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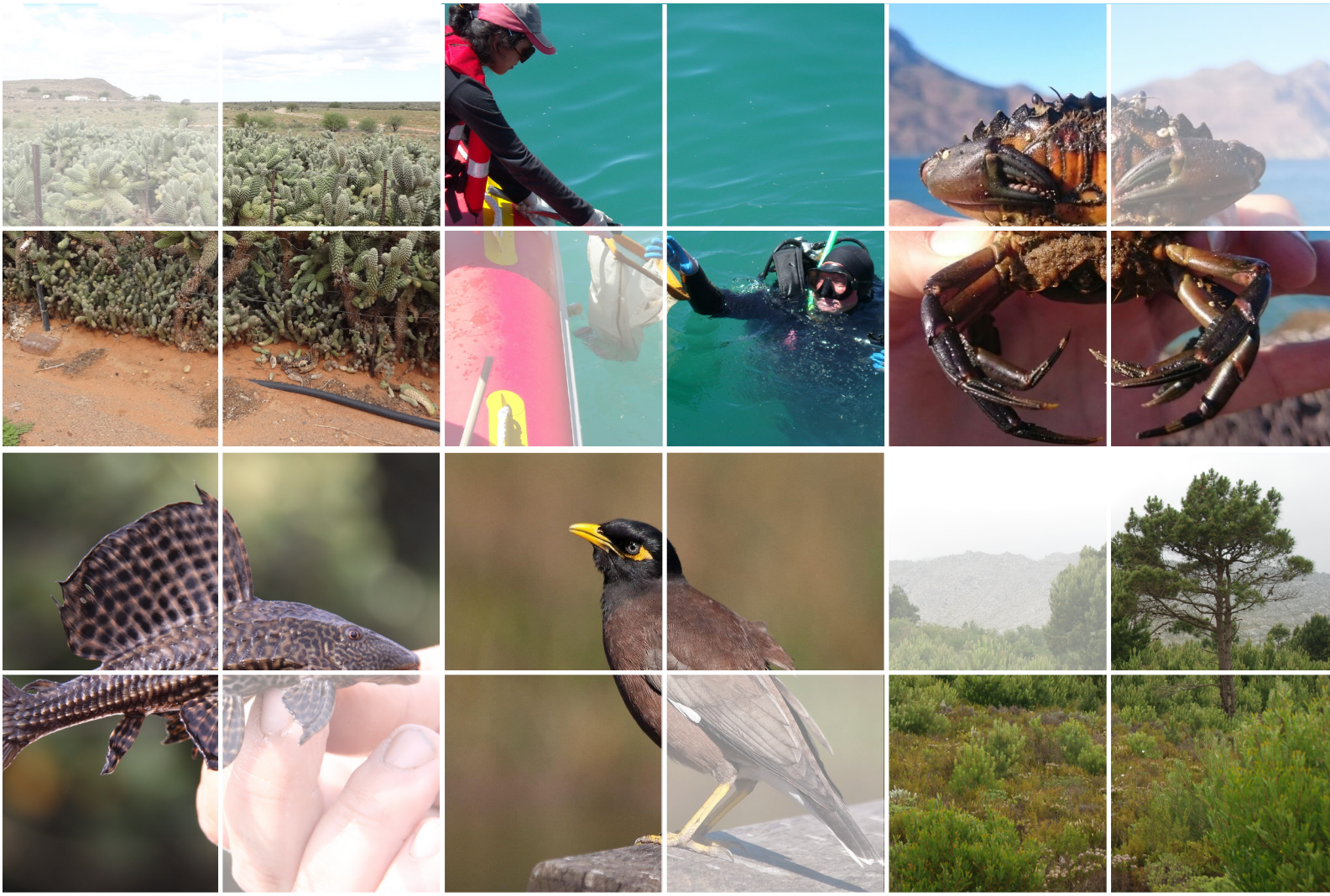
THE STATUS OF BIOLOGICAL INVASIONS AND THEIR MANAGEMENT IN SOUTH AFRICA



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THE STATUS OF BIOLOGICAL INVASIONS AND THEIR MANAGEMENT IN SOUTH AFRICA

SANBI
Biodiversity for Life

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Cover photographs:

Top left – boxing glove cactus (*Cylindropuntia fulgida* var. *mamillata*) - T. Xivuri
Top middle – diver team surveying harbours for marine alien species in Saldanha Bay - T. Robinson
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Bottom left – vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*) - R. Karsing
Bottom middle – Common myna (*Acridotheres tristis*) - R. Taylor
Bottom right – pine trees (*Pinus* species) - B. van Wilgen

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INDEPENDENCE OF THE STATUS REPORT

This status report constitutes an independent assessment of the status of biological invasions and their management in South Africa. The report is intended to inform the development and ongoing adaptation of appropriate policies and control measures, both to reduce the negative impacts of alien species on ecosystems, the economy, and people, and to retain any benefits of invasive species where possible and desirable. The compilation of the report was overseen by employees of the South African National Biodiversity Institute (SANBI) and the DSI-NRF Centre of Excellence for Invasion Biology (CIB). Inputs (including data, peer-reviewed papers, and unpublished reports) were also obtained from researchers and managers from diverse institutions across South Africa. Funding for the compilation of the report was obtained through the National Department of Forestry, Fisheries, and the Environment (DFFtE) as part of SANBI's Medium Term Expenditure Framework. In order to address any potential conflicts of interest, and to ensure independence of the report, the following steps were taken:

- Drafts of the status report were widely circulated to contributing authors and other stakeholders, who were invited to submit comments, concerns or additional information, with two dedicated rounds of review in 2019 and 2020;
- A close to final version of the report was also reviewed in depth by two South African and one international expert on biological invasions;
- Comments and concerns raised were captured in a database, along with the drafting team's responses to these comments and concerns. This database is available on request; and
- A Reference and Advisory Committee (RAC) oversaw the process taken to compile and review the report, as well as the drafting team's response to the comments and concerns raised by stakeholders, with a view to strengthening the process if necessary for future reports. The RAC was chaired by an expert on assessments from the University of the Witwatersrand, South Africa.

pines invading fynbos - B. van Wilgen

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SANBI Acting Chief Executive Officer:
Ms Carmel Mbizvo

PREFACE

The value of biosecurity to South Africa and the threat of biological invasions have never been clearer. Biological invasions are an ongoing threat to South Africa's biodiversity and ecosystem integrity, and to society through impacts on people's livelihoods and their health (including SARS-CoV-2 the invasive organism behind the Covid-19 pandemic). The polyphagous shot hole borer is sweeping across our country killing the trees in our gardens and on our streets, and imperiling agriculture. Invasive plants have exacerbated the droughts in Cape Town, the wildfires in Knysna, and the floods in KwaZulu-Natal. Invasive plants reduce the capacity of our natural rangelands to support livestock production, thereby threatening rural livelihoods and food production.

The South African government has implemented legislation to deal with biological invasions, investing over 1 billion ZAR per year to protect our natural assets from their impacts. To assist with these efforts, the South African National Biodiversity Institute (SANBI) has been mandated to report on the status of biological invasions and the effectiveness of their management in South Africa. This second report represents an important step towards the production of a dashboard where policy makers and managers can evaluate the status of biological invasions as they are playing out, and adapt their management accordingly.

Although some successes in the management of biological invasions have been achieved, current efforts would be greatly improved by the adoption of a national policy and strategy for managing biological invasions, project-level planning for prevention and management, formal programmes to monitor the effectiveness of interventions, and enhanced spatially explicit data. This report rightly highlights these needs.

This is an important, but deeply worrying, time to be working on biological invasions. SANBI occupies a unique position at the interface of science and policy, where it is able to generate and harness knowledge on biological invasions to provide evidence for decision-making.

This status report, published by SANBI together with the DSI-NRF Centre of Excellence for Invasion Biology, and with the assistance from authors at institutions across the country, is a significant contribution to policy, management, and research in the field, especially when there are very few reports globally that give such a comprehensive coverage of this field at a national level.

I would like to extend my gratitude to the Honourable Minister of Forestry, Fisheries, and the Environment, Ms. Barbara Creecy, together with her team, for their confidence in and support given to SANBI to carry out this work. I am grateful to the SANBI Board Chairperson, Ms. Beryl Ferguson, and the entire Board, for the vision and support they provide to staff working on these key national documents. Thanks to our partners in the biodiversity sector for providing data and information, and for constructive comments on this huge task. Lastly a heartfelt thanks to the report author team with guidance from the Reference and Advisory Committee, for their drive and commitment to the achievement of our mandate.

LIST OF ACRONYMS[1]

ASRARP	Alien Species Risk Analysis Review Panel
A&IS	Alien and Invasive Species (as referred to either in the regulations or the regulatory lists published under the auspices of the National Environmental Management: Biodiversity Act)
CBD	Convention on Biological Diversity of the United Nations
CIB	Department of Science and Innovation-National Research Foundation Centre of Excellence for Invasion Biology
DAFF	Department of Agriculture, Forestry and Fisheries (now split between DALRRD and DFFtE)
DALRRD	Department of Agriculture, Land Reform and Rural Development
DEA	Department of Environmental Affairs (now part of DFFtE)
DFFtE	Department of Forestry, Fisheries, and the Environment
EICAT	Environmental Impact Classification for Alien Taxa
HiP	Hluhluwe iMfolozi Park
IPPC	International Plant Protection Convention
IUCN	International Union for Conservation of Nature
NEM:BA	National Environmental Management: Biodiversity Act (Act No. 10 of 2004)
NIAPS	National Invasive Alien Plant Survey
NRM	Natural Resource Management (a division of the DFFtE)
PEI	Prince Edward Islands
PSHB	Polyphagous shot hole borer (*Euwallacea fornicatus*), also referred to as the invasive shot hole borer
qdgc	quarter-degree grid cell
RAC	Reference and Advisory Committee (of this second status report)
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SAPIA	Southern African Plant Invaders Atlas
SEICAT	Socio-Economic Impact Classification of Alien Taxa
SUSPECT	Species Under Surveillance for Possible Eradication or Containment Targeting
WfW	Working for Water
ZAR	South African Rands

[1]These acronyms are used either in this second report or in the supplementary material to the second report. For editorial conventions see Supplementary Material section S1.1.

GLOSSARY[1]

- **Abundance (cf. distribution, extent):** a measure of the number of individuals, coverage or biomass of an organism in a specified site.
- **Adaptive management:** a structured, iterative process that includes the setting of goals, regular monitoring of progress towards the achievement of those goals, and, based on the findings of the monitoring, the adaptation of management to improve its effectiveness or a revision of the goals. Adaptive management is useful where the outputs and outcomes of management are uncertain, and where an approach of learning-by-doing can reduce uncertainty over time.
- **Alien species (cf. extralimital, native species):** a species that is present in a site outside its natural range as a result of human action that has enabled it to overcome biogeographic barriers.
- **Assessment:** a critical evaluation of information.
- **Benefit: cost ratio:** see Returns on investment.
- **Biodiversity:** the variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.
- **Biological invasions:** the phenomenon of, and suite of processes that are involved in determining, the transport of organisms to sites outside their native range by human activities and the fate of the organisms in their new ranges.
- **Biological control (syn. biocontrol):** the use of specimens of one species for the purpose of preying on, parasitizing on, damaging, killing, suppressing or controlling a specimen of another species.
- **Biocontrol:** see Biological control.
- **Biome:** a large naturally occurring community of plants and animals that have common characteristics in similar physical environments, e.g. desert or forest.
- **Biosecurity:** measures that are taken to stop the introduction or dispersal of organisms harmful to human, animal or plant life.
- **Contested species:** alien species for which there is dispute about the appropriate (if any) regulatory listing. Also referred to as conflict-generating species. Such species have in some cases been listed as category 2 under the NEM:BA A&IS Regulations, whereby a permit can be issued to stakeholders to conduct otherwise illegal activities with the listed alien species. The contestation may thereby be resolved.
- **Compliance:** the action or fact of complying with instructions, in this second report such instructions primarily refer to the provisions of NEM:BA.

[1] These definitions are based on those in the first report, Richardson et al. (2011), Wilson et al. (2017), and van Wilgen et al. (2020a) with consideration of definitions given in relevant South African and international legislation, specifically the NEM:BA, its A&IS Regulations, and the CBD (https://www.cbd.int/invasive/terms.shtml). These cover terms used in this second report and in the supplementary material to the second report. For editorial conventions see Supplementary Material section S1.1.

- **Compliance notice (also pre-compliance notice):** an official document served by an environmental management inspector on a person when there are reasonable grounds for believing that that person has not complied with a provision of the law or with a term or condition of a permit, authorisation or other instrument issued in terms of such law. A pre-compliance notice is a written notice of intention to issue a compliance notice, which precedes the issuing of a compliance notice and invites the person to whom it has been issued to make representations to the environmental management inspector.

- **Containment:** the goal of preventing or reducing the spread of invasive species.

- **Contaminant:** the accidental introduction of an alien species with an intentionally transported commodity with which the organism has a specific, natural association.

- **Control:** any action taken to prevent the recurrence, re-establishment, re-growth, multiplication, propagation, regeneration or spreading of an alien species.

- **Conviction:** a verdict of guilty issued by a competent court following the prosecution of a person suspected of having committed a criminal offence.

- **Corridor:** the natural spread of an alien species into a new region through human-constructed transport infrastructure that connects previously unconnected regions, and in the absence of which dispersal would not have been possible.

- **Directive (also pre-directive):** an official document served by an environmental management inspector on a person when such person is: a) a permit holder who is suspected of not complying with the conditions under which a permit has been issued or not taking all the required steps to prevent or minimise harm to biodiversity by the alien species to which the permit relates; or b) a landowner who is suspected of not fulfilling their duty of care in relation to listed alien species on their land. A directive directs a person to take steps to remedy harm caused to biodiversity caused by such person's non-compliance or failure to fulfil the landowner's duty of care. A pre-directive is a written notice of intention to issue a directive, which precedes the issuing of a directive and invites the person to whom it is issued to make representations to the environmental management inspector.

- **Dispersal (syn. spread):** movement of organisms within a defined site that is facilitated either intentionally or accidentally by humans, or that occurs naturally.

- **Distribution:** the extent and abundance of a species over a given site.

- **Eradication:** the complete removal of all individuals and propagules of a population of an alien species from a particular site to which there is a negligible likelihood of reinvasion.

- **Escape (cf. release):** the spread of an alien species that was intentionally introduced and kept in captivity or cultivation to sites outside of captivity or cultivation; includes both natural spread and the accidental or intentional illegal human-mediated dispersal of live organisms from the site of captivity or cultivation.

- **Established:** see Naturalised.

- **Extent (cf. abundance, distribution):** the broad-scale area over which an organism occurs. The spatial scale over which extent is measured needs to be specified. The occupancy of sites at a fine-spatial scale is often equivalent to the abundance.

- **Extirpation (cf. eradication):** the result of a control operation whereby all individuals in a population are removed. Other populations might be close by or pathways of introduction and dispersal are still operating such that the probability of re-invasion is probable or not known.

- **Extralimital (cf. alien species, native species):** a native species that has been introduced by humans to a part of South Africa that is outside of the species' native distribution range. It does not include native species that have extended their distribution by natural dispersal.

- **Impact:** the effect of an alien species on the physical, chemical, and biological environment. It can include both negative and positive effects.

- **Incursion:** an isolated population of a pest, weed or alien species, that usually has a limited spatial extent and has been recently detected at a site. The management of incursions is referred to as incursion response.

- **Indicator:** a set of measurements that give specific information about the state of something.

- **Indigenous species:** see Native species.

- **Interventions:** the full variety of actions taken in response to biological invasions, including direct actions, i.e. control, and indirect actions like monitoring, regulation, and research.

- **Introduced:** see Introduction.

- **Introduction:** the movement of an alien species (either accidentally, intentionally and legally or intentionally and illegally) by human activity to a region outside its native range. Introductions can also refer to species which were introduced to one country by humans and spread naturally to neighbouring countries. In the context of introductions, the term 'accidental' is preferred to the synonymous term 'unintentional'.

- **Invasion:** see Biological invasions.

- **Invasion debt:** the potential increase in biological invasions at a site over a particular time frame in the absence of any interventions (Rouget et al. 2016). It is composed of the number of new species that will be introduced (introduction debt), the number of species that will become invasive (species-based invasion debt), the increase in area affected by invasions (area-based invasion debt), and the increase in the negative impacts caused by introduced species (impact-based invasion debt).

- **Invasive alien species:** see Invasive species.

- **Invasive species:** alien species that sustain self-replacing populations over several life cycles, produce reproductive offspring, often in very large numbers at considerable distances from the parent and/or site of introduction, and have the potential to spread over long distances.

- **Invasiveness:** the features of an alien organism, such as their life-history traits and modes of reproduction, that define their capacity to become an invasive species.

- **Listed alien species:** species which are listed under the NEM:BA A&IS Regulations either as 'listed invasive species' (which are intended to only include alien species that are present in South Africa) or 'prohibited alien species' (which are intended to only be species that are absent from South Africa).

- **Monitoring:** a systematic process of collecting and analysing information to track progress towards reaching stated goals that facilitates the assessment of the efficacy of interventions.

- **Native species (syn. indigenous species, cf. alien species, extralimital):** species that are found within their natural range where they have evolved without human intervention (intentional or accidental). Also includes species that have expanded their range as a result of human modification of the environment that does not directly impact dispersal (e.g. populations are still considered native if they result from an increase in range as a result of watered gardens, but are considered alien if they result from an increase in range as a result of spread along human-created corridors linking previously separate biogeographic regions).

- **Naturalised (syn. established):** alien species that sustain self-replacing populations for several life cycles or over a given period of time without direct intervention by people or despite human intervention.

- **Natural dispersal:** the dispersal of an alien species through natural spread from a region where it was previously introduced through human assistance or action to another region where it is not native.

- **Pathway:** a broadly defined term that refers to the combination of processes and opportunities that result in the movement of alien species from one place to another.

- **Permit:** an official document issued in terms of Chapter 7 of National Environmental Management: Biodiversity Act, 2004 (Act no. 10 of 2004).

- **Pest:** an organism that causes negative impacts. The affected sector might be specified, so an agricultural pest will impact negatively on agricultural production. Pests can be alien or native species, and are usually taken to refer to animals, with pest plants often rather referred to as weeds and pest fungi or microbes referred to as diseases.

- **Policy:** a high-level overall plan, adopted by the Executive Authority, for achieving identified outcomes through specified methods or principles that guide decision-making. A policy on biological invasions would be a high-level plan which identifies goals concerning biological invasions in South Africa and identifies the interventions that should be used to achieve those goals.

- **Pre-compliance notice:** see Compliance notice.

- **Pre-directive:** see Directive.

- **Propagule pressure:** a concept that encompasses variation in the quantity, quality, composition, and rate of supply of alien organisms resulting from the transport conditions and pathways between source and recipient regions.

- **Prosecution:** the institution and conducting of legal proceedings, usually by the State, against a person suspected of having committed a criminal offence.

- **Port of entry:** an official point of entry or departure from South Africa through which goods and people may enter or leave a country, for example a border post, airport or harbour.

- **Regulation:** 1) a law or rule made by the Executive Authority in terms of original legislation to regulate conduct (in this case the NEM:BA A&IS Regulations); 2) the act of regulating, i.e. to govern or direct according to rule, or to make regulations (authoritative rules) for certain conduct.

- **Regulatory lists/listing:** a list of alien species that are regulated under the NEM:BA A&IS Regulations. For a definition of the regulatory categories see Table 5.2 and Supplementary Material section S5.2.

- **Release (cf. escape):** the intentional introduction of an alien species to a site outside of captivity or cultivation. This refers to both legal and illegal introductions, however if a legally introduced alien species is illegally released outside of captivity or cultivation then it is classified as an escape.

- **Returns on investment:** the amount of value that is gained as a result of a particular amount spent on an intervention. This can be calculated as a benefit: cost ratio whereby each rand spent (the cost) is set against the amount of rands gained (benefit). An intervention is technically cost-effective if the benefit: cost ratio is greater than one, although more generally cost effectiveness is about maximising the ratio.

- **Risk:** the likelihood and consequence of an event, in this context the event is a biological invasion.

- **Risk analysis:** the process of identifying and assessing the likelihood and consequence of an event, as well as considerations as to how to manage and communicate the risk (see Figure S5.1).

- **Risk assessment:** a component of risk analysis that focuses on evaluating the likelihood and consequence of an event taking place. In this context, an event is the likelihood of an alien species becoming an invasive species and the negative impacts that would result.

- **Site:** a defined spatial area, for example a protected area (as defined by the National Environmental Management: Protected Areas Act, 2003), or an administrative unit (with national and provincial administrative boundaries as defined by the Constitution of the Republic of South Africa, 1996).

- **Spread:** see Dispersal

- **Strategy:** a high-level plan for achieving management goals in a specific time frame under conditions of uncertainty.

- **Stowaway:** the accidental introduction of an alien species attached to or within a transport vector or their associated equipment and media. The organism is transported by chance, and there is no specific, natural association with the vector.

- **Taxon (plural taxa):** a group of organisms that all share particular properties (usually evolutionary history). The grouping can be below, at or above the species level.

- **Threat:** the negative impacts that may occur if an event happens (cf. risk where the likelihood is explicit). In this context this refers to the negative impacts resulting from a component of the invasion debt being realised.

- **Unaided dispersal:** see Natural dispersal.

- **Unregulated introduction:** an introduction that was not approved by the relevant South African authorities under the relevant regulations prior to the date at which it arrived in the country.

- **Water Management Area:** an area established as a management unit in the National Water Resource Strategy within which a catchment management agency conducts the protection, use, development, conservation, management, and control of water resources.

SUMMARY

Biological invasions are a leading cause of global change and a major threat to South Africa's environment and socio-economic development. South Africa's response to this issue has been widespread and substantial. The government has spent in excess of 1 billion ZAR per year since 2013 on biosecurity and control projects and has listed 556 invasive taxa as requiring control. This report[1] assesses the status of biological invasions in the country and the effectiveness of South Africa's response.

