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Does public awareness increase support for invasive species management? Promising evidence across taxa and landscape types

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Abstract

Management of invasive species often raises substantial conflicts of interest. Since such conflicts can hamper proposed management actions, managers, decision makers and researchers increasingly recognize the need to consider the social dimensions of invasive species management. In this exploratory study, we aimed (1) to explore whether species taxonomic position (i.e. animals vs. plants) and type of invaded landscape (i.e. urban vs. non-urban) might influence public perception about the management of invasive species, and (2) to assess the potential of public awareness to increase public support for invasive species management. We reviewed the scientific literature on the conflicts of interest around the management of alien species and administered two-phased questionnaires (before and after providing information on the target species and its management) to members of the public in South Africa and the UK (n=240). Our review suggests that lack of public support for the management of invasive animals in both urban and non-urban areas derives mainly from moralistic value disagreements, while the management of invasive plants in non-urban areas mostly causes conflicts based on utilitarian value disagreements. Despite these general trends, conflicts are context dependent and can originate from a wide variety of different views. Notably, informing the public about the invasive status and negative impacts of the species targeted for management appeared to increase public support for the management actions. Therefore, our results align with the view that increased public awareness might increase the public support for the management of invasive species, independent of taxonomic position and type of landscape.

Introduction

Invasive alien species can cause significant negative environmental and socioeconomic impacts outside their native ranges (Richardson 2011; Simberloff and Rejmánek 2011). This includes impacts on biodiversity (Powell et al. 2013), economy (Pimentel et al. 2005; Holmes et al. 2009) and human health (Hulme 2014). Aiming to minimize such negative impacts, management actions have been developed and implemented in many parts of the world (Pyšek and Richardson 2010). Some examples are the management plans to control the invasive parthenium weed (*Parthenium hysterophorus* L.) developed by the Parthenium Action Group in Australia (Adkins and Shabbir 2014) or the numerous projects to control the invasive rat (*Rattus rattus*) that are in place in island natural areas around the world (Duron et al. 2016).

Some invasive alien species, despite causing negative impacts, also provide valuable benefits (Friedel et al. 2011, Le Houérou 1996), including food provision (Shackleton et al. 2011), soil stabilization (Novoa and González 2014) and aesthetics (Sharma 2007). The duality of such impacts, both positive and negative, influences the management of such invasive alien species and can raise substantial conflicts of interest (Dickie et al. 2014; Estévez et al. 2014). For example, Monterey pine (*Pinus radiata*) is used in commercial plantations in Table Mountain National Park (South Africa), where it is popular among hikers, cyclists and tree enthusiasts (Richardson and Brown 1986). However, *P. radiata* escaped from the plantations and became invasive, negatively impacting the biodiversity of this national park (Richardson et al. 1996). Although management actions aiming to reduce the negative impacts of *P. radiata* have been developed, managers have encountered strong public resistance to the removal of these trees from the current plantations (van Wilgen 2012). Since such conflicts of interest often challenge and undermine invasive species management actions (García-Llorente et al. 2008; Ford-Thompson et al. 2012), managers, decision makers and researchers increasingly recognize the need to consider the social dimensions of invasive species management (e.g. Stokes et al. 2006; García-Llorente 2008; Reed et al. 2009; Kueffer 2010; Sharp et al. 2011; Moon et al. 2015; Novoa et al. 2016a; Woodford et al. 2016).

Most conflicts of interests around the management of invasive species derive from value disagreements, including utilitarian (i.e. the invasive species provides a direct economic value), moralistic (i.e. any creature has the right to live, a notion often linked to animal rights), humanistic (i.e. the target species has a cultural or spiritual value), or naturalistic and aesthetic values (i.e. the target species satisfies humans through experiences or physical appeal; which is often linked to outdoor activities as hunting or fishing; Estévez et al. 2014). Given the contrasting values ascribed to different species, invasive species in certain taxonomic positions might be more likely to cause certain conflicts of interest than others (Fraser 2006). For example, the management of invasive animals is often opposed by animal rights organizations and public sensitivities (e.g. Fraser 2001; Bertolino and Genovesi 2003). For instance, in northern Italy the invasive North American grey squirrel (*Sciurus carolinensis*) has replaced the native Eurasian red squirrels (*S. vulgaris*) and damaged forests and tree plantations (McNeely 2005). However, legal actions initiated by animal rights groups had originally stopped the eradication of *S. carolinensis* in the country (Bertolino and Genovesi 2003). Similarly, in South Africa the mallard duck (*Anas platyrhynchos*) invading Cape Town was targeted for eradication to reduce its impacts on native biodiversity, but the eradication campaign failed due to public opposition (Gaertner et al. 2016). Opposition by public animal-rights groups and government officials also hindered the control of *Eleutherodactylus coqui* in Hawaii, an invasive frog that impacts invertebrate communities and affects ecosystem processes in the Hawaiian Islands (Kraus 2008).

