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Identifying opportunities for invasive species management: an empirical study of stakeholder perceptions and interest in invasive species

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Abstract Invasive species are one of the main reasons for the decline in global biodiversity. When it comes to the management of invasive species, stakeholders who are directly involved with this issue play a particularly important role, as they are directly engaged in management and can also influence the public's perception. This study therefore investigates how different stakeholder groups in Germany perceive invasive species. In total, more than 2200 people were surveyed, belonging to nine different stakeholder groups that are in contact with invasive species (hunters and members in hunting associations, farmers, members of environmental and conservation organizations, members in allotment garden clubs, animal welfare supporters, divers, employees in zoological gardens, administrative employees in the regulatory authority, speleologists). It was found that the number of invasive animal and plant species in Germany was roughly correctly estimated in all groups, but the economic damage caused by invasive species was substantially underestimated. When invasive species were mentioned, mainly conspicuous mammals or plants were listed (e.g. *Procyon lotor* or *Impatiens glandulifera*). In all surveyed groups, there was a notable level of interest in invasive species, and they were commonly regarded as environmental issues. While these results offer valuable insights into stakeholders' perspectives on invasive species, they also highlight the need for improvement. In particular, there is a need for greater education of stakeholders about inconspicuous invasive species, the spread of invasive species and the damage caused by them.

Keywords Economic damage · Interest in invasive species · Invasive species · Perception of invasive species · Stakeholders

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Introduction

Invasive species are considered as one of the main causes of biodiversity loss (IPBES 2019; Leadley 2010; Sala et al. 2000). These are species that are introduced by humans into an area where they

are not naturally present and cause damage, such as harm to local biodiversity, human development or health (Mainka and Howard 2010; Pyšek et al. 2020). In addition to the decline of native species (Bradley et al. 2019), invasive species can have very different effects, for example the reduction of the abundance of aquatic communities (Gallardo et al. 2016), alteration of food webs (David et al. 2017) or reduction of ecosystem services (Pejchar and Mooney 2009). Human life satisfaction can also be reduced by invasive species (Jones 2017).

Further, the migration and spread of invasive species is exacerbated by other environmental problems: For example, climate change (Rahel and Olden 2008; Walther et al. 2009), pollution (Crooks et al. 2011; Varó et al. 2015) and land use change (Bellard et al. 2013; Wang et al. 2016) enhance biological invasion. Estimating the annual damage caused by invasive species is a challenge due to the complexity of the issue. While it is impossible to determine the exact figure, various studies have attempted to provide quantitative estimates for different regions of the world (Pyšek et al. 2020). It is estimated that there are now more than 3500 invasive species worldwide (IPBES 2023) and the number of invasive species does not yet appear to have reached saturation point (Seebens et al. 2017). Projections suggest a potential increase of up to 36% in invasive species on different continents by 2050 (Seebens et al. 2020). In Europe, several thousand invasive species have been confirmed so far (DAISIE 2009; Keller et al. 2011), with calculations estimating annual damages at around 100 billion dollars (Haubrock et al. 2021a). Globally, the economic impact of invasive species is predicated to be between US$46.8 billion and US$162.7 billion in 2017 (Diagne et al. 2021), while other calculations estimate a $137 billion in damages in the United States alone (Pimentel et al. 2000). For Australia alone, the damage caused by invasive species is projected to be 13.6 billion dollars (Hoffmann and Broadhurst 2016). Especially in agriculture, the problem of invasive species will increase significantly in the future and lead to a productivity loss in the billions of US-Dollars (Ziska et al. 2011). Biodiversity hotspots in developing countries will be particularly affected by invasive species in the future (Early et al. 2016; Paini et al. 2016). Since not all invasive species cause the same amount of damage, they can be divided into different impact categories, also in the context of whether they

cause ecological or socio-economic damage (Bacher et al. 2018; Blackburn et al. 2014).

As invasive species pose a major problem for biodiversity (IPBES 2019) and can therefore also have negative consequences for humans and ecosystem services (Jones 2017; Pejchar and Mooney 2009), their management is becoming increasingly important. Depending on the habitat and species affected, different methods can be used to control invasive species. These methods are often based on the relocation or lethal control (Giakoumi et al. 2019). The prevention of the introduction or the spread of new invasive species are also part of management (Tobin 2018). However, especially when it comes to lethal management methods, there is always a risk of social conflict, which can disrupt or prevent management measures (Crowley et al. 2017). In order to coordinate and support management measures, government agencies are developing management plans (e.g. U.S. Department of the Interior 2021) and more and more scientific studies are establishing frameworks for management (Gaertner et al. 2016; Green and Grosholz 2021).

Public awareness and perception are essential for the implementation of management efforts for invasive species: Without public support, management processes for invasive species are almost impossible to implement (Veitch and Clout 2001). Especially when charismatic species are invasive or lethal methods are to be used as a management method, public support is vital (Höbart et al. 2020). The perception of invasive species depends on a number of factors. These include the attractiveness of invasive species (Jarić et al. 2020), as well as individual factors such as the perceived distance of species and psychometric factors encompassing values, emotions, and anthropomorphic views (Straka et al. 2022). People often also see the positive sides of invasive species, for example when they provide ecosystem services. It is especially in such situations that management becomes difficult (Ngorima and Shackleton 2019) and social conflicts can arise (Crowley et al. 2019). Age and level of education also play an important role in the perception of invasive species: it has been found that especially older and more educated people perceive invasive species as a problem (Potgieter et al. 2019). In this context, it was found that even simple and brief educational measures can raise social awareness of the problem (Bravo-Vargas et al. 2019) and community

awareness can make an important contribution to management (Shrestha et al. 2019).

Various studies have shown that the public has little knowledge about invasive species (Fraser 2001; Radek; Remmele and Lindemann-Matthies 2020). People are often unaware of invasive species and their impacts or even see them as beneficial (Jubase et al. 2021). Compared to other factors threatening biodiversity, invasive species tend to be underestimated (Kleespies and Dierkes 2020). The extent of the threat posed by invasive species is assessed very differently by the population (Bravo-Vargas et al. 2019). When it comes to dealing with invasive species, particular important groups are stakeholders, such as interest groups or decision makers in society, who are dealing with invasive species and their management in some form. Their perceptions are especially important because they help to shape public opinions about invasive species and are involved in management processes (Vanderhoeven et al. 2011; Vaz et al. 2020; Veitch and Clout 2001). Involving such stakeholders in the management process can make an important contribution (Shackleton et al. 2019b). However, knowledge deficits are often found in these groups as well. For example, one study revealed that even horticulture professionals have little knowledge regarding invasive species (Vanderhoeven et al. 2011). Additionally, most stakeholders and decision-makers also have problems identifying non-native species or appropriate management methods (Vaz et al. 2020). Studies on Mediterranean islands even found that stakeholders have a high tolerance for environmental changes triggered by invasive species (Bardsley and Edwards-Jones 2007).

While in recent years, the general population's awareness and perception of invasive species has been frequently studied in different disciplines using a great methodological diversity (Kapitza et al. 2019), there are currently only a few studies in Europe investigating the perceptions and views of stakeholders on invasive species (Andreu et al. 2009; Rodríguez-Rey et al. 2022). Therefore, the aim of this study is to investigate perception and knowledge of nine different groups of stakeholders on invasive species in Germany. To this end, the following three questions need to be answered:

(1) Can the number of invasive animal and plant species found in Germany and the economic damage caused by them be correctly estimated by the stakeholder groups?
(2) When invasive species are to be named, which species are primarily mentioned?
(3) Do stakeholders have an interest in invasive species and perceive invasive species as a problem?

Especially because there are sometimes significant differences in perceptions of invasive species among different stakeholder groups (García-Llorente et al. 2008), this study should provide important information about different stakeholders perceptions.

