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# Managing conflict-generating invasive species in South Africa: Challenges and trade-offs

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**Background**: This paper reviewed the benefits and negative impacts of alien species that are currently listed in the Alien and Invasive Species Regulations of the *National Environmental Management: Biodiversity Act* (Act no 10 of 2004) and certain alien species that are not yet listed in the regulations for which conflicts of interest complicate management.

**Objectives**: Specifically, it identified conflict-generating species, evaluated the causes and driving forces of these conflicts and assessed how the conflicts have affected management.

**Method**: A simple scoring system was used to classify the alien species according to their relative degree of benefits and negative impacts. Conflict-generating species were then identified and further evaluated using an integrated cognitive hierarchy theory and risk perception framework to identify the value systems (intrinsic and economic) and risk perceptions associated with each conflict.

**Results**: A total of 552 alien species were assessed. Most of the species were classified as inconsequential (55%) or destructive (29%). Beneficial (10%) and conflict-generating (6%) species made a minor contribution. The majority (46%) of the conflict cases were associated with more than one value system or both values and risk perception. The other conflicts cases were based on intrinsic (40%) and utilitarian (14%) value systems.

**Conclusions**: Conflicts based on value and risk perceptions are inherently difficult to resolve because authorities need to balance the needs of different stakeholders while meeting the mandate of conserving the environment, ecosystem services and human well-being. This paper uses the identified conflict-generating species to highlight the challenges and trade-offs of managing invasive species in South Africa.

## Introduction

South Africa has a long history of alien species introductions and interventions for managing biological invasions (Richardson et al. 2011). The primary reasons for introductions of alien species were to provide food and raw materials, for recreational ornamentation and as pets, and for erosion control and dune stabilisation. In addition, many species were introduced accidently (Richardson et al. 2003). These introductions have included commercially important trees such as many species of acacias, eucalypts and pines for forestry (van Wilgen & Richardson 2014), fish species such as salmonids and black bass for aquaculture and recreational fishing (Ellender & Weyl 2014) and mammals for the game industry (Brooke, Lloyd & de Villiers 1986; van Rensburg et al. 2011). Moreover, numerous species of birds, fishes, mammals and plants were introduced for ornamentation and as pets (Brooke et al. 1986; Foxcroft, Richardson & Wilson 2008; Picker & Griffiths 2017; Richardson et al. 2003). Such alien species with a high societal value have been widely disseminated across the country and in some areas they are now conspicuous components of natural ecosystems. Although considerable socio-economic benefits have been derived from many alien species, some have become invasive and have caused adverse ecological and socio-economic impacts in recipient areas (De Wit, Crookes & van Wilgen 2001; Ellender et al. 2014; Le Maitre et al. 2011; van Rensburg et al. 2011; van Wilgen et al. 2011). Impacts caused by alien species include loss of biodiversity (Powell, Chase & Knight 2013), changes to ecosystem functioning, economic losses (Holmes et al. 2009) or impacts on human health (Hulme 2014).

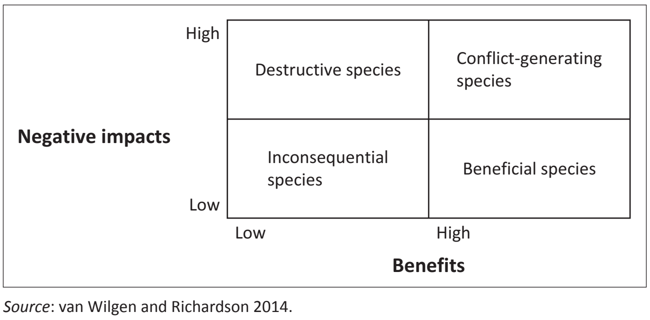
The main legislative instrument that guides the management of alien species in South Africa is the *National Environmental Management: Biodiversity Act* (NEM:BA) (Act 10 of 2004) and the regulations relating to this Act (Republic of South Africa [RSA] 2004). Management measures include interventions directed at restricting the importation of high-risk alien species, regulating



**Note:** This paper was initially delivered at the 43rd Annual Research Symposium on the Management of Biological Invasions in South Africa, Goudini Spa, Western Cape, South Africa on 18-20 May 2016.

the movement and utilisation of alien species, and interventions aimed at eradicating species that occur in low numbers over limited areas, containing invasions, and reducing the extent and impact of well-established invaders (RSA 2014). Management actions directed at species that have both benefits and negative impacts are, however, complicated. For such species (hereafter 'conflict-generating species'), there is current or potential disagreement between stakeholders regarding their benefits and the damage that they inflict on the ecosystems where they occur. Issues pertaining to such species are increasingly complicating the management of biological invasions worldwide (Woodford et al. 2016).

The benefits and negative impacts of alien species vary widely in type and magnitude and are dependent on the species, their invasive potential, the extent to which they have invaded, the nature of the invaded environment and socio-economic contexts (Kueffer 2013; Kueffer & Kull 2017; Kull et al. 2011; Shackleton et al. 2007; van Wilgen & Richardson 2014). Nevertheless, the relative degree of negative impacts of alien species and the benefits associated with their utilisation can be used to place them in a conceptual framework that divides species into four broad categories (van Wilgen & Richardson 2014) (Figure 1). In the first two categories, alien species have neither substantial negative impact nor benefit (these are termed 'inconsequential species') or are 'beneficial species' that have relatively low negative impact but provide significant benefit. The third category comprises species that have no substantial benefits but high negative impacts ('destructive species'). Species in these three categories usually have less complex dimensions to their management and the degree of social contestation regarding ways to control, eradicate or otherwise manage them is low. However, species in the fourth category – that is species with high negative impacts and benefits ('conflict-generating species') – generate most controversy because of the polarised perceptions of their impacts and benefits between different stakeholders and the options for managing them. Human attitudes and behaviours towards the use and management of conflict-generating species are largely influenced by individual or group demographics and knowledge and by properties of the species itself (Rotherham & Lambert 2011; van Wilgen & Richardson 2014). Furthermore, the complexity of societal issues around conflict-generating species can also vary from simple issues centred on one stakeholder's perception of the problem to complex issues that involve many conflicting stakeholders' perspectives (Novoa et al. 2016; Woodford et al. 2016). Therefore, the dimensions of conflicts that arise and the options that exist for resolving these conflicts can be highly taxon and region-specific.




