





# Chapter 24

## The Social Dimensions of Biological Invasions in South Africa



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**Abstract** This chapter examines current knowledge relating to the human and social dimensions of biological invasions in South Africa. We do so by advancing 12 propositions and examining the evidence for or against each using South African literature. The propositions cover four broad issues: how people cause invasions; how they conceptualise them; effects of invasive species on people; and peoples' responses to them. The propositions we assess include: (1) intentional introductions were and continue to reflect the social ethos of the time; (2) people go to great lengths to ensure that newly introduced species establish themselves; (3) human-mediated modifications help invasive species to establish; (4) how people think about and study invasive species is strongly shaped by social-ecological contexts; (5) knowledge and awareness of invasive species is low amongst the general public; (6) personal values are the primary factor affecting perceptions of invasive alien species and their control; (7) specific social-ecological contexts mediate how invasive species affect people; (8) research on social effects of invasive species primarily focuses on negative impacts; (9) the negative social impacts of invasive species on local livelihoods are of more concern to people than impacts on biodiversity; (10) people are less willing to manage species regarded as 'charismatic'; (11) social heterogeneity increases conflicts around the management of biological invasions; and (12) engagement with society is key to successful management. By advancing and questioning propositions, we were able to determine what is known, provide evidence for where gaps lie, and thus identify areas for future research.

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## 24.1 Introduction

Research that addresses the human and social dimensions of invasion science is crucial for understanding and responding to biological invasions as people are involved in all parts of the introduction-naturalisation-invasion-response continuum (Head 2017; Shackleton et al. 2019a). Despite the need for humanities and social science perspectives in invasion science, to date there has been relatively little work in this area (Le Maitre et al. 2004; Vaz et al. 2017a; Abrahams et al. 2019). Consequently, there are many research gaps and missed opportunities for interdisciplinary collaboration which is necessary to truly advance and address pressing challenges in dynamic and varied contexts (Vaz et al. 2017a; Abrahams et al. 2019). To promote uptake, Shackleton et al. (2019a) recently highlighted four broad issues in which research on the human and social dimensions of invasion science can help to improve understanding and guide management responses. These four areas are: (1) how people cause invasions, (2) how people conceptualise and perceive invasions, (3) the effects of invasions on people, and (4) how people respond to invasions.

In this chapter, for each thematic area, we advance three propositions (statements or proposals for consideration and which can help in asserting a generalisable trend or process—similar to a hypothesis) and examine the evidence in support of each of them in the South African context (Table 24.1). We tried to ensure that the propositions were pertinent to current research topics and trends, and to ensure that they would be useful and relevant to guide future work. We used propositions as a means to move beyond just a summary of current knowledge of the social contributions to invasion science towards a more focussed, analytic and critical stance as the necessary foundation for development of knowledge and theory and future research. The process of examining the available evidence for each proposition fosters in-depth thinking of what evidence is available, where different points conflict and where gaps in research persist. The propositions are not specific to South Africa, but the relative richness of research on biological invasions in the country offers a reasonable first opportunity to investigate them.

## 24.2 Humans as Causes of Alien Species Invasions

Humans are the primary agents for the deliberate or inadvertent introduction of alien species outside their native ranges, some of which become invasive. In South Africa, work by historians and, to a lesser degree, by researchers in other social science and humanities disciplines, has detailed the role that people play in facilitating biological invasions. In particular, many purposeful introductions have been driven by specific societal mind-sets or ethos, operating in different eras (Carruthers et al. 2011; Kull et al. 2011; Udo et al. 2019), and humans facilitated the establishment of invasions by modifying species and landscapes. In South Africa and globally, understanding the social drivers and processes of species introductions is probably the best researched of the four thematic areas.

**Table 24.1** A summary of key findings from the assessment of a set of 12 propositions that examine the social dimensions of invasion science, with notes on the degree to which the proposition can be supported by South African evidence

Proposition	Degree of support	Evidence level	Summary notes
1a. Intentional introductions were and continue to reflect the social ethos of the time	Supported	High	A large body of literature supports this proposition at a broad scale. Further research remains necessary to understand the trends that shape intentional introductions over smaller time scales and the role of different stakeholders
1b. People go to great lengths to ensure that newly introduced species establish themselves	Supported	Moderate	Good evidence in support of this proposition for some invasions. However, some invasions result from accidental introductions that required no or little effort to establish invasive populations
1c. Human-mediated modifications help invasive species establish	Supported	Moderate	Although this proposition is well supported, there is scope for much more work on this topic, especially for better integrating human actions into ecological based models
2a. How people think about and study invasive species is strongly shaped by social-ecological contexts	Supported	Moderate	Although supported for the South African context, it should be tested whether it also holds true for different contexts in other countries
2b. Knowledge and awareness of invasive species is low amongst the general public	Partially supported	Moderate	Generally, public knowledge and awareness of invasive species is low, however, in some regions, it can be high among certain actors or regarding certain species
2c. Personal values are the primary factor affecting perceptions of invasive alien species and their control	Partially supported	Moderate	Personal value systems do affect people's perceptions, but other factors such as utility and economic factors do so as well
3a. Specific social-ecological contexts mediate how invasive species affect people	Supported	Moderate	Although the effects of invasive species are often context specific, the way the effects of a single species can vary when considering different actors still needs to be elucidated
3b. Research on social effects of invasive species primarily focuses on negative impacts	Unsupported	Moderate	There is considerable social research discussing both the benefits and costs or even just the benefits of invasive species. Social research highlights acknowledging trade-offs

(continued)

**Table 24.1** (continued)

Proposition	Degree of support	Evidence level	Summary notes
3c. The negative social impacts of invasive species on local livelihoods are of more concern to people than impacts on biodiversity	Unsupported	Moderate	Mixed responses, where in some cases only social effects are mentioned and others where biodiversity effects are ranked higher or as high as many social effects. Context dependence and effects of study approaches and frameworks have great influence on findings
4a. People are less willing to manage species regarded as 'charismatic'	Partially supported	Moderate	We found evidence supporting that charisma can affect people's attitudes towards invasive species management, in South Africa attitudes are also dependent on the economic benefits of invasive alien species and personal value systems
4b. Social heterogeneity increases conflicts around the management of biological invasions	Partially supported	Low	There are too few cases to assess this proposition. A few cases suggest heterogeneity can increase conflict, others showed conflicts in non-diverse areas. More work is needed to evaluate this proposition
4c. Engagement with society is key to successful management	Partially supported	Moderate	Engagement can increase support for management and ensure successful outcomes. However, in some cases it increased public resistance to management and worsened conflict. More understanding on what works and what does not is needed