Methods

For the study, stakeholders and expert groups had to be selected in contact with the topic of invasive species. For this purpose, nine groups were selected by the team of authors (Table 1). On the one hand, groups were chosen that play an important role in the management of invasive species and, on the other hand, groups that have contact with the topic of invasive species. In addition, we selected groups organized in regional associations that were interested in helping us distribute the questionnaire. For the survey of hunters and speleologists, personal contacts with members were also used to distribute the questionnaire. Explanations of why the groups were selected can be found in Table 1. Appropriate survey instruments also had to be selected to capture the perceptions and interest of the expert groups.

Survey groups and procedure

Overall, 2272 participants (72.94% male, 26.12% female, 0.13% diverse, 0.8% no answer) have responded to the survey. As the gender distribution is also a characteristic of the stakeholder groups, this distribution does not distort the results of the study. In order to obtain meaningful results, the minimum sample size per expert group was set at 50. The sample sizes and an explanation of why each group is relevant in the context of the study can be found in Table 1. Additional information on the demographic data of the individual stakeholder groups can be found in Table S1. During data collection, there was an imbalance in the sample size between the individual stakeholder groups. Due to

Table 1 List of stakeholder groups surveyed in the study

Stakeholder group	Description and data collection
Hunters and members in hunting associations	In their work, hunters are regularly confronted with invasive species and are also involved in active management processes. Hunters were surveyed with the help of the German Hunting Association and the regional hunting associations Note: The high response rate for this group was due to the support of the German Hunting Association and the state hunting associations, which distributed the questionnaire via their mailing lists n = 1506
Farmers	Farmers must deal with the consequences of the spread of invasive species. The farmers were surveyed with the support of the regional farmers' and agricultural associations n = 88
Members of environmental and conservation organizations	An important reason for managing invasive species is to protect and preserve local ecosystems. In this context, members of environmental and conservation organizations play an important role, as their views may have important effects on society's perspective and the management process. For the survey, environmental and conservation organizations in Germany were contacted and asked for their cooperation n = 147
Members in allotment garden clubs	People who manage private garden plots and organize themselves into garden clubs have direct contact with the topic of invasive species. Information events on the subject of invasive species are occasionally offered in these groups n = 82
Animal welfare supporters	In this group, people were surveyed who are members of an animal welfare organization or who are engaged in animal welfare in an honorary role. This also includes people who work in animal rescue centers or animal shelters. For the purpose of the survey, animal welfare organizations, animal rescue centers and animal shelters were contacted n = 86
Divers	Diving associations are particularly committed to the conservation of aquatic ecosystems. Since aquatic ecosystems are also affected by invasive species, diving associations and diving stores were contacted and asked for support in distributing the questionnaire n = 92
Employees in zoological gardens	Employees in zoological gardens are involved in the care and welfare of species, some of which are endangered, as part of their job. For the survey, various zoological gardens were contacted via an e-mail distribution list n = 50

Table 1 (continued)

Stakeholder group	Description and data collection
Administrative employees in the regulatory authority	In Germany, this regulatory authority fulfills a wide variety of tasks, with a focus on maintaining order and safety. Since animal protection is also one of the tasks of the authority, they sometimes have to deal with the notification and handling of invasive species. For the survey, the offices of various cities and districts were approached n = 85
Speleologists	Members of German speleological associations regularly visit caves and cave-like structures to determine changes as well as species diversity within. For the survey, an email distribution list within a caving association was used n = 76

The different groups were selected to cover a broad spectrum of stakeholders that are in contact with invasive species. The sample size of each group is indicated by n

the support of the German Hunting Association, the number of participants in the group of hunters and members in hunting associations was much higher than in the other groups. As mean values were calculated for all evaluations and percentage distributions were considered, this uneven distribution of the sample size should have no influence on the results of the study.

In order to contact the mentioned groups, the various organizations, state associations, district associations, regional offices, etc. were contacted by an informal e-mail. In a correspondence letter, the research project and the objectives were presented and a request was made to distribute the digital questionnaire among members. At the beginning of the questionnaire, reference was made to the voluntariness of participation, anonymity and data protection. The survey was carried out from February 2022 to June 2022 and was conducted in German.

Measurements

Number of invasive species and damage caused by invasive species in Germany

The stakeholder groups were asked to estimate how many invasive animal species and how many invasive plant species currently occur in Germany. In addition, the respondents were asked to estimate the economic damage caused by invasive species in Germany per year. The aim of this question was to examine whether the extent of the invasive species distribution and the damage is correctly determined.

Naming of invasive species

This question asked study participants to name three invasive species which are found in Germany. The purpose of the question was to determine which species were most present in the groups' awareness and how many animals or plants were mentioned. If more than three invasive species were named, only the first three mentions were considered.

Perception of invasive species

To investigate whether there is an awareness of invasive species as an environmental problem in the stakeholder groups, six statements about invasive species, hereafter referred to as items, were created. As there was no existing validated instrument available for the specific research context, the items were created based on the researchers' expertise and judgment. The items focus on whether invasive species are seen as an environmental problem and therefore should be managed or not. The questions

were to be rated on a five-point Likert scale from "strongly disagree" to "strongly agree". Half of the questions were coded negatively so that the respondents could not mark the questionnaire without reading the questions completely. The selected items can be found in Table 2.

Interest in the topic of invasive species

To assess the interest of stakeholder groups in the topic of invasive species, an adapted version of the Nature Interest Scale (NIS; Kleespies et al. 2021) was used, in which the word "nature" was replaced by "invasive species" (Table 3). The scale is a validated instrument measuring interest based on the psychological construct of interest, that incorporates value-based, emotional, and cognitive interest

in an subject (Krapp 1993). The items were to be rated on a five-point Likert scale from "strongly disagree" to "strongly agree".

Analysis

For the estimation of the number of invasive animal species, plant species and the annual damage caused in Germany, the median was determined for each of the nine groups. The negatively coded items were recoded positively before calculating the mean. For the three invasive species that were to be named, each entry was assessed to determine if it was in fact an invasive species. To confirm or reject the status of an invasive species, the EU list of invasive species (No. 2022/1203) as well as the EASIN (European Commission 2023) database, Global invasive species database (GISD 2022) and published assessments of species not included in these databases were used.

Table 2 Factor scores of the six items to examine the perception of invasive species

Items	Factor scores
We need to take active action against invasive species	.715
Invasive species are one of the biggest environmental problems of our time	.702
If an invasive species is better adapted to a habitat than a native species, they should be allowed to take its place	−.700
Species migration is a natural process that we should not interfere with	−.686
As long as invasive species do not harm humans, they are not a problem	−.654
Invasive species are one of the main reasons for the decline in global biodiversity	.647
Bartlett test < 0.001 *Kaiser–Meyer–Olkin = .774* *Cronbachs Alpha = .769*	

Items in italics were coded negatively

Table 3 Factor scores of the nine items to examine interest in invasive species adapted from the NIS by Kleespies et al. (2021)

Items	Factor scores
The subject of invasive species is important to me	.808
I would like to learn more about invasive species	.808
I would like to know much more about invasive species	.806
I find it exciting to deal with the topic of invasive species	.804
I think it's important to be well informed about invasive species	.800
I find it meaningful to be involved with invasive species	.785
Learning about invasive species is fun for me	.781
In my free time I often deal with topics related to invasive species	.682
When I am engaged in the topic of invasive species, I am very concentrated and forget everything around me	.612
Bartlett test p < 0.001 *Kaiser–Meyer–Olkin = .885* *Cronbachs Alpha = .910*	

All statistical analysis was executed using IBM SPSS 28. To obtain an overall interest score for each person, the mean value was calculated from the nine interest items for each respondent. The same procedure was used for the perception in invasive species items, but the negatively formulated items were reversed first. In order to verify the appropriateness of this procedure, the factor structure of the items was verified using principle component analysis (PCA) after the Bartlett test and the Kaiser–Meyer–Olkin test had confirmed the applicability of this analysis method. PCAs are often used in social sciences to reduce the dimensionality of data sets while minimizing the loss of information. (Further information on the methods: Field 2018 and Jolliffe and Cadima 2016). Cronbach's alpha was calculated to assess the reliability of the instruments. Based on the theoretical considerations, the number of factors was set to one. The results of the factor analyses show that all items have a high factor loading (>|.600|; Tables 2 and 3). Thus, the usability of the items as a single factor construct can be assumed. The negative factor loadings can be explained by the negative wording of the items. Even though the hunters are overrepresented by their numbers, there is no bias in the analysis because mean and median values were used.