It has been estimated that three new alien taxa arrive in South Africa accidentally or illegally every year. While this rate appears to have declined, such introductions continue to add to the number of invasive species in the country. Notable recent introductions include the tomato leaf miner (*Tuta absoluta*), which was detected in 2016 and is now a major agricultural pest, and the polyphagous shot hole borer (PSHB, *Euwallacea fornicatus*), an ambrosia beetle from Southeast Asia which was first detected in 2017 in Pietermaritzburg. The PSHB and its associated fungus have already killed thousands of trees in South Africa's streets, gardens, protected areas, and orchards, and threaten millions more. South Africa's ability to know where, when, and how interventions should be implemented to prevent new introductions has been improved by recent research that has clarified how the pet trade, the medicinal plant trade, contaminants of animal imports, and shipping function as introduction pathways. Effective protocols are increasingly being implemented to regulate intentional legal introductions of alien species and to ensure that the risks of such imports are minimised. However, there is insufficient capacity to prevent accidental or intentional illegal introductions of alien species. More work is needed to elucidate the role of many pathways in facilitating introductions and invasions. Increasing volumes of trade and travel, particularly within Africa, represent enormous opportunities for South Africa's economic development, but unless judicious biosecurity measures can be implemented, South Africa will continue to import (and export) invasive species. Similarly, the development of systems to track and understand how invasive species move and are moved around the country are needed for the spread to be effectively managed.

This report provides information on 1880 alien species known to occur in South Africa. At least a third of these species have escaped (or were deliberately released) from captivity or cultivation and have become invasive. The impacts of 215 invasive species have been formally assessed, and seven of these were found to cause major or massive negative environmental impacts, while one species was found to have major negative socio-economic impacts. Impact assessments are needed on the remaining species, but in many cases there is a lack of reliable data. Invasive trees use up 3–5% of South Africa's surface water runoff each year, exacerbating the effects of droughts. If there were no invasive trees in the City of Cape Town's catchment, 'Day Zero'[2] would have been delayed by 60 days during the peak of the water crisis in 2017. The destructive wildfires in Knysna in 2018 were exacerbated by plant invasions (15% more fuel was burnt in invaded areas than uninvaded areas, increasing the severity of fires and making containment measures ineffective). Invasive plants reduce the value of livestock production from natural rangelands by ZAR 340 million per year, and this will grow rapidly if invasions are not controlled. Biological invasions are the third-largest threat to South Africa`s biodiversity (after cultivation and land degradation), and are responsible for 25% of all biodiversity loss.

[1] This second report focuses on the status as of December 2019 and the trends since the first report (i.e. since December 2016) as mandated under the NEM:BA A&IS Regulations. The report is composed of chapters addressing the pathways of introduction and spread, the status of alien species and their impacts, the degree to which sites are invaded, and the effectiveness of interventions; and discusses trends in four head-line indicators (Table A.1) and 20 lower-level indicators (discussed at the end of each chapter). The report concludes with a chapter identifying key gaps that, if addressed, would improve the ability of South Africa to respond to the challenges posed by biological invasions and improve the returns on investment.

[2] 'Day Zero' was the day during Cape Town's water crisis of 2015–2018 that the City's dams would have run out of potable water.

Several initiatives have been highly effective in controlling invasions, and dramatic positive returns on investment have been reported for the utilisation of biological control to reduce problems with invasive plants (benefit:cost ratios from 8:1 to ~4000:1). However, the efficacy of most interventions is not routinely monitored. Improved data on the outputs of interventions, and a focus on outcome-orientated targets, would allow managers to adapt their plans, and policy-makers to revise regulations and strategies accordingly. There are encouraging signs that the NEM:BA A&IS Regulations promulgated in 2014 are beginning to become effective—the first successful prosecution was in 2019, and the process for granting permits is now well-established and functional (~40 per month). However, proposals to revise the regulatory lists in early 2018 were substantially delayed due to contested species, in particular trout. This has adversely affected the ability to revise the current regulatory lists (proposed changes listed in early 2018 came into effect in March 2021, and risk analyses on 25 listed alien species recommend that the listing of 12 of them should be changed).

Biological invasions continue to be a significant, pressing, and in many cases increasing threat to South Africa. These challenges can and are being addressed—government and public initiatives have, in some cases, reduced the impacts and threats posed and provided valuable returns on investment in terms of rural development and job creation. However, the effectiveness of current interventions could be vastly improved with the introduction of goal-oriented management plans, by monitoring outcomes in terms of those goals rather than inputs, by applying a flexible approach based on the principles of adaptive management, focussing on priority sites and species, and by improving implementation of best-practice control methods in the field.

European shore crab (*Carcinus maenas*) - S. Miza

Common starling (*Sturnus vulgaris*) - C. Griffiths

Table A.1. The status of biological invasions in South Africa at the end of 2019 as per the four headline indicators.

Head-line indicator	Trend (confidence)	Desired trend	Current status	Outlook
A. Rate of unregulated introduction of new species	↘ (Low)	↘	Between 2010 and 2019 approximately 3 new taxa were introduced per year either accidentally or intentionally but illegally. This was lower than the estimated rate during the previous decade (~ 5 per year).	Despite the apparent recent decline in introductions, opportunities for the introduction of alien species are expected to increase as the volume of trade and travel increases. Whether this results in the introduction of more invasive species will depend on the degree to which key pathways are identified and prioritised for management. Improvements to inspection, management, and the incursion response at border would strengthen South Africa's biosecurity.
B. Number of invasive species that have major impacts	Not assessed	↘	In the first report, 107 alien species were identified by experts as particularly damaging. A process is under way to formally assess all invasive species using the IUCN's EICAT scheme. So far 215 species have been assessed, and eight found to cause major to massive impacts (five fish, two grasses, and one mammal species). However in many cases there was a lack of reliable data.	The number of alien species recorded to have major or massive negative impacts will increase as more species are formally assessed. The formal assessment of the impact of alien species provides the rationale for regulation and management, can improve compliance and implementation of intervention measures, and assist to resolve conflicts. However, impact assessments are hampered by a lack of reliable data for most species. If this situation persists, regulations will continue to be vulnerable to legal challenges. It is very difficult to control invasive species with major impacts in a way that will reduce such impacts to moderate or minor, but this has arguably been achieved by biological control for over 30 invasive taxa. On-going investment in biological control will likely result in more such successes. If alien species that currently have moderate or minor impacts are prevented from increasing in abundance and extent to the point where they have major impacts or, where feasible, such species are eradicated from South Africa, then a significant return on investment will also be made.

→ no change; ↗ increase; ↘ decrease

Table A.1 The status of biological invasions in South Africa at the end of 2019 as per the four headline indicators. (Contd)

Head-line indicator	Trend (confidence)	Desired trend	Current status	Outlook
C. Extent of area that suffers major impacts from invasions	Not assessed	↘	Biological invasions continue to cause major impacts on both rural and urban communities by, amongst other things, reducing South Africa's water resources, degrading pastureland, and making fires more intense and more difficult to control. Biological invasions continue to contribute to biodiversity loss and ecosystem change.	If control efforts focus on priority sites (e.g. sites that provide water to Cape Town's dams) then there will be significant returns on investment. However, without agreement on priorities, there is a substantial risk that control could remain ineffective, and the area that suffers from major impacts will continue to grow. Estimates of the full magnitude of impacts require more accurate assessments of the extent of invasions. This, in turn, requires effective mapping of the areas invaded and monitoring of spread. Such monitoring is currently lacking, and without which effective prioritisation is not possible.
D. Level of success in managing invasions	→ (Low)	↗	Recent studies support the conclusions of the first report that: 1) biological control can be highly effective; and 2) improvements both in monitoring and control efficiency will be needed if invasions are to be effectively controlled. In several water bodies, alien fish species have been extirpated in a manner that allows for the recovery of native species. This is a major new success.	An assessment of the effectiveness of control measures remains challenging in the absence of any formal programmes that monitor outcomes. Should this situation continue, then whether the goals of control – to reduce the number, abundance, extent, and impact of invasions – are being achieved will remain unknown, management cannot be adaptive, and levels of success will remain low. If these issues are not urgently addressed, the impacts and costs of invasions will rise significantly.

→ no change; ↗ increase; ↘ decrease

swift woodlouse (*Porcellio laevis*) - C. Griffiths

Pacific oyster (*Magallana gigas*) - S. Miza

1

INTRODUCTION

Authors:

John R. Wilson

Tsungai A. Zengeya

wattles and pines invading fynbos - B. van Wilgen

1.1. The importance of biological invasions to South Africa

Biological invasions have had varied and significant impacts on all sectors of South African society. They are a major threat to socio-economic sustainability, they have exacerbated droughts, floods and wild-fires, and have caused significant losses in agriculture, pastoralism, and forestry. Biological invasions account for a quarter of all biodiversity loss in South Africa to date (van Wilgen et al. 2008). The South African government spends well over 1 billion ZAR per year on their management (Figure 5.1, see pg. 42). Given South Africa's rich and varied cultural and biological diversity, and the long history both of alien species introductions and of attempts to regulate, manage, and study them, South Africa is a global exemplar of the impacts of and potential responses to biological invasions (van Wilgen et al. 2020b). South Africa has taken a world-leading stance in controlling invasions specifically in terms of combining efforts at alien plant clearing with poverty alleviation, the use of classical biological control, and its innovative Alien and Invasive Species (A&IS) Regulations of 2014. One feature of the A&IS Regulations is the requirement for the South African National Biodiversity Institute (SANBI) to report, every three years, on the status of biological invasions and their management in South Africa.

1.2. The mandate, purpose, and structure of the status report

The mandate for the status report arises from section 11 of the A&IS Regulations of 2014 that were promulgated under the National Environmental Biodiversity Act (NEM:BA) (Act 10 of 2004):

(1) The Institute [i.e. the South African National Biodiversity Institute (SANBI)] or a body designated by the Institute must, for the purpose of reporting as contemplated in section 11(1)(a)(iii) of the Act, submit a report on the status of listed invasive species to the Minister within three years of the date on which these regulations come into effect, and at least every three years thereafter [the regulations came into effect on 1 October 2014].

(2) A report contemplated in sub-regulation (1) must contain a summary and assessment with:
  (a) the status of listed invasive species and other species that have been subjected to a risk assessment; and
  (b) the effectiveness of these regulations and control measures based inter alia on information from:
    (i) notifications received from owners of land regarding listed invasive species occurring on their land;
    (ii) permits issued for listed invasive species;
    (iii) Invasive Species Monitoring, Control and Eradication Plans[1] received from organs of state and management authorities of protected areas; and
    (iv) emergency interventions and enforcement actions involving listed invasive species issued by the Minister.

(3) In preparing a report contemplated in sub-regulation (1), the Institute must carry out the research and monitoring necessary to identify the matters contemplated in sub-regulation (2).

More broadly, however, the status report aims to strengthen the links between basic research, policy, and management by detailing the current status and providing support to decision makers that is policy relevant but not policy prescriptive (see Figure 1.1 in the first report).

The first report – produced in 2017 and released in 2018 – was structured around an indicator framework that explicitly considers biological invasions in terms of pathways, species, sites, and interventions (separated into inputs, outputs and outcomes, see Figure 1.3). This indicator framework provides a transparent and objective method for the establishment of a baseline against which to assess trends, set realistic management targets, and for highlighting important gaps in the evidence needed to support decision-making. This second report is similarly structured around this indicator framework with the intention of refining and updating values in the first report. The second report focuses on the status as of the end of 2019, noting trends over the past three years for the four headline indicators (Table A.1) and for 20 indicators tracking pathways, species, sites, and interventions (sections 2.5, 3.5, 4.4, and 5.10). Data are more systematically curated with sources clearly indicated. Trends can be more easily tracked, but some baselines had to be revised. See Appendix 1 for details on sources of data, descriptions, levels of confidence, and indicators that were informed by such data. The longer-term plan is to develop an on-line resource with indicator values updated as soon as new information becomes available (i.e. a dashboard), a short status report summarising trends every three years as per the current regulatory requirement, and a comprehensive report every decade or so (see Supplementary Material section S1.2).

Each chapter starts with a summary of the state of the indicators, and then discusses key changes in the indicators. Much of the detail underlying the production of this second report is contained within the appendices and supplementary material available on-line (links to them are on the last page of this report).

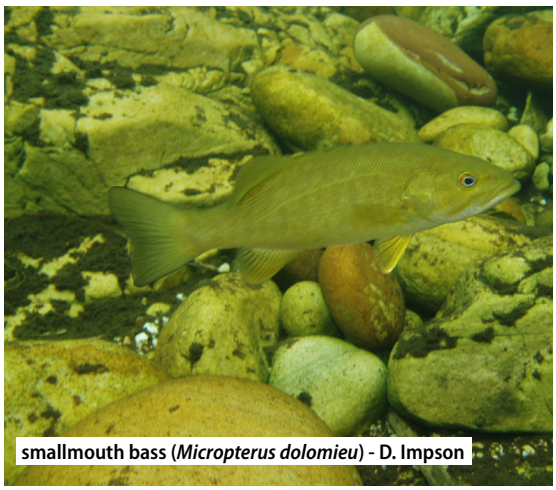
[1] The 'Invasive Species Monitoring, Control and Eradication Plans' referred to in the regulations are intended to be drawn up for specific sites. For the purposes of this second report these are referred to as site management plans. This is distinct from species management programmes which focus on controlling particular species often across the whole of South Africa.

1.3. Process for the compilation of the status report

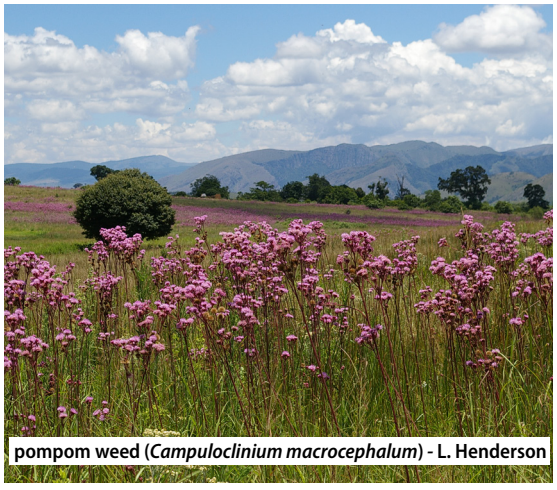
The process for compiling the second report was broadly similar to that for compiling the first report. A status report drafting team was appointed, and a Reference and Advisory Committee (RAC) established to oversee the process. The writing team drafted various versions of the second report in consultation both with the RAC and stakeholders (Figure 1.1). Each step is described in detail below.

Appoint status report drafting team: The SANBI-CIB drafting team is similar to that of the first report, but there has been a shift in emphasis from a team headed up by the CIB, to a team led by SANBI with the CIB providing assistance and advice. A notable change was the inclusion of a legal specialist (based at SANBI) on the drafting team.

Appoint the RAC: the RAC was established to provide oversight of the process and review documents produced. The first meeting of the RAC was on 31 May 2019. At the request of the RAC, a zero-order draft was produced and sent to the RAC on 1 July 2019, and subsequently approved. The RAC similarly reviewed a version of the first order draft before it went out for public comment, and reviewed the second order draft before the final report was produced. The Chair of the RAC also reviewed how the comments received during the stakeholder and expert review processes were addressed, i.e. acted in a review editor role. Finally, the RAC intends to provide advice both in terms of the public release of the second report, and on reflecting on the process.



smallmouth bass (*Micropterus dolomieu*) - D. Impson



pompom weed (*Campuloclinium macrocephalum*) - L. Henderson

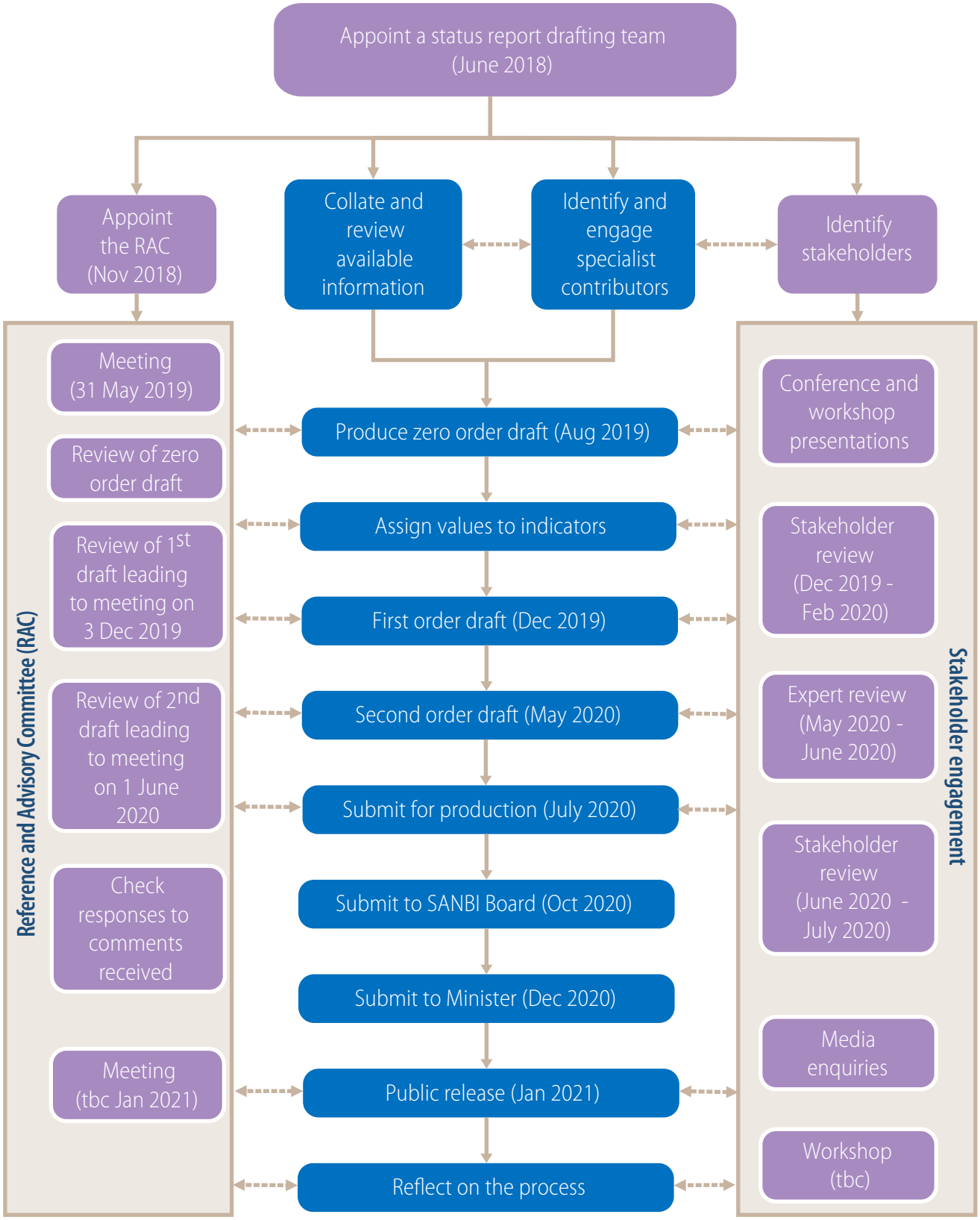


Figure 1.1. Key steps in the production of this second report: 'the Status of Biological Invasions and their Management in South Africa in 2019'. The Minister is the South African Minister of Forestry, Fisheries, and the Environment; and SANBI is the South African National Biodiversity Institute.

Collate and review available information: Information was incorporated into the second report from four main sources: 1) published literature; 2) an open-access book on biological invasions in South Africa (van Wilgen et al. 2020a) (Figure 1.2); 3) the national assessment on the status of South Africa's ecosystems and biodiversity (SANBI 2019); and 4) unpublished information provided by stakeholders. Information contained in the second report is based on data available to the second report writing team as of the end of December 2019 (Box 1.1).

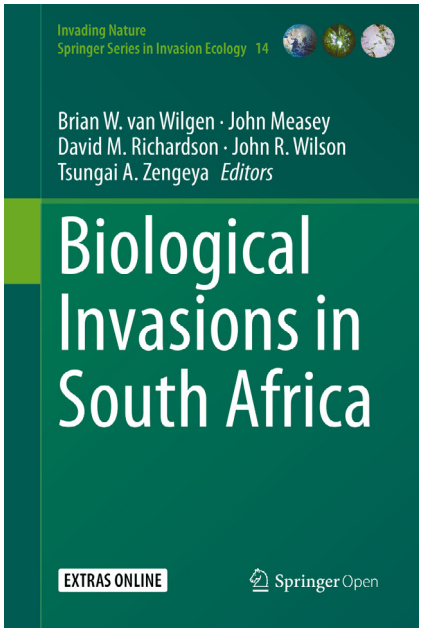


Figure 1.2. The, recent book on biological invasions in South Africa that informed the second report (van Wilgen et al. 2020a) available at http://dx.doi.org/10.1007/978-3-030-32394-3. See Table S6.2 for a summary of the key findings of relevance to this second report.

Stakeholder engagement: Stakeholder engagement was an on-going process linked to the other activities. Initially the drafting team engaged directly with specialist contributors to obtain information that was not readily accessible and identified stakeholders to be contacted for input and review. Contributors were identified within academic institutions; research institutes and science councils; and in national, provincial, and local government departments. Contributions from the identified stakeholders were in the form of data provision and commenting on drafts.

Specific engagements included consultations with the DFFtE; the holding of a discussion session at the National Symposium on Biological Invasions on 16 May 2019 in Tulbagh 'Data requirements for the second status report'; and the presentation of preliminary findings at local scientific forums such as the National Symposium on Biological Invasions, the Biodiversity Planning Forum, the DFFtE research indaba, the South African Association of Botanists' Annual Meeting, the Congress of the Zoological Societies of southern Africa, as well as international forums, e.g. the 15th International Conference on Ecology and Management of Alien Plant invasions, Prague, Czech Republic, 9 –13 September 2019. Feedback received was considered as to whether it could influence this second report. A formal process for tracking such feedback will be established for future reports in line with the current process of tracking and responding to comments received during stakeholder and expert review.

Produce and review of draft reports: A proposed first order draft was completed in November 2019 and sent to the RAC for internal review. This was then discussed at a meeting of the RAC on 3 December, revised, and sent out for public review by experts and stakeholders for a period of about 8 weeks (18 December 2019 –17 February 2020). The request for review was submitted to a South African list server on biological invasions (invasives@wordlink.co.za), heads of relevant national and provincial government departments, heads of relevant academic departments and institutions, and professional societies and forums (including the Royal Society of South Africa; the Akademie vir Wetenskap en Kuns; the Zoological, Entomological, and Botanical Societies; Birdlife South Africa; and the Wildlife and Environment Society of South Africa). A copy of the first order draft was attached to the formal notice and was available for download online (SANBI and CIB 2019; archived at http://dx.doi.org/10.5281/zenodo.3582036). The inputs and responses to the requests for review, were documented and are available for scrutiny from SANBI on request.