*Source*: van Wilgen and Richardson 2014.

**FIGURE 1:** A conceptual framework to categorise alien and invasive species based on their relative environmental and socio-economic negative impacts and benefits.

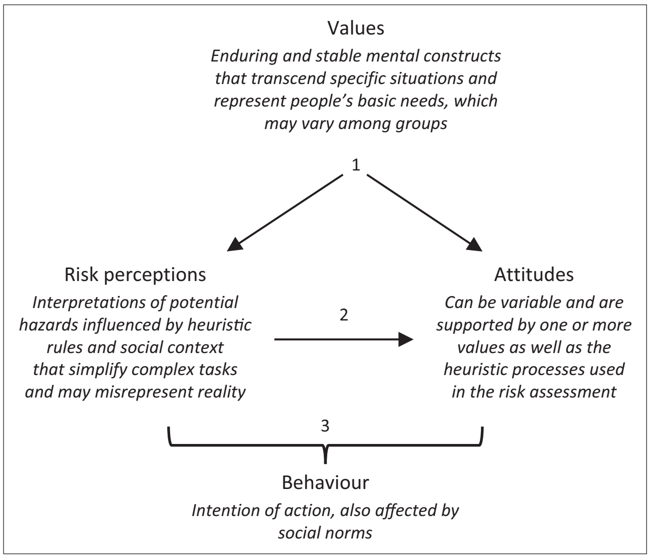
This paper, focusing on conflict-generating species, is directly aligned to one of the tenets of this special issue of *Bothalia – African Biodiversity and Conservation* on efficacy of interventions for managing biological invasions in South Africa (Wilson et al. 2017). This topic is, however, also relevant to global audiences as conflicts of interest around invasive species are a global issue (Pyšek & Richardson 2010). We review the benefits and negative impacts of alien species that are currently, or may be, listed in the Alien and Invasive Species (A&IS) Regulations (RSA 2014) of the NEM:BA (Act no 10 of 2004) (RSA 2004). Specifically, we aimed to identify conflict-generating species, evaluate the causes and driving forces of these conflicts and assess how the conflicts have affected management.

# Methods

The 549 alien species that are currently listed in the A&IS Regulations (2014) were classified as inconsequential, beneficial, destructive or conflict-generating species according to their relative degree of benefits and negative impacts (Online Appendix). Three additional contentious species that are either not listed or were removed from the A&IS Regulations (2014) to avoid conflicts were also classified. Species were classified through a simple scoring system (Table 1) that had two categories each for negative impacts [ecological and socio-economic (including intrinsic impacts under 'socio' part)] and benefits (economic and intrinsic). For each category, the negative impacts and benefits of each species were quantified by a three-level scale that ranged from 1 to 3 (no or little evidence of negative impacts or benefits), 4 to 6 (localised negative impacts or benefits) and 7 to 10 (widespread negative impacts or benefits). The final score from impact scoring systems can be obtained in several ways (see Nentwig et al. 2016) depending on the focus of the assessment. For this study, the overall scores of a species were obtained by taking the maximum score for any of the two categories of negative impacts and benefits. The scoring was done by the co-authors, all of whom are active researchers in the field of invasion biology in South Africa. The authors were divided into two groups (plants and animals) according to their expertise. Within each group, each author was allocated a number of species to independently evaluate them based on the available literature. Subsequently, all evaluations were discussed among all group members. We acknowledge that scoring could be improved if all the authors evaluated all the assessed species and through consultations with a broader stakeholder group and therefore recommend that this study should be expanded in future to get a more balanced assessment.

**TABLE 1:** The scoring system used to identify conflict-generating species on the list of the alien species in the Alien and Invasive Species Regulations of 2014.

| Impacts | Category | Score levels |
| --- | --- | --- |
| Negative impacts | Ecological impacts | *1–3:* No or little evidence of impact on other species and/or causes little to no changes to the supply of ecosystem services (provisioning, regulating, supporting and cultural): Low consequences – negligible impacts on ecological systems, pattern and processes and/or impacts arising are easily restored |
| | | *4–6:* Localised impact on a few species and/or reduces the supply one or more ecosystem service but does not result in the total loss of these services: Moderate consequences – impacts on ecological systems, pattern and processes and impacts arising are potentially restorable |
| | | *7–10:* Widespread impacts on multiple species and/or results in the loss of one or more ecosystem service, and has, or threatens to cause, a total loss in the services supplied: Substantial consequences – impacts on ecological systems, pattern and processes and impacts arising are difficult to restore/reverse |
| | Socio-economic impacts | *1–3:* Has no or very low economic impact on a few communities or stakeholders and/or has very little to no impact local human well-being at local levels: Low consequences – negligible impacts on social-economic systems, pattern and processes and impacts arising are easily restored |
| | | *4–6:* Has multiple economic impacts for several communities or stakeholders at localised levels and can hinder livelihoods and reduce economic returns and/or disrupts local livelihoods and well-being in some manner but does not prevent economic activity entirely: Moderate consequences – impacts on social-economic systems, pattern and processes and impacts arising are easily restored or reversed |
| | | *7–10:* Has multiple economic impacts for numerous communities or stakeholders at a national level that threatens livelihoods and economic returns and/or disrupts livelihoods and well-being on a large scale and considerably increases the vulnerability of local communities in a variety of ways: Substantial consequences – impacts on economic activities are difficult to restore or reverse |
| Benefits | Economic benefits | *1–3:* Has no economic benefits – it is not harvested or traded and provides no employment |
| | | *4–6:* Is harvested or traded by local communities on a small scale (informal and localised) (localised areas) – provides low employment |
| | | *7–10:* Is harvested or traded at a national scale – it contributes to national gross domestic product (GDP) and provides jobs to large numbers of people |
| | Intrinsic benefits | *1–3:* Provides little to no intrinsic (aesthetic appeal, moralistic appeal or recreation value) value to local communities. Local would not notice or care if the species was removed based on intrinsic reasons |
| | | *4–6:* Provides some intrinsic value (aesthetic appeal, moralistic appeal or recreation value) to local communities (small part of the population) and/or one particular stakeholders group. There might be resistance to removal because of intrinsic reasons |
| | | *7–10:* Provides high intrinsic value (aesthetic appeal, moralistic appeal or recreation value) for a large proportion of the population and numerous communities and/or is beneficial to multiple stakeholder groups: resistance to removal based on intrinsic reasons expected |




*Source*: Estévez et al. 2015

**FIGURE 2:** A conceptual framework created by integrating cognitive hierarchy theory (CHT) and risk perception theories.