Results

The results show both similarities and differences between the different stakeholder groups. The median of the estimated number of invasive plant species ranged from 100 to 200, and that of invasive animal species between 60 and 100. Overall, it was estimated that there are more invasive plant species than animal species (Fig. 1A and Table S2). The median of the estimated annual damage caused by invasive species in Germany was between 4 and 20 million among the groups (Fig. 1B and Table S2).

When naming three invasive species occurring in Germany, only a few invalid answers were given in all groups (< 15%). Most invalid responses were those that referred to an entire group of species rather than a single species (e.g. frogs, wasps, beans). Other invalid responses included animals or plants that do not exist, native species, or species that do not exist here outside of zoos (e.g. lions). In most stakeholder groups, more animal than plant species were

mentioned. An exception were members in allotment garden clubs and members of environmental and conservation organizations, where the number of animals and plants was almost equally distributed. In the case of hunters, employees in zoological gardens, divers and animal welfare supporters, animals were named predominantly (Fig. 2). Regardless of stakeholder group, raccoon *(Procyon lotor)*, common raccoon dog *(Nyctereutes procyonoides),* nutria *(Myocastor coypus),* Himalayan balsam *(Impatiens glandulifera),* giant hogweed *(Heracleum mantegazzianum)*, and Japanese knotweed *(Polygonum cuspidatum)* were frequently mentioned as invasive species (Table 4).

Both the awareness that invasive species are a problem and the interest in invasive species were high in all groups. Administrative employees in the regulatory authority showed a slightly lower interest than the other groups, while hunters tend to see invasive species as more of a problem than the other groups (Fig. 3 and Table S2).

Discussion

The collected data and results in the nine stakeholder groups in Germany provide important insights into how these groups view the issue of invasive species.

Number of invasive species and economic damage

Having stakeholders estimate the number of invasive species indicates whether the extent of the problem is properly understood and assessed. Awareness of invasive species is considered an important factor because it directly affects whether management is considered necessary (Burt et al. 2007). The exact number of invasive species in Germany is difficult to determine. Different lists and databases provide different results. The EU list for invasive species, which is also valid in Germany, names 88 invasive species occurring in Europe according to the 2022 update (European Commission, 2022). The Global invasive species database lists 196 invasive species (101 animals, 86 plants, 9 other kingdoms) occurring in Germany (GISD 2022). Despite differences in the numbers, there is an approximate order of magnitude of the number of invasive species in Germany.

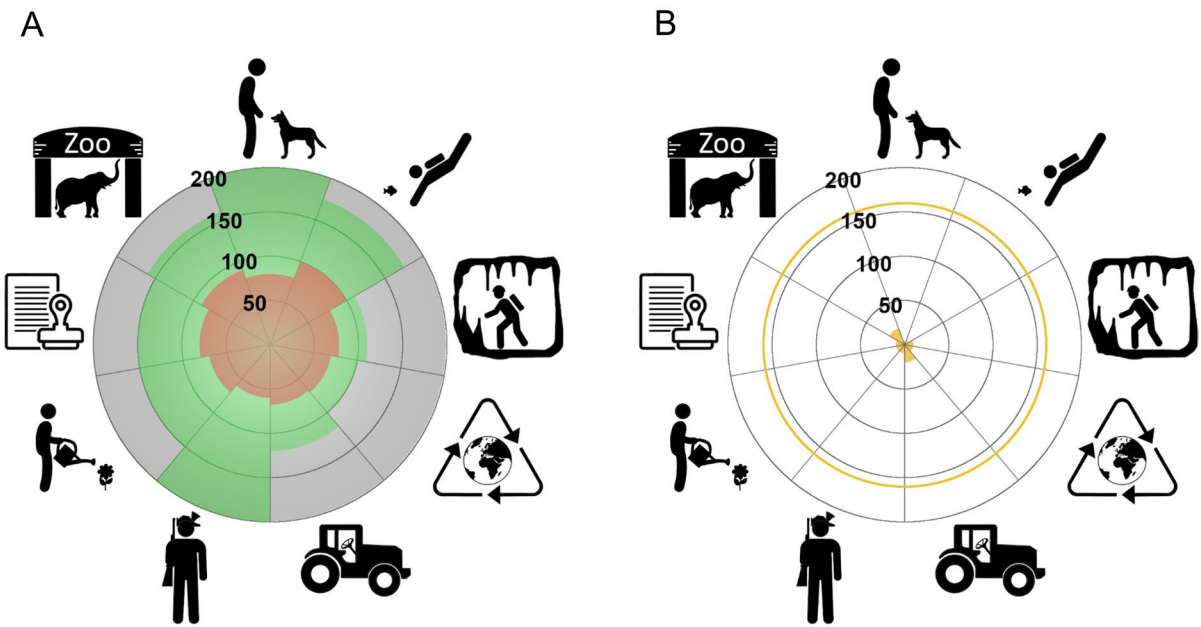Regardless of the stakeholder group, the results of this study indicate that the estimated number

Fig. 1 **A** Estimation of the number of invasive species by the expert groups (median). Green represents the number of estimated invasive plant species, red the number of estimated invasive animal species. **B** Estimated annual damage caused by invasive species in dollar, estimated by each expert group on a logarithmic scale (median). The yellow line represents the annual damage for Germany (160 million US-Dollar) cal-culated by Haubrock et al. (2021b). The surveyed stakeholder groups from top center clockwise are: animal welfare sup-porters, divers, speleologists, members of environmental and conservation organizations, farmers, hunters and members in hunting associations, members in allotment garden clubs, administrative employees in the regulatory authority, employ-ees in zoological gardens
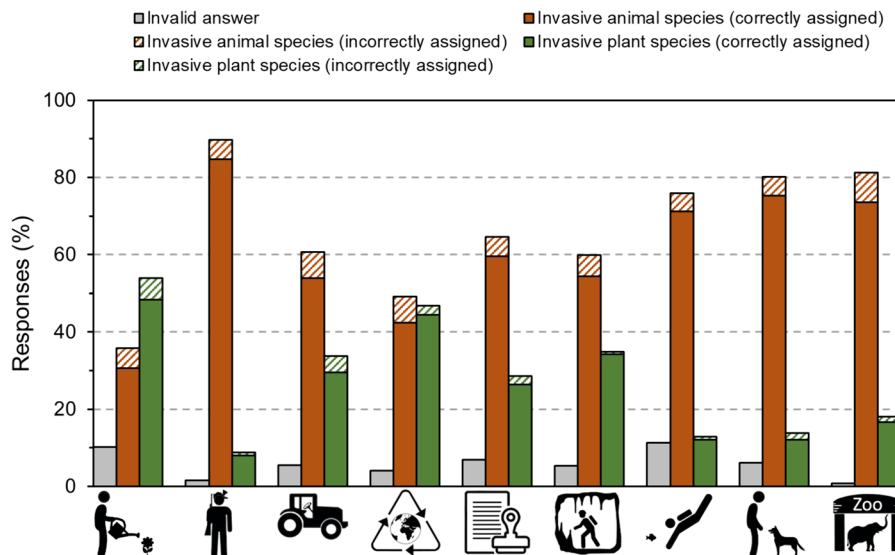

Fig. 2 Balance of responses between invasive plant species (green), animal species (orange) and invalid answers (gray) mentioned by each stakeholder group in percent. The striped areas represent incorrect answers (animal or plant species that were mentioned but are not invasive). The surveyed stakeholder groups left to right are: members in allotment garden clubs, hunters and members in hunting associations, farmers, members of environmental and conservation organizations, administrative employees in the regulatory authority, speleologists, divers, ani-mal welfare supporters, employees in zoological gardens

