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# Invasive Alien Species in Switzerland: Awareness and Preferences of Experts and the Public

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## Abstract

Invasive alien species (IAS) can cause ecological and economic damages. To reduce or prevent these damages different management and prevention strategies aim to impede new establishments or a further spreading of IAS. However, for these measures to be successful, public knowledge of risks and threats of IAS as well as public support for eradication measures are important prerequisites. We conducted a survey to examine (i) public and experts' awareness and knowledge of IAS, (ii) their preferences for six invasive plant species and (iii) their preferences for and trade-offs among management alternatives in Switzerland. In addition, a choice experiment was applied to analyse preferences concerning the intensity, priority and costs of interventions. Both, the Swiss public and the experts have a preference for intervening against invasive alien species. However, the public and the experts differ in their priorities of combatting particular species, resulting in a different ranking of intervention necessities. Further, differences were found in the willingness to pay for interventions between the German-, French- and Italian-speaking parts of Switzerland. The results suggest that a higher problem awareness increases the willingness to pay for countermeasures. We conclude that education programs or information campaigns are promising instruments to raise public awareness and to avoid conflicts concerning the management of invasive alien species.

### Highlights "Invasive Alien Species in Switzerland: Awareness and Preferences of Experts and the Public"

- The public and experts in Switzerland approve the management of invasive neophytes
- Willingness to pay estimates for the management of invasive alien species (IAS) vary between 7 and 38 Mio. Swiss Francs (SFr.)/year
- Ecological aspects in IAS management receive a higher priority than economic aspects
- However, only 40% of the public know the term IAS
- Providing information on the threats of IAS increases awareness and reduces aesthetic preferences for the respective species

**Keywords** Choice experiment · Willingness to pay · Exotic species · IAS · Environmental management · Attitudes

## Introduction

Invasive alien species (IAS) are one of the major threats to biodiversity worldwide (MAE 2005). By outcompeting native species they can cause major changes in communities and ecosystems and therefore are considered as a severe threat to ecosystem functioning (Vilà et al. 2011). In addition, IAS can have various negative economic impacts e.g. reducing agricultural production, damaging infrastructure such as railways, roads, buildings or water systems and, in addition, can negatively influence human health or well-being (McNeely 2001; Pejchar and Mooney 2009; Vilà and Hulme 2016). In Europe, over 1000 alien species have

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ecological or economic impacts and thus are considered to be invasive (Vilà et al. 2010). The current situation of IAS in Switzerland is comparable to other Central European countries, however, within Switzerland the distribution of IAS varies due to biogeographical differences with a lower pressure of IAS in high elevations of the Alps (Wittenberg et al. 2005). Climatically warmer regions, e.g. Southern Switzerland or the region of Lake Geneva, are more affected by IAS than colder regions (Taramarcaz et al. 2005; Walther et al. 2007). Currently, there are around 550 alien plant species in Switzerland, about 10% are invasive or potentially invasive and 41 species are listed on the black list for alien invasive plant species.[1]

The Convention of Biodiversity (CBD) defines three measures against the introduction and spread of harmful invasive species: prevention, control, and eradication (Genovesi and Shine 2004). As new introductions may lead to irreversible changes, prevention has highest priority in IAS management. If prevention fails, early detection and rapid response enable cost-effective removal (Simberloff et al. 2013). All these interventions have two typical characteristics (Gren 2008): 'non rivalry' and 'non excludability'. In case they are successful, on the one hand nobody can be excluded from the positive effect, and on the other hand there is no rivalry among individuals concerning the prevention from possible damages. In consequence, free-riding would prevail and no private entity would provide such public services to combat IAS. Therefore, to implement successful and sustainable measures, policies have to consider expert opinion, stakeholder awareness and public perception, as well as regional ecological and economic circumstances (Albers et al. 2010). Moreover, in-migration of alien species to new habitats or regions is closely linked to human activities due to transport systems, tourist activities and private gardening, as many invasive species are introduced as hitchhiker organisms, e.g. in ballast water of ships, seeds on car tyres or are still supplied by the flower and garden business. Thus, information and awareness raising of the public plays an important role in controlling invasive alien species (Hulme 2006; Humair et al. 2014b; McNeely 2001). In Switzerland, the federal authorities are responsible for the regulation, coordination and implementation of IAS management, and moreover, for enhancing the public awareness of IAS and informing and educating relevant target groups.[2] The support by the public can be crucial for the success or failure of IAS management, as invasive species—besides their mentioned negative effects—provide aesthetic benefits for humans, and are often introduced for economic reasons. Thus, control and eradication measures may cause public critique and conflicts (Buijs et al. 2011; Veitch and Clout 2001). In addition, strategies of combatting invasive non-native species, and the concept of invasion biology in general, are controversially discussed even among experts (e.g. Thompson and Davis 2011; Valéry et al. 2013). The lacking consensus among experts leads to misunderstandings and hinders the dialogue between science, practitioners and the general public (Humair et al. 2014a). In consequence, common management priorities and coordinated strategies are often missing.

Researchers and public authorities claim that prevention and thus information and sensitisation of the public are among the most important measures in IAS management (e.g. Hulme 2006; McNeely 2001). However, little is known about the knowledge of, attitudes towards and preferences for IAS species in the general public (Lindemann-Matthies 2016) and misleading public concepts such as an enrichment of local biodiversity by the invasion of "new" species need clarification (Simberloff et al. 2013). Research on public attitudes concerning IAS management reveals that (i) awareness and knowledge of invasive species have a decisive impact on attitudes towards invasive species management (Adams et al. 2011; Bremner and Park 2007) and that (ii) the support of different management regimes varies among stakeholder groups (García-Llorente et al. 2011; Sharp et al. 2011). A higher educational level and a 'nature-friendly' attitude have been identified as indicators of supporting IAS controlling, whereas economic interests reduce such preferences (Garcia Llorente et al. 2008; Sharp et al. 2011). Different preferences for species and management options might arise due to people's specific perceptions, beliefs and underlying values (Fischer and van der Wal 2007; Selge and Fischer 2011). Recent research shows that the negative impact on ecosystems and economy are strong motives for supporting species management, whereas the fact that species are alien is considerably less problematic (Van der Wal et al. 2015).

The present study contributes to the existing IAS literature by conducting a choice experiment, focussing on intensity, priority and costs of management alternatives in a public and expert survey in Switzerland. The main novelties are (i) the exploration of public and expert knowledge of and preferences for invasive alien plant species and (ii) the estimation of the willingness to pay for species-specific management options and for different intensities and priorities of IAS interventions. Further, this study is the first to test the influence of providing information on the threats and damages caused by IAS on the aesthetic valuation of

[1] The National Data and Information Center on the Swiss Flora; available online: https://www.infoflora.ch/en/neophytes/lists.html. Accessed 1 October 2018

[2] The Swiss national strategy on IAS management is available online (in German): https://www.bafu.admin.ch/bafu/de/home/themen/biodiversitaet/fachinformationen/massnahmen-zur-erhaltung-und-foerderung-der-biodiversitaet/erhaltung-und-foerderung-von-arten/invasive-gebietsfremde-arten.html Accessed 1 October 2018

invasive plant species. Given that decisions about management measures are taken by public authorities and experts, the preferences of experts are explored and compared with the general public to identify potential conflicts between them. One of the aims of the Swiss Strategy on IAS management is to harmonise the management of different administration levels and among different regions, e.g. different cantons. In this respect, regional differences in IAS awareness might play an important role in decision-making as the occurrence and, possibly in line with this, the public perception and knowledge of IAS might vary in different parts of Switzerland (Lindemann-Matthies 2016).