The identified conflict-generating species were then evaluated using an integrated cognitive hierarchy theory – risk perception framework (Estévez et al. 2015; Figure 2), to identify the conflict type and cognitive level at which the conflicts occurred. Two conflict types were identified – conflicts based on specific values or heuristic rules. Heuristic rules are simple and efficient ways in which people reduce complex mental tasks to simpler ones to form judgements and make decisions, for example, focusing on one aspect of a complex problem and ignoring others (Slovic 1999). Cognitive levels were defined as subjective classifications of conflicts based on whether there are based on values or perceptions. The conceptual framework is a tiered system of values, risk perceptions, attitudes and behaviour that has been applied to the management of conflict invasive species (Estévez et al. 2015). Values are the basis of the hierarchal framework and are defined as enduring and fundamental beliefs that represent people's needs and may vary among groups. For the purposes of this paper, we used Kellert's (1993) classification that describes eight fundamental values that humans associate with nature (Table 2). These vary from intrinsic values (aesthetic, dominionistic, humanistic, moralistic and naturalistic) that represent some form of emotional relationship between society and nature to values that represent a practical value or material benefit of nature (scientific and utilitarian). Risk perceptions are interpretations of potential hazards that are influenced by mental strategies or heuristic rules and social context (cultural backgrounds and personal values) that reduce complex mental task to simpler ones (Slovic 1999). Risk perceptions may either represent reality or generate substantial and persistent biases that lead to attitudes that misrepresent the magnitude or severity of risks (Burgman 2005). Attitudes are flexible constructs that are supported by one or several values and are affected by risk perception (Fulton, Manfredo & Lipscom 1996). Behaviour is defined as an intention of action that is directly influenced by attitudes and risk perception (Rokeach 1973).

# Results

## Negative impacts and benefits framework

Most of the 552 assessed alien species were classified as either inconsequential (55%) or destructive (29%). Far fewer species were classified as beneficial (10%) and conflict-generating species (6%) (Figure 3). The results for animals and plants showed similar general trends, where inconsequential and destructive species predominate and conflict and beneficial species make up the remainder. Inconsequential species

**TABLE 2:** Eight fundamental values that humans associate with nature.

| Conflict level | Value or heuristic rule | Definition |
|---|---|---|
| Value system | Naturalistic | Exploration of nature and outdoor recreation |
| | Aesthetic | Physical attraction and appeal of nature |
| | Dominionistic | Mastery and control over nature |
| | Humanistic | Emotional, spiritual, or symbolic affection for nature |
| | Moralistic | Moral concern about the right and treatment of nature |
| | Negativistic | Fear or aversion towards nature |
| | Scientific | Systematic and empirical study of nature |
| | Utilitarian | Practical value or material benefit of nature |
| Risk perception | Evaluation of potentials | Differences in evaluations of potential hazards |
| | Lack of institutional trust | Lack of trust between stakeholders and government agencies could result from lack of community engagement and transparencies in decision making processes, differences in evaluations of potential hazards, and lack of confidence in government authorities |

*Source*: Kellert 1993

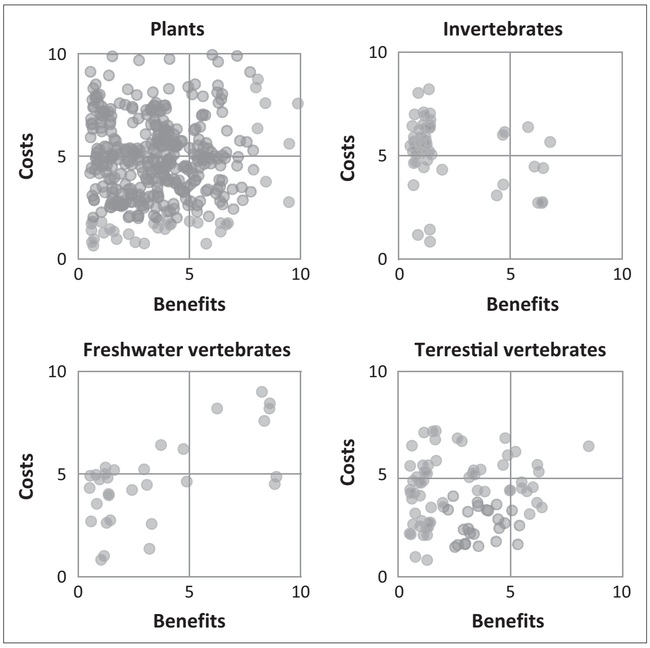



**FIGURE 3:** Categorisation of alien species listed under the A&IS Regulation (2014) based on the degree of their negative impacts (ecological and socio-economic) and benefits (economic and intrinsic). Jitter was used to indicate the density of dots where there is overlap.

consisted of 99 animal and 203 plant species that had a score ≤ 5 for both negative impacts and benefits. Nearly half of the animal (48 out of 100 species) and 30% (61/203) of plant species in this category recorded the lowest possible scores (< 3) for both negative impact and benefits. Furthermore, almost all the listed amphibian species (5 out of 7), bird (18/24) and reptiles (33/35) species were placed in this category.

