2022

The status of biological invasions and their management in South Africa in 2022






SANBI
Biodiversity for Life
South African National Biodiversity Institute

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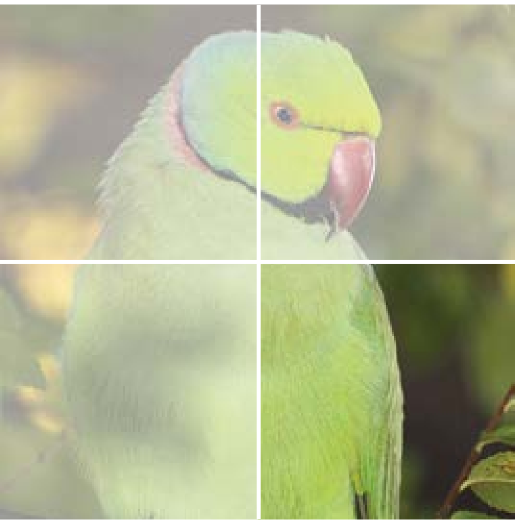

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Biodiversity for Life
South African National Biodiversity Institute

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Foreword by the Minister of Forestry, Fisheries and the Environment

Ms Barbara Creecy, MP

Biological invasions are a significant and growing threat to South Africa's natural, agricultural and urban ecosystems, as well as human livelihoods. Given the importance of these invasions, it is vital for us to regularly assess their status, as well as the effectiveness of our initiatives to respond to the problem. The South African National Biodiversity Institute has taken the lead in producing these reports, with support from a wide range of entities within national, provincial and local government, as well as the private sector. South Africa can take pride in the fact that it is the only country globally that regularly reports on the threat of biological invasions, and their management at a national level. In addition, my department provides substantial support to both state and private landowners to assist them with the management of invasive alien species, while also creating much-needed employment opportunities through the Expanded Public Works Programme that funds the Working for Water Programme. South Africa has demonstrated that we can achieve biodiversity outcomes by managing the threats of alien and invasive species, while at the same time creating much-needed jobs.

The report on the status of biological invasions and their management in South Africa is published following the launch in September 2023 by IPBES of the first comprehensive global assessment, the *Thematic assessment report on invasive alien species and their control*. The timing of this publication strategically positions South Africa to learn from the IPBES process, and to support the implementation of the Kunming-Montreal Global Biodiversity Framework and the Sustainable Development Goals.

The findings of this report paint a sobering picture. South Africa is confronted with a multitude of invasive species that have taken root in our ecosystems, altering native habitats, outcompeting indigenous species, and disrupting essential ecological processes. These invaders, introduced through human activities such as trade and travel, have demonstrated their ability to spread rapidly and wreak havoc on our fragile ecosystems.

It is essential to recognise that the impacts of biological invasions extend beyond the realm of biodiversity alone. They have far-reaching consequences on our economy, agriculture, water resources and public health. Invasive species can devastate agricultural lands, leading to reduced crop yields and increased production costs. They can also impair water quality, clog waterways and impact on our ability to access clean drinking water. Additionally, some invasive species pose risks to human health by acting as carriers of diseases or causing allergic reactions.

Addressing the challenges posed by biological invasions requires a coordinated and collaborative effort. No single entity can tackle this issue alone. Governments, scientists, civil society organisations, communities and individuals must come together, pooling their knowledge, resources and expertise to develop effective prevention, early detection and control strategies.

Fortunately, this report also highlights the progress we have made in managing biological invasions. South Africa has recently revised regulations pertaining to the management of biological invasions. We have supported numerous research institutions and networks dedicated to studying invasive species and developing innovative management techniques. Moreover, our partnerships with international organisations and neighbouring countries have strengthened our collective ability to combat this shared threat.

There is, however, still much work to be done. We must enhance our efforts to prevent the introduction of new invasive species through vigilance at our borders and risk analyses. Early detection and rapid response systems should be strengthened to identify and eradicate invaders before they become established. We must continue investing in research and innovation, supporting studies that enhance our understanding of invasive species dynamics and develop effective management strategies.

The national status report on biological invasions serves as a clarion call for action. It reminds us of the urgency of the situation and the imperative to act decisively. By working together, we can protect our natural heritage, restore damaged ecosystems and secure a sustainable future for South Africa.

As the Minister responsible for environmental stewardship, I urge all stakeholders to embrace the findings of this report. Let us unite in our resolve to address the challenges of biological invasions, ensuring that South Africa remains a beacon of biodiversity and a sanctuary for our precious indigenous plants, animals and ecosystems that support sustainable development and human wellbeing.

Together, we can make a difference.

Acacia longifolia (© Krzysztof Ziarnek).

Preface by the Chair of the Board of the South African National Biodiversity Institute

Prof. Edward Nesamvuni

Biological invasions pose a significant threat to our planet's ecosystems, biodiversity and human well-being. As the Chairperson of the South African National Biodiversity Institute (SANBI) Board, it is my pleasure to present to you this status report on biological invasions in South Africa. As with other parts of the world, we are grappling with the far-reaching consequences of the unprecedented scale and rate of species introductions and spread.

At SANBI, we recognise the vital role that biodiversity plays in supporting the functioning of ecosystems, providing essential services and contributing to human livelihoods. However, the ongoing expansion of human activities, including international trade and travel, has both intentionally and accidentally facilitated the movement of species across borders. Many of these alien species go on to become invasive, causing ecological imbalances and displacing native flora and fauna.

This report serves as an update of the current state of biological invasions in South Africa, following on from two previous reports produced at three-year intervals. It examines the drivers behind invasions, assesses their ecological and economic impacts, and highlights the critical efforts undertaken to mitigate their effects. It is our hope that this report will raise awareness, foster understanding, and catalyse action to address this urgent issue.

The findings within this report reveal the sobering reality of the challenges we face. Invasive species continue to be introduced and spread, jeopardising the integrity of ecosystems and threatening the survival of native species. From terrestrial habitats to freshwater systems and marine environments, no ecosystem has remained untouched. The economic costs associated with invasions are considerable, and they impact negatively on agriculture, forestry, fisheries and tourism, as well as on infrastructure, human health and safety.

Despite the concerning situation, there has been some progress. The report describes successful interventions, showcasing the power of collaboration, research and public engagement in addressing biological invasions. It underscores the importance of proactive management to prevent and control invasions.

Our ability to deal with biological invasions will require a collective effort, involving governments, scientific institutions, civil society and individuals alike. We must prioritise the conservation of our native biodiversity and work towards building resilience in the face of these threats. The SANBI Board remains committed to advancing the understanding of biological invasions by supporting innovative research and guiding policy development to protect and restore our natural heritage. SANBI continues to play a leading role in providing evidence through science and demonstration to inform policy, decision-making and management of biological invasions. This is in line with the Alien and Invasive Species-related strategy and frameworks, as well as the defined mandate of SANBI. Continued investment in research and human capital investment has positioned SANBI as a global leader in responding to challenges posed by biological invasions.

I would like to extend my gratitude to the researchers, experts and individuals who have contributed to the production of this report. Your dedication and passion for preserving our ecosystems inspires us all. I invite you to delve into the pages of this report, digest its findings, and join us in the ongoing mission to combat biological invasions. Together, we can make a difference and secure a sustainable future for generations to come.

Tecoma stans (© John Robert McPherson).

Preface by the Chief Executive Officer of the South African National Biodiversity Institute

Mr Shonisani (Shoni) Munzhedzi

It is my pleasure to present the third national status report on biological invasions and their management in South Africa. The South African National Biodiversity Institute (SANBI) is required to prepare these reports in terms of the National Environmental Management: Biodiversity Act every three years. Biological invasions are one of the key threats to biodiversity loss as indicated in the National Biodiversity Assessment and the IPBES global biodiversity assessment. SANBI will continue to invest, with the support of the DFFE, in internal capacity for generating evidence to support policy, decision-making and management. The status report is an important monitoring tool that provides up-to-date assessments of the status of biological invasions and their management. Biological invasions are an important component of global change, and are not only a significant threat to South Africa's remarkable biodiversity, but they also have a negative impact on our ecosystem services, livelihoods, health and safety. Biological invasions reduce scarce water resources, decrease the carrying capacity of rangelands, and increase the risk of damaging wildfires. For example, the economic cost of the recent introduction of a single invasive alien insect species and its fungal symbiont was recently estimated at ZAR 350 billion, equivalent to 0.66% of the country's GDP. This underscores both the severe economic impact that invasive alien species can have, and the imperative to manage them as effectively as possible.

The report shows that new (and potentially invasive) alien species continue to arrive in the country, and while the exact number of species that are present remains unknown, we have made significant progress towards the compilation of a detailed list of all alien species present in the country. This list provides a valuable baseline against which the status of biological invasions and the effectiveness of control measures can be continually assessed. For the first time, this report provides a separate assessment of the status of biological invasions and their management on the Prince Edward Islands. Although these islands are part of South Africa, their remote location and unique biodiversity warrant a separate assessment. While significant challenges to the effective management of biological invasions remain, there has been progress in reducing the threats in many areas through interventions funded by both government and private sector.

I would like to thank the Honourable Minister of Forestry, Fisheries and the Environment, Ms Barbara Creecy, for her confidence

in, and backing given to SANBI to carry out this work. I am also grateful to the SANBI Board Chair, Prof. Edward Nesamvuni, and the entire board for their ongoing support in matters related to this report, as well as to the Reference and Advisory Panel, chaired by Ms Kay Montgomery, for ongoing guidance. The degree to which we are able to report on the status of biological invasions has also been dependent on inputs from many organisations and people employed in the biodiversity sector in South Africa, and to whom I extend my grateful thanks.

Opuntia stricta (© Ben Tavener).

List of acronyms[1]

ASRARP .... Alien Species Risk Analysis Review Panel
A&IS .... Alien and Invasive Species as referred to either in the NEM:BA A&IS Regulations or the NEM:BA A&IS Lists published under the regulations
BMA.............. Border Management Authority
CBD .... the Convention on Biological Diversity of the United Nations
CIB .... the Department of Science and Innovation–National Research Foundation (DSI–NRF) Centre of Excellence for Invasion Biology
DALRRD.......... the Department of Agriculture, Land Reform and Rural Development
DFFE .... the Department of Forestry, Fisheries and the Environment
ECO .... Environmental Control Officers, in this report it is used specifically with relevance to staff working on the Prince Edward Islands
EICAT .... the International Union for Conservation of Nature (IUCN)'s Environmental Impact Classification for Alien Taxa
GBF .... the Kunming-Montreal Global Biodiversity Framework of the CBD
hmgc............. half-minute grid cell (used for mapping on the Prince Edward Islands)
InvaCost .... a database of estimates of the damage and management costs associated with invasive species from around the world
IPBES .... Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
NEM:BA .... the National Environmental Management: Biodiversity Act (Act No. 10 of 2004)
NEM:BA A&IS: ... see **A&IS**
PEIs .... the Prince Edward Islands, a collective term for South Africa's sub-Antarctic territories – Marion Island and the Prince Edward Island (note: the acronym PEI refers exclusively to the Prince Edward Island and so does not include Marion Island)
qdgc .... quarter-degree grid cell
RAC .... the Reference and Advisory Committee (of this third status report)
SANBI .... the South African National Biodiversity Institute
SAPIA .... the Southern African Plant Invaders Atlas
SEICAT .... Socio-Economic Impact Classification for Alien Taxa
sTWIST........... a working group on 'Theory and Workflows for Alien and Invasive Species Tracking'
WfW .... Working for Water
ZAR .... South African Rands

[1]These acronyms are used either in this report or in the supplementary material. For editorial conventions see Supplementary Material S0.1.

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.

biodiversity: the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems, and the ecological complexes they are part of; 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 invasions** affect all regions and **biomes** of the world, including marine, terrestrial and freshwater environments.

biological control (syn. **biocontrol**): the use of specimens of one species for the purpose of preying on, parasitising 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.

compliance: the action or fact of complying with instructions, in this report such instructions primarily refer to the provisions of the NEM:BA.

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, regrowth, multiplication, propagation, regeneration or spreading of an **alien species**.

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

dispersal (syn. **spread**): movement of organisms naturally or that is facilitated either intentionally or accidentally by humans.

distribution: the **extent** and **abundance** of a species in a specified **site**.

eradication: the complete removal of all individuals and propagules of an **alien species** from a specified **site** to which there is a negligible likelihood of reinvasion (for the purposes of this report the **site** is either continental South Africa or the Prince Edward Islands). If there is a likelihood of reinvasion or that possibility was not explicitly assessed the term extirpation would be preferred, in such cases other populations might be close by or pathways of introduction and dispersal are still operating such that the probability of reinvasion is probable or not known.

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.

[1]These definitions are based on those in the second report, Richardson et al. (2010), Wilson et al. (2017) and Van Wilgen et al. (2020), with consideration of definitions given in relevant South African and international legislation, specifically the NEM:BA and its A&IS Regulations, and the CBD (https://www.cbd.int/invasive/terms.shtml). These cover terms used in this third report and in the supplementary material to the third report. For editorial conventions see Supplementary Material S0.1.

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**.

extralimital: see **native-alien populations**

impact: the effect of an **alien species** on the physical, chemical and biological environment. Impact 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**. In general, the **management** of incursions is referred to as incursion response.

indicator: a set of measurements that give specific information about the state of something.

interventions: the full variety of actions taken in response to biological invasions, including direct actions, e.g., **control** and indirect actions, e.g., **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 that 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'.

introduction pathway prominence: an indicator used to assess the status of **introduction pathways**. The indicator assesses the introduction opportunities that are available for alien organisms to be introduced to a country from other regions. The indicator considers introduction opportunities in terms of how socioeconomically active the pathways are (e.g., amount of ballast water released), rather than how many organisms are introduced through a pathway.

invasion: see **biological invasions**.

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. **Invasive species** can be plants, animals, fungi or micro-organisms, and are found across the world throughout freshwater, marine and terrestrial environments.

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-alien populations (syn. **extralimital**; cf. **alien species**, **native species**): a population of a taxon that is native to a part of South Africa, but that was founded by individuals moved by direct human agency, over a biogeographical barrier, to an area beyond the species' native range (i.e., it can be considered a biological invasions) (see Box 2.1). This does not include **native species** that have extended their distribution by **natural dispersal**.

native species (syn. indigenous species, cf. **alien species**, **native-alien population**): 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 (syn. **unaided**): the **dispersal** of an **alien species** through natural spread from a region where it was previously introduced through direct human agency to another region where it is not native. Includes both self-propelled movement and movement with natural biotic (e.g., birds) and abiotic (e.g., wind or water) vectors.

pathway (cf. **vector**): 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. Includes the cause or reason why the organism is transported, the route along which it is transported and the **vector** that carries the organism.

permit: an official document issued in terms of Chapter 7 of the NEM:BA.

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 or pathogens.

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.

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.

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 report the event is a **biological invasion**.

risk analysis: the process of identifying and assessing the likelihood and consequence of an event (i.e., risk assessment), as well as considerations as to how to manage and communicate the **risk**.

risk assessment: a component of **risk analysis** that focuses on evaluating the likelihood and consequence of an event taking place. In the context of this report, such an event is the likelihood of an **alien species** becoming an **invasive species** and the negative **impacts** that would result. Note in the 2020 **NEM:BA A&IS Regulations** the term **risk assessment** is used as a synonym for **risk analysis**, i.e., risk management considerations are included.

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**

status: the state, condition or stage of affairs at a particular time.

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.

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

taxon (pl. **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).

unaided: 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.

vector (cf. **pathway**): the physical means or agent that transports the alien species. Can be both human mediated (e.g., ballast water, clothing, animal feed or land vehicles) or natural (e.g., wind, water, birds).

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 of key messages[1]

Biological invasions are a major threat to South Africa's water security, exacerbate fires, threaten sustainable agriculture, and are having ongoing major negative impacts on South Africa's unique and globally important biodiversity. This phenomenon is not unique to South Africa or to any one part of the country, and thus addressing biological invasions requires integrated governance from international to local levels. Of immediate concern, however, is that the number of alien species is increasing, the area invaded is growing, but South Africa's response has been declining.

These issues are addressed in detail in this report *The status of biological invasions and their management in South Africa in 2022*. The key messages from this report are summarised here in the form of a single headline followed by explanatory text with cross-references (in curly brackets) to the relevant sections of the report. Each statement is also ascribed one of four confidence levels (*inconclusive*, *unresolved*, *established but incomplete* and *well established*) as per the guidelines of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (see the Introduction Chapter for further details).

The messages are grouped around five themes with corresponding indicators for each theme: A) how alien species are introduced and move around the country ('pathways'); B) the status and impacts of alien species ('species'); C) how sites are invaded and impacted ('sites'); D) what has been done to address the problem ('interventions'); and E) the status and management of invasions on the Prince Edward Islands (PEIs), South Africa's sub-Antarctic territories. These messages are specifically intended to help gauge progress with management and advise those tasked with developing policy responses, though the messages should also provide useful general insights to all those interested and affected by biological invasions.

[1]This summary of key-messages is produced as part of fulfilling SANBI's mandate under the NEM:BA (Act 10 of 2004) and its A&IS Regulations of 2020 to submit a report on the status of invasive species and the effectiveness of measures to combat them to the Minister of Forestry, Fisheries and the Environment every three years. This is the third such report and presents an update on issues identified in the first and second reports. This summary will be available both as a stand-alone document and as part of the full report. For citations to this summary please cite the full report: SANBI and CIB 2023. The status of biological invasions and their management in South Africa in 2022. South African National Biodiversity Institute, Kirstenbosch and DSI-NRF Centre of Excellence for Invasion Biology, Stellenbosch. pp. 122. http://dx.doi.org/10.5281/zenodo.8217182.

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Table of key messages

A1: New alien species continue to arrive in South Africa every year through several different pathways.

A2: Native and alien species are spread by humans around South Africa.

A3: Intentional legal introductions are well regulated; the new National Border Management Authority promises to improve the prevention of illegal and accidental introductions.

B1: The process of documenting alien species in the country has been substantially improved and is now transparent; this will facilitate management and regulatory decisions.

B2: Knowledge of the distribution of alien species has been improved by citizen science and the digitisation of historical records; structured surveillance remains essential to inform management and track trends.

B3: Invasive species, in particular trees and freshwater fishes, have 'Major' negative impacts on people and nature across the country.

C1: Invasions are distributed across the country including in protected areas.

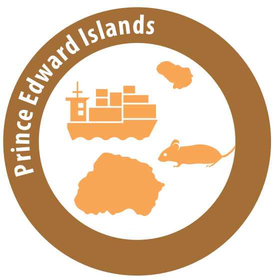
C2: The impact of invasions on water resources, rangeland productivity and biodiversity are severe; improved workflows to track these impacts are vital for prioritising interventions.

D1: The South African government invested over 1.5 billion Rand to address biological invasions 2020–2022; although this investment has declined recently, there are several major privately funded initiatives.

D2: South Africa has an innovative regulatory system to address biological invasions; this has been revised and decisions are now more directly informed by the available scientific evidence.

D3: Biological invasions have been successfully managed in some cases, particularly through biological control; planning and monitoring is needed for these successes to be replicated.

D4: With judicious investment and integrated governance the impact of invasions on South African society can be reduced.



E1: Invasive species are devastating the unique and sensitive biodiversity of the Prince Edward Islands.

E2: Biological invasions are being addressed through effective biosecurity and on-island management. These processes could be strengthened by focussing on regulations and planning specific to the Prince Edward Islands.

E3: Bold plans to eradicate the house mouse promise to save Marion Island's seabirds.

Robinia pseudoacacia (© Agnieszka Kwiecień).

A) How alien species are introduced and move around the country

Head-line indicator	Trend	Confidence	Notes
1. Rate of introduction of new unregulated species	→	low	Over the last decade (2013–2022) approximately three new taxa were introduced per year either accidentally or intentionally but illegally. This is similar to previous estimates.

Indicator	Trend	Confidence
1.1 Introduction pathway prominence	→	medium
1.2 Introduction rates	→	low
1.3 Within-country pathway prominence	not assessed	
1.4 Within-country dispersal rates	not assessed	

→ no change; ↗ an increase; ↘ a decrease.

A1: New alien species continue to arrive every year in South Africa through several different pathways

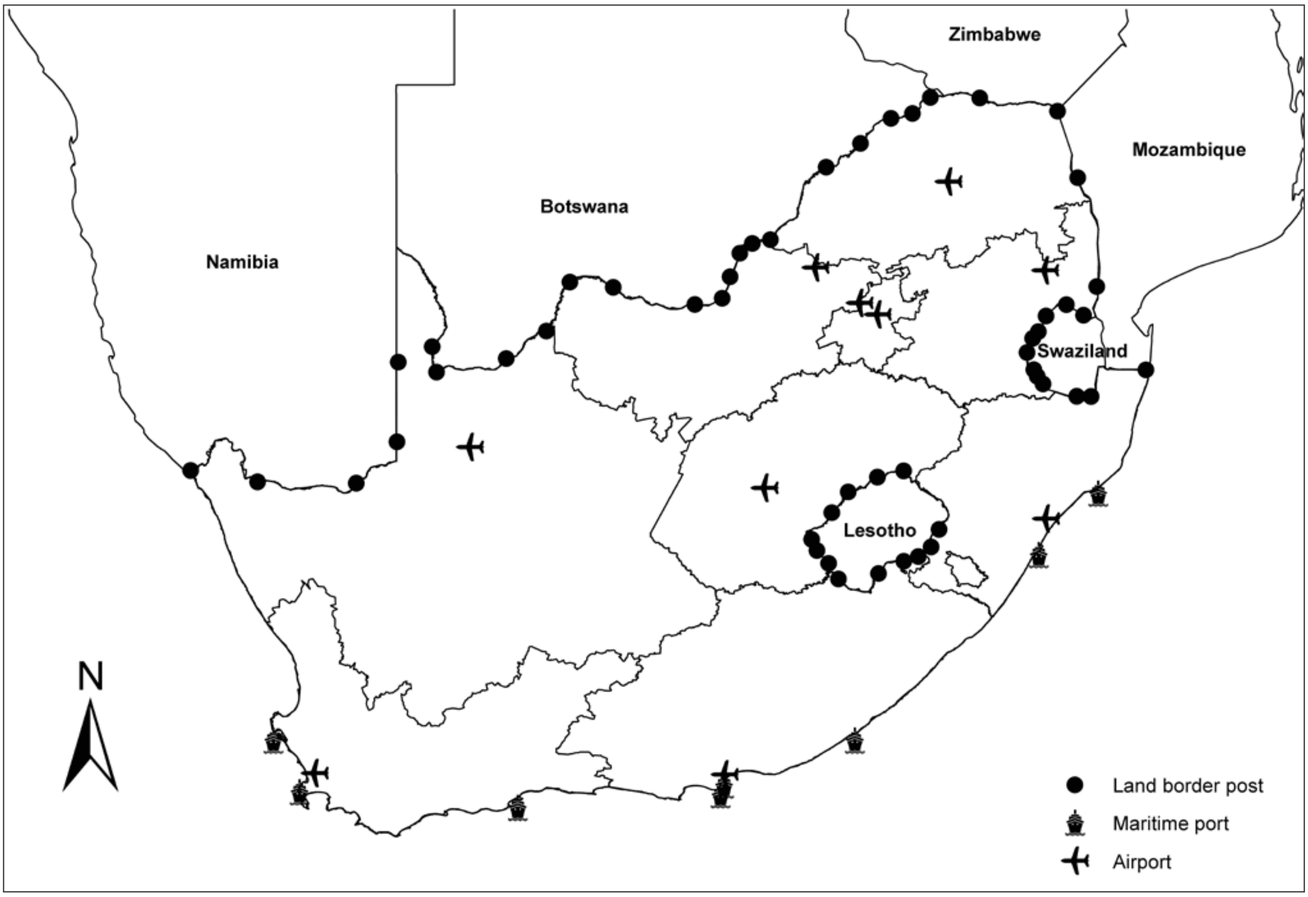
New alien species continue to arrive every year in South Africa (*well established*) {1.1, 1.2}, with the rate of their introduction remaining stable at around three species per year (*established but incomplete*) {1.1, 1.2}. These species have been introduced in various ways including accidentally as contaminants of nursery material, for horticulture, and through a tightly regulated process for classical biological control (*established but incomplete*) {1.2}. While biocontrol agents have often significantly reduced the negative impacts of invasions (*well established*) {4.8}, other new alien species are adding to the range, complexity and intensity of the negative impacts caused (*established but incomplete*) {2}. For example, the fungus *Seiridium neocupressi*, which causes the disease cypress canker, was first recorded in South Africa in 2021 on native trees [*Widdringtonia nodiflora* (mountain cypress)] (*well established*) {1.2}. The opportunities for invasive species to arrive are expected to increase as the volume of trade and travel increases; appropriate biosecurity can ensure such trade is sustainable.

A2: Native and alien species are spread by humans around South Africa

Alien species are being moved around the country (*well established*) {1.3, 1.4}. For example, species have been introduced to protected areas accidentally on visitors' shoes and vehicles (*established but incomplete*) {1.4}. Native species are also being moved and introduced to parts of the country where they are not native (*well established*) {1.4, Box 2.1}. At least 77 native species have formed 132 native-alien populations (*established but incomplete*) {1.4, Box 2.1}. Most of these native-alien populations are ornamental plants and mammals introduced to game farms, but accidental introductions are also occurring, particularly with transported plants and their products (*established but incomplete*) {1.4}. Preventing both native-alien populations and the further spread of existing alien species will require a greater focus on tracking and managing species movements within the country.

A3: Intentional legal introductions are well regulated; the new national Border Management Authority promises to improve the prevention of illegal and accidental introductions

All legal introductions of new alien taxa require import permits, with permits issued only if the risks are demonstrated to be sufficiently low (*well established*) {4.1}. Illegal and accidental introductions are, however, continuing (*established but incomplete*) {1.2}. For example, phytosanitary inspections of agricultural goods regularly intercept alien species not known to be present in the country {4.7}. Trade and travel controls put in place to prevent the spread of COVID-19 caused a temporary decline in introduction opportunities, but these are returning to pre-pandemic levels (*established but incomplete*) {1.1}. A major development to improve the integrated governance of South Africa's biosecurity was the establishment of the national Border Management Authority (BMA) in 2020, that became fully operational in 2023. The BMA promises to improve the prevention of illegal and accidental introductions.



South Africa's 72 official ports of entry (see Section S1.3).

B) The status and impacts of alien species

Head-line indicator	Trend	Confidence	Notes
2. Number of invasive species that have 'Major' impacts	↗	low (many taxa still need to be assessed)	The impact of 36 invasive species has been assessed using the methodology of the IUCN's EICAT scheme. Of these, 19 are reported to cause 'Major' or 'Massive' impacts in mainland South Africa.

Indicator	Trend	Confidence
2.1 Number and status of alien species	↗	high
2.2 Extent of alien species	→	medium
2.3 Abundance of alien species	not assessed	
2.4 Impact of alien species	↗	medium

→ no change; ↗ an increase; ↘ a decrease.

B1: The process of documenting alien species in the country has been substantially improved and is now transparent; this will facilitate management and regulatory decisions

There has been significant progress in collating a list of alien species in the country, with information, where available, on their distributions, impacts and management (*established but incomplete*) {2, 4.1, 4.5, 4.8}. The development of documented and repeatable workflows ensures it is clear why species are included on the list and facilitates updates to the list (*established but incomplete*) {Appendix 4}. To date the list includes records of over 3 500 alien species present outside of captivity or cultivation in South Africa, at least a third of which are recorded as invasive (*established but incomplete*) {2.1}. As data are captured and collated these numbers will increase: key sources still need to be verified and integrated into the list (particularly species in cultivation); and many alien species are yet to be detected and documented. A comprehensive list will facilitate tracking the **number and status of alien species** over time, feeding into management planning and facilitating regulatory decisions.

B2: Knowledge of the distribution of alien species has been improved by citizen science and the digitisation of historical records; structured surveillance remains essential to inform management and track trends

Citizen science platforms have increased knowledge of the distribution of some alien species and increased community engagement with issues around invasive species (*established but incomplete*) {2.2}. The digitisation of historical records, for example through the National Collections Facility and by the Freshwater Biodiversity Information System, means that field observations and records of physical specimens can be accessed through national and international databases (*well established*) {2.1}. A hiatus in the Southern African Plant Invaders Atlas (SAPIA) has inhibited the ability to track plant invasions across South Africa. Ensuring the long-term sustainability of structured surveillance efforts and integrating these with historical data and citizen science observations will support management planning and facilitate regulatory decisions.

B3: Invasive species, in particular trees and freshwater fishes, have 'Major' negative impacts on people and nature across the country

The negative impacts of invasive species on biodiversity and people's livelihoods are known to be substantial (*established but incomplete*) {2.4}. Eleven (11) tree or shrub species, five fish species, two grass species and one invertebrate species have been assessed to cause 'Major' or 'Massive' negative impacts at a national level (*established but incomplete*) {2.4}. This number is based on 36 assessments using the IUCN's Environmental Impact Classification for Alien Taxa (EICAT) methodology. The need for more studies and assessments on the impact of invasive species has been highlighted as a research priority for South Africa. The development and implementation of country-level species-specific management strategies informed by impact assessments would help protect biodiversity and ensure that ecosystem services essential to human wellbeing are maintained.



Examples of alien species with 'Major' impacts in South Africa (see Section 2.4). Photographs (from left to right): *Acacia saligna* (© Suzaan Kritzinger-Klopper); *Lantana camara* (© Juan Carlos Fonseca Mata); *Micropterus salmoides* (© Marnus Erasmus).

C) How sites are invaded and impacted

Head-line indicator	Trend	Confidence	Notes
3. Extent of area that suffers ‘Major’ impacts from invasions	not reassessed		Biological invasions continue to cause major impacts on biodiversity, ecosystem services and human livelihoods by reducing South Africa’s water resources, degrading pasturelands and exacerbating fires. These estimates, however, need to be updated and regularly revised. Ongoing work includes the development of systematic processes for evaluating impact studies and workflows that link to other biodiversity assessments and previous studies.

Indicator	Trend	Confidence
3.1 Alien species richness	↗	low
3.2 Relative invasive abundance	→	low
3.3 Impact of invasions	not reassessed	

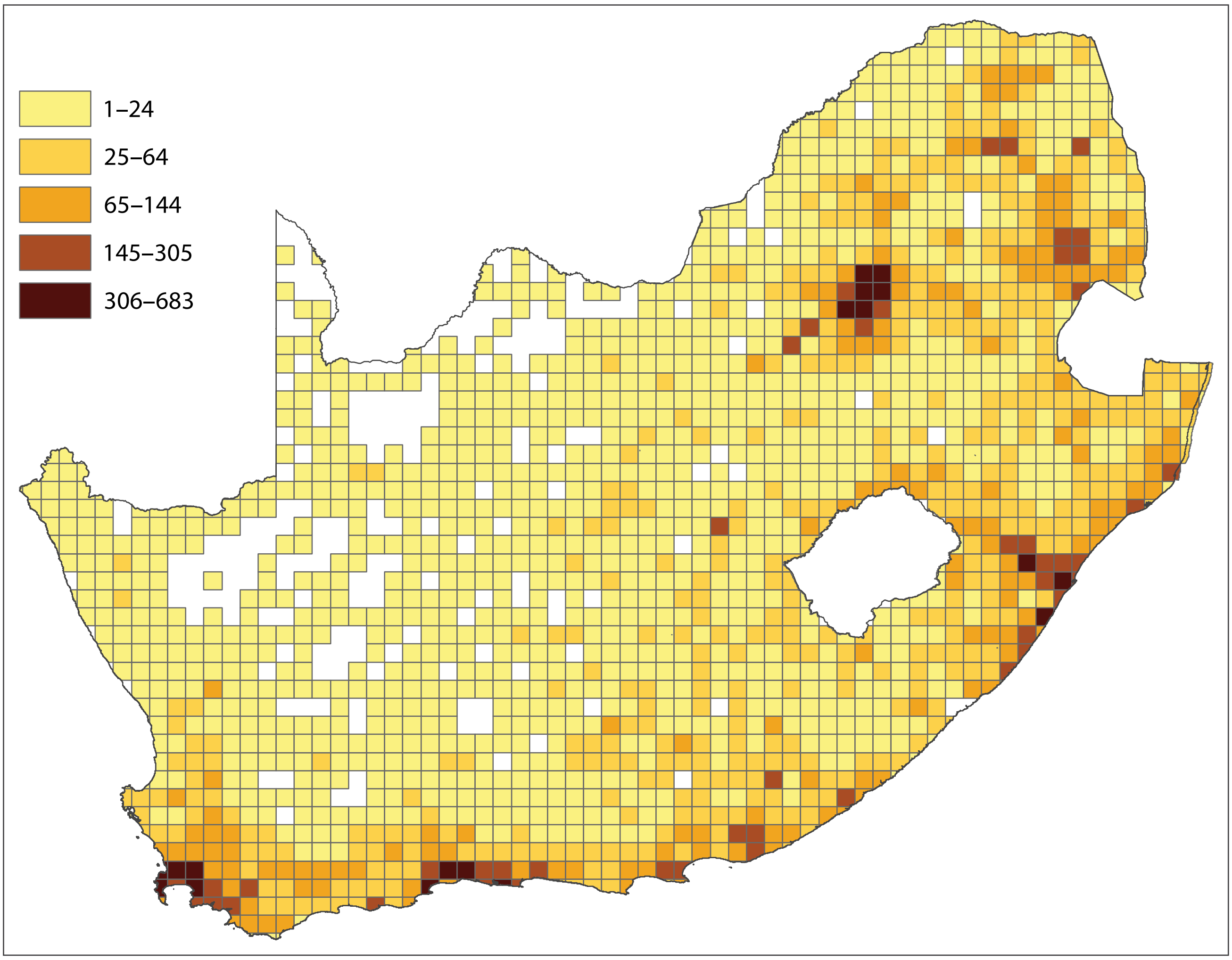
→ no change; ↗ an increase; ↘ a decrease.

C1: Invasions are distributed across the country including in protected areas

Invasive species are distributed across the country, with most broad-scale administrative units and biogeographical regions being invaded by a variety of taxa (*established but incomplete*) {3.1}. Most alien species are found in the Western Cape, Eastern Cape, and KwaZulu-Natal (*established but incomplete*) {3.1}, and around major urban centres (*established but incomplete*) {3.1}. This is likely because some species are commensal with humans, most were first introduced to urban centres, and because of greater sampling around urban areas (in particular there has been a rapid, recent increase in observations from citizen scientist platforms such iNaturalist) (*established but incomplete*) {3.1}. Robust and reliable monitoring systems that consistently track the distribution and abundance of alien species across the country are, however, lacking. This means that the extent of invasions and the effectiveness of interventions cannot be assessed with a high degree of certainty. 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. All protected area complexes are invaded to some degree (*well established*) {3.1}, with estimates of relative invasive abundance ranging from minor to extensive (no large recent changes have been noted) (*established but incomplete*) {3.1}. Over 700 invasive terrestrial and freshwater species (excluding biological control agents) are reported to occur across protected areas managed by SANParks and CapeNature (*well established*) {3.1}, with a few protected areas reporting particularly high numbers of invasive species (*well established*) {3.2}.

C2: The impact of invasions on water resources, rangeland productivity and biodiversity are severe; improved workflows to track these impacts are vital for prioritising interventions

A handful of influential historical studies have indicated the severe impacts of invasions on water resources, rangeland productivity and biodiversity. These studies showed that: i) invasive trees use 3–5% of South Africa's surface water run-off each year; ii) invasive plants reduce the value of livestock production from natural rangelands by ZAR 340 million per year; and iii) biological invasions are responsible for 25% of all biodiversity loss, placing them as the largest impact to South Africa's biodiversity after cultivation and land degradation (*established but incomplete*) {3.3}. These negative impacts have not recently been reassessed, and workflows are required to improve the applicability and repeatability of the methods. Systematically quantifying and monitoring impacts on sites would facilitate the prioritisation of interventions; provide the justification for government investment to control biological invasions; and provide important background to communicate the severity of the issue to society.



Alien plant species richness across South Africa (see Section 3.1).

D) What has been done to address the problem

Head-line indicator	Trend	Confidence	Notes
4. Level of success in managing invasions	not assessed		This indicator cannot be calculated as there are very few data on the effectiveness of control of invasions at specific sites.

Indicator	Trend	Confidence
4.1. Quality of regulatory framework	→	medium
4.2. Money spent	↘	low
4.3. Planning coverage	→	medium
4.4. Pathways treated	→	low
4.5. Species treated	→	low
4.6. Sites treated	not assessed	
4.7. Effectiveness of pathway treatments	→	low
4.8. Effectiveness of species treatments	→	low
4.9. Effectiveness of site treatments	not assessed	

→ no change; ↗ an increase; ↘ a decrease.

D1: The South African government invested over 1.5 billion Rand to address biological invasions 2020–2022; although this investment has declined recently, there are several major privately funded initiatives

Much of the spending on managing biological invasions is not systematically recorded (*established but incomplete*) {Box 3.1}. The data that are available indicate at least ZAR 1.5 billion has been invested to manage biological invasions over the period 2020–2022 (*established but incomplete*) {4.2}. About 72% of this funding has been directed towards priority areas, including Strategic Water Source Areas, protected areas and biodiversity hotspots (*well established*) {4.6}. This national-scale management has created employment particularly in rural areas (*well established*) {4.9}. However, the money spent by government has declined since 2015 (*established but incomplete*) {4.2}. NGOs such as the Nature Conservancy and the World Wide Fund for Nature (South Africa) have raised over ZAR 180 million from the private sector to fund the control of invasive freshwater fishes and alien plants in the water catchments of Cape Town (*well established*) {Box 4.2}. This is a model that could be replicated across other catchments and could be facilitated and implemented in many other priority areas.

D2: South Africa has an innovative regulatory system to address biological invasions; this has been revised and decisions are now more directly informed by the available scientific evidence

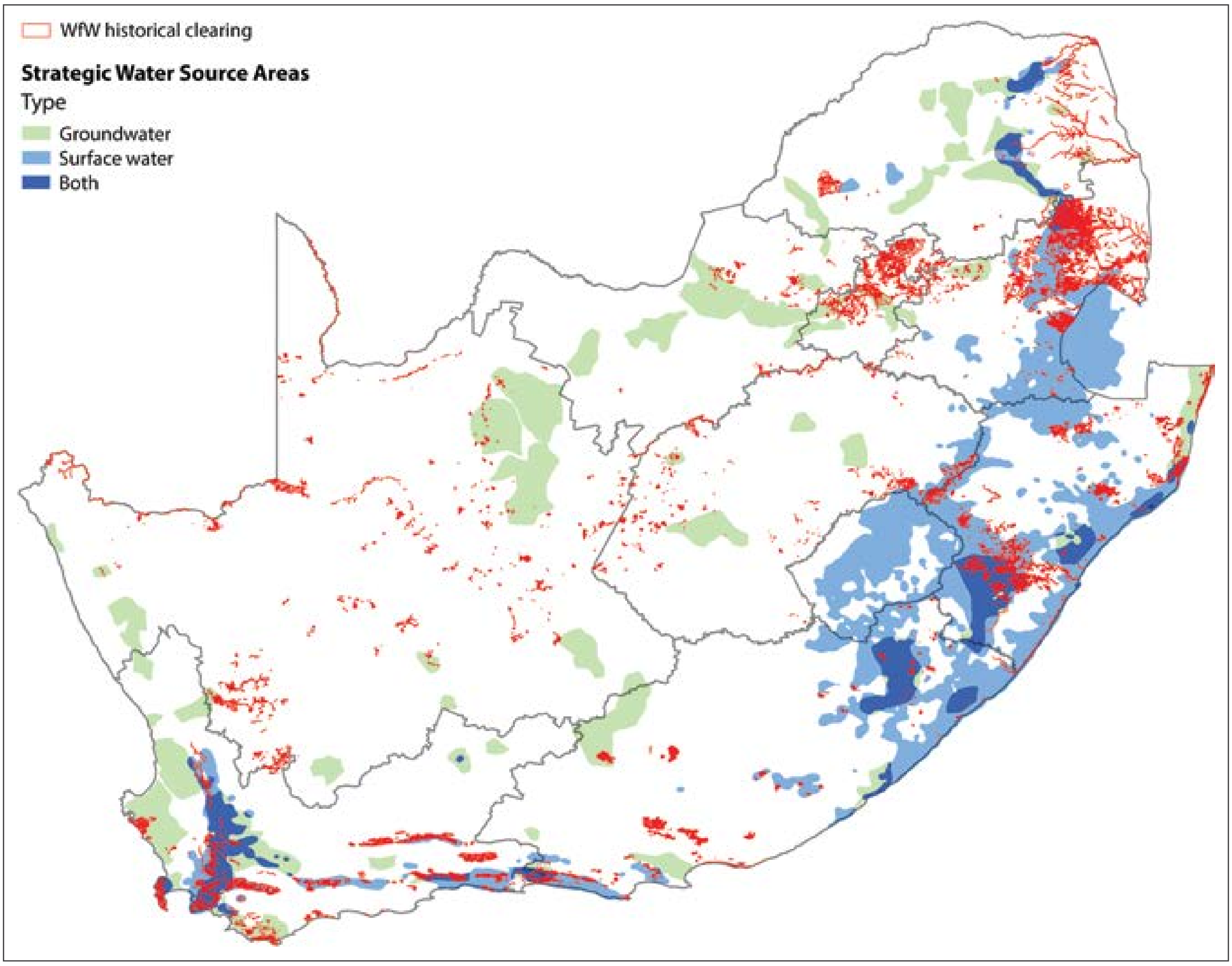
The National Environmental Management: Biodiversity Act's Alien and Invasive Species Regulations and Lists were revised in 2020 and came into effect in 2021. A process has been set up to ensure that regular, transparent changes informed by evidence can be made to the lists in future (*established but incomplete*) {4.1}. Monitoring the effectiveness of the regulations and engaging with stakeholders would help identify additional measures to improve the regulations and their acceptability.