Conflicts around the management of invasive species might also more frequently occur in certain invaded landscapes than in others. In particular, there are several reasons that conflicts are often abundant in urban areas (Kowarik 2011). Firstly, people independently of where they live, tend to forge cultural connections with invasive species. For example, invasive trees can become important symbols (e.g. Pinamar, a seaside town in Argentina's Atlantic coast, is named after *Pinus* and Jacaranda is the symbol of Pretoria, the capital city of South Africa; Dickie et al. 2014) or can be significant in local culture (e.g. the "Eucalyptus School" in California, USA or the "Festa da Mimosa", i.e. *Acacia dealbata*, in Galicia, Spain; Otero Pedrayo 1972; Nuñez and Simberloff 2005). Since cultural heterogeneity is one of the main elements defining urban areas (Dewey 1960), such cultural connections are expected to be more abundant in urban than in rural areas (Meyerson et al. unpublished). Secondly, invasive species often provide a wide range of ecosystem services in urban areas. For example, the tree species *Cinnamomum camphora* native to southern China and Japan was introduced to Australia in 1882. It soon became invasive, displacing native vegetation and being poisonous to native animals (Chien 1999). However, by 2011, in Bellingen, Australia, *C. camphora* trees were considered heritage trees, and an important source of shade. Therefore, the efforts to control the invasion of *C. camphora* failed – i.e. the removal of four 90-year-old trees in the downtown area created controversy over the more than a million additional invasive trees growing outside of the town (Dickie et al. 2014). In addition, many urban areas can be considered novel ecosystems (Hobbs et al. 2006; Kowarik 2011), which are characterized by a change in the original environmental conditions and species composition (Morse et al. 2014). People often do not perceive such urban areas as natural landscapes (Kueffer & Kull 2017). Therefore, in urban areas, people might not see conservation actions, such as the management of invasive alien species, as necessary as in more natural or pristine areas.

Independent of the species taxonomic position and the type of invaded landscape, engaging the public on the management of invasive species – i.e. establishing collaborations between all stakeholders with the goals of increasing mutual understanding and co-designing the management actions – may increase public support and help to ensure the success of the management actions (García-Llorente 2008; Shackleton et al. 2015, Novoa et al. unpublished). Such engagement can be done through workshops, social media, outreach and education activities, and training programs (e.g. Ford-Thompson et al. 2012; Estévez et al. 2015). For example, in South Africa, invasive cactus species pose a threat to biodiversity, ecosystem functioning, resource availability, national economy, and human health (Walters et al. 2011). However, they are also used for agriculture (Nefzaoui 2007) and horticultural purposes (Novoa et al. 2015), and they have potential health benefits and high nutritional value (Patel 2012). Despite these apparent conflicts, a workshop attended by all stakeholders who benefit from, or suffer the costs of, invasive cacti in South Africa improved participants' acceptance of the interventions and their willingness to collaborate on the design and implementation of management actions.

The need for engaging the public in the management of invasive alien species is stipulated by the Convention on Biological Diversity (CBD 2014) and acknowledged by several national and international strategies. For example, the Invasive Alien Species Strategy for Canada identifies the public as one of the essential players for "successfully responding to the challenge of invasive alien species" (Environment Canada 2004). Similarly, the Global Strategy on Invasive Alien Species emphasizes the need for coordination between stakeholders at all levels (McNeely 2001). However, due to a lack of funding, qualified human resources or time, public engagement might not always be possible. Organizing engaging activities can be costly, and certain stakeholders might not be able to attend them because of economic or logistic reasons. Moreover, since initiation of management efforts at an early stage of invasion is the most cost-efficient (Mgidi et al. 2007), time may not always be available to perform appropriate stakeholder engagement (Mackenzie and Larson 2010).

When active public engagement is not possible, public awareness – i.e. informing the public about the impacts of the target invasive species and the control methods available – might constitute a more effective approach to increase public support for invasive species management. Helping people to understand opportunities linked to invasive species management can reduce or even avoid conflicts around the management itself (Bremner and Park 2007). Several tools have been proposed to raise awareness such as developing websites or printed documents, establishing forums, organizing school talks or public events, creating informative films and publishing popular science articles. For example, Marchante and colleagues developed a website (<http://www.uc.pt/invasoras>) in 2003 with information on the invasive plants present in Portugal. By 2010, the website had been accessed by 130,200 visitors and was validated as an effective awareness tool (Marchante et al. 2010). The importance of public awareness to increase public support for the management of invasive species has been increasingly recognized (Westbrooks 2011; Gelcich et al. 2014; Rodgers et al. 2014; Funk 2015; Klapwijk et al. 2016), and the number of studies highlighting the need to raise awareness is growing (e.g. Martin 2007; Marchante et al. 2010; Reis et al. 2013, Cazetta and Zenni this issue). However, studies that document the effectiveness of increased public awareness in increasing public support for invasive species management are still scarce.

In this exploratory study, we reviewed the scientific literature on the conflicts of interest around the management of alien species and administered two-phased questionnaires to members of the public in South Africa and the UK, aiming to (1) explore whether the species' taxonomic position (i.e. animal or plant) and the type of invaded landscape (i.e. urban or non-urban) might influence public perception about the management of invasive species, and to (2) assess the potential of public awareness to increase public support for invasive species management.

Methods

Literature review

Firstly, we conducted an exploratory literature review to better understand how taxonomic position (plant or animal) and type of invaded landscape (urban or non-urban) influence human perception and the lack of public support for invasive species management. We consider urban landscape as an area with high population density (e.g. a city or a town), as opposed to a non-urban area, in which there are none or only few houses or buildings and low population density.