On 5 May 2020, the second order draft of the second report was produced and circulated to members of the RAC, two independent experts from South Africa, and one international expert for review (SANBI and CIB 2020; archived at http://dx.doi.org/10.5281/zenodo.3785048). Following discussion at the second meeting of the RAC on 1 June 2020, it was felt that the range of stakeholders who commented on the first order draft was rather limited (17 people), and it would be advisable to solicit a wider range of comments.

Therefore an additional round of stakeholder comments was set up (4 June – 6 July 2020), and the second order draft was circulated to a South African list server on biological invasions (invasives@wordlink.co.za), that consists of more than 465 public stakeholders interested in invasive species. Additional comments were received from 10 people.

Produce and release the final report: A complete version of the second report was sent in July 2020 to Nicole L. Meyer and to Harry's Printers Tshwane for layout, design, and printing, and then submitted to the SANBI Board in October 2020 for their consideration. After board approval, the SANBI CEO submitted the second report to the Minister of Forestry, Fisheries, and the Environment. At the same time a copy of the second report was submitted to the DFFtE and the DALRRD as the key receivers of the second report. This provided the departments with an opportunity to prepare for responding to media enquiries or public concerns raised by the second report. To maximise publicity and media uptake of the second report, the second report is intended to be released to the public in early January 2021 in time for the fresh news cycle of the year. The second report will also be referenced, and its Executive Summary included, in the South African Environment 2020 Report (SAE-2020) that will be published on the DFFtE state of environment website in April 2021 (http://soer.environment.gov.za/soer/).

Reflect on the process: After the public release of the second report the status report team will convene a meeting with key stakeholders (including members of the RAC) to reflect on the process used to compile the second report and to identify areas of improvement for subsequent reports.

1.4 Indicators used, updating the species list, and tracking change

This second report is structured around the 20 indicators and 4 high-level indicators outlined in Wilson et al. (2018) (Figure 1.3, see page 7), and adheres broadly to the published indicator factsheets[1]. These are very similar to those used in the first report (see Supplementary Material section S1.3 for details of the changes made). The technical details on scoring the indicators and the high-level indicators are available in the supplementary material and summarised in Table S2.6, sections S3.5–3.6, and Table S5.14).

[1]both the paper and the indicator factsheets and available free to download at https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.13251

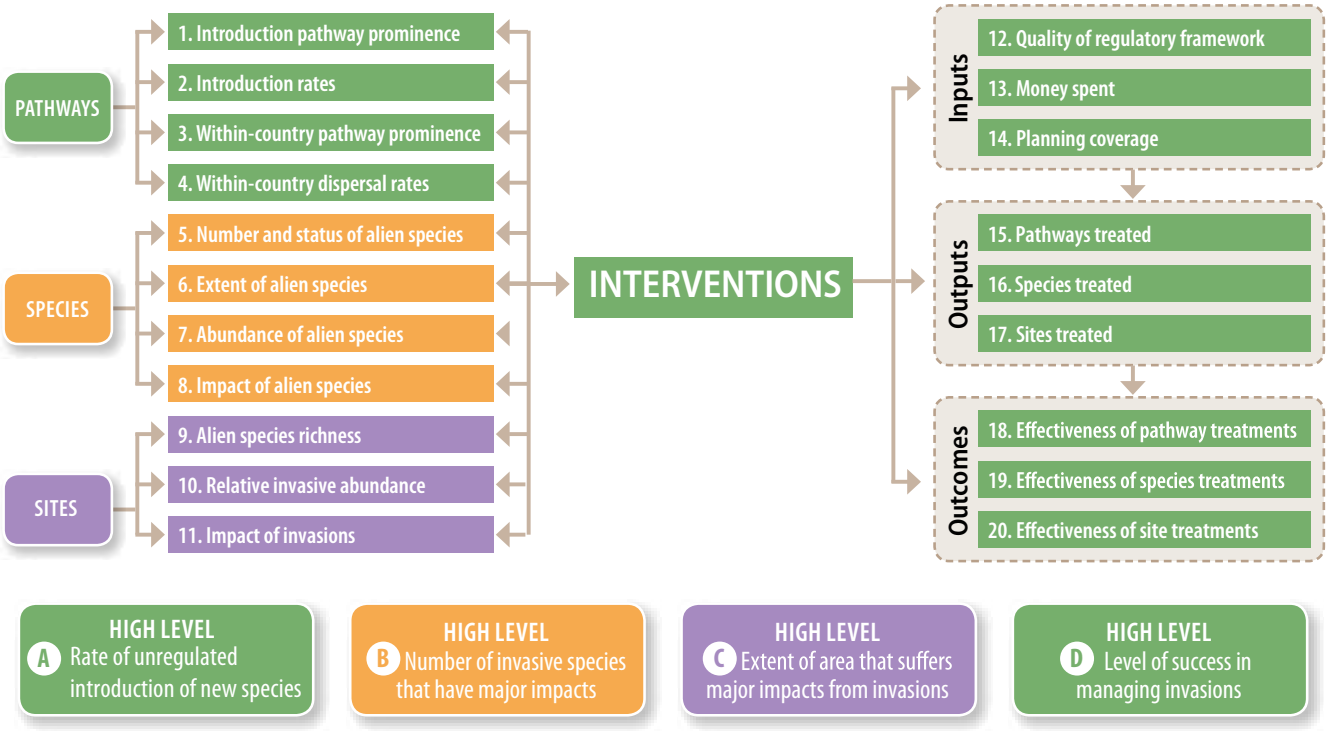


Figure 1.3. Indicators used in the second report (based on Wilson et al. 2018).

A key aim of the second report was to improve the curation of the data: in particular by adhering to the FAIR data principles (Wilkinson et al. 2016), and ensuring the data are tidy (Wickham 2014). In particular, it is now clearly stated why each taxon was included in the species list, where the data came from, and what level of confidence is associated with each record (see Supplementary Material section S1.4 and Appendix 2 for the species list). There is now also an explicit method for flagging species that are native to some parts of South Africa and alien to others. It is intended in future to list all alien taxa present in the country (i.e. including those known only from captivity or cultivation), but this has not yet been done systematically, and so the analyses presented tend to focus on invasive taxa rather than all aliens. Most of the indicators refer to species, and the regulations refer to species lists. However, in both cases this is not consistently applied. For sub-specific taxa that vary in their invasiveness or impacts and taxa that cannot be separated in practice at the species-level, it makes sense to manage and regulate at that level (Datta et al. 2020). Therefore, the species list used for this second report (Appendix 2) is, as per the NEM:BA A&IS Regulations, largely based on entries at the species level, but not entirely. A workflow was developed to track changes to the species list, with such changes logged in a dedicated file (Appendix 4).

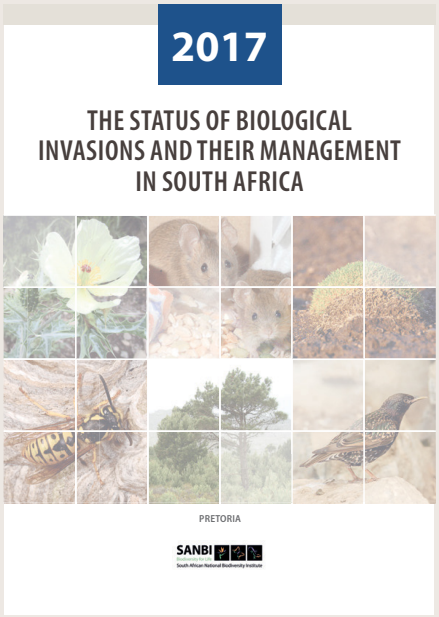
Another key aim of this second report was to start to document and track changes in indicator values and the underlying data. This second report broadly follows the scheme outlined in Table S1.1 to track and categorise changes in the underlying data (e.g. changes to taxonomy or sourcing datasets missed in the previous report) and how this would affect the baselines. Notably, the baselines proposed in the first report needed to be revised in some instances (e.g. due to errors in the original values). This means that it is not always appropriate to compare values between the reports, and in some cases the second report calculated the values that should have been in the first report. Changes over time from these revised baselines are presented and discussed in this second report, and differences in the calculation methods used between the first and second reports are noted in Supplementary Material section S1.4.

1.5. Aspects of biological invasions that are not covered

Given that the second report is an update, the aspects not covered in the second report are largely the same as those not covered in the first report (see Supplementary Material section S1.6). However, the degree to which knowledge and information gaps (identified as needing attention in the first report) have been addressed is discussed in Table S6.1.

Box 1.1

"Is this the 2019, 2020, or 2021 Report?"



The A&IS Regulations require a report every three years, but it takes time to compile, revise, and produce these reports. Therefore a cut-off date is needed, after which no new data are considered. In the first report, this cut-off was 31 December 2016. The first report was finalised and submitted to the (then) Department of Environmental Affairs during 2017 (i.e. three years after the promulgation of the A&IS Regulations in 2014, as required). However, the first report was only made publicly available in October 2018. Therefore, while the first report is based on data up to the end of 2016, the title indicates that it is the status in 2017, and the citation is for 2018 (SANBI and CIB 2018). To correct this (and make things more transparent), this second report is entitled 'The status of biological invasions and their management in South Africa in 2019', as it reports on the status up to the end of 2019, although it is due to be finalised in 2020 and released in January 2021.

2

PATHWAYS

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Costas Zachariades

goods sold in the medicinal plant trade - A. Burness

Key findings:

- Three new alien taxa arrived in South Africa either accidentally or intentionally, but illegally each year. While this rate appears to have declined, this is likely an underestimate and such introductions continue to add to the number of invasive species found in the country.

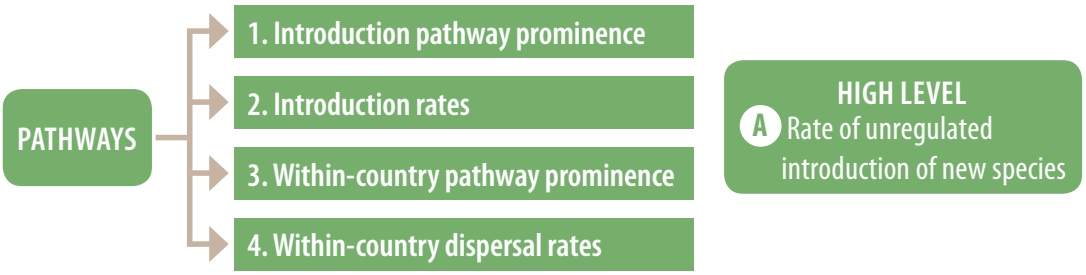
- Alien taxa continue to be introduced through a wide range of pathways, and during 2017–2019 new taxa were introduced accidentally through the timber trade, shipping, as contaminants on imported animals, and through natural dispersal from other African countries to which they were previously introduced. South Africa's ability to know where, when, and how alien taxa are being introduced, or are likely to be introduced, has been improved by recent research on the pet trade, medicinal plant trade, biofouling, and contaminants of animal imports.

- The movement of alien taxa between countries in Africa, in particular damaging agricultural pests, is a growing concern. For example, the tomato leaf miner (*Tuta absoluta*) was detected in 2016, and the fall armyworm (*Spodoptera frugiperda*) in 2017. Intra-African spread needs to be addressed in the context of proposed free-trade zones.

Key gap:

- There is insufficient information on how invasive species move and are moved around South Africa. A system to track within-country movement is required if South Africa is to manage the spread of invasive species.

Indicators covered in this chapter:



2.1. Introduction pathway prominence

Introduction pathway prominence considers the size of the pathways of introduction in terms of their socio-economic importance [in contrast, introduction rates (indicator 2) looks at whether alien organisms are being introduced along these pathways]. The pathway categorisation scheme used for all pathway indicators is that adopted by the Convention on Biological Diversity (CBD 2014), with proposed revisions by Harrower et al. (2018) [see Harrower et al. (2018) for details on how introductions are classified into the different pathways].

In most cases, introduction pathway prominence has not changed since the first report (39 of the 44 pathways; see Figure 2.1), but the number of fishing boats in South African waters has decreased by 40% and, therefore, so too has the prominence of the pathway related to stowaways on fishing equipment.

There has, however, been some significant research on pathways of introduction since the first report, facilitating more robust assessments for some pathways, and for others allowing introduction pathway prominence to be estimated for the first time. Recent research has shown that hundreds of invertebrate taxa are sold in the pet trade (195 tarantula species and 53 other invertebrates, but it is likely that many more are sold), although the role of the pet trade in new introductions versus within-country dispersal is unclear (see Nelufule 2018; Shivambu 2018). Based on these studies the prominence of the pet trade pathway is now scored as moderate (it was scored as minor in the first report). This increase in introduction pathway prominence is due to better knowledge. Whether there has been an actual change in the volume of trade is not known. One introduction pathway that had previously received little research attention is the traditional medicine trade. Hundreds of alien medicinal plant and fungal species (214 species, 101 as propagules) are imported into South Africa, often from multiple sources (Burness 2019; Byrne et al. 2017; Faulkner et al. 2020a). Some of these species (e.g. *Moringa oleifera*, *Nigella sativa* and *Zingiber officinale*) pose an invasion threat to the country as they are imported as viable propagules, have high propagule pressure, and history of invasion elsewhere in the world (Burness 2019).

The types of changes made to the data since the first report are shown in Table S2.2 and how these changes have influenced the indicator is shown in Figure S2.20, with details tracked in Appendix 3.

2.2. Introduction rates

Introduction rates consider the number of new alien taxa introduced through the pathways of introduction, and how this number has changed over time. The introduction pathway of most taxa (54%) introduced to South Africa is still not known. Of the alien taxa known to have been introduced to South Africa, most (15%) are plants that were introduced for horticulture and/or ornamental purposes. Many of the taxa that are known to have been accidentally introduced were introduced through shipping (5% of all introductions). Due to better data, it is clear that new alien taxa continue to be intentionally and accidentally introduced to South Africa, and there has been an increase in the number of taxa that are thought to have been introduced over all time, through 18 of the 44 pathways (Figure 2.1). During the 2017–2019 period new taxa are likely to have been introduced accidentally through the timber trade, shipping (hull fouling or the release of ballast water), as contaminants on imported animals, and through natural dispersal from other African countries where previously introduced.

In terms of legal intentional introductions, many alien taxa (157 taxa) have been released as biological control agents against invasive organisms such as invertebrates and plants, with four new taxa introduced to control alien plants during the 2017–2019 period (Table S5.10). Biological control is a highly regulated pathway and, as part of obtaining an import permit, these taxa are assessed and must be found unlikely to have important direct negative impacts. The introduction of biological control agents provides substantial benefits (see Chapter 5 for further details), and to date these introductions have caused no important negative impacts. Therefore, these introductions are not included in the estimate of the high-level indicator 'Rate of unregulated introduction of new species'. Besides those for biological control, no import permits were issued in the 2017–2019 period for specimens of taxa not previously recorded in the country or for which an import permit had not been previously issued (see Supplementary Material section S5.5 for details).

There has been an increase in the number of new alien taxa that are thought to have entered South Africa through natural dispersal from neighbouring countries where they had been previously introduced. Therefore, while many introductions are believed to be due to intercontinental human-mediated dispersal, it appears an increasing number of alien taxa are showing intra-African dispersal (Box 2.1).

The types of changes made to the data since the first report are shown in Table S2.3 and how these changes have influenced the indicator is shown in Table S2.4, with details tracked in Appendix 5.

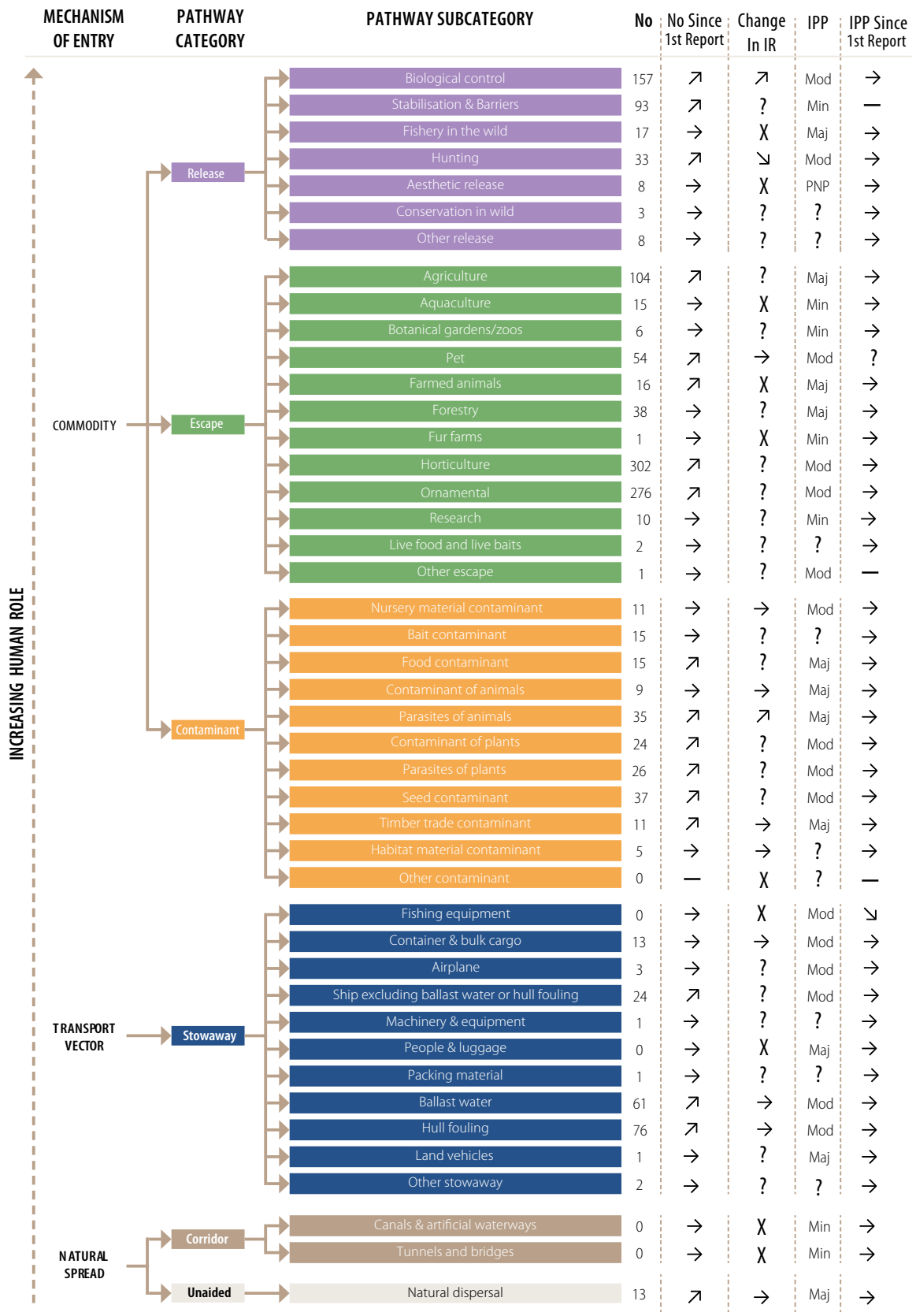


Figure 2.1. Current status of the pathways of introduction and changes to the pathways that have been recorded since the first report. No: number of taxa introduced; No since 1st report: change to the number of taxa introduced [↗ increase; → no change; — not applicable (new pathway)]; Change in IR: change in introduction rate relative to last decade [↗increase; ↘decrease; →minimal change; X no introductions; ? not known]; IPP: introduction pathway prominence [Min: minor; Mod: moderate; Maj: major; PNP: pathway not present; ? not known]; IPP since 1st report: change to introduction pathway prominence since the first report [↗ increase; ↘ decrease; → no change; ? not known; — not applicable (first estimate or new pathway)].

For nine of the pathways for which estimates were possible there have been minimal changes to the rate at which new alien taxa have been introduced in this decade (2010–2019) in comparison to the previous decade (Figure 2.1). There were fewer introductions for hunting in the current decade in comparison to the previous decade, which could be due to increasing anti-hunting sentiment (Taylor et al. 2015). There appears to have been an increase in the rate at which parasites of imported animals have been introduced. However, there has been a decline, since the previous decade, in live animal imports (Figure S2.8), and so this trend is likely due to recent, directed research interest in parasites of freshwater fish (Weyl et al. 2020) or due to time lags between introduction and detection. Date of introduction is often known for taxa that are intentionally introduced, but for taxa that are accidentally introduced, there is often a significant time delay between when the taxon is introduced and when it is detected. Over the current decade, 57 new alien taxa are known to have been introduced to South Africa, fewer than the 67 taxa recorded for the previous decade (Figure 2.2A). Notable introductions in the last decade include the polyphagous shot hole borer (*Euwallacea fornicatus*), tomato leaf miner (*Tuta absoluta*), and fall armyworm (*Spodoptera frugiperda*).

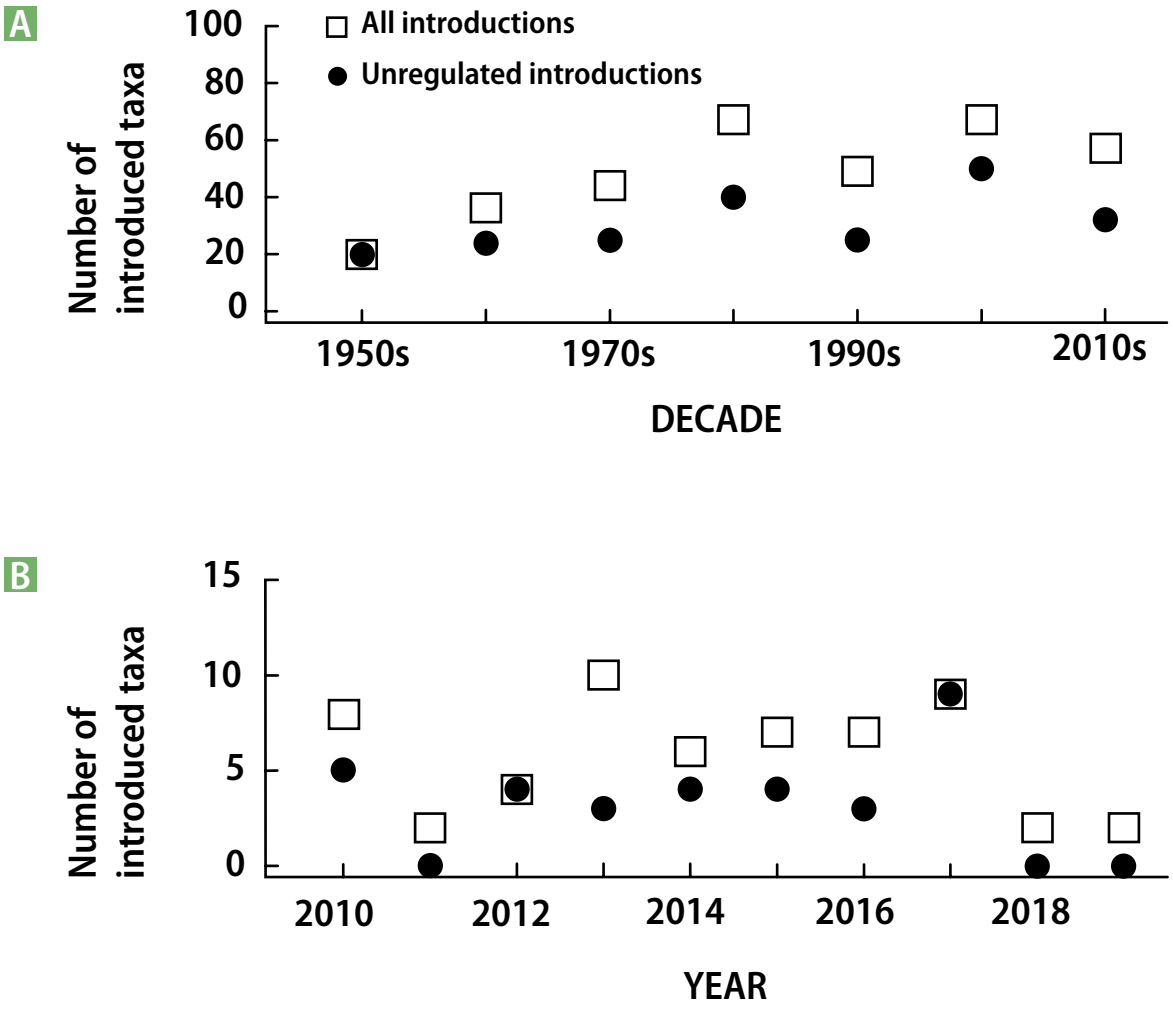


Figure 2.2. Number of recorded introductions to South Africa over time: (A) over the last seven decades and (B) during the last decade. These data are incomplete, particularly for more recent years, as there are time lags between the introduction of a taxon, when it is detected, and the publication of reports of the introduction.