D3: Biological invasions have been successfully managed in some cases, particularly through biological control; planning and monitoring is needed for these successes to be replicated

Invasive species have been brought under control in some cases (*established but incomplete*) {4.4–4.9}. In particular, investment into biological control of invasive species has resulted in at least 17 species being brought under permanent control and to reductions in many other invasions (*well established*) {4.8}. The limited success of other control efforts has been attributed to a lack of management plans with clear goals and the lack of monitoring of the outputs and outcomes of interventions in terms of their impact on biological invasions (*established but incomplete*) {4.3–4.9}. Existing management practices can be dramatically improved. Close collaboration between managers, planners and researchers (e.g., through working groups) are, and will likely continue to be, an important component of successful projects (*established but incomplete*) {4.10}.

D4: With judicious investment and integrated governance the impact of invasions on South African society can be reduced

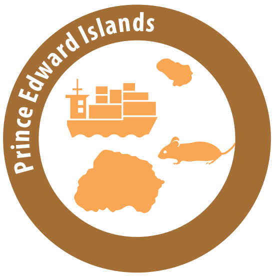
There have been several important recent developments at both national and international levels to evaluate and improve the management of biological invasions (*well established*) {Boxes 0.1, 0.2, 4.1, 6.6}. The Kunming-Montreal Global



Clearing of plant invasions (red) has focussed on Strategic Water Source Areas (blue, light blue and lighter green) (see Section 4.6).

Biodiversity Framework has set international goals to address biological invasions by 2030 and outlined a vision for 2050. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services' Invasive Alien Species Assessment has provided a strong foundation on how integrated governance can improve the response to biological invasions at local, national and regional levels. The White Paper on the 'Conservation and Sustainable Use of South Africa's Biodiversity' addresses part of the problems caused by biological invasions. A national strategy on biological invasions has been drafted for South Africa. And this status report provides a mechanism to integrate actions and help report on progress. Together these initiatives suggest that, with judicious investment and integrated governance, the impact of invasions on South African society can be reduced.

Solanum mauritianum (© Paul Venter).



E) The status and management of invasions in the Prince Edward Islands

Head-line indicator	Trend	Confidence	Notes
1. Rate of unregulated introduction of new species	→	medium	The rate of introduction has not changed in the last ten years.
2. Number of invasive species that have 'Major' impacts	→	medium	No new invasive species have been introduced to the islands recently, although existing invaders are spreading and their impacts might have increased.
3. Extent of area that suffers 'Major' impacts from invasions	↗	medium	Several alien species have not reached equilibrium with the environment across the Prince Edward Islands and are still spreading. Some of these have 'Major' impacts (e.g., *Sagina procumbens*).
4. Level of success in managing invasions	→	high	Some management actions have been successful, and species are being monitored to confirm eradication. The distribution of some other taxa has remained stable/been kept under control. However, a few taxa have increased in extent. So overall there is no change, and the level of success is partial.

→ no change; ↗ an increase; ↘ a decrease.

Foeniculum vulgare (© Wouter Hagens).

E1: Invasive species are devastating the unique and sensitive biodiversity of the Prince Edward Islands

Biological invasions are the main threat to biodiversity on the Prince Edward Islands (*well established*) {5.2.4}. Out of 44 alien species currently present on Marion Island, 26 are known to be invasive, one was found to cause 'Massive' environmental impacts [*Mus musculus* subsp. *domesticus* (the house mouse)], and three 'Major' environmental impacts [*Agrostis stolonifera* (creeping bent grass), *Festuca rubra* (creeping red fescue) and *Sagina procumbens* (birdeye pearlwort)] (*well established*) {5.2.1, 6.2.4}. There are eight alien species present on Prince Edward Island, all of which are invasive (*established but incomplete*) {5.2.1}. Assessments of impact and the degree of establishment of alien species on the islands are largely based on data from a decade ago or older (*well established*) {5.2.1, 5.2.4}, therefore improving these assessments will allow for better management prioritisation.

E2: Biological invasions are being addressed through effective biosecurity and on-island management. These processes could be strengthened by focussing on regulations and planning specific to the Prince Edward Islands

Introductions to the Prince Edward Islands have been dramatically reduced through the application of strict biosecurity measures (*established but incomplete*) {5.1.1, 5.4.3}. The only pathways along which alien species can still be introduced are as contaminants on goods (e.g., food, clothing and footwear) and as stowaways (e.g., on the ship or on items on the ship) (*well established*) {5.1.1}. Given that alien species continue to be introduced, understanding when and where these breaches happen will allow for further improvements to biosecurity (*established but incomplete*) {5.4.6}. Seven species are being actively managed on Marion Island using herbicide or mechanical control, and five species are being monitored to confirm eradication {5.4.1}. However, there is a mismatch between what is being managed and what is listed under national regulations. If management and regulatory decisions were fully ceded to the Prince Edward Islands Management Plan (with appropriate annual updates) it would likely cause fewer inconsistencies than trying to align management with national level processes and regulatory instruments (*unresolved*) {5.4.1}.

Cleaning of footwear on the SA Agulhas II before arrival at Marion Island (see Section 5.4.4). Photograph: © M. Nakwa.

E3: Bold plans to eradicate the house mouse promise to save Marion Island's seabirds

The house mouse is the most harmful alien species on Marion Island (*well established*) {5.2.4}. Mice feed on both adult and hatchling endangered seabirds (*well established*) {5.2.4}. Mice also eat many native invertebrates and plants and cause damage through burrowing (*well established*) {5.2.4}. Ultimately these impacts affect sediment movement rates, nutrient cycling and the integrity of the ecosystem as a whole (*established but incomplete*) {5.2.4}. A bold plan to eradicate the house mouse from Marion Island ('Mouse-Free Marion') is under development and is due to be implemented in 2025 if sufficient funding can be raised (*well established*) {5.4.3}. The eradication of mice from Marion Island is essential if the unique biodiversity of the island is to be preserved.

Eucalyptus grandis (© John Robert McPherson).

Introduction

Authors: John R. Wilson & Tsungai A. Zengeya

The significance of biological invasions to South Africa

Biological invasions are amongst the leading causes of global change – they have had profound negative impacts on people and nature for centuries; are currently a significant drain on South Africa's sustainable development and are negatively impacting native biodiversity; and pose a major threat to both the quality of life of future generations and the globally unique flora and fauna that are an integral part of this country (Pyšek et al. 2020; Van Wilgen et al. 2020). The problem is complicated and set to grow (Chapters 1 and 6). Invasive species come from many different taxa, invade different habitats, and cause various types of impacts, sometimes in ways which are not yet fully understood but that will have profound effects on the ability of ecosystems to deliver services to people (Chapters 3, 4 and 6; Van Wilgen et al. 2020).

Thankfully, significant progress has been made in reducing impacts and preventing new invasions (Chapter 4). Targeted interventions can be highly cost-effective, and so, whilst interventions can be complicated and costly, by working together as a society we can protect our biodiversity and natural capital from biological invasions. The nature of the impacts and the types of responses needed means that biological invasions are a significant cross-cutting issue for South Africa that is managed by a range of stakeholders using a variety of approaches.

South Africa's regulatory framework regarding biological invasions and the specific mandate for the third status report

The specific mandate for the status report originally arose from Section 11 of the National Environmental Management: Biodiversity Act, which stated:

11. (1) The Institute[1]—
(a) must monitor and report regularly to the Minister on-...
(iii) the status of all listed invasive species;

This requirement was elaborated in the Alien and Invasive Species Regulations (NEM:BA A&IS Regulations) that were published on 1 August 2014 and promulgated in October 2014. Revised regulations were published on 18 September 2020 and promulgated on 1 March 2021, with Section 13 stating:

13. (1) The Institute 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[2].

(2) A report contemplated in sub-regulation (1) must contain a summary and assessment of—
(a) the status of listed invasive species and other species that have been subjected to a risk assessment; and

[1] The South African National Biodiversity Institute (SANBI).
[2] Technically this report is due March 2024, although in keeping with a three-year cycle, the report was produced by October 2023.

(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 received from organs of state and management authorities of protected areas; and
(iv) emergency interventions and enforcement actions involving listed invasive species.

(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).

The 'invasive species' referred to in the Act and the Regulations are those that appear on a list of taxa published in the Government Gazette. These taxa are regulated in several different ways [see Wilson (2023) for the full lists]. The 2020 NEM:BA A&IS Lists (that came into effect March 2021) listed 560 valid taxa, as well as all hybrids between native and alien species of amphibians, birds, mammals and reptiles. In previous versions of the lists a further 562 taxa had been listed, many of these previously listed taxa were listed as 'prohibited' with the implication that they are not currently present in the country; the list of prohibited taxa was removed and not included in the 2020 lists (see Section 4.1). A further 153 have been proposed for listing. For the full lists see Wilson (2023). A handful of additional taxa have had 'risk assessments' conducted on them but are not currently or historically listed. These lists formed the starting point for this and previous reports; however, producing a report based simply on these taxa would not completely fulfil the mandate, nor address the broader issue of biological invasions.

The broader mandate, purpose and structure of the third status report

The issue of biological invasions has received significant recent global attention in particular with the production and release in October 2023 of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)'s *Thematic Assessment Report on Invasive Alien Species and their Control* (Box 0.1); and the Kunming-Montreal Global Biodiversity Framework (GBF) that was agreed under the Convention on Biological Diversity (CBD) in December 2022 (Box 0.2). This third status report sits firmly within this context. The status report aims to strengthen the links between basic research, policy and management, by providing support to decision makers that is policy relevant but not policy prescriptive (Figure S0.1).

Sagittaria latifolia (© Michel Gaubert).

The first report was produced in 2017 and released in 2018, and the second produced in 2020 and released in 2021. Both were structured around an indicator framework that explicitly considers biological invasions in terms of pathways, species, sites and interventions (with indicators on interventions divided into those considering inputs, outputs and outcomes). 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 third report outlines trends over the past three years for the four headline indicators and for the 20 indicators tracking pathways, species, sites and interventions. It takes time to compile, revise and produce these reports. Therefore, a cut-off date is needed, after which no new data are considered. This third report is thus entitled *The status of biological invasions and their management in South Africa in 2022*, as it reports on the status up to the end of 2022, although was finalised by October 2023 and released early in 2024. Nonetheless key events that happened in 2023 (e.g., Box 0.1) are acknowledged.

The report comprises chapters based on the framework (i.e., on pathways, species, sites and interventions). Each chapter starts with a summary of the findings, and then a discussion of key changes to the indicators and recent noteworthy events, with important case studies in the form of text boxes. In addition, for this report, a chapter-length case study is provided on 'The status of biological invasions and their management in the Prince Edward Islands'. The Prince Edward Islands (Marion Island and Prince Edward Island) lie in the Southern Ocean, 1 400 km from continental South Africa, and are distinct from the mainland both in terms of the nature of biological invasions and how they are managed. A final chapter evaluates the degree to which gaps identified in the previous reports have been filled, looks at additional key gaps that need to be addressed in future reports, and identifies recommendations relevant for how South Africa understands and manages biological invasions. Much of the detail underlying the production of the report is contained within the appendices and supplementary material available online (see p. 122 for links to these documents).

A focus of this report is to produce workflows and ensure data are FAIR[1] and tidy[2] in line with international best practice (IPBES 2018). In so doing, the report process should be more sustainable in that the processes used are documented and can be repeated. The longer-term plan is to develop an online resource with indicator values updated as soon as new information becomes available (i.e., a dashboard) that can be used to produce reports on demand, and form the basis both of semi-automated annual reports and less frequent comprehensive reports (see Section S.0.2, noting that such plans will need to be compatible with regulatory requirements – currently triennial reports are mandated). The intention of this report is thus to provide an update to the second report, and focus on the process, recognising that all identified data sources have not yet been incorporated (e.g., see Table S2.1 for a list of sources that have or need to be incorporated in the list of alien taxa).

[1]Findable, Accessible, Interoperable and Reusable: www.go-fair.org/.
[2]As defined by Wickham (2014), see Section S0.4 for more details.

Trachemys scripta subsp. *elegans* (© Johannes Maximilian).

The 'Summary of key messages' and communicating the degree of confidence

The report begins with a summary of key messages. This is formatted so that it can be produced and printed as a stand-alone document. The key messages from this report are summarised in the form of a single headline followed by explanatory text with cross-references to the relevant sections of the report. Each statement is also ascribed one of four confidence levels as per the guidelines of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES; Figure 0.1).

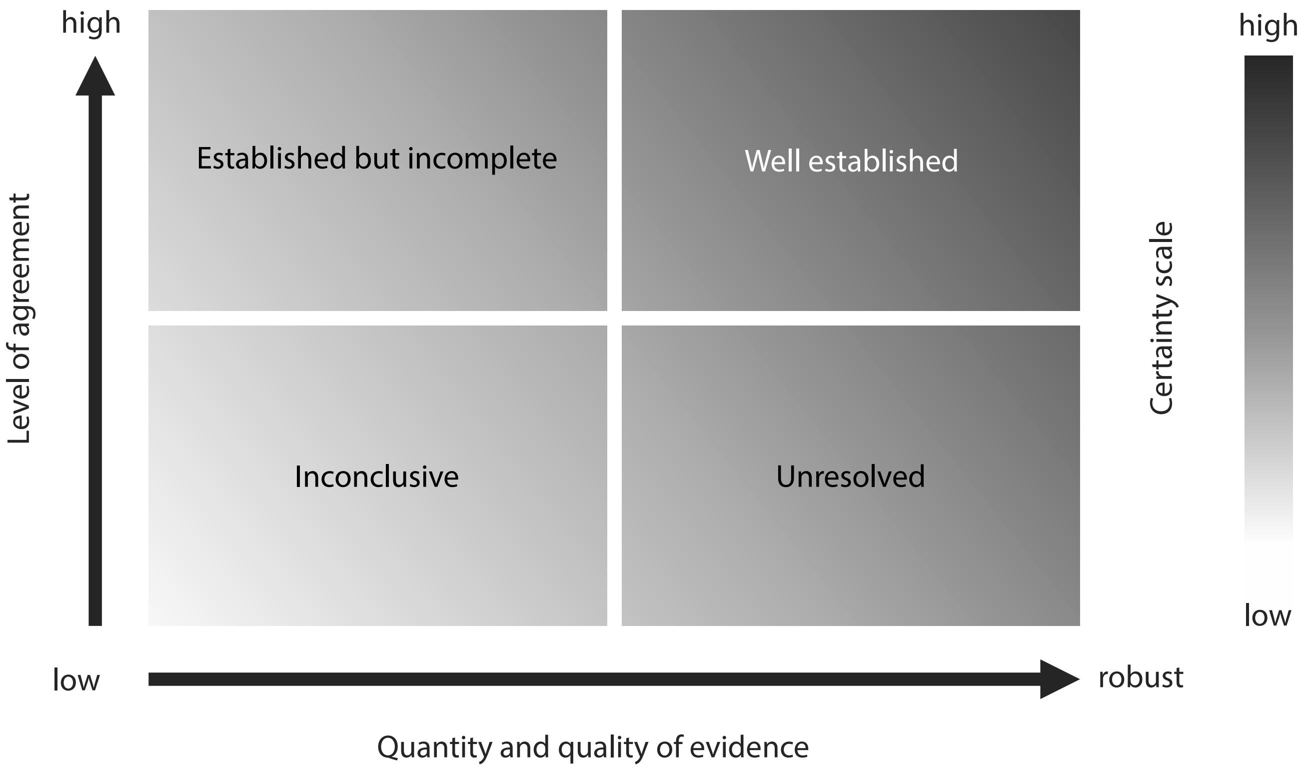


Figure 0.1. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)'s four-box model for quantitative communication of confidence. Confidence increases towards the top-right corner, as suggested by the increasing strength of shading (IPBES 2018). *Well established*: there is a comprehensive meta-analysis or other synthesis or multiple independent studies that agree; *Established but incomplete*: there is general agreement, although only a limited number of studies exist, there is no comprehensive synthesis and/or the studies that exist address the question imprecisely; *Unresolved*: multiple independent studies exist but their conclusions do not agree; and *Inconclusive*: there is limited evidence and a recognition of major knowledge gaps.

Schinus molle (© SAplants).

Process for the compilation of the report

The process was broadly similar to the first two reports (Figure 0.2), with largely the same team, consisting of the South African National Biodiversity Institute as the lead institute, the Centre for Invasion Biology as a collaborating partner, and various managers, researchers, private individuals and institutions providing information and comments on draft reports.

Review of release of the second report and essential workflows identified: The SANBI-CIB drafting team reflected on the report launch and how the report was received, and in particular identified the need for closer engagement with affected government departments. In particular, it was noted that by providing an opportunity to evaluate the findings and develop appropriate responses ahead of the report launch, affected agencies would be in a better position to respond to and uptake the findings. The drafting team also identified essential workflows for the production of the report that needed to be set up during this report cycle.

Appoint a reference and advisory committee (RAC): a RAC was established to provide oversight of the process and review documents produced. The first meeting of the RAC was on 22 February 2022 at which a proposed table of contents was approved. A draft of the report was sent to the RAC on 9 September 2022, and discussed at the second meeting of the RAC on 28 September 2022. The report was revised and sent out for public comment on 20 December 2022. The second draft for public comment was sent to the RAC at the same time as it was made public, and a meeting held on 26 June 2023. The Chair of the RAC also reviewed how the comments received during all rounds of review were addressed, i.e., acted in a review editor role. Finally, the RAC provided advice both in terms of the public release of the report and on reflecting on the process.

Collate and review available information: Information was incorporated into the report primarily from published literature and unpublished information provided by stakeholders. Information contained in the report is based on data available to the report writing team as of the end of December 2022 (see Supplementary Material for each chapter).

Stakeholder engagement: During report production, stakeholder engagement was an ongoing 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 initially based on those identified previously. Those who provided comments were asked for updates. New potential contributors were contacted on an ad hoc basis as information became available and in response to the public consultation. Contributions came from academic institutions; research institutes and science councils; national, provincial, and local government departments; and from private individuals who were interested and affected. Contributions from the identified stakeholders were in the form of data provision and commenting on drafts.

The report process is ongoing. There are information sources available that, given constraints, could not be fully incorporated in this third report (in particular see Table S2.1 for information sources that need to be incorporated into the species list). In cases where information was believed to be available but was not forthcoming, the lack of information is flagged either in the report or in the Supplementary Material. Finally, some information is simply not available. Important data have either not been gathered or appropriately curated. For a discussion on gaps see Chapter 6.

Review of draft reports: A draft was completed in September 2022 and sent to the RAC for internal review. This was then discussed at a meeting of the RAC on 28 September 2022, revised and sent out for public review by experts and stakeholders for a period of 10 weeks (20 December 2022–28 February 2022). 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 draft for public comment was attached to the formal notice and was available for download online (http://dx.doi.org/10.5281/zenodo.7414804).

In June 2023, the next draft of the report was produced and sent for public comment for six weeks using the same contacts as previously (20 June 2023–31 July 2023). In addition, the report was sent to one independent expert from South

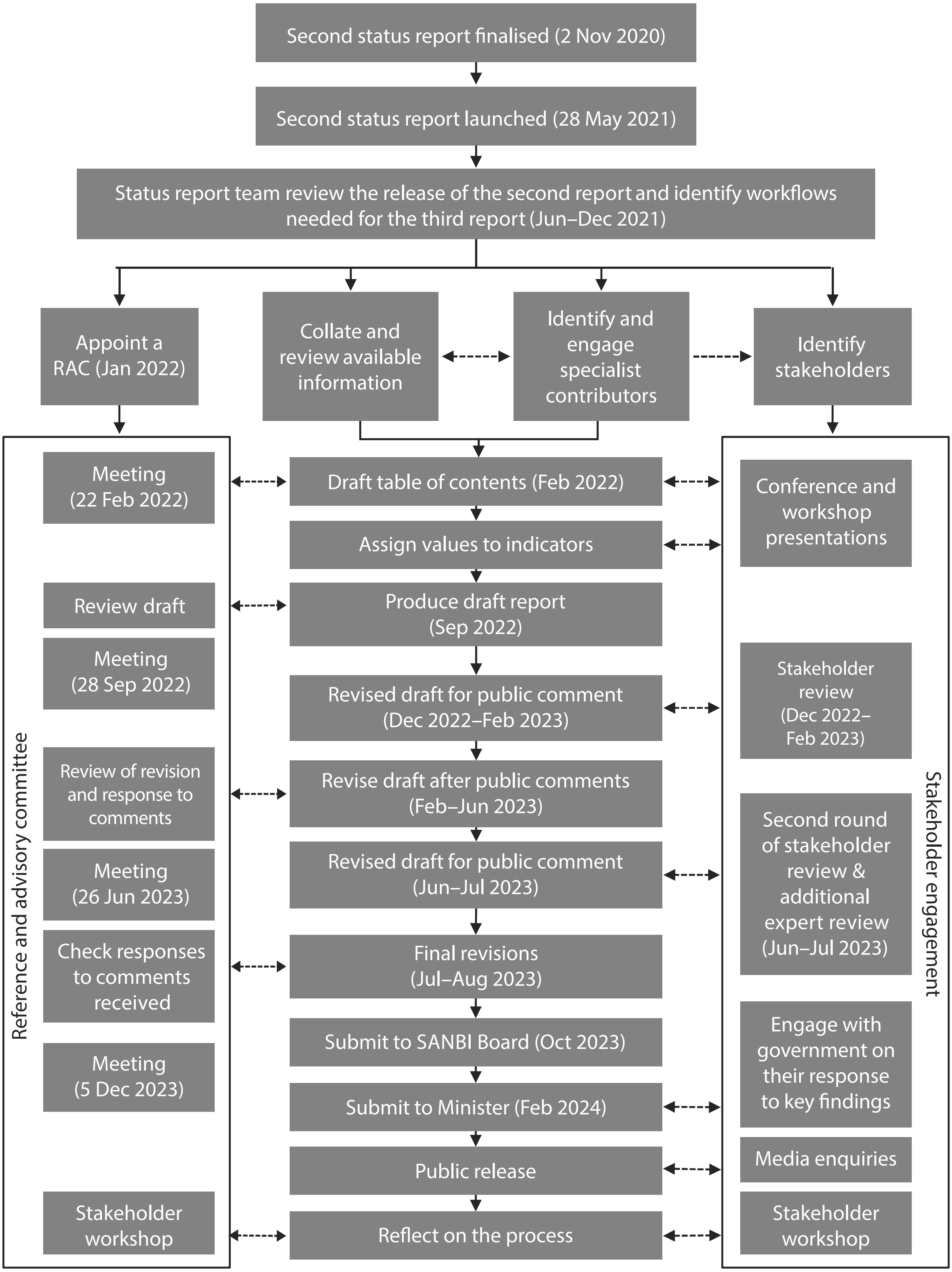


Figure 0.2. Key steps in the production of the report *The status of biological invasions and their management in South Africa in 2022*. The Minister is the South African Minister of Forestry, Fisheries and the Environment; the RAC is the research and advisory committee; and SANBI is the South African National Biodiversity Institute.

Africa, one international expert and members of the RAC. A copy of the second draft for public comment was attached to the formal notice and was available for download online (http://dx.doi.org/10.5281/zenodo.8037187).

During the first round of external public review, comments were received from 19 sources, representing ten institutions including the DFFE and the DWS. During the second round of external public review, comments were received from 13 sources, representing nine institutions (some commented in their private capacity). All feedback was recorded and the comments responded to in line with international best practice (IPBES 2018). The inputs and responses to the requests for review were documented and the responses were discussed with the RAC (with the RAC acting in the role of a review editor). The comment database is available for scrutiny from SANBI on request. On the second round of review, several comments were received after the deadline of 31 July 2023. These comments were captured in a separate database and, in cases where the comments could not be addressed before the report went into production, the comments will be used to inform future reports.

Produce and release the final report: After addressing the comments in the final round of review the report was edited, and a complete version sent on 20 September 2023 to the SANBI Graphics team for copy editing, layout, design and printing. In parallel, a copy of the report was also submitted to the SANBI Board in October 2023 for their consideration. After board approval, the report was laid out and printed, and then the SANBI CEO submitted the report to the Minister of Forestry, Fisheries and the Environment. At the same time a copy of the report was submitted to the DFFE and the DALRRD as the key receivers of the report. This provided the departments with an opportunity to prepare for responding to media enquiries or public concerns raised and to seek clarification from the report drafting team as needed, noting that no changes could be made to the report during this period save for any editorial changes made by SANBI Graphics & Editing. As with previous reports, information will be included in the *South African State of the Environment Report* process (http://soer.environment.gov.za/soer/).

Reflect on the process: After the public release of the 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 report and to identify areas of improvement for subsequent reports (see Chapter 6).

Nephrolepis cordifolia (© Forest and Kim Starr).

Indicators

This report is structured around four groups of indicators (24 in total) as outlined in Wilson et al. (2018) (Figure 0.3) and adheres broadly to the published indicator fact-sheets (available to download at https://tinyurl.com/5n6fbymh). However, there have been slight updates and corrections to how some things were scored, and the numbering of the indicators has changed slightly to reflect their hierarchy. As such, the indicators should be read in concert with the metadata to the species list and other workflows, with the more recent documents taking precedence. The technical details on scoring the indicators are available in the Supplementary Material. Fully revised and updated indicator factsheets will be provided together with the next report.

Notably, the baselines proposed in previous reports 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 report calculated the values that should have been in previous reports. Changes over time from these revised baselines are presented and discussed in this report and differences in the calculation methods used between the reports are noted in the Supplementary Material. Indicators are highlighted in bold throughout the main report, but are in plain text in the summary for policy-makers

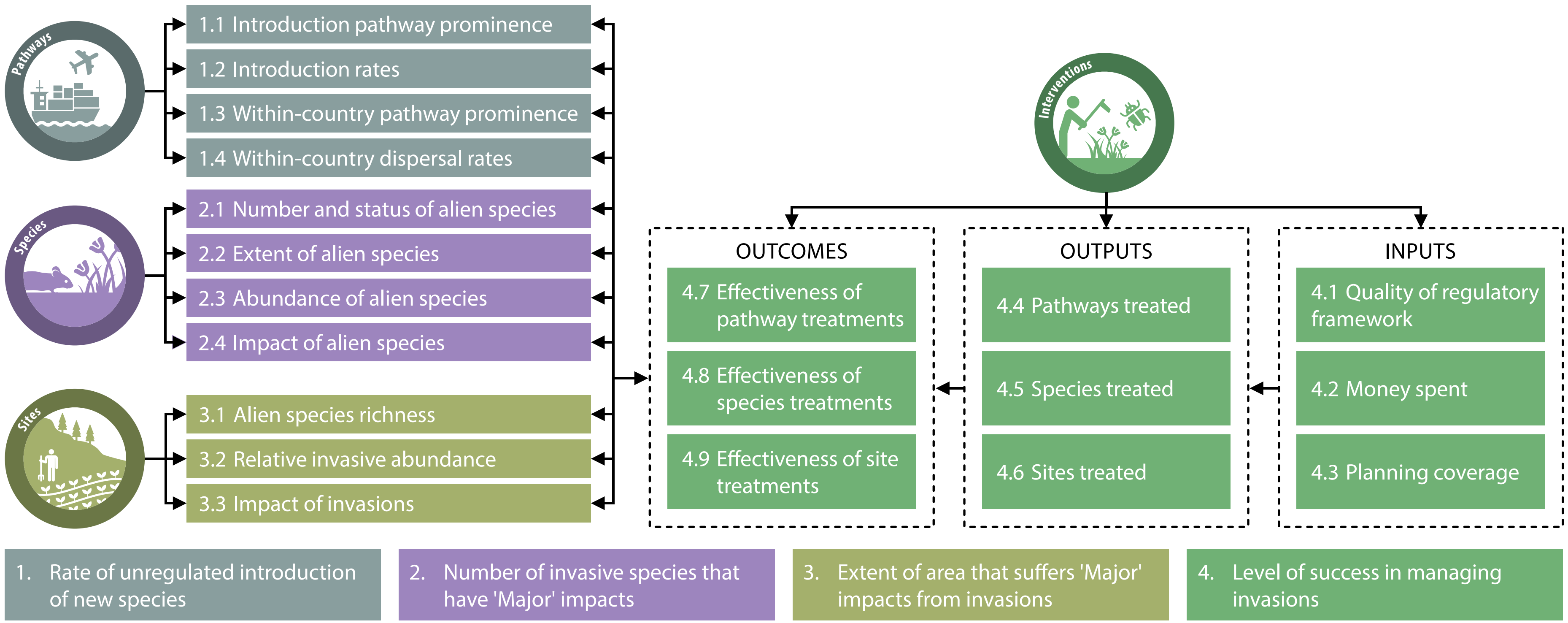


Figure 0.3. Indicators used in the report [based on Wilson et al. (2018)].

Workflows and protocols

Given the need for a repeatable and transparent process, various workflows were identified and constructed to outline how the report was put together and to inform future report production. These are discussed in the relevant chapters and presented in full in Appendix 4. They are listed here for reference:

- **Introduction pathway prominence**.
- Tracking data sources.
- Adding alien taxa and enrichment data to the species list.
- Updating the permit database.
- **Money spent**.
- Alien taxa impact assessment.
- Sourcing, capturing and reporting information for the Prince Edward Islands.

Each workflow is intended to be a step-by-step guide as to where data were sourced and how such data were collated, processed and analysed to produce specific outputs in terms of the indicators used in the report. Where appropriate R code is provided. The intention is that the calculations are transparent, they can be readily repeated and that future analyses can be automated as much as possible. Ultimately the aim is to develop processes such that all the indicators can be updated on an annual basis producing a regular dashboard that can inform policy and management. A schematic of one of the workflows is presented in Figure 0.4.

Some of these workflows required specific protocols with the intention for that to be applied for purposes other than the report. For example, a protocol has been set up to classify native-alien populations (Nelufule et al. 2022, Box 2.1).

For future reports, workflows are planned for: processing occurrence records to give species richness and abundance estimates at different spatial units; impacts on key ecosystem services; regulatory processes (beyond just the permit database); evaluating control plans and their implementation; and compliance, inspections and court cases.

Heliotropium amplexicaule (© SAplants).

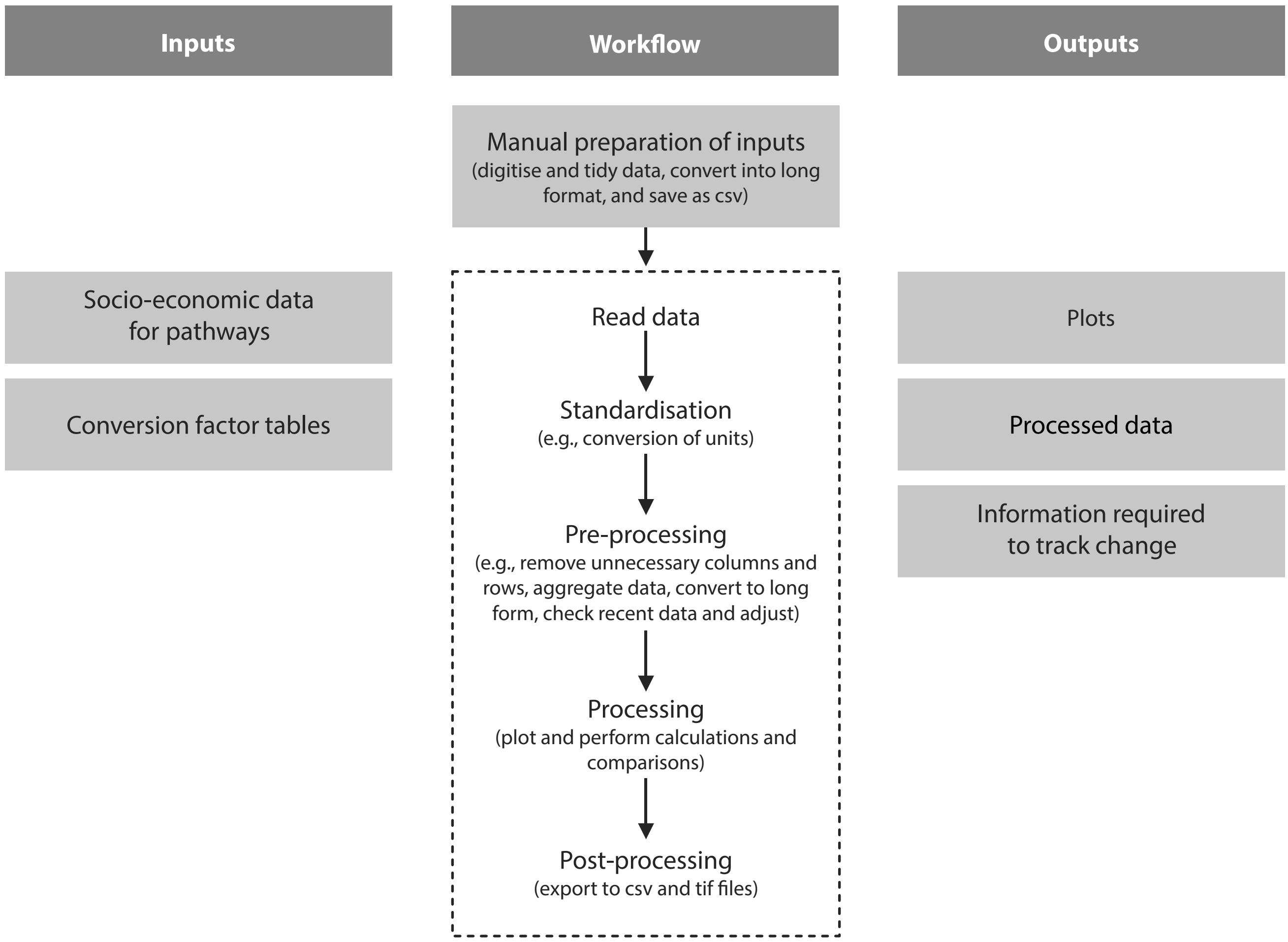


Figure 0.4. Overview of the workflow for indicator 1.1 **Introduction pathway prominence**. The steps in the box with the dashed grey line are automated. Automated steps are performed in R and details on these steps and the required R code are provided in Appendix 4. The overall structure was inspired by Seebens et al. (2020).

Cylindropuntia imbricata (© Agnieszka Kwiecień).

Aspects of biological invasions that are not covered

The aspects not covered in this report are largely the same as those not covered in previous reports (see Supplementary Material S0.6). COVID-19 has had profound impacts on the lives of South Africans. However, in the absence of an explicit analysis as to how the pandemic and the response by the government (e.g., the national lockdowns) directly affected biological invasions, the impact of COVID-19 is not explicitly considered here, except where there were palpable impacts on the indicators (e.g., the significant drop in trade and travel affected the indicators on **introduction pathway prominence** and **within-country pathway prominence**, cf. Figure S1.19).

Box 0.1. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services' *Thematic Assessment Report on Invasive Alien Species and their Control* (IPBES IAS Assessment)

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is an independent intergovernmental body established by states to strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development. In 2018, a global IAS Assessment was initiated. After five years, the final assessment was approved by the parties to IPBES at the 10th IPBES Plenary (28 August–2 September 2023) (IPBES, 2023). The IAS Assessment critically evaluated available evidence on the severity of the threat of biological invasions to underpin potential options for decision-making. The assessment was released to the public in October 2023. As such it was not possible to include the findings in this third report, but the assessment will form a core source for the development of the next comprehensive report. For details see https://ipbes.net/ias.

Box 0.2. The Kunming-Montreal Global Biodiversity Framework (GBF) of the Convention on Biological Diversity (CBD)

One purpose of this report is to facilitate South Africa's reporting to international bodies on biological invasions, including to the CBD. As such, the aim is to align this report with inter-governmental reporting processes and indicators. The CBD, at a meeting in December 2022, agreed to the Kunming-Montreal Global Biodiversity Framework (GBF). Target 6 of the GBF focusses on biological invasions:

> *'Eliminate, minimize, reduce and or mitigate the impacts of invasive alien species on biodiversity and ecosystem services by identifying and managing pathways of the introduction of alien species, preventing the introduction and establishment of priority invasive alien species, reducing the rates of introduction and establishment of other known or potential invasive alien species by at least 50 per cent, by 2030, eradicating or controlling invasive alien species especially in priority sites, such as islands.'*

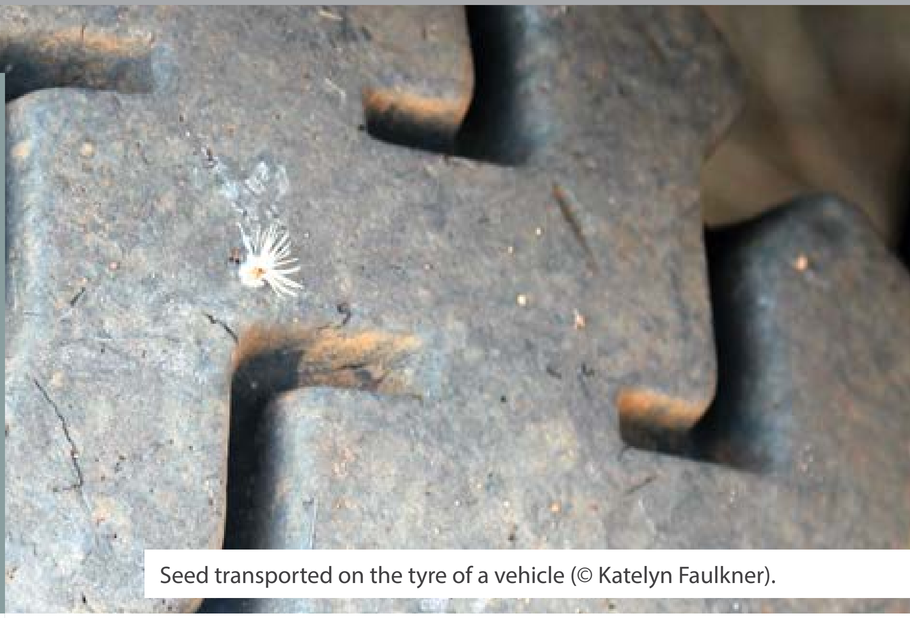
Given the timing of the finalisation of the target, this report does not explicitly address these elements, but notably the structure of the target is broadly addressed by the indicator framework [e.g., the focus on pathways, species, and sites; cf. Essl et al. (2020)]. The next comprehensive report will focus on specifically reporting on the target. The indicators to be used to track progress against Target 6 are still to be finalised. Nonetheless significant progress has been made. For example, the working group sTWIST 'Theory and Workflows for Alien and Invasive Species Tracking' (https://www.idiv.de/en/stwist.html) has proposed three indicators (McGeoch et al. 2021): 'Rate of Invasive Alien Species Spread' provides modelled rates of ongoing introductions of species based on invasion discovery and reporting; 'Impact Risk' estimates invasive species impacts on the environment in space and time and provides a basis for nationally targeted prioritisation of where best to invest in management efforts; and 'Status Information on Invasive Alien Species' tracks improvement in the essential dimensions of information needed to guide relevant policy and data collection and in support of assessing invasive species spread and impact. The applicability of these indicators to the South African context, and how they relate to the indicator framework used in this report, will be a focus of future reports.