For this review, we searched the ISI Web of Knowledge for publications on conflicts of interest around the management of alien species in May 2016. We conducted two separate searches using the following search terms: "Invasive species AND conflict* of interest*" and "Invasive species AND human* perception". We then screened the titles and abstracts of the resulting 110 papers, as well as of those papers cited in their reference lists. To avoid duplication, when several papers described an identical issue (i.e. the same target species, area and geographical location), we only registered the original reference. This screening process resulted in 53 papers (Online Resource 3) that described the perceptions of the public towards the management of alien invasive species.

For these 53 publications, we then identified the described species taxonomic position (animal/plant), the type of invaded landscape (urban/non-urban) and the occurrence of a conflict of interest (yes/no). Moreover, for the

37 papers that reported the occurrence of a conflict of interest, we also identified the main value system that determined the specific conflict (Aesthetic/ Domionistic/ Humanistic/ Moralistic/ Naturalistic/ Negativistic/ Scientific/ Utilitarian *sensu* Kellert 1980 and Estévez et al. 2014). Using the collected data, we explored the differences in the number of papers that reported lack of public support for invasive species management actions among target species and areas.

Face-to-face surveys

In addition to the literature review, we administered two-phased questionnaires to members of the public in South Africa and the UK to explore if specifics related to taxonomic position (i.e. animal or plant) and type of invaded landscape (i.e. urban or non-urban area) affect public perception of the management of invasive species, and to assess the potential of public awareness to increase public support for invasive species management.

We chose South Africa and the UK for this exploratory study because they have a different history of environmental modification, introduction of alien species and public awareness. South Africa is a geographical area of high conservation significance; it contains seven major terrestrial biomes, including the Fynbos Biome, which is one of the world's 'hottest biodiversity hotspots' (Turpie 2003). The introduction of alien species in the country is linked to European colonization, which only started in the 17th century (van der Weijden et al. 2007). In contrast, the biodiversity of the UK has been profoundly modified by human influence: the history of introduction of non-native species in the country dates back to Neolithic times (Stace and Crawley 2015) and by the 16th century its original vegetation had already been heavily modified (Ratcliffe 1984). However, the public are often relatively unaware of the impacts posed by invasive species (Genovesi and Shine 2004).

Aiming to explore the attitudes of the public towards the management of different target species, we developed four similar questionnaires using the erect prickly pear (*Opuntia stricta* Haw.) and the guttural toad (*Sclerophrys gutturalis* Power) in South Africa, and the Himalayan Balsam (*Impatiens glandulifera* Royle) and the grey squirrel (*Sciurus carolinensis* Gmelin,) in the UK as target species respectively. We chose these four target species due to their abundance on urban and non-urban landscapes within the studied areas and to the expertise of the authors. *Opuntia stricta* is native to Cuba, Mexico and the USA (Anderson 2001). It was introduced to South Africa as an ornamental plant, where it is recorded as invasive (Henderson 2015). This species is highly adaptable to both urban and non-urban areas, and it is currently present all over South Africa (Walters et al. 2011) – including Cambedoo National Park (near Graaff Reinett; Masubelele 2009) and Kruger National Park (Foxcroft et al. 2004). Although its attractive yellow flowers and sweet fruits make *O. stricta* a popular pot and hedge plant, *O. stricta* has also multiple ecological and socioeconomic negative impacts. It reduces food production, causes loss of grazing potential, transforms habitats and alters the biodiversity in the invaded areas. *O. stricta* might also cause injuries to people that get hurt by its spines (Novoa et al. 2016b).

S. gutturalis is native to tropical and sub-tropical southern and central parts of Africa. Its native range in South Africa only includes the Eastern and Northern parts of the country (Channing 2001). *S. gutturalis* is thought to have been accidentally introduced to Cape Town in the 1990s (de Villiers 2006). *S. gutturalis* was recorded as invasive in Cape Town in 2006 and by 2009 it was present across an area of approximately 5 km² characterized by peri-urban landscape (Measey et al. 2017). In Cape Town, toads are considered charismatic animals; this is mainly due to the occurrence of the endemic and endangered Western Leopard Toad (*S. pantherina*), which is

well known among the public. Hundreds of volunteers from several local groups, as well as various nature conservation organizations monitor the populations of *S. pantherina* in the city under the supervision of the Western Leopard Toad Conservation Committee (www.leopardtoad.co.za). Moreover, information on toad conservation is always present in the media, magazine articles, signboards, websites, etc. Despite this, general public may find difficult to distinguish *S. pantherina* from *S. gutturalis* (Measey 2011). The males of *S. gutturalis* make a very loud annoying call during night (Measey et al. 2017). Moreover, *S. gutturalis* might be threatening the survival of indigenous frog species, including *S. pantherina*, as they could compete for habitat, resources and breeding grounds (Richardson 2014).

I. glandulifera, native to the Himalayas, was introduced to Europe as an ornamental and nectar-producing plant at the beginning of the 19th century (Pyšek and Prach 1995). In the UK, it was first introduced in 1839 to Kew Gardens, and was noted as naturalised in the middle of the 20th century. Now listed on Schedule 9 of the Wildlife and Countryside Act 1981 (England and Wales), it is invading riparian habitats, damp woodlands and waste grounds (Beerling and Perrins 1993; Maule et al. 2000), where it displaces native vegetation (Hulme and Bremner 2006; Gruntman et al. 2014) and invertebrate communities (Tanner et al. 2013).