Knowledge on the public and expert perception on IAS and the respective management, as well as regional differences, provide a basis for designing appropriate awareness raising measures and education programmes. Moreover, insights on IAS perception can help to increase the acceptance of intervention measures and, in addition, can foster the dialogue between different stakeholders if conflicting interests are emerging. A common understanding of the IAS issue can help to increase the target achievement of the management aims formulated in the Swiss strategy on IAS management.

## Methods

### Public and Expert Sample

In July 2014, a public online survey with 1251 participants was conducted, using an online panel sample of a private provider. This Swiss panel consists of more than 50,000 participants of the German, French- and Italian-speaking parts of the country and meets quality standards of the ICC/ESOMAR International Code on Market and Social Research.

After data clearing, 1146 respondents were included in the analysis. The respondents were between 18 and 69 years old, 49.7% were female and 36.0% hold a degree in higher education. Most of the respondents were from the German language region (68.7%), 25.8% were from the French and 5.5% from the Italian language region. The observed frequencies of the sample do not significantly differ from the frequencies of these four variables in the Swiss public (age, grouped in 5 categories: $p = 0.736$, gender: $p = 0.560$, education level: $p = 0.540$, language region: $p = 0.219$; chi-square goodness of fit tests). Among the respondents 4.6% were farmers, 4.3% worked in horticulture, 3.0% had professions related to the field of conservation, landscape protection or landscape planning and 16.6% were members of environmental organisations. More than half of the respondents (55%) have their own garden and 59.4% indicated that they are active gardeners either in the garden or at the terrace or balcony.

To compare the attitudes of and preferences for IAS between the general public and experts, the same questionnaire was sent to 195 experts in the field of IAS and nature conservation in January 2015. As the choice experiment requires information on the basis of a private household decision, experts were asked to answer the questionnaire based on their expert knowledge but as a private person, representing a household. Members of the Swiss consortium of invasive neobiota, the federal and cantonal environmental and agricultural authorities, environmental organisations and environmental consulting companies, the horticulture sector and scientists in the field of IAS were invited. A total of 151 persons participated in the survey (response rate of 77.4%). Most of the respondents worked in nature or environmental protection (68.9%), 20.5% worked in agriculture, 9.3% in forestry and 6.0% in horticulture. A majority was employed in public administration (64.9%), 15.9% in science, 14.6% in the private sector and 7.9% at foundations or associations. The average age was 45.5 years, 68.9% were male and 77.5% were from the German language region, 14.6% from the French and 7.9% from Italian language region of Switzerland. A portion of 70.9% was member of environmental organisations and 78.8% had their own garden.

### Questionnaire and Choice Experiment

Six invasive neophytes were selected for the questionnaire: giant hogweed (*Heracleum mantegazzianum*), tree of heaven (*Ailanthus altissima*), goldenrod (*Solidago canadensis* and *S. gigantea*), himalayan balsam (*Impatiens glandulifera*), cherry laurel (*Prunus laurocerasus*) and knotweed (*Reynoutria japonica*, *R. sachalinensis* and *R. bohemica*); comparition in Fig. 1. These species are among the most common invasive neophytes in Switzerland[1] and were selected by the following criteria: (i) distribution, (ii) ecological or economic damage, (iii) health risk and (iv) regional differences. The selection process was based on expert discussions with 12 experts from science, administration, NGOs and environmental consulting companies. So far, tree of heaven and cherry laurel mainly cause problems in southern Switzerland but are currently increasing their spread in the northern part of Switzerland, predominantly near settlement areas. Both plant species are on sale (e.g. in garden centres), while the other four ones are under prohibition of sale.

Without providing any information on invasive neophytes beforehand, study participants were asked in a first step to indicate whether they know randomly ordered plant species by name or sight and to rate each plant species by attractiveness on a seven-step scale (ranging from 1: 'totally dislike it' to 7: 'totally like it'). Thereafter, they were asked (i) whether they know the term 'invasive alien species', (ii)

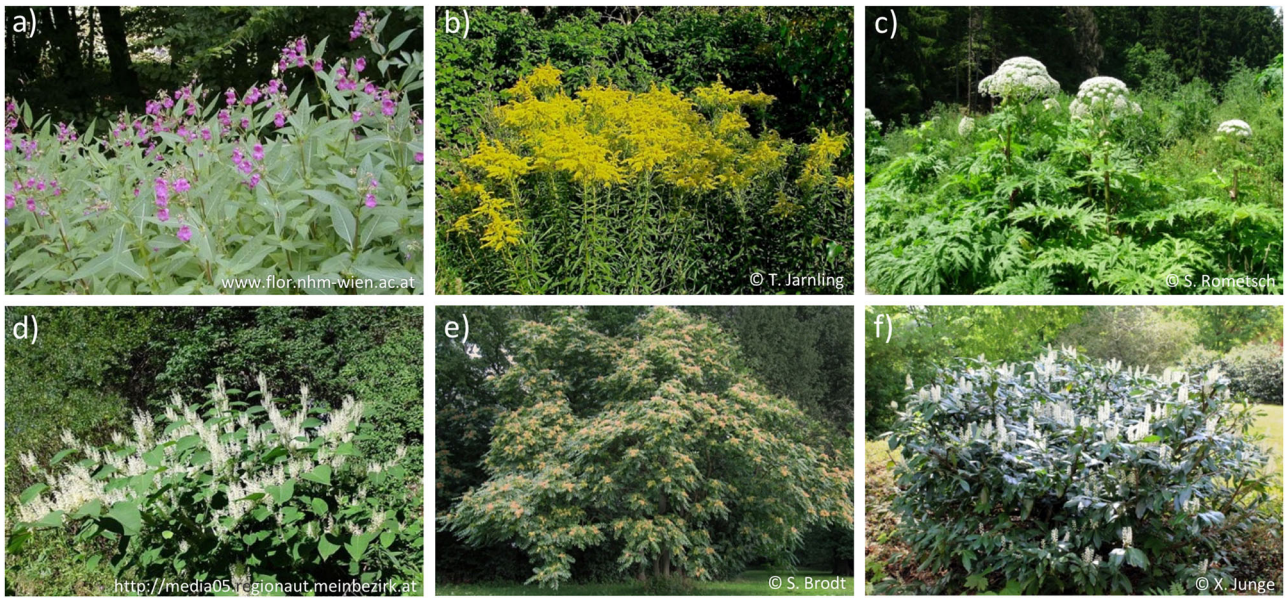


**Fig. 1** Invasive alien plant species considered in the survey: **a** himalayan balsam, *Impatiens glandulifera*, **b** goldenrod, *Solidago canadensis* or *S. gigantea*., **c** giant hogweed, *Heracleum mantegazzianum*, **d** knotweed, *Reynoutria japonica*, *R. sachalinensis* or *R. bohemica*, **e** tree of heaven, *Ailanthus altissima*, **f** cherry laurel, *Prunus laurocerasus*