2.3. Within-country pathway prominence

Within-country pathway prominence considers the size of the pathways of dispersal within South Africa, but does not take into account the importance of these pathways for the dispersal of alien organisms. As in the first report, data for within-country pathway prominence were not available for most pathways, and so the indicator could not be populated (see Chapter 6 for details on knowledge gaps and data requirements). However, South Africa has extensive transport networks (e.g. ~750 000 km of roads, https://www.transport.gov.za/web/department-of-transport/roads accessed September 2020) that are used frequently by a large proportion of the country's population, and that are used to transport a large amount of goods. As an example, in the 2018/2019 financial year there were over 135 000 domestic flight arrivals at South African airports (Airports Company South Africa 2019). The number of domestic flights and the number of passengers travelling on these flights has remained relatively consistent and these numbers are similar to those reported in the first report (see Figures S2.21–S2.23). There are a number of pathways that are facilitating the intentional transport of taxa within the country. For example: the pet trade (Nunes et al. 2017a), the medicinal plant trade (Byrne et al. 2017), and the cultivation of plants for uses related to the green economy (Canavan et al. 2019). It is not clear whether these processes have increased or decreased since the first report.

2.4. Within-country dispersal rates

Within-country dispersal rates consider the number of taxa that have dispersed within South Africa through the pathways of dispersal, and how this number has changed over time. Data for within-country dispersal rates have not been collated for the entire country, and so the indicator could not be populated (see Chapter 6 for details on knowledge gaps and data requirements). However, as in the first report, data collected from the literature indicates that alien and native taxa are being intentionally and accidentally transported around the country, and that these taxa are dispersing within the country through many pathways, with taxa dispersing through at least 22 of the 44 pathways of dispersal (Appendix 3). Recent research on biofouling has highlighted the importance of recreational yachts, particularly those used for cruising, in the dispersal of marine alien taxa within South Africa (Peters & Robinson 2017; Peters et al. 2019). Furthermore, 137 alien plant species are considered as transformers in South African National Parks, and most were intentionally introduced as ornamental plants or were dispersed by rivers and animals (Table S2.5), and many utilised multiple pathways (Foxcroft et al. 2019). It is expected that this pattern is applicable for South Africa more broadly. For example, a freshwater gastropod (*Tarebia granifera*) from South-East Asia, is dispersing rapidly within the country both through natural spread (e.g. on aquatic plants and by attaching to the feathers of birds) and as a stowaway on boats and trailers (Jones et al. 2017). However, it is unclear how the within-country dispersal pathways have changed since the first report.

Box 2.1

Movement of alien species within Africa

tomato leaf miner (*Tuta absoluta*) - D. Visser

The introduction of alien species to Africa has increased over time, at least for pests of forestry and agriculture (Graziosi et al. 2020; Sileshi et al. 2019). South Africa is often the entry point for alien species that disperse into other African countries (Faulkner et al. 2017b), and most forestry pests that have been introduced to Africa were first recorded in South Africa (Graziosi et al. 2020). However, in 2016 and 2017, three alien pests of agriculture [red palm mite (*Raoiella indica*), tomato leaf miner (*Tuta absoluta*), and fall armyworm (*Spodoptera frugiperda*)] that were detected in South Africa for the first time had dispersed, either naturally or with the help of humans, into South Africa from other African countries where they had previously been introduced (Faulkner et al. 2020a).

The increase in the movement of alien species between South Africa and other African countries (Faulkner et al. 2017b) is likely due to increasing trade and transport both between African countries and between African countries and the rest of the world. Changes to these processes and climate change could influence the intra-African movement of alien species in the future, and if the African Continental Free Trade Area (AfCFTA) is established the movement of alien species between African countries is likely to increase further. This is because imported goods will only be inspected for alien species at the first port of entry, and most African countries have limited capacity to respond to biosecurity threats (Early et al. 2016). It will be extremely difficult to prevent the dispersal of alien species within the continent once introduced (Faulkner et al. 2017b), and there could be conflicts of interest if some countries could benefit from the introduction of a species that could be harmful in other countries (Faulkner et al. 2020b). A co-ordinated regional response to alien species introductions is required to better manage the introduction and dispersal of alien species in Africa (Faulkner et al. 2017b; Graziosi et al. 2020; Sileshi et al. 2019).

2.5. Trends in pathway indicators

Indicator	Trend (confidence)	Desired trend	Current status	Outlook
1. Introduction pathway prominence	→ (Medium)	Not applicable	There has been little change since the first report. 11 introduction pathways play a major socio-economic role.	There is no desired trend for introduction pathway prominence as it is largely a function of global trade and travel. However, there is a need to track pathways and trends in trade to ensure that interventions respond to these trends, otherwise potentially harmful alien taxa will continue to be introduced. For example, growth in intra-African trade will increase the risk of importing invasive taxa to South Africa (and exporting them to other African countries).
2. Introduction rates	→ (Low)	Not applicable (for regulated taxa) ↘ (for unregulated taxa)	There has been little change since the first report, and alien taxa continue to be intentionally and accidentally introduced through a wide variety of pathways. During the 2017–2019 period, new taxa were legally introduced for biological control, and were accidentally introduced through the timber trade, shipping, as contaminants on imported animals, and through natural dispersal from other African countries where they had previously been introduced.	In many cases regulated taxa (for which the risks have been analysed and found to be acceptable) are expected to be a net benefit to the country, and in the case of biological control assist with the control of biological invasions. Therefore, no specific trend is desirable for regulated taxa, but what is desirable is that a process is in place to regulate them. There has been progress on this issue (see Chapter 5). The rate of introduction of unregulated taxa will increase as the volume of trade and travel increases. The rate of introduction of unregulated taxa is, however, sensitive to the intensiveness of survey activities and is likely to be relatively unresponsive to changes in actual introductions. This is because many accidental introductions can go undetected for a long time and are only discovered once a specialist survey is undertaken (cf. PSHB). Unless pathways are identified, prioritised, and managed, potentially harmful alien taxa will continue to be accidentally and illegally introduced.

→ no change; ↗ increase; ↘ decrease

Indicator	Trend (confidence)	Desired trend	Current status	Outlook
3. Within-country pathway prominence	Not assessed	Not applicable	Information was only obtained for a few pathways. Many pathways are likely playing a socio-economic role within the country, but the extent of this role and how it has changed since the first report is not known.	There is no desired trend for within-country pathway prominence as it is a function of internal trade and transport. However, trends in these pathways need to be tracked to ensure interventions are in place where they are needed. If this is not done harmful taxa will continue to spread, native taxa will be introduced and possibly cause impacts in parts of the country where they are not native, and valuable assets will be put at risk.
4. Within-country dispersal rates	Not assessed	↘ (for regulated taxa) Not applicable (for unregulated taxa)	National-scale data has yet to be collated, but information was available for alien plant taxa in South Africa's national parks. Most alien plants were intentionally introduced to national parks as ornamental plants or were dispersed by rivers and animals, and many utilised multiple pathways.	Increases in the volume of trade and travel will lead to increases in the within-country dispersal rates of taxa known to be invasive, or that are considered likely to become invasive. The spread of regulated invasive taxa is of particular concern, and while other taxa might also spread, it is not clear whether this should be a concern. Unless pathways that facilitate the within-country dispersal of regulated taxa are identified, prioritised, and managed, the spread of these taxa will increase, and so there will be increases in both the rate of expansion of currently invasive taxa, and in the likelihood that alien taxa will find a suitable part of the country in which to become invasive.
High level indicator A. Rate of unregulated introduction of new species	↘ (Low)	↘	Between 2010 and 2019 approximately 3 new taxa were introduced per year either accidentally or intentionally but illegally. This was lower than the estimated rate during the previous decade (~ 5 per year).	Despite the apparent recent decline in introductions, opportunities for the introduction of alien species are expected to increase as the volume of trade and travel increases. Whether this will result in the introduction of more invasive species will depend on the degree to which key pathways are identified and prioritised for management. Improvements to inspection, management, and incursion response at border would strengthen South Africa's biosecurity.

→ no change; ↗ increase; ↘ decrease

white garden snail (*Theba pisana*) - C. Griffiths

3

SPECIES

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Common myna (*Acridotheres tristis*) - R. Taylor

Key findings:

- The number of alien species in South Africa has increased from 1637 to 1880. A notable new invasive species that is predicted to have massive impacts is the polyphagous shot hole borer (PSHB).

- The impacts of 215 invasive alien species have been formally assessed, seven of these were found to cause major or massive environmental impacts, and one was found to cause major socio-economic impacts. Impact assessments are needed for the other alien species but in many cases there is a lack of reliable data.

- A national registry of alien species will help clarify which species are legally in the country, consolidate information on the status of invasive species, and provide an important reference resource for the biodiversity and broader community. This second report represents a major step towards this, in particular by improving how data are presented, how changes are tracked, and ensuring information is presented in a manner consistent with international best-practice.

Key gaps (shared with Chapter 4: Sites):

- Data on the distribution and abundance of alien species need to be collected, collated, and integrated into national and global databases to facilitate the planning of interventions.

- The systematic quantification of the impacts of biological invasions would: facilitate the prioritisation of interventions targeting particular species and particular sites; provide the justification for government investment to control biological invasions; and provide important background to communicate the issue to society.

Indicators covered in this chapter:

3.1 Number and status of alien species

While there are various estimates of the number of alien species in South Africa (e.g. van Wilgen et al. 2020b), it is not always clear how such estimates are arrived at, and the evidence underpinning the reported status of particular alien species is in some cases missing (e.g. several species listed as invasive under the NEM:BA A&IS Regulations do not appear to be present in the country, Kumschick et al. 2020). The A&IS Regulations require the Minister to develop and maintain a national list of invasive species that are known to occur in South Africa. As of December 2019, 556 taxa were listed under these regulations but there are many other alien species that might warrant regulating. However, for the majority of alien species found in South Africa, there are no studies documenting their occurrence status (Appendix 2). The alien species list in Appendix 2 therefore represents not just an update to the alien species list in the first report, but a step towards a national registry of alien species in the country. Appendix 2 captures current knowledge of the status of each alien species in a manner that allows for the information to be easily reviewed and updated. The changes since the first report are summarised in Table S3.1 and documented in detail in Appendix 4. These changes reflect both differences in how data were collated and changes in the actual status of specific alien species. The species listed in the second report have been carefully checked and only species for which a reliable record of their occurrence in South Africa have been included. This has resulted in a new baseline from which change can be tracked (Figure 3.1). Additional species have also been added to the list. These additions were either taxa that arrived in the period 2017–2019, or that arrived prior to 2017, but were only recently confirmed, for example the polyphagous shot hole borer (PSHB, *Euwallacea fornicatus*, Box 3.1).

Whether an alien species recorded as present is naturalised or invasive (i.e. its introduction status, see Table S3.2 for further details) is not well known at present. Currently this distinction is based on the assessment done in the first report that inferred invasiveness from known distribution range, literature, and expert opinion. This needs to be re-evaluated and should be based solely on documented evidence.

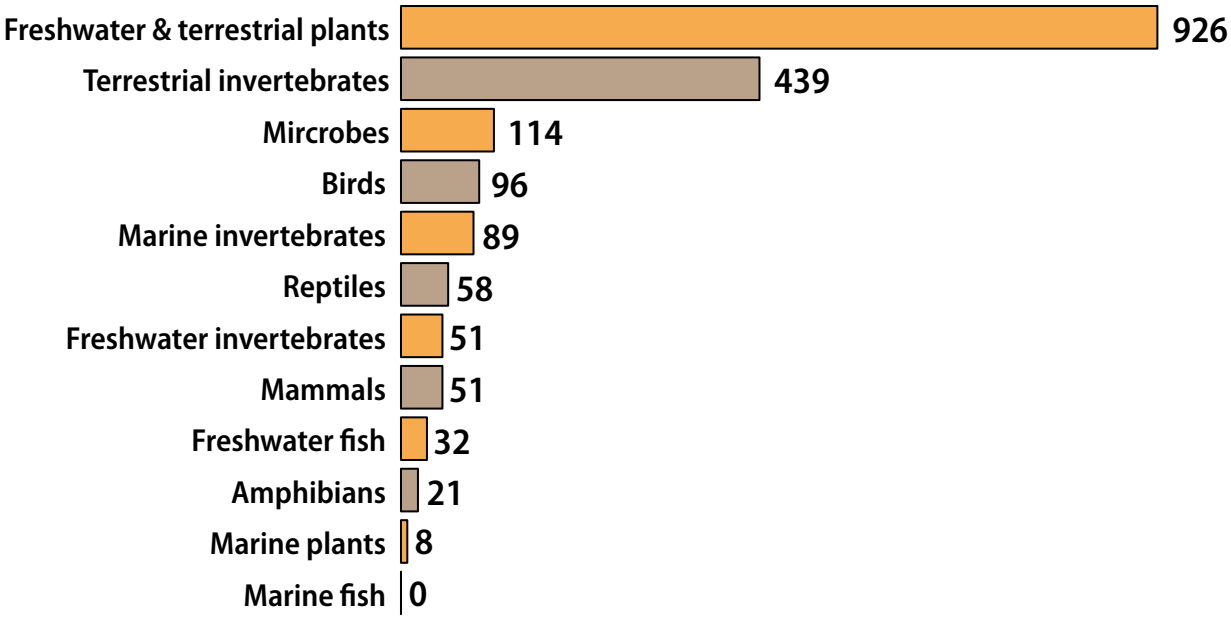

Figure 3.1. The number of alien species recorded as present in South Africa as of December 2019 (see Appendix 2) as per the regulatory groupings of the NEM:BA A&IS Regulations. Many of these taxa are not invasive and are only known from captivity or cultivation. The list is not comprehensive (many alien taxa in captivity or cultivation are not included yet); however the evidence for the presence of every taxon that is included is clearly specified.

3.2 Extent of alien species

Occurrence data published on the Global Biodiversity Information Facility (GBIF)[1] were only available for a few taxa. At a provincial scale, there has been minimal change in the extent of many alien species, and the majority are only found in three or fewer provinces (Table 3.1).

Table 3.1. The number of alien species that are recorded as present in a given number of provinces in South Africa as of December 2019 based on occurrence records from GBIF and the change in these values since the first report. The majority of alien species are localised, although approximately 9% are found in all nine provinces.

	Number of provinces								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
End of 2016	290	167	128	80	80	67	65	59	85
End of 2019	281	161	140	82	80	63	70	59	87
Change	-9	-6	12	2	0	-4	5	0	2

[1] GBIF is an international network and research infrastructure that is funded by the world's governments to provide open access data on global biodiversity. It provides common standards and open-source tools that enable sharing of information about where and when species have been recorded (see https://www.gbif.org/).

At a finer scale (qdgc) almost half (44%) of the alien species for which data were available showed an increase in spatial extent. Taxa that had small ranges (i.e. they are found in ≤ 10 qdgcs) have seen their broad-scale distributions double since the first report, while the extent of very widespread taxa (≥ 100 qdgcs) have, on average, increased by 12% (Figure 3.2). The annual proportional increase is similar to that seen for invasive plants when evaluated over the period 2000–2016 (Henderson & Wilson 2017) and supports the general assertion that the majority of alien species have a limited distribution, but that many of these are increasing in extent. However, the spatial extent of an alien species cannot decline as it is estimated here (but see Supplementary Material section S3.2. for examples of species that might have declined in distribution). A consistent method of detecting and documenting reductions in species' extents is needed.

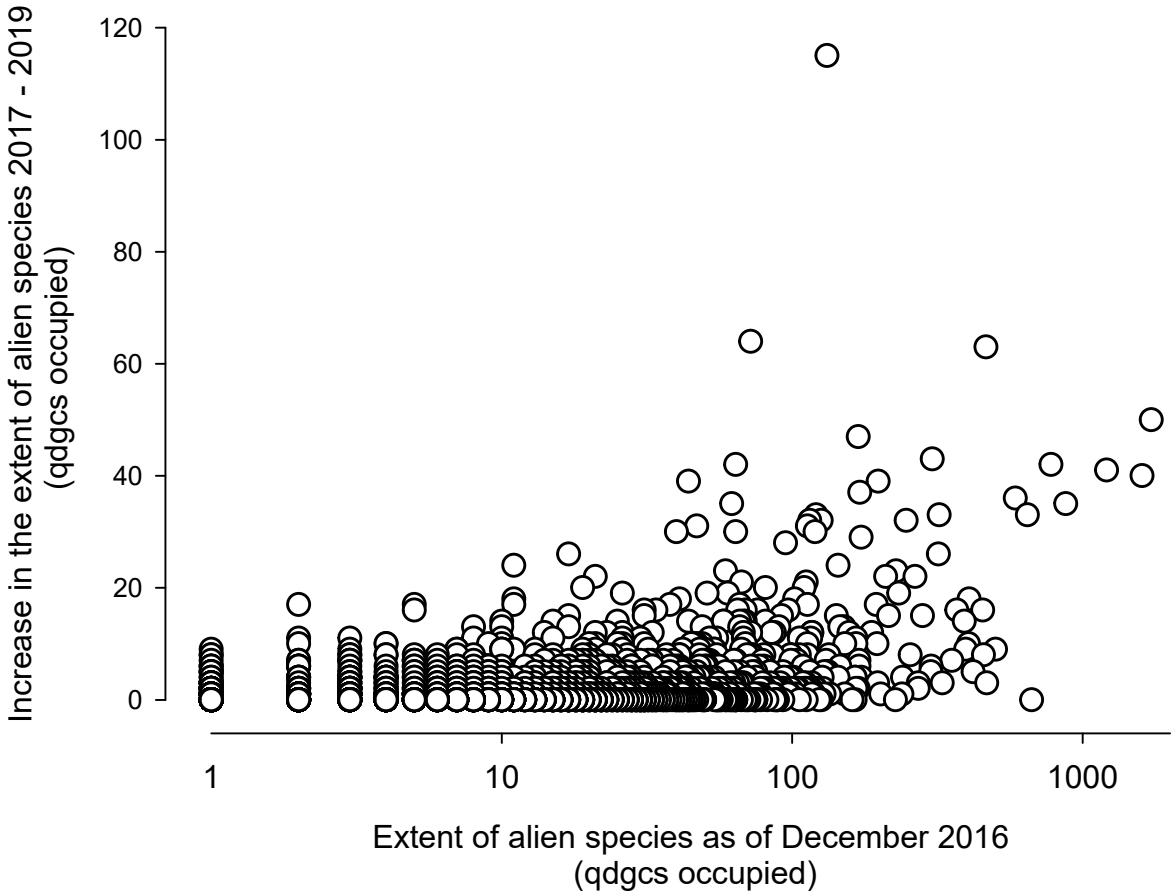

Figure 3.2. The increase in the recorded extent of 1065 alien species in South Africa 2017–2019 as compared to their extent as of December 2016. The values shown are the number of quarter degree grid cells (qdgcs) where taxa have historically been recorded, and do not take into account the possibility that taxa are no longer present in some qdgcs. Data for alien plant species are from SAPIA (accessed 17 March 2020) and data for other taxa are from GBIF (accessed 20 April 2020).

3.3. Abundance of alien species

In the first report, estimates of the abundance of alien species were based on two sources of data on terrestrial plants – a 1998 report to the Water Research Commission (Versfeld et al. 1998) and the National Invasive Alien Plant Survey (NIAPS) (Kotzé et al. 2010). This situation has not changed and both these estimates are made with low confidence. While some of the NIAPS survey approach was recently further described (Kotze et al. 2019), it is still difficult to assess if the method works because no results and no estimates of distribution or abundance for the three species studied are provided (see Supplementary Material section S3.3 for more details).

3.4. Impact of alien species

There have been major advances since the first report in monitoring the impact of alien species. The Environmental Impact Classification for Alien Taxa (EICAT; Blackburn et al. 2014; Hawkins et al. 2015) has been approved as an IUCN product, and has recently been published as a standard (IUCN 2020), and the Socio-Economic Impact Classification of Alien Taxa (SEICAT; Bacher et al. 2018) has been developed to deal with non-environmental impacts. There have been global EICAT assessments for amphibians (Kumschick et al. 2017), birds (Evans et al. 2016), mammals (Hagen & Kumschick 2018), bamboos (Canavan et al. 2019), gastropods (Kesner & Kumschick 2018), and some other invertebrates (Nelufule 2018) (Table S3.4). In South Africa, national-level EICAT assessments have been done for 32 species but in many cases (62%) there was no reliable data. Seven were recorded to cause major or massive impacts. These include, two grass species giant reed (*Arundo donax*) and reed meadow grass (*Glyceria maxima*) that competitively displace native species (Visser et al. 2017), and five fish species that threaten native fauna through direct predation [smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*)] and hybridisation [Nile tilapia (*Oreochromis niloticus*)] (Marr et al. 2017). SEICAT has only been applied to a limited range of taxa so far, including gastropods and some mammals alien to South Africa (Hagen & Kumschick 2018; Kesner & Kumschick 2018), and alien amphibians and marine fishes globally (Bacher et al. 2018; Galanidi et al. 2018) (Table S3.5).

