Chapter 17
An Evaluation of the Impacts of Alien Species on Biodiversity in South Africa Using Different Assessment Methods

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Abstract Studies of the impact of alien species on the environment are increasingly being carried out, and there has been ongoing debate about how to standardise the description of these impacts. This chapter evaluates the state of knowledge on the impacts of alien species on biodiversity in South Africa based on different assessment methods. Despite South Africa being one of the most biologically diverse countries in the world, there have been very few studies that formally document the impacts of alien species on biodiversity. Most of what is known is based on expert opinion, and consequently the level of confidence in the estimates of the magnitude of these impacts is low. However, it is clear that a significant number of alien species cause major negative impacts, and that there is cause for serious concern. There is a

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growing global effort to assess all alien species with standardised protocols to alleviate the problem of comparing impacts measured using different approaches. Formal assessments have been done for a few alien species in South Africa, but most naturalised and invasive species have not been evaluated, and, we suspect, for most alien species there has been no attempt, as yet, to document their impacts. However, red-listing processes found that alien species were frequently included as a significant extinction risk for several native species of fish, amphibians, and plants. There are very few studies that cover the combined impacts of co-occurring alien species in particular areas, and these studies could provide the rationale for regulation and management, which is often absent. While reductions due to alien species in the value of ecosystem services, the productivity of rangelands, and biodiversity intactness are relatively low at present these impacts are expected to grow rapidly as more invasive species enter a stage of exponential growth.

17.1 Introduction

South Africa occupies only 2% of the world's land area but it is one of the most biologically diverse countries globally (Mittermeier et al. 1997). For example, it is estimated that 7% of the world's vascular plants, 5% of mammals and 7% of birds are found in South Africa (Le Roux 2002). In addition, more than half of the plants, butterflies, amphibians and reptiles native to South Africa are endemic (Colville et al. 2014). This is partly because of the country's diverse environmental conditons that have resulted not only in high species diversity and endemism, but also in a diversity of terrestrial, freshwater and marine ecosystems (van Wilgen et al. 2020a, Chap. 1; Wilson et al. 2020, Chap. 13). The country's terrestrial vegetation types can be broadly grouped into nine biomes that range from deserts and Mediterranean-climate shrublands (fynbos) in the west to grasslands and savanna in the eastern interior, and evergreen forests in high rainfall areas along the east coast (Mucina and Rutherford 2006). Three areas within these biomes—the Cape Floristic Region, the Succulent Karoo, and the Maputaland-Pondoland-Albany region—have been designated global biodiversity hotspots (Myers et al. 2000; Mittermeier et al. 2004). The marine realm includes several ecosystems in the surrounding Indian and Atlantic oceans and offshore islands (van Wilgen et al. 2020a, Chap. 1). The marine ecosystems are also diverse with over 12,000 species that represent 15% of all known coastal marine species worldwide (Le Roux 2002; Griffiths et al. 2010).

Alien species can change the composition, structure and functioning of biodiversity in many ways. Examples include hybridisation with native species (e.g. Tracey et al. 2008), extirpation of native species through predation (e.g. Rodda and Fritts 1992) or disease transmission (Hulme 2014), alterations to the structure of vegetation by introducing novel growth forms (van Wilgen and Richardson 1985), and changes to ecosystem processes like fire (Brooks et al. 2004) and hydrology (Le Maitre et al. 2015). A recent study concluded, based on data from the IUCN Red List, that alien species were the most common threat associated with extinctions of mammals, amphibians and reptiles, and for vertebrate extinctions overall (Bellard et al. 2016a).

In South Africa, a total of 107 alien species are suspected to have major negative impacts on biodiversity, and most (75%) of these are plants (van Wilgen and Wilson 2018). Despite these concerns, there have been relatively few studies that have formally quantified the impacts of alien species on different facets of biodiversity in South Africa. In a review focussing on alien plants, Richardson and van Wilgen (2004) concluded that information on the ecological impacts of alien plants was generally poor, and that the consequences of invasions for the delivery of ecosystem goods and services were, with the notable exception of their influence on water resources, inadequately studied. Since then, the situation has improved to some degree.

This chapter evaluates the state of knowledge on the impacts of alien species on biodiversity in South Africa based on different assessment methods. It focuses mainly on explicit knowledge of impacts of alien species on compositional and structural aspects of biodiversity at a species scale, and less at genetic, community, and ecosystem scales (cf. Noss 1990). Some references are presented that discuss the cumulative impact of all invasions on biodiversity, but how these impacts interact with other global change drivers is not covered.