**Table 1** Labels, attributes and levels of the choice experiment

| Label | Attributes | | |
|---|---|---|---|
| Species | Intervention intensity | Prevention priority | Costs (CHF) |
| Giant Hogweed | Specific sites only | Ecological damages | 15 |
| Tree of Heaven | Main dispersal areas | Economic damages | 50 |
| Goldenrod | Swiss-wide | — | 100 |
| Himalayan Balsam | — | — | — |
| Cherry Laurel | — | — | — |
| Knotweed | — | — | — |

where they have heard about it and (iii) what associations they have with it. In a further step, we provided information on invasive neophytes in general, and on the six presented neophytes in particular.

The central part of the questionnaire comprised a choice experiment. This stated preference method analyses how people make decisions based on multiple criteria and aims to analyse people's preferences, in our case to combat invasive plant species. We used a labelled experiment, where the species' names were applied as labels for the different options to intervene. These options are defined as combinations of attributes and their levels. The choice sets comprised three attributes: intensity, priority and costs of intervention (Table 1). The 'intensity' levels were defined as intervening (a) at specific sites only, (b) in the main dispersal area or (c) Swiss-wide. Regarding the 'priority' we defined two levels: intervening mainly to prevent (a) ecological damages or (b) economic damages. The cost attribute referred to an increase in the households' annual income tax and comprised three levels: 15, 50 and 100 Swiss Francs (SFr approx. USD 15, 50 and 100).

In each choice set three options were given: two options to combat specific species and a further option not to intervene (opt-out). It is assumed that the respondents are households that decide as a unit and strive to maximise their utility. This means that they use all available information and make their decision based on comparing pros and cons of the respective options. The selection of one option over another implies that the utility of that option is higher than the utility of any other option (Louviere 2001). The households' decision behaviour is analysed based on random utility theory, which postulates that these choices can be modelled as a function of the attributes of the options, while recognizing that a researcher cannot observe all factors that influence the decision (McFadden 1973). Therefore, the utility $U$ of an alternative $i$ for an individual household $n$ is assumed to consist of an observable component $V$, which is given by the attributes described above,

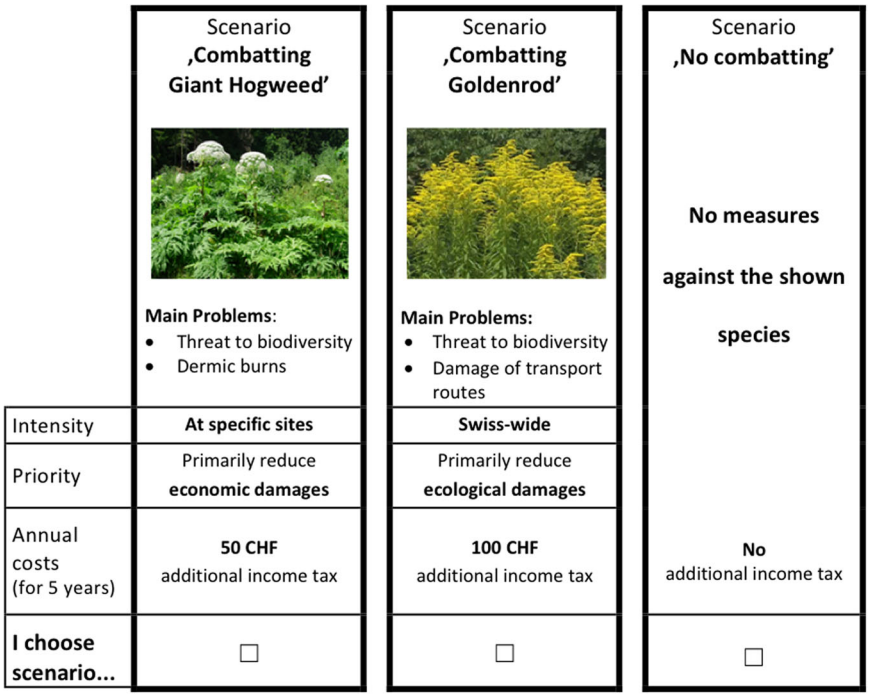


**Fig. 2** Example of a choice set in the questionnaire. In each choice set three options were given: intervention on specific sites only, intervention swiss-wide, no intervention

and an unobserved random component $\varepsilon$ (Louviere 2001).

$$U_{ni} = V_{ni} + \varepsilon_{ni} \tag{1}$$

The observable component is specified below, where β, γ and δ are the coefficients of the observable attributes 'intensity', 'priority' and 'costs', respectively. The alternative-specific constants ($\alpha = \text{ASC}$) capture a systematic variation in choices that cannot be explained by the considered attributes (Bennett and Adamowicz 2001).

$$\begin{aligned} V_{combat\,HB,GR,GH,KW,TH,CL} &= \alpha_{combat\,HB,GR,GH,KW,TH,CL} + \beta \cdot INT \\ &\quad + \overline{\gamma}_1 \cdot PRIO_1 + \gamma_2 \cdot PRIO_2 + \delta \cdot COST \\ V_{opt\,out} &= \overline{\alpha}_{opt\,out} \end{aligned} \tag{2}$$

Note that the alternative-specific constant $\alpha_{\text{opt out}}$ and the coefficient of the attribute 'priority of preventing of ecological damages' ($\gamma_1$) have been fixed in order to estimate differences between the labelled alternatives and the specific attribute levels, respectively.

The experiment consisted of 12 choice sets (compare Fig. 2). It was based on an efficient design generated by the 'Ngene' software in order to estimate parameters with the lowest possible standard errors (ChoiceMetrics 2012). Prior parameter values have been determined using results of a pre-test with 110 respondents. The statistical analysis has been conducted with the 'BIOGEME' software (Bierlaire 2003, 2008). After testing several model specifications we found that applying a labelled multinomial logit model provided the best data fit (Olschewski 2013).

In addition to the choice experiment, study participants were asked to give their opinion on a number of statements concerning the management of IAS on five-step rating scales (ranging from 1: disagree to 5: agree). To investigate the influence of the provided information about invasive neophytes on perceived attractiveness, study participants were asked again at the end of the study to rate the six plant species by attractiveness on a seven-step scale.