Beneficial species comprised 13 animal and 42 plant species that had a score ≤ 5 for negative impacts but > 5 for benefits (Figure 3). The highest economic (≥ 8) and intrinsic (≥ 8) benefit scores were allocated to three *Eucalyptus* species [*E. cladocalyx* (sugar gum); *E. diversicolor* (karri gum) and *E. grandis* (saligna gum)]. The 'destructive species' category had 54 animal and 107 plant species that scored > 5 for negative impacts but ≤ 5 for benefits (Figure 3). Among the animals, all the listed microbes and terrestrial insects (except stick insects; species in the order Phasmatodea) were classified as destructive species and the highest negative impact score of 8 was reached by *Phytophthora cinnamomi* (microbe) and *Trogoderma granarium* (khapra beetle). Among the plant species, 60 species were classified as highly destructive (score range 7–10) and the highest negative impact scores (> 9) were reached by lantana (*Lantana* spp.), three *Acacia* species (*A. decurrens*, *A. longifolia* and *A. saligna*), *Dolichandra unguis-cati* (cat's claw creeper), *Echium plantagineum* (Patterson's curse), *Chromolaena odorata* (triffid/siam weed), *Eucalyptus camaldulensis* (river red gum) and *Hakea sericea* (silky hakea).

Conflict-generating species consisted of 9 animal and 25 plant species that had a score > 5 for either negative impacts or benefits (Figure 3). The animal species assigned the highest scores (≥ 8) each for negative impacts and benefits were five fish species [*Micropterus salmoides* (largemouth bass), *Micropterus dolomieu* (smallmouth bass), *Oreochromis niloticus* (Nile tilapia), *Oncorhynchus mykiss* (rainbow trout) and *Salmo trutta* (brown trout)]. The plant species that reached the highest score include *Acacia* species (*A. cyclops*, *A. dealbata*, *A. mearnsii* and *A. melanoxylon*), *Pinus* species (*P. elliottii*, *P. patula* and *P. radiata*), *Prosopis* species and cacti (*Cylindropuntia fulgida* var. *mamillata*, *C. imbricata*, *C. leptocaulis*, *C. pallida* and *C. spinosior*). See Woodford et al. (2017) for a review of the conflicts that have arisen with introduced fish and Kaplan et al. (2017) for conflicts with introduced cacti.

## Conflict types and cognitive levels

The majority (46%) of the conflict cases could be explained by more than one conflict type and cognitive level (Table 3). Different conflict types occurred when a species was associated with both intrinsic and economic values. This was observed for two plant species: *Pinus radiata* (Monterey pine) and *Psidium guajava* (guava). Different cognitive levels were observed when a conflict was based on values and risk perceptions. Risk perceptions were mainly derived from a fear or aversion of possible adverse impacts associated with the species and control methods used in its management. Plant species in this category include mesquite (*P. glandulosa* and *P. velutina*), acacias (*A. cyclops*, *A. dealbata*, *A. mearnsii* and *A. melanoxylon*) and pines (*P. elliottii* and *P. patula*). The remainder comprised animal

**TABLE 3:** Conflict-generating invasive species showing the negative impacts (ecological and social-economic), benefits (economic and intrinsic), cognitive level (VS = value system and PB = perceptions based) and value system or heuristic rule at which conflicts occurred.

| Descriptive category | Common name | Species | Taxon | Costs | | Benefits | | Conflict level | Value or heuristic rule |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Ecological | Social-economic | Economic | Intrinsic | | |
| **Agricultural initiatives** | Leucaena | *Leucaena leucocephala* | P | 7 | 7 | 6 | 5 | VS | Utilitarian |
| | Mission prickly pear | *Opuntia ficus-indica* | P | 6 | 6 | 8 | 4 | VS | Utilitarian |
| | Blue-leaf cactus | *Opuntia robusta* | P | 6 | 6 | 7 | 4 | VS | Utilitarian |
| | Honey mesquite | *Prosopis glandulosa* | P | 9 | 9 | 8 | 6 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Velvet mesquite | *Prosopis velutina* | P | 9 | 9 | 8 | 6 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Guava | *Psidium guajava* | P | 6 | 4 | 9 | 6 | VS | Aesthetic, utilitarian |
| **Angling** | Smallmouth bass | *Micropterus dolomieu* | FV | 9 | 2 | 9 | 9 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Largemouth bass | *Micropterus salmoides* | FV | 8 | 2 | 9 | 9 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Brown trout | *Salmo trutta* | FV | 8 | 2 | 9 | 1 | VS, PB | Utilitarian, evaluation of potential hazard |
| **Aquaculture** | Marron | *Cherax tenuimanus* | I | 6 | 3 | 6 | 1 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Japanese oyster | *Crassostrea gigas* | I | 6 | 4 | 7 | 1 | VS | Utilitarian |
| | Nile tilapia | *Oreochromis niloticus* | FV | 8 | 2 | 7 | 1 | VS, PB | Utilitarian, evaluation of potential hazard |
| **Aquaculture, angling** | Rainbow trout | *Oncorhynchus mykiss* | FV | 8 | 2 | 9 | 1 | VS, PB | Utilitarian, evaluation of potential hazard |
| **Commercial important trees** | Golden wattle | *Acacia pycnantha* | P | 6 | 3 | 1 | 6 | VS | Aesthetic, naturalistic |
| | Red eye/rooikrans | *Acacia cyclops* | P | 10 | 7 | 6 | 3 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Silver wattle | *Acacia dealbata* | P | 10 | 7 | 6 | 3 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Black wattle | *Acacia mearnsii* | P | 10 | 7 | 9 | 4 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Australian blackwood | *Acacia melanoxylon* | P | 10 | 7 | 7 | 5 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Slash pine | *Pinus elliottii* | P | 8 | 4 | 8 | 5 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Patula pine | *Pinus patula* | P | 8 | 3 | 10 | 4 | VS, PB | Utilitarian, evaluation of potential hazard |
| | Monterey pine | *Pinus radiata* | P | 8 | 3 | 8 | 6 | VS | Aesthetic, naturalistic, utilitarian |
| **Erosion control, sand dune stabilisation** | Marram grass | *Ammophila arenaria* | P | 7 | 6 | 6 | 2 | VS | Utilitarian |
| **Escapees** | Domestic cat | *Felis catus* | TV | 7 | 5 | 1 | 8 | VS | Aesthetic, moralistic |
| | Himalayan tahr | *Hemitragus jemlahicus* | TV | 6 | 3 | 1 | 6 | VS | Humanistic |
| **Ornamentals** | Chain-fruit cholla | *Cylindropuntia fulgida* var. *fulgida* | P | 7 | 8 | 4 | 6 | VS | Aesthetic |
| | Boxing-glove cactus | *Cylindropuntia fulgida* var. *mamillata* | P | 7 | 8 | 4 | 6 | VS | Aesthetic |
| | Imbricate cactus | *Cylindropuntia imbricate* | P | 7 | 8 | 4 | 6 | VS | Aesthetic |
| | Pencil cactus | *Cylindropuntia leptocaulis* | P | 7 | 8 | 4 | 6 | VS | Aesthetic |
| | Pink-flowered sheathed cholla | *Cylindropuntia pallida* | P | 7 | 8 | 4 | 6 | VS | Aesthetic |
| | Cane cholla | *Cylindropuntia spinosior* | P | 7 | 8 | 4 | 6 | VS | Aesthetic |
| | Syringa | *Melia azedarach* | P | 6 | 1 | 2 | 8 | VS | Aesthetic |
| | Yellow bunny-ears | *Opuntia microdasys* | P | 6 | 6 | 3 | 7 | VS | Aesthetic |
| | Jerusalem thorn | *Parkinsonia aculeata* | P | 7 | 7 | 3 | 6 | VS | Aesthetic |
| | Belhambra | *Phytolacca dioica* | P | 8 | 4 | 2 | 6 | VS | Aesthetic |
| | Pink tamarisk | *Tamarix ramosissima* | P | 7 | 7 | 2 | 6 | VS | Aesthetic |