The 12 propositions correspond to 4 broad issues in which research on the human and social dimensions of invasion science can help to improve understanding and guide management responses: (1a,b,c) how people cause invasions, (2a,b,c) how people conceptualise and perceive invasions, (3a,b,c) the effects of invasions on people, and (4a,b,c) how people respond to invasions

### ***24.2.1 Proposition 1a: Intentional Introductions Were and Continue to Reflect the Social Ethos of the Time***

A vast number of alien species have been and continue to be purposefully or accidentally introduced into South Africa by people for various reasons (Richardson et al. 2003). Van Sittert (2002) argues that “*biological invasions are thus intrinsically historical processes primarily shaped not by the biology of the invader, but by the shifting cultural values of the invaded society*”. We suggest that most motivations for introductions are driven by an ethos that evolves over time and relates closely to social fashions, political-economic circumstances and scientific paradigms (Carruthers et al. 2011). To discuss this, we highlight differences in motivations for introducing alien species during three broad time periods—but we acknowledge there are subtler trends within the broad timelines we outline.

A substantial number of alien species were introduced and established during the colonial period (Bennett and van Sittert 2019)—often with the ethos of making “improvements” to colony landscapes and economies and for botanical interest (Carruthers et al. 2011). Such introductions were strongly influenced by the broad landscape context of South Africa. For example, many tree species were introduced for forestry, linked to economic development, as the country is poorly endowed with natural forests for timber (Bennett and Kruger 2015). Yet other introductions during this period were driven by emotionally related values—in the then Cape Colony *Pinus* species (Pines) were planted by settlers in the 1700s, partly to create a sense of place and familiarity within the treeless landscapes. Similarly, *Oncorhynchus mykiss* (Rainbow Trout) was introduced to improve sense of place and counteract nostalgia for fly fishing by local settler elites from Europe (Alletson 1997; Brown 2013). This phenomenon is emphasised by Thompson (1913) “*The Colonialist, especially of British blood, seemed unable to finally settle down in a new land until many of the animals and plants that minister his pleasure or profit in the homeland had followed him...*”. Canavan et al. (2018) showed that even slaves transported to South Africa during the colonisation by the Dutch East India Company (1652–1795) brought useful species, like bamboos, from their native lands with them. During the colonial period, many aesthetically pleasing species were also transferred between colonies, such as *Lantana camara* (Lantana), which was seen as an exotic novelty (Kannan et al. 2013). As a result, many former British colonies share similar issues with invasive ornamental plants brought in by colonial settlers. Collecting exotic plants for newly established public or private botanical gardens was a novelty within the colonies, and was a well-remunerated occupation and promoted by acclimatisation societies (Janick 2007).

By the 1900s appreciation and pride for native flora grew substantially and there was less attachment to species of the homeland by settlers (van Sittert 2003; Bennett 2015). By the mid-1900s, species were often introduced or purposefully dispersed in the context of livelihood development or environmental restoration, and promoted on a mass-scale by the state and non-governmental organisations alike (Carruthers et al. 2011), and less so to fulfil a sense of place for elite settlers or for primary

industry than before. This led to the introduction of many so-called “wonder plants” that could yield multiple benefits for people and ecosystems, but that brought many costs once they became invasive (Low 2012; Kull and Tassin 2012). For example, *Prosopis* (Mesquite) was promoted in the apartheid era (mid-1900s) by agricultural departments to solve the effects of drought in the arid Northern Cape (Shackleton et al. 2014). Elderly community members recount stories of how agricultural extension officers distributed *Prosopis* seedlings for planting on private farms and in communal villages (Shackleton and Shackleton 2018). *Leucaena leucocephala* (Leucaena), was promoted by development, agricultural and forestry-focused NGOs during the 1960s to 1980s as a multipurpose tree (Brewbaker 1987). Similarly, a new set of Australian *Acacia* species were introduced for dryland restoration (Carruthers et al. 2011). *Oreochromis niloticus* (Nile Tilapia) was introduced into South Africa in the 1950s for aquaculture, particularly for food security and income generation among poor African communities (Zengeya et al. 2011).

The current ethos (in the post-apartheid democratic area) could facilitate further purposeful introductions. For example, a shift in gardening practices to become less water intensive might lead to the introduction of a new set of non-native species that require little water or care, and yet may become invasive (van Kleunen et al. 2018). Similarly, the rising demand for biofuels and green energy may lead to the promotion of invasive plants such as *Jatropha curcas* (Physic Nut) (Witt 2010; Blanchard et al. 2011). Species of interest to collectors can easily be bought online (e-commerce trade) which is a modern, easy and novel pathway of potential invasive species (Martin and Coetzee 2011; Humair et al. 2015). Simultaneously, the growing ethos of either managing or preventing invasions might lead to fewer purposeful introductions (Carruthers et al. 2011; Udo et al. 2019), although the context of increasing global movement of people and goods could lead to more accidental introductions than in the past (Seebens et al. 2017). For example, biofouling and ballast water has led to the recent introduction of a number of alien marine species along the South African coastline (Faulkner et al. 2017, 2020, Chap. 12).

Overall, evidence from South Africa supports the proposition that there have been clear changes over time in the ethos for introducing and promoting alien species which follow trends in scientific, historical, political and economic contexts (Carruthers et al. 2011). We illustrate this using a very broad set of temporal scales—and there is further need for understanding and analysing changes at finer spatial and temporal scales (e.g. Bennett 2015). Another important aspect would be to analyse the role of different actors—i.e. maybe too much is contextualised under the broad colonial banner and further comparison between British and Dutch settlers might yield useful insights.

#### **24.2.2 Proposition 1b: People Go to Great Lengths to Ensure that Newly Introduced Species Become Well Established**

People have put effort into facilitating the establishment and spread of alien species. For example, decades of research went into ensuring that introductions of

*Eucalyptus* (Gums) for forestry were successful (Bennett 2011). Australian *Acacia* species were planted *en masse* (more than 300 million seeds) to stabilise sand on the Cape flats, and prizes were offered to individuals for successful planting and establishment (van Sittert 2000; Bennett and van Sittert 2019), leading to substantial invasions as a result of this high propagule pressure (Donaldson et al. 2014). Similarly, people made substantial efforts to ensure the establishment of *Prosopis* trees during the mid-twentieth century for silviculture (Shackleton et al. 2015a). Some farmers recount childhood memories of putting *Prosopis* seedlings by the Aga stove in winter and only planting them out in spring to ensure survival. But, in the hot summers, one farmer recounts how during the school holidays he was required to go out and water *Prosopis* seedlings to ensure their survival.