EICAT and SEICAT are based on published evidence and aim to make impact assessments comparable by providing a clearly defined protocol to identify impact mechanisms and their magnitudes, and to minimise assessor bias. Therefore, the aim of future reports is to fully incorporate EICAT and SEICAT assessments. However, and despite the methodological advances of EICAT and SEICAT, quantifying the impacts of alien species remains a major challenge, both globally and in South Africa. For most species, there is almost no documented evidence of impacts and available evidence is based on different assessment methods, which makes it difficult to compare impacts across taxa and regions (Zengeya et al. 2020). Reliable impact assessments for alien species in South Africa will require systematic data on impacts to be collected and collated.

Box 3.1

The polyphagous shot hole borer (PSHB) and Fusarium dieback in South Africa

polyphagous shot hole borer (*Euwallacea fornicatus*) - S. Bush

The PSHB[1], *Euwallacea fornicatus* (Coleoptera: Curculionidae: Scolytinae), looks set to become the most damaging biological invasion in South Africa's urban environments[2]. The PSHB is an ambrosia beetle from Southeast Asia that bores into tree trunks and branches laying its eggs inside woody tissue. The beetle carries three fungal symbionts, one of which is the pathogen *Fusarium euwallaceae*.

In suitable hosts, the fungus establishes in the tree, becoming a food source for the beetles and their larvae.

PSHB's sibling mating system means new adult female beetles emerge already fertilised, ready to spread and establish galleries in new trees. In susceptible hosts the fungus causes Fusarium dieback, which leads to branches dying and tree death. The PSHB was first detected in the KwaZulu-Natal National Botanical Gardens in Pietermaritzburg in 2017 (Paap et al. 2018), however, it quickly became clear that the beetle was already well established in the country, predominately in urban areas including Johannesburg, Bloemfontein, Cape Town (Somerset West), Durban, Nelspruit, George, and Knysna.

While it is not known precisely how it was introduced to South Africa, it was probably introduced through wood packaging material and dunnage that had not been appropriately treated for pests – a common pathway for the introduction of invasive insect pests globally. Now it is here, it has spread rapidly through the movement of infested wood (including firewood). PSHB has killed thousands of trees already and threatens millions more, including street and garden trees like maples (*Acer* species), liquidambar (*Liquidambar styraciflua*), plane trees (*Platanus* species), and oaks (*Quercus* species); agriculturally important trees like avocado (*Persea americana*); and native species like coral trees (*Erythrina* species).

While there are many claims of 'miracle' treatments, the only effective option currently available is to contain the spread of PSHB by quarantining affected areas, very carefully removing infected reproductive host trees, and disposing of the wood at dedicated sites. Selling infested dead wood for firewood is tempting but simply helps disperse PSHB to new sites (and has been implicated in the spread between towns in South Africa). Detection, control, and enforcement efforts are placing a massive burden on municipalities. In response the government has established an interdepartmental steering committee, led by the Department of Agriculture, Land Reform and Rural Development (DALRRD), to coordinate interventions required to manage the PSHB invasion.

The steering committee has commissioned a consolidated strategy and action plan, with input from research, engagement with stakeholders, and guidance from national government departments with a strong focus on effective communication and awareness campaigns. As of October 2020 it had not yet been listed under the NEM:BA A&IS Regulations, but an emergency listing has been proposed. It was, however, listed in 2019 as a quarantine pest of agricultural host plants in terms of the Agricultural Pests Act 1983 (Act No. 36 of 1983), and draft control measures were published by DALRRD in July 2020.

[1] PSHB in South Africa was in the past referred to as *E. whitfordiodendrus*. It has been proposed to change the common name to the invasive shot hole borer (ISHB), as the beetle only feeds on the fungus, whereas the fungus can grow on many different plant species.

[2] For more details visit: www.fabinet.up.ac.za/pshb. If you suspect a tree is infested with PSHB (particularly if your town is not yet recorded as affected or it is on a new host plant), send photographs and details to pshb@fabi.up.ac.za; or for those in the Western Cape fill in the online report form at www.capetowninvasives.co.za; and those in Johannesburg contact trees@jhbcityparks.com or Whatsapp 0828030748.

3.5. Trends in species indicators

Indicator	Trend (confidence)	Desired trend	Current status	Outlook
5. Number and status of alien species	↗ (Low)	↘ (for invasive species)	This second report contains details of 1880 alien species that are known to occur in South Africa. Over a third of these have become invasive. A notable new invasive species is the polyphagous shot hole borer (an ambrosia beetle from Southeast Asia), which was first detected in 2017 in Pietermaritzburg, but was already well established in several urban areas around the country at the time of its detection. It looks set to be one of the most damaging biological invasions faced by South Africa. It has already killed thousands of trees and threatens many more. The process of documenting and tracking changes of the status of alien species has been substantially improved. The report now follows international best principles in data curation (data are FAIR, i.e. findable, accessible, interoperable, and reusable; and tidy, i.e. organised in a consistent manner). Moreover, changes in indicator values are now consistently tracked.	South Africa faces a substantial invasion debt because most alien species are not yet invasive, and new alien species will continue to arrive. The number of alien species recorded in the country will also increase if more effort is spent on detection, even for well-studied groups like plants. The updated alien species list contained in this report represents a step towards a national registry of alien species in the country. It captures the current state of knowledge of the status of each alien species in a manner that allows for the information to be easily reviewed and updated. This promises to provide the foundational biodiversity information that is essential for management and policy makers.
6. Extent of alien species	↗ (Low)	↘	Occurrence data were only available for a few taxa. At a broad scale (e.g. provinces), there has been minimal change in the extent of many alien species, and the majority of species remain confined to a few sites. At a finer scale (e.g. quarter degree grid cell), taxa that had small ranges have seen their distributions double since the first report, while already very widespread taxa have on average increased by 12%.	The majority of alien species are localised and only a few are widespread. However, the potential for them to increase their distribution is large and the extent of most species will continue to increase unless effective control is put in place.

→ no change; ↗ increase; ↘ decrease

Indicator	Trend (confidence)	Desired trend	Current status	Outlook
7. Abundance of alien species	Not assessed	↘	No new data were available on the abundance of alien species Some exploratory work has been initiated to estimate the abundance of alien plant species using remote sensing, but there are still very few reliable data sources.	Understanding trends in abundance is important if the effectiveness of management interventions are to be monitored, and the magnitude of future impacts predicted.
8. Impact of alien species	→ (Medium)	↘	215 species have been assessed using an evidence-based framework, and 7 species have been reported to cause major to massive impacts using EICAT and 1 using SEICAT. However, there was no reliable data for the majority of the assessed species. This represents a shift from expert-based assessments of impact of alien species to evidence-based assessments.	This remains a major gap where detailed research is needed. Unless the impacts of invasive species can be quantified, attempts to regulate them will remain contentious in many cases.
Head-line indicator B. Number of invasive species that have major impacts	Not assessed	↘	In the first report, 107 alien species were identified by experts as particularly damaging. A process is under way to formally assess all invasive species using the IUCN's EICAT scheme. So far 215 species have been assessed, and eight found to cause major to massive impacts (five fish, two grasses, and one mammal species). However in many cases there was a lack of reliable data.	The number of alien species recorded to have major or massive negative impacts will increase as more species are formally assessed. The formal assessment of the impact of alien species provides the rationale for regulation and management, can improve compliance and implementation of intervention measures, and assist to resolve conflicts. However, impact assessments are hampered by a lack of reliable data for most species. If this situation persists, regulations will continue to be vulnerable to legal challenges. It is very difficult to control invasive species with major impacts in a way that will reduce such impacts to moderate or minor, but this has arguably been achieved by biological control for over 30 invasive taxa. On-going investment in biological control will likely result in more such successes. If alien species that currently have moderate or minor impacts are prevented from increasing in abundance and extent to the point where they have major impacts or, where feasible, such species are eradicated from South Africa, then significant returns on investment may also be made.

→ no change; ↗ increase; ↘ decrease

4

SITES

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clearing of mesquite (*Proposis sp.*) in the Northern Cape- J. Barnard

Key findings:

- Invasive species richness is highest in the Fynbos, Savanna, and Grassland biomes (251, 241, and 230 species, respectively) and lowest in the Desert (9 species) and Forest (10 species) biomes. Estimated increases in species richness range from 2 to 78 in individual biomes. The Agulhas marine ecoregion has the most invasive species followed by the Southern Benguela and Natal ecoregions (41, 39, and 25 species, respectively).

- Relative abundance of invasive plants has been estimated for some protected areas. Invasion in South Africa's National Parks were found to be minor to moderate. However, the reliability of these estimates is low and fine scale systematic surveys have recorded substantially different estimates. Should the criteria for management plans be amended by the DFFtE to include a simple standardised monitoring protocol, then it should be possible to track these values over time.

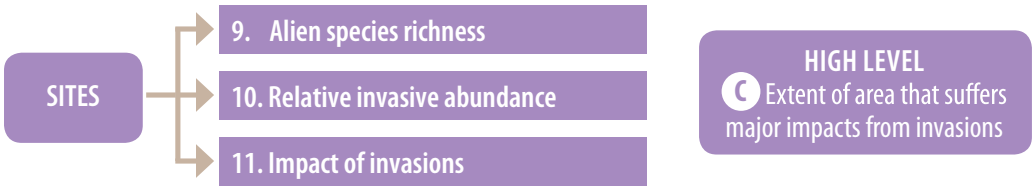
- Invasions cause major impacts through biodiversity loss, reducing water resources, reducing the productivity of rangelands, and by exacerbating fires. For example, annual surface water runoff has been reduced by between 1 and 321 m^3 per primary catchment, and carrying capacity has been reduced by 19 000 large livestock units in the grassland biome.

Key gaps (shared with Chapter 3: Species):

- Data on the distribution and abundance of alien species need to be collected, collated, and integrated into national and global databases to facilitate the planning of interventions.

- The systematic quantification of the impacts of biological invasions would: facilitate the prioritisation of interventions targeting particular species and particular sites; provide the justification for government investment to control biological invasions; and provide important background to communicate the issue to society.

Indicators covered in this chapter:



4.1. Alien species richness

The alien species reported from South Africa in this second report are distributed across the country, with most broad-scale administrative units and biogeographical regions being invaded by a variety of species (Table 4.1). The recorded invasive species richness has increased by 0–4.5% in individual provinces, with the highest invasive species richness still in Mpumalanga, while the Northern Cape still has the lowest richness (Table 4.1A). Invasive species richness is highest in the Fynbos, Savanna, and Grassland biomes and lowest in the Desert and Forest biomes (Table 4.1B). Only 2 of the 22 water management areas have no recorded invasive animal species, but the other water management areas only have at most 4 species recorded (Table 4.1C). 56 invasive species have been recorded in South Africa's marine ecoregions, with the highest richness being recorded in the Agulhas and Southern Benguela ecoregions. To date, no invasive species have been recorded offshore or in the ocean around the Prince Edward Islands (Table 4.1D).

Table 4.1. Invasive species richness in South Africa for different broad-scale administrative units and biogeographical regions. The estimates of change are made with low confidence because most reported increases arise from the formal recording of species that have probably been present for some time. Data are South African records available from GBIF (https://www.gbif.org/) and the Southern African Plant Invaders Atlas (SAPIA) for continental South Africa, from Robinson et al. (2020) for marine eco-regions, and from Greve et al. (2020) for the Prince Edward Islands. NA = not assessed. See Supplementary Tables S4.1–4.3 for more details, Appendix 1 for the data sources, and Appendix 2 for the full species list.

A) Invasive terrestrial species and invasive freshwater plant species richness per province.

Province / Region	End of 2016	End of 2019	Change
Eastern Cape	142	148	+6
Free State	85	88	+3
Gauteng	131	133	+2
KwaZulu-Natal	182	184	+2
Limpopo	103	106	+3
Mpumalanga	204	210	+6
Northern Cape	64	64	0
North West	81	81	0
Western Cape	178	186	+8
Prince Edward Islands	NA	35	NA

B) Invasive terrestrial species and invasive freshwater plant species richness per biome.

Biome	End of 2016	End of 2019	Change
Albany Thicket	86	108	+22
Desert	7	9	+2
Fynbos	173	251	+78
Forest	7	10	+3
Grassland	177	230	+53
Indian Ocean Coastal Belt	127	156	+29
Nama-Karoo	61	76	+15
Savanna	197	241	+44
Succulent Karoo	47	55	+8

C) Invasive freshwater animal species richness per water management area.

Water management area	End of 2019
A-Limpopo	4
B-Olifants North	2
C-Vaal	2
D-Orange	3
E-Olifants West	2
F-Buffels	0
G-Berg	3
H-Breede	1
J-Gouritz	1
K-Krom	2
L-Gamtoos	2
M-Swartkops	2
N-Sundays	1
P-Bushmans	0
Q-Great Fish	2
R-Keiskamma	2
S-Kei	4
T-Mzimvubu	2
U-Mkomazi	2
V-Tugela	4
W-Mfolozi	3
X-Komati	4

D) Marine invasive species richness per marine ecoregion.

Marine ecoregion	End of 2019
Agulhas	41
Delagoa	8
Natal	25
Prince Edward Island marine (offshore)	0
Southeast Atlantic (offshore)	0
Southern Benguela	39
Southwest Indian (offshore)	0

Data at a finer-spatial scale are available for invasive bird and plant species [one quarter-degree grid cell (qdgc) is 630–710 km^2 at the latitudes of South Africa]. Recorded invasive bird species richness appears to be highest around major urban centres (Figure 4.1A). This is likely because most alien bird species are commensal with humans, most were first introduced to urban centres, and because of greater sampling around urban areas. There have been few changes in invasive bird species richness at this scale with 15 qdgcs showing an increase in one bird species and 1 qdgc showing an increase in two species (Figure 4.1B). Invasive plant species richness is similarly high around urban areas (Figure 4.1C). Parts of the country have shown notable increases in invasive plant species richness (Figure 4.1D), however these increases are a direct result of a dedicated road-side survey from Pretoria through the Free-State to the southern Cape that was conducted in March 2018 as part of the SAPIA project (Henderson 2018). This suggests that current patterns of invasive plant richness are still highly sensitive to sampling effort. Data on invasive species richness of other taxonomic groups have not been updated since the first report.

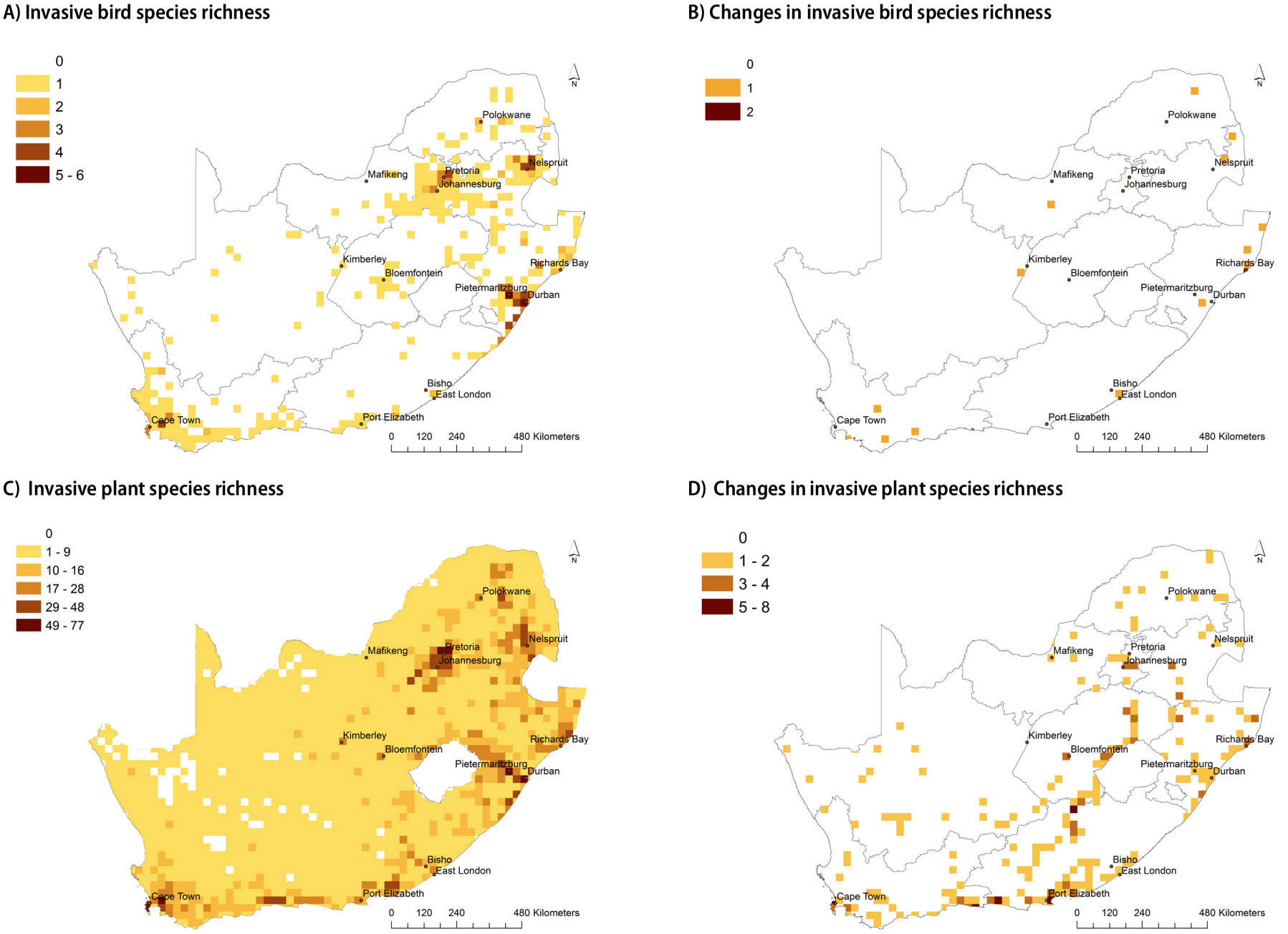


Figure 4.1. Invasive bird and plant species richness in South Africa at the scale of a quarter-degree grid-cell as of December 2019. Changes are shown for the period 2017–2019. See Figure S4.1 for more details. Reliable spatial estimates of richness were not available for all alien species, although alien species richness has been documented for some urban areas (Box 4.1) and for some protected areas (see section 4.2).

4.2. Relative invasive abundance

The distribution and cover of invasive plants have been estimated for some protected areas[1] (e.g. Baard & Kraaij 2019; Cheney et al. 2018; van Wilgen et al. 2016; van Wilgen & Herbst 2017). Estimates of relative abundance were provided by Cape Nature and Ezemvelo KwaZulu-Natal Wildlife for all of their protected areas for the first report (see Box 5.2 and Figure A1.9 in SANBI and CIB 2018). These estimates were not updated for the second report. However, estimates of relative abundance for the second report were provided by the South African National Parks. While no protected areas are currently dominated by invasive plants (Table 4.2), several important invasions are apparent. For example, parts of the Garden Route National Park are dominated by invasive plants although overall the park is only moderately invaded. The reliability of such estimates is, however, questionable, as fine-scale systematic surveys can produce estimates that are substantially different from datasets used for planning alien plant control operations (Cheney et al. 2018). Nonetheless carefully considered broad-scale estimates of relative abundance repeated over time would allow trends to be tracked with a moderate level of confidence in future reports. Achieving consistency in tracking relative abundance in protected areas could be facilitated by the inclusion of a standardised monitoring protocol in the criteria for the preparation of management plans developed by the DFFtE in terms of the NEM:BA A&IS Regulations.

Table 4.2. Estimates of relative invasive abundance in South Africa's protected areas based on percentage plant cover. Alien-free means that no alien species are recorded in the protected area.

Relative invasive abundance	Number of Cape Nature's protected areas (first report)	Number of Ezemvelo KwaZulu-Natal Wildlife's protected areas (first report)	Number of SANPark's protected areas (second report)
Alien-free	0	1	0
Minor <2%	19	59	14
Moderate 2–10%	4	39	2
Extensive 10–50%	1	22	0
Dominant >50%	0	0	0

a section of the Garden Route National Park showing a dominant invasion by alien *Pinus* species - B. van Wilgen

[1]South Africa has an extensive network of protected areas, which are either National Parks (managed by South African National Parks) or provincial reserves (managed by the provincial departments responsible for environmental conservation in each of the nine provinces)

4.3. Impact of invasions

The results of several studies that assessed the impacts of biological invasions at a number of scales have been published since the first report (Table 4.3). These studies strengthen the evidence base for quantifying the magnitude of impacts, but overall levels of confidence in these estimates remain low. This is because several of the studies are based on models in which assumptions have had to be made that were acknowledged to be tenuous, and results still have to be extrapolated from small scales (e.g. several hectares) to larger scales (e.g. provinces, biomes or water management areas). The impacts at particular sites are, however, increasingly well understood (e.g. urban areas, Box 4.1).

Table 4.3. Findings of research studies published in the period 2017–2019 with comparisons to indicator values from the first report where relevant.

Affected sector	Value in the first report	Value in the second report	Difference	Reference
Biodiversity	Moderate impacts on biodiversity intactness for South Africa	Major impacts on biodiversity over 10–50 ha	Scales differ, so not comparable	Mostert et al. 2017
Biodiversity	Not assessed	All major taxonomic groups have species directly threatened by invasions according to Red List assessments. Invasive species are the leading pressure on native amphibians and freshwater fishes. Invasive species were the primary driver of some species, especially plants and butterflies, being listed in higher categories of threat.	Not applicable	SANBI 2019 (The National Biodiversity Assessment)
Soil	Not assessed	Moderate impacts through soil nutrient enrichment following invasion over 10–50 ha	Not applicable	Nsikani et al. 2017, 2018
Fire severity	Not assessed	Major impacts on fire severity over ~10 qdgcs	Not applicable	Kraaij et al. 2018
Water runoff	Annual Surface water runoff reduced by 1–321 million m^3 per primary catchment	Annual Surface water runoff reduced by 1.15–2.11, and 7.98 million m^3 for two catchments	No change	Preston et al. 2018
Rangeland carrying capacity	Reduction in carrying capacity of 19 000 large livestock units in the grassland biome	Reduction in carrying capacity of 75% (from 5 to 1.25 large livestock units on 10 ha)	Scales differ, so not comparable	Yapi et al. 2018
Monetary value of impacts on sites	Annual losses of ZAR 5 864 million and ZAR 337 million for water resources and livestock production respectively for South Africa	Losses have net present value (NPV) of ZAR 34 and 1.9 billion for water resources and livestock production respectively for South Africa	Annual losses reported in the first report would have to be converted to NPV (6% discount rate over 25 years) to be able to compare estimates.	Stafford et al. 2017

Box 4.1

Urban invasions

Maderia vine (*Anredera cordifolia*) - N. Cole

Invasions in urban areas are particularly noteworthy both given the legal requirement for municipalities to report on biological invasions, and as urban areas are often the initial sites for introductions from which invasions spread (McLean et al. 2017; Padayachee et al. 2017).