Hibiscus trionum (© Krzysztof Ziarnek).

Crotalaria agatiflora (© SAPlants).

CHAPTER 1

PATHWAYS



Seed transported on the tyre of a vehicle (© Katelyn Faulkner).

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Findings for pathways

- The trade and travel controls put in place to prevent the spread of COVID-19 caused a temporary decline in the opportunities provided by some pathways for the introduction of alien organisms. These opportunities are returning to pre-pandemic levels.
- Alien organisms continue to be illegally or accidentally introduced every year through a variety of pathways, with no evidence of a significant change in the rate of introduction. These introductions have added to the number of invasive species found in the country.
- Alien species are being moved around the country and into the country's protected areas, with these introductions often being accidental and, in some cases, associated with visitors.
- Native organisms are being moved and introduced to parts of the country where they are not native, forming native-alien populations. To inform pathway management, there is a need to improve our understanding of the extent of this problem and of how these populations are being introduced.

Gap for pathways

- There is insufficient information on how organisms 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 organisms and the within-country dispersal of native organisms to sites outside of their native range.

Indicators covered in the pathways chapter

For all pathway indicators, the pathway classification framework of the Convention on Biological Diversity was used (CBD 2014). The pathways are shown in Figure 1.1 and details on the pathways, including descriptions and definitions, are provided in Harrower et al. (2018), an open access document. Specific details of values are provided in Appendix 5 and methodological changes from previous reports and details of how the calculations were made are outlined in the Supplementary Material (e.g., Table S1.1).

1.1 Introduction pathway prominence

Introduction pathway prominence assesses, based on socio-economic data, the opportunities available for alien organisms to be introduced to South Africa from other countries. This indicator does not consider how many introductions these opportunities have resulted in. If effective biosecurity is in place, then a large or increasing **introduction pathway prominence** (e.g., increasing food imports) is not a concern in terms of biological invasions.

There have been few qualitative changes to **introduction pathway prominence** (Figure 1.1). One exception is the promotion of aquaculture as a food source (Van Deventer et al. 2019), with production increasing steadily to 10 500 tonnes by 2021 (an increase of 30% from 2016 and 14% from 2019). The **introduction pathway prominence** for this pathway has increased from 'Minor' to 'Moderate'. **Introduction pathway prominence** was estimated for the first time for two pathways – conservation and imports of machinery and vehicles, both of which have 'Major' **introduction pathway prominence** (Figure 1.1).

There have been quantitative changes, with more than a 10% decline, over the period 2020–2022, in the introduction opportunities provided by nine of the 44 introduction pathways. For example, the number of aircraft arrivals from international and regional destinations declined by 18%, and the number of people entering the country declined by 47%. The controls placed on trade and travel to prevent the spread of COVID-19 drove these trends. However, these changes seem to have been temporary, and are not large enough to constitute a qualitative change in the indicator value. For example, in the 2019/2020 financial year over 50 000 aircraft arrived from regional and international destinations, and while in 2020/2021 this number declined to ~13 000, by 2021/2022 the number had increased to ~30 000, and by 2022/2023 to ~42 000 (Figure S1.14). Therefore, the number of aircraft arrivals is returning to pre-pandemic levels, and thus for this pathway, **introduction pathway prominence** has been 'Moderate' throughout (Figure 1.1).

Recent research on the pet trade and medicinal plant trade has confirmed the findings reported in the second report that both pathways have a 'Moderate' **introduction pathway prominence**. The pet trade is diverse (Shivambu et al. 2022a), with recent research focussing on alien gastropods (Shivambu et al. 2020), mammals (Shivambu et al. 2021), reptiles (Mantintsilili et al. 2022), and birds (Shivambu et al. 2022b). Pets are traded both in physical shops and online, with the vast majority of the trade in highly populated areas with relatively large economies, such as Gauteng, KwaZulu-Natal and the Western Cape (Shivambu et al. 2021, 2022b; Mantintsilili et al. 2022). A consolidated list of 475 alien plant taxa used as traditional medicine in South Africa has recently been published (Williams et al. 2021a). Although

Increasing human role

Mechanism of entry	Pathway category	Pathway subcategory	#	# since Dec 2019	IPP	IPP since Dec 2019
Commodity	Release	Biological control	278	↗	Mod	→
		Stabilisation & barriers	95	↗	Min	→
		Fishery in the wild	17	→	Mod	→
		Hunting	34	→	Maj	→
		Aesthetic release	10	→	PNP	→
		Conservation in wild	3	→	Maj	—
		Release for use	9	→	?	?
		Other release	0	→	?	?
	Escape	Agriculture	113	↗	Maj	→
		Aquaculture	15	→	Mod	↗
		Botanical gardens & zoos	5	→	Min	→
		Pet	56	→	Mod	→
		Farmed animals	16	→	Maj	→
		Forestry	39	→	Maj	→
		Fur farms	1	→	Min	→
		Horticulture	301	→	Mod	→
		Ornamental	277	↗	Mod	→
		Research	21	→	Min	→
		Live food & live bait	2	→	?	→
		Other escape	1	→	Mod	→
	Contaminant	Nursery material contaminant	14	↗	Mod	→
		Bait contaminant	15	→	?	→
		Food contaminant	15	→	Mod	→
		Contaminant of animals	9	→	Maj	→
		Parasites of animals	36	→	Maj	→
		Contaminant of plants	26	→	Mod	→
		Parasites of plants	30	→	Mod	→
		Seed contaminant	40	→	Mod	→
		Timber trade contaminant	14	→	Maj	→
		Habitat material contaminant	6	→	?	→
Transport vector	Stowaway	Fishing equipment	0	→	Mod	→
		Container & bulk cargo	13	→	Maj	→
		Airplane	3	→	Mod	→
		Ship	26	→	Mod	→
		Machinery & equipment	1	→	Maj	—
		People & luggage	0	→	Maj	→
		Packing material	4	→	?	→
		Ballast water	62	→	Mod	→
		Hull fouling	79	→	Mod	→
		Land vehicles	1	→	Maj	→
		Other stowaway	2	→	?	→
Natural spread	Corridor	Canals & artificial waterways	0	→	Min	→
		Tunnels & bridges	0	→	Min	→
	Unaided	Natural dispersal	15	→	Maj	→

Figure 1.1. Current status of the introduction pathways and changes to the pathways that have been recorded during 2020–2022. #: number of taxa introduced; # since Dec 2019: change to the number of taxa introduced since December 2019 (↗ increase; → no change); IPP: **introduction pathway prominence** (Min: minor; Mod: moderate; Maj: major; PNP: pathway not present; ? not known); IPP since Dec 2019: change to **introduction pathway prominence** since December 2019 [↗ increase; ↘ decrease; → no change; ? not known; – not applicable (first estimate or new pathway)].

some of these plants are harvested in South Africa (see Section 1.3), plants are also imported into the country (Williams et al. 2021b, 2022). These imported plants enter South Africa through air, sea and road transport, and often arrive through the land border posts shared with Zimbabwe and Mozambique (Williams et al. 2022).

New research on wildlife ranches has highlighted the opportunities for introduction that these ranches create. There are between 4.66 and 7.25 million herbivorous game animals living on wildlife ranches across South Africa (Taylor et al. 2021). These ranches include ecotourism and trophy hunting properties, and so **introduction pathway prominence** for the related pathways, hunting and conservation, is 'Major'. Although these ranches create many opportunities for introductions, South Africa has many native ungulate species, and so the threat this pathway poses in terms of the rate of introduction is likely to be low – only two alien taxa [*Kobus leche* (lechwe), including various subspecies, and *Dama dama* (common fallow deer)] were recorded on surveyed properties (Taylor et al. 2021). Such introductions (and within-country movements) have the potential to spread pests and diseases and impact native genetic diversity (see Sections 1.3 and 1.4).

1.2 Introduction rates

Introduction rates considers the number of new alien taxa that have been introduced over all time to South Africa from other countries through each of the introduction pathways, while the high-level indicator **rate of unregulated introduction of new species** estimates the total number of new alien taxa introduced accidentally or illegally each year.

Over the last decade (2013–2022), 32 new alien taxa were either illegally or accidentally introduced (i.e., unregulated introductions), a rate of approximately three introductions per year (Figure 1.2). This is slightly lower than the numbers seen for 2010–2019 (an average of about four new taxa introduced per year). This decline is likely due in part to delays in the recording and reporting of new introductions (see Box 1.1; Table S1.5).

For the alien taxa for which introduction pathways are known (~1 100 alien taxa) the introduction pathways are similar to those previously reported (Figure 1.1). Most introductions are plants introduced either for ornamental purposes and/or horticulture (~28%), or for agriculture (~10%). Many alien organisms (e.g., invertebrate pests) have been accidentally introduced along with imported plants, animals or their products (~13%); while shipping has facilitated many introductions (~9%), through the release of ballast water, through biofouling (including on hulls), and when organisms hitchhike on the ship itself [e.g., *Corvus splendens* (the house crow)].

New introductions have been reported for 22 of the 44 pathways. However, lags in reporting and in how information feeds through to this report continue to significantly affect the reported values, and for 17 of these pathways these new introductions were all recorded before 2020 (see Section S1.6). For example, the polychaete *Dipolydora socialis*, was first collected in the Knysna Estuary in 2015 but was only reported in 2021, following genetic analysis that confirmed its identification (David et al. 2021). This polychaete was likely introduced to South

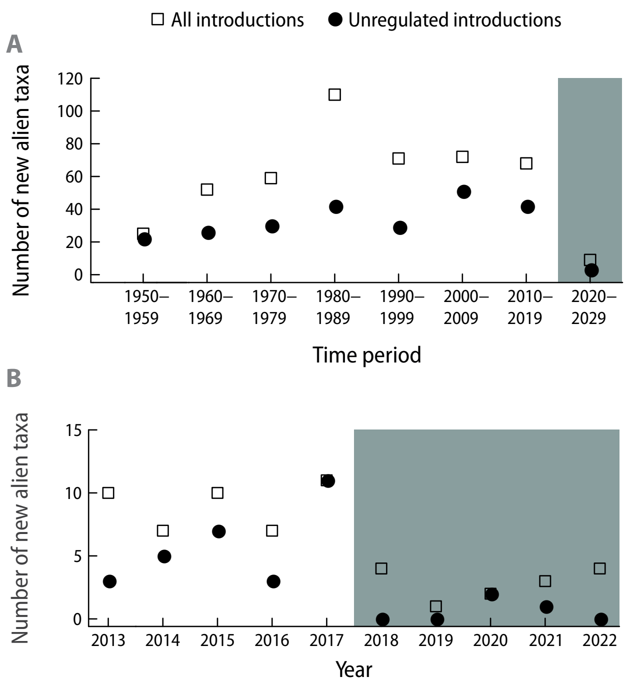
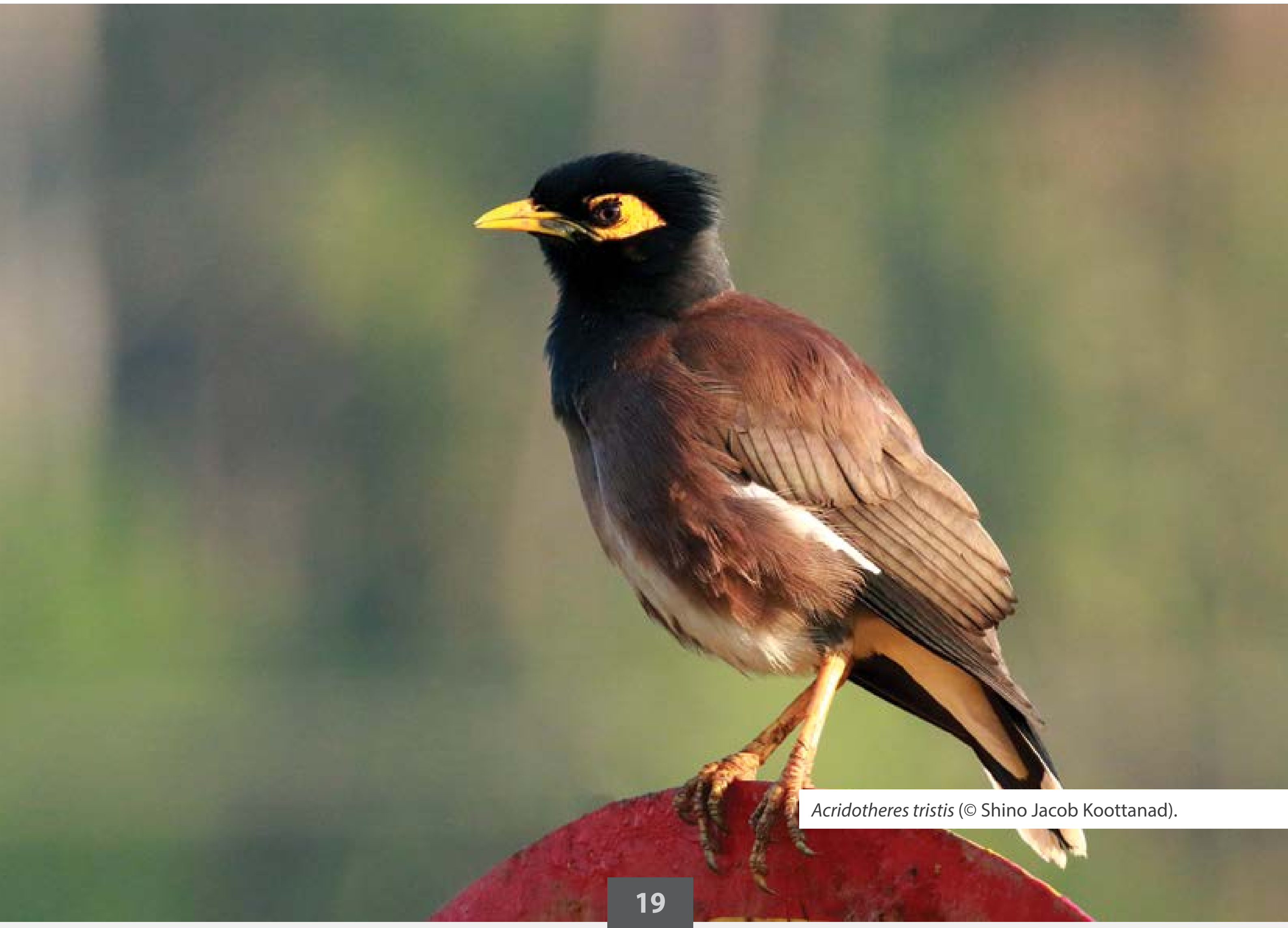


Figure 1.2. Number of new alien taxa recorded in South Africa over time: A, over the last eight decades; B, during the last decade. These are alien taxa not previously found or known to be present. The low number of recent unregulated introductions (shaded in grey) likely reflects delays in detecting and reporting alien taxa (see Box 1.1). Based on experiences from the past two reporting cycles, the number of recent unregulated introductions are likely severely under-reported, and the number reported will increase as new data become available (cf. Table S1.5).

Africa prior to 2015 through ballast water, hull fouling or with organisms imported for mariculture (David et al. 2021). In 2020, two new alien grass taxa were recorded in the country, *Poa humilis* and *Poa pratensis* subsp. *pratensis* (Soreng et al. 2020). These taxa are often seeded for lawns, pasture and soil stabilisation (Soreng et al. 2020), and, therefore, there has been an increase in the number of introductions over all time through the ornamental, agriculture, and stabilisation and barriers pathways (Figure 1.1). Importantly, while the subspecific entity *Poa pratensis* subsp. *pratensis* may be new to the country, *Poa pratensis* (Kentucky bluegrass) has long been in the country and was imported and cultivated at pasture research stations from 1934 (Visser et al. 2017). A particularly concerning new introduction, due to its potential to have negative impacts on native species, is the fungus *Seiridium neocupressi* (Wingfield et al. 2022). *S. neocupressi*, which causes the disease Cypress canker, was first recorded in 2021 on the native species, *Widdringtonia nodiflora* (mountain cypress) (Wingfield et al. 2022). The exact introduction pathway of this fungus is not known, but it was most likely introduced as a contaminant of nursery material (Wingfield et al. 2022), and thus there has been an increase in the number of alien taxa introduced through this pathway (Figure 1.1).

In terms of regulated legal introductions, six new biological control agents have been released against invasive plants in 2021/2022 (see Section 4.5). While the number of introductions for biological control has, therefore, increased (Figure 1.1), this is a well-regulated pathway and of minimal concern in terms of causing damaging invasions. Over the period 2020–2022 there was also one permit issued for the import of an alien taxon that was not already recorded as legally present in the country (see Appendix 6). The permit was issued to import *Meriones unguiculatus*, a type of gerbil, to be bred in quarantine facilities and used in medical research. However, it appears that this taxon is already present in the pet trade (Shivambu et al. 2021), though the legality of the initial import(s) is not known. It is not known if the permit has been exercised.



Acridotheres tristis (© Shino Jacob Koottanad).

1.3 Within-country pathway prominence

Within-country pathway prominence considers the opportunities available for the movement of organisms within the country, and does not take into account how many dispersal events these opportunities result in.

As in previous reports, data for **within-country pathway prominence** were not available for most pathways, and so the indicator could not be populated. However, some general trends were apparent, and recent research has provided information on the introduction opportunities provided by some dispersal pathways. As discussed above, opportunities for introductions to the country were impacted by the controls put in place to reduce the spread of COVID-19. These controls also impacted the opportunities available, through some pathways, for dispersal within the country. For example, the decline of ~67% in the number of domestic aircraft arrivals in the 2020/2021 financial year (Figure S1.19) was similar to that for international and regional aircraft arrivals (a decline of 74%). However, there are a wide range of pathways that create dispersal opportunities within the country, and it is likely that not all were impacted to this extent. Furthermore, these opportunities are returning to pre-pandemic levels (for an example see Figure S1.19). Recent research has highlighted the large role that wildlife ranching (Taylor et al. 2021), medicinal plant trade and the pet trade (Shivambu et al. 2022a) are playing in moving organisms around the country. A survey of pet shops indicated that the sources of pets in the trade are often local, with at least 40% of the respondents obtaining their animals from local sources such as animal rescues and other pet shops or breeding them themselves (Shivambu et al. 2022a). Many of the alien plants in the medicinal plant trade are also sourced locally and moved around the country for this purpose. A survey of the trade in Gauteng and KwaZulu-Natal showed that 41% of the plants for sale were harvested in southern Africa, with most of these plants being sourced in KwaZulu-Natal (Williams et al. 2021b). Alien plants have been incorporated into local traditional medicine not because they are used to treat different ailments than native taxa, but because they are versatile in terms of their uses – they can be used for many purposes besides medicine – and many have been in the country for a long time (Yessoufou et al. 2021, 2022).

1.4 Within-country dispersal rates

Within-country dispersal rates considers the number of alien taxa that have dispersed within the country through the pathways of dispersal, including both taxa alien to the country, and those that are native to the country but which have been introduced to parts of the country where they are not native [so-called native-alien populations (Nelufule et al. 2022); see Box 2.1 for alternative terms that have been used (e.g., extralimital species) and reasoning for the use of this term]. Data for within-country dispersal have not been collated for taxa that are alien to the country, and so the indicator could not be populated. However, based on the reviewed literature, alien and native taxa are dispersing within the country through at least 30 of the 44 pathways (68%) (see Appendix 5 for the data and sources used in this assessment).

Of 132 native-alien populations that could be categorised with confidence, most were intentionally transported to their new ranges (Nelufule et al. 2023a) (Table S1.4) and were either intentionally released (44 populations of 25 taxa) or escaped from captivity and cultivation (34 populations of 24 taxa). These intentionally introduced native-alien populations tended to be plants used for ornamental purposes (21 populations of 16 taxa) and mammals introduced to game farms (20 populations of 11 taxa). There have also been accidental introductions of native taxa, including: insects, gastropods, amphibians and reptiles accidentally transported with products (29 populations of 17 taxa), especially, plant products such as nursery materials; reptiles and marine crustacea transported as stowaways on land vehicles and boats (7 populations of 3 taxa); and fish that have spread through inter-basin water transfer schemes (8 populations of 4 taxa). Notably, as it is often difficult to confidently ascribe an introduction pathway, and as the native ranges of species being moved around are often not well delineated, it is expected that the number of native-alien populations ascribed to the introduction pathways is likely to be significantly underestimated. This, as well as their potential impacts [see below example of *Phacochoerus africanus* (warthog) translocations and Box 2.1], means that the benefits of managing within-country dispersal are likely to be much greater than suggested by current observed rates of within-country dispersal.

In addition to the creation of potentially invasive native-alien populations, the within-country movement of native taxa could have various negative impacts, including harmful co-introductions and the loss of native genetic diversity. As discussed in Section 1.3, wildlife ranches are facilitating the movement of mammals around the country and, as a consequence, most of these ranches have at least one native-alien population, but some have as many as 14 (Taylor et al. 2021). The most frequently found taxa with native-alien populations on these ranches were *Aepyceros melampus* (impala) and *Tragelaphus angasii* (nyala) (Taylor et al. 2021). A recent genetic analysis found that African Swine Fever Virus, a contagious and lethal disease of domestic pigs, is now found in the south of the country, beyond the controlled area declared in 1935 (Craig et al. 2022). The translocation of live *Phacochoerus africanus* (warthog) to game farms and nature reserves outside of their historical range has likely played a role in the dispersal of the virus (Craig et al. 2022). Similarly, a phylogeographic analysis of *Xenopus laevis* (African clawed frog) and its monogenean parasite *Protopolystoma xenopodis* indicated that human-mediated translocations of *X. laevis* had led to different lineages of the species coming into contact (Schoeman et al. 2022). Bulk exports of *X. laevis* from the southwestern part of the country to urban centres in the north for research and teaching, with subsequent escapes, have likely played a role (Schoeman et al. 2022). But *X. laevis* is also used as bait by recreational anglers, and while some of these individuals escape, anglers have apparently also released surplus bait and intentionally stock water bodies for future use. Therefore, it is likely that through recreational fishing individuals of different lineages are being moved to remote areas (Schoeman et al. 2022).

In terms of the within-country dispersal of taxa that are alien to the country, new research has shown that people and vehicles are accidentally dispersing these organisms to the country's protected areas, and that while the intentional movement of taxa around by country is important, natural dispersal mechanisms are also playing a role at the national level. Samples taken from the shoes of trail runners taking part in races in the Garden Route National Park were found to contain the seeds of 33 plant species, of which 18 (55%) were alien to the country, and two were native to the country but alien to the Garden Route National Park (Smith & Kraaij 2020). Along Sani Pass in the Maloti–Drakensberg Park, alien plant taxa have expanded their distributions from lower to upper elevations, with the pattern of expansion indicating that human-aided long-distance dispersal is playing a role, likely through the adhesion of plant propagules to vehicles and the shoes of hikers moving up the pass (Turner et al. 2021).

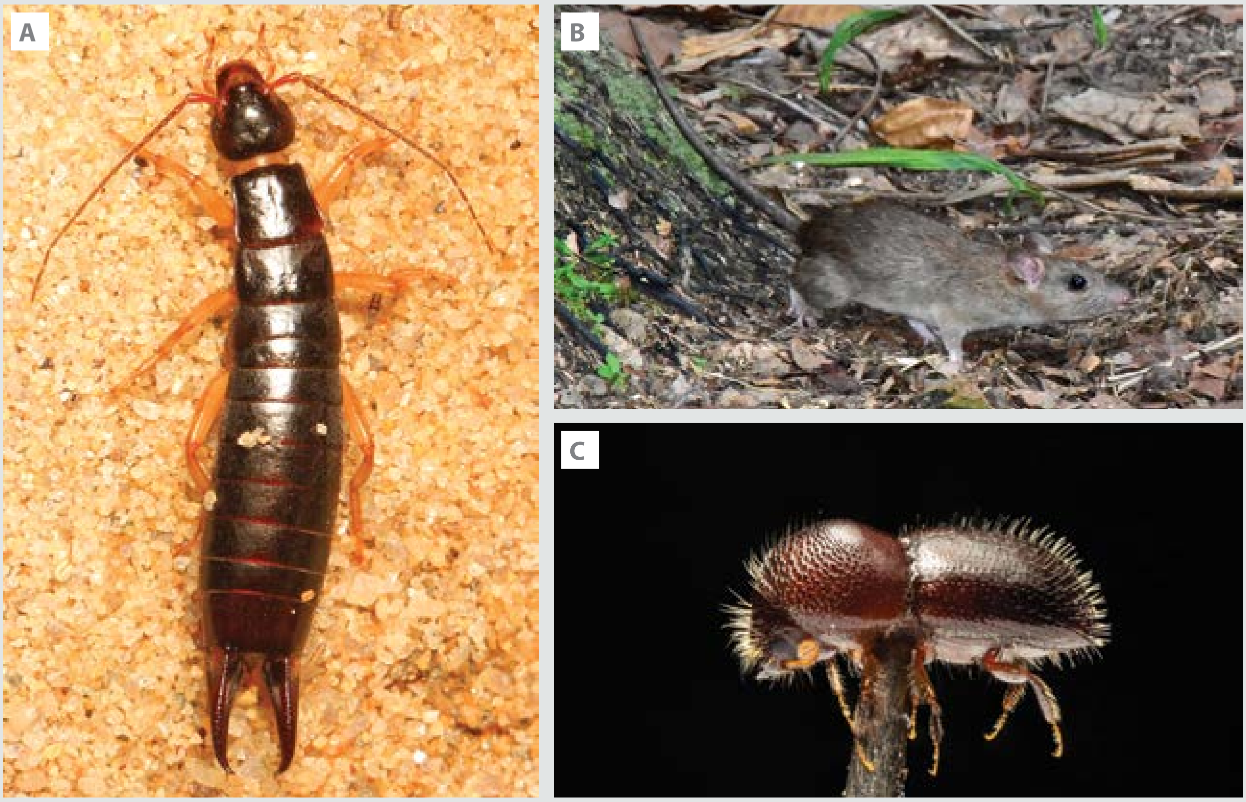
Humans also continue to intentionally move alien taxa around the country for various purposes, and the within-country dispersal of some taxa is being driven almost entirely by these processes. In South Africa asexual reproduction is solely responsible for the natural dispersal of the aquatic macrophyte *Pontederia cordata* (pickerel weed), which is spread via rhizomes, and thus most of its within-country dispersal is likely perpetuated by gardeners and horticulturists that trade in the taxon, and dump plants and propagules; and fish farmers and golf course owners that may be using the taxon to stabilise water bodies and banks (Wansell et al. 2022). A Bayesian dynamic species distribution model that was used to model the invasion of the plant *Plectranthus barbatus* var. *grandis* (also known as *Plectranthus barbatus*, Abyssinian coleus) in the southern Cape, showed the invasion of this species was also largely driven by human-mediated long-distance dispersal that originated from the cities of first introduction (Botella et al. 2022). Without human-mediated long-distance dispersal, the maximum population size of *P. barbatus* var. *grandis* would have been only 30% of the current population size (Botella et al. 2022). Natural processes are also playing an important role in the dispersal of some alien taxa. Comparisons between alien plant richness at dump sites and in the provinces in which the dump sites are found, have indicated that alien plant propagules are being dispersed between localities in South Africa, with the dispersal of some of these taxa likely being facilitated by omnivorous birds that fly long distances (Mokotjomela et al. 2022).

Box 1.1. Work to improve the pathway indicators

The implementation, over three reports, of the indicators used here to report on the status of pathways has highlighted several issues.

Pathway frameworks are used to classify similar pathways into discrete categories. A pathway framework proposed by the CBD as a global standard (CBD 2014; Essl et al. 2015; Scalera et al. 2016) has been set as a global biodiversity standard by the Darwin Core (dwc:pathway) (Groom et al. 2019). Because of this, the framework (see Figure 1.1) was incorporated into the pathway indicators used in this report (Wilson et al. 2018). However, implementing the framework in the South African context has been a challenge (Van Wilgen & Wilson 2018; Zengeya & Wilson 2020), and a number of issues have been identified (see Faulkner et al. 2020a). Work is currently underway to develop and test a framework that will meet South Africa's needs, by facilitating reporting at both international and national levels, and informing management; this will be a feature of the next report.

The high-level indicator **rate of unregulated introduction of new species** is based on the observed rate of introductions (Wilson et al. 2018). However, this is well known to be a biased metric that can lead to misleading patterns. A taxon recently recorded for the first time in the country, could have been in the country for many decades (Box Figure 1.1), and this recording delay will impact the rate of introduction if estimated based on raw introduction records (Solow & Costello 2004; Belmaker et al. 2009). Therefore, estimates of introduction rates must consider the rate of discovery, which is often unknown. To address this, an indicator rate of invasive alien species spread has been developed through the sTWIST project [cf. Box 0.2; and the preprint by McGeoch et al. (2021)]. Moreover, Target 6 of the Kunming Montreal Global Biodiversity Framework (Box 0.2) has a proposed headline indicator Number of invasive alien species introduction events. The next report will pilot these approaches to obtain unbiased estimates of introduction rates in line with the CBD's Global Biodiversity Framework.



Box Figure 1.1. Examples of alien taxa in South Africa that were first recorded many years after they are believed to have been introduced: A, *Anisolabis maritima* (the maritime earwig) (Griffiths 2018); B, *Rattus tanezumi* (the Asian house rat) (Bastos et al. 2005, 2011); C, *Euwallacea fornicatus* (the polyphagous shot-hole borer) (Stouthamer et al. 2017). Photographs: A,© J. Gallagher; B, © Nasser Halaweh; C, © Garyn Townsend.

1.5 Trends in pathway indicators

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
1. Rate of unregulated introduction of new species	→	low	↘	Over the last decade (2013–2022) approximately three new taxa were introduced per year either accidentally or intentionally but illegally. This is similar to previous estimates.	Estimated rates of introduction are sensitive to search effort and there is often a delay of several years between introductions happening and them being formally recorded (Box 1.1). New methods and approaches are needed to ensure that estimates of rates of unregulated introduction are responsive and can be used to evaluate the effectiveness of interventions. The rate of introduction of unregulated taxa is expected to be a function of the volume of trade and travel. However, this will depend on the degree to which key pathways are identified, prioritised and managed. See Chapter 4 for details on some positive developments that could strengthen South Africa's biosecurity.
1.1 Introduction pathway prominence	→	medium	not applicable	13 introduction pathways play a major socio-economic role. There have been few qualitative changes to this during the period 2020–2022 despite temporary quantitative reductions due to COVID-19 response measures. For two pathways **introduction pathway prominence** was estimated for the first time.	The trade and travel controls put in place to prevent the spread of COVID-19 caused a temporary decline in some introduction opportunities, but these introduction opportunities are returning to pre-pandemic levels and trends. Unless trends in travel and trade are tracked and interventions respond to such changes, new harmful alien species will continue to be introduced. If, however, effective biosecurity measures are in place, the new biological invasions caused by increases in travel and trade will be reduced.

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
1.2 Introduction rates	→	Low	not applicable (for regulated taxa) ↘ (for unregulated taxa)	For regulated taxa: during 2020–2022, six new taxa were legally introduced for biological control and one taxon that was already in the country was legally introduced for other purposes. For unregulated taxa: during 2020–2022, one new taxon was accidentally introduced probably as a contaminant of nursery materials, and two new taxa were introduced for ornamental or agricultural purposes, or to stabilise soil. However, several taxa introduced and recorded prior to 2020 were reported for the first time during 2020–2022. These taxa were likely introduced through 17 different introduction pathways. There is no strong evidence that the number of taxa introduced through the different pathways has changed greatly.	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. Stringent processes are in place to minimise the risk that such introductions result in harmful invasions (Section 4.1. in Chapter 4). Unless pathways are identified, prioritised and managed, potentially harmful alien taxa will continue to be accidentally and illegally introduced.
1.3 Within-country pathway prominence	not assessed		not applicable	Information was only obtained for a few pathways. Many pathways are likely playing an important socio-economical role, but the extent of this role and how it has changed recently is not known. Restrictions on within-country trade and travel to prevent the spread of COVID-19 had a short-term impact on the within-country dispersal opportunities provided by some pathways.	Internal trade and transport are expected to increase over time. 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.

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
1.4 Within-country dispersal rates		not assessed	not applicable (for regulated taxa) ↘ (for unregulated taxa)	Alien and native taxa are dispersing within the country through at least 30 different pathways. National-scale data have yet to be collated for alien taxa, but information has become available for native-alien populations. Most recorded native-alien populations are plants introduced for horticulture, or mammals for aesthetics. But native-alien populations are also the result of accidental introductions, for example, organisms moved with transported plants or plant products, or that disperse through inter-basin water transfer schemes. Alien organisms are being introduced, often accidentally, to protected areas, and while human-aided dispersal is driving the dispersal of some taxa, natural processes are also playing an important role at a national scale.	Unless pathways that facilitate the within-country dispersal of 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. Native-alien populations likely differ in their impacts to other alien populations, and to inform pathway management, there is a need to improve our understanding of the extent of this problem, and how these populations are being introduced.

→ no change; ↗ an increase; ↘ a decrease.

Columba livia (© Satdeep Gill).

CHAPTER 2

SPECIES

Micropterus salmoides (© Marnus Erasmus).

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Findings for species

- South Africa is a hotspot of plant invasions with several freshwater fishes also causing significant negative impacts on biodiversity. Preliminary findings indicate 13 plants, five freshwater fishes, and one invertebrate have had 'Major' or 'Massive' impacts (as per the IUCN's EICAT scheme). However, as only few taxa (36) have been formally assessed, this number is expected to increase.

- The process of documenting and tracking changes in the status of alien species has been substantially improved through the development of workflows to ensure analyses are properly documented and repeatable. This will facilitate tracking of alien species over time that can then feed into management planning and facilitate regulatory decisions.

- The number of distribution records from citizen science platforms has substantially increased the knowledge of the distribution of some alien taxa, but a decline in recent active surveillance at least for plants (i.e., a hiatus in the Southern African Plant Invaders Atlas) represents a significant reduction in the ability to systematically evaluate trends in invasions over time.

- The majority of alien species are localised and only a few were widespread. However, the potential for spread is large, and the extent of most species will continue to increase unless effective control is put in place.

- The phenomenon of native-alien populations has been circumscribed and quantified for the first time – 77 native taxa have formed 132 native-alien populations. Preventing such invasions will require a greater focus on managing species movements within the country.

Gaps for species and sites[1]

- 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 the species chapter

- 2.1 Number and status of alien species
- 2.2 Extent of alien species
- 2.3 Abundance of alien species
- 2.4 Impact of alien species

2.1 Number and status of alien species

A total of 5 878 taxa were assessed for presence in South Africa of which 3 511 taxa are present, the presence of 1 628 taxa is doubtful[2] and 738 are absent[3] (Table 2.1, Supplementary Material S2.1). Over half of the alien taxa recorded as present are plants, in line with the view that South Africa is a hotspot for plant invasions (Van Wilgen et al. 2020).

For each taxon recorded as present, the evidence is specified in Appendix 2 and the names have been checked against various taxonomic sources. However, the list is not comprehensive. The presence of many alien taxa needs to be confirmed and documented; many data sources still need to be incorporated into the list; and it is likely that many alien taxa have not, as yet, been

Table 2.1. The number of alien taxa present or possibly present in South Africa for which information has been formally collated as of December 2022. For more details, including taxa assessed and scored as absent, see Table S2.2 and Appendix 2.

Taxa	Doubtful	Present
Bacteria	0	3
Chromista	1	15
Fungi	8	104
Invertebrates	228	900
Plantae	1278	2106
Vertebrates	113	383

[1]The gaps listed are the same as in the second report as the situation has not changed.
[2]Taxa were assessed as doubtful if there is some evidence of the taxa having been present in South Africa, but there is doubt over the evidence or whether it is still present as of December 2022, including taxonomic or geographic imprecision in the records.
[3]The vast majority of taxa alien to South Africa have never been introduced. For example, assuming there are ~350 000 vascular plants alien to South Africa, the status of <1% of these has been formally assessed in this report. Most taxa assessed and found to be absent were assessed as they were listed as prohibited under the A&IS Regulations of 2014 or 2016 (see Section 0.2).

recorded (see Supplementary Material S2.2 for further details on progress made to update the list). As examples: many alien taxa in captivity or cultivation need to be added; well over half of the 200 most common mushrooms seen in South Africa are likely to be alien but are not yet included on the lists [cf. Goldman & Gryzenhout (2019)]; and in-depth research and surveys on even a well-studied alien taxon like Australian *Acacia* species identified many new alien taxa (Magona et al. 2018). Given that the process for constructing the species list was revised, and that substantive and systematic gaps remain in terms of collating available information, it is not meaningful to either compare values with previous reports or to produce an updated baseline. An additional issue with such lists is how to incorporate native-alien populations (i.e., taxa which are native to a part of South Africa but have been introduced to and naturalised in parts of South Africa to which they are not native). These populations are generally under-reported but numerous native-alien populations have become established across South Africa (see Box 2.1). The processes set up will, however, enable the **number and status of alien species** to be accurately reported and tracked in future.

2.2 Extent of alien species

2.2.1. Number of broad-scale regions occupied per species

Occurrence data were updated based on data published by the Global Biodiversity Information Facility (GBIF) for 2 402 taxa (~70% of alien taxa recorded as present). As in previous reports, a few taxa are widespread invaders, but many alien taxa are only known from a few sites (Figure 2.1).