Finally, *S. carolinensis* was introduced as a pet from the United States to England, Scotland and Wales between 1876 and 1929. It soon became invasive, damaging broadleaved trees and displacing the native red squirrel (*Sciurus vulgaris* L.; Middleton 1931). Nowadays, *S. carolinensis* lives in broad-leaved woodlands, garden and parks, and in coniferous woodlands. Moreover, its population range has been expanding significantly in Britain over the last 50 years (Mayle and Broome 2013).

In each geographical location, we visited areas invaded by the target species and frequented by a broad range of residents. In South Africa, we visited the centre of Graaff Reinet, a town of 35 672 inhabitants in the Eastern Cape Province, surrounded by the Cambedoo National Park. Despite being at the heart of historical cacti invasions (Henderson 2015), including *O. stricta*, a project called “Giant Flag” is creating a 66-hectare South African flag just outside the town. The flag consists of 2.5 million succulent plants (including cacti) and solar panels that will be visible from outer space (<https://www.giantflag.co.za/>). The population of Graaff Reinet perceives the project as an opportunity that will supply power to 4000 homes, combat climate change, create jobs for 700 people and boost tourism in the area. In South Africa, we also visited a shopping area in the urban suburb of Constantia (Cape Town, Western Cape), which is invaded by *S. gutturalis* (Measey et al. 2017). In the UK, questionnaire-based interviews were conducted in a public centre square in the city of Coventry which is located in the West Midlands, England, and has about 350 000 inhabitants. As many other parts of the UK, Coventry and its surrounding areas are affected by both invasive Himalayan Balsam and the grey squirrel.

In each visited area (Graaff Reinet, Cape Town, and Coventry), we purposefully selected 80 people (to include a variety of people from different gender, age and ethnical groups) who were willing to answer our hard-copy questionnaire (Online Resource 1). Each questionnaire comprised three sections: 1) a section to assess the perceptions of the public on the target invasive species and its management in urban and non-urban areas, 2) a text including information on the invasive status and impacts of the target invasive species and the control methods available, and 3) a section designed to assess the changes in public perceptions after receiving information on the target species and its management.

In the first section, we showed respondents pictures of the target species (Online Resource 2) and asked if they recognized the animal or plant. We also asked them to describe the target species using three words. Moreover,

they were asked to indicate how positive or negative they felt about the species on a scale from -2 (strongly negative) to 2 (strongly positive). Both these questions were asked without indicating the invasive nature of the target species. Then we asked respondents to indicate how they would feel if they would encounter a control team removing the species in a non-urban area, on a scale from -2 (strongly against) to 2 (strongly in favour) showing a picture of a neighbouring non-urban area at the same time (e.g. a picture of Cambedoo National Park near Graaf-Reinet for the questionnaire on *O. stricta*, Online Resource 2). Finally, we asked them to indicate how would they feel if they would encounter a control team removing the species in an urban area on a scale from -2 (strongly against) to 2 (strongly in favour) while showing a picture of an urban area (e.g. a picture of Graaff Reinett for the questionnaire on *O. stricta*, Online Resource 2).

In the second section, we asked participants to read the text provided (Online Resource 1), which included information on the origin and negative impacts of the target species. We then repeated the process above, showing them two images of the target species both in a neighbouring non-urban and in an urban area, and asking for their response to an imaginary control team.

Analysis Using the words describing the target species provided by our respondents, we constructed a word cloud for each target species in Tag Crowd (<http://tagcrowd.com/>). To show the effect of providing information about the target invasive species and the control methods available on the respondents' perceptions, we constructed plots using the ggplot R package (Wickham, 2009).

We conducted all statistical analyses in R (R Development Core Team 2012) and evaluated significance at $\alpha = 0.05$. We performed Pearson's Chi-square tests to explore whether taxonomic position (i.e. animal or plant) and type of invaded landscape (i.e. urban or non-urban area) affect the perceptions of respondents on the target species and their management. We used Wilcoxon Signed-Rank tests to assess the changes on the perceptions of respondents regarding the management of the target species before and after receiving information about the target invasive species and the control methods available.

Ethics

Before commencing the project, this study was submitted to the Departmental Ethics Screening Committee of the Department of Botany and Zoology for review, and ratified by the Research Ethics Committee of Stellenbosch University. The project was also approved by Coventry University's ethics committee. All participants were informed about their right to refuse to answer any of the questions and to withdraw from participation at any time. We did not collect any personal identifiers.

Results

Literature review

In the 37 research papers that described lack of public support for invasive species management actions, 14 focused on an invasive animal species, 22 on invasive plant species, and one on invasive species in general. The

majority of them took place in non-urban settings (25 papers) that included diverse areas such as agricultural land, nature reserves and rivers (see Figure 1).

Most of these 37 papers (83%) described utilitarian or moralistic value disagreements (Figure 1). 77% of the papers focusing on the management of invasive plants described primarily utilitarian value disagreements, of which 82% were reported in non-urban areas. On the other hand, 71% of the papers focusing on invasive animals described primarily moralistic value disagreements in both urban and non-urban areas.