There has been significant research on urban invasions since the first report, with the publication of a special issue of the journal Biological Invasions in December 2017 (Gaertner et al. 2017a; https://link.springer.com/journal/10530/19/12/page/1), and the development of the Global Urban Biological Invasions Consortium of which South Africa is a part (https://cubes-labs.com/gubic/).

Protocols for mapping alien plants in towns (McLean et al. 2018) and identifying sites for contingency planning (Padayachee et al. 2019) have been developed; a framework has been proposed to understand the urban-natural gradient as a filter for invasions (Holmes et al. 2018); and decision support tools to assist with management planning (Gaertner et al. 2017b) and prioritisation have been developed (Potgieter et al. 2018).

Moreover, we now have a better understanding of the role of urban areas as hotspots and sentinel sites for invasions (Paap et al. 2017), and of both perceived and realised impacts (Potgieter et al. 2018, 2019a, 2019b, 2020). There have also been significant investments in control operations (in particular by the City of Cape Town and eThekwini) focusing on both plants and animals (Davies et al. 2020).

4.4. Trends in site indicators

Indicator	Trend (confidence)	Desired trend	Current status	Outlook
9. Alien species richness	↗ (Low)	↘	Invasive bird and plant species richness remain high around major urban centres with minimal changes except for some apparent changes that are probably due to localised sampling efforts. Invasive species richness in marine ecoregions was assessed for the first time and the highest invasive species richness was recorded in the Agulhas (41 alien species), Southern Benguela (39 species), and Natal (25 species) ecoregions.	The development of a robust and reliable monitoring methodology should be seen as a priority, because in the absence of reliable information on species richness and relative abundance, neither the magnitude of impacts nor the effectiveness of management can be properly assessed.
10. Relative invasive abundance	Not assessed	↘	There are no country-wide estimates for the relative abundance of invasive species, but estimates for invasive plants in protected areas managed by the South African National Parks indicate invasions are minor to moderate. However, the reliability of these estimates is low, as some fine scale systematic surveys have recorded substantially different estimates.	Achieving consistency in tracking relative abundance in protected areas could be facilitated by the inclusion of a standardised monitoring protocol in the criteria for the preparation of management plans which were developed by the DFFtE in terms of the A&IS regulations. It is expected that existing invasions will densify unless managed. The costs of control and the impacts caused often increase dramatically with the level of invasion.
11. Impact of invasions	Not assessed	↘	Several studies have explored the impact of invasions at particular sites since 2017, but these were either done using different approaches or were done at different scales and are therefore unsuitable for drawing robust general conclusions. However, it is clear that alien species continue to cause major impacts through biodiversity loss, reductions in water resources, and reductions in rangeland productivity. In addition, alien species exacerbate fires and alter important ecosystem functions such as nutrient dynamics.	Impacts are likely to increase as invasive species continue to spread, and as control efforts are scaled back in response to fiscal constraints. This underscores the importance of re-focussing control efforts on agreed priority sites, and taking steps to improve control effectiveness.
High-level indicator C. Extent of area that suffers major impacts from invasions	Not assessed	↘	Biological invasions continue to cause major impacts on both rural and urban communities by, amongst other things, reducing South Africa's water resources, degrading pastureland, and exacerbating fires. Biological invasions continue to contribute to biodiversity loss and ecosystem change.	If control efforts focus on priority sites (e.g. sites that provide water to Cape Town's dams) then there will be significant returns on investment. However, without agreement on priorities, there is a substantial risk that control could remain ineffective, and the area that suffers from major impacts will continue to grow. Estimates of the full magnitude of impacts require more accurate assessments of the extent of invasions. This, in turn, requires effective mapping of the areas invaded and monitoring of spread. Such monitoring is currently lacking, and without which effective prioritisation is not possible.

→ no change; ↗ increase; ↘ decrease

house mouse (*Mus musculus*) - C. Griffiths

5

INTERVENTIONS

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Key findings:

- The quality of the regulatory framework is considered partial. The regulations are comprehensive and innovative, but are being implemented without a guiding policy. While the regulations have not changed since 2016, proposed amendments were published for comment in 2018; the regulations are increasingly being enforced (with the first successful prosecution in 2019); and the evidence underpinning the lists is being formalised (with 25 peer-reviewed risk analyses completed, 12 of which recommend a change to the current listing).

- The South African government has been spending over 1 billion ZAR per year to control biological invasions. This is an underestimate as it does not include data from conservation agencies, NGOs, and the private sector.

- 35 of 44 pathways by which alien species are introduced ~ (80%) have management plans in place, across a range of government departments. All of these pathways are being managed to some extent, except ballast water, where management plans have been developed for some ports, but are not yet implemented.

- New technologies have been developed to support pathway treatments. The new technology, which is referred to as 'lab-in-a-box', will enable inspectors to perform DNA analysis at ports of entry, thus reducing the time required to assess compliance.

- Effective procedures are in place and are being implemented to regulate the legal introduction of alien species and to ensure that the risks of approved introductions are acceptable. However, efforts to manage accidental and illegal pathways appear to be ineffective.

- 75 species, two genera, and one family are covered by specific management plans or strategies, but the process for quality control and approval of these plans is not clear, nor the degree to which they are being implemented.

- Contested species continue to pose a major challenge and are detracting resources away from controlling and regulating alien species that are not contested.

- Of the 556 listed invasive taxa, 189 taxa were subjected to some form of management (a rise of 40% since 2017). The spending per species is highly skewed – 77.2% of all money spent was directed at only ten species.

- Ten new species-specific control interventions have been reported since 2017. These dealt with four freshwater fish, two bird, two plant, one marine, and one freshwater invertebrate species. Four new biological control agents were released during the 2017–2019 period against four target alien plants.

- The outcome of alien species control programmes is not monitored, except for species that are eradication targets and or have been the subject of biological control. There are 42 alien plant species that are nation-wide eradication targets, but no species have been declared as eradicated in the past three years, and only a third are still the focus of eradication efforts as many are now suspected to be inappropriate targets for eradication. Two new studies on plants support earlier conclusions that biological control can be highly effective.

- Planning coverage for sites has increased slightly to cover 4.5% of the country.

- Government-supported teams treat about 160 000 hectares of invaded land annually. At the few sites where the effectiveness of such control has been assessed, the control efforts appear to be largely ineffective.

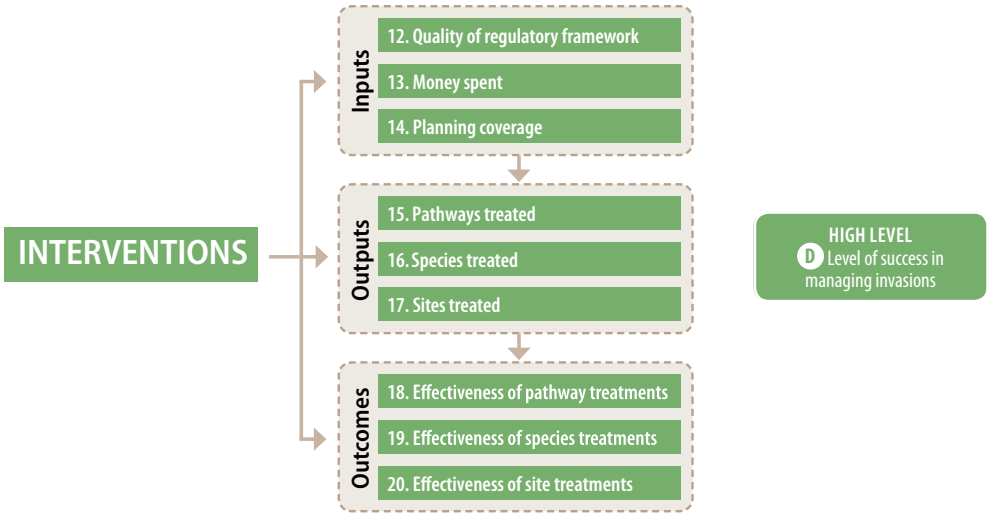
- Three treatments have successfully extirpated several co-occuring alien freshwater fish species from wetlands or stretches of river, and this represents a major success in the treatment of such sites.

Key gaps:

- A comprehensive policy, and a strategy to implement such a policy, are needed to guide interventions on biological invasions in South Africa.

- The absence of formal programmes to monitor the effectiveness of interventions in terms of outputs and outcomes means that the efficacy of control cannot be demonstrated, control measures cannot be compared and improved, and it is not clear whether progress is being made to reduce the negative impacts of invasions.

Indicators covered in this chapter:



5.1. Input – quality of the regulation framework

Since the first report, there have been significant developments regarding the implementation of the regulations governing the management of biological invasions. However, the primary legislation on biological invasions in South Africa (the NEM:BA of 2004; and its associated A&IS Regulations and Lists of 2014 as amended 2016) did not change between January 2017 and December 2019. In February 2018, the late Minister of Environmental Affairs published a notice of intention to amend the regulations and the lists of alien and invasive species. In the notice, the Minister invited the public to submit comments on her intention within 30 days of the date of the notice (the period was extended). The procedure for amending the regulations and the lists was subject to a legal challenge and as of June 2020 the NEM:BA A&IS Regulations and Lists have not been amended (Box 5.1, see p.51). The legal challenge has highlighted the need to clearly document why particular species were listed or are proposed for listing.

In the first report, it was noted that the process followed by the Minister in listing species was unclear and that there was no evidence that the risk of each listed alien species had been properly assessed (see Kumschick et al. 2020). The first report also highlighted some errors in the A&IS Lists (see section 7.2, Chapter 7, SANBI and CIB 2018). The DFFtE requested that SANBI convene a scientific advisory panel that could deal with issues pertaining to the risks posed by alien species. The Alien Species Risk Analysis Review Panel (ASRARP) was then constituted and tasked with reviewing risk analyses underpinning the listing of species under national legislation (as well as risk analyses attached to import applications) to ensure that they are scientifically robust (see Kumschick et al. 2020).

In an effort to ensure that the evidence underpinning the regulations is transparent, consistent, and in line with international best practice on risk analysis, Kumschick et al. (2018) in collaboration with ASRARP, developed and tested a risk analysis framework tailored for South Africa. To date risk analyses have been completed, as per the published guidelines, primarily by SANBI staff, students, and post-doctoral researchers. As of December 2019, risk analyses for 25 species had been reviewed and approved by ASRARP (Table S5.1). Notably, for 12 of these risk analyses the recommendation does not agree with the current listing category under the A&IS Regulations. There are various reasons for this (e.g. uncertainty as to whether the species is present in South Africa; field evaluations have found the species to be unsuitable targets for eradication; or the effectiveness and need for regulation has been questioned; see Supplementary Material section S5.9 for more details).

These risk analyses have been submitted to the DFFtE and are intended to be tabled for consideration at an interdepartmental committee tasked with making decisions as to whether and how to list species under the NEM:BA A&IS Regulations. The committee had not, as of mid-2020, been formed. The risk analyses have also not yet been made publicly available.

Separate to the ASRARP process, 128 risk assessments were completed between January 2017 and March 2018 and collated by DFFtE. Most of these concerned alien plant species (104 assessments) and were based on the modified Australian Weed Risk Assessment Protocol (Gordon et al. 2010). The remainder were done for birds, mammals, reptiles, amphibians, and invertebrates, and used different methods. These documents have not been standardised, subjected to quality control or made publicly available.

The process for publishing the 2018 proposed amendments to the lists of invasive species under the A&IS Regulations could not be influenced by ASRARP and the risk analysis process, as these were not in place when the proposed amendments were being developed. The process for publishing the 2018 amendments was illuminated in the court papers in the matter between Fly-fishers Association of Southern Africa v Minister of Environmental Affairs and others (Box 5.1, see p.51). Evaluations of the risks posed by eleven of the listed alien species or candidates for listing were conducted as part of the process and were reviewed by international experts.

There are various aspects of the regulations that are problematic. These include some errors and inconsistencies, mechanisms to implement parts of the regulations are missing, and there are few explicit mechanisms to facilitate intergovernmental collaboration. In addition, there is still no guiding policy governing biological invasions in South Africa (Lukey & Hall 2020). Lukey and Hall (2020) also raise a concern about faultless liability in NEM:BA and the A&IS Regulations. They argue that liability for the breach of the duty of care on landowners to manage invasive species on their land can be faultless. The liability is faultless when the presence of invasive species on their land is not of their own making; i.e. when the species spread to the property by means other than the actions of the landowner. They further point out that faultless liability provisions are often seen as being unfair or unjust, and are vulnerable to constitutional challenge. Enforcement agencies are usually reluctant to enforce such provisions.

It is also noteworthy that neither NEM:BA nor the A&IS Regulations make provision for the imposition of administrative fines or penalties on those who have contravened or failed to comply with the provisions of NEM:BA dealing with the management of alien and invasive species or the A&IS Regulations. Administrative penalties are monetary penalties that are imposed by an authorised enforcement agency on a person for contravening the provisions of an Act. The imposition of an administrative penalty does not require a conviction in a criminal court, but merely a preceding fair administrative process. They have been effectively employed in the UK and by the Competition Tribunal in South Africa (Fourie 2009; Hugo 2014).

Regulation 10 of the A&IS Regulations also provides that ' a proposal on any research and biological control relating to any aspect of the invasiveness or potential invasiveness of an alien species or a listed invasive species or the prevention, eradication or control of such invasive or potentially invasive species must be lodged with [SANBI] or a body designated by [SANBI]…' where such research or biological control is wholly or partially state-funded. Copies of the findings of such research must be provided to SANBI. In the first report, it was noted that 'no such proposals or findings had been lodged with the Institute'. Subsequently, the DSI-NRF Centre of Excellence for Invasion Biology (CIB), headquartered at Stellenbosch University, submitted information on 41 projects in 2018 and 43 projects in 2019. In addition, the CIB supplied copies of all published research, which is also contained in their annual reports, available at http://academic.sun.ac.za/cib/reports.htm. The Centre for Biological Control (based at Rhodes University) also provided access to project information through the chair of the former Research Advisory Panel that used to be SANBI's designated body to receive this information. In addition, since the first report, 12 permits have been issued for activities involving research on listed invasive species (Appendix 6).

Regulation 29(3) provides that the seller of any immovable property must, prior to the conclusion of a sale agreement, notify the purchaser of that property in writing of the presence of listed alien species on that property. It would be extremely difficult to monitor compliance with that regulation. A written notification in terms of that sub-regulation is required to be given to a potential purchaser. There is no requirement in the A&IS Regulations for written notifications to be sent to the issuing authority or SANBI for monitoring. Given the volume of property transactions in the country, it would be unreasonably burdensome on the issuing authority or on SANBI to collect information pertaining to that regulation. Consequently, the extent of compliance with this regulation cannot be assessed.

It appears that the permit system is functional, with a steady stream of around 20–60 permits issued for restricted activities on listed alien species each month (Figure S5.2). However, an analysis on the degree to which those who need permits are applying for permits or simply ignoring the regulations would substantially increase the ability to evaluate the effectiveness of the permit system (a list of permits issued for particular taxa is presented in Appendix 6). Between January 2017 and August 2019, 794 permits were issued for conducting restricted activities involving listed alien species (Table S5.3). The majority of the permits were issued for freshwater fish and mammal species such as Nile tilapia (*Oreochromis niloticus*), lechwe (*Kobus leche leche*), grass carp (*Ctenopharyngodon idella*), and fallow deer (*Dama dama*). A few permit applications were refused, three for hairy marron (*Cherax tenuimanus*) and three for *O. niloticus*. 436 permits were granted for moving listed alien species within the Republic, of which only 1 permit involved the movement of a taxon for the intended exportation from the Republic (Table S5.4). In the period in question, 46 permits that were granted involved the importation of listed alien species into the Republic. No permit applications for pathway-related activities involving listed alien species were refused.

As highlighted in the first report (though cf. Box 3.1), it is still not clear if compliance and enforcement actions are done in accordance with an overarching strategy focusing on priority species, pathways, and sites (section 7.7 in SANBI and CIB, 2018). In addition, there is still no evidence that any emergency interventions were implemented since the first report. There is also no evidence of an environmental management inspector utilising its powers in terms of section 73(4) of NEM:BA to implement a directive and to recover all costs reasonably incurred in implementing the directive from the person on whom a directive was served, but failed to comply with the conditions of the directive.

The NEM:BA and the A&IS Regulations do not specifically regulate pathways, rather pathways through which alien species are introduced or spread are regulated by listing certain restricted activities in relation to those species that are prohibited, controlled in terms of a permitting system or generally authorised subject to certain conditions (so-called exempted activities). The proposed 2018 amendments to the A&IS Regulations include a new regulation that would prohibit the importation of an alien species into the Republic through ports of entry other than 11 listed ports of entry. The insertion of such a regulation would improve the quality of the A&IS Regulations in so far as they deal with the management of pathways. There are, however, other laws that focus explicitly on pathways. For example, agricultural produce is regulated in terms of phytosanitary procedures of the Agricultural Pests Act, 1983 (Act No. 36 of 1983) and the Plant Health (Phytosanitary) Policy published under that Act. Legislation to manage the ballast water released by ships was drafted in 2013, and the International Maritime Organisation's Ballast Water Management Convention entered into force in September 2017. However, although South Africa is a signatory to this convention, and so is committed to manage ballast water, the legislation has yet to be passed by Parliament.

In summary, the quality of the regulatory framework is scored as partial in this second report, having been scored as substantial in the first report. The regulations have not changed since the first report, and this change is due to a reinterpretation of the situation (Table S5.5).

5.2. Input – money spent

The DFFtE's Natural Resource Management programmes continue to spend a significant amount of money on controlling biological invasions, well over a billion ZAR per year (Figure 5.1). However, while the absolute annual spending by DFFtE has stayed fairly constant over the period 2012–2019, in real terms this represents a decline. The expenditure is, however, an underestimate, as it does not take into account funds allocated to the control of invasive species by, for example, other government departments, national and provincial conservation bodies, metros and municipalities, NGOs, and the private sector.

With respect to spending on individual species, information supplied by a range of implementing agencies indicated that at least 237 invasive species were targeted for management (Table 5.1, for full details see Tables S5.6 and S5.9). The spending per species is highly skewed – 45% of the money was spent on controlling black wattle (*Acacia mearnsii*), and 77.2% of all money spent was directed at only ten species (Figure 5.2).

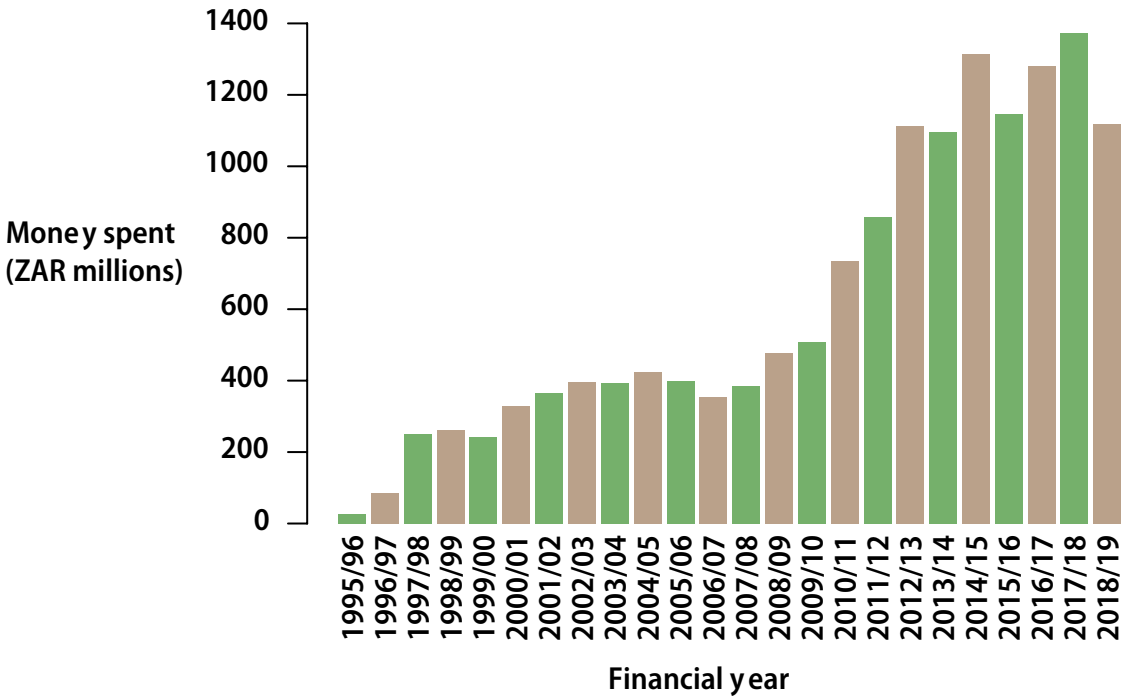


Figure 5.1. The amount of money spent (unadjusted for inflation) by the DFFtE's Natural Resource Management programmes on biological invasions in South Africa. Data are from annual reports as summarised on the site https://sites.google.com/site/wfwplanning downloaded December 2019; the financial year is from 1 April to 31 March.

Table 5.1. Spending by selected organisations on the management of invasive species in South Africa in 2018 and 2019. Note that the same species can be targeted by several agencies (i.e. the total number of species targeted in South Africa is not the sum of the third column). These costs will generally include some overheads, though it is not clear if this is full cost accounting.

Organisation	Money spent (ZAR)	Number of species	Notes
DFFtE Natural Resource Management (NRM) programmes	662 012 652	108	The value includes the total expended by Working for Water on contracts to implementing agents, plus 30% to cover overheads.
South African National Parks	180 535	11	The species treated are additional to those funded by WfW in National Parks.
CapeNature	4 093 214	21	The species treated are additional to those funded by WfW in CapeNature`s protected areas.
Agricultural Research Council and the Centre for Biological Control at Rhodes University	111 133 897	68	Funding for biological control research and implementation provided by NRM
SANBI	20 170 000	63	Investment to assess the feasibility of eradication and attempt eradication provided by NRM BioSecurity.