17.2 Assessing the Impact of Alien Species on Biodiversity

Different approaches have been used to quantify, assess and summarise the impacts caused by alien species on native biodiversity. Here, we focus on three main methods: impact-scoring schemes, expert opinion assessments, and impacts identified during red-listing processes. Impact scoring schemes such as the Environmental Impact Classification for Alien Taxa (EICAT; Blackburn et al. 2014; Hawkins et al. 2015; see also Box 17.1) and the Socio-Economic Impact Classification of Alien Taxa (SEICAT; Bacher et al. 2018), amongst others, can be used to formally assess and quantify impacts of individual alien species. Impact-scoring schemes are based on published evidence, and aim to make impacts comparable between taxa and regions by assigning them to semi-quantitative classes which are clearly defined to minimise assessor bias. We focus here on the EICAT scheme as it is most relevant for impacts of a particular alien species on native species. Expert opinion studies (e.g. Zengeya et al. 2017) also assess impacts of specific alien species, but use experts rather than published impact evidence to gauge impacts. Expert opinion studies can be done at a species level (impact of a particular alien species on native species) and or on the entirety of invasions on an ecosystem (e.g. ecosystem services; van Wilgen et al. 2008). Lastly, the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species reports threats from a combination of invasions on a particular native species (Mace et al. 2008).

Box 17.1 The Environmental Impact Classification for Alien Taxa (EICAT)

EICAT is a simple, objective and transparent method to classify alien taxa according to the magnitude of environmental impacts caused in their introduced ranges (Blackburn et al. 2014; Hawkins et al. 2015). It assesses impacts caused by a specific alien taxon (mostly a species) on native species in the recipient area and can help identify taxa with different levels of impacts as well as facilitate comparisons of impacts between taxa and regions. Based on published records of impacts, EICAT classifies detrimental impacts based on 12 mechanisms, namely:

- Competition
- Predation
- Hybridisation
- Transmission of diseases
- Parasitism
- Poisoning/toxicity
- Bio-fouling
- Grazing/herbivory/browsing
- Chemical, physical or structural impact on ecosystem
- Interaction with other taxa

Furthermore, if records of impact are available, EICAT distinguishes between five impact levels based on the organisational level of the species affected, as follows:

Minimal Concern (MC)—the alien taxon does not affect the performance of any native species it interacts with through any of the above mentioned mechanisms

Minor (MN)—the alien taxon affects the performance of at least one native species through any of the above mentioned mechanisms, but does not affect population size

Moderate (MO)—the alien taxon reduces the population size of at least one native species through any of the above mentioned mechanisms, but the native species is still present in the community

Major (MR)—the alien taxon leads to the local or metapopulation extinction of at least one native species changing the native community, with the impacts being reversible when the alien taxon is no longer present

Massive (MV)—irreversible community changes caused by the alien taxon through the local, sub-population or global extinction of at least one native species

If no data on impacts of the taxon in the alien range is available, it is classified as Data Deficient (DD).

(continued)

Box 17.1 (continued)

EICAT is in the process of being adopted by the IUCN as a standard system for classifying invasive alien species based on the nature and magnitude of their impacts (see https://www.iucn.org/theme/species/our-work/invasive-species/eicat for more details).

17.2.1 Impact-Scoring Schemes

The Environmental Impact Classification for Alien Taxa has been applied to various taxa that are known to occur as alien species in South Africa including grasses (Visser et al. 2017; Nkuna et al. 2018; Canavan et al. 2019), amphibians (Kumschick et al. 2017), birds (Evans et al. 2016), mammals (Hagen and Kumschick 2018), fish (Marr et al. 2017), gastropods (Kesner and Kumschick 2018), and some other invertebrates (Nelufule 2018). Most EICAT assessments performed to date have been done at a global scale, i.e. including all records of impact of a given species in its global alien range. It is important to note that although global assessments are comprehensive, there will need to be regularly updated as further assessments are done at national scales. In South Africa, national-level EICAT assessments have been done for some alien grasses (Visser et al. 2017) and fishes (Marr et al. 2017) (Table 17.1).

A global effort is in progress to use EICAT to assess all species in their alien ranges, and researchers from South Africa have contributed many assessments to date. Evidence-based assessments are also needed in South Africa for regular reporting on the status of biological invasions (van Wilgen and Wilson 2018; Wilson et al. 2018; van Wilgen et al. 2020a, Chap. 1). Moreover, the risk analysis framework currently used as evidence to support listing of alien species in South Africa (Kumschick et al. 2018) requires impact assessments analogous to EICAT (Kumschick et al. 2020, Chap. 20). However, while some progress has been made, there is still a very large number of species that have to be formally assessed in South Africa.

17.2.1.1 Grasses

There are six grass species that have had EICAT assessments done at a national scale for South Africa, with *Arundo donax* (Giant Reed) and *Glyceria maxima* (Reed Meadow Grass) evaluated as having major impacts (Visser et al. 2017; Nkuna et al. 2018; VK Nkuna, unpublished data). These two species have been implicated in competitively displacing native species; *A. donax*, for example, dominates riparian areas and can locally exclude native plants (Holmes et al. 2005; Guthrie 2007), while *G. maxima* has locally displaced some native wetland species (Mugwedi 2012).