Face-to-face surveys

In South Africa, 66% of the participants recognized the invasive plant *O. stricta* in the pictures provided (Figure 2), whereas only 16% of the participants correctly recognized the invasive toad *S. gutturalis*. In the UK, only 18% of the respondents recognized the invasive plant *I. glandulifera*. However, all participants recognized the invasive squirrel *S. carolinensis*.

The words provided by the participants to describe the target species reveal the wide variety of perceptions among the public. For all target species, positive words like beautiful, pretty or cute were mixed with neutral words like frog, small or spotty and also negative words like dangerous, scary, invasive or pest. The word cloud images (Figure 3) provide a snapshot of the divergent views that the public have of invasive plant and animal species.

Before reading the text provided (which reports information concerning invasive status and impacts of the target invasive species as well implemented or available control methods), most respondents felt strongly or somewhat against management of the target invasive species (Figure 4). Interestingly, this aversion was not linked to species taxonomic position (animal/plant) in South Africa, or to type of invaded landscape (urban/non-urban) in both South Africa and the UK. However, in the UK, a larger number of respondents were significantly more ($p < 0.05$) against the management of the invasive squirrel than that of the invasive plant *I. glandulifera*.

Irrespective of species taxonomic position and type of invaded landscape, the provided text significantly changed the perceptions of those participants that were originally against the management of the target species (Figure 4). The only exception was *S. carolinensis*, for which the information had a positive effect (i.e. the information changed the participants' perceptions, from feeling against to feeling in favour or neutral about the management actions) in only a small number of participants. Moreover, only a small minority of participants (15 out of 240) had a negative reaction towards the management actions after reading the text.

When we asked respondents if they had any further comments, the answers revealed a variety of reactions to the information provided. For example, additional responses after the questionnaire on *O. stricta* ranged from an appreciation of the new information ("I thought it was indigenous, I didn't know it was invasive", "Oh...now I understand...I saw kids getting injured") to a defence of the cactus existence, both in the specific area around Graaf Reinet ("I grew up with it, I will not change my mind", "People come here just for the cactus. It has been here for years"), but also more generically ("Any species has to live" or "People shouldn't take away nature. Kids in urban areas cannot access nature"). Appreciation of the additional information was also apparent among some respondents in Cape Town regarding *S. gutturalis*, e.g. "They should be eradicated outside this area then", "I did not know this before...", "You should circulate more information about the difference between the guttural toad

and the western leopard toad", "This was good, I needed more knowledge". However, not everyone there expressed a change of attitude towards the management of the guttural toad, e.g. "I feel bad for the leopard toads, but it is not the guttural toad's fault", "You should not kill them, you should move them to the Eastern Cape", or "Everything can be annoying, because it is alive...we have to accept it, I'm against killing". A similar range of sentiments was expressed after information was provided about *I. glandulifera* in the UK (e.g. "Shocked. People should be made aware" and "Get rid of it. Thanks for letting me know", but also "Feeling a bit sorry about the plant - not its fault"). Finally, for the grey squirrel *S. carolinensis*, additional comments expressed by participants also ranged from an appreciation of the presented facts ("Good to have this information", "Very interesting. Good to get facts I didn't know"), an agreement with the proposed management intervention ("Sorry to say but you have to get rid of them", "If it is to control numbers...") to an expression of discomfort and rejection of a cull of grey squirrels (e.g. "Would prefer red ones here, but I don't like the idea of slaughtering grey ones", "I don't like to see them killed but to be moved", and "They're here now, we can't get rid of them", "Don't kill animals - they're innocent").

Discussion

Target species and area

The results of our literature review suggest that the species taxonomic position (i.e. animal or plant) and the type of invaded landscape (i.e. urban or non-urban) may influence public support for the management action. Firstly, and in agreement with previous studies (e.g. Fraser 2001; Bertolino and Genovesi 2003), we found that most of the papers focusing on the management of invasive animals described moralistic value disagreements. Some examples are the public reaction to the management of feral cats in the United States (*Felis catus*; Ash and Adams 2003) or feral horses in Australia (*Equus caballus*; Nimmo et al. 2007). Intriguingly, we found that the number of papers does not differ between urban and non-urban areas. This is surprising because urban areas are characterised by larger human population densities and therefore are thought to have higher probabilities of showing public opposition to invasive animal management actions (Gaertner et al. 2016).

Secondly, we found that most of the papers focusing on the management of invasive plants described utilitarian value disagreements. Some examples are the opposition of South African local communities to the management of invasive Australian Acacias where they are being used as building materials and firewood, and for medicine extraction (de Neergaard 2005), or the opposition of Australian pastoralists to the management of the invasive pasture grass *Cenchrus ciliaris* (Marshall et al. 2011). Almost all the papers describing utilitarian value disagreements (90%) were reported in non-urban areas and involved species that are primarily used in non-urban areas (e.g. for farming, sport-fishing or livestock grazing). However, while there is currently a lack of evidence, we expect that utilitarian value disagreements can also occur in urban areas since invasive species often provide important ecosystem services in urban areas. Furthermore, urban areas generally accommodate a large number of stakeholders that might enjoy the benefits of alien species (Gaertner et al. 2016).