Species were grouped into four descriptive taxon categories were *P* = plants, I = invertebrates, TV = terrestrial vertebrates, FV = freshwater vertebrates.

species such as *M. dolomieu*, *M. salmoides*, *O. niloticus*, *O. mykiss*, *S. trutta* and *Cherax tenuimanus* (marron).

Conflicts centred on intrinsic value systems collectively accounted for 40% of all the examined cases of conflict-generating species (Table 3). The detected value systems included naturalistic, humanistic, aesthetic and moralistic values that were associated with 12 ornamental plants and 2 vertebrate species [*Hemitragus jemlahicus* (Himalayan tahr) and *Felis catus* (domestic cat)]. The ornamental plants include *A. pycnantha* (golden wattle), cacti (*C. fulgida* var. *fulgida*, *C. fulgida* var. *mamillata*, *C. imbricata*, *C. leptocaulis*, *C. pallida*, *C. spinosior* and *Opuntia microdasys*), *Melia azedarach* (syringa), *Parkinsonia aculeate* (Jerusalem thorn), *Phytolacca dioica* (ombu) and *Tamarix ramosissima* (pink tamarisk). Conflicts based on only utilitarian values made up 14% of observed conflicts and were identified mainly from commercial important species such as *Leucaena leucocephala* (leucaena), *Ammophila arenaria* (marram grass), *Opuntia ficus-indica* (prickly pear), *Opuntia robusta* (blue-leaf cactus) and *Crassostrea gigas* (Japanese oyster).

# Discussion

## Inconsequential species

The negative impacts and benefits framework indicated that almost half of the 552 assessed species could be classified as 'inconsequential species' that have neither substantial benefits nor negative impacts. Most of these inconsequential species have either limited distribution or no known impacts in South Africa or elsewhere in the world. For example, freshwater fish can only spread within a river system and their spread across the country is facilitated by human movement. Some of the species such as *Perca fluviatilis* (European perch) are of little interest to the mainstream angling and aquaculture fraternity (major pathways of fish introductions in South Africa; Richardson et al. 2011). They are therefore not moved as much as commercially important and widely used introduced species such as trout, carp and black basses (Ellender et al. 2014). Moreover, most inconsequential mammal and bird species were introduced for novelty, and as ornamentals for private collections and game ranching. Some of these species have not established self-sustaining populations and are either no longer present in the country or actively maintained in captive facilities such as botanical and zoological gardens or in private properties where they have not caused any documented impact on the environment. For example, there is no evidence that the rare *Elaphurus davidianus* (Père David's Deer) that is endemic to China is invasive anywhere in the world, and known populations outside its native range are in captivity (Long 2003). It is important to note that because of the limited data on the potential impact and benefits associated with species in this category, reassessments might be necessary as more information becomes available. For example, the eastern grey squirrel (*Sciurus carolinensis*) has relatively minor impacts on biodiversity although some potentially major impacts such as predation on native birds have not yet been thoroughly assessed and any future management plans of the species needs an increased appreciation of its potential impacts on native biota. Similarly, some plant species have long lag phases (low initial population growth rate) after introduction and as a result they may become widely utilised and accepted as either inconsequential or beneficial species. The benefits are, however, often surpassed by negative impacts when the species become invasive (Geerts et al. 2013; Shackleton et al. 2007).