Table 17.1 Alien species that have been assessed by the Environmental Impact Classification for Alien Taxa (EICAT) scheme to have major (MR) and massive (MV) impacts on biodiversity in South Africa[a]

Taxon	Species	Assessment category	Mechanisms	Impacts	Source
Fish	*Oreochromis niloticus* (Nile Tilapia)	MV	Hybridisation	Native *Oreochromis* species such as *O. mossambicuss* are under threat from hybridisation with *O. niloticus*	Marr et al. (2017)
Grass	*Arundo donax* (Giant Reed)	MR	Competition	Dominates riparian areas and can locally exclude native species	Visser et al. (2017), Nkuna et al. (2018), VK Nkuna (unpublished data)
Grass	*Glyceria maxima* (Reed Meadow Grass)	MR	Competition	Outcompetes native wetland species	Visser et al. (2017), Nkuna et al. (2018), VK Nkuna (unpublished data)
Fish	*Micropterus dolomieu* (Smallmouth Bass)	MR	Competition and predation	Causes changes in the community structure of invertebrates and local extirpations and fragmentation of native fish populations through predation	Marr et al. (2017)
Fish	*Micropterus salmoides* (Largemouth Bass)	MR	Competition and predation	Causes changes in the community structure of invertebrates and local extirpations and fragmentation of native fish populations through predation	Marr et al. (2017)
Fish	*Oncorhynchus mykiss* (Rainbow Trout)	MR	Competition and predation	Causes declines, and in some cases local extirpation, of native invertebrates, frogs and fish through predation	Marr et al. (2017)
Fish	*Salmo trutta* (Brown Trout)	MR	Competition and predation	Causes declines, and in some cases local extirpation, of native invertebrates, frogs and fish through predation	Marr et al. (2017)

[a]Major impacts lead to community changes, which are reversible; and massive impacts leads to irreversible community changes and extinctions

17.2.1.2 Gastropods

Thirty-four gastropod species alien to South Africa have formal global EICAT assessments. Four of these—*Helisoma duryi* (Seminole Rams-Horn), *Tarebia granifera* (Quilted Melania Snail), *Oxychilus draparnaudi* (Drapanaud's Glass Snail) and *Theba pisana* (White Garden Snail)—are known to change community structures in their global invaded range (Kesner and Kumschick 2018). For example, *H. duryi* outcompetes and displaces native snail species (e.g. Christie et al. 1981), *T. granifera* has been implicated in causing local extinctions of native snails in wetlands (e.g. Karatayev et al. 2009) and *O. draparnaudi* is a predator that causes the local disappearance of prey species (e.g. Frest and Sanders Rhodes 1982).

In South Africa, the only documented impacts are for *Tarebia granifera* and *Theba pisana*. The former was accidentally introduced into South Africa through the aquarium trade and has since invaded several rivers, lakes, wetlands and estuaries in the eastern and northern parts of the country (Appleton et al. 2009). It can reach high population densities, and has been implicated in displacing native snails and becoming the dominant component of invertebrate assemblages in invaded areas (Miranda and Perissinotto 2014). *Theba pisana* can reach high densities on the west and south coast of South Africa, with the potential to impact on native fauna and flora (Odendaal et al. 2008).

17.2.1.3 Fish

No fish species have been globally assessed with EICAT to date, but an assessment of alien fish species naturalised in South Africa identified five species that have negative impacts (Marr et al. 2017). *Micropterus dolomieu* (Smallmouth Bass), *M. salmoides* (Largemouth Bass), *Oncorhynchus mykiss* (Rainbow Trout), *Salmo trutta* (Brown Trout) and *Oreochromis niloticus* (Nile Tilapia) are known to have adverse impacts in South Africa that span all levels of biological organisation from gene to ecosystem (Ellender and Weyl 2014). On a genetic level, the integrity of native *Oreochromis mossambicus* (Mozambique Tilapia) is under threat from hybridisation with *O. niloticus*, a species introduced for aquaculture (Firmat et al. 2013). Evidence of species and population-level impacts are mainly linked to direct predation by *O. mykiss*, *S. trutta* and *Micropterus* species (Black Basses), which have resulted in local extirpations of native fishes and invertebrates (Ellender and Weyl 2014; van der Walt et al. 2016; Shelton et al. 2018).

Oncorhynchus mykiss and *S. trutta* are cold water species that, as a result of stocking for sport fishing, have naturalised in many cool, well-oxygenated headwater streams in the country (Ellender et al. 2017; Weyl et al. 2017a). They are generalist predators that feed primarily on aquatic invertebrates, but will also opportunistically prey on terrestrial invertebrates, fish and amphibians. Their impacts therefore span numerous trophic levels, and in South Africa include the decline, and in some cases local extirpation, of native invertebrates, frogs and fish

(Karssing et al. 2012; Rivers-Moore et al. 2013; Jackson et al. 2016). *Oncorhynchus mykiss* and *S. trutta* have also been implicated in the decline of populations of *Hadromophryne natalensis* (Natal Cascade Frog) in a streams in the uKhahlamba Drakensberg Park (Karssing et al. 2012). The two trout species have aslo been implicated in the extirpation of the endangered fish *Amatolacypris trevelyani* (Border Barb) in headwater streams of the Keiskamma River in the Eastern Cape. In the Breede River system, Shelton et al. (2015b) demonstrated that the abundance (mean density and biomass) of native fish species—*Pseudobarbus burchelli* (Breede River Redfin), *Sandelia capensis* (Cape Kurper) and *Galaxias zebratus* (Cape Galaxias), were 5–40 times lower where *O. mykiss* was present, and that invertebrate species assemblages in streams with *O. mykiss* were distinctly different from those found in streams without *O. mykiss*. In addition, Shelton et al. (2015a) observed that *O. mykiss* had a weaker predation effect on aquatic invertebrates relative to the native fishes that it had replaced. As a result, there was also evidence of cascading effects, with algal biomass being significantly lower when *O. mykiss* was present because of higher abundance of herbivorous invertebrates relative to uninvaded sites. In the Drakensberg, and the Keiskamma River system, *O. mykiss* and *S. trutta* also share emerging insects as a food resource with riparian spiders, causing a decline in spider abundance at invaded sites (Jackson et al. 2016).