We acknowledge the likelihood of a reporting bias. Although the registered scientific publications might be indicative of which factors may influence the lack of public support for invasive species management actions, other factors might also influence the amount of issues reported. For example, we only focused on academic publications published in English, thereby excluding the academic literature on invasive species management originating from Asia, Europe or South America that are published in non-English languages (e.g. Böhmer 2003, Hubo and Krott 2010, Aracil Amat 2016, Téllez et al. 2016, Zenni et al. 2016).

In contrast to the results of the literature review, the results of our questionnaires showed that before providing any additional information to the participants, public reactions to the management of invasive species were similar, independent of the target species (i.e. animal or plant) in South Africa or the area (i.e. urban and non-urban area) in both South Africa and the UK. This was especially true for moralistic value disagreements. Several of those respondents that were against the management of the target species mentioned that they were opposed to killing any creature, regardless of it being an animal or a plant – e.g. a South African respondent mentioned that "any species has to live". Similarly, Bremner and Park (2007) assessed the attitudes of the public in Scotland towards the management of invasive species, and found several respondents that were against killing creatures in general. In contrast, in the UK, we found less public opposition to the management of the invasive plant than to the management of the invasive animal. These differences might be just a consequence of the invasive squirrel being a charismatic species (Goldstein et al. 2014). However, it is noteworthy that elsewhere in the UK, in places where *S. vulgaris* is still present, control of *S. carolinensis* has been supported by the public and successfully helped the recovery of *S. vulgaris* in some areas (Stokstad 2016). There is now a major initiative

underway to recruit volunteer members of the public to support control activities (<http://www.redsquirrelsunited.org.uk/>). These activities are focused on areas bordering remaining red squirrel territories. This may explain why respondents in our survey – conducted in an area with no remaining red squirrel occurrences – were less aware of the negative impacts of grey squirrels and less willing to support a cull.

Overall, our results suggest that there might be a general trend: lack of public support for the management of invasive animals often derives from moralistic value disagreements, while lack of public support for the management of invasive plants often derives from utilitarian value disagreements. However, contentious situations can originate from a wide variety of different views (e.g. the management of both animal and plants can create moralistic value disagreements).

Public awareness

Results from our questionnaires support the view that public awareness might increase public support for the management of invasive species (see also Mack et al. 2000; Bremner and Park 2007; Klapwijk et al. 2016): independent of the species taxonomic position and the type of invaded landscape, a relatively large number of respondents showed a general willingness to support such actions after receiving the limited amount of information provided on the origin and negative impacts of the target species. Moreover, informing the public about the invasive status and negative impacts of the target species did not increase public opposition to the management actions.

However, when considering the only mammal in our study, only a small number of those respondents that were originally against the management of *S. carolinensis* subsequently supported the management actions after receiving the additional information. Facing similar challenges to the UK, in Italy, a trial grey squirrel eradication programme was suspended in 1997 due to the opposition of radical animal rights groups which started a legal action that only ended in July 2000 (Bertolino and Genovesi 2003; Bertolino 2008). Since then, a large number of awareness and engagement activities aiming to increase public support for managing grey squirrels took place in Italy. As a result, nowadays management actions aiming to control *S. carolinensis* in Italy are generally accepted and are being implemented (Ministry of the environment, land and sea, 2014), mirroring the experience in parts of the UK (Stokstad 2016). This demonstrates that, if funding and time are available, an engagement process through workshops, social media, outreach, citizen science and education activities or training programs (e.g. Ford-Thompson et al. 2012; Estévez et al. 2015; Miralles et al. 2016; Novoa et al. submitted) might improve public support.

In instances where there is a lack of funding or time, two different approaches can be followed. Sometimes it may be possible to proceed with the management actions despite an existing opposition. For example, in Cape Town the management of the invasive Himalayan thars (*Hemitragus jehlahicus*) met substantial public opposition, but the management actions were nonetheless implemented (Gaertner et al. 2016). In other cases when there is strong opposition to the management actions, the target invasive species might need to be partially or totally tolerated (Gaertner et al. 2016). An example is the invasion of *Jacaranda mimosifolia* in Pretoria, South Africa (Dickie et al. 2014). The management actions aiming to remove *J. mimosifolia* from the city met huge public resistance. As a result, although no new trees can be planted, the presence of Jacaranda trees

in urban areas is currently tolerated by law – i.e. by the *National Environmental Management: Biodiversity Act, Alien and Invasive Species Regulation* (NEM:BA).

Conclusions

Here we provide important insights regarding public support for invasive species management and demonstrate the benefit of increasing public awareness to improve such public support. However, our study is not free of limitations. Firstly, although we documented that providing a limited amount of information noticeably helped to increase support, it is not clear whether this positive response is a genuine change of perception or is rather a labile short-time reaction to the text we provided. Future more extensive studies should be conducted to explore success and long-time effects of information provision and other public engagement strategies aiming to facilitate invasive species management. Secondly, the limited number of case studies reported in our paper could impede to identify some general trends; at this scope, we call for more analogous studies based on administering questionnaires not only across taxa but also between urban and non-urban areas, i.e. between landscapes characterized by contrasting social dimensions linked to the invaded area. This is pivotal not only to identify the emergence of conflicts of interests among stakeholders but also to estimate whether a context dependent approach should more often be performed to socially support invasive species management.