Table 4 The three most commonly named invasive animal and plant species for each of the stakeholder groups

	Animals			Plants		
Hunters and members in hunting associations	Procyon lotor (29.98%)	Nyctereutes procyonoides (18.34%)	Myocastor coypus (12.78%)	Impatiens glandulifera (2.74%)	Heracleum mantegazzianum (2.24%)	Polygonum cuspidatum (1.07%)
Farmers	Procyon lotor (17.89%)	Myocastor coypus (5.98%)	Harmonia axyridis (5.13%)	Impatiens glandulifera (9.40%)	Heracleum mantegazzianum (7.69%)	Polygonum cuspidatum (2.99%)
Members of environmental and conservation organizations	Procyon lotor (12.89%)	Nyctereutes procyonoides (4.30%)	Alopochen aegyptiaca (3.82%)	Impatiens glandulifera (11.93%)	Polygonum cuspidatum (11.46%)	Heracleum mantegazzianum (8.11%)
Members in allotment garden clubs	Procyon lotor (13.95%)	Harmonia axyridis (3.26%)	Sciurus carolinensis (1.86%)	Heracleum mantegazzianum (8.37%)	Polygonum cuspidatum (7.91%)	Impatiens glandulifera (7.44%)
Animal welfare supporters	Procyon lotor (28.57%)	Sciurus carolinensis (5.71%)	Trachemys scripta elegans (5.31%)	Impatiens glandulifera (5.31%)	Heracleum mantegazzianum (2.45%)	Ailanthus altissima (1.22%)
Divers	Procyon lotor (13.65%)	Lithobates catesbeianus (9.64%)	Faxonius limosus (6.43)	Heracleum mantegazzianum (3.21%)	Impatiens glandulifera (2.41%)	Elodea nuttallii (1.20%)
Employees in zoological gardens	Procyon lotor (24.31%)	Myocastor coypus (9.03%)	Nyctereutes procyonoides (7.64%)	Impatiens glandulifera (4.17%)	Heracleum mantegazzianum (3.47%)	Polygonum cuspidatum (2.78%)
Administrative employees in the regulatory authority	Procyon lotor (23.64%)	Myocastor coypus (7.73%)	Nyctereutes procyonoides (5.00%)	Heracleum mantegazzianum (12.27%)	Impatiens glandulifera (4.55%)	Polygonum cuspidatum (4.09%)
Speleologists	Procyon lotor (21.50%)	Myocastor coypus (4.00%)	Harmonia axyridis (3.50%)	Heracleum mantegazzianum (12.00%)	Impatiens glandulifera (11.00%)	Polygonum cuspidatum (7.50%)

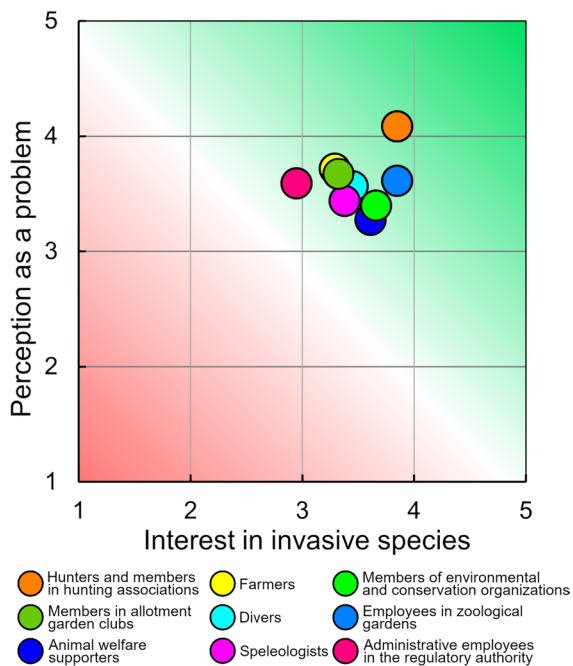The percentage in parentheses is based on the number of all mentions

Fig. 3 Perception of invasive species as a problem plotted against interest in invasive species. A high value represents high interest or strong perception as a problem. Each circle stands for a stakeholder group

of invasive species was at least in the correct order of magnitude (in the upper two or lower three-digit range). Thus, this result is consistent with a past study from New Zealand where respondents did not know the exact number of invasive species, but were at least in the correct range (Fraser 2001). The good estimates of the stakeholder groups surveyed could be due to a variety of reasons. Membership in one of the surveyed stakeholder groups puts the respondents in direct contact with the topic of invasive species. Past studies have shown that proximity to the topic or being personally affected by invasive species leads to individuals being aware and motivated for the topic (Schüttler et al. 2011; Verbrugge et al. 2013). However, it's important to acknowledge the limitations associated with these estimates. For instance, knowing the number of invasive species alone does not provide information about their distribution within Germany, which may differ regionally. This limitation could be addressed in future studies by conducting more localized surveys or incorporating geospatial data.

Similar to the number of invasive species, the economic damage caused by invasive species is also a significant factor influencing the management processes (Fraser et al. 2014; Larson et al. 2011). Similar to their numbers, the annual damage caused by invasive species is difficult to determine. An estimate conducted for Germany suggests approximately 160 million US-Dollar per year (Haubrock et al. 2021b). Here, the annual damage due to invasive species was significantly underestimated by all stakeholder groups. This result is also consistent with a previous study, which also found the damage done by invasive species is often underestimated (Waliczek et al. 2017). One possible explanation for this could be that invasive species are not only associated with economic or environmental problems, but also perceived positively in the population, especially if they are attractive or bring value in the form of ecosystem services (Dickie et al. 2014; Jubase et al. 2021). In addition, the economic damage caused by invasive species is not always directly visible. Therefore, this is why the extent of damage is not perceived and thus underestimated. It is also possible that the study participants only took into account the direct economic damage and not the management costs, which also make up part of the total economic damage.

Another reason for the significantly undervalued damage could be that large numbers and their relations to each other are often misjudged: First, a million is often perceived as a half way point between a thousand and a billion, or scale words such as thousand or million often serve as categories for large values rather than denoting exact sizes (Landy et al. 2013, 2017). Second, particularly large values are often underestimated (Izard and Dehaene 2008).

Regularly mentioned invasive species

When invasive species are named, there are only a few invalid or incorrect responses in each group (< 12%). This indicates that at least some invasive species are present in the stakeholders' knowledge and that the study participants were generally able to name at least three invasive species correctly. In almost all groups, significantly more animals were named than plants. This result could be due to the concept of "plant blindness" (Wandersee and Schussler 1999). This term describes the phenomenon that individuals are less interested in plants than animals, and plants are

more likely to be overlooked (Jose et al. 2019). For example, although there is a greater amount of invasive plant species estimated, animal species are listed for the most part. Interestingly, the number of studies dealing with invasive plants also predominates (Kapitza et al. 2019). An exception are the members in allotment garden clubs and members of environmental and conservation organizations, where the number of plants mentioned was higher or animals and plants almost equally distributed. The reason for this could be the focus of their work: Garden clubs focus on plants, so invasive plants play an important role in their work. Environmental and conservation organizations focus on the protection of ecosystems, which are also threatened by invasive plants.

On the contrary, a particularly high proportion of animals were mentioned by hunters, farmers, divers, and employees in zoological gardens, who prioritize animals: Animal rights activists advocate for the protection of animals, diving is primarily focused on observing animals in their habitat, zoo employees mostly manage animals, and hunters are usually confronted with the consequences and management of invasive animal species.