## Destructive species

Species that were classified as destructive (no substantial benefits but high negative impact) made up the second largest proportion of all the listed species on the A&IS Regulations. Species in this category are largely regarded as pests and weeds because of the deleterious effect they have on society and the environment. Many of these species were also accidental introductions. As a result, the degree of social contestation regarding ways to control or eradicate them is low. For example, there has been little public resistance to the management of invasive rodents (*Rattus* spp.) in several townships in Gauteng because the species have been implicated in causing damage to infrastructure and transmission of zoonotic diseases (Jassat et al. 2013). The same is true for most of the listed microbes and terrestrial insects that are known pests and pathogens of agricultural crops (Burgess et al. 2007; Durán et al. 2009; Hunter et al. 2011; Picker & Griffiths 2017; Wingfield et al. 2008a, 2008b, 2010). Several animal species that were classified as destructive have been introduced globally as part of the pet trade and game ranching industry (Brooke et al. 1986; Picker & Griffiths 2017; Richardson et al. 2003; van Rensburg et al. 2011). Many of these species escaped captivity through direct or accidental releases by the public into the wild. In the wild, the species have been linked to a variety of impacts on native biota (see Long 2003). However, because we are concerned only with populations in the wild, species that are important in the pet trade or game ranching industry might not have much value once they escape captivity. While eradicating such species from the wild would therefore cause little conflict, banning them from the trade would result in conflict. Examples of destructive plants – that is plants that have little use, high negative impacts and a low degree of social contestation regarding ways to control them – include *Lantana* spp., which outcompetes and replaces indigenous species and forms dense thickets that obstruct access to land, and *Parthenium hysterophorus*, which reduces grazing potential and causes human health related problems (McConnachie et al. 2011; Strathie 2015; Vardien et al. 2012; Zachariades et al. 2009).

## Beneficial species

There are also some species that were categorised as beneficial but not harmful. This suggests that active management is not necessary or should only be done in particular cases. Some of these perceived beneficial species still create conflict even though there is not much evidence of negative impacts and represent some unique cases. Previous attempts to manage these unique cases have led to some controversy where either proposed management actions have been completely put aside or there have been some trade-offs and compromises. For example, *Jacaranda mimosifolia* (jacaranda) is an iconic tree species in the city of Pretoria, where the species is regarded as part of the identity and 'sense of place' of the city. There was huge public resistance to their removal and to regulations preventing replanting (Dickie et al. 2014; Kasrils 2001). The conflicts were resolved through active stakeholder engagement and through compromises, which involved regulating the species by area (management interventions that are area specific). As a result, jacarandas are not listed as invasive species in urban areas and around farm houses in several provinces where they occur (Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga and North-West). It is envisaged that in these areas, trees will be gradually phased out by preventing further replanting of jacaranda. The seed source is, however, likely to remain for years (see Irlich et al. 2017 for a review of such issues facing municipalities). Similarly, several individual alien trees and groups of alien trees comprising 41 species were classified as champion trees and given protected status under Section 12 of the *National*

*Forests Act* of 1998 by the Department of Agriculture, Forestry and Fisheries (DAFF) because of their remarkable size, age and aesthetic, cultural, historic or tourism value (DAFF 2016). An example is the large *Cinnamomum camphora* (camphor trees) that were planted in the Vergelegen Estate in Somerset West more than three centuries ago by Governor Willem Adriaan van der Stel (DAFF 2016). These trees were classified as national heritage or champion trees and are not listed on the A&IS Regulations. The species as a whole is, however, regulated by area, and camphor trees that are not listed as heritage/champion trees have to be controlled in the Eastern Cape, KwaZulu-Natal, Limpopo and Mpumalanga, but utilisation is allowed in the Western Cape, subject to certain prohibitions (e.g. no selling or distribution). Camphor trees are not listed in A&IS Regulations in other provinces such as the North-West, Free State, Gauteng and Northern Cape.

Similar compromises have also been made for other listed plants that have high economic and intrinsic values, such as eucalypts (*E. cladocalyx*, *E. diversicolor*, *E. grandis*) (RSA 2014) which is also regulated by area. For all biomes, eucalypt trees must be removed from riparian areas, protected areas (nature reserves and national parks) and ecosystems of conservation concern. Eucalypt trees that occur in the Nama-Karoo, Succulent Karoo and Desert biomes are exempt from removal, but trees in all other biomes are to be controlled except when they occur in a formal plantation, in urban areas, close to farm homesteads and within cultivated land.

Examples of beneficial animal species where compromises had to be made for their management include rock doves (*Columba livia*) and ungulate mammal species. Feral rock doves are regarded as a health risk to humans and indigenous bird species and as a result were initially listed in Category 1b ('Invasive species requiring compulsory control as part of an invasive species control programme. These species are deemed to have such a high invasive potential that infestations can qualify to be placed under a government sponsored invasive species management program. No permits will be issued to introduce or use this species in South Africa'). This caused some consternation among the pigeon racing community. The regulations were amended to accommodate their concerns in the A&IS list that was published in July 2016 (RSA 2016). The rock doves are now listed in Category 2 where utilisation for all restricted activities related to racing and showing of pigeons is permitted subject to certain prohibitions. On the contrary, some alien ungulate species have been promoted by the game industry because of their economic importance for hunting. These species are now regulated by area as a compromise between conservation authorities that advocated for control and the game industry that preferred unrestricted movement. Among animal species, *Anas platyrhynchos* (European mallard) represents an extreme example. Proposed management actions of removal (i.e. killing) of the species were met with fierce resistance and were stopped, because the perceived value was considered to outweigh the impacts (Gaertner et al. 2016). The mallard hybridises with the native *A. undulata* (yellow-billed duck), but impacts on the genetic integrity of indigenous congeneric species are insidious and more difficult to explain to the public and local policy-makers than other more evident ecological impacts of other invasive species such as predation and overgrazing. The current management option in the City of Cape Town is to tolerate the species and apply no management (Gaertner et al. 2016).