Significant research went into discovering how to introduce fishes for sport and recreation by British colonists, and how to ensure their survival. Tens of thousands of *O. mykiss* and *Salmo trutta* (Brown Trout) eggs were sent from the UK to South Africa in the late 1800s and early 1900s, which failed to establish, but efforts continued until appropriate strategies were implemented to ensure survival during transport (also see Weyl et al. 2020, Chap. 6). In the Cape, special hatcheries were built and a bounty was even established for killing otters that were presumed to pose a threat to the newly introduced fish (Britz 2015). In KwaZulu-Natal, railway sidings were built specifically to ensure that the water did not have time to heat up during transport (Alletson 1997). The time and money that went into ensuring introduction and survival must have helped to promote invasions in the long run.

The available evidence and examples above support the proposition that great perseverance and effort to ensure the survival and establishment of some non-native species was important for facilitating invasions. The degree of human tenacity during the pre-introduction and post-introduction stages is typically poorly accounted for in purely ecological models of invasion dynamics.

### **24.2.3 Proposition 1c: Human-Mediated Modifications Help Invasive Species to Establish**

Humans can modify both species and landscapes, which may facilitate or limit the invasion of some species (Kueffer 2017; Shackleton et al. 2018). Human agency is often not well acknowledged in the biological sciences, often being treated as an “unwelcome extraneous variable”, but is actually a key factor in explaining many biological invasion processes (van Sittert 2002).

Le Roux et al. (2013) show how humans have altered the genetic make-up of *Acacia pycnantha* (Golden wattle) through artificial selection both prior to and after introduction, which may facilitate its invasiveness. At a broader scale, human alteration or disturbance of landscapes has facilitated invasions. Initially, many invasive species can only survive and proliferate in human-altered landscapes. For example, the creation of ponds, urban garden microclimates and farm dams has

aided the invasion of frogs in South Africa (Davies et al. 2013; Measey et al. 2017). Similarly, the distribution of the invasive bird *Acridotheres tristis* (Common Myna) in South Africa is closely tied to large urban areas (Peacock et al. 2007; Measey et al. 2020, Chap. 5). Environmental degradation and land use change also affects invasions (Kueffer 2017). In South Africa, overstocking of domestic livestock helped *Opuntia ficus-indica* (Mission Prickly Pear) to become a dominant in the Eastern Cape—“farmers became increasingly aware of their own hand in the gradual transformation of the landscape around them, so opuntia intruded from the margins to the centre” (van Sittert 2002). In the marine context, *Carcinus maenas* (Green Crab) has established and become invasive only in human-made harbours and small bays nearby because the species cannot maintain a grip on rocks under high wave action (Mabin et al. 2017). In South Africa one of the 26 inter-basin transfer schemes (i.e. channels or tunnels constructed to link different river systems) has aided the spread of at least five non-native species (Ellender et al. 2014).

These few examples show that human modifications of species and landscapes can facilitate invasions, supporting our proposition. This shows some support to the “passenger” part of the driver vs passenger debate—whereby degradation might facilitate invasions rather than invasions causing initial degradation. Despite this, a lot more work can be done on how human modifications facilitate invasions and maybe incorporating this more into models would be useful (e.g. niche modelling, Vimercati et al. 2017; Walker et al. 2017).

## 24.3 People’s Conceptualisation and Perceptions of Invasive Alien Species

A fast-growing body of literature in the field of invasion science considers how people view and conceptualise invasive species, both from a theoretical level to more of a personal and individual level (Kull et al. 2011, 2019; Estévez et al. 2015; Shackleton et al. 2019b). South Africa provides a fertile testing ground for different theories within this topic due to its diverse social and ecological contexts.

### 24.3.1 *Proposition 2a: How People Think About, Value and Study Invasive Species is Strongly Shaped by Social-ecological Contexts*

Historical, geographical, ecological, social and institutional contexts help to determine how people think about invasive species. For instance, attention to biological invasions is weak in South America (Speziale et al. 2012), whereas in colonial island landscapes, settings of rapid ecological change caused by the settlers as well as strong scientific interest by the same people, environmental concerns rose to the fore (Grove 1995). Such influence is also apparent in South Africa, where concern over



invasions historically arose out of the particular ecological and social context of the Cape Colony (Pooley 2014), an influence that evolved with different periodic ethos (Carruthers et al. 2011), and which continues to this day. As noted by Bennett and van Sittert (2019), “*One fact dominates the history of invasive plants in South Africa. The Cape has consistently led national planning and action on weeds and alien invasive species, especially relating to agricultural weeds and invasive trees.*” We expand on four key aspects relating to this important statement: (1) the focus on Cape biota, (2) the focus on trees, (3) the national spread of the invasion concept, and (4) the institutional structures that embody and permit this dominance.

First, Cape ‘exceptionalism’, both real and perceived, shapes South African understanding of the phenomena of biological invasions. The distinctive ecology of the Cape, with the Fynbos Biome, combined with its strategic location and early history of European settlement, became the epicentre for species introductions and attracted a lot of scientific attention (Bennett and van Sittert 2019). In this context, scientific concern about the impact of introduced plants on the Fynbos Biome emerged in the late nineteenth century, and this concern continues, fortified with references to the Cape having one of the six global ‘Floristic Kingdoms’ (Lidström et al. 2016). One consequence is that invasion science research in South Africa has emphasised plants.

Second, a peculiarity of invasion science in South Africa is its focus on trees. The dearth of native forests in the Fynbos Biome, not to mention in the country’s vast Grassland and Karoo Biomes, led to particularly strong efforts during the 19th and 20th centuries to introduce and promote trees (Brown 2013; Bennett 2011). These in turn led to highly visible, landscape-transforming invasions and the early catalysts for nascent invasion research and policy in South Africa (Bennett and van Sittert 2019). Possibly as a result, other invasive growth forms, like grasses, have received less attention than they should have (Milton 2004).