Further, we asked several questions to investigate human-nature relationships among the participants, using a 10-item NEP-scale to measure attitudes and values of nature (New Environmental Paradigm (Dunlap and van Liere 1978), adapted by Schultz and Zelezny (1999)). The New Environmental Paradigm Scale measures environmental attitudes or pro-environmental orientation with a balanced set of pro- and anti-NEP items. In the NEP, the facets of the reality of limits to growth, anti-anthropocentrism, the fragility of nature's balance, the rejection of exemptionalism and the possibility of an eco-crisis are represented. Dunlap et al. (2000) encourage the researchers to factor-analyze the set of items to see if two or three dimensions actually emerge as the dimensions are often sample specific. A factor analysis revealed two factors: (1) the 'nature lovers' have a strong pro-environmental orientation and agree with items related to the reality of limits to growth, fragility of nature's balance, and the possibility of an eco-crisis; (2) the 'nature framers' have an anthropocentric orientation, disagree with items describing anthropocentrism and agree with exemptionalism, i.e. the idea that the relationship between humans and nature is not important as humans are

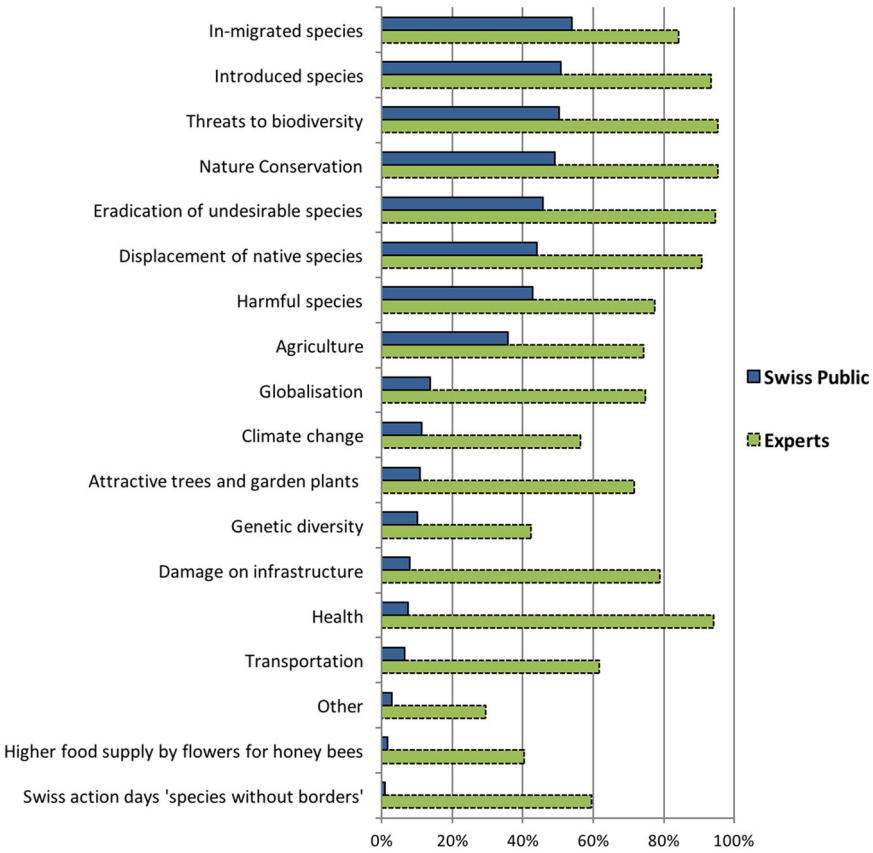


**Fig. 3** Topics the general public and experts associate with 'invasive alien species'. Multiple answers were allowed. (Filter: 'have heard about IAS'; Public $N = 769$; Experts $N = 151$)

'exempt' from environmental forces as they can adapt and control nature. The factor scores were later included in the analysis of the choice experiment by building groups of 0/1 for nature lovers or framers, respectively.

To investigate socio-demographic differences the following variables were collected in the survey: age, gender, education, language region, place of residence and profession. Study participants were further asked to indicate whether they are members of environmental organisations or not and whether they do gardening or not. A last set of questions dealt with the commerce of IAS in garden centres.

## Results

### Awareness of IAS in Switzerland

#### Knowledge of the term and associations with IAS

The definition of the term 'invasive alien species' is known by 40% of the general public. About a quarter has heard about the term, but with unknown (21%) or wrong (6%) definition, whereas 29% have never heard about it or do not know (4%). The term is well known by all experts. The most often stated sources of information are television/radio and the newspaper (53% and 50%, respectively; respondents of the public sample). The general public mainly associates IAS with in-migrated and introduced species and with threats to biodiversity and nature conservation (Fig. 3). Experts have similar, though much stronger associations with IAS. However, in contrast to the general public, they strongly associate health and damage on infrastructure with IAS.

#### Knowledge of six selected IAS in Switzerland

Only a small percentage of the general public knows the six presented IAS by name with knotweed being the least known species (Fig. 4). Giant hogweed is best known, however, only 8.5% of the public knows the correct name. Not surprisingly, experts know the species very well with the exception of tree of heaven and cherry laurel.

#### Group differences

In the Italian-speaking (southern) part of Switzerland the term IAS is known better than in the other language regions, while it is least known in the German-speaking (north-eastern) part (Fig. 5). Men (50.5%) know the term IAS better than women (40.8%; $p < 0.001$, Mann–Whitney $U$-test) and the term is better known by older participants (>40 years; 52.6%) than by younger ones (<40 years; 38.2%, $p <$