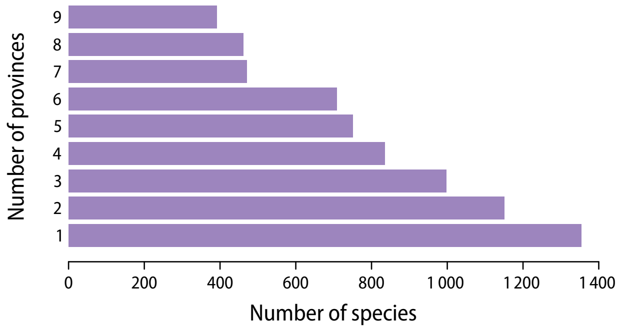
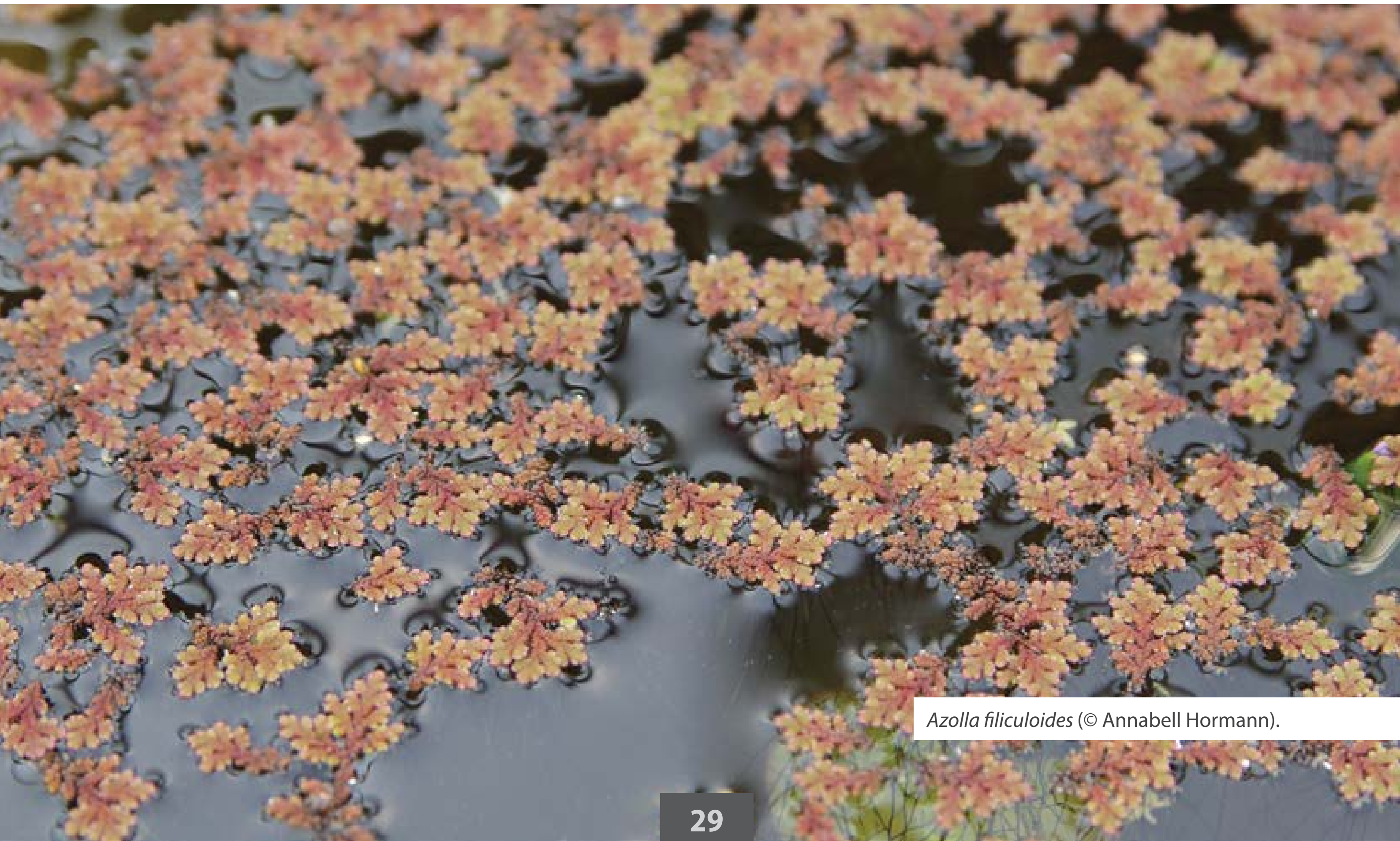


Figure 2.1. The **extent of alien species** at the provincial scale as of December 2022. This is based on occurrence records from GBIF and SAPIA for mainland South Africa.



Azolla filiculoides (© Annabell Hormann).

2.2.2. Number of quarter degree grid cells occupied per species

Most alien taxa have relatively restricted distributions and only some plants and birds are widespread (e.g., more than 500 qdgcs occupied) (Figure 2.2). Several species had major changes in their ranges (e.g., an increase of 50 qdgcs occupied or more): 44 species of plants (including *Tagetes minuta*, *Argemone ochroleuca*, *Plantago lanceolata*, *Lantana camara* and *Hibiscus trionum*); seven bird species (*Acridotheres tristis*, *Sturnus vulgaris*, *Psittacula krameri*, *Columba larvata*,

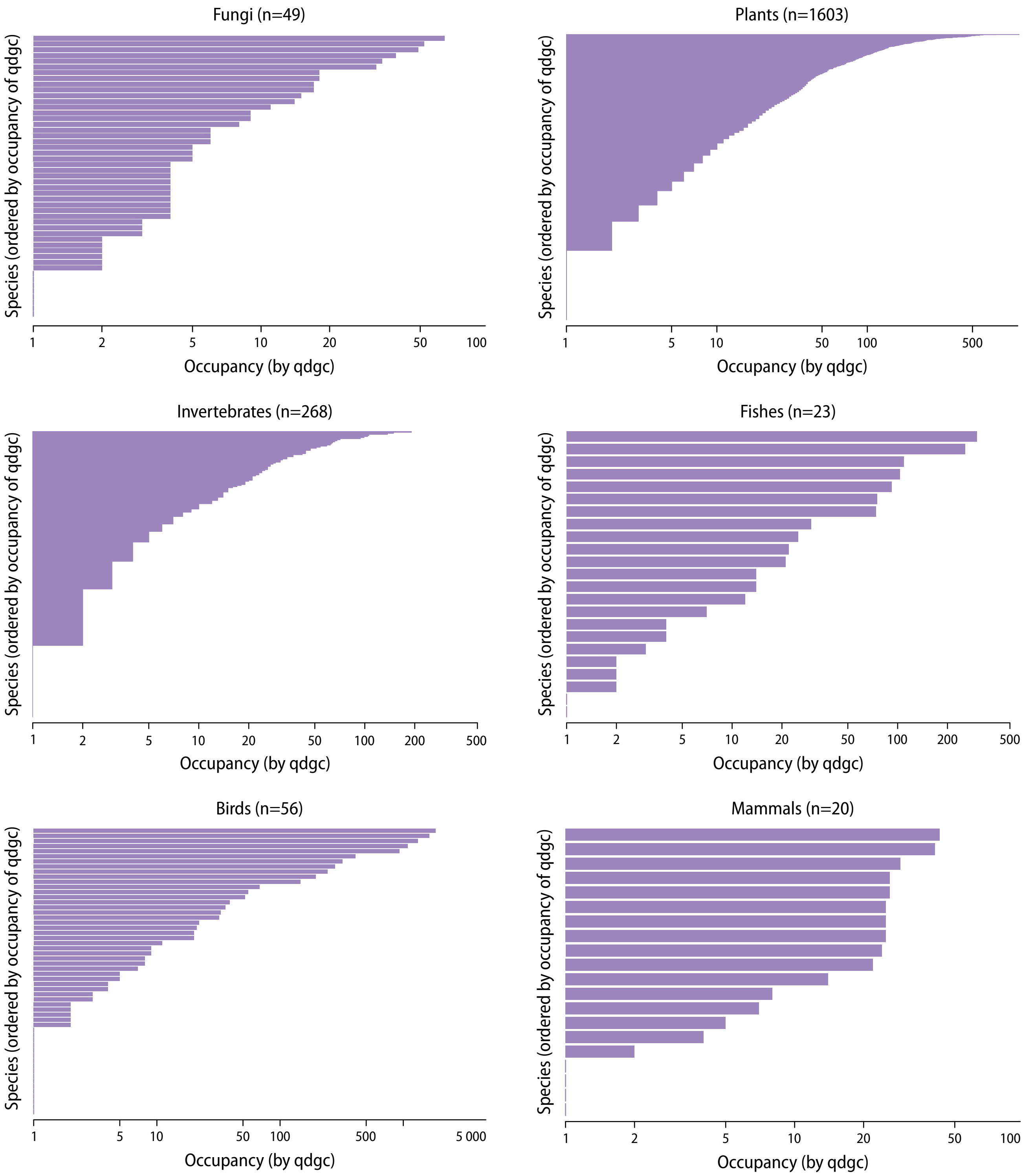


Figure 2.2. The distribution in broad-scale range sizes of alien taxa in South Africa. Range sizes are plotted on a log scale (qdgc is quarter degree grid cell).

Fringilla coelebs, *Lagonosticta nitidula* and *Columba livia*) and two species of fungi (*Aseroe rubra* and *Uromycladium morrisii*) (Table S2.3). These increases are similar to previous increases noted in 2019, supporting the assertion that although the majority of alien species have limited distribution many are spreading (Figure 2.3).

The integration between GBIF and widely used citizen science platforms such as iNaturalist means that the flow of information from observations to incorporation into this report has improved significantly (see Figure S2.1 and Supplementary Material S2.3). For example, iNaturalist records (97% of human observation records) now account for the majority of occurrence records of alien plants in South Africa (Figure 2.4). Similarly, iNaturalist accounts for the majority of GBIF records of alien fungi (90% of distribution records) and the Southern African Bird Atlas Project 2 accounts for most of the alien animal taxa (62% of distribution records) in South Africa (Figure S2.1).

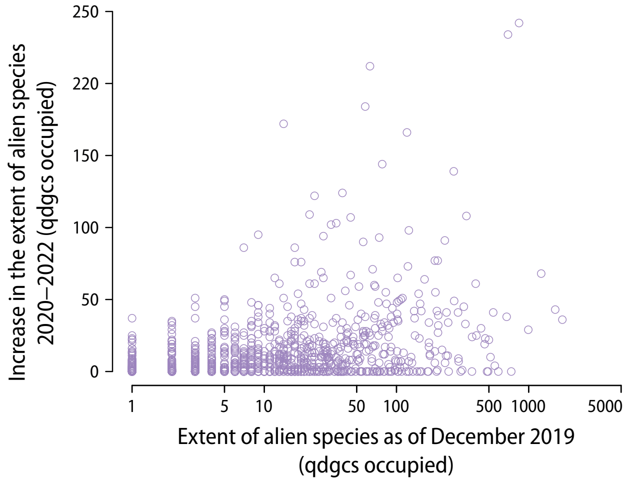


Figure 2.3. The increase in the recorded extent of 2 402 alien species in South Africa (December 2019 vs. December 2022). The values shown are the number of quarter degree grid cells (qdgcs) in which taxa have historically been recorded. The possibility that taxa are no longer present in a qdgc is not assessed (and so no taxa can have decreased in extent). Data are from SAPIA (accessed 17 March 2020) and GBIF (accessed 26 August 2023). Occupancy is plotted on a log scale (i.e., the x-axis) and change in occupancy is on a linear scale.

The Southern African Plant Invaders Atlas (SAPIA) was put on hiatus in the first quarter of 2020. This was due both to the retirement of the founder and lead of SAPIA, Lesley Henderson, and ongoing uncertainty about ownership of the brand. SAPIA provided standardised data on the distribution of alien plants through collating submissions from experts (which can now occur via iNaturalist, though with different quality control procedures) and through dedicated roadside surveys across the country (which are no longer happening). The active surveillance effort of SAPIA allowed for trends in the extent of plant invasions to be reliably evaluated over time (cf. Henderson & Wilson 2017). The loss of this monitoring represents a significant decline in the ability of South Africa to track plant invasions. Various remote sensing techniques continue to offer great promise in addressing some of these issues, but are not without their own limitations and cannot replace on-ground active surveillance by trained botanists (Canavan et al. 2021; Keet et al. 2022). As such, the systematic and repeatable information required to track invasions over time are not yet available.

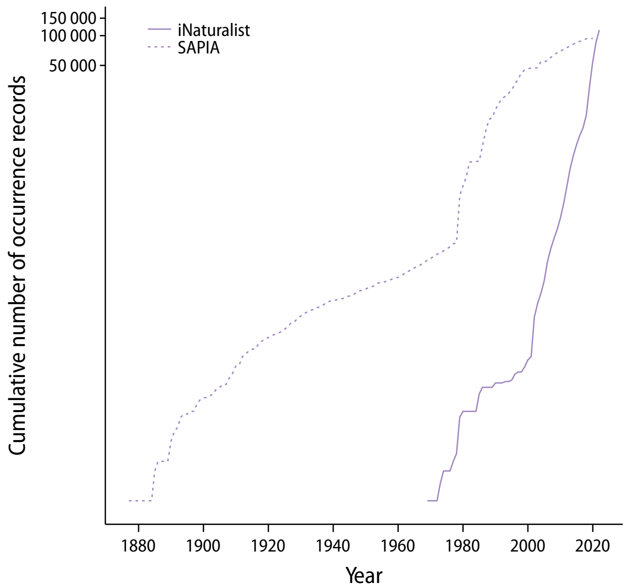


Figure 2.4. Cumulative number of occurrence records of alien plant taxa recorded in South Africa up to December 2022 from the Southern African Plant Invaders Atlas (SAPIA) (accessed 17 March 2020, noting no additional records have been added since then) and iNaturalist records obtained from GBIF (accessed 26 August 2023). The cumulative number of occurrence records is plotted on a log scale.

2.3 Abundance of alien species

In previous reports, 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 (Kotzé et al. 2010). This situation has not changed. There have been some recent developments, for example, the National Invasive Alien Plant Survey approach was recently further described (Kotzé et al. 2019) and applied at a small scale in the Agulhas Plain in South Africa (Kotzé et al. 2020).

2.4 Impact of alien species

A recent review of the ecological and social impacts of biological invasions in South Africa confirmed previous findings. Experts believe many invasive species cause 'Major' negative impacts on biodiversity. However, there are few studies that formally document impacts (see Supplementary Material S2.5; Zengeya & Wilson 2020; Van Wilgen et al. 2022b). An evaluation of the monetary costs of invasions to South Africa has recently been completed using the InvaCost methodology (see Box 3.1), though even fewer studies contained relevant information than those analysed by Van Wilgen et al. (2022b).

National-level EICAT assessments have been completed for 36 species (Table 2.2), with three of these taxa estimated to have 'Moderate' impacts, 18 'Major' impacts and one a 'Massive' impact. The seemingly high proportion of taxa with harmful impacts is, however, an artefact as taxa known to cause impact were prioritised for assessment. As efforts to collate information on the impacts of alien species using standardised protocols increase, a more complete picture will emerge. Examples of plant taxa assessed to date include: *Eucalyptus camaldulensis* (red gum) that forms dense thickets along waterways and dominates or excludes native vegetation (Tererai et al. 2013; Hirsch et al. 2020); two *Neltuma* species (previously *Prosopis*; mesquite) that competitively displace native vegetation, birds and invertebrate communities (Steenkamp & Chown 1996; Dean et al. 2002; Schachtschneider & February 2013); five Australian *Acacia* species (wattles) that cause 'Major' impacts on native species through competition and changes to ecosystem functioning (Jansen & Kumschick 2022); and *Lantana camara* (lantana) and *Chromolaena odorata* (triffid weed) that cause physical changes to ecosystem structure, leading to a change in invertebrate species community composition with a decline in some taxa and a loss of others (Samways et al. 1996; Mgobozi et al. 2008). In terms of animals, *Linepithema humile* (the Argentine ant) competitively displaces and reduces the abundance of native ants (Schoeman & Samways 2011). Few national-level Socio-Economic Classification of Alien Taxa (SEICAT) assessments have been done in South Africa (see Supplementary Material S2.5).

Alien species can cause both positive and negative environmental impacts (Vimercati et al. 2020). A major advance since 2019 in monitoring the **impact of alien species** has been the development of the EICAT+ framework (Vimercati et al. 2022) that enables the classification of positive impacts of alien taxa on native biodiversity. The framework can be applied to all alien taxa and at different spatial and organisational scales. If EICAT+ is used in combination with EICAT, it can help to forecast unwanted consequences of alien taxa control. EICAT+ can also help quantify the degree to which restoration and biocontrol programmes based on alien species offer positive outcomes to native biodiversity conservation (e.g., identify biological control agents that offer the highest positive impacts on native biodiversity).

Table 2.2. The number of taxa that have impact assessments for South Africa in terms of the Environmental Impact Classification for Alien Taxa (EICAT) as of December 2022 (see Table S2.4 for more details). Only four taxa (all trees and shrubs), have impact assessments for South Africa in terms of the Socio-Economic Classification of Alien Taxa (SEICAT).

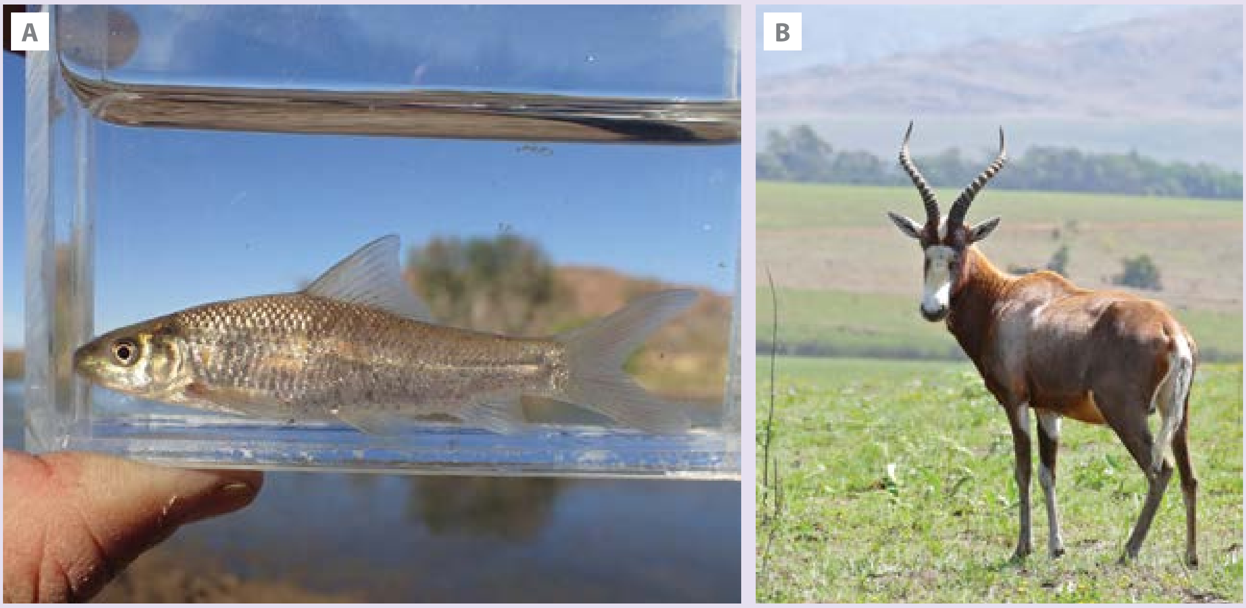
Group	Data Deficient	Minimal Concern	Minor	Moderate	Major	Massive	Total
Grasses, annuals and vines	7	0	2	2	2	0	**13**
Trees and shrubs	0	1	0	1	11	0	**13**
Freshwater fishes	0	0	0	0	4	1	**5**
Freshwater invertebrates	4	0	0	0	0	0	**4**
Terrestrial invertebrates	0	0	0	0	1	0	**1**
Total	11	1	2	3	18	1	**36**

Box 2.1. Native-alien populations

Species that are native to South Africa have been intentionally and accidentally moved around the country by humans and introduced to parts of the country where they are not native (see Section 1.4 and Table S1.4. for details on pathways of dispersal). In a recent paper, Nelufule et al. (2022), systematically reviewed the phenomenon and defined it as a 'population that is: 1) within a country to which the species is native, 2) founded by individuals moved by direct human agency [or substantial indirect human agency, see (Essl et al. 2018)], 3) over a biogeographical barrier, and 4) to an area beyond the species' native range'. A variety of terms have been used for this phenomenon in South Africa, including 'extralimital introductions' (Ellender & Weyl 2014) and 'domestic exotics' (Measey et al. 2017); however, building on the term used in the Global Register of Introduced and Invasive Species (Pagad et al. 2018), and to more closely reflect existing terminology, the term 'native-alien populations' was adopted (Nelufule et al. 2022).

To facilitate uptake into policy, management, and reporting, Nelufule et al. (2023b) developed a protocol to classify native-alien populations, and, using this protocol, collated an inventory of native-alien populations in South Africa (Nelufule et al. 2023a). The inventory contains information on 77 native taxa from nine classes that have formed 132 native-alien populations across the terrestrial (101 populations), freshwater (26 populations), and marine environments (5 populations). Most of these populations are established (59%), but a few are invasive (18%). Some of these native-alien populations have had significant negative impacts (Box Figure 2.1). Although the phenomenon appears to be rare in comparison to the number of alien species introduced from other countries (Section 2.1), native-alien populations are under-reported.

Native-alien populations are understudied globally and they deserve more attention (Vitule et al. 2019). This is because although these populations are a subset of alien populations, they tend to differ from other alien populations in terms of their invasion potential and the type of impacts they have. They also pose a specific management and regulatory challenge, and as their prevalence will likely increase with global change (Nelufule et al. 2022). The definition, protocol, and database that are now available will make it possible to monitor and report on the status of these native-alien populations.



Box Figure 2.1. Taxa with native-alien populations in South Africa that have threatened native biodiversity through hybridisation. A, populations of *Labeo capensis* (Orange River mudfish) translocated to the Eastern Cape have hybridised with *L. umbratus* (moggel), leading to introgression and threatening moggel's genetic integrity (Ramoejane et al. 2020); B, *Damaliscus pygargus* subsp. *phillipsi* (blesbok) native-alien populations in the Western Cape hybridised with the endemic *D. p.* subsp. *pygargus* (bontebok), and only through concerted and intensive interventions was the extinction of bontebok prevented (Van Wyk et al. 2017). Photographs: A, © M. Desai; B, © B. Dupont.

2.5 Trends in species indicators

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
2. Number of invasive species that have 'Major' impacts	↗	low (many taxa still need to be assessed)	↘	The impact of 36 invasive species has been assessed using the methodology of the IUCN's Environmental Impact Classification of Alien Taxa (EICAT) scheme. Of these, 19 are reported to cause 'Major' or 'Massive' impacts in mainland South Africa.	The number of invasives that have 'Major' impacts will increase as more impact assessments are conducted. 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. Ongoing 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 might also be made.
2.1 Number and status of alien species	↗	high	↘ (for invasive species)	Of 3 511 alien taxa systematically recorded as present in South Africa, over a third are invasive. The process of documenting and tracking changes in the status of alien species has been substantially improved through the development of workflows to ensure that work is properly documented and repeatable.	South Africa faces a substantial invasion debt because most alien species are not yet invasive and new alien species continue to arrive. The number of alien species recorded in the country will 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 managers and policymakers.

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
2.2 Extent of alien species	→	medium	↘	The majority of alien species have limited distribution but many of these are increasing in extent.	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.
2.3 Abundance of alien species		not assessed	↘	No new data were available on the **abundance of alien species**.	Understanding trends in abundance is important if the effectiveness of management interventions is to be monitored, and the magnitude of future impacts predicted.
2.4 Impact of alien species	↗	medium	↘	19 species have been reported to cause 'Major' or 'Massive' impacts using the IUCN's EICAT scheme. However, as most invasive taxa have not been assessed, this number is expected to increase with time.	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.

→ no change; ↗ an increase; ↘ a decrease.

Araujia sericifera (© SAPlants).

Sphagneticola trilobata (© SAPlants).

Clearing of alien plants in the Western Cape (© Wesley Black).

CHAPTER 3 SITES

Lead authors: Tsungai Zengeya, Emily J. McCulloch-Jones & Brian W. van Wilgen

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Findings for sites

- Alien species are distributed across the country, with most broad-scale administrative units and biogeographical regions being invaded by a variety of taxa. Most alien species are found in the Western Cape, Eastern Cape and KwaZulu-Natal. Recorded **alien species richness** is also highest around major urban centres. A recent increase in recorded **alien species richness** around urban areas is due to an increase in records from citizen science platforms such as iNaturalist.

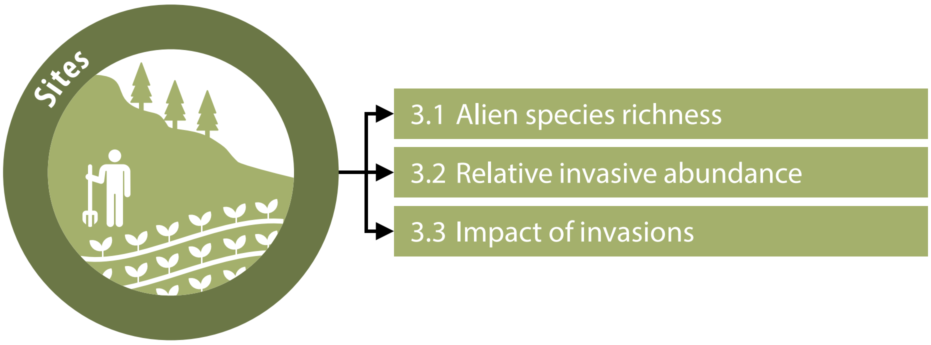
- The relative abundance of invasive plant species has been estimated for protected areas managed by SANParks and CapeNature. Invasions in these protected areas were found to be minor to extensive and these estimates have not changed since 2019.

- Biological invasions continue to cause major impacts on biodiversity, ecosystem services, and human livelihoods by reducing South Africa's water resources, degrading pasturelands, and exacerbating fires. These estimates need to be regularly reassessed. Work is ongoing to develop systematic processes to evaluate impact studies, to scale up and link estimates to other biodiversity assessment processes, and to incorporate previous studies to allow for tracking trends over time.

Gaps for species and sites[1]

- 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 the sites chapter



3.1 Alien species richness

Alien species are distributed across the country, with most broad-scale administrative units and biogeographical regions being invaded by a variety of taxa (Table 3.1 and Table S3.1–S3.3). At a provincial scale, there has been substantial changes in **alien species richness** (Table 3.1). Most alien plant species are found in the Western Cape, Eastern Cape and KwaZulu-Natal (Table 3.1a). The most prominent increase in the number of alien plant taxa per province was in the Western Cape, Gauteng and Limpopo. There were moderate to low increases in **alien species richness** in the other provinces (Table 3.1a). Alien plant species richness was highest in Fynbos, Savanna and Grassland biomes, and lowest in Desert and Forest biomes (Table 3.1b). **Alien species richness** doubled or more in most biomes (Abany Thicket, Desert, Fynbos, Forest and Succulent Karoo) and increased by at least a half in the other biomes. Twenty-three (23) alien freshwater fishes have been recorded in South Africa's Water Management Areas (WMAs), with over 10 species being recorded in the Berg, Komati, Mkomazi, Mfolozi and Tugela (Table 3.1c). There have been few recent changes to these numbers.

The observed increases in **alien species richness** are largely a result of records on iNaturalist (for plants) and digitisation of historical records by the Freshwater Biodiversity Information System (for fish) feeding through to GBIF (Figure S2.1). **Alien species richness** for marine ecoregions was not updated. Comprehensive estimates for **alien species richness** are limited to small areas and for particular taxa [e.g., McLean et al. (2018); Baard & Kraaij (2019); Cheney et al. (2019)]. Broad-scale **alien species richness** estimates are usually reliably estimated only for invasive species, noting that the introduction status of alien species (i.e., the degree to which a species has established and become invasive) was also not updated in this report.

[1]The gaps listed are the same as in the second report as the situation has not changed.

Table 3.1. Alien 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. The values are based on records available from GBIF (https://www.gbif.org/) and the Southern African Plant Invaders Atlas (SAPIA) for continental South Africa; and Robinson et al. (2020) for marine ecoregions. Further details are provided in the Supplementary Material, see Appendix 2 for the full species list. Information on **alien species richness** in the Prince Edward Islands is presented in Chapter 5 and the accompanying appendices and Supplementary Material.

a) Alien terrestrial and freshwater plant species richness per province.

Province	End of 2019	End of 2022	Increase
Eastern Cape	463	615	152
Free State	220	283	63
Gauteng	308	540	232
KwaZulu-Natal	542	708	166
Limpopo	277	467	190
Mpumalanga	344	457	113
Northern Cape	174	221	47
North West	215	289	74
Western Cape	504	841	337

b) Alien plant species richness per biome.

Biome	End of 2019	End of 2022	Increase
Albany Thicket	99	261	162
Desert	5	10	5
Fynbos	300	660	360
Forest	38	113	75
Grassland	293	494	201
Indian Ocean Coastal Belt	234	393	159
Nama-Karoo	67	128	61
Savanna	314	587	273
Succulent Karoo	55	134	79

c) Alien freshwater fish species richness per Water Management Area.

Water Management Area	End of 2019	End of 2022	Increase
A–Limpopo	8	9	1
B–Olifants North	9	10	1
C–Vaal	8	9	1
D–Orange	7	8	1
E–Olifants West	7	7	0
F–Buffels	0	0	0
G–Berg	13	15	2
H–Breede	8	9	1
J–Gouritz	7	8	1
K–Krom	9	10	1
L–Gamtoos	6	7	1
M–Swartkops	6	6	0
N–Sundays	4	5	1
P–Bushmans	4	5	1
Q–Great Fish	6	6	0
R–Keiskamma	6	6	0
S–Kei	10	10	0
T–Mzimvubu	8	9	1
U–Mkomazi	12	13	1
V–Tugela	16	17	1
W–Mfolozi	11	12	1
X–Komati	11	12	1

Table 3.1. (Continued) **Alien 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. The values are based on records available from GBIF (https://www.gbif.org/) and the Southern African Plant Invaders Atlas (SAPIA) for continental South Africa; and Robinson et al. (2020) for marine ecoregions. Further details are provided in the Supplementary Material, see Appendix 2 for the full species list. Information on **alien species richness** in the Prince Edward Islands is presented in Chapter 5 and the accompanying appendices and Supplementary Material.

d) Marine invasive species richness per marine ecoregion (not updated for 2022).

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

e) Invasive species in protected areas in South Africa.

Invasive species richness	Cape Nature			SANParks		
	End of 2019	August 2021	Increase	End of 2019	End of 2022	Increase
0	0	0	0	0	0	0
1–10	3	3	0	0	0	0
10–20	10	10	0	6	6	0
21–30	4	4	0	3	3	0
31–40	10	10	0	4	4	0
41–50	3	3	0	1	1	0
>50	1	1	0	6	6	0

At a quarter-degree grid cell (qdgc) scale, only 9% of qdgcs (184 out of 1 966) had 50 or more alien taxa. The recorded **alien species richness** for birds and plants appears to be highest around major urban centres (Figure 3.1a, c). This is likely because some species are commensal with humans, most were first introduced to urban centres, and because of greater sampling around urban areas. Increases in observations from citizen scientist platforms such as iNaturalist (for plants) and the Southern African Bird Atlas Project 2 (for birds) will have contributed to the increases in **alien species richness** around urban areas (Figure 3.1b, d and S3.1).

Information on **alien species richness** was also available for SANParks and Cape Nature protected areas (Table 3.1e). No protected area complex is alien-free, but the distribution of invasives between protected areas is highly skewed. The number of invasive species (excluding biocontrol agents and marine species) that are reported to occur across the SANParks estates are 1 014. Of these, there are 256 animal species and 758 plant species. Of these taxa 333 are listed under the A&IS Regulations, the remaining 681 species are unlisted. Three protected areas (Garden Route National Park, Kruger National Park and Table Mountain National Park) had more than 100 invasive species. In 2022, Cape Nature listed 759 invasive species across their estate of 31 protected area clusters. The number of invasive species included 502 plants and 257 animals, of which 404 are listed under the A&IS Regulations.

3.2 Relative invasive abundance

There are no country-wide estimates for the relative abundance of invasive species. Estimates are available for invasive plants in protected areas managed by the South African National Parks and Cape Nature. Estimates of **relative invasive abundance** in these protected areas from 2019 indicate that invasions were 'Minor' to 'Extensive' (Table 3.2). There have been no major changes to these estimates.

Table 3.2. Estimates of **relative invasive abundance** in South Africa's protected areas based on percentage plant cover. Alien-free means that no alien species were recorded in the protected area.

Relative invasive abundance	Number of Cape Nature's protected areas		Number of SANParks' protected areas	
	2018	2021	2019	2022
Alien-free	0	0	0	0
Minor <2%	12	11	14	14
Moderate 2–10%	5	7	2	2
Extensive 10–50%	12	11	0	0
Dominant >50%	0	0	0	0

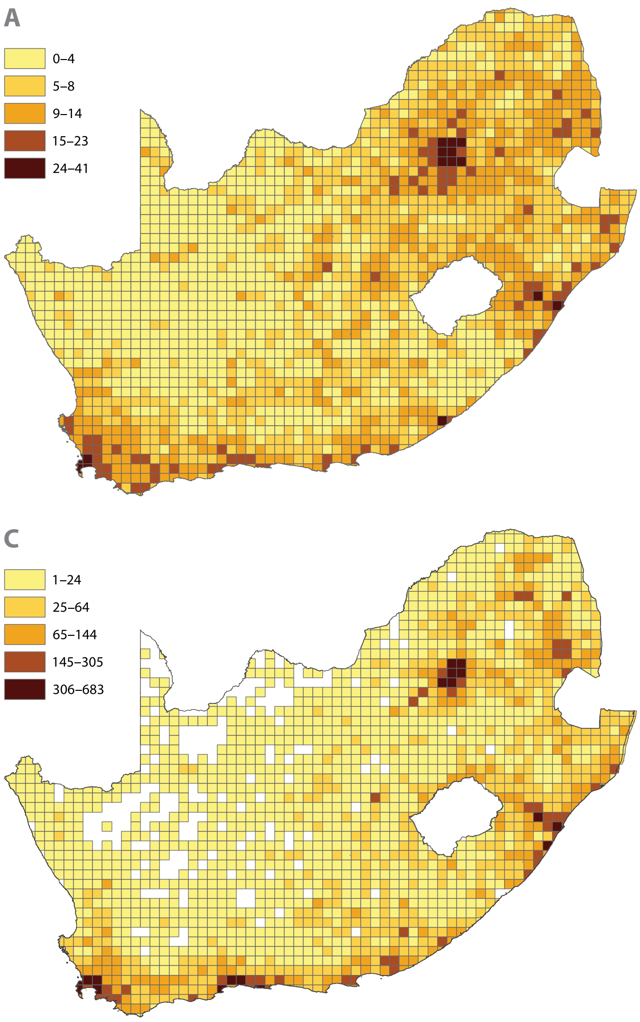


Figure 3.1. Alien species richness of birds and plants in South Africa per quarter-degree grid cell (qdgc) as of December 2022 and the change in these values since December 2019. A, alien bird species richness; B, increases in alien bird species richness; C, alien plant species richness; D, increases in alien plant species richness. Maps are based on occurrence records from GBIF and SAPIA.

3.3 Impact of invasions

Van Wilgen et al. (2008) undertook a biome-scale assessment of the impact of invasive plants on ecosystem services in South Africa. This study has been pivotal in our understanding of the impacts of invasive plants (invasive trees in particular), but the study has not been updated, revised or reassessed. The intention is to replicate the Van Wilgen et al. (2008) study and develop workflows [*sensu* Seebens et al. (2020)] to improve the applicability and repeatability of the methods. The process is intended to help identify gaps in the study and aspects of the methods that could benefit from updated data sources and recent modelling techniques. Ultimately, the workflow would provide a synthesised, reproducible and transparent method that can be used to assess the impacts of invasive plant species over time. It should be noted that particular focus will be given to the impacts of invasive trees on water resources in South Africa. The metric used to communicate this impact over time has varied greatly and the intention is to identify a standard metric that can be used to express impact to allow for continued comparisons. As such it remains the case that evaluations of impact on particular sites are often piecemeal or fraught with major assumptions.

Jacaranda mimosifolia (© Forest and Kim Starr).

Box 3.1. Estimating the monetary cost of biological invasions to South Africa

Biological invasions can cause substantial economic losses through impacts on ecosystem functioning and the delivery of ecosystem services (Vaissière et al. 2022). However, historically, there have been few monetary estimates of these impacts and estimates that have been made can often not be compared (Cuthbert et al. 2020). To address this gap, Diagne et al. (2020) collated monetary costs associated with biological invasions from peer-reviewed and grey literature sources around the world. These costs were systematically incorporated into a single database (the InvaCost Project: https://invacost.fr/en/outcomes/).

As part of this report, the InvaCost approach was applied to South Africa. Sixty documents over the period 1960–June 2023 were found to contain relevant information on biological invasions. The reported costs of damage amounted to ZAR 52.7 billion with ZAR 9.6 billion spent on management (Box Table 3.1). The majority of both damage and management costs were due to plants, e.g., 17% of all management costs were spent on *Acacia* spp. (wattles), with wattles also responsible for ~70% of all damage costs. However, estimates of what the costs might have been (e.g., based on extrapolations and models), suggest both damage and management costs were much greater than actually reported (Box Table 3.1).

A major issue with these values is that they do not directly indicate whether the management was appropriate. Did spending on management significantly reduce damage costs? Would more spending on management be cost-effective (i.e., is there a return on investment such that for every Rand spent on management at least one Rand in damage would be saved)?

The other major concern is that these values and estimates are heavily biased and based on a few studies of a few taxa. The money spent on controlling invasions by the DFFE and by agencies financially supported by the DFFE for controlling biological invasions is known in some detail. This information forms a large part of the reported costs of management. Detailed studies are needed to evaluate the costs carried by other government agencies and other stakeholders noting that even the current amount spent on management is likely a large underestimate.

The InvaCost study is thus a first step in: developing robust and policy-relevant economic estimates of the costs of invasions to South Africa; the amount of money spent to manage invasions; and how levels of spending might affect the return on investment of different interventions.

Box Table 3.1. Summary of the monetary costs of biological invasions to South Africa (1960–June 2023) based on an InvaCost approach. Here and elsewhere in this box, these values were adjusted to 2022 ZAR values.

	Number of documents	Total cost (ZAR billion)
Damage (reported cost)	3	52.7
Management (reported cost)	36	9.6
Damage (estimated cost)	11	195.2
Management (estimated cost)	19	231.8

3.4 Trends in sites indicators

Indicator	Trend	Confidence	Desired trend	Current status	Outlook
3. Extent of area that suffers 'Major' impacts from invasions	not reassessed		↘	Biological invasions continue to cause 'Major' impacts on biodiversity, ecosystem services and human livelihoods by reducing South Africa's water resources, degrading pasturelands and exacerbating fires. These estimates, however, have not been recently revised.	If control efforts focus on priority sites (e.g., sites that provide water to South Africa's towns and cities – Strategic Water Source Areas) 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. Ongoing work (including the development of systematic processes for evaluating impact studies and workflows that link to other biodiversity assessments and previous studies) should assist with these processes.
3.1 Alien species richness	↗	low	↘ (for invasive species)	Significant increases were seen in various provinces and biomes, although without active surveillance this might be an artefact of more records being submitted to the citizen science platform iNaturalist.	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.
3.2 Relative invasive abundance	→	low	↘	Estimates were only available for protected areas managed by SANParks and CapeNature. There have been no major changes in the relative abundance of invasive plants in these protected areas.	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 DFFE 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.

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status	Outlook
3.3 Impacts of invasions	not reassessed		↘	Several studies have provided estimates for impacts of invasions at particular sites that indicate that biological invasions cause 'Major' impacts on biodiversity and ecosystems services, by among other things, reducing water resources, degrading pasture lands and exacerbating fires. However, these evaluations are often piecemeal or are limited by major assumptions.	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 refocussing control efforts on agreed priority sites and taking steps to improve control effectiveness. Impacts of invasions on sites have been quantified using different approaches and metrics over time and it is not yet possible to compare values with previous reports. There is therefore a need to develop systematic processes for evaluating the combined impacts of invasions at a given site.

→ no change; ↗ an increase; ↘ a decrease.

Cistus ladanifer (© Krzysztof Ziarnek).

Canna indica (© Esin Üstün).

Working for Water clearing alien vegetation (© Brian van Wilgen).

