Lack of appreciation for the species *Lupinus polyphyllus* was positively correlated with measures taken to control IAS in the BART model (Fig. S3), but when tested for individual study areas using the Bayesian proportion test, no correlation was found for the Blekinge Archipelago study area (Table S3, test 9–12).

For respondents stating the presence of *Lupinus polyphyllus* growing in their garden, lack of appreciation for this species was positively correlated with a determinate belief in having experienced local biodiversity loss due to IAS, while weak or strong appreciation of *Lupinus polyphyllus* was negatively correlated with a determinate belief in having experienced biodiversity loss (Table S5, test 1).

Among garden owners reporting to have the species growing in their garden, a lack of appreciation of *Impatiens glandulifera*, *Lupinus polyphyllus* and *Reynoutria japonica,* respectively, correlated positively with measures taken to control IAS, while no correlation was found for garden owners who had *Rosa rugosa* or *Syringa vulgaris* growing in their garden (Table S3, test 13–41). However, a strong appreciation of *Rosa rugosa* and *Syringa vulgaris* both correlated negatively with not having taken measures to control IAS in their garden.

3.2. Socio-demographic factors

Tests of the correlation between measures taken to control IAS and additional socio-demographic factors revealed no correlation with neither age nor gender. However, garden owners reporting very strong interest in gardening were significantly more likely to have taken measures to control IAS (Table S3, test 43–44, S6, test 4).

Self-rated identification skills were significantly higher among respondents holding a strong garden interest. Holding a strong garden interest was positively correlated with both the female gender and the respondent being at least 60 years of age which suggests that the higher identification skills observed among respondents having a strong garden interest may partially be explained by the fact that they were more likely to be over 60 years of age and women. However, the female gender was not correlated with being older than 60 years (except for the species *Impatiens glandulifera*) (Table S6, test 5–9, S7, test 1–10, Table S8, test 1–10, Table S9, test 1–5).

Being very interested in gardening was positively correlated with having a definite belief that one had experienced local biodiversity loss due to IAS (Table S10, test 2).

4. Discussion

A key component for a garden owner's ability to make decisions regarding IAS, whether it comes to planting, eradication, or reporting, is to be able to identify the IAS (Prinbeck 2011; Balding and Williams, 2016; Lindemann-Matthies, 2016; Robinson et al., 2016; Jose et al., 2019). In the present study, the garden owners' invasive plant species identification skills varied greatly depending on species (Table S1). Only approximately half of the garden owners stated to be able to identify the species *Rosa rugosa* in each of the study areas respectively, and less than half of the garden owners stated to be able to identify *Reynoutria japonica* in the study areas Voxnadalen and Lake Vänern Archipelago and Mount Kinnekulle, while two thirds of the garden owners in the study area Blekinge Archipelago stated that they could identify the species (Table S1). For *Impatiens glandulifera*, approximately half of the garden owners in the study areas Voxnadalen and Lake Vänern Archipelago and Mount Kinnekulle stated that they are able to identify the species while only one fourth of garden owners in the study area Blekinge Archipelago stated that they are able to identify the species. These species represent some of the most common IAS in Sweden (Swedish Environmental Protection Agency, 2022). It has been observed that the general public sometimes lacks the necessary skills to identify IAS in other parts of the world as well (Netherlands: Verbrugge et al., 2013; Portugal: Cordeiro et al., 2020; South Africa: Shackleton and Shackleton, 2016; Colorado, USA: Daab and Flint, 2010).

The fraction of garden owners who had taken measures to control IAS were found to vary geographically with approximately two thirds of the garden owners having taken measures to control IAS in the Voxnadalen study area, one third in Lake Vänern Archipelago and Mount Kinnekulle study area, and one third in the Blekinge Archipelago study area (Table S4). Nevertheless, in all of the study areas, the garden owners' measures taken to control IAS correlated with their beliefs in having experienced local biodiversity loss that they attributed to invasion of alien species. Thus, H1, which states that the strength by which garden owners believe they have experienced biodiversity loss locally due to invasive species correlates positively with measures taken to control invasive species in their gardens, was corroborated.

Climate change and IAS are stressors that can both act independently and also exacerbate each other's impacts on biodiversity loss (Hellmann et al., 2008; Mainka and Howard, 2010), and hence climate change is important to consider in IAS management (Beaury 2020). However, in this study, a large proportion of garden owners in all three study areas reported that they do not know if climate change impacts the invasiveness of species (Table S3, test 5–8). Not only does this demonstrate a widespread lack of knowledge of climate change impacts on the invasiveness of species but it also substantially reduces the number of observations on which to base statistical tests of correlation in the present study. Hence, a negative correlation between a determinate belief that climate change has no impact on the invasiveness of alien species and measures taken to control IAS in the Voxnadalen study area was based on the responses of only a few garden owners (Table S3, test 5–8). Therefore, the test of H2, stating that the strength by which garden owners believe in the impacts of climate change on the invasiveness of invasive species correlates positively with measures taken to control invasive species in their gardens, was inconclusive.