Black bass is the collective name for species of the genus *Micropterus* which, in South Africa, includes *M. salmoides*, *M. dolomieu*, *M. punctulatus* (Spotted Bass) and *M. floridanus* (Florida Bass) (Weyl et al. 2017b). As warm water species, Black Bass were introduced for sport fishing in the lower reaches of rivers and impoundments (see Khosa et al. 2019). Their impacts are similar to those documented for *O. mykiss* and *S. trutta*, and include the alteration of invertebrate communities (Weyl et al. 2010) and local extirpations and fragmentation of native fish populations (e.g. Kimberg et al. 2014; van der Walt et al. 2016; Ellender et al. 2018). A quantitative assessment of aquatic invertebrates in the Wit River, Eastern Cape, found that *M. salmoides* changed relative abundance and community structure (Weyl et al. 2010). In sections with *M. salmoides*, several members of large or conspicuous taxa (Odonata, Hemiptera and Coleoptera) were significantly reduced or even absent, while members of cryptic/inconspicuous taxa (Trichoptera, Leptoceridae, Mollusca, and Physidae) were significantly more abundant. In the headwaters of the Swartkops River system in the Eastern Cape, for example, *M. salmoides* predation has fragmented populations of the now endangered *Pseudobarbus afer* (Eastern Cape Redfin) (Ellender et al. 2018). Similarly, in the Olifants River system in the Western Cape, *M. dolomieu* and *M. punctulatus* invasions have restricted native *Cedercypris calidus* (Clanwilliam Redfin) and *Pseudobarbus phlegethon* (Fiery Redfin) to headwater reaches above physical barriers to invasion (van der Walt et al. 2016) and in the Marico River in the North West, *M. salmoides* and *M. punctulatus* have depleted mainstream *Enteromius motebensis* (Marico Barb) populations (Kimberg et al. 2014).

Trout and black bass often act synergistically on native fish populations. Trout are cold water species that are established in cooler headwater reaches of rivers (Ellender et al. 2016; Shelton et al. 2018), from which they exclude native fishes through predation and competition. Downstream trout populations are limited by temperature, which also mediates their predatory impacts (Shelton et al. 2018). Black bass, on the other hand, are warm water species that invade up rivers from mainstream source populations, and their penetration of headwaters is limited only by physical barriers such as waterfalls or gradients (see van der Walt et al. 2016; Ellender et al. 2018). This has resulted in an increasing compression of native fish populations between these two invaders, a situation which has resulted in the loss of more than 80% of habitat in some catchments (van der Walt et al. 2016).

17.2.1.4 Amphibians

A total of 104 species of alien amphibians globally have been assessed with EICAT (Kumschick et al. 2017), of which 21 are alien species in South Africa (van Wilgen and Wilson 2018). *Duttaphrynus melanostictus* (Asian Common Toad) is the only one of these species with major impacts globally that also occurs as an alien in South Africa, but there is no evidence for it having any impact in the country to date, probably due to its lack of establishment within the country (Measey et al. 2017). The only cases of documented impacts in the country are restricted to native species. *Xenopus laevis* (African Clawed Toad), native to South Africa but traded intensively globally, hybridises with the endemic *X. gilli* (Cape Platanna) (Picker 1985), but importantly there is no evidence of introgression (Furman et al. 2017). Even though these two species might have likely overlapped for millennia (Schreiner et al. 2013), densities of *X. leavis* have probably been artificially increased in the last 400 years (Measey et al. 2017), leading to intense competition and predation (Vogt et al. 2017; de Villiers et al. 2016). *Sclerophrys gutturalis* (Guttural Toad), native to much of the country but introduced to a peri-urban area of Cape Town (Vimercati et al. 2017), could potentially threaten the native endangered *Sclerophrys pantherina* (Western Leopard Toad), but no evidence of the extent of this threat has been reported to date (Measey et al. 2017). *Hyperolius marmoratus* (Painted Reed Frog) is also native to some parts of South Africa but has become invasive in other areas of the country that are outside its natural range (Tolley et al. 2008; Davies et al. 2013). No studies on its impacts on biodiversity have been conducted to date, but it is suspected that it may impact the endemic *Hyperolius horstocki* (Arum Lily Frog) (Measey et al. 2017).