Third, the impact of such trees on fynbos landscapes facilitated the early development of interest in biological invasions beyond agricultural weeds in the Cape. This radiated outward to the national level only in the 1980s–1990s, with new policy openings in South Africa after the end of apartheid coming at the same time that an international conception of invasive species was emerging (Lidström et al. 2016; Bennett and van Sittert 2019). The national Working for Water (WfW) programme drew heavily on hydrological and ecological scientific insights from tree invasions in the Cape as motivating evidence for this poverty-relief project (van Wilgen and Wannenburgh 2016).

Fourth, a consequence of the Cape-based origins of thinking, research, and policy-making on invasions is the deep anchoring of this work in Cape-based institutions. The WfW program “*draws its core ideas and leadership from this region*” (Bennett 2014), and urban middle-class whites from the Cape have driven the agenda about invasions (Bennett and van Sittert 2019). The primary institution that has gained agenda-setting authority in the field is the Centre for Invasion Biology (C-I-B), a nationally funded Centre of Excellence established in 2004, based at Stellenbosch University (van Wilgen et al. 2014; Lidström et al. 2016; Abrahams et al. 2019; Richardson et al. 2020, Chap. 30). The C-I-B is not only

important at a national level, but also internationally, where it has strongly shaped the development of invasion science (Pyšek et al. 2006; Pouris 2007; Abrahams et al. 2019). It works closely with the South African National Biodiversity Institute, the Council for Scientific and Industrial Research, WfW and many other partners. A recent bibliometric review of research sponsored by WfW shows that people with C-I-B affiliation—closely overlapping with a Stellenbosch affiliation—(co)authored almost half of this work; and that a small number of Stellenbosch-based C-I-B researchers are core authors who play a strong role in maintaining, mediating, and perhaps even controlling relationships and networks in the field (Abrahams et al. 2019). The C-I-B is built upon local expertise in forestry and botany, and previous programs in biological control and plant protection, and as a result has strongly emphasised, until recently, ecological research over other disciplines (Abrahams et al. 2019; Kull 2018).

This illustrates that specific contexts and events can shape the way people think about invasions. South Africa has a unique story where one region, the Cape, has really shaped what is thought and done today. This suggests that maybe some of the knowledge and theory that is accepted as normal might need to be adapted for different contexts to ensure relevance.

### **24.3.2 *Proposition 2b: Knowledge and Awareness of Invasive Alien Species is Low Amongst the General Public***

Globally, a growing body of research has focussed on understanding factors that influence people's knowledge and awareness of invasive species. This is an important component in building educational plans and adaptive management strategies (Cole et al. 2019). By knowledge and awareness, we mean what people understand and recognise biological invasions in general but also have knowledge about specific invasive species.

Studies assessing knowledge and perceptions of invasive species in South Africa, display varying results. Despite South Africa being a leading country in terms of policy, outreach and management of biological invasions (Byrne et al. 2020, Chap. 25), 77% of people in a small city (Makhanda (Grahamstown)), did not know that they had one or more listed invasive alien trees in their garden (Shackleton and Shackleton 2016). A similar number could not name a single invasive plant. Of those who did, they mainly knew of *Acacia* species or *Jacaranda mimosifolia* (Jacaranda). This study also suggested that people with higher education and incomes had a broader understanding and knowledge of invasive species. Potgieter et al. (2019), working in Cape Town, highlighted a stark contrast in knowledge levels across different socioeconomic groups, largely as a result of the legacy of apartheid, with more affluent and well-educated citizens having a better knowledge of invasions.

Focusing on *Prosopis*, the second most widespread invasive tree genus in South Africa, Shackleton et al. (2015) highlight greater knowledge and understanding by citizens than the previous two studies. The research did take place in areas of high infestation and where native tree biodiversity is very low, which might explain these results. However, differences in knowledge between social settings and actors was evident. Rural commercial farmers and communal land dwellers who had the greatest exposure to *Prosopis* and whose livelihoods were more closely linked to nature had a much greater knowledge than urban residents. Furthermore, unlike previous studies, Shackleton et al. (2015) revealed greater knowledge of the species amongst poor, urban dwellers (some of whom were reliant on the tree for fuelwood) as compared to affluent urban citizens. Another study in rural villages in the Northern Cape highlighted that knowledge and awareness of invasive species is highly species-dependent (Shackleton and Shackleton 2018). The majority of respondents knew that *Prosopis*, *Eucalyptus* and *J. mimosifolia* were non-native, but very few respondents knew other common invasive alien plants like *Schinus molle* (Pepper Tree), *Tecoma stans* (Yellow Bells), *Melia azedarach* (Seringa), *Morus alba* (White Mulberry) and *O. ficus-indica*, despite them being in the same landscape for similar durations. Differing levels of knowledge across species are likely influenced by factors like species traits, residence time, reasons for introduction, rates of spread and densities of invasions, impacts on people as well as management and outreach efforts.

For this proposition, we suggest knowledge of invasions can be context-dependent, and knowledge is generally low except for a few flagship taxa. Similarly, certain sectors of society are more knowledgeable regarding invasions, such as elites, and those living in rural areas who are likely to be more in contact with invasions and their impacts.

### **24.3.3 Proposition 2c: Personal Values are the Primary Factor Affecting Perceptions of Invasive Alien Species and Their Control**

Various emotionally-related factors can influence people's attitudes and perceptions of invasive species (Urgenson et al. 2013; Shackleton et al. 2019b). For example, the global literature shows that people often "fall in love" with beautiful, cute or charismatic species due to their emotional appeal, while others might be detested based on their ugliness or threat, such as fire ants, wasps or rats (Shackleton et al. 2019b).

Only a few studies have addressed this question in South Africa. Novoa et al. (2017) illustrated that, in South Africa, there was not much difference in the support for management between different taxa, whereas in the UK, the control of a charismatic animal species was less supported than that of an ornamental plant. This might be linked to differences in attitudes by those living in more rural areas (South Africa), but also to the presence and diversity of native flora and fauna.