CHAPTER 4 INTERVENTIONS

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Findings for interventions

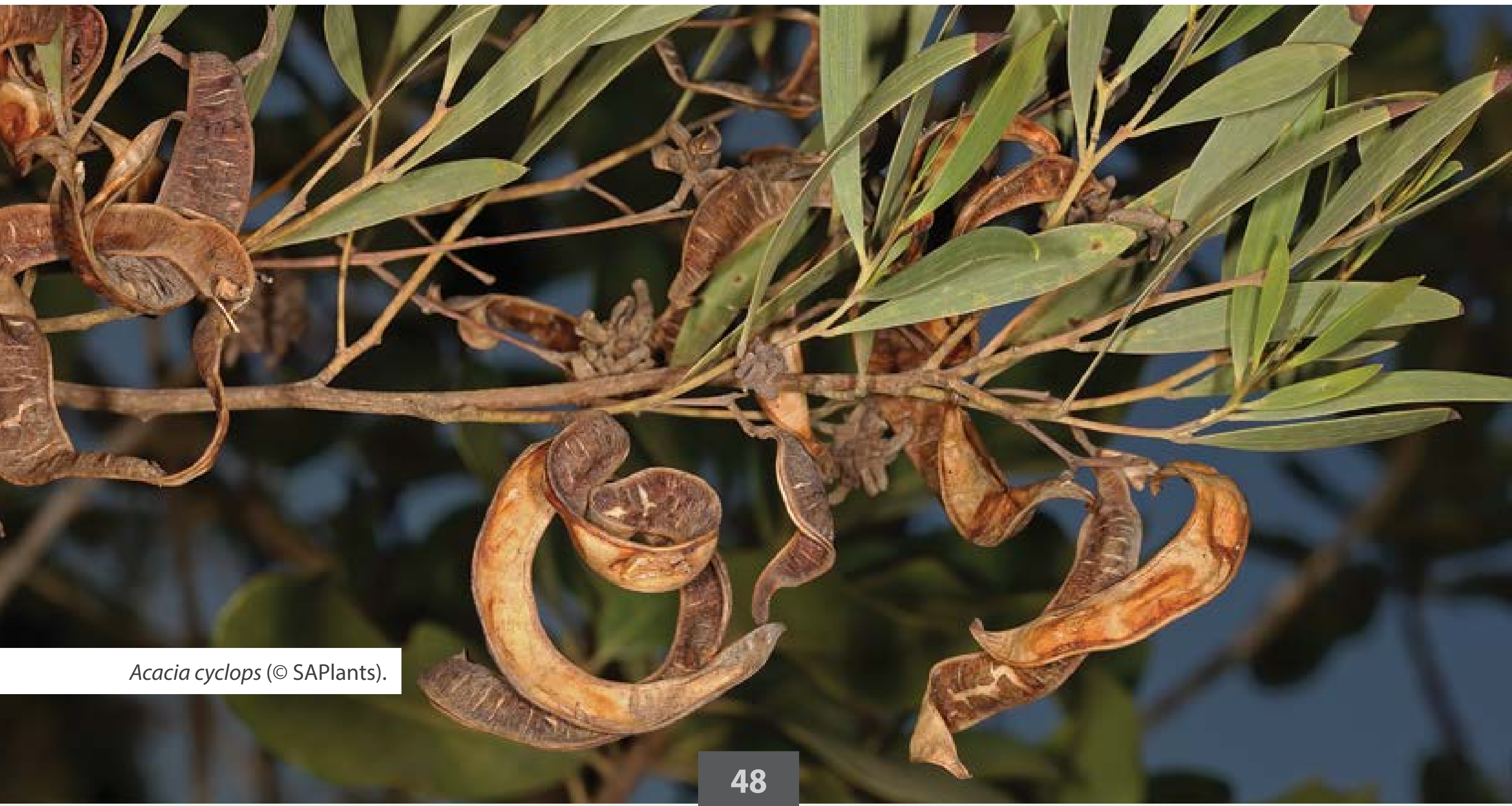
- The Alien & Invasive Species Regulations under the National Environmental Management: Biodiversity Act (the NEM:BA A&IS Regulations) were revised and published in 2020. These amendments are considered to have improved the regulatory regime.
- The NEM:BA A&IS Lists were also changed with the prohibited list removed and the listings for 73 taxa changed.
- A process has been set up to ensure that changes to the NEM:BA A&IS Lists can be made more regularly, transparently and informed by evidence.
- Over ZAR 1.5 billion has been spent on the management of biological invasions over the period 2020–2022.
- The **money spent** controlling invasions has declined steadily in real terms since 2015.
- Several NGOs have provided funding for the control of invasive trees in catchment areas and of invasive freshwater fish. This is an encouraging development.
- All legal introductions of new alien taxa require import permits, with permits issued only if the risks are demonstrated to be sufficiently low.
- Illegal and accidental introductions are continuing. The national Border Management Authority offers the opportunity for increased co-ordination of South Africa's biosecurity.
- Twenty-three (23) species (of which 16 are regulated and seven are unregulated) have management plans in place. These are all actual or potential targets for national eradication.

- One third of the 560 taxa listed under the NEM:BA A&IS Regulations and a further 136 unregulated species, have been subjected to some form of control over the past three years.
- Most species subjected to control were plants (236 species) or insects (76 species).
- The effectiveness of control could only be estimated for 30% of the treated species. Seventeen (17) species were assessed as being under permanent control and a further 41 as being under effective control (based predominantly on an assessment of biological control).
- The area covered by current site management plans has more than doubled (from 2.4 to 5.3 million ha) since 2016; and there has been a substantial improvement in the adequacy of planning.
- Control operations reached 1% of the estimated invaded area between 2020 and 2022. There is evidence that control efforts have reduced the area invaded at some sites, but most invasive species have continued to expand their range when assessed at a national scale.

Gaps for interventions[1]

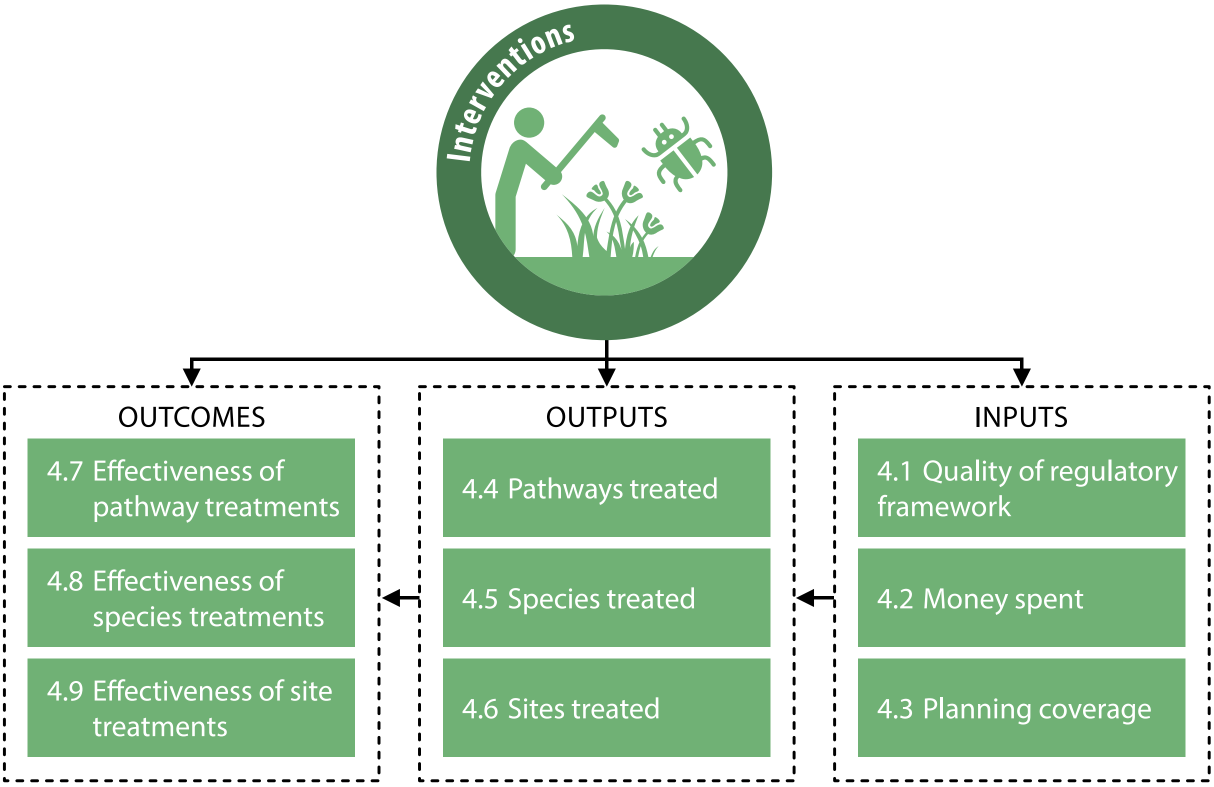
- A comprehensive policy, and a strategy to implement such a policy, is needed to guide interventions on biological invasions in South Africa.
- A lack of adequate planning with clear goals and the paucity of monitoring of the outcomes of interventions in terms of their impacts on biological invasions remain constraints to effective management and a substantial impediment to assessing the effectiveness of control measures.

[1]These key gaps have not changed since the second report.



Acacia cyclops (© SAPlants).

Indicators covered in the interventions chapter



4.1 Input – quality of the regulatory framework

Between January 2020 and December 2022, the primary legislation governing biological invasions in South Africa (the NEM:BA of 2004) has not changed[1]. However, revisions to the NEM:BA A&IS Regulations of 2014 and the Lists of 2016 were published in September 2020 (see Supplementary Material S4.1 for the full details). The revised regulations and lists came into force on 1 March 2021, with the inclusion of two invasive trout species, *Oncorhynchus mykiss* (rainbow trout) and *Salmo trutta* (brown trout), suspended until further notice.

Several key changes are highlighted below (for full details see Supplementary Material S4.1):

- Provision for 'Category 1b Control Plans' (includes taxa in other categories that are beyond permitted or exempt areas).
- Ports of entry for import are specified.
- A general obligation is specified requiring efforts to prevent spread and control any escapes of listed alien taxa.
- The removal of the prohibited list.
- Applications for permits for listed alien taxa need to include information specified in the 'Risk assessment framework'.
- The issuing authority must notify potentially affected municipalities (not just provinces) of an application for a permit.

[1]The National Environmental Management Laws Amendment Act, 2022 came into effect 30 June 2023.

- Where other regulatory processes also govern the restricted activities, and the issuing authority is also the decision-maker in terms of the other regulatory processes, the applicable decision-making timeframes must be aligned.
- Permits may be issued for a period not exceeding ten years (previously five) under specific circumstances.
- If listed alien taxa are present on land that is sold, permits may be transferred to the new owner providing the new owner contacts the department (previously, the seller was obligated to notify the buyer of the presence of alien and invasive species on the land and the buyer had to apply for permits); this does not apply to the sale of listed alien taxa.
- The heading 'Prohibited alien and listed invasive species directives' was removed. The obligation to keep a record of directives has been retained but moved to another regulation.
- There were no changes to the annexures.

The decision to remove the prohibited list[1] was on the basis that: a) all alien taxa not legally present in South Africa require an import permit regardless of whether they are listed as prohibited; and b) the evidence as to why taxa were included on the prohibited list was not available. This does not affect the activities that are prohibited with regard to other listed taxa and the requirement to apply for a permit to import a taxon not legally present in South Africa still remains.

Other than the prohibited list, the majority (almost 90%) of listings in 2020 were as they were in 2016. There were changes to the listings of 73 taxa: four taxa were added, all freshwater fishes; 14 taxa were deleted, mostly birds; 20 taxa previously prohibited were added to the lists; for 19 plant taxa the provision that 'sterile cultivars or hybrids are not listed' was removed, although this provision remains for 14 plant taxa. For full details of the changes see Wilson (2023) and Supplementary Material S4.2. Notably, the current 2020 lists still contain several inconsistencies between the listed name and the recognised name as per various taxonomic backbones (261 out of 560 taxa see Table S4.3). In most of these cases this is due to the listing of synonyms in the regulatory name, but at least two regulated taxa are listed under names that are not recognised.

Requests to change the listings of taxa under the NEM:BA A&IS Regulations have, to date, been dealt with on an ad hoc basis. A standardised official process for publishing proposals to revise the regulatory lists is under development. To support this, risk analyses are produced in a consistent format using a risk analysis framework developed specifically for South Africa (Kumschick et al. 2020b). These risk analyses are reviewed by an independent scientific panel [the Alien Species Risk Analysis Review Panel (ASRARP); see Kumschick et al. (2020a) for more details] set up and run by SANBI on DFFE's behalf. However, the risk analyses themselves are not yet in the public domain, and the framework is not yet an official government document.

Risk analyses on 68 taxa were reviewed by the ASRARP and processed by SANBI between 2020 and 2022, this was a significant increase on the previous period (risk analyses on 25 taxa were finalised in 2018 and 2019) (see Supplementary Material S4.4). Of the 68 risk analyses, ten were on taxa that are not listed, and of the remaining 58 listed taxa, 33 suggested no change to the listing (changes to nomenclature excepted).

Terms of reference for a governmental decision-making body [The Risk Analysis Review Committee (RARC)] have been circulated to the RARC and the body had its inaugural meeting on 2 February 2023. The RARC, amongst other functions, intends to review proposals to change listings received by SANBI (based on ASRARP's recommendations). This process would facilitate regular revisions to the lists as new information becomes available, as new requests are made and as nomenclature changes.

In terms of permits, 27 import permits were issued by DFFE in 2020–2022 for 13 taxa with some of these for research and display purposes; by comparison 114 import permits were issued on 25 taxa in the period 2015–2019 (no permits were issued in 2014). This means half the number of import permits were granted per year in 2020–2022 compared to the preceding three years. This trend was not seen for other types of permits. During 2020–2022, 891 permits were

[1]Interpreted here as a list of taxa that were not legally in the country and that may not be imported.

issued (excluding import permits and permits for research, biocontrol or display purposes that can be issued for any listed taxon). At ~300 permits per year this was slightly fewer that the number issued in the previous years (an average of ~350 per year for 2015–2019), but there was no noticeable decline during the COVID-19 lockdowns (Figure S4.1).

Notably, of the 117 listed taxa for which there is provision for permits to be issued for their usage in the 2020 lists (i.e., Category 2) 26 taxa have never had a permit issued, a further 39 taxa have had five or fewer permits issued, but the five most frequently permitted taxa have had over 300 permits issued each [in order *Kobus leche* subsp. *leche* (red lechwe); *Oreochromis niloticus* (Nile tilapia); *Ctenopharyngodon idella* (grass carp and triploid grass carp); *Dama dama* (fallow deer); and *Psittacula krameri* (rose-ringed parakeet)] (see Table S4.5; for the full list of permits see Appendix 6). Permits for Category 2 tree species used in commercial forestry are subject to pragmatic interpretations of the regulations, which could have consequences for containing the spread of the species used (Box 4.1).

There were no successful prosecutions under the NEM:BA A&IS Regulations in the period covered by this report. Two cases went to court but were dismissed. In the first case, the state failed to prove intention [for the transport of *Trachemys scripta* subsp. *elegans* (red-eared sliders)]. The second case involved a pet shop that had applied for a permit to trade in Category 2 listed species, and then sold them before a permit was issued. The court ruled that the DFFE had taken an excessively long time to issue the permit (i.e., exceeded the 60 days stipulated in the NEM:BA A&IS Regulations Section 23 to reach a decision after receiving a risk assessment report), thus unreasonably preventing the trader from conducting business and the case was dismissed.

The National Environmental Laws Amendment Act, 2022 (NEMLAA) was assented by the President in June 2022 and came into effect on 30 June 2023. The Amendment Act amended, among other Acts, the NEM:BA. Under the NEMLAA, the NEM:BA has clearer definitions of the terms 'eradicate' and 'control'. It is also clearer from the text that invasive species must be either eradicated or controlled depending on what is possible under the circumstances, whereas presently, landowners and other role-players are required to both eradicate and control invasive species. Furthermore, the NEM:BA no longer requires landowners to notify competent authorities of the presence of invasive species on their land. The Minister has the power to specify the circumstances under which such notification must be given to the competent authority.

Melia azedarach (© Zeynel Cebeci).

A national strategy for biological invasions is under development, led by the DFFE with input from other departmental officials and scientists from SANBI. As of October 2023, a draft strategy is yet to be made available for public comment.

A White Paper on the 'Conservation and Sustainable Use of South Africa's Biodiversity' was published on 14 June 2023. Biological invasions were referred to in one policy objective: '*1.4. Identify and manage harmful, and potentially harmful, invasive species, their potential and existing introduction pathways and biological invasions.*' For details of the expected outputs and outcomes see Supplementary Material S4.6. The White Paper represents an important step, but as the White Paper does not cover all aspects of biological invasions (e.g., the focus is on biodiversity rather than other impacts that invasive species can have on built-infrastructure and food security) it is unclear if it would negate the need for a policy specifically on biological invasions. The White Paper will be evaluated in the next report. However, Lukey and Hall (2020) make it clear that the law can be used to implement policy. If a law does not make provision for a means to implement policy, it may be necessary to introduce new laws or regulations. A White Paper is a precursor to law, but there is still no policy on biological invasions, so it is not immediately clear what has informed the drafting of references to invasions in the White Paper.

At an international level, South Africa is party to the Convention on Biological Diversity (CBD) and, as such, the recently agreed Kunming-Montreal Global Biodiversity Framework (GBF, Box 0.2), provides an important basis for developing strategic action and determining monitoring and reporting actions.

4.2 Input – money spent

In total, 14 organisations reported on money spent on biological invasions for 2020–2022, amounting to ~R1.5 billion (Table 4.1), values reported here are adjusted to 2020 values of ZAR unless otherwise specified. A retrospective analysis of the available information on spending by the DFFE's Working for Water programme (WfW) between 1999 and 2020 (Van Wilgen et al. 2022a) considered five categories of spending: 1) efforts to control established invasive species; 2) an incursion response programme that assessed and controlled alien plant taxa that were either not listed or that were eradication targets; 3) value-added projects; 4) high-altitude sites; and 5) biological control research and implementation.

The total amount spent on these five interventions by the WfW programme between 1999 and 2020 amounted to ZAR 7.1 billion. The bulk of this (ZAR 5.3 billion) was spent on the control of species that were well-established. Annual amounts spent on contract teams rose steeply between 2000 and 2003, and then stabilised until 2010. Further increases followed, peaking in 2015 and declining steadily thereafter (see Supplementary Material S4.7). Some of the relative decline in amount spent on control projects after 2015 was due to funding being diverted to value-added projects. Between 2015 and 2020, available information shows that an average of ZAR 62.7 million was spent on biological control research and implementation per year (2020 ZAR values). Of this, 87% was spent on locating, screening, releasing and monitoring new biological control agents, and 13% on mass-rearing and release programmes for established agents.

Another estimate of the money spent was from an effort to consolidate information from various sources using the InvaCost approach (see Box 3.1). For South Africa, there was limited information regarding funding for pre-introduction management and no records of costs associated with other pre-invasion efforts. Total management costs from 1960 to June 2023 amounted to ZAR 9.6 billion (expressed in 2022 values). This figure is known to be an underestimate but is moderately higher than the estimate of Van Wilgen et al. (2022a).

Jubase et al. (2021) surveyed the contributions made by volunteer hack groups in the Western Cape. They broadly estimated that half of these groups cleared nearly 5 300 ha of land per year, with estimated labour contributions of ZAR 5.1 million per year when aligned with formal state management cost estimates. This was not included in the above figures. Maluleke et al. (2021) retrospectively estimated the relative herbicide cost-saving associated with the use of biological control instead of chemical control. The study used a cost-benefit analysis framework with an 8% discount rate. The estimated cost of the biological control on four invasive aquatic plant species [*Azolla filiculoides* (azolla), *Myriophyllum aquaticum* (parrot's feather), *Pistia stratiotes* (water lettuce) and *Salvinia molesta* (Kariba weed), in order of cost-effectiveness], which are under complete biological control in South Africa, was about ZAR 7.8 million. The estimated cost of chemical control to achieve the same level of control varied between ZAR 150 million and ZAR 1 billion, depending on the method of application and number of follow up operations.

Table 4.1. Money reported as having been spent on the management of biological invasions in South Africa by different organisations between 2020 and 2022. The amounts are totalled for three years, unadjusted for inflation. Inputs from various organisations and many stakeholders, particularly in the private sector, were not available (and so the overall figure should be viewed as a lower estimate). However, it is also possible that there may be some double counting, as some of the money spent by implementing agencies may also have been reported by the Department of Forestry, Fisheries and the Environment's (DFFE's) Working for Water Programme.

Organisation	Money spent on	Money spent (ZAR)	Notes
Agricultural Research Council	Biological control research	104 495 930	ZAR 69 700 073 from the DFFE and ZAR 34 795 857 from the ARC.
Buffalo City (East London)	Protected areas within the municipal boundaries	9 151 000	This includes other activities such as clearing of vegetation along road verges.
Cape Nature	31 protected areas in the Western Cape	9 299 189	Most of this money came from the Working for Water programme and so there may be some double counting.
Centre for Biological Control, Rhodes University	Biological control research and implementation	82 000 000	ZAR 59 million from Working for Water; ZAR 15 million from the DST-NRF via the South African Research Chairs Initiative; ZAR 8 million from other sources. The bulk is spent at Rhodes University, but part of the funding is distributed to the universities of Cape Town, Witwatersrand, KwaZulu-Natal, Mpumalanga and Fort Hare.
City of Cape Town	Management of invasive species in municipal protected areas Mass-rearing of biological control agents	106 007 412	The City of Cape Town is the only municipality that reported that they were actively controlling the polyphagous shot-hole borer (*Euwallacea fornicatus*).
City of Ekurhuleni (Gauteng)	Management of aquatic ecosystems	17 700 000	Funding has been expended mostly on *Pontederia crassipes* (water hyacinth), *Arundo donax* (giant reed) and *Nymphaea mexicana* (yellow water lily) invading aquatic ecosystems.
Department of Agriculture, Land Reform and Rural Development	Responsible for Conservation of Agricultural Resources Act (CARA) and other legislation Maintains a presence at all border posts	No estimate available	The expenditure on these activities was requested from DALRRD but no input was received.
DFFE animal control projects	Control of invasive animals	No estimate available	The expenditure on these activities was requested from DFFE but no input was received.

Table 4.1. (Continued) Money reported as having been spent on the management of biological invasions in South Africa by different organisations between 2020 and 2022. The amounts are totalled for three years, unadjusted for inflation. Inputs from various organisations and many stakeholders, particularly in the private sector, have not been included (and so the overall figure should be viewed as a lower estimate). However, it is also possible that there may be some double counting, as some of the money spent by implementing agencies may also have been reported by the Department of Forestry, Fisheries and the Environment's (DFFE's) Working for Water Programme.

Organisation	Money spent on	Money spent (ZAR)	Notes
DFFE Biosecurity	Monitoring activities aimed at interception of alien species at OR Tambo International Airport	13 820 241	The figure reported here does not cover the costs of all of the biosecurity activities undertaken by the DFFE, nor does it include departmental overheads.
DFFE high altitude teams	Specially trained teams deployed to control invasive plants in inaccessible or mountainous terrain	255 298 699	Budgeted amount for financial years. The DFFE reported an amount of ZAR 208 237 112 and 22.6% was added to account for overheads (Van Wilgen et al. 2022a).
DFFE Natural Resource Management programmes (Working for Water)	Approximately 250 projects to control established invasive plants across all nine provinces	470 972 650	This covers the period 1 January 2020 to 30 April 2022. The DFFE was not able to supply data for the period 1 May to 31 December 2022. The DFFE reported an amount of ZAR 384 153 875 and 22.6% was added to account for overheads (Van Wilgen et al. 2022a). Funding (including overheads) can be broken down into: ZAR 413 206 893 for widespread alien plants (See Table 4.2 for a breakdown by the most costly species); ZAR 47 812 384 for eradication targets; ZAR 37 336 449 for native bush encroachers; and ZAR 10 475 934 for alien aquatic weeds.
DFFE value added industries	Establishment and operation of factories intended to produce a range of products with biomass sourced from alien plant control operations	237 223 158	Budgeted amount for financial years. The DFFE reported an amount of ZAR 193 493 604 and 22.6% was added to account for overheads (Van Wilgen et al. 2022a).
Gauteng provincial reserves (North)	Three protected areas in the north of Gauteng	6 000	Only includes costs of herbicide and a pair of scissors, staff time not included.
Gauteng provincial reserves (South)	Three protected areas in the south of Gauteng	2 300 000	
Invasive Fish Species Management (IFSM)	Control of *Cyprinus carpio* (common carp) in Groenvlei Lake, Western Cape.	450 000	IFSM is an NGO in the Garden Route. Amount spent between 2018 and 2022 was ZAR 750 000 (estimate supplied by the director, Johnny Snyman). Assuming an equal amount spent each year, the estimate for 2020 to 2022 is ZAR 450 000.

Table 4.1. (Continued) Money reported as having been spent on the management of biological invasions in South Africa by different organisations between 2020 and 2022. The amounts are totalled for three years, unadjusted for inflation. Inputs from various organisations and many stakeholders, particularly in the private sector, have not been included (and so the overall figure should be viewed as a lower estimate). However, it is also possible that there may be some double counting, as some of the money spent by implementing agencies may also have been reported by the Department of Forestry, Fisheries and the Environment's (DFFE's) Working for Water Programme.

Organisation	Money spent on	Money spent (ZAR)	Notes
South African National Biodiversity Institute	Preparation of status reports, risk analyses, incursion response, taxonomy, research, and human capacity development (placement of interns)	145 454 000	Money obtained on contract from DFFE.
South African National Parks	22 national parks across South Africa and outside of parks in buffer zones	3 985 260	SANParks reported an amount of ZAR 199 263 000, but only 2% of this came from the SANParks budget, the rest from DFFE.
The Greater Cape Town Water Fund	Catchments of the Berg and Theewaterskloof dams, and Atlantis aquifer, Western Cape	~100 000 000	Estimated amount provided by the project manager.
Volunteer groups	52 volunteer groups from the Western Cape who clear invasive plants	15 318 723	Data from Jubase et al. (2021). This is the current cost to clear the equivalent area that has been cleared by volunteer groups.
World Wide Fund for Nature South Africa (WWF-SA)	11 Strategic Water Source Areas in the Western Cape fynbos catchments and in the Eastern Cape and KwaZulu-Natal Drakensberg.	26 603 201	Some of this money may be included in the Greater Cape Town Water Fund estimate.

Table 4.2. Money spent clearing selected invasive plants in South Africa by the Working for Water programme. This is for the period 2020 to the end of April 2022. Values include a 22.6% overhead. Spending on these taxa represent about two thirds of all the money disbursed.

Taxon	Money spent (ZAR)	% of total cost
Acacia mearnsii (black wattle)	88 634 536	18.8
Lantana camara (lantana)	55 549 985	11.8
Acacia saligna (Port Jackson willow)	32 342 218	6.9
Neltuma species and hybrids (mesquite)	28 605 969	6.1
Acacia melanoxylon (Australian blackwood)	22 182 801	4.7
Acacia dealbata (silver wattle)	21 189 774	4.5
Rubus cuneifolius (American bramble)	13 391 654	2.8
Pinus pinaster (cluster pine)	13 204 338	2.8
Chromolaena odorata (triffid weed)	12 114 313	2.6
Acacia cyclops (*rooikrans*)	9 079 521	1.9
Psidium guajava (and possibly other *Psidium* spp.) (guava)	8 307 475	1.8
Eucalyptus camaldulensis (and possibly other *Eucalyptus* spp.) (river red gum)	8 144 657	1.7

4.3 Input – planning coverage

Pathway management plans: As reported in the previous report, no formally approved management plans for pathways have been developed by DFFE, and there is no requirement for pathway management plans under the NEM:BA A&IS Regulations. However, management is in place for 39 of 44 pathways. Therefore, it is assumed that plans are in place for those pathways, though no records of the plans being formally approved were available. In addition, ballast water management plans have been developed, but not implemented, thus 40 pathways are assumed to have plans in place (see Supplementary Material S4.8).

Species management plans: The NEM:BA requires [Section 75(4)] the Minister to ensure the coordination and implementation of plans (called programmes in the Act) for the prevention, control and eradication of invasive species. No plans have been formally adopted, although, as reported previously, plans have been prepared for two species [*Parthenium hysterophorus* (parthenium) and *Campuloclinium macrocephalum* (pom-pom weed)], two genera [*Acacia* (wattles) and *Neltuma* (previously *Prosopis*, mesquite)], and one family [Cactaceae (cacti)] of invasive plants. In addition, 22 plans have been developed for species targeted for, or considered for, nationwide eradication. Of the 22 species management plans, 12 were scored as adequate, eight as partially adequate and two as inadequate. Most (15) of these species are Category 1a, the other seven are not currently listed (see Supplementary Material S4.9 for how the plans were scored and Table S4.6 for the list of taxa).

Site management plans: In terms of the NEM:BA A&IS Regulations the responsibility for drawing up management plans for sites lies with individual landowners (state or private), because they are responsible by law for the control of listed alien taxa on their land. A database has been developed to track **planning coverage** for sites (see Table 4.3 and Supplementary Material S4.10). All plans submitted to SANBI for the first three status reports were captured into this database.

To date, 99 plans covering 7.9 million ha have been submitted to SANBI for inclusion in this and previous reports. Assuming there is no spatial overlap between plans, this amounts to 19.5 million ha or 40.5% of the estimated area covered by invasions in South Africa (Van Wilgen et al. 2022a). Of these, 67 plans are considered to be current and 32 have lapsed and are assumed not to have been updated. Therefore, it is assumed that current plans cover 5.3 million ha

Table 4.3. Management plans for biological invasions at particular sites. In cases where no plans were submitted to SANBI the area covered by the plans is considered to be zero.

Organisation	Sites to be managed	Area covered by plans (ha)	Adequacy of plans	Notes
Department of Forestry, Fisheries and the Environment Natural Resource Management programmes (Working for Water)	Working for Water has many projects across all nine provinces	0	NA	No plans were submitted. Working for Water does not prepare management plans as this is the responsibility of individual landowners (private and state) to who they provide support. However, Working for Water has funded the development of six demonstration 'management unit control plans' (MUCPs)[1] for the upper catchment of the Berg River; Cape Nature's Waterval Centre; the catchments of the Holsloot, Keurbooms, and Karatara rivers; and the Greater Simonsberg Conservancy. They will be assessed once they are received.
Cape Nature	Protected areas in the Western Cape Province	607 142	Adequate (486 476 ha) Partially adequate (120 666 ha)	19 plans covering 31 protected areas were submitted by Cape Nature; some plans cover more than one protected area 'complex'. In addition, demonstration 'management unit control plans' (see above) have been prepared for the upper catchment of the Berg River and the Waterval complex, both managed by Cape Nature.
South African National Parks	National Parks in South Africa	3 990 856	Adequate (3 755 927 ha) Partially adequate (214 514 ha) Inadequate (20 415 ha)	South African National Parks provided site management plans for 18 out of 22 national parks. Plans for the remaining national parks are being compiled.
Gauteng provincial reserves	Six protected areas within Gauteng	25 000	Partially adequate	Plans were prepared for the Abe Bailey, Alice Glöckner, Leeuwfontein, Roodeplaat Dam, Suikerbosrand Nature Reserves, and the Marievale Bird Sanctuary.

[1]The MUCP software can be downloaded from a site maintained by Andrew Wannenburgh (awannenburgh@dffe.gov.za) of the Operational Support and Planning Directorate in the Natural Resource Management programmes of the Department of Forestry, Fisheries and the Environment (https://sites.google.com/site/wfwplanning/monitoringandevaluation).

Table 4.3. (Continued) Management plans for biological invasions at particular sites. In cases where no plans were submitted to SANBI the area covered by the plans is considered to be zero.

Organisation	Sites to be managed	Area covered by plans (ha)	Adequacy of plans	Notes
Municipalities	Municipal management plans vary in their coverage. Some focus on protected areas within the municipal boundaries and others on the entire municipal area.	567 329	Adequate (250 000 ha) Partially adequate (317 329 ha)	Plans were submitted by the Berg River, Bitou, Buffalo City (East London), Cape Town, Ekurhuleni (Johannesburg), eThekwini (Durban), Knysna, uMdoni and Witzenberg municipalities.
Other Government	The plans submitted by large government agencies (for example Eskom and Transnet) cover some, but not all, of the land on which they operate.	371 442	Adequate (863 ha) Partially adequate (370 485 ha) Inadequate (94 ha)	Plans were submitted by the Breede-Gouritz Catchment Management Agency, Denel, Eskom, Transnet, and the Maloti Drakensberg Transfrontier Conservation and Development Programme.
The Greater Cape Town Water Fund	Catchments of the Berg and Theewaterskloof dams and Atlantis aquifer, Western Cape	0	NA	The Greater Cape Town Water Fund has developed a decision support system, which guides management decisions based on ongoing monitoring of progress towards goals. Plans were not received and so the adequacy of the system has not yet been assessed.
Private landowners	Six plans were submitted by privately owned companies or individuals	19 856	Adequate (4 ha) Partially adequate (19 852 ha)	A demonstration management unit control plan was also developed in 2016 for the Greater Simonsberg Conservancy near Stellenbosch, which includes 33 private landowners. The plan is no longer current.

or 27.3% of the estimated invaded area. However, this is an overestimate, because an unknown proportion of the area covered by plans is not invaded.

South African National Parks provided the largest coverage by submitting 18 plans covering 4 million ha for protected areas under their control (Figure 4.1). Cape Nature, the provincial conservation authority in the Western Cape, submitted 19 plans covering 607 142 ha for protected areas under their control. Plans submitted by eight municipalities (3% of the 257 municipalities in the country) accounted for the next largest area (567 329 ha) planned. The only other conservation agency that submitted plans was the Gauteng provincial conservation authority. The plans for six protected areas in Gauteng covered 25 000 ha and are included in Figure 4.1 under 'Government (other)'. Plans in this category covered 371 442 ha. There was a small contribution (in terms of area covered) from the private sector.

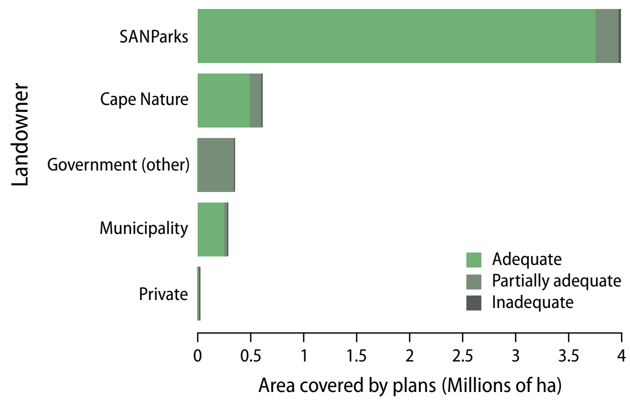


Figure 4.1. The area of South Africa covered by current management plans for biological invasions. Data presented here are for plans that are still current in terms of the stated planning horizon (plans that did not include a planning horizon were assumed to be valid from the date of submission for five years). Plans that were submitted for previous status reports and that are still current, or have been updated, are included. Shading indicates the adequacy of the plan. This is based on information submitted to SANBI by different groups within government and the private sector.

In the first status report (SANBI and CIB 2018) **planning coverage** was estimated to be 2.4 million ha on the basis of plans submitted. The area covered by current plans therefore appears to have more than doubled since the first report was produced; other plans probably exist but were not available for assessment. There has also been a marked improvement in the adequacy of planning. In the first report, plans for 98% of the area covered were assessed as inadequate. The current estimate is that planning in ~85% of the area was adequate and ~15% was partially adequate, with less than 1% of the planning being scored as inadequate. The adequacy of **planning coverage**, where it is done, thus appears to have improved substantially.

4.4 Output – pathways treated

Thirty-nine (39) of 44 pathways are managed to some extent and this has not changed recently. However, for almost half of these pathways (19), management is partial as it is focused on specific species that pose a threat to agriculture or human health and overlooks other threats (see Supplementary Material S4.11). Important pathways that are still not managed include ballast water and biofouling on aquatic vessels. South Africa is a signatory to the International Maritime Organisation (IMO) and must give effect to the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM) through national legislation. However, there has been no progress on the draft Ballast Water Management Bill since 2017, when it was out for public comment. The BWM will have a relatively low global financial cost in comparison to other environmental policies, and if the IMO standards are implemented uniformly across the world, then the estimated costs to South Africa are low [exports are estimated to decrease by 0.01% (USD 15M) and imports by 0.03% (USD 31M)] (Wang et al. 2020). Transnet National Ports Authority had planned to implement in-water hull cleaning; however, this initiative appears to have stalled (Jacka 2021). Research has explored alternatives, including encapsulating yachts, where a structure (e.g., hull) is wrapped in plastic to deprive biofouling organisms of oxygen and food, and ultimately causing their death (Keanly & Robinson 2020). Further testing is required before widespread implementation can be considered.

There has been little change since 2019 in the operations carried out by DFFE at OR Tambo International Airport. As of December 2019, officials performed inspections at the mail centre, as well as at the arrivals, departures and cargo terminals. Subsequently, inspections at the private terminal, Fireblade, commenced. Although inspections are being performed at more locations at OR Tambo, hiring and keeping officials to perform these inspections is a challenge, and the time and resources required to capacitate new officials is high. DFFE runs one joint operation with other entities per quarter, and while this assists to alleviate capacity constraints, some of these operations were cancelled in 2020/2021 to reduce the risk of officials contracting COVID-19. Between January 2020 and December 2022 DFFE performed ~98 000 inspections at OR Tambo International Airport, with most of these being performed at the arrivals (~64 000) and departures (~17 000) terminals and at the mail centre (~17 000) (Figure S4.3). No inspections were performed between March 2020 and October 2020, due to COVID-19 (Figure S4.3). Almost all the imported cargo consignments inspected (98% of ~260 consignments) were of *Psittacula krameri* (rose-ringed parakeet), with one consignment inspected for each of: *Lissachatina fulica* (giant African land snail), *Morelia spilota* (diamond python), *Oreochromis niloticus* (Nile tilapia) and *Hydrochoerus hydrochaeris* (capybara). These taxa are all listed under the NEM:BA A&IS Regulations [see Appendix 2 and Wilson (2023) for details].

Inspections for agricultural threats (of imported plants, animals and their products) are performed by DALRRD at various ports of entry and other sites (e.g., National Plant and Plant Product Inspection Services regional offices). If a suspected plant pathogen or pest is found during an inspection, tests are performed for 'quarantine pests' by Plant Diagnostic Services. Plant Diagnostic Services also performs these tests on 'audit samples', and some imported animals and plants are also kept under quarantine while further tests are done. 'Quarantine pests' are those that have been assessed through a pest risk analysis, have been deemed to pose an unacceptable risk to agriculture, and are prohibited from entering the country (in terms of agricultural regulations rather than the NEM:BA A&IS Regulations). Over the period from April 2022 to January 2023, DALRRD performed ~14 000 inspections of animal/animal product imports, ~67 000 inspections of plants/plant product imports and ~50 000 inspections of phytosanitary certificates. The vast majority of these inspections (90% of the animal imports, 85% of the plant imports and 100% of the phytosanitary certificates) were of imports for commercial purposes. In addition, 286 plant and 966 animal imports were placed in quarantine for further testing and Plant Diagnostic Services performed over 9 000 tests on over 4 000 samples. In this report, information on the at-border inspections and related activities by DALRRD is reported for 2022 only, as DALRRD was unable to supply the information for 2020 and 2021.

The Border Management Authority (BMA), which was established through the Border Management Authority Act of 2020, and which will be fully operational in 2023, is an important development in the management of pathways. In previous reports, it was highlighted that South Africa's uncoordinated approach to border management was likely costly and ineffective, and that species that pose environmental threats were likely to be overlooked at ports of entry where inspections largely focus on agricultural pests or animal and human diseases (Van Wilgen & Wilson 2018; Zengeya & Wilson 2020). The BMA intends to be the single authority for the management of South Africa's borders, integrating and co-ordinating the functions currently performed by various government departments at ports of entry, including those performed by DFFE and DALRRD. This promises to be an improvement on the current approach which comprises multiple authorities with different mandates.

4.5 Output – species treated

Based on submissions received, 319 taxa were subjected to control measures during 2020–2022 (Table 4.4). Of these, 184 are (or were) listed under the NEM:BA A&IS Regulations. The remaining 135 unregulated taxa included 74 insect species (68 of which were pest species of commercial agricultural crops), 59 plant species (seven of which were potential eradication targets), one freshwater fish, one mollusc, one amphibian and one bird species.

During 2020–2022, 48 biological control agents (released to control alien plants) were actively managed to increase their abundance or extent (e.g., through mass rearing, re-release or distribution to new areas, see Table S4.9). However, these taxa are not considered under the indicator **species treated** and not included in Table 4.4, as the interventions were not designed to reduce invasions of the agents themselves.

A retrospective analysis of the of the DFFE Natural Resource Management's records between 1999 and 2020 was reported by Van Wilgen et al. (2022a). Control efforts targeted 219 invasive plant species, with roughly a fifth of the amount being spent on just three taxa [the widespread invasive wattles *Acacia mearnsii* (black wattle), *A. decurrens* (green wattle) and *A. dealbata* (silver wattle)]. Control operations over the past 20 years have also typically reached < 15% of the estimated area invaded by individual species (see Supplementary Material S4.13).