17.2.1.5 Birds

There are 415 alien bird species that have been assessed with EICAT at a global scale (Evans et al. 2016), of which 37 occur as aliens in South Africa (van Wilgen and Wilson 2018). Two species, *Anas platyrhynchos* (Mallard) and *Pycnonotus jocosus* (Red-Whiskered Bulbul) are known to cause major impacts in their global invasive range (Evans et al. 2016). *Anas platyrhynchos* threatens the genetic integrity of native congeners through hybridisation (e.g. Tracey et al. 2008). In southern Africa *A. platyrhynchos* hybridises with endemic species such as *Anas undulata*

(Yellow-billed Duck), but currently there are low levels of introgression of *A. platyrhynchos* genes into *A. undulata* (Stephens et al. 2020). Introgression could become more extensive in the future if *A. platyrhynchos* populations are not controlled (Stephens et al. 2020; Davies et al. 2020, Chap. 22). *Pycnonotus jocosus* have been shown to damage crops, spread weeds, prey on native species and compete with them elsewhere (Mo 2015), but their impact in South Africa is unknown. Similarly, *Psittacula krameri* (Ring-necked Parakeet) is thought to compete for breeding holes with bats and other birds in other alien ranges leading to population declines of affected species. It has a very limited but expanding distribution in South Africa, and only ancedotal observations of impacts have been reported so far (Hart and Downs 2014). The species is a conflict species because it has both societal benefits (as a pet) and negative impacts (see Zengeya et al. 2017; Shackleton et al. 2020, Chap. 25).

17.2.1.6 Mammals

There are 42 alien mammal species that have been recorded outside of captivity in South Africa (van Wilgen and Wilson 2018), eleven of which have formal global-scale EICAT assessments. All of these species cause large impacts in their invasive range globally (Hagen and Kumschick 2018). For example, several alien rodent species such as *Rattus rattus* (Black Rat), *Rattus norvegicus* (Norwegian Rat) and *Mus musculus* (House Mouse) have caused local extinctions of native species of invertebrates, birds, bats and rodents on several islands through predation, competition for food, and disease transmission (e.g. Steadman 1995; Marris 2000; Courchamp et al. 2003). The feral species *Capra hircus* (Goat), *Equus asinus* (Donkey) and *Sus scrofa* (Pig) cause massive impacts through competition with native species for food, altering the structure and composition of plant communities by grazing and rooting (e.g. Kurdila 1998; Campbell and Donlan 2005; Means and Travis 2007). This has led to habitat loss, resulting in local extinction of some native species and accelerated soil erosion. Other domestic species such as *Felis catus* (Cat) can cause major impacts through predation leading to population declines, and in some cases local extirpation, of native mammals, reptiles, and birds (Fitzgerald and Veitch 1985; Winter and Wallace 2006).

For a few species, impacts have been recorded in South Africa. For example, *M. musculus* and *F. catus* have caused major impacts on offshore islands (Berruti 1986; Greve et al. 2017, 2020, Chap. 8). *Mus musculus* was introduced on Marion Island before 1818, likely as a stowaway on ships whose crews were engaged in seal hunting (Watkins and Cooper 1986). On the island, it preys on invertebrates (Jones and Ryan 2010; Dilley et al. 2016) and this changed the population densities, reproduction strategies and growth rates of some invertebrates on the island (Treasure and Chown 2014). Similarly, declines in albatross populations have been ascribed to predation of chicks by *M. musculus* (Dilley et al. 2016). *Felis catus* was introduced onto Marion Island in 1949 to control *M. musculus* (Bester et al. 2002). Although *F. catus* fed on *M. musculus*, it also preyed on seabirds and this severely affected seabird populations, especially burrowing species such as petrels (Procellariidae), leading to decreased breeding success, population declines and the local extinction of at least one species (van Rensburg 1983; Bester et al. 2002). *Felis catus* was eventually eradicated from the island in 1991 (Bester et al. 2002; Davies et al. 2020, Chap. 22), but the population of summer-breeding burrowing petrels is still to recover (Cerfonteyn and Ryan 2016).

Rattus norvegicus, *R. rattus*, *S. scrofa* and *C. hircus* have all caused massive impacts in other alien ranges (Hagen and Kumschick 2018), but their impacts in South Africa have not been studied apart from a few unpublished reports on wild boar impacts on vegetation and soil erosion (as mentioned in Spear and Chown 2009). The two rat species were unintentionally introduced into South Africa through the shipping trade (Long 2003). These two species are amongst the most invasive *Rattus* species with a global distribution in urban areas (Aplin et al. 2011). *Rattus rattus* is believed to be widely distributed but restricted by the drier parts of South Africa, while *R. norvegicus* is assumed to be limited to coastal areas of the country (De Graaf 1981). The two rat species are widely regarded as pests; in South Africa, specifically, they damage infrastructure, contaminate foodstuffs, and act as reservoirs of zoonotic diseases (e.g. Jassat et al. 2013; Julius et al. 2018; Potgieter et al. 2020, Chap. 11). *Sus scrofa* damages some critically endangered plants in the Western Cape, affecting succession and facilitating alien plant spread (Picker and Griffiths 2011). *Capra hircus* grazing has reduced the cover and density of endemic geophytes and succulents shrubs in thicket vegetation, and conservation of this endemic-rich flora is seriously threatened (Moolman and Cowling 1994).