## Conflict-generating species

Actual and potential conflict-generating species made up the smallest proportion (6%) of all listed species. Species in this category had both benefits and negative impacts. The majority of these conflicts could be explained by more than one cognitive level, such as utilitarian values based on practical or material benefits and risk perceptions of possible impacts from invasive species. Examples include *Prosopis* species that were introduced to provide fodder, firewood and shade in arid parts of the country (Shackleton et al. 2014). However, they have also been implicated in adverse social and ecological impacts (Shackleton, Le Maitre & Richardson 2015a, 2015c; Shackleton et al. 2015b). This has led to conflicts between communities who see the species as a resource [some farmers and non-governmental organisations (NGOs)] and others who are concerned about its negative impacts (conservation managers and some farmers) (Shackleton et al. 2015c). The use of the species is still promoted by NGOs in many countries and as a result it has spread widely. Millions of Dollars are being spent on control of this species in South Africa annually (van Wilgen 2012). Further conflicts have been observed in the use of biological control agents (lethal vs. non-lethal agents). The biological control of *Prosopis* using seed-attacking insects has been ineffective and there is a need to use more lethal options. However, risk perception over potential loss of benefits has previously prevented the use of the latter option (Shackleton et al. 2016; Wise, van Wilgen & Le Maitre 2012; Zachariades, Hoffmann & Roberts 2011). However, as negative impacts increase and managing interventions lag behind invasion rates the willingness to use alternative and more lethal agents is increasing (Shackleton et al. 2016; Wise et al. 2012).

Similarly, *Acacia* species such as *A. mearnsii* (black wattle) are commercially important and contribute to livelihoods but are also aggressive invaders that have significant ecological impacts and have caused major conflicts of interests (De Wit et al. 2001; Shackleton et al. 2007). Research on biological control for these *Acacia* species was blocked for many years to protect the interests of the wattle growers (Pieterse & Boucher 1997). Eventually, there was reluctant acceptance of biological control to reduce seed output, but the use of lethal biological control remains blocked (Impson et al. 2011; Stubbings 1977; van Wilgen et al. 2011). Another example is the use of *Pissodes validirostris* (a cone-feeding weevil) for biological control of invasive *P. pinaster*. The forestry industry was concerned that adult weevils fed on shoots of pines, thereby potentially facilitating infection by *Fusarium* fungi which pose a possible risk to commercially important *Pinus* species. This risk led to the discontinuation of research on the use of biological control agents on pines in South Africa (Hoffmann, Moran & van Wilgen 2011).

The aversion of possible impacts of invasive species with utilitarian values is clearly illustrated by conflict around the proposed regulation of *S. trutta* and *O. mykiss* that are utilised for recreational angling and commercial aquaculture (Ellender et al. 2014; Woodford et al. 2017). Angling is dependent on introductions into the wild where trout reduce native biota (see Ellender & Weyl 2014; Jackson et al. 2015; Shelton, Samways & Day 2015). Management of trout has been contentious because of conflicting values of stakeholders. The differences are mainly centred on risk perception (evaluation of potential hazards and lack of institutional trust) and benefits derived from the trout industry. The trout fraternity (concerned stakeholders) refused to acknowledge that trout are invasive species and highlighted the lack of scientific evidence of the risks posed by trout to biodiversity (Cox 2013). There is also a lack of institutional trust because the trout fraternity view A&IS legislation as an instrument for destroying the trout industry. Because of the strong opposition to the inclusion of trout in the A&IS legislation, both *S. trutta* and *O. mykiss* were removed from the national lists of regulated invasive species until a consensus on options for their management could be reached (Woodford et al. 2017). Consultations are continuing in the hope of reaching consensus among stakeholders; issues remain highly polarised among stakeholders and it is unclear whether an end to the deadlock is in sight (Woodford et al. 2016). Similar conflicts could emerge for other angling species such as black bass species (e.g. *M. salmoides* and *M. dolomieu*) that have been implicated in causing adverse ecological impacts on native biota but also contribute to local and regional economies through industries that provide goods and services to anglers (e.g. fishing tackle, boats and bed-nights) (Ellender et al. 2014). The proposed management of these species has, however, been less contentious than that of trout because concerned stakeholders have seen little threat to their industry from the legislation. This is because black bass are fully established in many reservoirs and the fisheries that they support are therefore less dependent on stocking than those based on trout.

The utilisation of *O. niloticus* in aquaculture is also likely to create major conflicts soon because of contrasting values among stakeholders. Its introduction into river systems in southern Africa is a cause for concern for the conservation of indigenous congeneric species that risk extirpation through hybridisation and competition arising from habitat and trophic overlaps (Zengeya, Booth & Chimimba 2015). In areas where *O. niloticus* has established, it has rapidly replaced indigenous congeneric to the extent that some populations have become extirpated (Firmat et al. 2013; Weyl 2008; Zengeya & Marshall 2007). Despite these well-documented adverse ecological effects, it remains one of the most widely cultured and propagated fish species in aquaculture and stock enhancements in the southern Africa sub-region (Denies et al. 2016). Decisions on its management will be based on the trade-offs between socio-economic benefits and potential adverse ecological effects.

In some cases, species were associated with different conflict types that could be either intrinsic or utilitarian values. For example, the removal of invasive trees in urban or peri-urban environments in the City of Cape Town created conflicts because of the intrinsic and utilitarian values attached to certain species such as acacias, eucalypts and pines (Gaertner et al. 2016; van Wilgen 2012). The intrinsic (naturalistic and aesthetic) values were derived from the physical attraction and appeal of nature, while utilitarian values were centred on derived practical or material benefits from the invasive trees species such as carbon sequestration, economic value of timber and honey production (Allsopp & Cherry 2004; van Wilgen 2012). Some of these concerns could not be substantiated based on current knowledge and were set aside. Trade-offs were proposed for supported concerns. For example, some plantations of *E. diversicolor* that are less invasive than pines (Forsyth et al. 2004), were retained to maintain aesthetic value, for recreational purposes and honey production (Gaertner et al. 2016; van Wilgen 2012). Concerns continue to be raised periodically but, despite opposition, the policy promoting alien plant removal has remained in place, and considerable progress has been made towards clearing alien plants from the park. This is largely attributed to political support, arising largely from job creation, and a strong body of scientific evidence that could be cited in support of the programme (van Wilgen 2012).