There are 42 alien plant species listed under the NEM:BA A&IS Regulations that are deemed to be national eradication targets, of these 14 species have been treated using WfW-style contracts. In addition, several unregulated species with limited distributions are being investigated and controlled by SANBI staff or collaborators (see Supplementary Material S4.12).

Table 4.4. The number of alien species listed under the NEM:BA A&IS Regulations that were subjected to management interventions between 2020 and 2022 broken down into the different groups (see Supplementary Material S4.12 for a full list).

Group	1a	1b	2	3	Context-specific	Not listed	Total
Plants	16	113	12	10	25	59	235
Birds	1	0	1	0	0	1	3
Freshwater fish	0	0	0	0	1	1	2
Mammals	0	0	0	0	1	0	1
Insects	0	2	0	0	0	74	76
Molluscs	0	0	0	0	0	1	1
Amphibians	0	1	0	0	0	0	1
Total	**17**	**116**	**13**	**10**	**27**	**136**	**319**

Six new biological control agents were released against five invasive plant species during 2020–2022 (Table 4.5). This brings the total of biological control agents released against invasive plant species to 142, with 92 biological control agents established in the field on 66 invasive plant species (Zachariades 2021).

Invasive Fish Species Management (an NGO operating in the Western Cape) have been involved in the control of *Cyprinus carpio* (common carp) in Groenvlei Lake since 2018, using five different types of nets combined with bow hunting. This methodology has, over the past 38 months, seen the capture and removal of over 18 tons of invasive carp from Groenvlei Lake (Johnny Snyman, personal communication; see https://www.greenfamilyguide.com/green-stars/johnny-snyman-protecting-and-restoring-our-freshwater-lakes/, accessed 25 May 2023). The control can only be regarded as partially effective as, in February 2020, CapeNature estimated that there were still 160 tonnes of carp in Groenvlei (60 000 fish) (https://www.knysnaplettherald.com/News/Article/General/carping-on-about-groenvlei-202101270201, accessed 25 May 2023).

Table 4.5. Biological control agents of plants released outside of quarantine for the first time in South Africa 2020–2022. Various other *Dactylopius tomentosus* lineages have previously been released to control other alien cacti, the release of this lineage represents a new taxon against a specific target.

Scientific name (biological control agent)	Type	Scientific name (plant taxon targeted)	Year of release	Status
Evippe sp.	Leaf-tying moth	*Neltuma* spp.	2021	Release permit issued Released in field
Coelocephalapion gandolfoi	Seed-feeding weevil	*Neltuma* spp.	2021	Release permit previously issued Re-collected and released in field
Polymorphomyia basilica	Gall-forming fly	*Chromolaena odorata*	2022	Release permit issued Released in field
Heikertingerella sp.	Root-feeding flea beetle	*Tecoma stans*	2022	Release permit issued Released in field
Cochylis campuloclinium	Flower-feeding moth	*Campuloclinium macrocephalum*	2022	Release permit previously issued Re-collected and released in field
Dactylopius tomentosus (Lamarck), '*californica* var. *parkeri*' lineage	Cochineal insect	*Cylindropuntia pallida*	2022	Release permit previously issued Re-collected and released in field

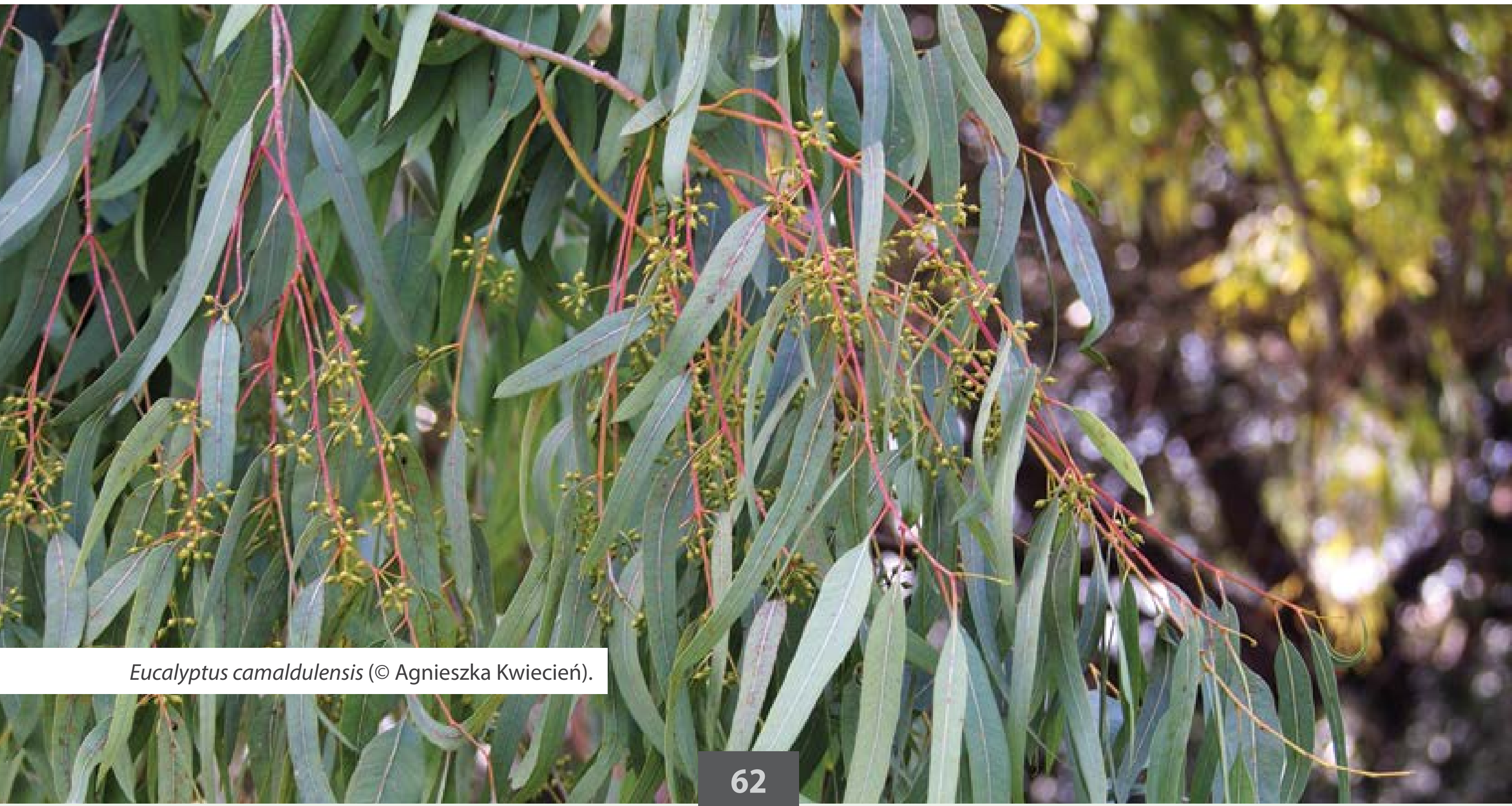
Msimang et al. (2022) investigated the extent to which farmers in the Free State and Northern Cape used biosecurity measures to protect livestock from infectious diseases. The biosecurity measures included: 1) maintaining fencing around properties; 2) keeping different animal species in different or divided areas on properties; 3) having separate equipment for different species; 4) feeding, treating and working with sick animals after (and not before) working with healthy animals; 5) keeping pregnant animals separate from the herd; 6) quarantining of new animals before joining the existing herd; 7) cleaning and disinfecting vehicles before and after transporting animals; 8) vaccination; 9) tick control (e.g., dipping animals, using pour-ons or giving an injection); and 10) biting fly/mosquito control. Msimang et al. (2022) found that 99% of farmers reported using at least one of the ten biosecurity measures investigated. The study did not differentiate between diseases caused by alien species and those caused by native species, but it is known that at least some serious diseases were due to alien pathogens (Van Helden et al. 2020).

Pyšková et al. (2022) found that *Acridotheres tristis* (Common Myna) seem to be increasing their range in Kruger National Park; despite over 20% of the birds sighted being shot by the park rangers.

Many agricultural pest species are alien and the implementation of biological control against these species began over 100 years ago. Pretorius (2008) reported that 211 natural enemies (mainly insects) were imported for biological control programmes on 52 pest species on crops such as citrus, wheat, forestry, fruit and vegetables between 1892 and 2008. Of these 142 were released and 49 became established (see Appendix 2). These biological control agents are used against 39 alien agricultural pest species, only one of which is listed under the NEM:BA A&IS Regulations.

4.6 Output – sites treated

The DFFE's Natural Resource Management Programmes reported that invasive plants were subjected to control measures over an area of 200 329 ha across all nine provinces. The average cover of invasive plants at the sites subjected to control was 13%, based on the condensed hectares reported. Additional information on the sites subjected to control was supplied by several other agencies. However, this is not included here, as there is a large but unspecified overlap with the sites reported by DFFE, from whom agencies derive most of their funding.



Eucalyptus camaldulensis (© Agnieszka Kwiecień).

A retrospective analysis of the area treated by the DFFE's Natural Resource Management Programmes between 1998 and 2020 was reported by Van Wilgen et al. (2022a). Site treatments reached a relatively small proportion (~14%) of the estimated invaded area. About 72% of treatments were at sites that met at least one criterion for being a priority site for control (i.e., a Strategic Water Source Area, a protected area or an endangered or critically endangered ecosystem; see Supplementary Material S4.13 for more details).

A new development was the implementation of the Greater Cape Town Water Fund, which has led to an expansion of the area subjected to control measures in the invaded water catchments of Cape Town (Box 4.2).

4.7 Outcome – effectiveness of pathway treatments

There is no systematic monitoring of pathway treatments and their effectiveness is not assessed by the management agencies that implement them. Therefore, the **effectiveness of pathway treatments** was determined based on recently published data and data obtained from management agencies. For 21 of the pathways (48%) there is either no management or management was ineffective [for 15 pathways (34%) the effectiveness of management could not be estimated]. There has been little recent change to the estimated effectiveness of pathway management, with the estimates remaining the same for 89% of pathways. In many cases, recently published research or data obtained from management agencies confirmed the assessment made in the previous report (see Supplementary Material S4.14). For one pathway the effectiveness of treatments could be estimated for the first time – introductions for conservation. This pathway was estimated to be partially effectively managed as biosecurity measures are in place and very few species alien to the country are being kept on wildlife ranches used for ecotourism (Taylor et al. 2021).

A consolidated database of interceptions made by DALRRD officials during agricultural inspections between 2006 and 2019 was recently published (Saccaggi et al. 2021). The database contains records of over 25 000 inspections of which 30% were positive (i.e., had at least one contaminant) and 13% had multiple contaminants. The inspections performed by DALRRD over the period from April 2022 to January 2023 found that ~3% of the animals/animal products, ~14% of the plants/plant products and ~6% of the phytosanitary certificates inspected were non-compliant. Non-compliance was due to a variety of reasons including incomplete/invalid documentation (import permits and certificates), non-compliance with label regulations, contamination (for animals/animal products), and the detection of quarantine pests (plants/plant products). Of the quarantined animals, 9% were non-compliant due to incorrect testing or the presence of quarantine diseases that were not declared on the import permit. Of the plant imports that were grown under quarantine conditions, 22% were non-compliant. Tests performed by Plant Diagnostic Services indicated that there were 62 interceptions of quarantine pests over this period, with more than one pest identified in some interceptions and ~35 different quarantine pests intercepted (Table S4.10). Some of these pests were intercepted more than once including *Aculus schlechtendali* (apple rust mite), *Diptacus gigantorhynchus* (plum gall mite) and *Callosobruchus maculatus* (cowpea weevil). Therefore, despite the actions taken to prevent the transport of quarantine pests to South Africa (e.g., phytosanitary mitigation measures that are implemented pre-border), these species continue to be intercepted, although at a relatively low rate. Species with an unknown quarantine status, that could also pose a threat, are often intercepted in agricultural inspections (Nnzeru et al. 2021; Saccaggi et al. 2021; Tshikhudo et al. 2021a, 2021b).

There were very few instances of interceptions and one instance of non-compliance identified during the inspections carried out by DFFE at OR Tambo International Airport between January 2020 and December 2022. In six instances the identity of the organisms found during the inspection was unknown, and samples were sent for DNA analysis. For example, boxes of unknown plants were intercepted at the mail centre and samples taken for DNA analysis. None of the analyses found evidence that taxa listed under the NEM:BA A&IS Regulations were present. The one instance of non-compliance occurred when a consignment of *Lissachatina fulica* (giant African land snail) was imported and was detained (the taxon is listed as Category 3).

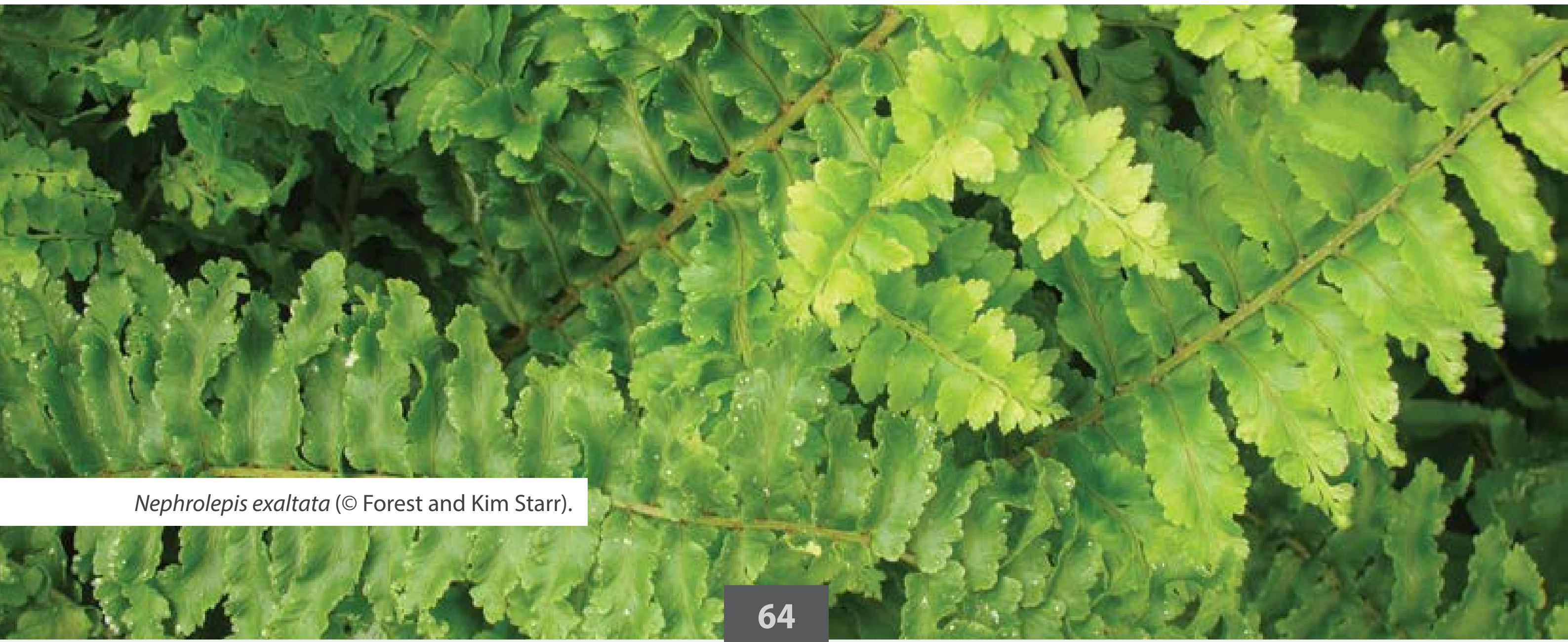
Studies on the pet, aquarium and traditional medicine trades have confirmed that the management of these specific pathways is ineffective, and that regulated species continue to be illegally sold (Nelufule et al. 2020; Shivambu et al. 2020; Williams et al. 2021b; Niemann et al. 2022). In traditional medicine markets, 16 Category 1b species, one Category 1a species and one Category 2 species were illegally sold (Williams et al. 2021b). A survey of aquarium and pond plant retailers in Johannesburg used DNA barcoding to identify traded macrophytes, and found that among the identified species, 12% (nine species) were listed under the NEM:BA A&IS Regulations (Niemann et al. 2022). Interestingly, a survey of pet shops around the country showed that most respondents (68%) were aware of the NEM:BA A&IS Regulations, but 71% were against the regulation of the trade despite 58% admitting to losing organisms through escapes (Shivambu et al. 2022a). Unfortunately, most pet traders (83%) were not registered with the association of pet traders, making it difficult to monitor the trade (Shivambu et al. 2022a).

4.8 Outcome – effectiveness of species treatments

For almost two thirds of the species that were reported to have been treated over the 2020–2022 period, the effectiveness of treatments could not be evaluated (Table 4.6). The **effectiveness of species treatments** could, in most cases, only be scored for plant or invertebrate pest species under biological control, with control scored as permanent in cases where biological control was assessed as complete (Prinsloo & Uys 2015; Zachariades 2021, see Supplementary Material S4.15 for full details).

Table 4.6. The number of invasive species in different categories of control effectiveness that were subjected to management interventions between 2020 and 2022.

Group	Category of control effectiveness					Total
	Permanent	Effective	Partially effective	Ineffective	Not evaluated	
Plants	12	34	10	9	170	**235**
Birds	0	1	0	1	1	**3**
Freshwater fish	0	0	1	1	0	**2**
Mammals	0	1	0	0	0	**1**
Insects	5	5	12	2	52	**76**
Molluscs	0	0	1	0	0	**1**
Amphibians	0	0	0	0	1	**1**
Total	**17**	**41**	**24**	**13**	**224**	**319**



Nephrolepis exaltata (© Forest and Kim Starr).

In terms of specific outcomes, Motitsoe et al. (2020) reported that biological control of the alien aquatic plant *Salvinia molesta* (Kariba weed) by the introduced weevil *Cyrtobagous salviniae* facilitated the recovery of epilithic algae and aquatic macroinvertebrate communities. Coetzee et al. (2022) reported that releases of the biological control agent *Megamelus scutellaris* at Hartbeespoort Dam resulted in a reduction in cover of *Pontederia crassipes* (water hyacinth) from over 37% to less than 6% over two consecutive years (Box 4.3). Castañeda et al. (2020) monitored native fishes over five years after the eradication of invasive *Micropterus dolomieu* (smallmouth bass) from the Rondegat River in the Western Cape, and concluded that the native fish community had recovered, but that the removal of smallmouth bass was not sufficient for full recovery of all species (i.e., other threats remained). Additional conservation measures would be needed to secure the population stability and persistence of endangered fishes.

4.9 Outcome – effectiveness of site treatments

The ongoing scarcity of formal systems that monitor the outcomes of site treatments remains an obstacle to the assessment of the effectiveness of treatments. The Working for Water programme, which provides ~80% of funding for alien species control measures in the country, does not compile management plans nor monitor the outcomes of their funding. This is because the legal obligation to plan and monitor lies with individual landowners, who are supported by Working for Water, and not with Working for Water itself. Working for Water's performance is measured in terms of employment created, money spent (inputs), and area cleared (an output), but not in terms of changes in the extent of invasions or restoration of ecosystem function (outcomes). It therefore plans to spend money, employ people and clear sites, but does not explicitly plan to achieve control.

No recent research reports or publications were found that have assessed the **effectiveness of site treatments**. Nonetheless, Cape Nature assessed the effectiveness of alien plant control measures on 31 protected area clusters, based on estimates of the cover of alien plants as: effective for five protected area clusters; partially effective for 20 clusters; ineffective for three clusters; and unknown for three clusters (see Supplementary Material S4.16 for further details). Notably effectiveness was expressed in terms of an increase or decrease in the cover of invasive plants, and not in terms of the recovery of biodiversity and ecosystem functioning in the target ecosystem.

Keet et al. (2022) assessed the level of compliance with the NEM:BA A&IS Regulations by comparing the number of listed alien plants species in 36 'camps' (staff villages, ranger outposts and tourist areas) in the Kruger National Park in 2001 with numbers in 2020 (noting the regulations first came into effect in 2014). The number of alien plant species almost doubled after the first survey (from 231 to 438) likely due to a more systematic search by trained botanists. Despite this overall increase, there were 38% fewer listed alien plant species found during the 2020 survey and the number of listed aliens found per camp declined by 56%. The conclusion was that the regulations provided clear guidance for conservation managers, and that there were promising signs of reductions in targeted alien plant species.

Of concern is that few clearing operations explicitly link through to the biodiversity outcomes, in particular as some evidence suggests that active restoration is necessary after the removal of invasive plants. The costs of active restoration interventions might, in some cases, be economically justifiable, but the cost of fully restoring ecosystem structure, functioning and composition in highly degraded ecosystems has rarely been deemed economically justifiable in South Africa (Holmes et al. 2020; Van Wilgen et al. 2022a). Generally, government-supported control operations have not included restoration efforts, at least in part because there is little or no funding for implementing active restoration projects at the necessary scale – most sites are left for passive restoration (Van Wilgen et al. 2022a).

Box 4.1. The regulation of invasive species used in commercial timber plantations

One of the major sources of plant invasions in South Africa is commercial timber plantations. This is ongoing despite the forestry sector being heavily regulated. Several tree species used in plantations are listed under the NEM:BA A&IS Regulations, and a permit is required to establish a new plantation or to extend an existing plantation involving those species [see Appendix 6 for the permits issued per taxon and Wilson (2023) for details of the listed taxa]. Before a permit for restricted activities involving a listed alien species is issued, applicants must demonstrate that adequate measures will be taken to prevent spread. Importantly, the Minister of Forestry, Fisheries and the Environment has, in terms of the NEM:BA, exempted existing plantations – those plantations that were established and operational before 1 August 2014, when the A&IS Regulations first came into operation – from the requirement to obtain a permit in terms of the NEM:BA and the A&IS Regulations.

Permits issued under the NEM:BA are not the only regulatory tool relevant for plantations. Additional regulatory requirements for plantation forestry include:

- A water use licence (WUL) in terms of the National Water Act, 1998 (Act No. 36 of 1998) (NWA) for any 'stream flow reduction activities', which includes the use of land for commercial afforestation.
- Environmental authorisation for a plantation exceeding 300 ha in extent in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA).
- A licence to establish or recommission a plantation in a State Forest in terms of the National Forests Act, 1998 (Act No. 84 of 1994) (NFA).
- Consent from the relevant authorities to grow specified invasive plant species in areas other than those identified in WULs or other specifically demarcated areas in terms of the Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983) (CARA).

The additional regulatory approvals above may be subject to appropriate conditions, but they do not require the operators to prevent the spread of the invasive species beyond the approved area. This may well become problematic in the case of existing plantations (those established before 1 August 2014) for which permits issued under the A&IS Regulations are not required.

While there is a general duty to eradicate or control taxa listed under the A&IS Regulations, that responsibility only applies to owners of land on which the invasive species is present. Commercial forestry companies that operate existing commercial plantations (those established before 1 August 2014) in State Forests (owned by the State) therefore do not have that general duty of care. In those instances, the State bears the duty of care. Evidentiary proof that invasive plants have spread from a particular property is often also difficult to obtain, especially where there are multiple plantations in an area. Thus, a substantial area of commercial forestry remains as an unregulated seed source for reinvading adjacent areas that have been cleared.

Box Figure 4.1. Forestry plantations (background) are a major and ongoing source of propagules for invading adjacent areas (foreground). Photograph: © Brian van Wilgen.

Box 4.2. The Greater Cape Town Water Fund

Concern about the growing impact of invasive trees on Cape Town's water supplies led to the establishment of the Greater Cape Town Water Fund in 2018. The fund was based on a feasibility study (Turpie et al. 2017) and business case (Stafford et al. 2018), which showed that clearing Cape Town's priority water catchments by removing invasive trees could generate annual water gains of 50 billion litres within five years – equivalent to one-sixth of the city's current supply needs. These gains could double to 100 billion litres annually within 30 years. This approach was estimated to be significantly more cost-effective than other water augmentation solutions.

The fund is co-ordinated by the Nature Conservancy (a US-based NGO) and is a partnership between national, provincial, and local government departments, corporate sponsors (including Nedbank, Coca-Cola, AB-InBev, and REMGRO), and NGOs (the Nature Conservancy and the South African branch of the World Wide Fund for Nature).

The fund has targeted the catchments of Cape Town's major supply dams at Theewaterskloof, Bergriver, Wemmershoek and Steenbras, as well as the recharge basin of the Atlantis aquifer. The fund has a blended funding model and a 30-year time horizon. It has raised ZAR 182 million of the required ZAR 372 million in funding for its first six years of operation, with contributions from corporate sponsors (28% of funds raised to date), philanthropic individuals and foundations (46%), and the City of Cape Town (26%).

The fund's key objective is to reduce the cover of mature alien trees to below 5% within 30 years and restore a cover of natural vegetation where possible. The fund has already spent ~ZAR 100 million and is now half way to achieving its initial six-year target of clearing 55 300 ha. About 75% of the cleared area was upper catchments invaded by alien pine (genus *Pinus*) trees. The fund uses a custom-built decision support system to guide its operations. The system tracks all clearing and follow-up operations and prioritises sites for interventions. Interventions are also regularly monitored to assess the effectiveness of operations, as well as ecosystem recovery and social benefits generated.

The implementation of this fund, which targets carefully prioritised areas, and includes the necessary components of planning and monitoring, provides an exceptional example of the implementation of best practice in the control of plant invasions with clear goals and timeframes. It is also unique in that it obtains funding from multiple sources and provides a model for the planning of similar interventions elsewhere.

Box Figure 4.2. Workers from the Greater Cape Town Water Fund removing invasive pine trees from the catchment of the Theewaterskloof Dam (visible in the right-hand background). Photograph: © Louise Stafford.

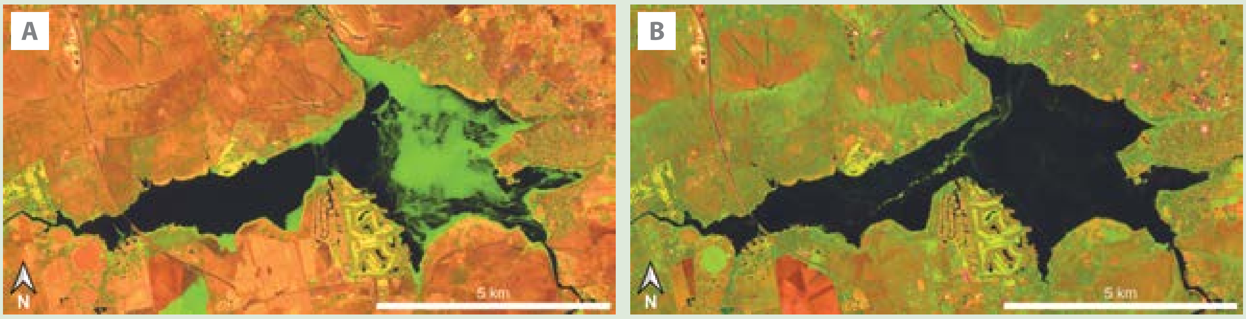
Box 4.3. Successful biological control of water hyacinth on a eutrophic subtropical waterbody

Pontederia crassipes (water hyacinth) has caused 'Major' impacts worldwide by covering water bodies in vegetation, reducing oxygen levels in the water, and thereby altering the diversity of freshwater benthic communities and impacting the provision of ecosystem services (including opportunities for fishing, swimming and boating). Biological control has been highly successful in tropical areas, but in more subtropical, eutrophic waters biological control has been less successful, especially where cooler winter climates prevail.

In South Africa authorities have resorted, at considerable expense, to spraying herbicides from aircraft and boats. However, plants are able to re-colonise these sprayed areas rapidly, temporarily escaping biological control. This means that spraying operations need to be constantly repeated, adding another source of chemical pollution to the waters.

A relatively new addition to the suite of biological control agents was *Megamelus scutellaris*, which was first released in South Africa in 2013. This insect was promising because it responds well to mass rearing, reproduces rapidly, and recovers quickly after periods of cooler temperatures. In addition, it can be exceptionally damaging to water hyacinth. Insects were mass-reared and released in a stand-alone intervention on Hartbeespoort Dam in 2018 in the absence of herbicide treatments.

Following frequent inundative releases of the agents (i.e., many releases each of a large number of insects), Coetzee et al. (2022) reported that water hyacinth cover was reduced from over 37% to less than 6% over two consecutive years (Box Figure 4.3). The recommendation was to release the insects often and in high numbers to inundate and overwhelm the water hyacinth and to achieve control at a fraction of the cost of herbicide applications. This represents a major breakthrough in the control of water hyacinth in South Africa (and potentially in other subtropical and temperate eutrophic water bodies worldwide).



Box Figure 4.3. Declines in the cover of *Pontederia crassipes* (water hyacinth) between: A, January 2017 and B, February 2020 due to biocontrol by *Megamelus scutellaris*. Water hyacinth is the bright green against the black water in the satellite images. This control happened in the absence of herbicide applications. Figure from Coetzee et al. (2022).

Ligustrum vulgare (© Krzysztof Golik).

4.10 Trends in interventions indicators

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
4. Level of success in managing invasions	not assessed		↗	This indictor cannot be calculated as there are very few data on the effectiveness of control of invasions at specific sites.	Making a reasonably accurate assessment of the overall success of managing invasions remains challenging due to the paucity of stated goals in management plans against which to assess progress, as well as the scarcity of activities to regularly monitor progress towards goals. These issues need to be urgently addressed because without them effectiveness cannot be known, management cannot be adaptive, and the impacts and costs of invasions will continue to rise. The draft national strategy and action plan on biological invasions might help address these issues explicitly.
4.1 Quality of regulatory framework	→	Medium	↗	The amendments to the NEM:BA and the A&IS Regulations and Lists have improved the regulatory regime slightly. The law reform has clarified some concepts and the changes may help government to prioritise scarce law enforcement interventions. However, there is still an absence of a comprehensive strategy to guide implementation of the regulations and lack of flexibility in the regulatory regime. A draft national strategy on biological invasions has been developed but not, as yet, sent for public comment.	The recent publication of the White Paper on the 'Conservation and Sustainable Use of South Africa's Biodiversity' is an indication that DFFE plans to amend the NEM:BA in the near future. However, the White Paper does not address the problems with the current regulatory regime and does not comprehensively address issues around biological invasions. The development and implementation of a national strategy for biological invasions has the potential to be a milestone in the management of biological invasions in South Africa. The development and implementation of a process to regularly and transparently update the regulatory lists informed by the best available scientific evidence is promising.

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
4.2 Money spent	↘	Low	↗[1]	An estimated ZAR1.5 billion was spent between 2020 and 2022. This is an underestimate as not all government entities, NGOs or the private sector have provided estimates. The amount spent has been declining in real terms since 2015 (Van Wilgen et al. 2022a).	Government's ability to fund the control of biological invasions has been reduced due to adverse economic conditions that have prevailed over the past few years. Large increases in funding are unlikely in the near future. The Greater Cape Town Water Fund may provide a new model for fundraising (Box 4.2).
4.3 Planning coverage	→	Medium	↗	Pathways: 40 of the 44 pathways are assumed to have management plans in place, but these have not necessarily been formalised. No formal plans have been developed by DFFE and there is no legal requirement to do so. There has been no change since the previous report. Species: 22 (15 listed and 7 unlisted) species have management plans in place. Of these plans, 13 were scored as adequate, 8 as partially adequate, and 2 as inadequate. This is 2.8% of the 560 listed alien taxa. None of these plans have been formally adopted, nor is the process for formal adoption clear, although landowners are required by law to control species on their land in accordance with such plans, should they exist [the NEM:BA Sections 75(4) and 75(5)].	There is still a need to identify priority pathways and develop and formally adopt plans to support the management of those pathways. There is a similar lack of formal planning processes to address species and sites. Without such planning it will not be possible for management to be strategic and difficult for management to be adaptive.

→ no change; ↗ an increase; ↘ a decrease.

[1]Technically the trend should be towards an estimate of the money required to cost-effectively address the problem (e.g., so that returns on investment of additional spending on average end up as zero). However, estimates of the money required to bring biological invasions under effective control suggest this figure is roughly 4.6 times greater than current budgets (Van Wilgen et al. 2016). At present, if spent strategically, there are significant returns on investment to be had by spending money on controlling invasions, and therefore the desired trend is for an increase in the **money spent**.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
				Sites: Current management plans cover 7.9 million ha (all of which is not necessarily invaded). Planning coverage appears to have increased significantly from the previous report, probably because existing plans were not previously submitted for assessment, noting that many more plans likely exist but were still not received. Site plans that were resubmitted were assessed as having improved	
4.4 Pathways treated	→	Low	↗	All pathways through which alien organisms can be introduced require management, and currently 39 of the 44 pathways (89%) are managed to some extent. Many of the pathways (19 pathways) that are managed are partially managed, but most (20 pathways) have complete management. There has been no change since 2019.	The establishment of the Border Management Authority should result in more co-ordinated management of pathways. The implementation of the ballast water management bill would also improve the situation. However, unless priority pathways are identified, and pathway-focused management for those pathways is implemented, harmful invasive species will continue to be introduced.
4.5 Species treated	→	Low	↗	320 alien taxa were subjected to control measures during 2020–2022, of which 58% were listed. Most effort is directed towards widespread or damaging taxa or towards taxa that are potential eradication targets.	Several invasive taxa are expanding their ranges rapidly, so capacity to deal with all taxa will be further reduced. The draft national strategy on biological invasions, in concert with the GBF (Box 0.2) is likely to incentivise greater prioritisation of control efforts against the most damaging listed alien taxa and those that present the greatest future threats.

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
4.6 Sites treated	not assessed		↗	The area that has been treated in 2020–2022 is estimated to be 2003 km^2, this includes all land parcels that have been worked on by public works alien plant control teams. The estimated total invaded area in South Africa is 194 943 km^2, so control operations have therefore reached just over 1% of the estimated invaded area. A recent study estimated that control operations between 1998 and 2020 had reached 14% of the estimated area over 22 years (Van Wilgen et al. 2022a). Because control operations are not followed up every year, it may be necessary to examine the extent of treatment over longer periods. There are substantial uncertainties regarding the estimated extent of invasion. Control also often does not cover the full area mapped as having received control, so the 1% (and the 14%) are probably overestimates.	It is expected that the area invaded in South Africa will increase. Processes are, however, in place to ensure greater prioritisation of control efforts to ensure priority sites are cleared and kept clear (cf. outlook for **species treated**).
4.7 Effectiveness of pathway treatments	→	Low	↗	There has been no change to the estimated effectiveness of pathway management for most pathways. For one pathway, releases for conservation, the effectiveness of management could be estimated for the first time and was estimated to be partially effective. Five pathways are not managed, 16 have ineffective management, one has partially effective management, six have effective management and one has permanent management.	The establishment of the Border Management Authority, and through that the co-ordination of the at-border management of pathways will hopefully improve the efficacy of at-border management. Measuring the efficacy of management and implementing adaptive management where required would further improve biosecurity.

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
4.8 Effectiveness of species treatments	→	Low	↗	For most (66%) of the 560 regulated taxa, there is no evidence that any management is taking place, and with the exception of species under biological control, the effectiveness of management is largely unknown.	Assessing the **effectiveness of species treatments** at a national scale is based on changes in the size of the population (for animals) or the extent of invasion (for plants). These are currently not monitored except for some alien plants that are the target of biological control. The absence of a reliable baseline and regular updates will continue to prevent accurate assessments of control effectiveness, especially at a national scale. When assessed at finer scales, there are examples of partially effective treatments of species at some sites.
4.9 Effectiveness of site treatments	not assessed		↗	The paucity of management plans with clear goals and regular monitoring of those plans makes it difficult to assess effectiveness, which would have to be expressed in terms of progress towards achieving the goal. For some sites where information is available, there are indications that some interventions are at least partially effective, but the goals of management are typically unstated, making such assessments difficult. There is no information to suggest that the situation has changed since the second report.	There are almost no routinely collected data to assess the **effectiveness of site treatments**, either in terms of changes in the extent of the area invaded, or in terms of ecosystem recovery following control. Accurate assessments are only possible for small sites that have been the subject of research studies.

→ no change; ↗ an increase; ↘ a decrease.

Rumex acetosella (© Krzysztof Golik).

CHAPTER

5

THE STATUS OF BIOLOGICAL INVASIONS AND THEIR MANAGEMENT IN THE PRINCE EDWARD ISLANDS

Bait trials for the Mouse Free Marion eradication plan (© Anton Wolfaardt).

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Findings for the Prince Edward Islands (PEIs)

- The only pathways along which alien species can be introduced to the PEIs are as contaminants (e.g., of food) and as stowaways (e.g., on ships or on items on ships like the helicopters and cargo containers or on clothing and footwear). Nonetheless, alien species continue to be introduced. Improvements to the implementation of biosecurity measures could further reduce the rate of introduction of alien taxa, particularly if it is known how and why previous breaches occurred.

- Forty-four (44) alien taxa are currently present on Marion Island, 26 of which are known to be invasive. A further 41 species were introduced in the past but are no longer present. Eight alien taxa are currently present on Prince Edward Island (all also found on Marion Island), all eight are invasive.

- Of 20 invasive species assessed for their impact, four were found to cause 'Major' or 'Massive' environmental impacts.
- The house mouse (*Mus musculus*) is the most harmful alien species on Marion Island and is feeding on adult and hatchling seabirds, several plant and invertebrate species and impacts ecosystem functioning.
- However, assessments of impact and the degree of establishment of alien species on the islands are often based on data from a decade ago or older.
- The management of biological invasions are organised through the PEIs Management Plan. Nine taxa are subject to control on Marion Island and a further five are being monitored to confirm potential eradication. A plan to eradicate the house mouse from Marion Island ('Mouse-Free Marion') is under development and is due to be implemented in 2025 if sufficient funding can be raised.
- There is a mismatch between which taxa are listed under South African national level regulations as requiring management on the PEIs and the taxa that are listed and actively managed under the auspices of the PEIs Management Plan. Given the unique status of and challenges to management on the PEIs, if management and regulatory decisions were fully ceded to the PEIs Management Plan it would likely cause fewer inconsistencies than trying to align management on the PEIs with national level processes and regulatory instruments.