17.2.2 Expert Opinion Assessments

Given that few taxa have been formally evaluated for the impacts using EICAT in South Africa, a classification based on expert opinion rather than on published literature was used as an interim measure in South Africa's first national status report on biological invasions (van Wilgen and Wilson 2018). Here, experts scored species according to their perceived ecological impacts and their socio-economic impacts (separately for negative and positive impacts) (see Zengeya et al. 2017 for more details). Using this scheme, 25 species were assessed as having severe impacts, and 82 as having major impacts (Table 17.2), the majority of these being terrestrial and freshwater plants (80 species). Here, using selected examples we highlight impacts on biodiversity of some of these alien species.

17.2.2.1 Plants

There are 893 alien plants species that are known to occur outside of cultivation in South Africa (van Wilgen and Wilson 2018). For a majority (56%) of these plant species, their impact on biodiversity has not been evaluated (Table 17.2). Of the 379

Table 17.2 The number of species that have been assessed by means of expert opinion as having impacts at different levels in South Africa[a]

Taxon	Not evaluated	Data deficient	Negligible	Few	Some	Major	Severe
Amphibians	0	15	1	2	1	2	0
Birds	73	0	5	5	8	1	0
Freshwater fish	6	1	0	5	9	4	1
Freshwater invertebrates	4	0	7	9	4	1	4
Mammals	3	0	4	16	11	8	0
Marine invertebrates	4	73	2	1	4	1	0
Marine plants	0	8	0	0	0	0	0
Microbial species	103		6	0	1	0	0
Reptiles	80	18	11	11	8	0	0
Terrestrial and freshwater plants	514	2	48	116	133	63	17
Terrestrial invertebrates	460	5	94	16	20	2	3
Totals	1247	122	178	181	199	82	25

[a]Adapted from Zengeya et al. (2017) and van Wilgen and Wilson et al. (2018)
Assignment to impact levels was based on an assessment of impact on both ecological or socio-economic aspects, with the assignment to a level being determined by the highest impact for either ecological or socio-economic aspects. Species that were identified by the experts as having insufficient information to formulate an opinion on its impacts were classified as "Data deficient" and a species was classified as "Not evaluated" if it was not evaluated against the criteria

species that have been assessed by expert opinion, the majority (33%) were categorised as low-impact species (i.e. species with negligible, few or some impacts). Only 80 plants were classified as having major and severe impacts, 17 of which had severe impacts, most of them Australian wattles (genus *Acacia*) and mesquite trees (genus *Prosopis*).

Prosopis are some of the few alien plants whose impacts (ecological and economic) have been examined in some detail in South Africa. The genus consists of several species and their hybrids that are regarded among some of the world's most damaging invasive plants. They were introduced to South Africa to provide supplemaneraty feed and shade for livestock, but similar to other countries where they have been introduced in the world, they have become invasive, generating negative impacts. In South Africa they have been found to have pronounced effects on insects, birds, and plants. Steenkamp and Chown (1996) found that invasion reduced the abundance and diversity of dung beetles. Native bird communities in invaded sites were found to be less diverse; some feeding guilds such as raptors were eliminated, and there was a marked decline in the abundance of frugivores and insectivorous species (Dean et al. 2002). However, other guilds such as nectarivores and seedeaters were less affected. Invasion also reduced the abundance and diversity of native plants. For example, in some plots the number of native tree species declined by 37% (n = 8) when the denstity of *Prosopis* doubled, while native perennial grasses and herbaceous plants were eliminated (Shackleton et al. 2015).

Invasive *Prosopis* competes with the native *Vachellia erioloba* (Camel Thorn) for groundwater, increasing the likelihood of competive exclusion of Camel Thorn trees when water resources are limiting (Schachtschneider and February 2013).

Other than for the genus *Prosopis*, there are very few studies that have quantified the impact of alien plants on biodiversity in South Africa. Richardson et al. (1989) reviewed published and unpublished data on plant species richness in the Fynbos Biome with different levels of invasion by alien trees and shrubs in the genera *Pinus*, *Hakea* and *Acacia*. They found significant declines in native plant species richness at the scale of the sample quadrats used in their study (4–256 m^2), notably when the cover of alien plants exceeded 50%. Similarly, Yapi et al. (2018) recorded marked declines in the cover of native grass species with increases in the canopy cover of alien *Acacia mearnsii* (Black Wattle) trees in the Eastern Cape. Such declines in the abundance and richness of native plant species, and associated faunal species, are likely to take place where any alien plant species becomes dominant. Given that many alien plant species have recently entered a phase of rapid spread, it can be expected that these kinds of impacts will increase. For example, Henderson and Wilson (2017) showed that the number of quarter degree grid cells occupied by alien plants in South Africa increased by ~50% between 2000 and 2016, with at least nine species having expanded rapidly over the past decade (see also van Wilgen et al. 2020a, Chap. 21).

Besides trees, some grasses have been shown to affect native biodiversity in South Africa. In addition to the examples mentioned earlier, *Ammophila arenaria* (European Beach Grass) has changed native dune communities (Hertling and Lubke 1999). *Avena barbata* (Slender Wild Oat) has invaded some lowland fynbos and can dominate old field habitats (Heelemann et al. 2013), and a recent study on *Paspalum quadrifarium* (Tussock Paspalum) showed its ability to affect native species communities (Nkuna 2018).