For the invasive species mentioned by the participants, there is a clear overlap between the expert groups for both plants and animals. Large mammals such as the raccoon (*Procyon lotor*), the nutria (*Myocastor coypus*) or the raccoon dog (*Nyctereutes procyonoides*) are particularly often mentioned as invasive animal species. Other vertebrate classes or other taxa are named much less often. It is proven that animals that are larger and whose appearance is more similar to humans are preferred (Gunnthorsdottir 2001). Particularly charismatic species that are perceived as beautiful or attractive and are portrayed in a positive light in the media are more likely to be accepted by society (Jarić et al. 2020). Especially for mammals more empathy and compassion is felt (Miralles et al. 2019) and they are perceived as particularly attractive and interesting (Landová et al. 2018; Moss and Esson 2010). This may result in larger mammals among the invasive species being noticed and remembered. Invasive carnivores in particular are widespread in the survey area and are especially conspicuous in their appearance (Peter et al. 2023). It is therefore understandable that the stakeholder groups are aware of these species in particular.

In almost all stakeholder groups, the most frequently mentioned plants were Himalayan balsam (*Impatiens glandulifera*), Japanese knotweed (*Polygonum cuspidatum*) and the giant hogweed (*Heracleum mantegazzianum*). All three species have distinctive characteristics that may be one reason these invasive plants are well known and therefore often named regardless of stakeholder group. *Heracleum mantegazzianum* has a whole range of defense mechanisms. In particular, the UV-dependent toxins that can cause photo dermatitis present a risk to the public (Hattendorf et al. 2007). Because of this negative impact, *Heracleum mantegazzianum* is well known and present in people's knowledge. *Impatiens glandulifera* on the other hand originated in the Himalayas and was brought to Europe in the seventeenth century. Because of its appearance, it has long been a desirable addition to gardens (Cockel and Tanner 2012) and because of its conspicuous appearance and its rapid growth rate it is unlikely to be overlooked (Pyšek and Prach 1995). Therefore, it is likely that this species is known to many people because of its aesthetics and spread. *Polygonum cuspidatum* is a perennial plant up to three meters tall (Barney et al. 2006). Daily growth can be up to 30 cm a day during the main growing season. This plant was also introduced in the seventeenth century as an ornamental and forage plant (Böhmer et al. 2006). Due to its size, distribution, and rapid growth, it is understandable that *Polygonum cuspidatum* is often recognized as an invasive species, regardless of stakeholder group.

Additionally, the attention that various species receive in the media could also be a reason for the increased mentions. A search in google news shows 26,300 hits for "Waschbär" [*Procyon lotor*] in Germany, while for example there were only 559 hits for "Drüsiges Springkraut" [*Impatiens glandulifera*] (Google 2023).

Interest and perception of invasive species

A positive picture emerges for interest in invasive species and perception of invasive species. Interest in a subject is an important factor that is closely related to learning and understanding of a topic (Schiefele and Schreyer 1994). For instance, interest leads to a more focused performance of tasks (Renninger and Hidi 2002) and more successful learning about a topic (Ainley et al. 2002). Therefore, interest in invasive

species can help acquire this necessary knowledge. Knowledge and awareness are important influencing factors when dealing with invasive species and their management process (Bravo-Vargas et al. 2019; Cole et al. 2016; Cordeiro et al. 2020; Höbart et al. 2020; Sosa et al. 2021). In our study, all stakeholder groups demonstrated a high level of interest in the topic of invasive species. This clearly distinguishes the stakeholder groups from the general population, where a previous study found that a good third were not interested in invasive species at all (Jubase et al. 2021). Only administrative employees in the regulatory authority showed slightly less interest, but this can be explained by the regulatory authority's focus. The authority's tasks cover a very broad spectrum to ensure public order and the reporting of invasive species is therefore only a small part of these tasks. As a result, not every employee actually deals with invasive species on a regular basis.

Invasive species are also considered an environmental problem in all groups. These results are consistent with previous studies. Although individuals in the general population tend to care less or only partially about invasive species and are less likely to perceive them as an issue (Verbrugge et al. 2013), stakeholder groups, on the other hand, are generally aware of their responsibilities and also perceive them as a problem (Bardsley and Edwards-Jones 2007; Burt et al. 2007; Colton and Alpert 1998; Kapler et al. 2012).

Implications

Stakeholder groups play a crucial role in invasive species management and the results of the study provide important evidence how these critical groups perceive invasive species. While the estimate of the number of invasive species had decent accuracy, the economic damage caused by these species was significantly underestimated in all groups. Because the impacts caused by invasive species are an important factor in how the issue is perceived (Shackleton et al. 2019a; Veitch and Clout 2001), more should be done to educate key stakeholder groups about the potential consequences of invasive species. For example, educational programs addressing invasive species and their consequences could be provided to stakeholder groups. These programs need to be designed to meet the needs of each stakeholder group. For instance, invasive terrestrial plants could be a particular focus for members in allotment garden clubs, while for divers the focus should be on aquatic invasive species. Other educational initiatives such as citizen science projects could also make a positive contribution. Stakeholders themselves could participate in monitoring or data collection on invasive species. This would help them to learn more about the problems and the damage caused by invasive species. For this purpose, such programs must be specifically developed and also made accessible to stakeholders.

In the case of the mentioned invasive species, especially conspicuous animal species were mostly named, while smaller inconspicuous species and plants were mentioned less often. To overcome this focus on charismatic invasive plants and animals, awareness campaigns and education programs should highlight the ecological and economic impacts of inconspicuous and smaller species. Information material could be provided to the stakeholder groups that also educates them about less conspicuous or small invasive species.

Interest in and awareness of invasive species as a problem was high among all groups. This result shows that the stakeholder groups recognize the problem, and through their interest are probably also open to receive more knowledge on the topic. Therefore, education in all different forms like seminars, courses or in online formats can be seen as a potential opportunity to improve stakeholder perceptions. However, it is important that educational programs are tailored to the target group. It is possible, for example, that arguments that work for hunters may have less of an impact on other groups such as animal rights activists. Social conflicts that can arise as a result of the management of invasive species in this context must also be taken into account (Crowley et al. 2017).

Conclusion

Stakeholder groups play an important role in the management of invasive species. The views and perceptions of invasive species by stakeholder groups are therefore an important topic that is still in urgent need of research. This study investigated how different stakeholder groups in Germany assess the spread and

damage of invasive species and which invasive species are particularly present in their perception. It also investigated whether there is interest in the topic and how invasive species are perceived.

The results reveal both common views and nuanced differences between the groups. The number of invasive animal and plant species occurring in Germany was estimated to be in the right order of magnitude by all stakeholder groups. However, the underestimation of economic damage indicates a potential awareness gap, highlighting the need for education programs that should be customized to the needs of stakeholders. When invasive species were named, particularly conspicuous and charismatic species were mentioned. Species with special characteristics were also mentioned particularly often, while smaller and inconspicuous species were rarely referred to. The high level of interest and perception of invasive species as an environmental problem across all stakeholder groups shows that the topic is important to them and that invasive species are perceived as a problem that requires action.

The results make an important contribution to the current scientific discourse. Despite the contribution, however, further research is needed, especially on the perception of stakeholders at an international and global level.