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FIGURES

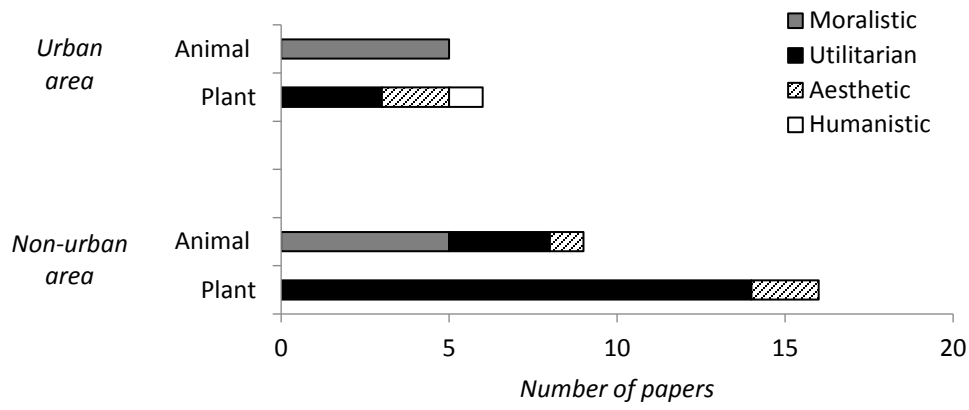


Fig. 1. Number of papers compiled through a literature review reporting lack of public support for the management of alien invasive species by area, species type, and value system.

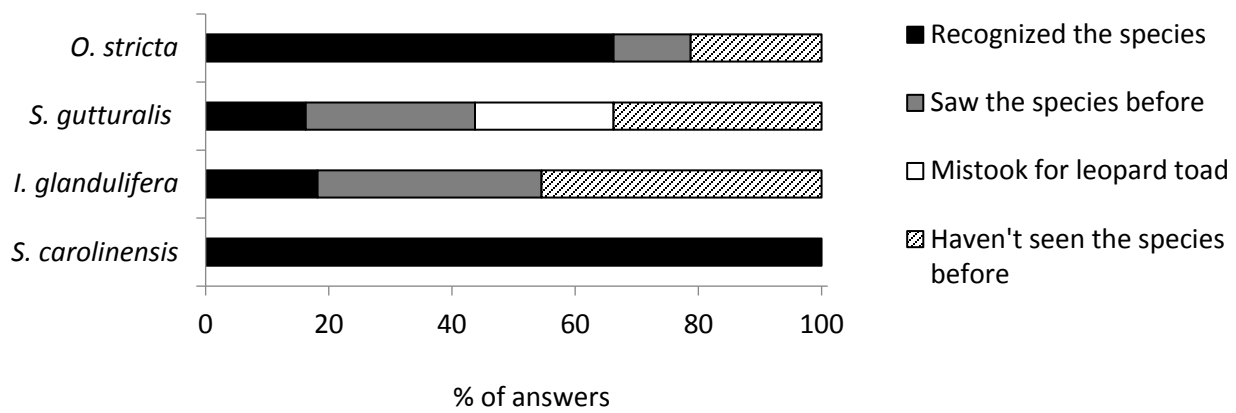


Fig. 2. Percentage of questionnaire participants that recognized the target species, saw them before, did not see them before or mistook them for a similar native species.