17.2.2.2 Invertebrates

Many alien invertebrates are major pests of agriculture, but here we focus on taxa that have negatively impacted native biodiversity. There are 629 alien freshwater and terrestrial invertebrates that are known to occur outside of captivity in South Africa (van Wilgen and Wilson 2018). For a majority (74%) of these, their impacts on biodiversity have not been evaluated. Of the remainder, 25% were assessed using expert opinion as low-impact species, and less than 2% had major to severe impacts (Table 17.2). Five species of terrestrial invertebrates that purportedly have major to severe impacts include *Cornu aspersum* (Common Garden Snail), *Deroceras invadens* (Tramp Slug), *Linepithema humile* (Argentine Ant), *Thebia pisana* and *Trogoderma granarium* (Khapra Beetle). *Linepithema humile* has invaded fynbos, where it displaces native ants. The displacement of native ants is a direct impact on biodiversity, but the role that native ant species play in the dispersal of the seeds of fynbos plants has also been disrupted. Bond and Slingsby (1984) found that *L. humile* differed from native ants in moving seeds shorter distances, and in failing to store them in nests below the soil. The seeds were left on the soil surface, where they were eaten by vertebrate and invertebrate seed predators. Bond and Slingsby (1983) estimated that *L. humile* displacement of native ants could threaten the long-term survival of approximately 1000 fynbos plant species that were dependent on native ants for the dispersal and protection of their seeds.

Among the marine invertebrates, *Mytilus galloprovincialis* (Mediterranean Mussel) has had significant impacts in South African marine environments (Robinson et al. 2020, Chap. 9). First recorded in South Africa in the late 1970s, it presently occurs along the whole of the west coast and as far east as East London (approx. 2000 km of coastline) (Robinson et al. 2005). Within its invaded range, it has been implicated in causing impacts on native species and altering the structure of rocky shore communities. Along the west coast, *M. galloprovincialis* competively excludes native species such as mussels and limpets from prime habitas (Robinson et al. 2007), while along the south coast it co-exists with the native *Perna perna* (Brown Mussel) (Bownes and McQuaid 2006). Interestingly, *M. galloprovincialis* forms complex mussel beds that have increased habitat availability leading to an increase in the diversity and abundance of native fauna on invaded shores (Sadchatheeswaran et al. 2015).

17.2.2.3 Mammals

Of the 42 alien mammal species that have been recorded in South Africa, 8 species have been assessed using expert opinion as causing major impacts in South Africa (van Wilgen and Wilson 2018). Six of these (*R. rattus*, *R. norvegicus*, *F. catus*, *M. musculus*, *S. scrofa* and *C. hircus*) cause massive impacts in the country, in similar ways to those identifed by formal global EICAT assessments (see Sect. 17.2.1.6). For the remainder, *Hippotragus equinus koba* (Western Roan) has been implicated in hybridising with local sub-species (Mathee and Robinson 1999; Alpers et al. 2004; van Wyk et al. 2019) and the impacts of *Macaca fascicularis* (Crab-Eating Macaque) are not well documented in South Africa, so their potential impacts can only be inferred from their global invasive range.

17.2.2.4 Fishes

Five fish species were classified by experts as causing major to severe impacts in invaded catchments in South Africa (Zengeya et al. 2017). *Micropterus dolomieu*, *M. salmoides, O. mykiss* and *S. trutta* had major impacts through mainly competition and predation. *Oreochromis niloticus* was assessed as having severe impacts mainly through hybridisation with congeneric native species.

17.2.3 Impacts Identified During Red-Listing Processes

Some recent studies have used data from the IUCN Red List of Threatened Species (Mace et al. 2008) to assess the role of alien species as drivers of recent extinctions (Bellard et al. 2016a), and global patterns of threats to vertebrates posed by biological invasions (Bellard et al. 2016b). In South Africa, several taxa have undergone formal red list assessments and these include plants, dragonflies, freshwater fishes, amphibians, reptiles, birds and mammals (Child et al. 2015; Taylor et al. 2015; IUCN 2018; SANBI 2019). Following a similar approach as Bellard et al. (2016b), we assessed whether and how species listed under the IUCN Red List in South Africa were affected by alien species. We calculated the proportion of threatened native species, i.e. those in the upper tier of extinction risk (Vulnerable, Endangered, and Critically endangered), where alien species were indicated as a threat (Table 17.3).

A total of 23,609 native species were assessed, of which 17% had alien species as a major threat to their extinction risk. The proportion of threatened species that are imperilled by alien species varied across threat categories, being higher for Endagered (60%, $N = 609$ out of 1007) and Vulnerable species (48%, $N = 788$ out of 1641) and lower for Critically Endangered (40%, $N = 276$ out of 688) (Table 17.3). This trend is also reflected when comparions are made across taxa in each threat category (Table 17.3). More than half of the taxa assessed as Endangered (five out of eight), Critically Endangered (three out of five) and Vulnerable (three out of five) were threatened by alien species. Across all three threat categories, the proportion of species that are being threatened by alien species was highest for fishes, amphibians and plants. The Red List assessments identified and classified 12 major threats to the persistence of a species, and alien species were rarely considered to be the sole extinction risk for most species. For example, most of the fish and amphibian species listed as Critically Endangered have small distributional ranges, experience a continuous decline in habitat quality through several anthropogenic activities (e.g. pollution, excessive water abstraction and altered flow regimes), and are additionally threatened by invasive species through predation, competition and physical alteration of ecosystems (van Wilgen et al. 2020b, Chap. 29).