Linking to the rural-urban debate, people in urban areas were more interested and emotionally attached to charismatic species whereas in natural areas perceptions were more based on species utility. This is mirrored by Dickie et al. (2014) and Gaertner et al. (2016) who highlight that, particularly in cities, people's values relate to aesthetic and recreational benefits, and often take precedent over economic ones. In Cape Town, Potgieter et al. (2019) showed that whilst utilitarian and economic factors play a role in shaping perceptions, cultural values (e.g. aesthetic appearance) also helped to explain people's perceptions—suggesting that multiple interacting factors shape people's attitudes. However, in more rural areas, Shackleton et al. (2015) showed that for *Prosopis* invasions, personal values, whilst important, were not of as much concern as those relating to economic and livelihood benefits and costs. Furthermore, Novoa et al. (2017) indicated that promoting public awareness can assist in changing perceptions and in increasing public support for control, but individuals who are hostile to any invasive species management programs will remain—based on their personal ethical values. Mukwada et al. (2016) discussed how personal or professional values founded on various worldviews and means of living can influence people's perceptions; with park wardens wanting to manage *Acacia* species around Golden Gate National Park and communal villagers having different opinions on the matter as the trees provide utility value for them. Similar socio-political factors relating to biological invasions and different actors' social anxieties are highlighted by Comaroff and Comaroff (2001).

These examples suggest that, overall, multiple factors might influence people's perceptions of biological invasions, including the landscape context, the stakeholder group, their experiences and the species traits. In South Africa, we suspect that people's perceptions are more likely related to the economic and livelihood effects of invasive species, although intrinsic and emotional aspects cannot be discounted, and are likely to be more prominent in urban areas.

## 24.4 The Effects of Invasive Species on People

Invasive species can affect people positively or negatively in a variety of ways. For instance, invasive species provide both ecosystem services and disservices, which have different implications for livelihoods and human wellbeing (Shackleton et al. 2007; Vaz et al. 2017b; Shackleton et al. 2019c). Seminal works on the role of invasive species on people's livelihoods come from South Africa and have focused on rural settings (de Neergaard et al. 2005; Shackleton et al. 2007).

### 24.4.1 *Proposition 3a: Specific Social-Ecological Contexts Mediate How Invasive Species Affect People*

The local socioeconomic and ecological context can greatly influence how biological invasions affect people. For example, invasive *Acacia* species are extremely

important for local livelihoods in the high-altitude communal grasslands in South Africa, where other trees are rare. *Acacia* species provide fuelwood, which is a primary source of heating and cooking fuel for almost all rural households (de Neergaard et al. 2005; Shackleton et al. 2007; Aitken et al. 2009). Despite increases in access to electricity in South Africa, *Acacia dealbata* (Silver Wattle) is still highly important for livelihoods today with almost no change in use levels in the past decade (Ngorima and Shackleton 2019). A number of households also earn incomes from selling the wood. However, when they reach high densities, *Acacia* species also have negative implications for water resources (Le Maitre et al. 2020, Chap. 15), grazing (O'Connor and van Wilgen 2020, Chap. 16) and people's health and safety (Shackleton et al. 2018). In the relatively treeless Fynbos Biome, invasive tree species are also an important source of fuelwood and income for rural villagers and foresters (Kull et al. 2011). However, this is a fire-prone biome and *Pinus* species can greatly increase the risk and negative implications of wild fires (Kraaij et al. 2018), highlighting how ecological contexts can result in this unique disservice (Comaroff and Comaroff 2001; Pooley 2014). Shackleton et al. (2015b) show that most local stakeholders from the Karoo and Savanna Biomes prefer to use native trees instead of the invasive *Prosopis* for fuelwood. In these areas, overall use of *Prosopis* for fuelwood is declining with increasing access to and use of electricity, unlike in the high-altitude Grassland Biome.

Research on *Opuntia ficus-indica* invasions in South Africa has provided insights into the complex interaction between invasions and human wellbeing and how benefits and costs are not static in time and space (Novoa et al. 2015a, b; Hill et al. 2020, Sect. 19.3; O'Connor and van Wilgen 2020, Sect. 16.5.5). *Opuntia ficus-indica* was promoted in arid areas to improve agricultural production (Beinart and Wotshela 2012), and at first it greatly benefited commercial farmers and rural villagers (Beinart and Wotshela 2003). Over time, it became invasive and spread over large areas, and its negative impacts started to outweigh its benefits, leading to control measures to reduce its spread, densities and negative impacts. Biological control was highly successful and reduced its spread and population densities, leading to the lowering of costs and the increase of benefits (Zimmermann and Moran 1991). Currently, with lower densities, *O. ficus-indica* has been adopted into society and provides a number of benefits for poor rural people, particularly through the collection and sale of fruits (Shackleton et al. 2007, 2011), showing the important role of spatial and temporal contexts.

Evidence from South Africa therefore supports this proposition and suggests that the effects of biological invasions on people are influenced by specific social and ecological contexts and can be highly dynamic in space and time. It highlights that in some cases some actors benefit more than others or some impacts are more external to people directly in contact with invasions (such as loss of water for cities downstream).

### **24.4.2 Proposition 3b: Social Science Research on Invasive Species Primarily Focuses on Negative Effects of Invasive Alien Species for People**

Traditionally, ecological research on biological invasions has focussed on negative effects and ignored benefits of invasive species (Tassin and Kull 2015), and therefore we expect that to be similar in the social sciences and humanities.

Unlike ecological studies, two studies in South Africa discussed only the positive aspects of invasive species for local livelihoods and ignored any negative effects. Shackleton et al. (2011) showed the importance of selling *O. ficus-indica* fruits in rural areas of the Eastern Cape. In the same region the invasive fish *Cyprinus carpio* (Common Carp) benefits livelihoods, as a source of both food and cash income from the sale of fish (Ellender et al. 2010)—as yet no negative livelihood effects have been investigated from this introduction.

Most other studies acknowledge a suite of benefits and costs and often weigh them against each other. For example, the benefits of *O. ficus-indica* and Australian *Acacia* species were viewed as greater than the costs to rural communal land villagers (de Neergaard et al. 2005; Shackleton et al. 2007; Beinart and Wotshela 2012)—although some costs were highlighted as well. For *Prosopis*, both benefits and costs were assessed, and findings indicated that negative impacts outweighed benefits (Wise et al. 2012; Shackleton et al. 2015a). Potgieter et al. (2019) showed that many urban invasives provide both ecosystem services and disservices to people, as is the case for small rural villages in the Kalahari (Shackleton and Shackleton 2018). Harris et al. (2016) argued that work on *Columba* spp. (Pigeons) has traditionally focused on negative issues and control, but their research actually showed the opposite—that people on the University of South Africa’s Muckleneuk campus would rather encourage Pigeons.