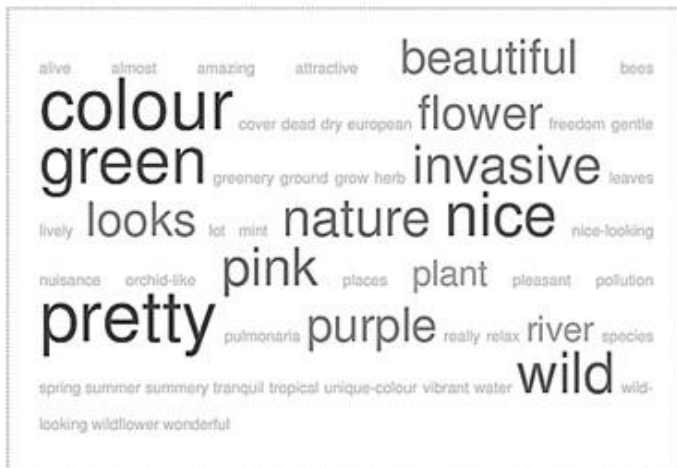
A) *O. stricta*



B) *A. gutturalis*



C) *I. glandulifera*



D) *S. carolinensis*

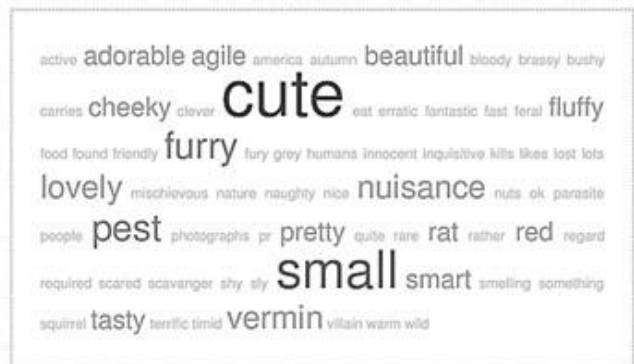
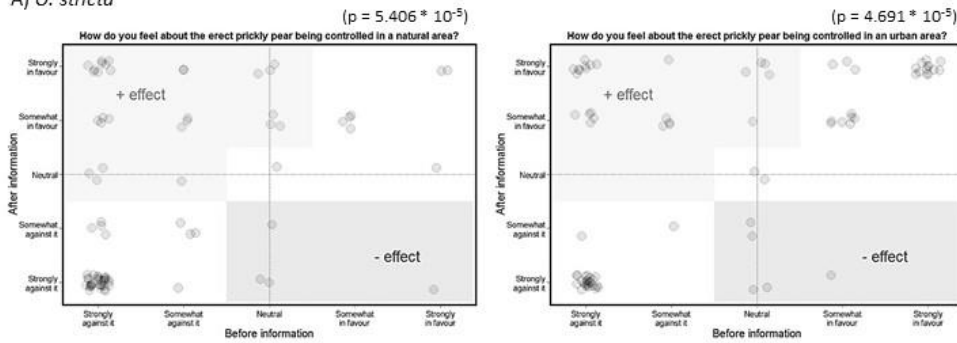
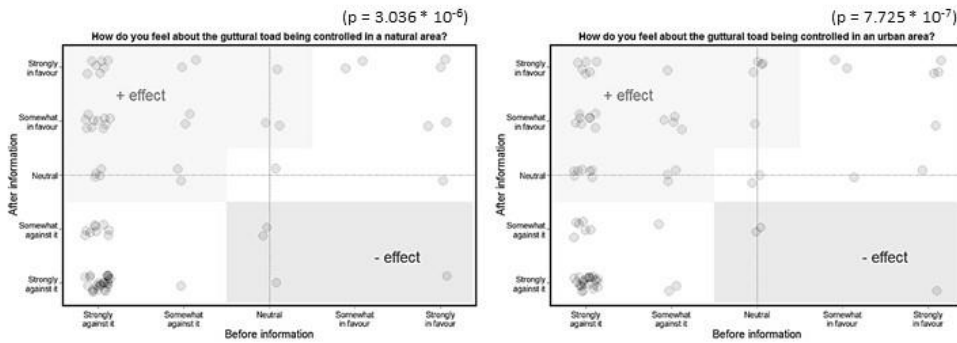


Fig. 3. Word clouds compiling the words used by the questionnaire participants to describe A) *O. stricta*, B) *S. gutturalis*, C) *I. glandulifera*, and D) *S. carolinensis*. The size of words is proportional to the number of times the words were mentioned by the participants.

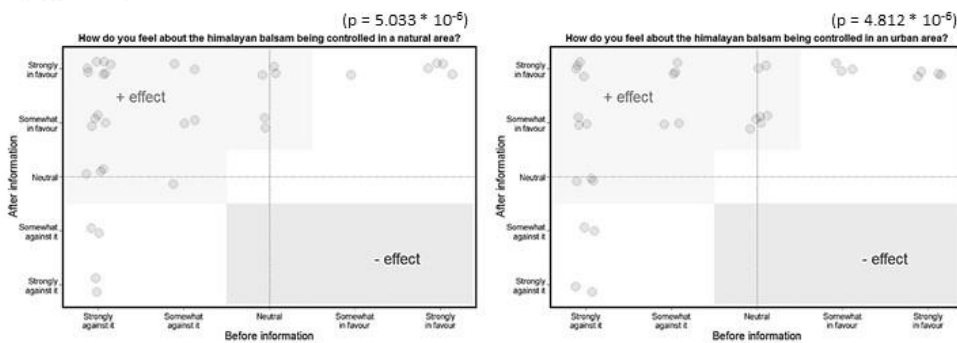
A) *O. stricta*



B) *A. gutturalis*



C) *I. glandulifera*



D) *S. carolinensis*

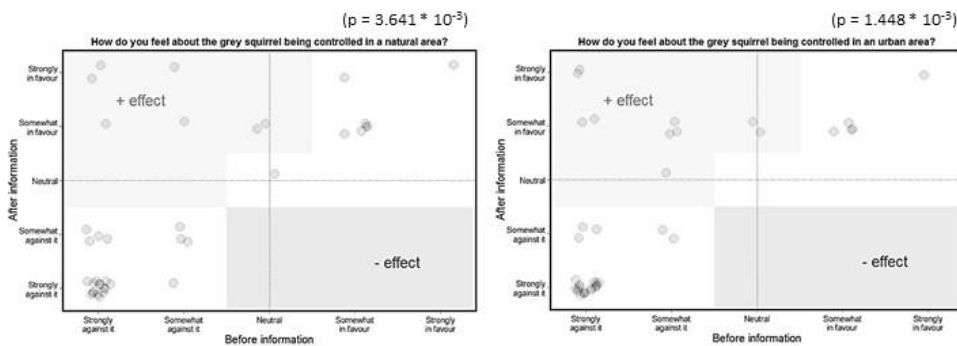


Fig. 4. Change in public perceptions towards the management of A) *O. stricta*, B) *A. gutturalis*, C) *I. glandulifera*, and D) *S. carolinensis* before and after reading a text including information on the impacts of the target invasive species and the control methods available. The green section indicates a positive change in perception where the red section indicates a negative change. P values were calculated using a paired Wilcoxon signed-rank test.