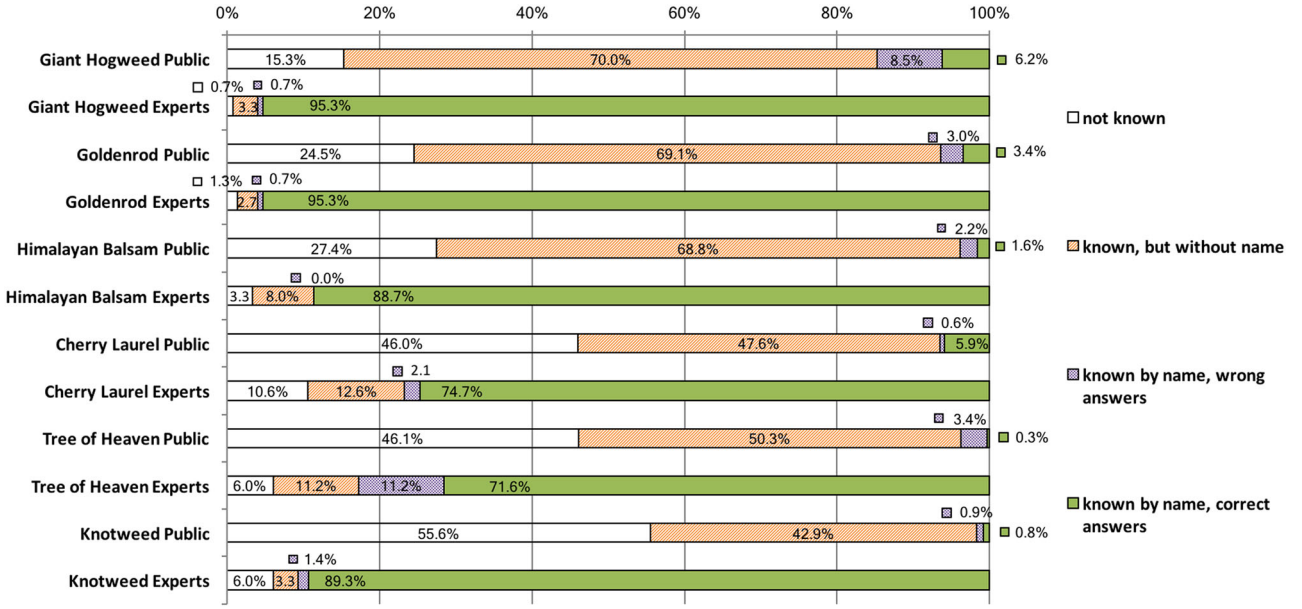


**Fig. 4** Public and expert knowledge of six invasive alien plant species (compare Fig. 1; $N_{Public} = 1146$; $N_{Experts} = 151$)

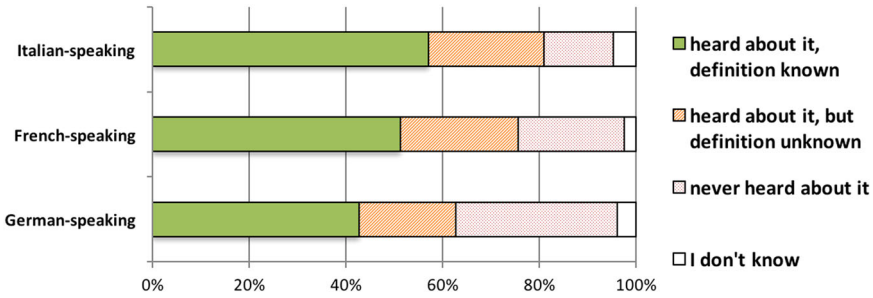


**Fig. 5** Public knowledge of the term invasive alien plant species ($N = 1146$). Regional differences between the Swiss language regions ($p < 0.001$, Kruskal–Wallis test)

0.001, Mann–Whitney *U*-test). Moreover, 51.6% of active gardeners know the term compared to 42.2% of non-active gardeners ($p < 0.01$, Mann–Whitney *U*-test).

### Aesthetic preferences for six IAS

The aesthetically most preferred plant species by the general public is himalayan balsam followed by the tree of heaven (Fig. 6). After providing information on the invasive character of the species and on the problems the species cause, the public's aesthetical preferences for all six species decreased significantly. Preference scores of experts are lower for all species and information on the species did not influence the expert's aesthetical preferences except for tree of heaven and goldenrod.

### General attitudes towards IAS

The majority of the general public (62.7%) approves a prohibition of selling IAS in garden centres and 71.5% stated that the information that a species is invasive would prevent them from buying such species. However, only 9.1% have ever been informed about IAS in garden centres. Among the experts, 90.1% support a prohibition of selling IAS, 92.1% would not buy a plant species when being informed about its invasiveness and 13.2% have so far been informed about IAS in garden centres.

Both groups believe that it is more important to combat IAS to protect native species than for the prevention of health risks (Fig. 7), while experts put even more emphasis on native species protection than on preventing health problems. In addition, experts, and to a lower degree also the general public, disagree with the statement that a Swiss-wide combatting of IAS is not reasonable because costs would be too high.

## Choice Experiment

### General Results

The results of the public sample show that the alternative-specific constants ($\alpha_{combat\ HB,GR,GH,KW,TH,CL}$) for intervening

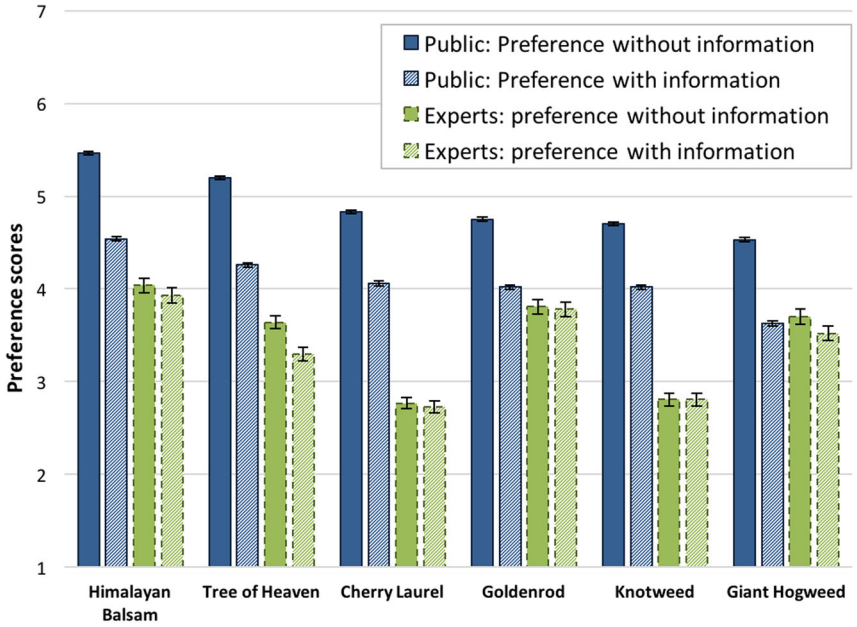


**Fig. 6** Public ($N = 1146$) and expert ($N = 151$) aesthetic preferences for six invasive alien plant species (compare Fig. 1) before and after information on the invasive character of the species. Shown are mean rating scores on a seven-step scale from 1 = totally dislike to 7 = totally like it. Information influenced public preferences significantly for all species ($p < 0.001$, GLM for repeated measures) and expert preferences for tree of heaven and giant hogweed (both $p < 0.01$, GLM for repeated measures)

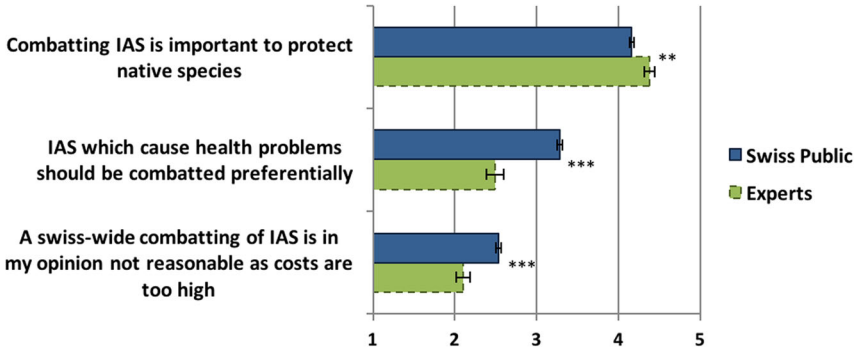


**Fig. 7** Attitudes towards the management of invasive alien species (IAS) of the general Swiss public ($N = 1146$) and Swiss experts ($N = 151$) Shown are mean rating scores on a five-step scale from 1 = totally disagree to 5 = totally agree. Significance level of group differences (tested by one-way ANOVA): $^{**}p < 0.01$, $^{***}p < 0.001$