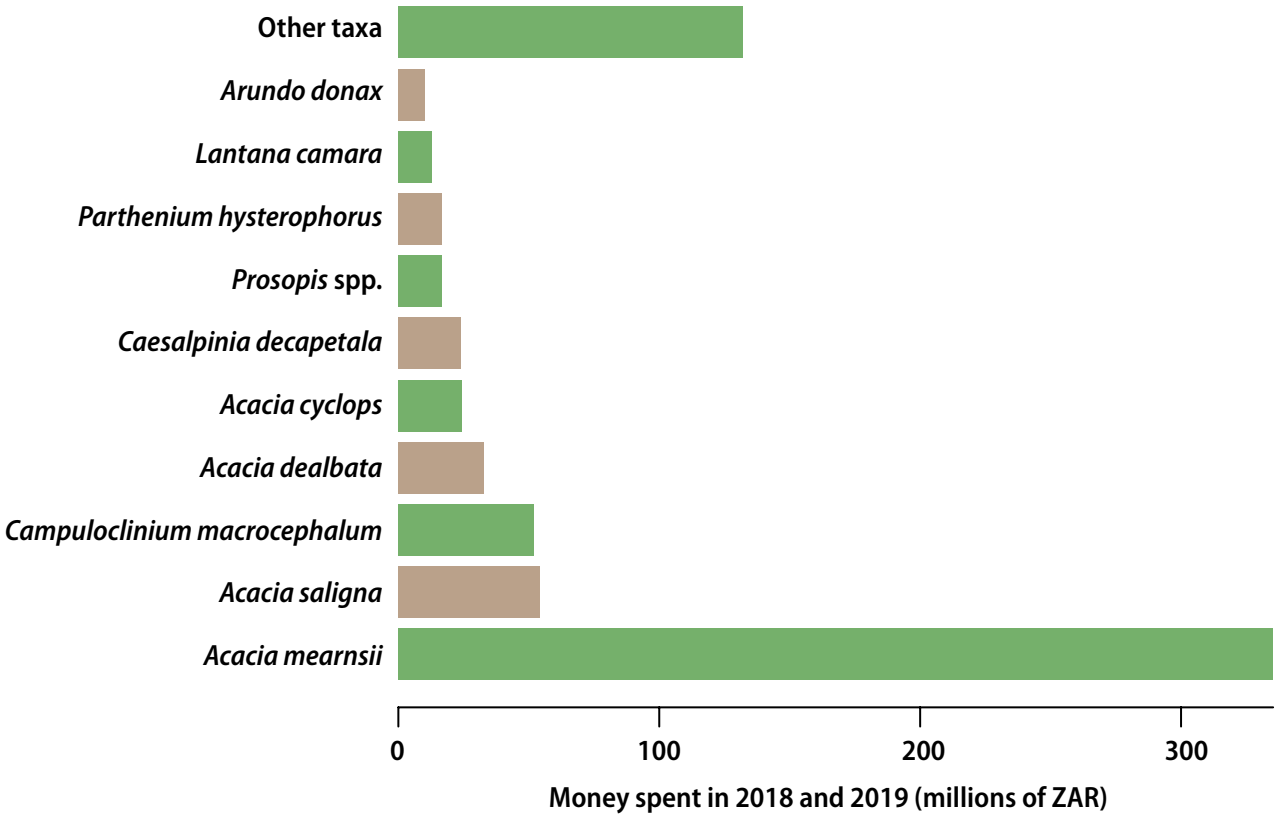


Figure 5.2. The amount of money spent in 2018 and 2019 by the DFFtE on controlling individual invasive plant taxa. There are 227 other taxa.

5.3. Input – planning coverage

There has been no change to the proportion of pathways of introduction with management plans in place ~ (80%). There has been no attempt to prioritise pathways for management, and consequently no formal management plans for pathways have been developed by the DFFtE. Although ballast water management plans have been drafted for some South African ports, they appear not to have been implemented (Calitz 2012). In order to manage the species that are transported on the hulls of ships, the Transnet Ports Authority plans to introduce in-water hull cleaning, however, it appears that this has not yet been put into practice. See Supplementary Material section S5.7 for more details.

As highlighted in the first report, section 75(5) of NEM:BA empowers the Minister to establish a body to co-ordinate species-specific management plans, but no evidence was found that such a body had been established. No species have dedicated management plans in place. Those listed in the first report for pompom weed (*Campuloclinium macrocephalum*) and parthenium weed (*Parthenium hysterophorus*), and for taxa in the genera *Acacia* and *Prosopis*, and in the family Cactaceae are yet to be formally approved. Species-specific eradication management plans have been prepared for some species (Table S5.6), but none have yet been formally approved, though it is not clear what the process for this is. In addition, the quality of the plans has not yet been assessed. A detailed plan for the eradication of house mouse (*Mus musculus*) from Marion Island has also recently been developed (Preston et al. 2019).

Since the first report, 25 new site management plans covering 648 294 hectares have been submitted, increasing the proportion of sites covered by management plans to 4.5% of the country (Table S5.8). Plans for the Maloti Drakensberg Conservation and Development Area (312 105 hectares[1]), Buffalo City Metropolitan Municipality (250 000 hectares), and uMdoni Local Municipality (23 800 hectares) constitute the largest additions. Three site management plans were submitted by private landowners, two of which were submitted pursuant to the issuing of pre-directives on the relevant landowners.

The site management plans were assessed using the guidelines outlined in the first report (see section 7.4 in SANBI and CIB 2018). The majority (84%) of the new plans were assessed as partially adequate. Three plans were found to be adequate and one was inadequate. Most site management plans identified the alien plant species that were present, detailed general measures that can be taken for their control, and described invaded sites. However, few of the plans linked the measures to a specific timeframe and budget or reviewed the efficacy of previous control efforts.

5.4. Output – pathways treated

Since the first report there has been no change to the proportion of pathways requiring management that are being managed (77%). Inspection operations by the DFFtE at OR Tambo International Airport have been expanded and now cover a greater number of locations including the passenger terminals, cargo terminal, and mail centre. Environmental management inspectors use the 'Lifescanner' application to assist with identifying species at ports of entry, and in cases where the inspector cannot identify the taxon, a DNA analysis (performed off-site at a laboratory) is used to assess whether there is compliance. This analysis can take some time and in instances of compliance the imported specimens are only released to their owner once the results are returned. This also leads to a delay in seizures and arrests. However, a new tool, the lab-in-a-box, which was recently developed, might in future enable inspectors to perform a DNA analysis at the port of entry, and reduce the time required to assess compliance. During the 2017/2018 and 2018/2019 financial years the DALRRD inspected more than 180 000 animal and plant product import permits, and 3 658 animal and plant imports. Additionally, over 12 000 plant import samples were tested for quarantine pests by Plant Inspection Services. See Supplementary Material section S5.8 for further details.

[1]The Maloti Drakensberg Conservation and Development Area (312 105 hectares) is the transfrontier conservation area that straddles the northeastern border between Lesotho and South Africa. The coverage of the site management plan reported here only reflects the extent to which the site management plan covers the South African part.

5.5. Output – species treated

Without formal species-specific plans in place, it is not possible to evaluate the degree to which management is targeting the species that need to be treated. Of the 556 listed invasive taxa, 189 taxa (34%) were subjected to some form of management in 2018 and 2019. By comparison, 136 taxa (24%) were reported to be subject to regular management in the first report (Table 5.2, see Table S5.9 for a full list). It is possible that, for some taxa, the need for further management interventions might have been assessed and deemed to be not needed.

Table 5.2. Number of taxa[1] that were subjected to management interventions, by regulatory or other category. NA = not applicable. See Supplementary Table S5.9 for a full list.

Regulatory or other category	Description	Number of species or taxa targeted	Number of species or taxa listed
1a	Taxa that are targets for eradication	38	52
1b	Taxa that must be controlled	98	248
2	Taxa where cultivation, ownership and trade are allowed subject to the issuing of a permit, and that must be controlled in the absence of a permit	17	75
3	Taxa that are subject to exemptions, but that cannot be further traded or propagated, and otherwise must be controlled	6	44
Context-specific	Taxa that are listed in different categories depending on the area or ecosystem in which they are found	30	137
Prohibited	Taxa that are assumed to not yet be in the country, and for which a permit may not be issued	1	560
SUSPECT	Acronym for '*Species Under Surveillance for Possible Eradication or Containment Targeting*', not listed in the regulations	21	NA
Unlisted alien species	Alien taxa that are not listed in the regulations	23	NA
Unlisted extralimital species	Taxa native to a part of South Africa that have been translocated outside of their natural distribution range, but that are not listed in the regulations	3	NA

A number of new species-specific control interventions have been reported (Table 5.3). The application of treatments to remove invasive freshwater fishes has been very promising, and there are several notable success stories where native biodiversity has recovered within a few years of treatment. These projects involved a range of stakeholders and rigorous monitoring to assess whether there was any adverse impact of the treatment. This suggests that this technique is viable in South Africa.

Four new biological control agents of invasive plants were released in South Africa during 2017–2019 and three were released in 2016 that were not reported on in the first report (Table S5.10). These were released against the following targets: Bailey's wattle (*Acacia baileyana*) and green wattle (*A. decurrens*) [also attacks silver wattle (*A. dealbata*) and pearl acacia (*A. podalyriifolia*)], Madeira vine (*Anredera cordifolia*), dense water weed (*Egeria densa*), lantana (*Lantana camara*), Australian albizia (*Paraserianthes lophantha*), Mexican sunflower (*Tithonia diversifolia*), and white-flowered wandering Jew (*Tradescantia fluminensis*). No new biological control agents were released against invasive animals or fungi.

[1]In some cases, a genus or family may be regulated instead of a species

Table 5.3. Invasive taxa for which management interventions were initiated in the period 2017–2019, or for which information not incorporated in the first report was obtained. See Supplementary Material section S5.2 for definitions of the legal listing categories of the NEM:BA A&IS Regulations. The 'extent of treatment' is the degree to which populations requiring management are being managed and the 'quality of treatment' is based on an assessment of the quality of intervention in terms of best practice as outlined in indicator 16, species treated. The 'effectiveness of treatment' and the 'adverse impacts of treatment' are scored as per indicator 19, effectiveness of species treatments. See the indicator factsheets supplementary to Wilson et al. (2018) for details.

Scientific name	Vernacular name	Regulatory category	Extent of treatment	Quality of treatment	Effectiveness of treatment	Adverse impacts of treatment	Notes	Source
Anas platyrhynchos	mallard	2	Partial	Adequate	Effective	Not recorded	Localised removals of individuals are taking place at some sites. Management goals are not tightly defined, so that the level of success cannot be assessed.	Davies et al. 2020
Australian *Acacia* species	wattles	1b (*A. saligna, A. cyclops, A. longifolia);* 2 (*A. mearnsii*)	Partial	Partially adequate	Effective	Minimal	Models based on data from Table Mountain National Park clearly demonstrate that the goal of achieving long-term control will not be achieved unless the efficiency of control projects is improved.	Cheney et al. 2018
Carcinus maenas	European shore crab	1b	Partial	Adequate	Ineffective	Minimal	A management trial substantially reduced the population of crabs in one of the invaded harbours, however the population quickly rebounded once management ceased and so management would need to be sustained. Nation-wide eradication was considered not to be feasible. As the benefits of management are unclear and currently the likelihood of spread and impact appear low, it was recommended that no further control be employed at this stage. The traps caught other organisms as well as the intended target (crabs). The majority of this bycatch was released apparently unharmed once the traps were inspected, although some cormorants were caught in the traps and drowned.	Mabin et al. 2017, 2020
Clarias gariepinus	sharptooth catfish	Not regulated	Partial	Partially adequate	Ineffective	Minimal	The attempt at extirpation from one dam was not successful.	Davies et al. 2020

Scientific name	Vernacular name	Regulatory category	Extent of treatment	Quality of treatment	Effectiveness of treatment	Adverse impacts of treatment	Notes	Source
Corvus splendens	house crow	1a	Substantial	Partially adequate	Partially effective	Minimal	Attempts to extirpate the species from two cities have made good progress, but extirpation has not yet been achieved in either case. Control programmes have not been continuous and control becomes much more difficult when numbers are low (both as the crows learn quickly and as they change behaviour at low densities). The species is now present in two more coastal cities where management projects have not yet been initiated. The likelihood of re-colonisation has not been assessed, and so it is unclear if eradication is a feasible goal.	Davies et al. 2020
Cyprinus carpio	common carp	Context-specific	Partial	Inadequate	Ineffective	Not known	The attempt at extirpation from one wetland was not successful.	Davies et al. 2020
Micropterus punctulatus	spotted bass	Context-specific	Partial	Adequate	Permanent	Major but transient; ~full recovery is apparent within a few years.	The species was successfully extirpated from one stretch of river. Fish were captured by chasing them into gill nets or by catching them with hand nets. The remainder were removed using spearguns, seine nets, and by back-pack electrofishing. Three years after the extirpation, native fiery redfin (*Pseudobarbus phlegethon*) and Cape galaxias (*Galaxias zebratus*) were observed in pools where they had been absent during the bass invasion.	van der Walt et al. 2019
Oncorhynchus mykiss	rainbow trout	Not regulated	Partial	Inadequate	Ineffective	Major but transient	The attempt at extirpation from one stretch of river was not successful.	Shelton et al. 2017
Procambarus clarkii	red swamp crayfish	Prohibited	Partial	Inadequate	Ineffective	Not known	The attempt at extirpation from one dam was not successful.	Nunes et al. 2017b
Salvinia molesta	Kariba weed	1b	Complete	Adequate	Effective	None	Update on effectiveness of biological control (complete or substantial control was achieved at different sites).	Martin et al. 2018

5.6. Output – sites treated

A number of new site-specific control interventions have been identified (Table 5.4). In relation to private land, a person who is the owner of land on which a listed alien species occurs has a duty of care in relation to those species. They are required to notify the competent authority of the occurrence of such invasive species on their land; to take steps to control and eradicate the listed alien species and to prevent it from spreading; and to take all the steps required to prevent or minimise harm caused by the invasive species to biodiversity.

In terms of regulation 13 of the A&IS Regulations, the Department is obligated to establish and maintain registers of notifications received from landowners and directives served on landowners for non-compliance with NEM:BA and the A&IS Regulations and to provide the DFFtE and SANBI with copies of those registers.

SANBI has not been provided with any copies of such registers by the DFFtE. It is therefore unclear if any notices were received from landowners since the first report. However, details of directives and pre-directives issued in terms of the A&IS Regulations are recorded in the Department's overall environmental compliance and enforcement registers.

Information on the full number of pre-compliance notices, compliance notices, pre-directives or directives that have been issued subsequent to those reported in the first report were not made available (see Table S5.11 for a proposed format for presenting these data). The type of properties served with notices and directives for restricted activities with listed alien and invasive animal species were mainly private landowners and nurseries (Table S5.12). Enforcement action was also taken against some organs of state, such as municipalities, national departments, and management authorities of protected areas. Over the period 2017–2019, six non-compliance cases against private landowners were handed over to the National Prosecuting Authority (NPA) for criminal prosecution (Table S5.12). The NPA has secured one criminal conviction (Box 5.2, see p.52), while the other five cases are still pending.

5.7. Outcome – effectiveness of pathway treatments

At the time of the first report, the effectiveness of pathway treatments could be estimated for 25 of the 44 pathways, and for all but one of these pathways there have been no changes to these estimates. However, for most pathways (61%) management appears to be either absent or ineffective. The effectiveness of pathway treatments can be estimated for the first time for several pathways. Listed alien species are being sold in nurseries (Cronin et al. 2017) and as part of the medicinal plant trade (Byrne et al. 2017), and undocumented bamboo species have been imported for a number of purposes related to the green economy [e.g. for biofuel and mine rehabilitation (Canavan et al. 2019)]. Furthermore, of the inspections performed by the DALRRD during the 2017/2018 and 2018/2019 financial years, 47% of the animal and plant product import permits inspected were non-compliant due to invalid documentation, contamination or the detection of quarantine pests; 8% of the animal and plant imports inspected were quarantined; and 62 quarantine pest interceptions were recorded by Plant Inspection Services [including Eriophyidae *Aculus schlectendali* and *A.* cf. *wagnoni*), *Pseudomonas* sp., and *Paenibacillus* larvae]. Therefore, for the eight pathways for which management effectiveness could be assessed for the first time, management appears to be either absent or ineffective (Table S5.13). Additionally, further research into the pet trade has highlighted that prohibited and regulated species are being sold (Nunes et al. 2017a; Nelufule, 2018), which supports the assessment in the first report that management of this pathway is either absent or ineffective. See the Supplementary Material section S5.11 for more details.

Table 5.4. Invaded sites for which management interventions have been initiated and/or assessed in 2017–2019 or where information from earlier years has been obtained.

Site	Purpose	Quality of treatment	Effectiveness of treatment	Adverse impacts of treatment	Management notes	Source
All South African National Parks	Assessment of alien plant data, and its usefulness for supporting decision-making	Partially adequate	Effective	Minor	Multiple goals, onerous reporting requirements, and low-quality monitoring data hamper the ability to make informed (and adaptive) management decisions.	Loftus 2013
Table Mountain National Park	Assessment of impact of data accuracy on efficiency of alien plant control	Partially adequate	Effective	Minor	Low-quality data used to inform management led to poorly-informed management decisions and increased costs. Improving data quality would lead to cost-savings and more effective management.	Cheney et al. 2018
Catchments of the City of Cape Town	To reduce water loss from invaded catchment areas	Partially adequate	Effective	Minor	These projects are funded by two NGOs (The Nature Conservancy and WWF South Africa), in collaboration with DFFtE NRM programmes and CapeNature. No data are yet available on progress towards goals.	Box S5.1
Berg River, Western Cape	Assessment of medium-term vegetation recovery after removal of *Eucalyptus camaldulensis*	Partially adequate	Effective	Minor	Native vegetation was on a positive recovery trajectory following removal of eucalypts, but the site is at risk of re-invasion.	Ruwanza et al. 2018
Paardevlei and Die Oog wetland, Cape Town	Extirpation of four species of alien fish from the wetlands	Adequate	Effective	Major, but transient	In 2005, Paardevlei was treated by aerial spraying of Rotenone and over 35 tons of fish, mostly common carp (*Cyprinus carpio*) were removed after treatment. The fish have not been detected since the termination of monitoring in 2014, so the operation appears to have succeeded. At Die Oog, Rotenone treatment was initiated in 2005. This successfully removed all the alien fish species and restored ecosystem functioning. The fish have not been detected since and the wetland is in a good condition and supports a number of native bird and amphibian species.	Davies et al. 2020
Lourens River, Western Cape	Extirpation of three species of alien fish from an off-stream dam	Adequate	Effective	Major, but transient	An off-stream dam in the Lourens River catchment was treated with Rotenone in 2005 to remove three alien fish species. Removal of the invasive species allowed for the establishment of a refuge population of native fish from the Lourens River. The extirpation was successful.	Davies et al. 2020

5.8. Outcome – effectiveness of species treatments

Most invasive species are subjected to mechanical and chemical control, but because the outcomes are not monitored, essentially the only information available on the effectiveness of species treatments is on those species targeted for eradication, or for biological control. No alien species has been formally declared as eradicated during the past three years (van Wilgen et al. 2020c). There are 42 alien plant species listed as category 1a for continental South Africa, i.e. are nation-wide eradication targets. However, only around a third of these species are still the focus of on-going control efforts aimed at eradication – many are suspected to be inappropriate targets for eradication (see Supplementary Material section S5.9). The mismatch between legal status and feasibility of eradication highlights the need to set eradication as the management goal only once a formal detailed assessment of eradication feasibility has been conducted. Such assessments require investment in delimitation and control trials. It is also clear that there is a substantial invasion debt in the country – many alien plants have only naturalised or invaded a few sites, and there are likely to be many that are still to be detected – a significant number of these new detections are likely to be suitable targets for eradication. Suitable monitoring data are not routinely collected so it is difficult to judge whether these eradication campaigns are making appropriate progress or what, if any, remedial measures are needed.

The biological control of invasive plant species was assessed in the first report as being notably successful for a small number of species. A further study has confirmed this assessment for the invasive aquatic plant Kariba weed (*Salvinia molesta*) (Martin et al. 2018: Table 5.3). These authors noted that the average percentage cover of water bodies by *S. molesta* declined from 51–100% to 0–5% between 2003 and 2017. Observations suggested that biological control of *S. molesta* was most effective at small sites and more difficult at larger and shaded sites, and that in some cases repeat releases of the biological control agent would be required.

The biological control community in South Africa conducts a comprehensive review of the effectiveness of biological control for addressing invasive plants, at roughly 10-year intervals. These reviews have been conducted three times, the most recent was published in 2011 (Moran et al. 2011). The fourth review, which will cover the period 2011 to 2020, is currently in preparation, and is expected to be published in 2021.

5.9. Outcome – effectiveness of site treatments

As for the first report the effectiveness of site treatments has been evaluated for a few specific sites or projects (e.g. Table 5.4; Box 5.3, see p.53). In addition, limited information on the effectiveness of control operations was supplied by the DFFtE NRM programmes. The information available was based on a sample of 1 130 management units (individual areas on which alien plant clearing contracts were awarded between 1998 and 2018), drawn from 68 projects across all nine provinces. The sample covered approximately 217 000 ha, or about 5% of all management units in the country. Initial densities were recorded on each management unit, which was then subjected to initial clearing and a varying number of follow-up clearings (Figure S5.3).

It is difficult to draw robust conclusions from this, as the outcomes of the interventions are not measured. In addition, the assessment is based on data records and not on assessments in the field. It appears that the treatments are moderately effective in less than half of the areas treated, and ineffective in the rest. In addition, the area covered by the management units is only a proportion of the site under management (for example a protected area or catchment), so no information on areas not covered by management units is available.

Box 5.1

The proposed listing of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) as invasive species in terms of NEM:BA

rainbow trout (*Oncorhynchus mykiss*) - Cape Nature

The proposed NEM:BA A&IS lists published in February 2018 included the addition of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) as category 2 invasive species, the implication being that a permit would be required for conducting a restricted activity involving those species. The proposed amendment, however, meant that permits were not required to possess fish, exercise physical control over them, or catch and release them. Nonetheless, the proposal was contentious (see for instance Stephen Coan (2014) 'Trout safe for now', The Witness [available at https://www.news24.com/news24/archives/witness/Trout-safe-for-now-20150430, accessed on 6 August 2019]. The Federation of South African Flyfishers (FOSAF) challenged the legal validity of the notice of intention to amend the invasive species list on procedural grounds. They requested the Court to, inter alia, declare that the notice was unlawful and that it be set aside on review.