Lack of appreciation for *Lupinus polyphyllus* correlated positively with measures taken to control IAS in the Voxnadalen study area as well as in the Lake Vänern Archipelago and Mount Kinnekulle study area (Table S3, test 10–12). The only species for which the degree of appreciation of the species was uncorrelated with measures taken to control IAS, were *Rosa rugosa* and *Syringa vulgaris.* They were both highly appreciated by garden owners and have characteristics such as large colourful flowers and a pleasant scent that are considered typically desirable by laypersons (Mack and Lonsdale, 2001; Lindemann-Matthies and Bose, 2007). The detrimental effects they can cause may thus be outweighed by their perceived beauty (Lindemann-Matthies, 2016).

The empirical consequences stating that the strength of Swedish garden owners' appreciation of the IAS correlated negatively with their measures taken to control invasive alien plants were corroborated for the species (3a) *Impatiens glandulifera*, (3 b) *Lupinus polyphyllus*, (3c) and *Reynoutria japonica,* while the empirical consequences for the species (3 d) *Rosa rugosa* and (3e) *Syringa vulgaris* were not. Thus, the hypothesis was corroborated but only for the species *Impatiens glandulifera*, *Lupinus polyphyllus* and *Reynoutria japonica*. A positive correlation between a lack of appreciation for *Lupinus polyphyllus* and having experienced local biodiversity loss because of IAS indicates that experience of impact on local biodiversity attributed to IAS can reduce the strength of appreciation for the species, and contribute to enhance the garden owner's propensity to take measures to control the IAS. Indeed, Cordeiro (2020) report that knowing that a plant is invasive can have a larger influence than perceived beauty on willingness to control IAS (Cordeiro, 2020).

4.1. Guidelines for effective communications

The following guidelines were developed based on the communication needs identified for effective communications with garden owners in Sweden.

Garden owners.

- who cannot identify IAS need information on how to identify various IAS morphologically. This communication need is particularly common in relation to the species *Impatiens glandulifera* in the study area Blekinge Archipelago, *Reynoutria japonica* in the study areas Voxnadalen and Lake Vänern Archipelago and Mount Kinnekulle and *Rosa rugosa* in all study areas,
- with no, weak, or uncertain belief in having experienced local biodiversity loss due to invasion of alien species need information that can help them perceive local biodiversity loss due to IAS. Such garden owners were predominately found among garden owners without a strong garden interest and irrespective of study area.
- with no, weak or uncertain belief in climate change impacts on the invasiveness of alien species need information on how climate change can impact on the invasiveness of alien species,
- who appreciate species even if they are invasive, most common for the species *Rosa rugosa* and *Syringa vulgaris*, need information on how invasion of the species can affect biodiversity.

5. Conclusions

The study aimed to identify the communication needs of Swedish garden owners with regards to taking measures to control IAS in their gardens. The study found that communication efforts should focus on enhancing garden owners' identification skills for common IAS and locally adapting communications to meet geographic variations in IAS distribution. Communications that fortify the belief that one has experienced impacts of IAS on the local biodiversity can be expected to increase measures to control IAS among those who have no, or only weak, belief that they have experienced the impacts of IAS on the local biodiversity. Additionally, communication efforts should also provide information on the impacts of climate change on the invasiveness of alien species.

The study found that lack of appreciation for certain IAS species, such as *Impatiens glandulifera*, *Lupinus polyphyllus*, and *Reynoutria japonica*, positively affected measures taken to control IAS in the garden owners' gardens. Lack of appreciation for *Lupinus polyphyllus* was also positively correlated with garden owners' belief in having experienced local biodiversity loss due to IAS, indicating that communication focusing on local biodiversity loss can also enhance measures to control IAS.

The findings from this study suggest that evidence-based guidelines for effective communications can help meet the communication needs of garden owners in different parts of Sweden for controlling IAS in their gardens by giving examples of what to focus the communications on. However, further research is necessary to evaluate the effectiveness of the guidelines for effective communication and ensure successful dissemination to those who can take action to prevent the spread of IAS.

Credit author statement

CP - Conceptualization, Formal analysis, Writing – original draft. AW - Conceptualization, Writing – review & editing. JP - Conceptualization, Writing – review & editing. MA - Writing – review & editing. KB - Conceptualization, Formal analysis, Writing – review & editing, Project administration, Funding acquisition.

Declaration of competing interest

The authors have declared no competing interests.

Data availability

The data can be accessed (registrator@slu.se) by anyone with a legitimate interest in the data, as long as the transfer of data complies with the Swedish and European regulation on data protection.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2023.117995.

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