**Table 2** General results of the choice experiment (estimated coefficients in bold, conditional logit model for the overall sample, number of observations = 13752)

| | Swiss population | | | |
|---|---|---|---|---|
| Attributes | Value | Std err | *t*-test | *p*-val |
| Alternative-specific constants | | | | |
| No intervention | 0.0000 | Fixed | | |
| Combating Giant Hogweed | 1.5200 | 0.1330 | 11.38 | 0.00 |
| Combating Tree of Heaven | 1.4600 | 0.0870 | 1676 | 0.00 |
| Combating Goldenrod | 1.1900 | 0.1100 | 10.77 | 0.00 |
| Combating Himalayan Balsam | 1.1100 | 0.0955 | 11.58 | 0.00 |
| Combating Cherry Laurel | 1.0000 | 0.1120 | 8.98 | 0.00 |
| Combating Knotweed | 0.8100 | 0.0670 | 12.10 | 0.00 |
| Costs | −0.4020 | 0.0247 | −14.66 | 0.00 |
| Type/Intensity of intervention | −0.1300 | 0.0348 | −3.73 | 0.00 |
| Priority of intervention | | | | |
| Reducing ecological damages | 0.0000 | Fixed | | |
| Reducing economic damages | -0.3480 | 0.0318 | −10.92 | 0.00 |

against invasive plant species have a positive sign and are significant for all species (Table 2). Given that ASC of the different intervention measures are a component of the households' utility function, the positive sign indicates that combating invasive species has a systematic and positive impact on the households' utility and is significantly preferred compared to not intervening. Most preferred are interventions against giant hogweed and tree of heaven followed by goldenrod and himalayan balsam, whereas combating cherry laurel and knotweed are of least importance. As regards the priority of intervention, preventing ecological damages is significantly preferred compared to preventing economic damages. Concerning the intensity of combating invasive species, we found a significant preference towards regional (main distribution areas) or local interventions at specific sites only instead of a Swiss-wide eradication. The cost coefficient is negative and significant, indicating a negative impact on utility due to the lost opportunity to spend the respective money on other goods.

**Table 3** Region-specific results of the choice experiment (estimated coefficients in bold, conditional logit model for the regional sub-samples, number of observations: German = 9444/French = 3552/Italian = 756)

| | German-speaking region | | | | French-speaking region | | | | Italian-speaking region | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Attributes | Value | Std err | *t*-test | *p*-val | Value | Std err | *t*-test | *p*-val | Value | Std err | *t*-test | *p*-val |
| Alternative-specific constants | | | | | | | | | | | | |
| No intervention | 0.0000 | | Fixed | | 0.0000 | | Fixed | | 0.0000 | | Fixed | |
| Combating Giant Hogweed | 1.4100 | 0.1580 | 8.92 | 0.00 | 1.7600 | 0.2790 | 6.33 | 0.00 | 1.7700 | 0.6690 | 2.64 | 0.01 |
| Combating Tree of Heaven | 1.3400 | 0.1040 | 12.91 | 0.00 | 1.6700 | 0.1790 | 9.32 | 0.00 | 1.8400 | 0.3900 | 4.70 | 0.00 |
| Combating Goldenrod | 1.1200 | 0.1310 | 8.51 | 0.00 | 1.4100 | 0.2290 | 6.14 | 0.00 | 0.9990 | 0.5240 | 1.91 | 0.06 |
| Combating Himalayan Balsam | 0.9830 | 0.1120 | 8.74 | 0.00 | 1.4500 | 0.2020 | 7.16 | 0.00 | 0.9980 | 0.4830 | 2.07 | 0.04 |
| Combating Cherry Laurel | 0.8800 | 0.1320 | 6.68 | 0.00 | 1.3200 | 0.2350 | 5.61 | 0.00 | 1.1400 | 0.,5650 | 2.02 | 0.04 |
| Combating Knotweed | 0.6680 | 0.0796 | 8.39 | 0.00 | 1.2100 | 0.1400 | 8.64 | 0.00 | 0.7640 | 0.3170 | 2.41 | 0.02 |
| Costs | −0.4150 | 0.0329 | −12.64 | 0.00 | −0.3860 | 0.0557 | −6.93 | 0.00 | −0.2540 | 0.1310 | −1.94 | 0.05 |
| Type/Intensity of intervention | −0.0690 | 0.0413 | −1.67 | 0.09 | −0.1740 | 0.0756 | −2.30 | 0.02 | −0.3500 | 0.1620 | −2.16 | 0.03 |
| Priority of intervention | | | | | | | | | | | | |
| Reducing ecological damages | 0.0000 | | Fixed | | 0.0000 | | Fixed | | 0.0000 | | Fixed | |
| Reducing economic damages | −0.3330 | 0.0385 | −8.66 | 0.00 | −0.4070 | 0.0630 | −6.46 | 0.00 | −0.2890 | 0.1470 | −1.97 | 0.05 |

## Regional Results

When comparing the regional alternative-specific constants it can be observed that the ranking of species to be combated is almost identical with the overall Swiss population. However, preferences for intervening are stronger in the French- and Italian-speaking region (Table 3). Further, the cost coefficients in both parts have a lower value than in the German-speaking region indicating a lower negative impact of this attribute on households' utility. In consequence, the willingness to pay (per household) for interventions against IAS is expected to be higher in the French and Italian-speaking parts (compare sub-chapter 'willingness to pay').

In addition, the preference to combat IAS for ecological reasons (in contrast to preventing economic damages) is more distinct in the French-speaking part, while it is lowest in the Italian-speaking part. Concerning the intensity of intervention all coefficients show a negative sign indicating a preference against a Swiss-wide intervention—though not significant in the German-speaking part.

## Expert survey results

The main difference between Swiss experts and the general public is the ranking of species to be combated. While intervening against knotweed is ranked as least important by the public, experts put highest priority on it followed by goldenrod and giant hogweed (Table 4). As far as the priority of intervention is concerned, public's and experts' opinion correspond: both prefer intervening to prevent ecological instead of economic damages. The same holds for the intensity of intervention, both significantly prefer local and regional interventions compared to nation-wide interventions. Finally, the experts' cost coefficient is significant and has the expected negative sign.