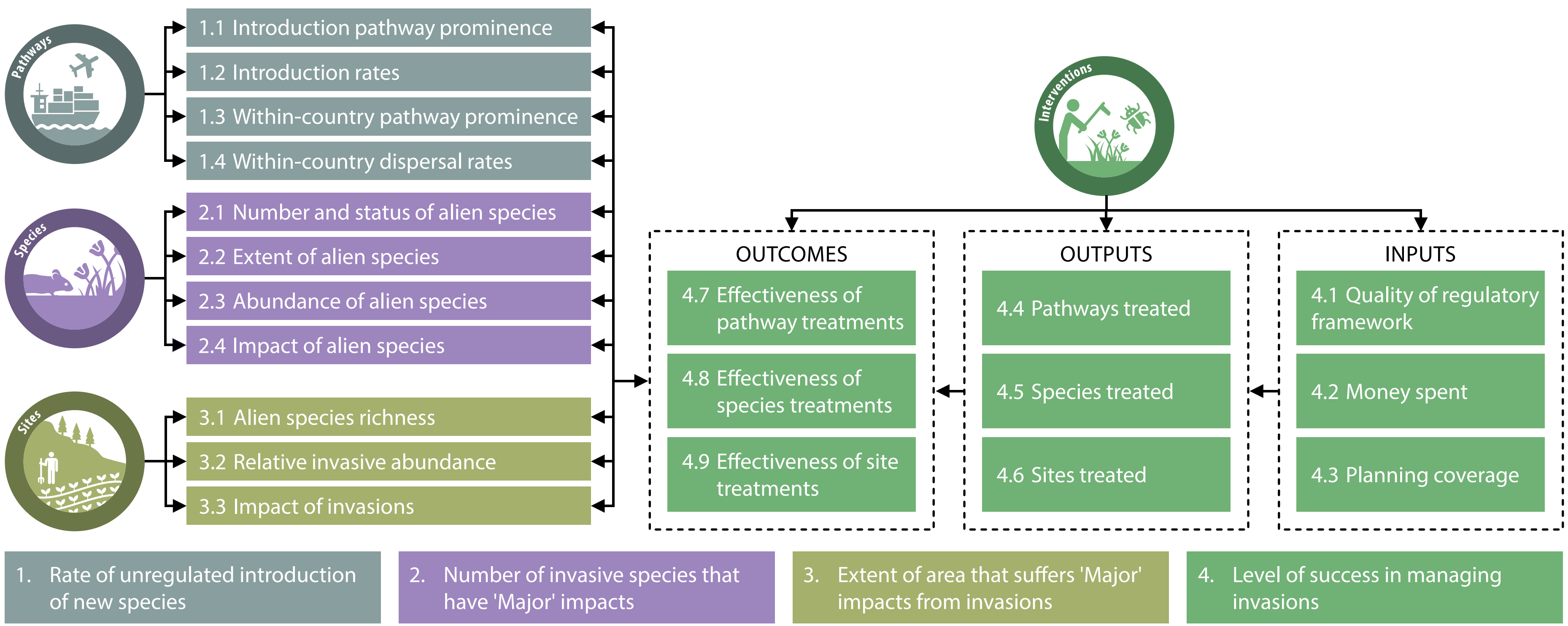
Gaps for the PEIs

- The PEIs Management Plan could be improved, and interventions prioritised, with additional data on how alien taxa are moving around the islands, systematic mapping and monitoring of alien taxa, and a basic update of the status of invasions.
- Gaps in biosecurity could be identified and improved if all taxa that are detected en route, at the research base or outside of the research base on the island are sampled and identified. This would be facilitated if taxa collected by the environmental control officers were carefully curated and partnerships developed with appropriate taxonomists.
- The importance of biosecurity and the returns on investment of management will be clarified if the impacts and threats of specific invasive species and the overall impact of biological invasions on the PEIs are estimated.
- Regular updates and review of management plans would facilitate adaptive management, especially if matched with broader consultation with relevant experts, given the high search intensity that is possible and the small extent of the island overall.
- A dedicated integrated process for reporting on biological invasions and their management on the PEIs, which involves all relevant stakeholders, would ensure interventions are appropriate, adaptive and responsive.

Mus musculus (© George Shuklin).

Indicators covered in the PEIs chapter

All 20 indicators and four high-level indicators are addressed.



5.1 Pathways

5.1.1. Introductions to the islands

Out of 44 potential introduction pathways (Figure 1.1), six pathways play a minor role and two play a moderate role, and a further six pathways of introduction used to be present but are no longer (Table 5.1). Specifically, biosecurity measures implemented in the late 1990s prohibited the deliberate introduction of live animals or plants, as well as fresh food, organic material, soil and rocks (DFFE 2010). A brief synopsis of the history of introductions to the PEIs and further details on **introduction pathway prominence** are provided in Supplementary Material S5.1.

For many alien taxa, the pathway responsible for their introduction is not known (57 out of 96), although it is likely that most of these taxa were introduced as contaminants on goods brought to the islands or as stowaways with transport vectors (Table 5.1; also see Supplementary Material S5.2). Of the alien taxa still present for which introduction pathway information is available, the most common pathways were accidental introductions as contaminants with food or as stowaways with machinery/equipment. Several species whose introduction pathway is 'unknown' were also introduced as stowaways, but the specific vector is not known. All deliberate introductions were historical. In the 1800s, sealers introduced domestic animals (e.g., pigs, sheep) to the PEIs as a food source (Cooper 2008).

Table 5.1. Pathways along which alien species have or could be introduced to the Prince Edward Islands (PEIs). Some taxa are no longer present (all those introduced that were released or escaped). The introductions have been classified into corresponding pathways according to the framework proposed by the Convention on Biological Diversity (CBD 2014), with adjustments proposed by Harrower et al. (2018). Some species have more than one pathway, and some species were introduced more than once; hence, pathway numbers do not equate to the total number of species introduced to the PEIs. The table only represents dispersal events to the archipelago and does not represent dispersal events between islands, for example unaided dispersal of some plant species from Marion to Prince Edward Island.

Mechanism of entry	Pathway category	Pathway subcategory	Introduction pathway prominence	Number of species introduced (introduction rates)
Commodity	Release	Biological control	Pathway no longer present	4
		Fishery in the wild	Pathway no longer present	2
		Hunting	Pathway no longer present	2
		Landscape improvement	Pathway no longer present	3
	Escape	Pet	Pathway no longer present	8
		Farmed animals	Pathway no longer present	5
	Contaminant	Food contaminant	Minor	10
Transport vector	Stowaway	Container and bulk cargo	Moderate	0
		Ship (excluding ballast water or hull fouling)	Minor	3
		Machinery & equipment	Minor	8
		People & luggage	Moderate	1
		Ballast water	Minor	0
		Hull fouling	Minor	0
Natural spread	Unaided	Natural dispersal	Minor	1
Not known			NA	57

Recorded introductions of alien taxa peaked following the annexation of the PEIs by South Africa in the late 1940s and the subsequent construction of a research base on Marion Island (Figure 5.1). The first expeditioners intentionally introduced alien taxa to Marion Island (Prince Edward has never been inhabited by scientists), mainly animals for food, some trees in the 1950s and 1960s (La Grange 1954), and some pets (Watkins & Cooper 1986). *Felis catus* (domestic cats) was introduced in 1949 apparently both as pets for companionship (Van Aarde 1981; Bloomer & Bester 1992) and to control the accidentally introduced *Mus musculus* (the house mouse) at the meteorological station (Bester et al. 2000, Cooper 2008) [i.e., both the 'pet' and the 'biocontrol' pathways as per the pathway classification framework of the CBD (CBD 2014, Harrower et al. 2018)]. The cats did not reduce nor control mice populations in the meteorological station (and would never have been allowed on the islands if there had been any regulation in place or risks considered). Cats escaped from the station, spread across Marion Island and caused significant negative impacts on native seabird communities. The feline panleucopaenia virus was released as a biological control agent in 1977 to control the invasive cats (Bester et al. 2002).

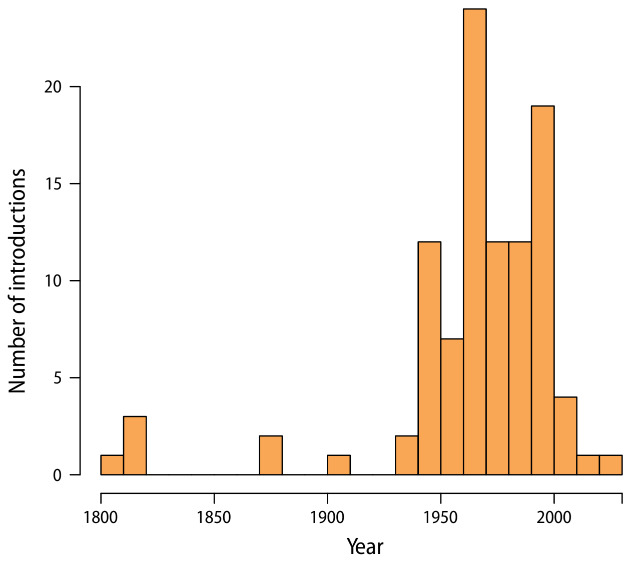


Figure 5.1. Number of recorded introductions to the Prince Edward Islands (PEIs) reported by decade. Detections from the last two decades are thought to be an underestimate due to the lack of identification of the specimens found; it is likely that detections were not even recorded in previous years, and so the pattern seen here is unlikely to be a true reflection of introduction rates (see Box 1.1).

Festuca rubra (© Emőke Dénes).

Biological control aside, the most recent intentional release in nature was *Salmo trutta* (brown trout) in 1964 (Cooper et al. 1992). None of these intentionally introduced taxa are still present on the islands. Nowadays, no alien taxa may be intentionally introduced to the islands.

Strong biosecurity measures were adopted in the 2000s, but numerous introductions were detected despite these efforts. The detected organisms were killed upon detection and either identified in situ, sent to experts for identification or simply disposed of. Taxa reported by environmental control officers (ECOs) in their reports to the DFFE included cockroaches, house and fruit flies, crickets, and a number of plant propagules. The last detection was a cockroach spotted in 2022 at the research station; a specimen was taken which is yet to be identified (Greve pers. comm. 2023). Given that most detections are not identified to species level, the current rate of unregulated introductions is not known with certainty (e.g., organisms found one year might be the same or different species as in previous years). It is also difficult to evaluate where the biosecurity breach occurred. Nevertheless, given the only entry point to Marion Island is the research base, and that biologists are stationed there year-round, the delay between introductions and detections is likely to be very short.

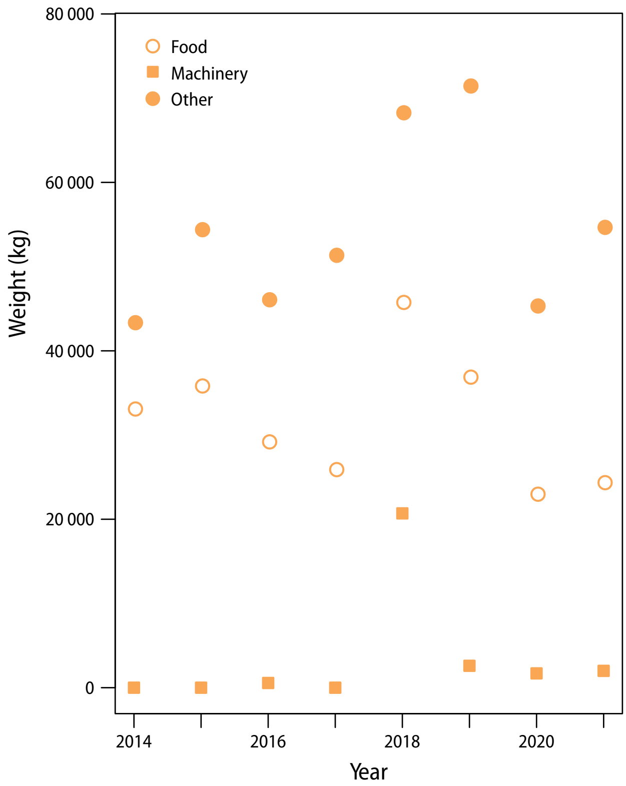


Figure 5.2. The volume of goods transported to the PEIs (2014–2021). The volume of food and other cargo transported to the PEIs has been variable over time and no long-term pattern is apparent. Occasional work on the research base or upgrading of facilities results in peaks in the machinery transported (cf. 2018). These data were used to estimate **introduction pathway prominence** for the food contaminant, container and bulk cargo, and machines and equipment pathways. While both the food contaminant and machines and equipment pathways have 'Minor' **introduction pathway prominence**, the **introduction pathway prominence** of the container and bulk cargo pathway is 'Moderate' (Table 5.1).

The only transport vessel that regularly visits the islands is the South African government owned SA Agulhas II. The SA Agulhas II visits Marion Island in April–May every year transporting people, food and supplies to the island, and bringing waste and people back. As there is no dock on the island, helicopters are used to transport people and supplies between the vessel and the island. Occasionally, the SA Agulhas II visits the islands more than once a year, and on very rare occasions other vessels also visit (e.g., a documentary crew travelled to Marion Island in 2020). Marion Island is inhabited year-round by approximately 20 scientists and support staff; this group changes every year during the relief voyage of the SA Agulhas II. During the relief voyage, other people visit the island for approximately four weeks to perform research or maintenance to the base and meteorological station. However, no more than 80 people are allowed to overnight on the island. No tourism is allowed. Almost all activity and researchers are based at the research base, although there are a number of research huts dotted around the island, which are visited by research staff. During the relief voyage the huts have a high occupation rate; this is much lower during the rest of the year. Information on the number of visitors per year to the islands has been requested from DFFE but was not received by the time this report was finalised.

Although quarantine measures are adopted at Cape Town harbour before the ship can depart, historically a significant number of propagules (alien plant seeds) and live insects have been found in, or on, containers and expeditioner's clothing and luggage (Lee & Chown 2009). The release of ballast water or galley waste is prohibited within 200 nautical miles of the PEIs (DFFE 2010), but this is still a potential pathway, as is hull fouling (Lee & Chown 2007). Finally, alien taxa that have been introduced by humans to Marion Island could naturally disperse to Prince Edward Island by wind or seabirds (Ryan et al. 2003), i.e., the 'unaided' pathway is potentially active.

The current PEIs Management Plan (DFFE 2010) provides provision to visit Prince Edward Island at most every four years by a maximum of ten expeditioners for a period of eight days. Prince Edward Island was visited in 2010, but only again in November 2023. Results of the recent visit could not be included in this report.

5.1.2. Within-island pathways

Out of 44 pathways, only three are present within the islands (Table 5.2). On the PEIs, wind and seabirds likely create opportunities for the dispersal of invasive plants (Ryan et al. 2003). These are classified here as moderate pathways on both islands as strong winds are frequent and there are many seabirds (though Marion Island has seen some decreases in seabird populations as a result of cats and mice). Some species may spread with people and their luggage as they travel around the island, but the extent to which people move around the island is not known. The stowaway route (via helicopters) is likely less prominent due to the low frequency of these types of movements (this pathway is usually present for three to four weeks a year, while humans are present at all times), and also less prominent now than previously as stricter biosecurity regulations have been introduced (DFFE 2010). The confidence for this ranking is low.

On Prince Edward Island the dispersal of invasive plants [e.g., *Sagina procumbens* (birdeye pearlwort) and *Poa annua* (annual meadow grass)] has likely occurred via wind and with seabirds (Ryan et al. 2003). Evidence from Prince Edward Island, where humans are absent for years at a time and where the spread of alien species is rapid (Le Roux et al. 2013), suggests that the unaided pathway is important for alien plants on the islands; this is likely a common pathway of dispersal for alien species. On Marion Island, it is thought that *S. procumbens* was spread from the research base by helicopter during annual restocking of the huts (Gremmen & Smith 1999). The construction of a steel helicopter pad at the new research base has likely reduced dispersal through this pathway, although the helicopter still lands on vegetation at the huts and so might be responsible for spreading propagules. It is likely that some propagules are spread by field workers; this has not been investigated.

Table 5.2. Only three within-country pathways are present on the Prince Edward Islands by which alien species are known, or strongly suspected.

Pathway category: subcategory	Within-country pathway prominence	Examples of within-country dispersal
Transport-stowaway: People/equipment	Not known	Lee and Chown (2011) found 420 seeds carried on 225 different clothes items on expeditioners that were returning to the South African mainland from Marion Island. These propagules could have potentially been spread around the island (at least three seeds were of invasive plant species). The prominence of the pathway on the island has not, however, been specifically monitored.
Transport-stowaway: Container and bulk cargo	Minor	*Sagina procumbens* was possibly spread across the island during hut restocking, when containers are dropped at huts by helicopter. This happens once a year. Other plants could have been spread by this means too. The invasive slug *Deroceras panormitanum* has been spread around Marion Island through wooden crates that are packed around the research station prior to aircraft and ship operations (Chown et al. 2002).
Unaided	Moderate	Several plant species have spread over fairly large distances on Prince Edward Island during a time when no humans visited the island. It can be expected that most increases in the range of invasive species on Marion Island are similarly unaided.

5.2 Species

5.2.1. Number and status of alien species

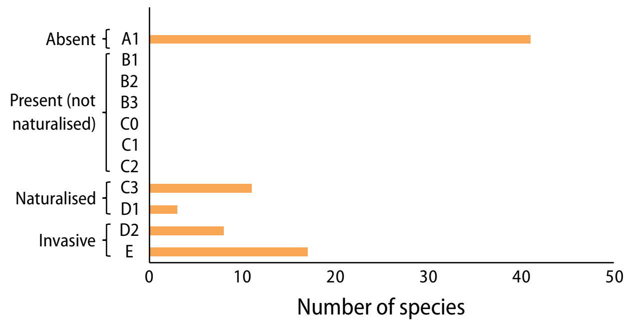


Figure 5.3. The status of alien taxa introduced to the Prince Edward Islands (PEIs) as per the Unified Framework for Biological Invasions (Blackburn et al. 2011). Species that were present but are no longer (A1) are included. See Supplementary Material S5.2 for a break-down into functional groups. The introduction status of five taxa is not known and these are not shown on this figure.

Ninety-one (91) alien taxa have been recorded at some point on the PEIs; two taxa are recorded as cryptogenic (i.e., nativity has not been confirmed)[1]; and one plant, *Ochetophila trinervis* (floating-heart) is thought to have arrived unaided via vagrant birds from South America since humans first arrived on the island (Kalwij et al. 2019) and so is considered native (Appendix 7). Two spider species (genus *Myro*) were cited as alien in the 1980s (Watkins & Cooper 1986) but were later corrected to be native (Chown & Froneman 2008). Out of the 91 alien taxa ever recorded, 44 are still present, the presence of six taxa is doubtful until eradication is confirmed and the remaining 41 are no longer present. There are currently no alien taxa in captivity or under cultivation. Of the 44 alien taxa currently present, 26 are invasive, 13 are naturalised but not invasive, and five cannot be assigned to one of the basic introduction status categories (i.e., it is unclear if they are naturalised, invasive or neither) (Figure 5.3). Therefore, more than half of the alien taxa present on the PEIs are invasive. Of the 26 invasive taxa, 17 are invertebrates, seven are plants, one is a fungus and one is a mammal (Figure 5.4); there are no alien birds, reptiles or amphibians (see Supplementary Material S5.2). All alien taxa are either terrestrial or freshwater species, as, despite an active search, no marine alien species have been detected to date (Greve et al. 2020).

5.2.2. Extent of alien species

The most widespread species on both islands are *Sagina procumbens* (present in 166 half-minute grid cells, hmgcs[2]), *P. annua* (204 hmgcs), and *Cerastium fontanum* (common mouse-ear chickweed; 162 hmgcs) (DFFE 2010; Le Roux et al. 2013; Mairal et al. 2022). The invasive springtail *Pogonognathellus flavescens* has increased its distribution to higher altitudes due to rising temperatures associated with climate change (Kgopong 2019). For further details see Appendix 7.

The ECOs on Marion Island have started to map the extent of invasions and to create polygon maps to assess progress on plant control measures. DFFE provided data for three species: *Agrostis gigantea* (black bent grass, 1.39 ha); *Rumex acetosella* (sheep sorrel, 0.1 ha); and *Luzula multiflora* (woodrush, 1.2 ha) (see maps in Supplementary Material S5.3).

5.2.3. Abundance of alien species

Plant cover has been assessed during 2018–2020 along various transects on Marion Island (Greve & Le Roux, unpublished data). Native plants were found to have the highest percentage cover (54.6%), followed by bare ground/rocks (42.8%), and lastly alien plant cover (2.6%). Of the alien plants, *S. procumbens* had the highest abundance (mean cover = 0.9%), followed by *P. annua* (0.39%), *Agrostis stolonifera* (creeping bent grass; 0.1%), *C. fontanum* (0.07%), and *P. pratensis* (0.04%).

The abundance of invasive (and cryptogenic) invertebrates has been assessed for different taxonomic groups [e.g., springtails (Collembola) and mites (Acari)], in terms of individuals per square metre in different vegetation types or habitats (Barendse et al. 2002; Hugo et al. 2006; Treasure et al. 2019; Chown et al. 2022). In some studies, more detail is provided (e.g., life stage, sex; Khoza et al. 2005), but there have been no estimates of total population sizes for any

[1]An unidentified mite species from the family Cillibidae was first recorded from Marion Island during 1996 or 1997 (Marshall et al. 1999). This family had not previously been recorded in the sub-Antarctic and this species was considered 'likely' an introduced species (Marshall et al. 1999). However, since this initial collection no progress has been made in determining the identity or status of the species, despite it frequently being the numerically dominant mite species in some habitats (see e.g., Barendse et al. 2002).
[2]hmgcs are ~0.59 km^2, roughly 926 m by 635 m.

Figure 5.4. Different landscapes and taxa on Marion Island: A, black lava fellfield and *Leptinella plumosa–Poa annua* coastal herb-field landscape; B, mire-slope habitat with intermittent black lava outcrops, scoria hill in the background; C, invasive *Deroceras panormitanum* (European slug); D, invasive *Sagina procumbens* (birdeye pearlwort) in light green rapidly invading a habitat that was previously dominated by the native cushion *Azorella selago*; E, invasive *Mus musculus* (house mouse) damaging a native *A. selago* cushion; and F, native Endangered albatross at risk due to predation by *M. musculus*. Photographs: A, B, C, E, © Elsa van Ginkel; D, © Michelle Greve; F, © Anton Wolfaardt.

invertebrates on the PEIs. For both islands, the invasive (and cryptogenic) abundance of invertebrates varied strongly between habitat types and, for Marion Island, with altitude (Figure 5.5, Supplementary Material S5.4). For Marion Island, invasive springtails were more abundant in mires characterised by *Sanionia uncinata* (40 380 individuals/m^2), and mites were more abundant in the salt-spray vegetation dominated by the native *Cotula plumosa* (2 623 individuals/m^2) (Figure 5.5). Similarly, on Prince Edward Island the salt-spray vegetation type of *C. plumosa* was the most common habitat for mites (15 039 individuals/m^2), although for springtails the highest abundance was found on slopes covered by the native *Blechnum penna-marina* (234 individuals/m^2).

The highest density of mice on the island was 231.8 mice/ha between 2008–2011, with a total estimated population size of 1 760 740 (McClelland et al. 2018). Annual peak density of mice increased by 430% in the thirty years between 1979–1980 and 2008–2011 (McClelland et al. 2018).

5.2.4. Impact of alien species

The impacts of individual invasive taxa have been quantified in a few cases for Marion Island: e.g., for the now eradicated *F. catus* (Van Rensburg & Bester 1988; Hunter 1990), for *M. musculus* (Crafford 1990; Jones et al. 2019) and for

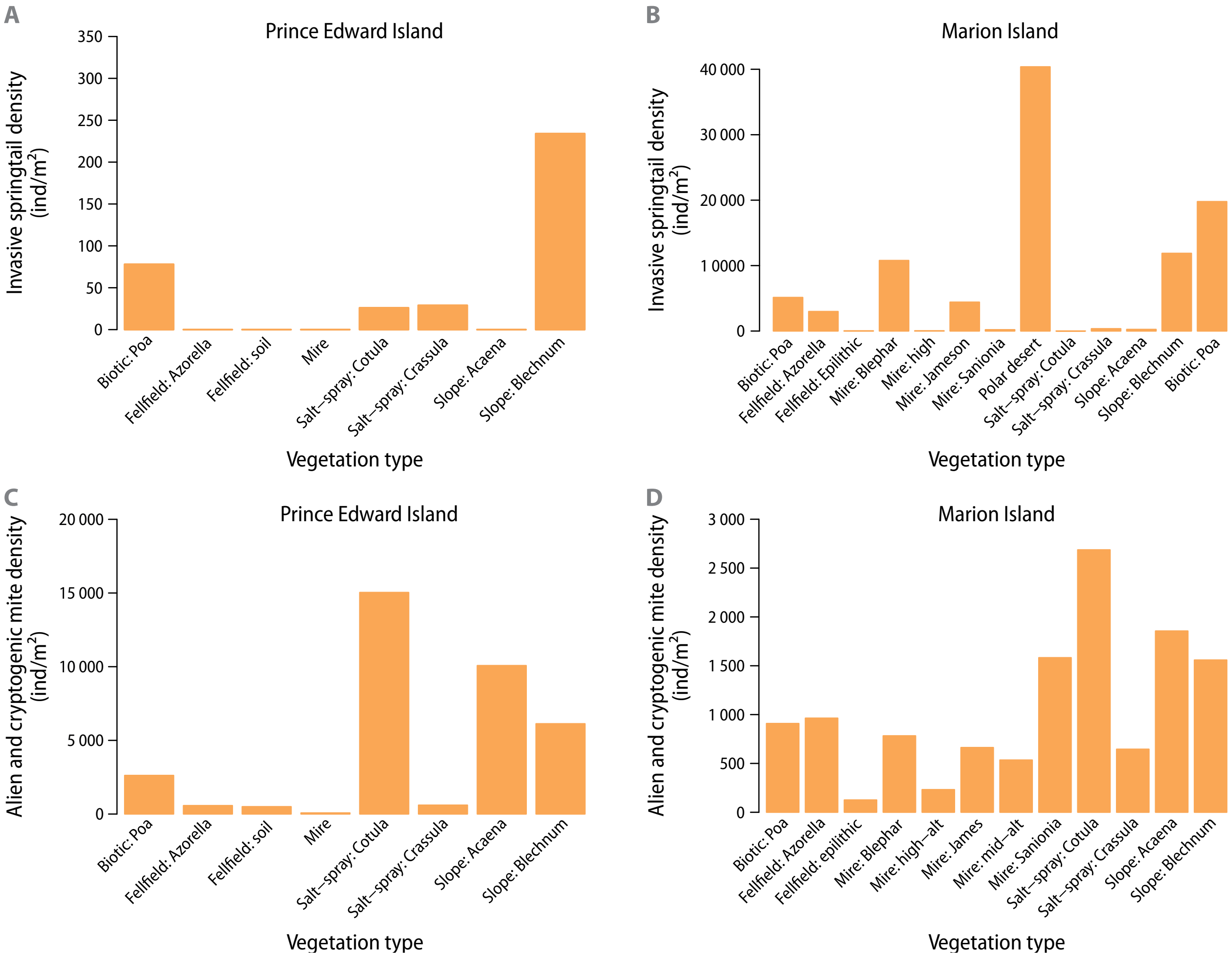


Figure 5.5. Abundance of: A, invasive springtails on Prince Edward Island; B, invasive springtails on Marion Island; C, cryptogenic (i.e., uncertain origin) mites on Prince Edward Island; D, cryptogenic mites on Marion Island, in terms of individuals per square metre. Labels on the x-axis indicate vegetation type and, where appropriate, the plant species or the altitude sampled within the vegetation type – Biotic: Poa = Biotic grassland and herbfield (*Poa cookii*); Azorella = *Azorella selago*; Salt-spray = Coastal salt-spray; Cotula = *Cotula plumosa*; Crassula = *Crassula moschata*; Acaena = *Acaena magellanica*; Blechnum = *Blechnum penna-marina*; Blephar = *Blepharidophyllum densifolium*; high-alt = high-altitude; James = *Jamesoniella colorata*; mid-alt = mid-altitude; Sanionia = *Sanionia uncinata*. Note that the y-axis limits differ between panels.

Table 5.3. The number of alien taxa with different levels of recorded environmental impact on the Prince Edward Islands (PEIs). Taxa were assigned to various categories of impact based only on studies from the PEIs (Greve et al. 2017). See Supplementary Material S5.2 for the approach taken. This table only includes the 44 taxa currently present and so does not include cats (which had caused 'Major' impacts).

Taxon	Environmental Impact (~EICAT)					
	Data Deficient	Minimal	Minor	Moderate	Major	Massive
Mammals	0	0	0	0	0	1
Microbial species	0	0	0	1	0	0
Terrestrial and freshwater plants	6	4	2	3	3	0
Terrestrial invertebrates	24	0	5	1	0	0

the grass *A. stolonifera* (Gremmen 1997; Gremmen et al. 1998). Of the 20 taxa still present on the PEIs for which an environmental impact has been recorded on the PEIs, the impact magnitude, as per the EICAT scheme, is shown in Table 5.3.

The greatest recorded impacts (i.e., 'Massive') are associated with the house mouse. The house mouse is fortunately only present on Marion Island, but it has had impacts at the ecosystem- (Crafford 1990) and species-levels, affecting the island's only shorebird (Huyser et al. 2000), seabirds (Jones et al. 2019; Jones & Ryan 2010; Dilley et al. 2017), native vegetation (Phiri et al. 2009), and invertebrates (Van Aarde et al. 2004). The house mouse has had negative impacts on plant species survival (*Azorella selago*; Phiri et al. 2009) and reproduction (*Uncinia compacta*; Chown & Smith 1993), invertebrate abundance, biomass and body size (Chown & Smith 1993; Crafford & Scholtz 1987; Treasure & Chown 2014; McClelland et al. 2018), and albatross chick survival (Jones & Ryan 2010; Dilley et al. 2017). House mouse burrowing also alters sediment movement rates (Eriksson & Eldridge 2014) and likely impacts on nutrient cycling (Crafford 1990; Smith & Steenkamp 1990). Evidence shows that there has been a shift in mouse behaviour with predation on seabirds' chicks increasing over time and recent records of mice attacking adult seabirds (Jones et al. 2019). The recent increase in mouse impacts on seabirds further emphasises the importance of achieving eradication soon.

Three invasive plant species, including the grass *A. stolonifera,* have had 'Major' impacts on native vegetation and soil fauna communities (Gremmen 1997; Gremmen et al. 1998). Very little has been documented on the impacts of terrestrial invertebrates. Lastly, the fungal ascomycete *Botryotinia fuckeliana* was found to significantly affect the distribution and abundance of a native plant species (Kloppers & Smith 1998).

5.3 Sites

5.3.1. Alien species richness

Alien plant species richness is highest close to the Marion Island base and meteorological station, and high along the northern and eastern coastal areas, particularly in areas with current or historic anthropogenic disturbances (e.g., research field huts; Le Roux et al. 2013). The highest alien plant richness at the hmgc-scale was eight species (at the research station). Alien plant richness on Prince Edward Island is more evenly spread across the island, with the highest richness along the coast and the steep escarpment on the northwestern side of the island [maximum alien plant species richness at the hmgc-scale was three species; Le Roux et al. (2013)].

5.3.2. Relative invasive abundance

Estimates from a 2008 study suggested that less than 5% of the PEIs had been covered by alien plants (Gremmen & Smith 2008). In a more recent study, Le Roux et al. (2013) determined that alien plant species were present in 42% of Marion Island's hmgcs and in 53% of Prince Edward Island's hmgcs. The mean cover of all invasive plant species is 2.6%

on Marion Island (Greve unpublished data). This estimate is based on 501 plots of 3 x 3 m that are spread across the island, though largely excluding the polar desert interior where no vascular plants occur. Given that these plots cover only a small percentage of the island, confidence in this estimate is low. There is spatial variation in **relative invasive abundance** across Marion Island. Coastal habitats are generally more invaded than inland habitats. No data are available on the relative abundance of alien plants for Prince Edward Island.

For both islands, the **relative invasive abundance** of invertebrates varied strongly between habitat types and, for Marion Island, along the altitudinal gradient (Figure 5.6). Springtails are relatively well surveyed and have a **relative invasive abundance** that varies between 0 and 2% on Prince Edward Island and between 0 and 90% on Marion Island (mean relative abundance = 28%; Treasure et al. 2019; Chown et al. 2022). The **relative invasive abundance** of springtails is highest at lower altitudes and in bryophyte- and fern-dominated vegetation types. Spiders have only been adequately sampled on Marion Island (and only from five locations on the eastern side of the island) to document **relative invasive abundance**, and data show **relative invasive abundance** varying from 0–98% (mean = 37%; Khoza et al. 2005). The relative abundance of alien spiders was lowest at the two sites with the highest elevation. Alien mites comprise 0–26% of all mites on Prince Edward Island (mean = 8%; Hugo et al. 2006) and 3–28 % of mites on Marion Island (mean = 14%; Barendse et al. 2002). However, due to uncertainty regarding the identity (and status) of a mite taxon in the Cillibidae, which comprises 95–100% of the alien mite individuals sampled from the islands, there is considerable uncertainty in these estimates. **Relative invasive abundance** of Isopoda is 100% due to the absence of native isopods.

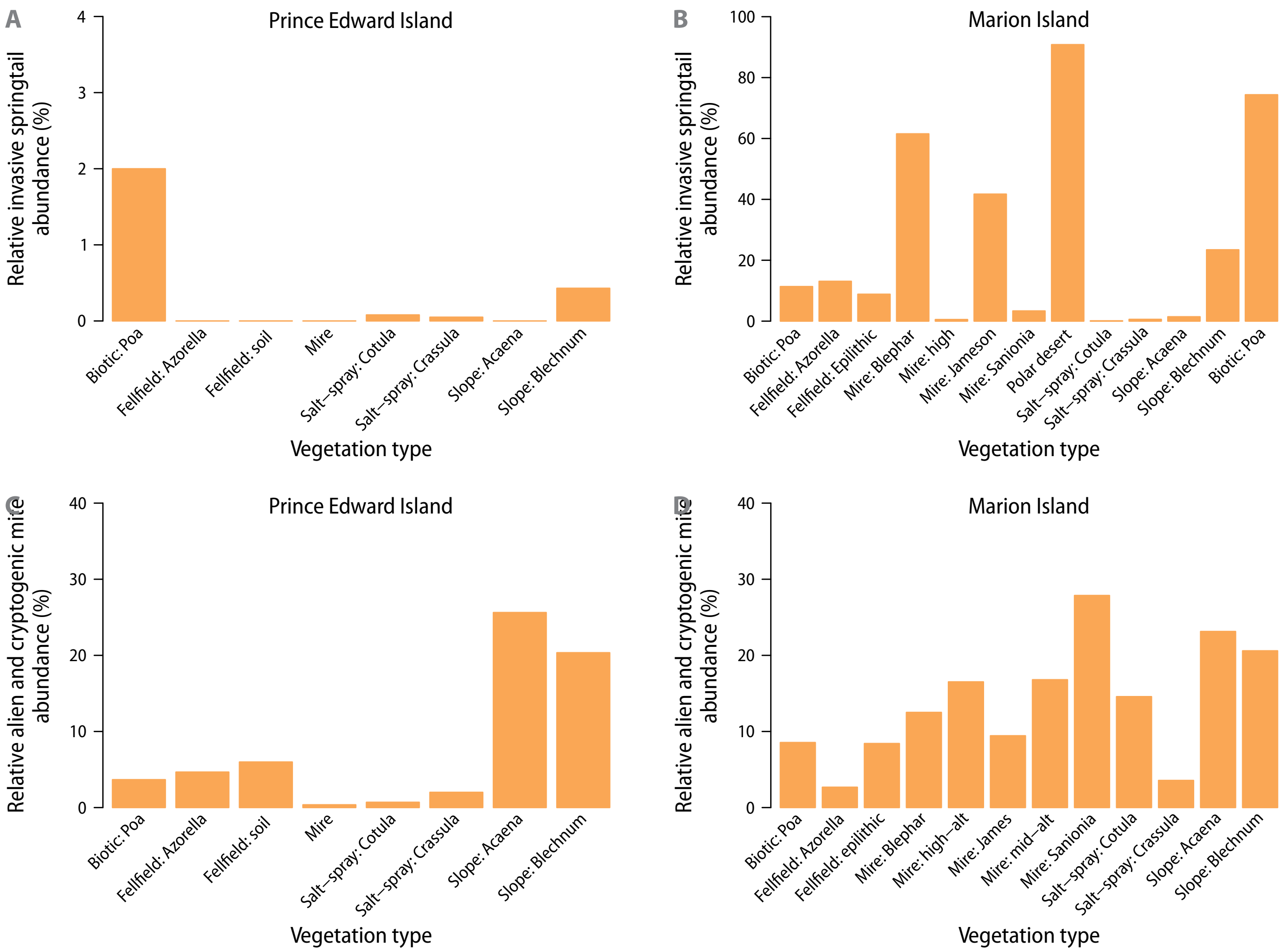


Figure 5.6. Relative abundance of: A, invasive springtails on Prince Edward Island; B, invasive springtails on Marion Island; C, alien and cryptogenic (i.e., uncertain origin) mites on Prince Edward Island; D, alien and cryptogenic mites on Marion Island. Labels on the x-axis indicate vegetation type and, where appropriate, the plant species or the altitude sampled within the vegetation type – Biotic: Poa = Biotic grassland and herb field (*Poa cookii*); Azorella = *Azorella selago*; Salt-spray = Coastal salt-spray; Cotula = *Cotula plumosa*; Crassula = *Crassula moschata*; Acaena = *Acaena magellanica*; Blechnum = *Blechnum penna-marina*; Blephar = *Blepharidophyllum densifolium*; high-alt = high-altitude; James = *Jamesoniella colorata*; mid-alt = mid-altitude; Sanionia = *Sanionia uncinata*. Note that the y-axis limits differ between panels.

Relative abundance data for some taxa (e.g., Insecta) are not available due to the lack of complete surveys (i.e., not all species within the taxon recorded during sampling).

5.3.3. Impact of invasions

Gremmen (1997) estimated that invasion by grasses (plots dominated by *A. stolonifera* but with presence of other aliens) led to a 50% decrease in native vegetation richness in invaded drainage lines. Bryophyte biomass was also 16 times lower in these habitats, but the species richness of macroinvertebrates and mites was higher in invaded areas (Gremmen et al. 1998). Gabriel et al. (2001) did not find a negative impact of invasive springtails on either the richness or abundance of native springtails across 13 habitats on Marion Island. However, a comparison of Marion and Prince Edward islands with the uninvaded Heard Island suggested that invasive springtails caused at least a four-fold decline in the density of three native springtail species (Chown et al. 2022).

5.4 Interventions

5.4.1. Input – quality of regulatory framework

The PEIs have the highest level of protection afforded to any natural area under South African law. The islands were declared a Special Nature Reserve in 1995 and are reserved primarily for scientific research and environmental monitoring (DFFE 2010). Recreation activities are prohibited. The PEIs were designated a Ramsar Wetland Site of International Importance in 2007, and in 2013, the Prince Edward Island Marine Protected Area was formally declared (DFFE 2010). Alien species are not allowed to be introduced to the PEIs.

The NEM:BA A&IS Lists of 2020 include 13 of the 50 taxa currently present (or doubtful) on the islands. However, two taxa which are being managed are not currently listed and four taxa which are listed (and therefore should be managed) are not being managed (Table 5.4). None of the invasive species currently listed for the PEIs are listed on the mainland. No risk analyses have been performed for taxa listed on the PEIs (Table S4.4). Given that ideally the PEIs should be alien-free an evaluation of management options conducted and regularly updated within the scope of the PEIs Management Plan would likely provide the necessary and sufficient information to guide interventions rather than conducting risk analyses solely for the PEIs.

Sagina procumbens (© Nicolas Weghaupt).

Table 5.4. Alien taxa listed under the NEM:BA A&IS Regulations of 2020 for the Prince Edward Islands (PEIs) or for which an eradication plan has been developed [cf. Appendix 7; Wilson (2023)]. Only listings relevant to the PEIs are included here. Information on the implemented control measure was obtained mainly from the Department of Environmental Affairs (DEA) and DST-NRF CIB 2012–2013, last updated in 2021, personal communication with DFFE Specialist Programme Manager Debbie Muir, or indicated otherwise. Technically, as the PEIs are off-shore islands, the following are also listed as 1b [*Alectoris chukar* (Chukar partridge), *Oryctolagus cuniculus* (the European rabbit), *Rattus norvegicus*, *R. rattus*, and *R. tanezumi* (the Norwegian, brown and Asian house rat respectively)], and the following as 1a [*Capra hircus* (goat) and *Felis catus* (domestic cat)], but none of these are currently present on the island. PEI is the Prince Edward Island and MI is Marion Island.

Scientific name	Vernacular name	Regulatory listing	Introduction status	Treated or monitored	Notes on control implemented
Agrostis castellana	bent grass	1a PEI 1b MI	Present but not naturalised	Yes	Inflorescences are cut and bagged and the remaining parts of the plants sprayed with herbicide (Debbie Muir pers. comm. 22 May 2023). However, the form of *A. castellana* occurring on MI is very difficult to distinguish from *A. stolonifera*, and further efforts are required to clarify the distribution of this species, likely supplemented with DNA barcoding as a means to validate identification based on morphology.
Agrostis gigantea	black bent grass	1a	Naturalised but not invasive	Yes	Mechanical removal of aboveground biomass and herbicide application (Glyphosate; 2.5% Kilo Max).
Agrostis stolonifera	creeping bent grass	1a PEI 1b MI	Invasive	No	None implemented (successful eradication deemed unfeasible; Greve et al. 2017).
Alopecurus geniculatus	marsh foxtail	1a	Doubtful (eradication to be confirmed)	Yes	Manual removal was conducted; assumed to be no longer present since 2012 (Greve et al. 2017).
Cerastium fontanum	common mouse-ear chickweed	1b	Invasive	No	None implemented because it is widespread (Greve et al. 2017; DEA & DST-NRF CIB 2021).
Elymus repens[1]	couch grass	1a	Naturalised not invasive	Yes	Mechanical removal of aboveground biomass and herbicide application (Glyphosate; 2.5% Kilo Max 700 g/kg.)
Festuca rubra	creeping red fescue	1a	Naturalised not invasive	Yes	Herbicide application (Glyphosate; 2.5 Kilo Max).
Holcus lanatus	common velvet grass	Not listed	Doubtful (eradication to be confirmed)	Yes	The species was manually removed in 2012, site and surrounding areas have been monitored monthly since removal to detect any regrowth or new plants.