Conflicts centred on intrinsic values represented some form of emotional relationship between society and nature. The detected value systems included naturalistic, humanistic, aesthetic and moralistic values systems. For example, moralistic values are centred on the right of invasive animals to live and not to be abused. Control measures often involve culling which is strongly opposed by some sectors of society such as animal rights organisations (Bremner & Park 2007; Ford-Thompson et al. 2012). For example, the introduced *H. jemlahicus* in Table Mountain National Park has been the focus of eradication attempts, despite strong opposition to control – in this case because the perceived impacts (overgrazing) are clearly evident and outweigh the benefits (recreational values) (Gaertner et al. 2016). Active engagement was needed to offset opposition through equal but opposite support for the eradication from government conservation agencies, NGOs and leading academics. In contrast *F. catus* represents a case where proposed management actions (control and or eradication) have either been completely put aside because they would be too controversial or there has been some trade-offs and compromises. Feral cats have been introduced worldwide as pets, for biological control of rodents and accidentally via shipping (Brooke et al. 1986). Conversely, feral cats have also been implicated in causing adverse impacts on biodiversity through predation, hybridisation, competition for resources and transmission of diseases (Tennent, Downs & Bodasing 2009; but see Le Roux et al. 2015). Because the perceived benefits outweigh negative impacts the species is to be tolerated, and is not listed on the A&IS Regulations on the South African mainland. The species has, however, been successfully eradicated from Marion Island (Nogales et al. 2004).

Conflicts based on utilitarian values were observed for species that are economically important because they provide food and raw materials for industry and local communities. For example, many cactus species were introduced as part of agricultural initiatives to improve fruit production for human consumption, fodder for livestock and ornamental purposes (Novoa et al. 2015a). Unfortunately, some of the introduced cactus species have also been implicated in causing adverse ecological impacts and this dichotomy has caused conflicts (Novoa et al. 2015). Cactus species associated with utilitarian benefits include *O. ficus-indica* and *O. robusta*. The other seven listed species of cactus (*C. fulgida* var. *fulgida*, *C. fulgida* var. *mamillata*, *C. imbricate*, *C. leptocaulis*, *C. pallida*, *C. spinosior* and *O. microdasys*) are mainly associated with intrinsic values (aesthetic and naturalistic) as they are utilised for ornamental purposes. Active stakeholder engagement is ongoing to try and resolve the conflicts and the results will be used to advise and develop a national cactus management strategy for South Africa (Kaplan et al. 2017; Novoa & Shackleton 2015; Novoa et al. 2016). There are many approaches to enable stakeholders and managers to find common ground in such contentious situations. One useful method is the deliberative multi-criteria evaluation approach (Liu et al. 2011). In this method, participants assess the different risk factors associated with managing an invasive species, and by assigning risk weighting to different management strategies chart the management approach that will cause the least conflict among the stakeholders (Liu et al. 2011; Woodford et al. 2016).

Species that are on the margins (i.e. scoring high on the benefits) but medium on the negative impacts (and vice versa) should be prioritised for directed research as they represent areas where new conflicts might emerge. For example, *Cyprinus carpio* and *Micropterus floridanus* were classified as beneficial but are likely to have substantial negative impacts. The medium score for negative impacts reflects a lack of research effort on the species in South Africa (see Ellender & Weyl 2014). The situation is similar for species such as *Cherax quadricarinatus* (redclaw crayfish) that scored high on negative impacts and medium on benefits because the benefits derived from the species have not yet been quantified.

## Conclusions

Most conflicts around the management of invasive species in South Africa could be explained by more than one value system (intrinsic vs. utilitarian) and cognitive level (values systems vs. risk perception). Value-based conflicts are inherently difficult to resolve because management authorities have to balance the needs of different stakeholders while still conserving the environment. An ideal management plan is where parties with different value systems agree on a win-win solution where invasive species can still deliver benefits, but adverse impacts are reduced. This is potentially possible through open dialogue among stakeholders, trade-offs and compromises. In cases where the perceived benefits outweigh impacts such as those observed for most of the intrinsic-based conflicts, the management approach has generally been to tolerate the species and monitor whether they potentially cause impacts in the future. In contrast, when the impacts outweigh perceived benefits, management options have involved trade-offs and compromises that have minimised impact of the invasive species but retained a large proportion of their amenity values. In extreme cases, control efforts have proceeded despite opposition because of a strong body of scientific evidence and political support. Conflicts based on risk perception were mainly centred on the fear and aversion of impacts of the invasive species or the control methods proposed for it management. In some cases, such as the use of biological agents to control invasive plants species, management authorities have employed strategies to try and effectively communicate the risks through open dialogue among stakeholders and this has resulted in trade-offs and compromises (Zachariades et al. 2017). Only one case (trout species) identified a lack of trust between stakeholders and government agencies that could have resulted from lack of community engagement and transparencies in decision-making processes, differences in evaluations of potential hazards and lack of confidence in government authorities. Consultations are continuing in an attempt to reach consensus on issues among stakeholders; these issues, however, remain highly polarised, and no obvious solution is in sight. This might be a case where a formal process of scientific assessment is required (Scholes, Schreiner & Snyman-Van der Walt 2017).

The majority of invasive alien species listed in the A&IS Regulations were not considered to be conflict-generating. However, the small proportion of species identified as conflict-generating hold the potential to negatively impact the future efficiency of conservation management in South Africa by forcing regulators and managers to spend great amounts of time and resources addressing stakeholder complaints and concerns instead of discharging their duties in dealing with the species that do not generate controversy. The initial delay in promulgating the lists because of the objections of the trout lobby, and the subsequent amount of time and energy spent by the Department of Environmental Affairs (DEA) staff in negotiating the relisting of trout (Woodford et al. 2017), is a stark reminder to managers to anticipate potential management conflicts before they have a chance to disrupt problem-solving. When assessing the best strategy to deal with conflict-generating species, it is critical to identify all stakeholders at the outset and to recognise that they might hold severely divergent perceptions on the problem posed by the invasive species (Woodford et al. 2016). When these issues are addressed from the start of the development of management plans, and when stakeholders are directly engaged to determine their perceptions of the risks posed by these species, the chance of arriving at practical, equitable and non-controversial management strategies is greatly increased.

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The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

## Authors' contributions

All authors collected data (scored species) and T.Z. analysed the data. R.T.S. developed the scoring framework. T.Z. drafted the manuscript with input from all other authors.

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