**Table 4** Results of the expert choice experiment (estimated coefficients in bold, conditional logit model for the expert subsample, number of observations = 1812)

| | Swiss experts | | | |
|---|---|---|---|---|
| Attributes | Value | Std err | *t*-test | *p*-val |
| Alternative-specific constants | | | | |
| No intervention | 0.00 | | Fixed | |
| Combating Giant Hogweed | 2.05 | 0.45 | 4.57 | 0.00 |
| Combating Tree of Heaven | 2.02 | 0.29 | 7.05 | 0.00 |
| Combating Goldenrod | 2.18 | 0.38 | 5.75 | 0.00 |
| Combating Himalayan Balsam | 1.79 | 0.33 | 5.40 | 0.00 |
| Combating Cherry Laurel | 1.08 | 0.38 | 2.89 | 0.00 |
| Combating Knotweed | 2.61 | 0.23 | 11.31 | 0.00 |
| Costs | −0.24 | 0.09 | −2.67 | 0.01 |
| Type/Intensity of intervention | −0.27 | 0.11 | −2.39 | 0.02 |
| Priority of intervention | | | | |
| Reducing ecological damages | 0.00 | | Fixed | |
| Reducing economic damages | −0.49 | 0.09 | −5.17 | 0.00 |

## Integrating respondents' characteristics and latent variables

In a further step, we included respondents' characteristics such as level of education *(EDUC)*, knowledge about IAS *(KNOW)* and whether they are gardeners or not *(GARD)*. In addition, we tested the influence of latent variables such as attitudes towards nature (NEP). Based on factor analysis we were able to group the respondents according to different

**Table 5** Results of integrating latent variables and respondents' characteristics (estimated coefficients concerning interaction with the attribute 'intensity of intervention' in bold)

| | Swiss population | | | | Swiss Experts | | | |
|---|---|---|---|---|---|---|---|---|
| Relation to intensity of intervention | Value | Std err | *t*-test | *p*-val | Value | Std err | *t*-test | *p*-val |
| Nature framer | −0.0772 | 0.0170 | −4.53 | 0.00 | −0.2990 | 0.0590 | −5.07 | 0.00 |
| Nature lover | 0.1400 | 0.0170 | 8.23 | 0.00 | 0.6080 | 0.0598 | 10.17 | 0.00 |
| Knowledge | 0.1930 | 0.0174 | 11.11 | 0.00 | n.a. | | | |
| Garden | 0.0353 | 0.0170 | 2.08 | 0.04 | 0.1260 | 0.0711 | 1.78 | 0.08 |
| Education | −0.0081 | 0.0179 | −0.45 | 0.65 | n.a. | | | |

**Table 6** Willingness to pay (WTP) for interventions (in Swiss Francs per household and overall per region (percentage in brackets); population shares are provided for comparison)

| Intervening against | WTP per HH (in CHF) | | | | | Overall WTP (in Mio. CHF) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Switzerland | GE region | FR region | IT region | Experts | Switzerland | GE region | FR region | IT region | Experts |
| Giant Hogweed | 3.78 | 3.40 | 4.56 | 6.97 | 8.54 | 13.2 | 8.5 | 3.8 | 1.1 | 29.8 |
| Tree of Heaven | 3.63 | 3.23 | 4.33 | 7.24 | 8.42 | 12.7 | 8.1 | 3.6 | 1.1 | 29.4 |
| Goldenrod | 2.96 | 2.70 | 3.65 | 3.93 | 9.08 | 10.3 | 6.7 | 3.1 | 0.6 | 31.7 |
| Himalayan Balsam | 2.76 | 2.37 | 3.76 | 3.93 | 7.46 | 9.6 | 5.9 | 3.1 | 0.6 | 26.0 |
| Cherry Laurel | 2.49 | 2.12 | 3.42 | 4.49 | 4.50 | 8.7 | 5.3 | 2.9 | 0.7 | 15.7 |
| Knotweed | 2.01 | 1.61 | 3.13 | 3.01 | 10.88 | 7.0 | 4.0 | 2.6 | 0.5 | 37.9 |

categories, such as 'nature lovers' (*NATLO*) or 'nature framers' (*NATFR*). The respective indicators have been integrated by combining them with the attribute 'Intensity of intervention' *(INT)*. The results are given in Table 5.

$$
\begin{aligned}
V_{combat\,HB,GR,GH,KW,TH,CL} &= \alpha_{combat\,HB,GR,GH,KW,TH,CL} + \beta \cdot INT \\
&\quad + \overline{\gamma}_1 \cdot PRIO_1 + \gamma_2 \cdot PRIO_2 + \delta \cdot COST \\
&\quad + \lambda_1 \cdot (NATFR \cdot INT) + \lambda_2 (NATLO \cdot INT) \\
&\quad + \lambda_3 \cdot (KNOW \cdot INT) \\
&\quad + \lambda_4 \cdot (GARD \cdot INT) + \lambda_5 \cdot (EDUC \cdot INT) \\
V_{opt\,out} &= \overline{\alpha}_{opt\,out}
\end{aligned}
\tag{3}
$$

Considering the Swiss public, we found that 'nature lovers' have a significant preference for a broader (Swiss-wide) intervention, while 'nature framers' are slightly against it. Further, being a gardener and especially having knowledge about IAS significantly increase preferences for more intensive interventions. In contrast, the educational level has no significant impact on preferences. Similar results have been found for the experts. However, knowledge and education levels did not vary sufficiently within this group and consequently did not show any impact.

### Willingness to pay

Building the ratio of the alternative-specific constants ($\alpha_{\text{combat HB,GR,GH,KW,TH,CL}}$) and the cost coefficient ($\delta$) allows to estimate the willingness to pay (WTP) for interventions against the different species. Note that due to the characteristics of the alternative-specific constants, these WTP estimates refer to unobserved aspects related to invasive species, i.e. others than those explicitly covered by our CE attributes (e.g. aesthetic aspects or health reasons; Colombo and Hanley 2008; Czajkowski and Hanley 2009).

Table 6 shows that the willingness to pay (per household) in the French- and Italian-speaking parts exceeds the Swiss average. This result holds for all species. The experts' WTP per household is even higher: more than five times higher for knotweed and more than twice as high as for most of the other species compared to the Swiss average. Taking 3.49 million Swiss households (Federal Statistical Office 2015) into account the overall population's annual willingness to pay for interventions results in about 13 million Swiss Francs (SFr) for interventions against giant hogweed and about 7 million SFr against knotweed. In contrast, approximating the population's WTP based on experts' preferences would lead to substantially higher values: about 30 million SFr for giant hogweed and 38 million SFr for knotweed.

## Discussion

This study analysed public and experts' awareness and knowledge of and preferences for invasive alien plant species, and their preferences for and trade-offs among management alternatives in Switzerland. Contrary to studies that have focussed on the costs of managing invasive alien species (Holmes et al. 2009), studies focussing on public

preferences for IAS or IAS management alternatives with stated preference methods are scarce (Adams et al. 2011; Nunes and van den Bergh 2004). García-Llorente et al. (2011) concluded that contingent valuation is a viable method to explore preferences related to the management of invasive species. However, several studies have shown that the way relevant information is presented during the experiment has an impact on the respondents' decisions (Bateman and Mawby 2004; Jacobsen et al. 2008). In addition, the level of respondents' familiarity with the respective species can substantially influence willingness to pay estimates (Barkmann et al. 2008; Christie et al. 2006). Therefore, to assure an appropriate level of knowledge of all respondents, we provided all relevant information concerning IAS before conducting the choice experiment.