References

Ainley M, Hidi S, Berndorff D (2002) Interest, learning, and the psychological processes that mediate their relationship. J Educ Psychol 94:545–561. https://doi.org/10.1037/0022-0663.94.3.545

Andreu J, Vilà M, Hulme PE (2009) An assessment of stakeholder perceptions and management of noxious alien plants in Spain. Environ Manage 43:1244–1255. https://doi.org/10.1007/s00267-009-9280-1

Bacher S, Blackburn TM, Essl F, Genovesi P, Heikkilä J, Jeschke JM, Jones G, Keller R, Kenis M, Kueffer C, Martinou AF, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Roy HE, Saul W-C, Scalera R, Vilà M, Wilson JRU, Kumschick S (2018) Socio-economic impact classification of alien taxa (SEICAT). Methods Ecol Evol 9:159–168. https://doi.org/10.1111/2041-210X.12844

Bardsley DK, Edwards-Jones G (2007) Invasive species policy and climate change: social perceptions of environmental change in the Mediterranean. Environ Sci Policy 10:230–242. https://doi.org/10.1016/j.envsci.2006.12.002

Barney JN, Tharayil N, DiTommaso A, Bhowmik PC (2006) The biology of invasive alien plants in Canada. 5. Polygonum cuspidatum Sieb. & Zucc. [= Fallopia japonica (Houtt.) Ronse Decr.]. Can J Plant Sci 86:887–906. https://doi.org/10.4141/P05-170

Bellard C, Thuiller W, Leroy B, Genovesi P, Bakkenes M, Courchamp F (2013) Will climate change promote future invasions? Glob Chang Biol 19:3740–3748. https://doi.org/10.1111/gcb.12344

Blackburn TM, Essl F, Evans T, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Marková Z, Mrugała A, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Ricciardi A, Richardson DM, Sendek A, Vilà M, Wilson JRU, Winter M, Genovesi P, Bacher S (2014) A unified classification of alien species based on the magnitude of their environmental impacts. PLoS Biol 12:e1001850. https://doi.org/10.1371/journal.pbio.1001850

Böhmer HJ, Heger T, Alberternst B, Walser B (2006) Ökologie, Ausbreitung und Bekämpfung des Japanischen Staudenknöterichs (*Fallopia japonica*) in Deutschland: Ecology, dispersal and control of the Japanese Knotweed (*Fallopia japonica*) in Germany. Anliegen Natur 30:29–34

Bradley BA, Laginhas BB, Whitlock R, Allen JM, Bates AE, Bernatchez G, Diez JM, Early R, Lenoir J, Vilà M, Sorte CJB (2019) Disentangling the abundance-impact relationship for invasive species. Proc Natl Acad Sci U S A 116:9919–9924. https://doi.org/10.1073/pnas.1818081116

Bravo-Vargas V, García RA, Pizarro JC, Pauchard A (2019) Do people care about pine invasions? Visitor perceptions and willingness to pay for pine control in a protected area. J Environ Manage 229:57–66. https://doi.org/10.1016/j.jenvman.2018.07.018

Burt JW, Muir AA, Piovia-Scott J, Veblen KE, Chang AL, Grossman JD, Weiskel HW (2007) Preventing horticultural introductions of invasive plants: potential efficacy of voluntary initiatives. Biol Invasions 9:909–923. https://doi.org/10.1007/s10530-007-9090-4

Cockel CP, Tanner RA (2012) *Impatiens glandulifera* Royle (Himalayan balsam). In: Francis RA (ed) a handbook of global freshwater invasive species. Routledge, Abingdon, pp 67–78

Cole E, Keller RP, Garbach K (2016) Assessing the success of invasive species prevention efforts at changing the behaviors of recreational boaters. J Environ Manage 184:210–218. https://doi.org/10.1016/j.jenvman.2016.09.083

Colton TF, Alpert P (1998) Lack of public awareness of biological invasions by plants. Nat Areas J 18:262–266

Cordeiro B, Marchante H, Castro P, Marchante E (2020) Does public awareness about invasive plants pays off? An analysis of knowledge and perceptions of environmentally aware citizens in Portugal. Biol Invasions 22:2267–2281. https://doi.org/10.1007/s10530-020-02247-z

Crooks JA, Chang AL, Ruiz GM (2011) Aquatic pollution increases the relative success of invasive species. Biol Invasions 13:165–176. https://doi.org/10.1007/s10530-010-9799-3

Crowley SL, Hinchliffe S, McDonald RA (2017) Conflict in invasive species management. Front Ecol Environ 15:133–141. https://doi.org/10.1002/fee.1471

Crowley SL, Hinchliffe S, McDonald RA (2019) The parakeet protectors: understanding opposition to introduced species management. J Environ Manage 229:120–132. https://doi.org/10.1016/j.jenvman.2017.11.036

DAISIE (ed) (2009) Handbook of Alien Species in Europe. SpringerLink Bücher, vol 3. Springer Netherlands, Dordrecht

David P, Thébault E, Anneville O, Duyck P-F, Chapuis E, Loeuille N (2017) Impacts of invasive species on food webs: a review of empirical data. Adv Ecol Res 56:1–60. https://doi.org/10.1016/bs.aecr.2016.10.001

Diagne C, Leroy B, Vaissière A-C, Gozlan RE, Roiz D, Jarić I, Salles J-M, Bradshaw CJA, Courchamp F (2021) High and rising economic costs of biological invasions worldwide. Nature 592:571–576. https://doi.org/10.1038/s41586-021-03405-6

Dickie IA, Bennett BM, Burrows LE, Nuñez MA, Peltzer DA, Porté A, Richardson DM, Rejmánek M, Rundel PW, van Wilgen BW (2014) Conflicting values: ecosystem services and invasive tree management. Biol Invasions 16:705–719. https://doi.org/10.1007/s10530-013-0609-6

Early R, Bradley BA, Dukes JS, Lawler JJ, Olden JD, Blumenthal DM, Gonzalez P, Grosholz ED, Ibañez I, Miller LP, Sorte CJB, Tatem AJ (2016) Global threats from invasive alien species in the twenty-first century and national response capacities. Nat Commun 7:12485. https://doi.org/10.1038/ncomms12485

European Commission (2022) Commission Implementing Regulation (EU) 2022/1203 of 12 July 2022 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern: 2022/1203. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022R1203

European Commission (2023) European Alien species information network (EASIN): Joint Research Centre

Field A (2018) Discovering statistics using IBM SPSS statistics, 5th edn. SAGE Publications Ltd, London

Fraser EJ, Macdonald DW, Bryce R, Lambin X (2014) Controlling invasive species by empowering environmental stakeholders: ecotourism boat operators as potential guardians of wildlife against the invasive American mink. Oryx 48:605–612. https://doi.org/10.1017/S003060531300046X

Fraser W (2001) Introduced wildlife in New Zealand: A survey of general public views. Landcare Research science series, vol 23. Manaaki Whenua Press, Lincoln, Canterbury, New Zealand

Gaertner M, Larson BMH, Irlich UM, Holmes PM, Stafford L, van Wilgen BW, Richardson DM (2016) Managing invasive species in cities: a framework from Cape Town, South Africa. Landsc Urban Plan 151:1–9. https://doi.org/10.1016/j.landurbplan.2016.03.010

Gallardo B, Clavero M, Sánchez MI, Vilà M (2016) Global ecological impacts of invasive species in aquatic ecosystems. Glob Chang Biol 22:151–163. https://doi.org/10.1111/gcb.13004

García-Llorente M, Martín-López B, González JA, Alcorlo P, Montes C (2008) Social perceptions of the impacts and benefits of invasive alien species: Implications for management. Biol Cons 141:2969–2983. https://doi.org/10.1016/j.biocon.2008.09.003

Giakoumi S, Katsanevakis S, Albano PG, Azzurro E, Cardoso AC, Cebrian E, Deidun A, Edelist D, Francour P, Jimenez C, Mačić V, Occhipinti-Ambrogi A, Rilov G, Sghaier YR (2019) Management priorities for marine invasive species. Sci Total Environ 688:976–982. https://doi.org/10.1016/j.scitotenv.2019.06.282

GISD (2022) The global invasive species database. http://www.iucngisd.org/gisd/

Google (2023) Google news, search terms "Waschbäre" & "Drüsiges Springkraut"

Green SJ, Grosholz ED (2021) Functional eradication as a framework for invasive species control. Front Ecol Environ 19:98–107. https://doi.org/10.1002/fee.2277

Gunnthorsdottir A (2001) Physical attractiveness of an animal species as a decision factor for its preservation. Anthrozoös 14:204–215. https://doi.org/10.2752/089279301786999355

Hattendorf J, Hansen SO, Netwig W (2007) Defence systems of *Heracleum mantegazzianum*. In: Pyšek P, Cock MJW, Netwig W, Ravn HP (eds) Ecology and management of giant hogweed (*Heracleum mantegazziannum*). CABI, Wallingford, pp 209–225