17.2.4 Impacts on Biodiversity at a Biome Scale

A limited number of studies have quantifed the impact of invasive species on ecosystem services at a landscape scale. Several studies have either focused on a particular ecosystem service (e.g. surface water supplies, Le Maitre et al. 2000), or on a single species (e.g. *A. mearnsii*, De Wit et al. 2001). This has led to problems in extraplolating the results generated by the different studies to make broad conclusions about the entirety of impacts of invasions on an ecosystem. Van Wilgen et al. (2008), however, assessed current and potential impacts of alien plants on selected ecosystem services (surface water runoff, ground water recharge, livestock production and biodiversity) in

Table 17.3 Numbers of of threatened taxa found in South Africa that have formal IUCN Red list assessments and where alien species are indicated as a threatening process[a]

Threat category	Taxa	Number of assessed species	Proportion (%) of species threatened by alien species
Critically endangered	Freshwater Fishes	7	100
	Amphibians	6	67
	Reptiles	4	50
	Plants	632	40
	Butterflies	20	40
	Mammals	5	20
	Birds	13	15
	Dragonflies	1	0
	All taxa combined	688	40
Endangered	Amphibians	9	100
	Freshwater Fishes	24	92
	Dragonflies	5	80
	Plants	874	62
	Butterflies	30	57
	Reptiles	7	29
	Mammals	20	25
	Birds	38	21
	All taxa combined	1007	60
Vulnerable	Amphibians	1	100
	Freshwater Fishes	11	73
	Plants	1516	50
	Reptiles	12	42
	Dragonflies	14	29
	Butterflies	23	26
	Mammals	31	13
	Birds	33	12
	All taxa combined	1641	48

[a]Threatened taxa are species that were assessed as experiencing the highest extinction risk (Vulnerable (VU), Endangered (EN), and Critically endangered (CR). Data sources: Child et al. (2015), Taylor et al. (2015), IUCN (2018), SANBI (2019)

five terrestrial biomes (Savanna, Fynbos, Grasslands, Succulent Karoo and Nama Karoo) in South Africa. With the exception of the fynbos, the current invasions had no measurable impact on biodiversity intactness (an estimate of impact of land-use changes on populations of various taxa such as plants, mammals, birds, reptiles and amphibians in a particular area, see Scholes and Biggs 2005) at a landscape scale. While the current impacts of alien plants were relatively low, the future impacts were predicted to be very high. In addition, while the errors in these estimates are likely to be substantial, the predicted impacts were sufficiently large to suggest that there is cause for serious concern. De Lange and van Wilgen (2010) used the above estimates of intactness to estimate the economic value of ecosystem services based on biodiversity. It was estimated that the reduction in value of selected ecosystem services due to invasive alien plants was the highest for fynbos, but still substantial for others like savanna, thicket, grassland, succulent karoo and Nama karoo. Overall, terrestrial ecosystems in South Africa would deliver biodiversity-based ecosystem services valued at ZAR 22.1 billion per annum if no invasions were present. The estimated value of the annual flow of these services was reduced by 2% (ZAR 428 million) each year due to alien plant invasions at current levels; under a scenario where alien plants are allowed to invade all available habitat, these losses were estimated to increase to more than 50% (ZAR 12.9 billion) annually. Other studies have also estimated the total value of ecosystem services in South Africa (Anderson et al. 2017; Turpie et al. 2017). Anderson et al. (2017) estimated this value to be about ZAR 8 trillion per year—this is nearly double that of South Africa's gross domestic product of ZAR 4.7 trillion for the same period. Turpie et al. (2017) estimated the value of ecosystem services provided by terrestrial, freshwater and estuarine ecosystems to be at ZAR 245 billion annually. The differences in the estimates between these assessments reflect methodological differences and the general challenges associated with attempts to monetise the values of biodiversity. Nevertheless, they highlight that ecosystem services make a substantial contribution to the economy.

17.3 Synthesis

The issue of quantifying the impacts of alien species on biodiversity remains a major challenge, both globally and in South Africa. For the majority of species found in South Africa, there are no studies documenting impacts, and there has been no formal assessment of impacts at a national scale. Evidence-based impact assessments are needed to support calls for management interventions. For example, in South Africa 556 taxa are listed as invasive, and landowners have an obligation to manage them (van Wilgen et al. 2020a, Chap. 1, Box 1.2). However, the regulations should arguably focus on priority species because not all of the listed species are necessarily harmful to the extent that would justify management especially when the current capacity to manage and to regulate them is limited (Zengeya et al. 2017). The use of expert opinion and or formal assessments such as EICAT could help to identify and priotise those species that should be targeted for management.

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