The litigation focussed on the public participation process that was followed by the Minister in publishing the proposed amendments, and not on the risks posed by the species themselves. The DFFtE (the DEA at that time) had conducted evaluations of the risk posed by these species, and these were published on the DFFtE's website during the public participation process[1]. As of the end of June 2020, the litigation had not yet been finalised.

[1]https://www.environment.gov.za/extensiononpubliccommenting

Box 5.2

The first criminal conviction for a contravention of the alien and invasive species provisions of NEM:BA

In the matter of the State v Granada Home Builders CC, Granada Home Builders CC (Granada) was held criminally liable for not fulfilling its duty of care relating to invasive species on its land (Pine Town Magistrates' Court, case number 601/02/2017). In May 2016, the then Department of Environmental Affairs (DEA) received a request to issue a directive to Granada to clear certain listed alien plant species [including seringa (*Melia azedarach*), bugweed (*Solanum mauritianum*), and caster-oil plant (*Ricinus communis*)] which were growing on its property. The requester was concerned that the invasive plant species posed a fire risk to neighbouring properties. Granada, like all owners of land, has a duty in terms of section 73(2) to notify the competent authority of the presence of listed alien species on its property, to take steps to control and eradicate those species and to prevent them from spreading, and to take all required steps to prevent or minimise harm to biodiversity. Granada did not fulfil this duty of care.

DEA's environmental management inspectorate served a directive on the sole member of Granada in terms of section 73(2) of NEM:BA, directing Granada to clear the invasive species on its property. Granada did not comply with the directive and, as a result, DEA instituted criminal proceedings against Granada for conducting a restricted activity involving listed alien species without permits and failing to comply with a directive. Granada pleaded guilty to both counts and was sentenced by the Pine Town Magistrates' Court to the payment of a fine of ZAR 50 000 or two years imprisonment. The sentence was suspended for two years on the condition that the necessary steps are taken to control and eradicate the relevant listed alien species on its property. Granada has met the conditions of its sentence. It has spent ZAR 350 000 on environmental reports and the removal of the relevant listed alien species from its property.

Box 5.3

The control of triffid weed (*Chromolaena odorata*) in the Hluhluwe-iMfolozi Park in KwaZulu-Natal: an example of changing fortunes

triffid weed (*Chromolaena odorata*) invading savanna vegetation - Plant Protection Research Institute, Agricultural Research Council

In the first report, the control of triffid weed (*Chromolaena odorata*) in the 90 000 ha Hluhluwe-iMfolozi Park (HiP) in KwaZulu-Natal was included as an example of a successful control attempt that illustrated the value of adhering to best management practice. Infestations were first noticed in 1978, and increased to cover almost half of the HiP (40 000 ha) by 2003. After a substantial investment in control (ZAR 103 million in funding and 2000 person-years of effort), invasions were reduced to acceptably low levels by 2011. It was noted at the time that a number of clear factors contributed to this success. They included ongoing direction from a diverse project steering committee (including managers, researchers, the private sector, and community representatives), a rapid response team, a focus on areas of low infestation, a very flexible management approach, regular monitoring, and generous funding. In addition, te Beest et al. (2017) reported that 'the team was only paid following completion of a contract and after a thorough inspection of the quality of the work by the Project Manager'. It was noted that these features of the HiP project were often in marked contrast to those associated with most other cases of management that had been recorded, and in all likelihood accounted for the differences in success.

However, these gains have apparently been reversed due to a number of complicating factors. One of the project workers was killed by an elephant, and this led to a directive from the Department of Labour to the effect that teams would not be allowed to work in the field unless accompanied by an armed guard. Additional armed guards were not available (the staff component of conservation agencies had been markedly reduced), and it was not possible within the rules of the Extended Public Works Programmes to train and adequately remunerate new armed guards. Alternative sources of funding had to be sought, and new guards had to be trained. This led to a two-year absence of control within the reserve, during which *C. odorata* populations re-invaded cleared sites (although areas buffering the Park outside the reserve were identified and cleared). The implementing agency's failure to spend all of the funding allocated to clearing also resulted in the funds being withdrawn and re-directed to alternative projects in line with Treasury rules (although a portion of these funds were re-directed within the programme to address alien plant clearing in other protected areas). In addition, some areas cleared of *C. odorata* became invaded by parthenium weed (*Parthenium hysterophorus*), a more recent arrival. Overall, therefore, the gains appear to have been reversed, and additional funding, which is unlikely to materialise under current economic conditions, would be needed to bring the situation back under control. This experience illustrates the complexity of alien species control operations, the need for more flexible approaches to be able to deal with them, and the fact that invasions can rebound quickly if maintenance management is not consistently and continuously implemented.

5.10. Trends in intervention indicators

Indicator	Trend (confidence)	Desired trend	Current status	Outlook
12. Quality of regulatory framework	→ (Medium)	↗	The regulations have not changed, but new information has allowed a reassessment of the regulatory framework. In particular, a recent review has highlighted that the regulations are comprehensive and innovative, but are being implemented without a guiding policy. In addition, a process to evaluate the scientific evidence underpinning the lists of regulated alien species has been established. As a result the quality of the regulatory framework is now considered partial.	Regulations are in the process of being revised, but are also the subject of a court challenge. Assuming that the revisions go ahead as planned, the process of listing should become more dynamic and responsive to recommendations (e.g. through risk analyses).
13. Money spent	↘ (Low)	Not applicable	At least ZAR 1 billion is spent each year on control measures for biological invasions, but this is obviously an underestimate as there are no reliable records of spending by conservation agencies, NGOs, and the private sector. The spending per species is highly skewed – 77% of all money spent was directed at only ten species.	The ability of government to continue funding will almost certainly decline due to the impacts of prevailing circumstances on the fiscus. There are, however, some encouraging signs that NGOs may be able to fill some of this gap.
14. Planning coverage	↗ (Low)	↗	35 of the 44 pathways (~80%) have management plans in place and there has been no change to this estimate since 2017. It appears that there has been no attempt to prioritise pathways for management and consequently no formal management plans for pathways have been developed by the DFFtE. Ballast water management plans have been developed for some ports, but have yet to be implemented. There are still no dedicated species-specific management plans in place, and plans developed prior to 2017 (two species-specific plans for *Parthenium hysterophorus* and *Campuloclinium macrocephalum*, and two genus-level plans for *Acacia* and *Prosopis* species) are still yet to be formally approved. 174 species-specific eradication management plans have been prepared since 2017 for some species, but these are also yet to be formally approved. 26 site management plans have been submitted since 2017 and as a result the planning coverage for sites has marginally increased from 4.0 to 4.5% of the country.	There is still a need to improve planning coverage as most of the pathways, species, and sites do not have formal approved management plans in place. In addition, a large number of management plans that have been developed fall short of what is optimum, but improved project-level planning, with clear goals and accompanying monitoring programmes could improve efficiency. The number of pathways with plans in place could increase slightly if the plans for in-water hull cleaning are made official. There will be little change unless priorities are identified and plans for priority pathways are developed.

→ no change; ↗ increase; ↘ decrease

Indicator	Trend (confidence)	Desired trend	Current status	Outlook
15. Pathways treated	→ (Low)	↗	All pathways by which alien species can be introduced require management, but in 2017 only 34 of the 44 pathways (77%) were being managed to some extent. There has been no change to this estimate in 2019.	The number of pathways managed would increase if the draft ballast water legislation is passed and if ballast water management plans and plans to manage hull fouling are put into action. However, there will be little change in effectiveness unless pathways that require management are identified and prioritised, and at-border interventions are put in place for these pathways. There is still a need for more detailed information from the various Government Departments responsible for managing particular pathways of introduction. Assessments are also needed for the quality of the interventions in place for each pathway or groups of similar pathways. Without this, the risks of accidental introductions of potentially damaging species remain high.
16. Species treated	↗ (Low)	↗	Of the 556 listed invasive taxa, 189 species were subjected to some form of management in 2019, in comparison to 136 species in 2017. In addition, 10 new species-specific control interventions have been reported since 2017, with notable success for treatments to remove invasive freshwater fishes. Four new biological control agents have been released against four target alien plant species.	The ability to effectively treat individual species would be considerably improved if species could be prioritised, and if species-specific management plans could be developed to guide the management of high-priority species. In the absence of such planning and prioritisation, there is a large risk that funding could be diluted by targeting too many species, leading to ineffective control and a concomitant increase in impacts.
17. Sites treated	Not assessed	↗	Information on sites treated is available from the DFFtE's contractor database, with limited information gleaned from a few projects reported on elsewhere. Currently it appears that a relatively small proportion of the country's invaded area is subjected to treatment.	The government's capacity to effectively treat sites is set to decline under predicted fiscal constraints. This underscores the need to prioritise sites for interventions, and to direct funding to priority sites. A failure to do this would dilute funding, leading to ineffective control and a concomitant growth in impacts.

→ no change; ↗ increase; ↘ decrease

Indicator	Trend (confidence)	Desired trend	Current status	Outlook
18. Effectiveness of pathway treatments	→ (Low)	↗	In 2017, the effectiveness of pathway treatments was estimated for 25 out of 44 pathways and management for 19 of these pathways was absent or ineffective. There has been no change to these estimates in 2019, except where alien species are brought in for the purpose of hunting and for which management is now rated as effective. In addition, the effectiveness of pathway treatments can be estimated for the first time for eight pathways, including the nursery trade, medicinal plant trade, agriculture, and contaminants on plant and animal products. The management of these pathways also appears to be either absent or ineffective.	The effectiveness of pathway treatments is unlikely to increase until priority pathways are identified, and effective and adaptive management interventions that are informed by good data, are put in place for these pathways. Furthermore, there is unlikely to be major changes until the various entities that manage pathways co-ordinate their approaches.
19. Effectiveness of species treatments	Not assessed	↗	Many invasive species are subject to some form of control, but outcomes are not monitored and the only information available to assess the effectiveness of species treatments is on species that are eradication targets and/or have been subject of biological control. There are 42 alien plant species that are nation-wide eradication targets, but no species have been declared as eradicated in the past three years and only a third are still the focus of eradication efforts, as many are now suspected to be inappropriate targets for eradication. Two new studies on plants support earlier conclusions that biological control can be highly effective. At a national scale and for terrestrial plants, the Southern African Plant Invaders Atlas (SAPIA) has provided some indications that control efforts are not succeeding at a national scale.	The effectiveness of biological control of invasive plants is well understood. The effectiveness of other control efforts is not understood due to a complete lack of monitoring. Should this situation continue, it will not be possible to improve management efficiencies based on improved understanding of the outcomes of various interventions, and inefficiencies may continue, leading to growing impacts.

→ no change; ↗ increase; ↘ decrease

Indicator	Trend (confidence)	Desired trend	Current status	Outlook
20. Effectiveness of site treatments	Not assessed	↗	Government-supported teams treat about 160 000 hectares of invaded land annually, but the effectiveness cannot be assessed as there is no effective monitoring of the outcomes. At the few sites where the effectiveness of control has been monitored, the control efforts appear largely ineffective.	There is a complete lack of monitoring programmes that assess progress towards goals. What monitoring there is has focussed on inputs (money spent, jobs created), and on area treated, although this is uncritical as the quality of treatment is largely ignored. Should this situation continue, it will not be possible to improve management efficiencies based on improved understanding of the outcomes of various interventions, and inefficiencies may continue, leading to growing impacts.
High-level indicator D. Level of success in managing invasions	→ (Low)	↗	Recent studies support the conclusions of the first report that: 1) biological control can be highly effective; and 2) improvements both in monitoring and control efficiency will be needed if invasions are to be effectively controlled. In several water bodies, alien fish species have been extirpated in a manner that allows for the recovery of native species. This is a major new success.	An assessment of the effectiveness of control measures remains challenging in the absence of any formal programmes that monitor outcomes. Should this situation continue, then whether the goals of control – to reduce the number, abundance, extent, and impact of invasions – are being achieved will remain unknown, management cannot be adaptive, and levels of success will remain low. If these issues are not urgently addressed, the impacts and costs of invasions will rise significantly.

→ no change; ↗ increase; ↘ decrease

vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*) - R. Karsing

6

GAPS

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setting traps for European shore crab (*Carcinus maenas*) as part of a management trial - T. Robinson

Key findings:

- The indicators developed for this report need to be tested and aligned to other government reporting processes.
- There is insufficient information on how invasive species move and are moved around South Africa. A system to track within-country dispersal is required if South Africa is to manage the spread of invasive species.
- Data on the distribution and abundance of alien species need to be collected, collated, and integrated into national and global databases to facilitate the planning of interventions.
- The systematic quantification of the impacts of biological invasions is needed to facilitate the prioritisation of interventions, provide a defensible rationale to underpin government investment, and provide background to efforts to communicate the severity of the issue.
- A comprehensive policy, and a strategy to implement such a policy, is needed to guide interventions on biological invasions in South Africa.
- The absence of formal programmes to monitor the effectiveness of interventions in terms of outputs and outcomes means that the efficacy of control cannot be demonstrated, control measures cannot be compared and improved, and it is not clear whether progress is being made to reduce the negative impacts of invasions.

monitoring fringed wattle (*Acacia fimbriata*) as part of an eradication attempt - J. Wilson

6.1. Process for identifying gaps

In the first report, gaps affecting the ability to report on both biological invasions and on the effectiveness of interventions were identified and solutions were proposed. Gaps were identified for each indicator, and the progress to fill these gaps is outlined in Table S6.1. A recent comprehensive overview of biological invasions in South Africa (van Wilgen et al. 2020a) also highlighted factors that facilitate or hinder research and management. These are summarised in Table S6.2. Gaps were also identified during the production and review of this report (see Supplementary Material section S6). Based on these sources six key gaps were identified and are discussed here.

6.2. Indicators – improving how invasions are measured and providing a link to other reports

While the theory and framework behind the indicators has been published (Wilson et al. 2018), there has been no explicit test of indicator performance. A method of mapping or aligning the indicators used in this reporting process to global initiatives on monitoring and reporting on biological invasions and to national reporting processes on broader topics (e.g. conservation or global change) is needed.

6.3. Pathways – tracking invasions across South Africa

Information on how and why alien species are spreading within South Africa needs to be collated and evaluated if important within-country dispersal pathways are to be identified and managed. This will require the development of a framework to categorise such pathways as there are substantive quantitative and qualitative differences between introductions to the country and within-country dispersal (e.g. seeds of a horticultural species might be imported, screened on entry, and grown at a few nurseries; but once in South Africa, mature plants, cut flowers, and packets of seed might be sent to shops all over the country and sold on to many different people). Information recorded in the literature and other data sources (e.g. permits issued for interprovincial movement of alien species) will provide valuable data, but explicit monitoring might also be required. Research projects that focus on specific groups or parts of the country [e.g. on plants in South African National Parks (Foxcroft et al. 2019)] have provided some valuable information, but nation-wide studies are in the early stages.

Without this information the pathways of dispersal that need to be managed cannot be identified, the interventions required to manage the within-country movement of alien species cannot be determined, and the effectiveness of the interventions that are currently in place (e.g. provincial permitting systems and restrictions on the movement of certain plants to prevent the spread of agricultural pests) cannot be assessed. In the absence of such control, invasive species, once established in the country, will continue to spread rapidly and impacts will increase.

6.4. Species & Sites – mapping invasions in space and over time

Various atlassing projects are recording alien species on an ongoing basis (e.g. the government-funded Southern African Plant Invaders Atlas; and the South African National Bird Atlas). Ensuring the long-term sustainability of these is a priority. Much more still needs to be done to integrate these datasets with citizen science platforms, and to consider other taxa that are not currently covered by a specific atlassing project. In terms of determining the extent of plant invasions at particular sites, some exploratory work has been initiated on remote sensing, and some general guidelines are available on the types of data that need to be collected (e.g. Cheney et al. 2018). However, there are still very few reliable data sources on the relative abundance (cover, biomass or population size) of alien species at specific sites. A process to source and interpret data from national and provincial conservation agencies will be needed if change over time is to be tracked. Without detailed maps at national and local scales, estimates of the impact of invasions will remain crude, it is not possible to appropriately prioritise interventions across sites, and the ability to adapt interventions to respond more efficiently to invasions before they become widespread and damaging will be limited.

6.5. Species & Sites – determining the impacts and costs

For the government to continue to invest substantial resources in managing biological invasions the benefits that interventions bring in alleviating the negative impacts caused to all sectors of South African society and to the country's unique biodiversity must be clearly documented. Data on impacts are essential if control measures are to be prioritised and to track the effectiveness of interventions (e.g. in terms of increasing the resilience of South African cities, towns, and rural communities to droughts and fires; ensuring agricultural sustainability; and protecting our natural capital for future generations).

The impacts of alien species presented in this second report are based on assessments of available data using international best practice (i.e. EICAT and SEICAT). This represents a significant advance from the assessments of impact in the first report that were based solely on expert opinion. This process needs to be completed.

A systematic method for assessing the impacts of biological invasions at a site is needed (i.e. the combined impacts of all alien species present). Such assessments will require directed research to estimate the impacts of biological invasions in economic and social terms (De Lange & van Wilgen 2010; Shackleton et al. 2017; Witt et al. 2019). Consideration should also be given to the value of long-term monitoring to track impacts and how they change in response to different interventions.

6.6. Interventions – the need for an over-arching policy and strategy

South Africa does not currently have a comprehensive overarching national government policy on biological invasions. This 'policy vacuum' has been flagged as an important factor limiting the effectiveness of past efforts to control biological invasions (Lukey & Hall 2020). A comprehensive, evidence-based policy on biological invasions would clarify the government's position, guide decision-makers when implementing legislation, and assist the legislature when making and amending relevant laws. Such a policy would also provide a vision for what South Africa aspires to regarding biological invasions (Wilson et al. 2020). If the policy were in place, it would provide a structure for coordination, a basis for strategies and implementation plans, and guide monitoring and reporting by all affected parties.

A better understanding of South Africa's goals in respect of the management of biological invasions is critical for devising short- and medium-term implementation plans, estimating the annual budget required for giving effect to those implementation plans, and monitoring and reporting on the fulfilment of implementation plans.

An additional consequence of there being no comprehensive policy or strategy addressing biological invasions in South Africa is that there is no or little intergovernmental coordination among environmental authorities and other organs of state responsible for biological invasions (e.g. the national departments responsible for the environment, agriculture, water and health, transport, and provincial conservation departments). These organs of state are responsible for the administration of various Acts that deal with the management of biological invasions, such as the Conservation of Agricultural Resources Act, 1983; Agricultural Pests Act, 1983; Animal Diseases Act, 1984; and the Animal Health Act, 2002. There is, however, little evidence that these organs of state have taken steps to ensure that the legislation they administer are is aligned and that monitoring and enforcement actions are streamlined to ensure better results. At a narrow level the lack of a policy poses a challenge for reporting on the status of biological invasions, but ultimately it negatively impacts the effectiveness of interventions.

6.7. Interventions – measuring the effectiveness of interventions

Monitoring of interventions in terms of their outputs and outcomes is essential if their effectiveness is to be assessed and for management to improve by being adaptive. The effectiveness of interventions cannot be assessed (and improved) unless monitoring and reporting provides clearly documented information that is also made available for scrutiny. However, there appear to be no long-term plans for monitoring control interventions in terms of how they reduce biological invasions and their negative impacts, and it is unclear how the collection and reporting of accurate monitoring data is incentivised or penalised if it is not forthcoming. Moreover, while there are several research projects designed to assess the impact of particular policies, these are mostly still in the early stages. A systemic focus on monitoring and evaluation across the board would help both to demonstrate the impact of interventions and to increase the efficacy of the interventions themselves. Good data on monitoring costs money, but is a prerequisite for effective adaptive management, and, particularly in the light of the judicious use of new technologies, such monitoring would provide significant returns on investment.

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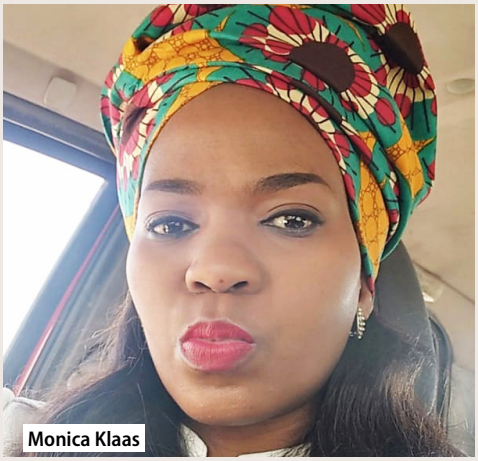
Siyasanga Miza



Monica Klaas

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guttural toad (*Sclerophrys gutturalis*) - N. Telford

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LINKS TO APPENDICES AND SUPPLEMENTARY MATERIAL

Pacific barnacle (*Balanus glandula*) - T. Robinson

- Appendix 1. List of data sources used: http://dx.doi.org/10.5281/zenodo.3947603
- Appendix 2. The species list: http://dx.doi.org/10.5281/zenodo.3947659
- Appendix 3. Data on the status of pathways: http://dx.doi.org/10.5281/zenodo.3947666
- Appendix 4. Species list change tracker: http://dx.doi.org/10.5281/zenodo.3947778
- Appendix 5. Pathways change tracker: http://dx.doi.org/10.5281/zenodo.3947799
- Appendix 6. Permit database: http://dx.doi.org/10.5281/zenodo.3947810
- Supplementary material. Additional information chapter by chapter on the methods used, discussion points, and tables and figures: http://dx.doi.org/10.5281/zenodo.3947817

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Biological invasions are a major threat to South Africa's biodiversity, economy, and sustainable development. This report is a part of South Africa's commitment to alleviating these impacts. It is a comprehensive national-scale assessment with contributions from 36 experts from 16 institutions. Drafts of the report were available for comment in two substantive rounds of review, with over 350 comments received from 17 institutions. This report is unique in the world in focussing specifically on invasions and is an important part of South Africa's global leading position on the issue (the government invests over 1 billion ZAR per year to deal with the problem). The report is based around a suite of 20 indicators that provide details on: 1) how alien species are introduced and move around the country; 2) the status and impacts of 1880 alien species of which 776 are invasive; 3) the degree to which sites are invaded and impacted; and 4) the effectiveness of the full range of interventions that South Africa has used to address the problem. This report provides valuable insights into how South Africa can reduce the negative impacts of biological invasions on ecosystems, the economy, and people while retaining the benefits alien species provide where this is possible and desirable. It collates foundational information essential for researchers of the topic and provides an assessment of interventions that is vital for policy makers and managers.

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