Haubrock PJ, Turbelin AJ, Cuthbert RN, Novoa A, Taylor NG, Angulo E, Ballesteros-Mejia L, Bodey TW, Capinha C, Diagne C, Essl F, Golivets M, Kirichenko N, Kourantidou M, Leroy B, Renault D, Verbrugge L, Courchamp F (2021a) Economic costs of invasive alien species across Europe. NB 67:153–190. https://doi.org/10.3897/neobiota.67.58196

Haubrock PJ, Cuthbert RN, Sundermann A, Diagne C, Golivets M, Courchamp F (2021) Economic costs of invasive species in Germany. NB 67:225–246. https://doi.org/10.3897/neobiota.67.59502

Höbart R, Schindler S, Essl F (2020) Perceptions of alien plants and animals and acceptance of control methods among different societal groups. NB 58:33–54. https://doi.org/10.3897/neobiota.58.51522

Hoffmann BD, Broadhurst LM (2016) The economic cost of managing invasive species in Australia. NB 31:1–18. https://doi.org/10.3897/neobiota.31.6960

IPBES (ed) (2023) Summary for policymakers of the thematic assessment report on invasive alien species and their control of the intergovernmental science-policy platform on biodiversity and ecosystem services. IPBES secretariat, Bonn

Izard V, Dehaene S (2008) Calibrating the mental number line. Cognition 106:1221–1247. https://doi.org/10.1016/j.cognition.2007.06.004

Jarić I, Courchamp F, Correia RA, Crowley SL, Essl F, Fischer A, González-Moreno P, Kalinkat G, Lambin X, Lenzner B, Meinard Y, Mill A, Musseau C, Novoa A, Pergl J, Pyšek P, Pyšková K, Robertson P, Schmalensee M, Shackleton RT, Stefansson RA, Štajerová K, Veríssimo D, Jeschke JM (2020) The role of species charisma in biological invasions. Front Ecol Environ 18:345–353. https://doi.org/10.1002/fee.2195

Jolliffe IT, Cadima J (2016) Principal component analysis: a review and recent developments. Philos Trans A Math Phys Eng Sci 374:20150202. https://doi.org/10.1098/rsta.2015.0202

Jones BA (2017) Invasive species impacts on human well-being using the life satisfaction index. Ecol Econ 134:250–257. https://doi.org/10.1016/j.ecolecon.2017.01.002

Jose SB, Wu C-H, Kamoun S (2019) Overcoming plant blindness in science, education, and society. Plants People Planet 1:169–172. https://doi.org/10.1002/ppp3.51

Jubase N, Shackleton RT, Measey J (2021) Public awareness and perceptions of invasive alien species in small towns. Biology (Basel). https://doi.org/10.3390/biology10121322

Kapitza K, Zimmermann H, Martín-López B, von Wehrden H (2019) Research on the social perception of invasive species: a systematic literature review. NB 43:47–68. https://doi.org/10.3897/neobiota.43.31619

Kapler EJ, Thompson JR, Widrlechner MP (2012) Assessing stakeholder perspectives on invasive plants to inform risk analysis. Invasive Plant Sci Manag 5:194–208. https://doi.org/10.1614/IPSM-D-11-00067.1

Keller RP, Geist J, Jeschke JM, Kühn I (2011) Invasive species in Europe: ecology, status, and policy. Environ Sci Eur. https://doi.org/10.1186/2190-4715-23-23

Kleespies MW, Dierkes PW (2020) Personal assessment of reasons for the loss of global biodiversity—an empirical analysis. Sustainability 12:4277. https://doi.org/10.3390/su12104277

Kleespies MW, Doderer L, Dierkes PW, Wenzel V (2021) Nature interest scale—development and evaluation of a measurement instrument for individual interest in nature. Front Psychol 12:774333. https://doi.org/10.3389/fpsyg.2021.774333

Krapp A (1993) The construct of interest: characteristics of indvidual interests and interest-related actions from the perspective of a person-object-theory. Stud Educ Psychol 4:1–18

Landová E, Poláková P, Rádlová S, Janovcová M, Bobek M, Frynta D (2018) Beauty ranking of mammalian species kept in the Prague Zoo: does beauty of animals increase the respondents' willingness to protect them? Naturwissenschaften 105:69. https://doi.org/10.1007/s00114-018-1596-3

Landy D, Silbert N, Goldin A (2013) Estimating large numbers. Cogn Sci 37:775–799. https://doi.org/10.1111/cogs.12028

Landy D, Charlesworth A, Ottmar E (2017) Categories of large numbers in line estimation. Cogn Sci 41:326–353. https://doi.org/10.1111/cogs.12342

Larson DL, Phillips-Mao L, Quiram G, Sharpe L, Stark R, Sugita S, Weiler A (2011) A framework for sustainable invasive species management: environmental, social, and economic objectives. J Environ Manage 92:14–22. https://doi.org/10.1016/j.jenvman.2010.08.025

Leadley P (2010) Biodiversity Scenarios: Projections of 21st century change in biodiversity and associated ecosystem services: a technical report for the global biodiversity outlook 3. Secretariat of the convention on biological diversity, Montreal, QC, Canada

Mainka SA, Howard GW (2010) Climate change and invasive species: double jeopardy. Integr Zool 5:102–111. https://doi.org/10.1111/j.1749-4877.2010.00193.x

Miralles A, Raymond M, Lecointre G (2019) Empathy and compassion toward other species decrease with evolutionary divergence time. Sci Rep 9:19555. https://doi.org/10.1038/s41598-019-56006-9

Moss A, Esson M (2010) Visitor interest in zoo animals and the implications for collection planning and zoo education programmes. Zoo Biol 29:715–731. https://doi.org/10.1002/zoo.20316

Ngorima A, Shackleton CM (2019) Livelihood benefits and costs from an invasive alien tree (Acacia dealbata) to rural communities in the Eastern Cape, South Africa. J Environ Manage 229:158–165. https://doi.org/10.1016/j.jenvman.2018.05.077

Paini DR, Sheppard AW, Cook DC, de Barro PJ, Worner SP, Thomas MB (2016) Global threat to agriculture from invasive species. Proc Natl Acad Sci U S A 113:7575–7579. https://doi.org/10.1073/pnas.1602205113

Pejchar L, Mooney HA (2009) Invasive species, ecosystem services and human well-being. Trends Ecol Evol 24:497–504. https://doi.org/10.1016/j.tree.2009.03.016

Peter N, Dörge DD, Cunze S, Schantz AV, Skaljic A, Rueckert S, Klimpel S (2023) Raccoons contraband—The metazoan parasite fauna of free-ranging raccoons in central Europe. Int J Parasitol Parasites Wildl 20:79–88. https://doi.org/10.1016/j.ijppaw.2023.01.003

Pimentel D, Lach L, Zuniga R, Morrison D (2000) Environmental and economic costs of nonindigenous species in the United States: David Pimentel, Lori Lach, Rodolfo Zuniga. Doug Morrison Biosci 50:53. https://doi.org/10.1641/0006-3568(2000)050[0053:EAECON]2.3.CO;2

Potgieter LJ, Gaertner M, O'Farrell PJ, Richardson DM (2019) Perceptions of impact: invasive alien plants in the urban environment. J Environ Manage 229:76–87. https://doi.org/10.1016/j.jenvman.2018.05.080

Pyšek P, Prach K (1995) Invasion dynamics of Impatiens glandulifera—a century of spreading reconstructed. Biol Cons 74:41–48. https://doi.org/10.1016/0006-3207(95)00013-T

Pyšek P, Hulme PE, Simberloff D, Bacher S, Blackburn TM, Carlton JT, Dawson W, Essl F, Foxcroft LC, Genovesi P, Jeschke JM, Kühn I, Liebhold AM, Mandrak NE, Meyerson LA, Pauchard A, Pergl J, Roy HE, Seebens H, van Kleunen M, Vilà M, Wingfield MJ, Richardson DM (2020) Scientists' warning on invasive alien species. Biol Rev Camb Philos Soc 95:1511–1534. https://doi.org/10.1111/brv.12627