We found that the Swiss public, as well as the experts, have a significant general preference for interventions against invasive plant species. This result corresponds to other studies, where high approval rates of about 75% or more for IAS management programmes were found (Bremner and Park 2007; Philip and MacMillan 2005). Our results show that the Swiss public, and to an even higher degree the experts, place more importance on reducing ecological damages than economic damages in IAS management programs. This is in line with the findings of García-Llorente et al. (2011), where the IAS impact on ecosystem influenced the WTP for IAS management positively. One reason for this might be an increasing nature awareness and a growing acknowledgement of the intrinsic value of nature in western countries (de Groot and van den Born 2003; van den Born et al. 2001). Another reason might be that information on IAS in media might mainly be linked to threats for biodiversity, and possibly to a lesser degree to health and infrastructure problems.

Although there is a public and expert preference for intervening against IAS, both groups opt against nationwide interventions in general. This seems to be in line with the species-specific approach of the Swiss strategy on IAS management: IAS are categorised in different management priorities depending on (i) the damages a species is causing, (ii) ecological facts (e.g. dispersal strategies, distribution area) and (iii) available management measures[2]. However, isolated actions are often not sustainable and in the long run costs of repeated local interventions might be higher compared to intervention strategies that focus on larger areas. In our study, the general public and, more strongly, the experts did not think that costs are too high for a Swiss-wide removal of IAS. Thus, the costs of interventions might play a less important role than other reasons (e.g. effort versus success of intervention measures) to opt against a Swiss-wide removal. 'Nature lovers', gardeners and persons with a better knowledge of the topic showed a preference towards intervention on a broader scale. This is in line with findings of other studies (Adams et al. 2011; Bremner and Park 2007; Sharp et al. 2011) where acceptance of invasive species control increased with a higher knowledge of the topic or with environmental-friendly attitudes.

We did not find a major conflict potential between the general public and experts: although, not surprisingly, expert preferences for interventions against IAS are stronger, the public in general is in line with expert opinions on IAS management. However, public and experts differ in their priorities of combatting particular species as interventions against some species (e.g. giant hogweed for the public and knotweed for the experts) are more preferred than intervention against others. The overall public annual WTP for combatting giant hogweed is with 13.2 Mio SFr almost twice as high as the overall public annual WTP for combatting knotweed (7.0 Mio. SFr). In contrast, approximating the overall public WTP based on expert preferences for combatting knotweed results in 37.9 Mio. SFr. A possible reason might be the expert knowledge on the severe problems knotweed is causing, as well as the difficulties to combat it, whereas for the public it seems to be most important to intervene against the risk of skin burns caused by giant hogweed. This is supported by our finding that the public more strongly agrees to combat those IAS which cause health problems.

Regional differences in priorities for interventions indicate that problem awareness, and moreover, the urgency of interventions differ in these regions. This is in line with different levels of knowledge of the term IAS and with varying levels of willingness to finance interventions in these regions. In this respect, a comparison of the share of households and their willingness to contribute to interventions among the study regions is revealing: The German-speaking region comprises about 2.5 million households (i.e. 72% of all Swiss households), while the French and Italian-speaking parts make up for 0.84 million (24%) and 0.15 million (4%), respectively (see Table 6). Compared to these population shares, the willingness to pay share of the German-speaking households is under-proportionally low, lying between 65 and 57%. In contrast, the other parts of the population seem to be disposed to contribute more than what could be expected based on their population share: between 28 and 37% for the French-speaking part and between 6 and 9% for the Italian-speaking part. These findings reflect a higher acceptance of interventions in regions where the knowledge and awareness of the problem is higher. Thus, the public in the Italian- and the French-speaking part of Switzerland, where the impact of several IAS is higher than in the German-speaking part (Tamarcaz et al. 2005; Walther et al. 2007), seems to be better informed and sensitised. In line with the Swiss strategy on IAS management which aims to increase tailored information campaigns, our results can therefore help to define regional specific information campaigns.

Interestingly, the general public supports the management of IAS although there is a rather weak knowledge of the topic in general and a very limited knowledge of the species themselves. Threats like infrastructure damage and health problems are hardly known. This is in line with a recent study by Lindemann-Matthies (2016) where most IAS were perceived as rather ordinary, familiar and native to Switzerland. While several studies found that knowledge of the topic influences acceptance of IAS control positively (Adams et al. 2011; Bremner and Park 2007; García-Llorente et al. 2011), Lindemann-Matthies (2016) could show that with increasing appeal of IAS, agreement for removal of the respective species decreased. However, we found that providing information about the problems caused by invasive species reduces aesthetic preferences for these species and, in addition, that a better knowledge of the topic increases preferences for more intensive interventions.

Our choice experiment was limited to preferences for controlling IAS. Future research might address this limitation by focusing on prevention measures to reveal insights on this high priority management goal. Moreover, due to design limitations, our model comprised only six plant species. Although these reflect the currently most problematic species in Switzerland, future research might include further plant species, as well as species of other taxonomic groups. In addition, it would be interesting to know, (i) how private entities, such as land or garden owners, can be involved in controlling invasive species, e.g. by designing payment schemes for protection measures (Sheremet et al. 2018), and (ii) how these measures could be implemented in a spatially optimal way (Epanchin-Niell and Wilen 2012).

## Conclusions

One of the goals of the Swiss national strategy on IAS management is a target-specific information and sensitisation of different stakeholder groups, as well as the general public. Moreover, the strategy claims a need for a raise in (financial) resources, mainly for eradication measures. Our findings lead to the conclusion that knowledge of the threats and risks of IAS might be a key factor in sensitising the general public in regard to successful preventive measures and, in addition, in raising public support for higher costs of more intensive intervention measures. Information campaigns, aimed at raising problem awareness and tailored to specific target groups, might be a promising approach to prevent undeliberate introductions of new (potentially) invasive species. The general preference for intervening against IAS is a good starting point to further increase the acceptance of intervention measure on a broader scale. However, to overcome the gap between experts and the general public for different levels of willingness to finance interventions, increasing efforts in sensitising the public for (species-specific) broader-scale intervention measures are needed. Information on the threats of IAS on infrastructure and human health might be valuable here, as these threats are currently hardly known by the public.

The regional differences we found, with a higher acceptance of interventions, and, in addition, a higher problem awareness in the French- and Italian-speaking parts of Switzerland, call for increased efforts on information campaigns and awareness raising mainly in the German-speaking part, where most of the Swiss people live and where problems of IAS will probably increase, e.g. due to global warming (e.g. Huang et al. 2011; Walther et al. 2009).

In this respect, our study provides valuable insights for policy makers, regional and federal authorities, as well as non-governmental organisations. Knowledge on public and expert perceptions of IAS provides important information for tailored IAS communication strategies and campaigns and, consequently, for successful and sustainable prevention strategies.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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