On a commercial level, the invasive Mediterranean Mussel (*Mytilus galloprovincialis*) is an important aquaculture species in South Africa and benefits are acknowledged (Hecht 1992). Similarly, invasive trees used in forestry provide financial benefits and employment (Tewari 2001; Louw 2004; Bennett and Kruger 2015). At the same time, they have negative implications for other livelihood activities and broader society (Le Maitre et al. 2011). For these kinds of species, economic research commonly applies cost-benefit analyses to estimate both positive and negative impacts (de Wit et al. 2001) and better understand conflicts and trade-offs (van Wilgen and Richardson 2014; Zengeya et al. 2017).

Research that has examined the social effects of invasive species in South Africa is fairly balanced and reports on both positive and negative impacts. This is contrary to our proposition. This also differs substantially from ecological research that tends to focus only on the negative implications (Tassin and Kull 2015). There are many invasive species globally that have mostly negative impacts and a lot of work elsewhere focuses on reporting and quantifying just these negative social effects as opposed to more balanced views (Shackleton et al. 2019c).

This difference in South Africa is likely because of a focus on livelihoods, rather than a species-centred framing. We suggest therefore that more people-centred frameworks could be useful to promote more integrated understanding of invasions and their effects on human wellbeing. For improving further understanding, incorporating larger spatial and temporal frames would be useful. Most studies cover a restricted time period and do not adequately show how longer-term changes in benefits and costs affect people (Shackleton et al. 2007), and what drives the change. Similarly, many studies only focus on one group of actors.

### ***24.4.3 Proposition 3c: The Negative Social Impacts of Invasive Species on Local Livelihoods are of More Concern to People than Impacts on Biodiversity***

Most of the work on invasion science in South Africa has focused on biological aspects, with relatively little work on the social aspects (Abrahams et al. 2019), and this bias is common globally (Kull and Tassin 2012; Vaz et al. 2017a). Despite this, some South African research has examined the interaction between invasive species and people's livelihoods—commonly in rural areas (Shackleton et al. 2019c).

Local communities in the Eastern Cape were mainly concerned about the social impacts of *A. dealbata* (Ngorima and Shackleton 2019) and mentioned the impacts of its roots on buildings, effects on cropping activities, issues with crime, and impacts on cultural sites. A handful of villagers mentioned the impacts of *A. dealbata* on water resources but none mentioned its impacts on biodiversity. In the Drakensberg region of the Eastern Cape, over 50% of villagers mentioned the impacts of *Acacia* invasions on crime rates, while 41% mentioned their impacts on water supply and security (although the authors note that “one may question whether this is a real perception or one borrowed from the WfW programme” (de Neergaard et al. 2005). Other concerns, voiced by a minority, included their impacts on grazing land and detrimental effects on native species (de Neergaard et al. 2005). In the Kalahari, local communities mentioned eight disservices as a result of *Prosopis* tree invasions (Shackleton and Shackleton 2018). The highest-ranked disservices were social (water resources, human health, infrastructure); the second lowest-ranked (7th) was its effects on species richness. In the same study, the impacts of invasive *O. ficus-indica* on human health were ranked highly (30% of respondents), while only 1% mentioned biodiversity impacts.

Other studies showed that people place importance on the negative impacts of biological invasions on biodiversity, although these impacts are also cited amongst social issues too. For example, communal villages and commercial farmers most commonly mentioned the negative effects of *Prosopis* on water, followed by loss of grazing on commercial farms, and detrimental effects on native plant biodiversity and to a lesser extent a variety of socioeconomic effects, such as reducing property value, revenue loss and effects on human health and infrastructure (Shackleton et al.

2015a). The impacts of tree invasions on fynbos biodiversity were considered by rural communities on the Agulhas Plain as a key threat, because it hampered the collection of wild flowers, with impacts on fire and water viewed as an issue only by a minority of the respondents (de la Fontaine 2013). However, in the same area, farmers considered the impacts of invasive trees on water as a major issue, followed by their impacts on livestock health, and grazing and crop land. In Cape Town, people were mainly concerned about the negative effects of invasive species on native biodiversity, followed by impacts on water supply, fire risk, human health and safety (Potgieter et al. 2019).

In summary, it appears that the literature is quite divergent. In some areas and for some social groups, loss of biodiversity is considered as one of the main impacts of invasive species, while in other areas or for other social groups it is hardly considered at all. Therefore, this proposition is not strongly supported. These differences might also be partly caused by the analytical frameworks used, researcher bias, the methods used and the kinds of questions asked. The findings also suggest that in some cases the concern over biological impacts are a manifestation of social values and therefore in reality biodiversity impacts are a threat to social concepts relating to human values and systems (e.g. preservation, heritage, stewardship, protected areas) (Carruthers 1995). Similarly, biodiversity might underpin many social related services or practices, e.g. flower collection or grazing potential.

## 24.5 People's Response to Invasive Species

### 24.5.1 *Proposition 4a: People are Less Willing to Manage Species Regarded as 'Charismatic'*

Many instances of resistance to invasive species management have arisen within South Africa. Whilst this is undoubtedly a function of the interplay of species traits, stakeholder values and local contexts, resistance is often met due to the charisma of certain species. By "charisma" we mean species that are linked to emotional values such as plants with large, bright flowers or unique growth forms, animals with neoteric features (big eyes and large heads), those that are entertaining and quirky, cute, colourful or those that are majestic, as opposed to less charismatic species which are often thorny, drab, do not have fur, and may sting or bite (Shackleton et al. 2019b). Characteristics that relate to charisma can overwhelm many other considerations, and can hinder or derail proposed management strategies (Dickie et al. 2014; Gaertner et al. 2016).

Control of the charismatic *Anas platyrhynchos* (Mallards) was met with significant resistance from local residents in Cape Town (Gaertner et al. 2016). Residents enjoyed these colourful and friendly ducks that provided them with entertainment and pleasure. In particular, they enjoyed feeding them which is not as easy with native ducks. Also, in Cape Town, there was controversy over the control of *Hemitragus jemlahicus* (Himalayan Tahr), which many residents viewed as majestic



(see Davies et al. 2020, Chap. 23, Sect. 23.8.2). However, in this instance control continued because the animals were within a national park and so ecological imperatives overrode public sentiment. In Pretoria, residents successfully opposed the listing of *J. mimosifolia* in the city because it produces an abundance of beautiful purple flowers that residents admire; so much that the city is colloquially known as the Jacaranda City (Dickie et al. 2014). This resonates with the ongoing vocal and active opposition to the control of charismatic *Pinus pinea* (Umbrella Pine) on Table Mountain (Gaertner et al. 2016).