Radek C How people's activities affect their knowledge. https://www.iiseagrant.org/NabInvader/Lakes/admin/AIS_stewardshipProejcts/ProjectsType/Invasive_Species_Paper-Chris%20Radek.pdf

Rahel FJ, Olden JD (2008) Assessing the effects of climate change on aquatic invasive species. Conserv Biol 22:521–533. https://doi.org/10.1111/j.1523-1739.2008.00950.x

Remmele M, Lindemann-Matthies P (2020) Dead or Alive? Teacher students' perception of invasive alien animal species and attitudes towards their management. EURASIA J MATH SCI T. https://doi.org/10.29333/ejmste/115105

Renninger AK, Hidi S (2002) Student interest and achievement. In: Wigfield A, Eccles J (eds) Development of achievement motivation. Academic Press, Cambridge, MA, pp 173–195

Rodríguez-Rey M, Borrell YJ, Dopico E, Muha TP, Rolla M (2022) Understanding public perceptions toward invasive species in different parts of Europe. J Environ Planning Manage 65:2257–2275. https://doi.org/10.1080/09640568.2021.1969899

Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Wall DH (2000) Global biodiversity scenarios for the year 2100. Science 287:1770–1774. https://doi.org/10.1126/science.287.5459.1770

Schiefele U, Schreyer I (1994) Intrinsische Lernmotivation und Lernen. Ein Überblick zu Ergebnissen der Forschung: [Intrinsic motivation to learn and learning: a review of recent research findings]. Z Pädag Psychol German J Educ Psychol 8:1–13

Schüttler E, Rozzi R, Jax K (2011) Towards a societal discourse on invasive species management: a case study of public perceptions of mink and beavers in Cape Horn. J Nat Conserv 19:175–184. https://doi.org/10.1016/j.jnc.2010.12.001

Seebens H, Blackburn TM, Dyer EE, Genovesi P, Hulme PE, Jeschke JM, Pagad S, Pyšek P, Winter M, Arianoutsou M, Bacher S, Blasius B, Brundu G, Capinha C, Celesti-Grapow L, Dawson W, Dullinger S, Fuentes N, Jäger H, Kartesz J, Kenis M, Kreft H, Kühn I, Lenzner B, Liebhold A, Mosena A, Moser D, Nishino M, Pearman D, Pergl J, Rabitsch W, Rojas-Sandoval J, Roques A, Rorke S, Rossinelli S, Roy HE, Scalera R, Schindler S, Štajerová K, Tokarska-Guzik B, van Kleunen M, Walker K, Weigelt P, Yamanaka T, Essl F (2017) No saturation in the accumulation of alien species worldwide. Nat Commun 8:14435. https://doi.org/10.1038/ncomms14435

Seebens H, Bacher S, Blackburn TM, Capinha C, Dawson W, Dullinger S, Genovesi P, Hulme PE, van Kleunen M, Kühn I, Jeschke JM, Lenzner B, Liebhold AM, Pattison Z, Pergl J, Pyšek P, Winter M, Essl F (2020) Projecting the continental accumulation of alien species through to 2050. Glob Chang Biol. https://doi.org/10.1111/gcb.15333

Shackleton RT, Richardson DM, Shackleton CM, Bennett B, Crowley SL, Dehnen-Schmutz K, Estévez RA, Fischer A, Kueffer C, Kull CA, Marchante E, Novoa A, Potgieter LJ, Vaas J, Vaz AS, Larson BMH (2019a) Explaining people's perceptions of invasive alien species: a conceptual framework. J Environ Manage 229:10–26. https://doi.org/10.1016/j.jenvman.2018.04.045

Shackleton RT, Adriaens T, Brundu G, Dehnen-Schmutz K, Estévez RA, Fried J, Larson BMH, Liu S, Marchante E, Marchante H, Moshobane MC, Novoa A, Reed M, Richardson DM (2019b) Stakeholder engagement in the study and management of invasive alien species. J Environ Manage 229:88–101. https://doi.org/10.1016/j.jenvman.2018.04.044

Shrestha BB, Shrestha UB, Sharma KP, Thapa-Parajuli RB, Devkota A, Siwakoti M (2019) Community perception and prioritization of invasive alien plants in Chitwan–Annapurna landscape. Nepal J Environ Manage 229:38–47. https://doi.org/10.1016/j.jenvman.2018.06.034

Sosa AJ, Jiménez NL, Faltlhauser AC, Righetti T, Mc Kay F, Bruzzone OA, Stiers I, Fernández Souto A (2021) The educational community and its knowledge and perceptions of native and invasive alien species. Sci Rep 11:21474. https://doi.org/10.1038/s41598-021-00683-y

Straka TM, Bach L, Klisch U, Egerer MH, Fischer LK, Kowarik I (2022) Beyond values: How emotions, anthropomorphism, beliefs and knowledge relate to the acceptability of native and non-native species management in

cities. People Nat 4:1485–1499. https://doi.org/10.1002/pan3.10398

Tobin PC (2018) Managing invasive species. F1000Res. https://doi.org/10.12688/f1000research.15414.1

U.S. Department of the Interior (2021) U.S. Department of the interior invasive species strategic plan, Fiscal Years 2021–2025. https://www.doi.gov/sites/doi.gov/files/doi-invasive-species-strategic-plan-2021-2025-508.pdf

Vanderhoeven S, Piqueray J, Halford M, Nulens G, Vincke J, Mahy G (2011) Perception and understanding of invasive alien species issues by nature conservation and horticulture professionals in Belgium. Environ Manage 47:425–442. https://doi.org/10.1007/s00267-011-9621-8

Varó I, Redón S, Garcia-Roger EM, Amat F, Guinot D, Serrano R, Navarro JC (2015) Aquatic pollution may favor the success of the invasive species *A. franciscana*. Aquat Toxicol 161:208–220. https://doi.org/10.1016/j.aquatox.2015.02.008

Vaz AS, Ribeiro J, Honrado JP, Vicente JR (2020) Stakeholders' perceptions towards non-native acacias and implications for their management in Portugal. For Int J For Res 93:557–566. https://doi.org/10.1093/forestry/cpz060

Veitch CR, Clout MN (2001) Human dimensions in the management of invasive species in New Zealand. In: McNeely JA (ed) The great reshuffling: Human dimensions of invasive alien species. IUCN—The World Conservation Union, Gland, pp 63–71

Verbrugge LNH, van den Born RJG, Lenders HJR (2013) Exploring public perception of non-native species from a visions of nature perspective. Environ Manage 52:1562–1573. https://doi.org/10.1007/s00267-013-0170-1

Waliczek TM, Williamson PS, Oxley FM (2017) College student knowledge and perceptions of invasive species. Hortte 27:550–556. https://doi.org/10.21273/HORTTECH03709-17

Walther G-R, Roques A, Hulme PE, Sykes MT, Pysek P, Kühn I, Zobel M, Bacher S, Botta-Dukát Z, Bugmann H, Czúcz B, Dauber J, Hickler T, Jarosík V, Kenis M, Klotz S, Minchin D, Moora M, Nentwig W, Ott J, Panov VE, Reineking B, Robinet C, Semenchenko V, Solarz W, Thuiller W, Vilà M, Vohland K, Settele J (2009) Alien species in a warmer world: risks and opportunities. Trends Ecol Evol 24:686–693. https://doi.org/10.1016/j.tree.2009.06.008

Wandersee JH, Schussler EE (1999) Preventing plant blindness. Am Biol Teach 61:82–86. https://doi.org/10.2307/4450624

Wang W, Zhang C, Allen J, Li W, Boyer M, Segerson K, Silander J (2016) Analysis and prediction of land use changes related to invasive species and major driving forces in the state of Connecticut. Land 5:25. https://doi.org/10.3390/land5030025

Ziska LH, Blumenthal DM, Runion GB, Hunt ER, Diaz-Soltero H (2011) Invasive species and climate change: an agronomic perspective. Clim Change 105:13–42. https://doi.org/10.1007/s10584-010-9879-5