In other situations, charisma is not at the forefront of opposition to the management of particular species and other human values can inspire opposition. For example, a woman in Makhanda said she would refuse the removal of a *M. azedarach* tree from her garden, not because of its beauty or charisma, but because she had fond memories of her children playing in the tree. On the other hand, some see it as ethically wrong to control invasive alien species. The killing of *Columba* species (Pigeons), which some might view as uncharismatic, faced a lot of opposition, as it is an animal and people enjoyed seeing them (Harris et al. 2017). Similarly, citizens in Cape Town have responded “*Everything can be annoying, because its alive. . . we have to accept it*” and “*You should not kill them, you should move them back to the Eastern Cape*” with regards to the management of *S. gutturalis* (Guttural Toad) that would not traditionally be considered as charismatic (Novoa et al. 2017), and did not come from the Eastern Cape (Telford et al. 2019). Many invasive species provide livelihood benefits, which lead to opposition to their control, and has nothing to do with charisma (Shackleton et al. 2007). The commercial importance of some species, e.g. in forestry or aquaculture, promote resistance to management (van Wilgen and Richardson 2014; Zengeya et al. 2017).

While there was some evidence in support of this proposition, it generally appears that a range of different motivations can catalyse resistance to control efforts, of which species charisma is only one. The relative importance of each motivation can only be tested through carefully chosen experiments with different stakeholders or social groups. Moreover, in socially and culturally diverse countries, like South Africa, the very construct of uniform notions of charisma may be questionable, particularly when more important factors, such as economics, are taken into consideration. Therefore, improved engagement and decision support tools might help to guide and prioritise management in the future (Gaertner et al. 2016; Novoa et al. 2018).

#### **24.5.2 Proposition 4b: Social Heterogeneity Increases Conflicts Around the Management of Biological Invasions**

South Africa is colloquially known as the “rainbow nation”, reflecting its diversity and mixing of multiple ethnic groups, cultures, races, languages and worldviews. We propose that social heterogeneity increases conflicts around invasive species

management. In South Africa, longstanding conflicts include the listing and control of trout as a sport fish (Woodford et al. 2017), managing commercially important species of forestry trees (van Wilgen and Richardson 2014), and managing charismatic species in urban areas (Dickie et al. 2014; Gaertner et al. 2016). From these few, but prominent, cases, it appears that conflicts around management between the state and other actors are driven more often by elite and middle-class individuals and institutions who have resources, power and influence. More often than not, the voices of the poor and marginalised are not heard and therefore are rarely considered.

The literature does however highlight a conflict situation surrounding *Acacia* species in communal lands bordering the Golden Gate Highlands National Park in the Free State (Mukwada et al. 2016), showing the different worldviews among the local villagers and park officials. This has resulted in park-community conflicts relating to perceived threats and management responses, which might also partly be a manifestation of other deeper underlying issues relating to land and resource use, land claims and economic benefit-sharing that result from historic injustices to some marginalised ethnic groups. Narratives and experiences by heterogeneous groups are not always accounted for, and can therefore increase complexity and conflict surrounding management (Lidström et al. 2016). These authors describe how environmental engagement does not always transcend, but can sometimes increase, ecological and social inequities in South Africa (Lidström et al. 2016).

Overall, we found this proposition hard to test due to a lack of in-depth information surrounding causes of conflict, although we would suggest it is likely to be true. The results of the few mentioned cases suggest that conflicts are often very context-dependent, relating to different species and different issues (e.g. ethical vs economic debates) and can be a manifestation of other deeper issues often relating to heterogeneity. However, most of the reported conflicts surround elite citizen interests and conservationists rather than between different groups of citizens. However, many studies focus on one specific set of actors or lump all citizens into one group with a lack of comparison between different actors.

### ***24.5.3 Proposition 4c: Engagement with Society is Key to Successful Management***

It is increasingly acknowledged that involving people in the development and implementation of management is crucial for the success of natural resource conservation programmes (Ntshotsho et al. 2015; Turner et al. 2016; Novoa et al. 2018). With specific reference to the management of biological invasions, South Africa is unique, because it has the renowned Working for Water programme which has both social and ecological goals. Due to the large variety of social and ecological contexts, as well as the diversity of invasive species in the country, South Africa has been very forward thinking in engaging with different actors and stakeholders to develop policies and management actions aimed at solving contentious issues and ensuring the long-term stability of management through benefiting society (van

Wilgen and Wannenburg 2016). Research conceptualised in South Africa has led to the development of a stakeholder engagement framework (Novoa et al. 2018).

A number of projects in South Africa have worked with stakeholders to understand how to implement control programs more effectively. Urgenson et al. (2013) highlighted that many private landowners in South Africa understand the need to share management responsibility with the state. However, many of these landowners also emphasised the need for financial and other incentives to improve compliance, but there was a lack of agreement on what these should be. Harris et al. (2017) highlighted that manager's views and methods for control differed very much from the perceptions and desires of staff at the University of South Africa. They suggested that public participation would be needed to develop appropriate management strategies. A number of other projects have engaged with a broad set of actors to help plan and prioritise management strategies. Suggested approaches have included stakeholder workshops, and decision-making tools to develop spatial prioritisation plans (e.g. Roura-Pascual et al. 2009; Forsyth et al. 2012) and adaptation responses (Shackleton et al. 2016). These interventions have led to the development of special prioritisation plans for parts of the Western Cape (e.g. Forsyth et al. 2012), and national taxon-specific plans as in the case of *Prosopis* (Shackleton et al. 2017) and Cactaceae (Kaplan et al. 2017)—although current uptake of these plans is poor (see van Wilgen et al. 2020a, b, Sect. 21.4).

In working through contentious issues, some engagement processes have been highly successful (Novoa et al. 2016), while others have resulted in little change (Woodford et al. 2016). Novoa et al. (2016) showed that, for controlling cacti in South Africa, engagement increased understanding between opposing parties (those promoting different species for ornamental and production purposes, conservationists worried about invasions, and landowners affected by their impacts) and led to better recognition of each other's viewpoints. Furthermore, through engagement, opposing actors came to consensus relatively easily on which taxa in the Cactaceae should be listed as invasive under the National Environmental Management: Biodiversity Act (NEM:BA) regulations (see van Wilgen et al. 2020a, Chap. 1; van Wilgen et al. 2020b, Chap. 21; Box 1.2). Only certain genera and growth forms that are more likely to be invasive were listed, allowing for the use and trade of all others (Novoa et al. 2015a). This allowed for win-win outcomes for both parties. This successful example was due to having a good understanding of Cactaceae ecology, but also having open and bottom-up discussions.

For highly established and profitable industries, such as forestry, engagement has been more difficult (van Wilgen and Richardson 2014; Woodford et al. 2016). These industries have powerful lobby groups and economic interests, making compromise more difficult to achieve. Another big conflict issue has been in listing trout, where engagement has been confrontational and has potentially even worsened the situation. A number of powerful, elite fishers almost derailed the creation of invasive species lists as required under NEM:BA in South Africa. Much of this is to do with elite "recreational selfishness" but there are also economic arguments to be made, with trout fisheries contributing to the economies of a number of small towns across South Africa. The conservation actors were willing to allow mutually beneficial

strategies, in which some areas now stocked with trout would be re-prioritised for biodiversity conservation while other localities would allow trout fishing. But proposals for compromise solutions were not accepted by the trout fishing fraternity (Brown 2013, 2016), and because the government is insistent on listing trout, the issue may still end up in court (Ellender et al. 2014). This is driven by a lack of trust in authorities, inadequate communication and understanding (Cox 2013), a similar issue in other regions of the world (Wald et al. 2019). In contrast, Bass (*Micropterus* species) anglers have been more supportive of management suggestions and have engaged with researchers in citizen science projects to control and monitor invasive fish (Weyl et al. 2014). The different outcomes of trout and bass anglers engagement comes down to context. While bass fishing primarily takes place in human-made dams and reservoirs that are already disturbed, allowing for invasives to be present (not needing control), the best trout-fishing takes place in undisturbed mountain rivers with endemic native fishes threatened by trout predation, making regulation desirable (see Davies et al. 2020, Sect. 23.5).

Our proposition finds some support and we have shown instances where engagement has been highly beneficial, but also other cases where it has been difficult. Moreover, most research on management and engagement seeks to improve knowledge as opposed to finding ways to implement it, i.e. there is a research-implementation gap (see Foxcroft et al. 2020, Chap. 27). Involvement of non-research stakeholders can help to swing the balance and thus there is need for better engagement with different actors (Ntshotsho et al. 2015). Often there are social-ecological barriers that can be addressed by meaningful engagement and collaboration (Esler et al. 2010, Shackleton et al. 2016; Angelstam et al. 2017). Having more bottom-up and collaborative management that involves co-design and co-implementation could improve control in the long-term (Reed et al. 2017). Also, better understanding why, where and how engagement works, or doesn't, would benefit planning in the future. South Africa could also learn lessons from elsewhere. For example, from the successful collaboration between parties to better control mink invasions in Scotland (Bryce et al. 2011), and the role of citizen science and volunteering in many parts of Europe (Adriaens et al. 2015; Pagès et al. 2019).

## 24.6 Conclusions

The chapter has highlighted the important role of human and social dimensions of invasion science in South Africa. Work on this topic in the country has provided better understanding of a number of aspects relating to invasion processes and impacts, and has in some cases improved management responses. South African research has contributed much toward understanding the effects of biological invasions on people's livelihoods, particularly in poor rural areas (e.g. de Neergaard et al. 2005; Shackleton et al. 2007). Historians have theorised the role of past social processes in facilitating invasions and their management (Carruthers et al. 2011; Bennett and van Sittert 2019). Social studies have also helped in developing

engagement and management processes to be used in South Africa and elsewhere (Forsyth et al. 2012; Novoa et al. 2015b, 2018). Due to different social-ecological settings within the country, work in South Africa has also shed light on how and why people contextualise biological invasions, and why conflicts arise (Lidström et al. 2016; Shackleton et al. 2015a; Potgieter et al. 2019).

Despite its importance, the volume of work in the social domain still lags behind ecologically-focused research, both in South Africa and elsewhere, and there are many pressing areas and questions where further and deeper contributions are needed. In this chapter we investigated social science and humanities contributions for 12 pertinent propositions, covering four broad topics, using South Africa as a case study region. We found that that substantial evidence was lacking for supporting all but one of these propositions (Table 24.1). Similarly, only five of the 12 propositions could be fully supported (Table 24.1). Those that were unsupported have contradictory information or lack concrete evidence, making further work necessary.

A number of gaps and opportunities were identified relating to the four broad thematic areas outlined in Shackleton et al. (2019a). Regarding people causing invasions, there is need for better examining the role of different sectors of society, and effectively incorporating human actions into models of invasion processes. Concerning people conceptualising invasions, studies have revealed that public knowledge about biological invasions and their effects is low in most, albeit not all, situations, particularly in urban areas. Several techniques from the education and social disciplines could be used to improve public education and awareness, which could lead to more informed and collaborative management efforts in the future (see Byrne et al. 2020, Chap. 25). Better understanding the social-ecological contexts and knowledge systems under which people conceptualise biological invasions would also be beneficial.

Many studies investigating the effects of biological invasion only focus on one group of actors. However, invasions are complex and can have different effects for different groups of people and these can lead to conflicts and trade-offs, and more research is needed to assess this. Most research also lacks deeper considerations of various power dynamics and outcomes relating to the impacts of biological invasions. Such work requires historical nuance, grounding in the social realities of different geographic and institutional contexts, and attention to relationships, practices, perceptions, and discourses. Moreover, a few large-scale cost-benefit analyses have been conducted, but assessing benefits and costs and value chains of invasive species at local levels and between different actors could help to improve understanding and management planning. Linking biological impacts to human wellbeing would also provide further evidence to guide or justify management. Lastly, relating to responding to invasions, increased collaborative research and management planning involving various actors could help to shape better policy, and to effectively control biological invasions in the country (Novoa et al. 2018; Shackleton et al. 2019d). Also, a better understanding of in which forms and the contexts engagement works, and what makes engagement activities fail would help

to guide future actions. This might link to improved analysis and understanding of power dynamics and social networks.

In conclusion, structuring this chapter around a series of propositions has highlighted what is known and what is not, whilst simultaneously reviewing meaningful social science theory on biological invasions in South Africa and beyond. Further work in the area should be promoted; South Africa is a superb place to test theories and advance knowledge regarding social dimensions, because of its complex and diverse social-ecological setting and well-developed research capacity (van Wilgen et al. 2020a, b, Chap. 1, Chap. 21).

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