[1]Listed as *Elytrigia repens* (L.) Desv. ex Nevski (= *Agropyron repens* (L.) P. Beauv., *Elymus repens* (L.) Gould) under the A&IS Lists of 2020.

Table 5.4. (Continued) Alien taxa listed under the NEM:BA A&IS Regulations of 2020 for the Prince Edward Islands (PEIs) or for which an eradication plan has been developed [cf. Appendix 7; Wilson (2023)]. Only listings relevant to the PEIs are included here. Information on the implemented control measure was obtained mainly from the Department of Environmental Affairs (DEA) and DST-NRF CIB 2012–2013, last updated in 2021, personal communication with DFFE Specialist Programme Manager Debbie Muir, or indicated otherwise. Technically, as the PEIs are off-shore islands, the following are also listed as 1b [*Alectoris chukar* (Chukar partridge), *Oryctolagus cuniculus* (the European rabbit), *Rattus norvegicus*, *R. rattus*, and *R. tanezumi* (the Norwegian, brown, and Asian house rat respectively)], and the following as 1a [*Capra hircus* (goat) and *Felis catus* (domestic cat)], but none of these are currently present on the island. PEI is the Prince Edward Island and MI is Marion Island.

Scientific name	Vernacular name	Regulatory listing	Introduction status	Treated or monitored	Notes on control implemented
Juncus effusus	common rush	Not listed	Doubtful (eradication to be confirmed)	Yes	Potentially eradicated, currently being monitored to confirm eradication.
Luzula multiflora	woodrush	1a	Naturalised not invasive	Yes	Herbicide application (Glyphosate; 2.5% Kilo Max). A genetic study has been recommended to confirm that it differs from the native subantarctic *Luzula* species (and so unequivocally alien).
Mus musculus	house mouse	1a MI	Invasive	Yes	Baited traps are deployed both outside and inside the base and huts to protect food and human health (Wolfaardt pers. comm. 2022). Mice are not otherwise subject to control, although an eradication attempt is being planned through the 'Mouse-free Marion Project', due to start in 2025 if enough funds are raised.
Poa pratensis	Kentucky bluegrass	1a PEI 1b MI	Invasive	No	None implemented (Greve et al. 2017; DEA & DST-NRF CIB 2021).
Porcellio scaber	common rough woodlouse	Not listed	Doubtful (eradication to be confirmed)	Yes	The woodlouse is believed to have been successfully eradicated in 2012, but this needs to be monitored for confirmation. Control is recommended via application of pyrethroid (Super Crackdown).
Rumex acetosella	sheep sorrel	1a	Naturalised not invasive	Yes	Mechanical removal of aboveground biomass (inflorescence is cut and then plant pulled) (Debbie Muir pers. comm. 22 May 2023).
Sagina procumbens	birdeye pearlwort	1b	Invasive	No	None implemented (successful eradication deemed unfeasible by Greve et al. 2017), but the potential for classical biocontrol is under investigation.
Stellaria media	common chickweed	1a PEI 1b MI	Doubtful	Yes	It used to be sprayed with herbicide (2.5% Kilo Max). It has not been seen by the ECOs lately, currently being monitored.

5.4.2. Input – money spent

Given the discrete nature of the PEIs and the limited number of people involved, it should be possible to estimate the **money spent** to control invasions. However, no such estimates have been made, as detailed expenditures have not, as of yet, been accessible. The following information is available. The DFFE budget for herbicides (two different types) and equipment, including personal protective equipment, for the control of alien species on the PEIs 2011–2022 was ZAR 58 664 (see Supplementary Material S5.5). The only pesticide applied on Marion Island to control invertebrates was donated; the value of this has not yet been obtained. In 2006 there was a specific targeted effort to control the invasive plant *Elymus repens* (couch grass), where above-ground material and some of the below-ground rhizomes were removed and herbicide was applied. The total cost of the operation was ZAR 201 378, which included human resources, as well as helicopter trips to transport the removed biomass.

The major cost controlling biological invasions on Marion Island will be the time of the ECOs. ECOs perform various duties, but there is no current estimate available of the time allocated to alien species monitoring and control. No continuous control (or monitoring) is possible on Prince Edward Island due to the lack of regular human presence on the island.

5.4.3. Input – planning coverage

The current management plan determines the quarantine and biosecurity measures to be applied to introduction pathways and makes recommendations for the management of invasive species. The PEIs Management Plan includes both islands and so all sites have a management plan in place.

There have been two management plans developed for the PEIs: one published in 1996 and another in 2010 (Version 0.2). The second plan was officially adopted by the then Department of Environmental Affairs (DEA) in 2014. Management plans were set to be revised and updated every four years, but the latest updated management plan is still under development. It was scheduled to be circulated for public comment by mid-2023. Therefore, the estimates provided for this indicator and subsequent ones are related to the management plan from 2010.

All eight active introduction pathways, besides the unaided pathway for which management is impractical, are covered by the plan. The intentional introduction of any live alien organism is prohibited. The plan outlines a large set of biosecurity control measures to reduce the risk of accidentally introducing alien species, either with the vessel, with people and their belongings and/or with cargo. There are specific regulations on how the vessel's hull must be cleaned of fouling taxa before voyages to the island, and ballast water cannot be discharged within 200 nautical miles of the islands (DFFE 2010). The plan also regulates the number of expeditioners that can travel to the islands (and the frequency and duration in the case of Prince Edward Island), what they can bring in their luggage and the equipment they are allowed to transport.

As part of the Management Plan, the then DEA and the then DST-NRF Centre of Excellence for Invasion Biology (CIB) jointly developed an eradication plan ('Eradication, monitoring, and control of alien and invasive species on Marion Island') for six priority invasive plant species and one invertebrate. This plan is revised and updated every year by the DFFE alien species management team. The current plan has three different categories according to priority of control (high, medium and low). These priorities will be revised, as some of the species that used to be high priority have not been detected for several years and are now potentially eradicated. The list is intended to be split into an active priority list (taxa currently present and managed) and a historical list of taxa that requires only monitoring (taxa for which presence is doubtful and eradication needs to be confirmed). This facilitates an assessment of how the extent of invasive species has changed and of how successful control measures have been. To help this process, data have been incorporated into a map to show historical and current invasions (see Figures S5.2–5.6).

The Management Plan considers only 14 species as invasive, although this report found evidence that 26 taxa are invasive. Out of 13 species present (or doubtful) on the PEIs, which are listed under the NEM:BA A&IS Regulations (2020), only seven are included in the eradication plan. There are also two species in the eradication plan, which are deemed a priority for eradication that are not currently listed under the national regulations.

Mus musculus (house mouse) has a separate eradication project, namely 'Mouse-Free Marion' (https://mousefreemarion.org/), which is currently in its planning phase and funds are being raised with the aim of implementing the project in 2025. The planned cost for the mouse eradication as of December 2022 was ~ZAR 450 million. It is a partnership between the DFFE and BirdLife South Africa. It would be the largest eradication of rodents from an island (Springer 2022).

5.4.4. Output – pathways treated

A DFFE 'Gear Checks' document provides guidance for all expeditioners on how to clean their gear, clothes and personal equipment, and to check for the presence of alien species or propagules during packing before departure. A further Biosecurity Check is conducted en route on board the SA Agulhas II, during which all participants' outer field gear and equipment not packed away in the cargo hold is inspected for any biological material. All participants must sign the 'Biosecurity self-audit checklist and declaration' confirming that they have adhered to DFFE's biosecurity measures. Measures are also in place to reduce the movement of propagules (e.g., seeds) from sites close to the base on Marion Island to less invaded sites. There is a 'minimum Velcro policy' given that propagules are known to attach to this material. All new standard issue protective clothing supplied by DFFE is Velcro-free as from mid-2022, and all expeditioners are encouraged to have only Velcro-free clothing.

Additional biosecurity measures are in place before travelling to Prince Edward Island. For example, personnel are dropped at Prince Edward Island first (i.e., there is no prior deployment to Marion Island), and only new camping equipment and protective clothing is to be taken onto the island.

Containers which transport cargo are to be properly cleaned with a high-pressure hose before packing and storing cargo, and cargo (including machinery) must be inspected to check for the presence of alien organisms or propagules. The same biosecurity rules are applied for other vessels as for the SA Agulhas II. All this is clearly stated in the 2010 management plan (Goal 5.1, DFFE 2010).

To avoid alien taxa from being transported with food (unintentional contamination), fresh produce is not allowed on the islands. Food taken to the island must be irradiated (e.g., eggs), frozen (e.g., meats and vegetables), or otherwise sterilised (e.g., canned).

5.4.5. Output – species and sites treated

Of the 13 regulated invasive taxa (11 currently present, two doubtful), nine taxa have been subjected to some form of management (Marion Island only; no species have been treated on Prince Edward Island) (Table 5.4). Three species which are not listed and for which presence is doubtful [*Holcus lanatus* (common velvet grass), *Juncus effusus* (common rush), and *Porcellio scaber* (common rough woodlouse)] are being monitored to confirm eradication, taking the number of total managed species to twelve.

Poa pratensis (© Matt Lavin).

Six vascular plant species, one invertebrate species (*P. scaber*) and *Mus musculus* (the house mouse) are currently being treated on Marion Island. All of these, except for the *M. musculus*, are treated at all the sites where they are known to have occurred (from one to three locations; Neethling 2019; DEA & DST-NRF CIB 2021). These sites are all on the eastern side of Marion Island and all but one are within a kilometre of the research base (the most distant site is still < 5 km from the research base). *Mus musculus* is being controlled at the research base and all field huts, but this only represents a very small fraction of the species range on Marion Island (DEA & DST-NRF CIB 2021).

5.4.6. Outcome – effectiveness of pathway treatments

There have been introductions in the past through six pathways that have subsequently been closed (Table 5.1). There have been no marine introductions to date, possibly helped in recent years by the fact that ballast water and hull fouling are managed, but also maybe because the marine environment (e.g., sea water temperatures) is quite different to the environment found off the coast of mainland South Africa. It was not possible to quantify the effectiveness of current pathway treatments, however, due to the detection of several alien taxa on the ship and at the research base in recent years, it would seem that the pathway treatments are partially effective.

5.4.7. Outcome – effectiveness of species and site treatments

The **effectiveness of species treatments** is assessed on Marion Island each year by the ECOs in terms of herbicide 'kill rate' (percentage of plants or plant cover killed per area treated) and regrowth for invasive plants, with two species having a 90–100% kill rate, two species having a 60–80% kill rate, and one species a 30–40% kill rate. Secondary herbicide application effects are still being monitored. However, the assessments are not performed in a systematic manner. In future, the annual plan of operations that the ECOs will write will be linked to a herbicide usage sheet and will record the density of infestations at each site (Debbie Muir pers. comm. 22 May 2023). ECOs will do a first party assessment at each site once a year to ascertain effectiveness of herbicide and changes to alien plant density. DFFE:EP (Environmental Programmes) will do a second party assessment every three years of the work done on the island to link the effectiveness of the control measures to the plan. Recommendations will then be made regarding control methods if necessary.

Five species are thought to no longer be present due to successful chemical and mechanical interventions, four plants *Alopecurus geniculatus* (marsh foxtail), *H. lanatus*, *J. effusus*, *Stellaria media* (common chickweed) and the invertebrate *P. scaber*. However, these species are still included in the eradication plan for monitoring until eradication is confirmed after four second party assessment reports (12 years).

There are conflicting reports on the effectiveness of the control measures for some species. For *A. gigantea* herbicide treatments were reported to kill 90–100% of plants (DEA & DST-NRF CIB 2021), but Neethling's report (2019) states that although the species was killed at three sites, new populations were found a short distance from each of those sites. For the grass species *H. lanatus*, control appears to have been completely effective, with this species currently being absent from the single sites from which the species was known in the mid-2000s. The treatment of the isopod *P. scaber* also appears to have been completely effective. Treatment initially comprised targeted searches by researchers (Janion-Scheepers, pers. comm. 2022), and after the initiation of chemical control in 2012, no further individuals have been observed (latest data from 2017). Much of the implementation of the management plans appears to be adequate, but there appears to be a lack of up-to-date management plans, and progress reports often contain inadequate detail. As a result, the quality of implementation of management plans is not known.

The number of mice captured with traps at the research station varies per year with survey effort. For example, 255 mice were captured in 2018, 62 in 2019, and a record of 412 in 2022 (data collected by ECOs Mr Mishumo Masithembi and Gcobani Tshangana) (Table S5.3). No data are available to assess the effectiveness of the control of house mice at the field huts. However, given the small fraction of the species range that the research station and huts comprise and the species' ability to move across the landscape, it can be assumed that the impact of the control is negligible, with at most localised and temporary reductions in densities.

The treatments applied to alien plant species appear to be effective at killing individuals [30–100% mortality of individual plants (DEA & DST-NRF CIB 2021)], but accurate monitoring at the site level is lacking (Neethling 2019). To address this, implementation and monitoring maps have been included after second party assessment to indicate density at site level (polygons).

5.5 Trends in indicators for the PEIs

The trends for the PEIs have been assessed considering changes in the last 10 years (as this is the first detailed report on the situation on the PEIs it was not possible to compare with any previous reports).

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
1. Rate of unregulated introduction of new species	→	medium	↘	The rate of introduction has not changed in the last ten years.	No change is envisaged. Traffic to, and pathways to the islands are not expected to change because the same protocol is strictly followed every year and is unlikely to change in the near future. Recent improvements (e.g., no Velcro) and continuing work on biosecurity would be needed if the goal of zero introductions is to be achieved. However, if the 'Mouse Free Marion' eradication plan goes ahead, more introductions could be expected as eradication efforts will bring a higher number of people onto the island and result in a large amount of traffic across the island. Faster spread of invasive species might be expected as they will be operating from areas other than the base.
1.1 Introduction pathway prominence	→	high	not applicable	No changes in practices and regulations.	No change is envisaged. Traffic to, and pathways to the islands are not expected to change because the same protocol is strictly followed every year and is unlikely to change in the near future.
1.2 Introduction rates	→	medium	↘	All intentional introductions were historical. In the 2000s strict biosecurity measures were implemented. Escape and release pathways are no longer present. Pathway of introduction remains unknown for most alien taxa, but accidental introductions as stowaways or food contamination have been the most common recent pathways.	No major change is envisaged due to strict control of pathways. However, a biological control agent could be introduced in the future for *Sagina procumbens* if tests are successful and the PEIs Advisory Committee approves it. Biosecurity efforts (e.g., no Velcro) might result in lower numbers of introductions, but this decline will be hard to detect without careful screening.

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
1.3 Within-country pathway prominence	→	medium	not applicable	Number of persons walking around islands has changed little and no known changes in spatial coverage of research actions on the island.	No change expected. Highly regulated environment; practices on islands hardly change from year to year. If the 'Mouse Free Marion' Project goes ahead, the trend could increase due to more movement of goods using air support around the island.
1.4 Within-country dispersal rates	→	medium	↘	Three pathways are suspected to be the cause of alien species spread [unaided (wind and seabirds) and stowaways (fieldworkers and helicopter)], but exact number of species using each pathway is unknown.	No change envisaged, except if the 'Mouse Free Marion' project goes ahead in the future, since biosecurity measures will have to be reinforced to avoid alien species spread during deployment of poison around Marion Island.
2. Number of invasive species that have 'Major' impacts	→	medium	↘	No new invasive species have been introduced to the islands recently, although existing invaders are spreading and their impacts might have increased.	Expectation is that current range restricted taxa will be managed to avoid spread, and so any changes to this will be due to existing widespread invaders increasing in terms of the impacts they cause.
2.1 Number and status of alien species	→	medium	↘	No known introductions or successful eradications. Eradication attempts for six taxa are underway.	Six taxa for which presence is doubtful could be confirmed as eradicated for the next status report, as they will have been undetected for more than ten years by 2025. This will reduce the number of alien species present on the PEIs, although new introductions could increase the number.
2.2 Extent of alien species	↗	low	↘	The assumption is that several alien species have not reached equilibrium with the environment across the PEIs and are still spreading. Some data for *Poa pratensis* show recent spread.	Might increase because some species are not being treated (as eradication deemed unfeasible), and climate change is expected to benefit some taxa (some invasive plants, springtails, and mice). The range of some taxa might decline if control is effective (to the point of eradication in some instances).

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
2.3 Abundance of alien species	↗	low	↘	Abundance of alien plants, invertebrates, and mice has been assessed. Abundance on both islands depends strongly on habitat type and varies with altitude on Marion Island. There are no data on trends in abundance, except for mice that have increased in abundance (McClelland et al. 2018).	Because most alien species are not being controlled, abundance is expected to increase.
2.4 Impact of alien species	↗	low	↘	Twenty alien species have been assessed for impacts. One has a 'Massive' impact (house mouse) and three plants have 'Major' impacts. The fungus has 'Moderate' impact and most invertebrates are 'Data Deficient'. The house mouse is causing the greatest impacts, it has reduced the density of invertebrates (McClelland et al. 2018) and impacts seabirds, as well as native vegetation. Few data have been collected for other taxa.	Expected to increase as species spread across the islands, increasing island-wide impacts; but also expected to increase as climate amelioration may make the environment more favourable for generalist invaders.
3. Extent of area that suffers 'Major' impacts from invasions	↗	low	↘	Several alien species have not reached equilibrium with the environment across the PEIs and are still spreading. Some of these have 'Major' impacts (e.g., *Sagina procumbens*).	Expected to increase as species spread across the islands, increasing island-wide impacts; but also expected to increase as climate amelioration may make the environment more favourable for generalist invaders.
3.1 Alien species richness	→	medium	↘	No known introductions or successful eradications. Eradication attempts are underway.	Will depend on the success of eradication and the ability to prevent or remove new incursions.

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
3.2 Relative invasive abundance	↗	low	↘	Mean plant cover on Marion Island (MI) 2.6%; no plant data for this indicator on PEI. Invertebrates' **relative invasive abundance** varies between 0–2% for PEI springtails to 28% on MI; for mites between 8% at PEI and 14% at MI; however, the uncertainty of nativity status for Cillibidae make this estimate very low confidence. Spiders have been studied only on MI (37% mean relative abundance) and there are no data for insects due to a lack of complete surveys.	Expected to increase as species spread across the islands, and also as climate amelioration may make the environment more favourable for generalist invaders.
3.3 Impact of invasions	↗	low	↘	Because abundance is increasing, and because there are some indications that the amelioration of climate on the PEIs is benefitting invasive over native species, the impact is assumed to increase. [e.g., mice have increased populations, McClelland et al. (2018)].	Expected to increase as species spread across the islands, increasing island-wide impacts; but also expected to increase as climate amelioration may make the environment more favourable for generalist invaders.
4. Level of success in managing invasions	→	high	↗	Some management actions have been successful and species are being monitored to confirm eradication. The distribution of some other taxa has remained stable (in some cases, due to taxa being controlled). However, a few taxa have increased in extent. So overall there is no change and the level of success is partial. Assessment done in 2023 based on data from 2020–2022 were compared to previous assessment to indicate changes and achievements of managing invasions.	If successful, the 'Mouse-free Marion' Project would be a significant achievement, and although less pressing, other eradications would also lead to an increase in this indicator.

→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
4.1 Quality of regulatory framework	↗	high	↗	The current management plan was developed in 2010. The eradication plan is revised and updated every year. The **quality of regulatory framework** is considered partial.	Regulations are in the process of being revised and a new Management Plan is meant to go out for public comment in 2023. The process of prioritising management targets will likely be more effective if decoupled from national-level regulations and processes.
4.2 Money spent	↗	medium	↗	The DFFE budget for herbicides and equipment for the control of alien species on the PEIs during 2011–2022 was ZAR 58 664. This is an underestimate, as a full value was not provided. For example, the cost of hours invested by ECOs on control of alien species has not been estimated.	A reduction in total costs of invasive clearing is expected in line with the invasive species management plan if eradication of currently doubtful species is confirmed. Significant funds will be spent in a short period of time if the 'Mouse Free Marion' Project is implemented.
4.3 Planning coverage	↗	high	↗	All seven active human-mediated pathways have management plans in place. The invasive species management plan is compliant with the NEM:BA A&IS Regulations Section 76 (A), Section 70 (1)(2)(3). The management plan covers Marion and Prince Edward Island, so all sites have a management plan in place, although outdated.	Eradication plan to be updated after second party assessment (April/May 2023) to include historical and active species sites. A mapping system that can reflect historical and active control methods will be available. Mapping system can be used for estimating changes in invasions, allowing for adaptive management and update of eradication plans.
4.4 Pathways treated	→	high	↗	All pathways by which alien species can be introduced require management, and they are all being managed under strict biosecurity measures.	Information on biosecurity breaches (e.g., identifications) can be used to improve protocols.

*→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
4.5 Species treated	→	high	↗	Of the 13 listed alien taxa (12 plant species and one mammal), 8 plants are subjected to some form of management (either inflorescences cut and bagged, plants pulled, or herbicide). Five potentially eradicated species are being monitored to confirm status (four plant species and the isopod). Mice are only controlled at the base and huts. Invasive plants' historical sites and active sites are being mapped and monitored.	Confirmation of eradication for five species will only be done if they have not been seen for four consecutive second party assessments (12 years). If the 'Mouse Free Marion' eradication plan goes ahead in 2025 a contingency plan after mass baiting must be implemented.
4.6 Sites treated	→	high	↗	Marion Island is treated on a regular basis; however, Prince Edward Island can only be visited every four years (but has not been visited in the last ten years), therefore there is no management currently applied on that site.	Mapping and monitoring plan will indicate historical, as well as active sites to indicate effectiveness of control plans.
4.7 Effectiveness of pathway treatments	not assessed		↗	The necessary quantitative data to assess this indicator are not available.	Information on biosecurity breaches (e.g., identifications) can be used to improve protocols.
4.8 Effectiveness of species treatments	↗	high	↗	Many invasive species are subject to some form of control and outcomes are monitored. There are 11 taxa that are eradication targets, with five that are potentially eradicated and that have become monitoring targets, as they have not been seen for several consecutive years. DFFE three-year assessment results indicate a reduction in active sites. Four widespread invasive plant species are considered inappropriate targets for eradication and therefore are not being treated.	Mapping and monitoring programme will indicate effectiveness of control programmes in future. New control technologies will likely be needed if current widespread invasive taxa, other than the house mouse, are to be effectively controlled.

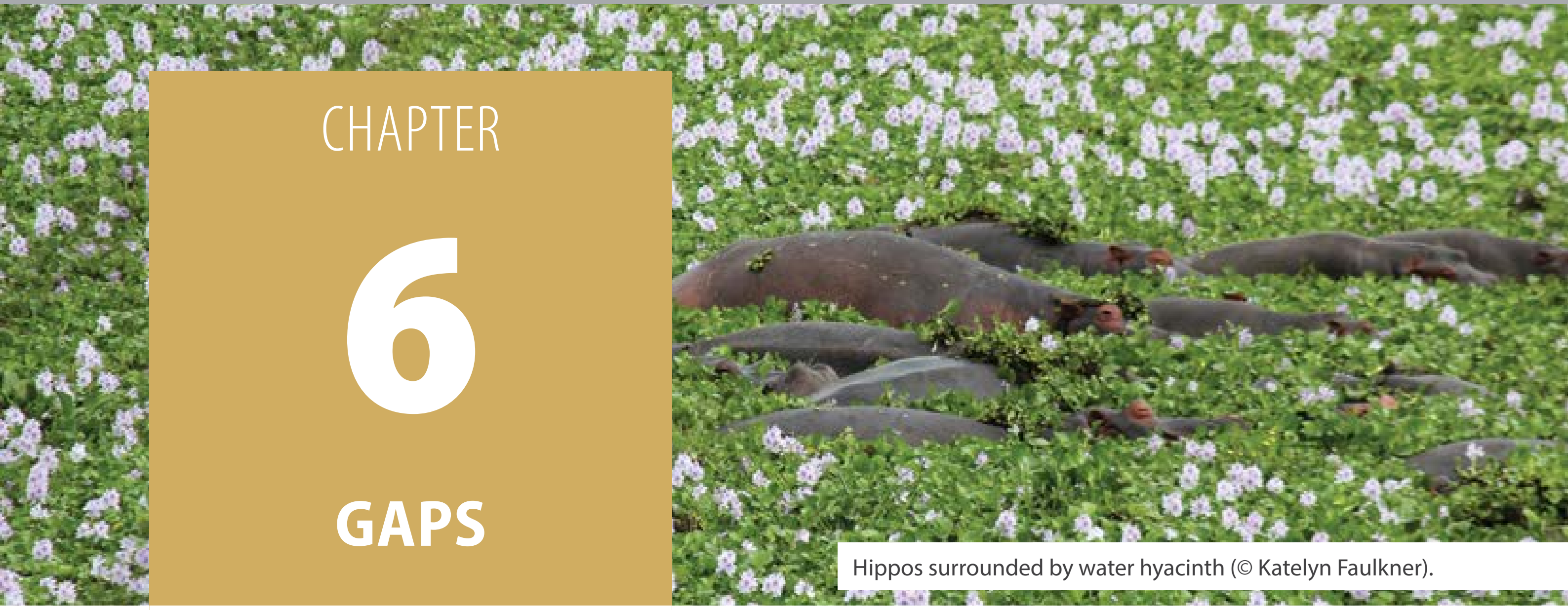
→ no change; ↗ an increase; ↘ a decrease.

Indicator	Trend	Confidence	Desired trend	Current status and trend	Outlook
4.9 Effectiveness of site treatments	↗	high	↗	Second party assessment implemented three-yearly at Marion Island to quantify effectiveness of treatments and possible reductions of alien species populations (plants, isopod and mice).	Monitoring plan data will be used to amend and update the invasive species management plan.

→ no change; ↗ an increase; ↘ a decrease.

Juncus effusus (© Josep Gesti).

Agave sisalana (© Forest and Kim Starr).



Hippos surrounded by water hyacinth (© Katelyn Faulkner).

CHAPTER 6 GAPS

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Chapter structure and gaps[1]

- This chapter evaluated gaps using four approaches: 1) progress in collating information needed for the indicators used in this report was evaluated and gaps in this process noted (Section 6.1 and Table 6.1); 2) gaps identified in the second report (including gaps in information, management and governance) were re-evaluated (Sections 6.2–6.7); 3) the key findings and implications highlighted in the book on biological invasions (Van Wilgen et al. 2020) were evaluated (Section 6.8 and Table 6.2); and 4) gaps in the scope of this report identified during the review of the report were summarised (Section 6.9). The chapter concludes with Section 6.10: the way forward. Key gaps are highlighted below.

- Testing the indicators developed for this report and aligning them to other government reporting processes could improve the flow of information from observations to policy and management.

- There is insufficient information on how invasive species move and are moved around South Africa to develop strategies to effectively manage the spread of invasions.

- The planning of interventions would be facilitated if data on the presence, distribution and abundance of alien species were systematically collected, collated and integrated into national and global databases.

- The systematic quantification of the impacts of biological invasions is needed to facilitate the prioritisation of interventions,

[1] All but the last two key gaps are the same as the second report albeit with some minor rephrasing. While there has been progress addressing some of these gaps, none are fully addressed yet (see Tables S6.1, S6.2).

provide a defensible rationale to underpin government investment, and provide background to efforts to communicate the severity of the issue.

- Interventions on biological invasions in South Africa are occurring without a comprehensive policy or a strategy to guide and implement such a policy. Existing and new policies only address part of the issue of biological invasions. A national strategy is under development.
- Formal programmes that monitor progress towards reducing the negative impacts of invasions (outputs and outcomes) are not available, but, if established, would allow for control measures to be compared and improved.
- Several gaps specific to the Prince Edward Islands were identified (e.g., in terms of identifying incursions and the need for closer co-operation between management and research); these are discussed in Chapter 5.
- There has, to date, been no systematic evaluation of how the report is currently used, what can be done to improve uptake, and how the report can better address stakeholder needs. Broad stakeholder engagement exercises have been used very effectively in similar contexts.

6.1 Progress since the last report

For each indicator, the evaluation of the progress made towards getting an accurate reflection of the actual situation was evaluated by the report authors based on the information contained in each chapter (Table 6.1).

Passiflora caerulea (© Alan Lorenzo).

Table 6.1. Progress gathering information required to populate the indicators reported on in this report: a) pathway indicators; b) species indicators; c) site indicators; and d) intervention indicators (cf. Figure 0.3). The exact wording, the level of knowledge and information gaps for the first report, the proposed solution and the consequence if the gap is not filled are provided in Table S6.1. Progress is scored as: regression – less information is available than previously; none – the information is the same as in previous reports (with appropriate updates as needed); minimal – there has been some more information or processes set up, but these are unlikely to be sufficient to affect the scoring of the indicators; moderate – additional information were obtained allowing for some changes to be detected or necessitating a revised baseline; substantial – the processes have seen a step change in what information is available and/or the information that could be obtained. As the Prince Edward Islands chapter is new, there was no base-line to consider progress against and it is not included below.

a)	Pathway indicators	Progress 2017–2019	Progress 2020–2022	Notes
1.	Rate of unregulated introduction of new species	minimal	moderate	A database on historical interceptions of agricultural pests was recently published, although this is still to be processed and included in the species list. With new indicators being developed, there is a greater recognition of the need to separate search effort from observations (Box 1.1). This promises to be an area where substantial progress can be made.
1.1	Introduction pathway prominence	moderate	moderate	Recent research on pathways of introduction means that our understanding of certain pathways, such as the pet trade and medicinal plant trade, has improved significantly. But many pathways of introduction remain poorly studied. A workflow has been developed to support this indicator.
1.2.	Introduction rates	moderate	moderate	While progress has been made (see indicator 1), there are still significant gaps, e.g., in terms of pathways and dates of introduction. These data are being incorporated through the new workflow to add enrichment data to the species list.
1.3	Within-country pathway prominence	none	minimal	There have been insights into certain pathways due to research on the pet trade, medicinal plant trade and game farms, but these are only a few of the pathways active within South Africa.
1.4	Within-country dispersal rates	none	moderate	A database of native-alien populations, including information on pathways, has been constructed. Information is also available for alien plants in South African National Parks. The pathways for other taxa dispersing within the country, however, remain unknown or the available information needs to be collated.

Table 6.1. (Continued) Progress gathering information required to populate the indicators reported on in this report: a) pathway indicators; b) species indicators; c) site indicators; and d) intervention indicators (cf. Figure 0.3). The exact wording, the level of knowledge and information gaps for the first report, the proposed solution and the consequence if the gap is not filled are provided in Table S6.1. Progress is scored as: regression – less information is available than previously; none – the information is the same as in previous reports (with appropriate updates as needed); minimal – there has been some more information or processes set up, but these are unlikely to be sufficient to affect the scoring of the indicators; moderate – additional information were obtained allowing for some changes to be detected or necessitating a revised baseline; substantial – the processes have seen a step change in what information is available and/or the information that could be obtained. As the Prince Edward Islands chapter is new, there was no base-line to consider progress against and it is not included below.

b)	Species indicators	Progress 2017–2019	Progress 2020–2022	Notes
2.	Number of invasive species that have 'Major' impacts	minimal	moderate	Improved impact assessment methodologies have aided in identifying highly impactful species. There is ongoing development of frameworks and models assessing potential impacts and risks posed. There is additional progress towards developing standards and assessing alien taxa at a global level.
2.1	Number and status of alien species	substantial	substantial	The species list has seen major improvements, with, in this report, clearer metadata, the development of explicit links to taxonomic backbones, and the production of a workflow for adding species and enrichment data to the list. The focus for the next phase is to increase the number of data-sources incorporated into the species list and to formalise processes (e.g., for declaring a taxon alien and present).
2.2	Extent of alien species	minimal	minimal	While information from citizen science platforms can be useful, the lack of activity around the Southern African Plant Invaders Atlas means that arguably our knowledge of invasive plant distributions has regressed. However, digitisation of records through the National Collections Facility and the Freshwater Biodiversity Information System have improved the flow of information for primary records to national and international databases. This is significant progress. On balance the progress has been scored as minimal.
2.3	Abundance of alien species	minimal	none	No additional progress has been made when compared to the second report.
2.4	Impact of alien species	minimal	minimal	Improved impact assessment methodologies have aided in identifying highly impactful species. There is ongoing development of frameworks and models assessing potential impacts and risks posed. There is additional progress developing standards and assessing alien taxa at a global level. However, these methodologies have only been applied to very few alien taxa found in South Africa to date.

Table 6.1. (Continued) Progress gathering information required to populate the indicators reported on in this report: a) pathway indicators; b) species indicators; c) site indicators; and d) intervention indicators (cf. Figure 0.3). The exact wording, the level of knowledge and information gaps for the first report, the proposed solution and the consequence if the gap is not filled are provided in Table S6.1. Progress is scored as: regression – less information is available than previously; none – the information is the same as in previous reports (with appropriate updates as needed); minimal – there has been some more information or processes set up, but these are unlikely to be sufficient to affect the scoring of the indicators; moderate – additional information were obtained allowing for some changes to be detected or necessitating a revised baseline; substantial – the processes have seen a step change in what information is available and/or the information that could be obtained. As the Prince Edward Islands chapter is new, there was no base-line to consider progress against and it is not included below.

c)	Site indicators	Progress 2017–2019	Progress 2020–2022	Notes
3.	Extent of area that suffers 'Major' impacts from invasions	minimal	minimal	Despite several remote sensing initiatives under development there has still been little tangible progress.
3.1	Alien species richness	minimal	none	No progress has been made since the second report.
3.2	Relative invasive abundance	minimal	none	No progress has been made since the second report.
3.3	Impact of invasions	minimal	moderate	Economic estimates of impact have been collated as part of this report (cf. Box 3.1), with an accompanying workflow. Some work has compared indicators for the risk of extinction to the impact of alien species, however, there is still a need to look at other measures of impact (e.g., water loss and impact on grazing potential) and to ensure these are repeatable.

d)	Intervention indicators	Progress 2017–2019	Progress 2020–2022	Notes
4.	Level of success in managing invasions	minimal	none	A recent analysis of the effectiveness of control (Van Wilgen et al. 2022a) provided some useful estimates of the effort taken, but served to highlight the lack of monitoring of control effectiveness meaning that this indicator could not be calculated.

Table 6.1. (Continued) Progress towards gathering information required to populate the indicators reported on in this report: a) pathway indicators; b) species indicators; c) site indicators; and d) intervention indicators (cf. Figure 0.3). The exact wording, the level of knowledge and information gaps for the first report, the proposed solution and the consequence if the gap is not filled are provided in Table S6.1. Progress is scored as: regression – less information is available than previously; none – the information is the same as in previous reports (with appropriate updates as needed); minimal – there has been some more information or processes set up, but these are unlikely to be sufficient to affect the scoring of the indicators; moderate – additional information were obtained allowing for some changes to be detected or necessitating a revised baseline; substantial – the processes have seen a step change in what information is available and/or the information that could be obtained. As the Prince Edward Islands chapter is new, there was no base-line to consider progress against and it is not included below.

d)	Intervention indicators	Progress 2017–2019	Progress 2020–2022	Notes
4.1	Quality of regulatory framework	moderate	moderate	A process is now in place to systematically evaluate the risks posed by all listed taxa and underpin future changes to the A&IS Lists; however, many taxa still need to be evaluated. A workflow has been developed to process information on permits issued.
4.2	Money spent	none	moderate	A workflow to evaluate the amount of money spent has been developed and existing data collated. However, from this exercise, it is clear that there are significant gaps in information.
4.3	Planning coverage	minimal	minimal	The quality of plans increased, but the coverage decreased as some plans assessed during previous reports have lapsed and updates have not been provided for assessment.
4.4	Pathways treated	minimal	minimal	Information became available on plant health inspections. Many government departments are involved in the management of pathways, the challenge is to ensure that the collected information can be made accessible and used to inform the report.
4.5	Species treated	minimal	minimal	There have been few improvements in the design of databases that record control efforts against individual species, except in the case of biological control.
4.6	Sites treated	none	minimal	There has been an increase in the number of entities that have reported on treatments at sites.
4.7	Effectiveness of pathway treatments	minimal	minimal	Information was obtained from both DALRRD and DFFE on at-border inspections and the results of those inspections. Whether these interventions reduce introduction rates is not estimated, and clear information on procedures followed is not available.
4.8	Effectiveness of species treatments	none	minimal	The few taxon-specific management plans that have been developed were evaluated in this report, although noting none of the plans have been formally approved. Populations of alien plant taxa that are potential targets for eradication or for biological control are regularly monitored, but this accounts for a small number of taxa.
4.9	Effectiveness of site treatments	minimal	none	Data were not available. What monitoring there is continues to focus on inputs and outputs rather than outcomes. The scarcity of adequate plans with clear goals in terms of outcomes exacerbates this situation.

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

The indicator framework as a whole was tested using the Prince Edward Islands (Chapter 5). This work has highlighted some issues with the indicators (currently addressed through edits to the metadata of the species lists). Additional indicators that link to the Global Biodiversity Framework (GBF) are under development, and a recent study has identified essential properties for such indicators (Vicente et al. 2022). As the reports continue, and in light of international developments (Box 1.1), the indicator framework will be adjusted, in particular with revised factsheets produced as part of the next report.

6.3 Pathways – tracking invasions across South Africa

There is still a need to develop a framework to categorise pathways within a country as there are substantive quantitative and qualitative differences between introductions to and within countries (Padayachee et al. 2017). In the absence of such a framework, information on how species are dispersing within the country, and processes to reduce such dispersal [e.g., restrictions on the transportation of certain taxa across the country or into certain areas of the country, such as those to prevent the spread of *Candidatus Liberibacter africanus* (citrus greening disease) and its vector, *Trioza erytreae* (African citrus psyllid) (Faulkner et al. 2020b)], invasive species will continue to spread rapidly and impacts will increase. Some progress has been made to adjust the pathway classification scheme for South Africa (cf. Faulkner et al. 2020a), and this will be implemented in future (Box 1.1).

6.4 Species and sites – mapping invasions in space and over time

The Southern African Plant Invaders Atlas (SAPIA) was last updated in March 2020. The hiatus in SAPIA represents a major decline in South Africa's ability to track spatial patterns in plant invasions over time, noting that such systematic and verified monitoring can only be partially addressed through ad hoc citizen science. As noted in the second report, there are significant gaps in our knowledge of the presence and distribution of taxa not currently covered by specific atlasing projects. Remote sensing is still a promising approach to improve distribution data, but has not yet delivered tangible results that can be used in this report. There continue to be very few reliable data sources on the relative abundance (cover, biomass or population size) of alien species at specific sites. National and local scale estimates and maps of the impact of invasions are needed to appropriately prioritise interventions across sites and so that interventions can be adjusted to respond to invasions before such invasions are widespread and damaging.

6.5 Species and 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 water security; and protecting our natural capital for future generations). While the development of a workflow and the collation of economic estimates represents a significant advance, a systematic method for assessing the impacts of biological invasions at a site is still 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. 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 have a comprehensive overarching national government policy on biological invasions. A national strategy on biological invasions has been drafted, but as of October 2023, has not gone for public comment. 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. Crucially, such a strategy or policy will need to be cognisant of recent international agreements (e.g., the GBF) and best international practice (e.g., IPBES IAS Assessment, Box 0.1). Within this context, the timing for an over-arching national strategy for South Africa is particularly propitious. The development of a comprehensive science-informed strategy promises to provide impetus to address all the gaps identified in this report and ensure we have a South Africa protected from the harm caused by biological invasions for the benefit of the environment and human livelihoods.

6.7 Interventions – measuring effectiveness

There are no long-term plans for monitoring 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. Very few research projects have assessed the impact of particular policies – 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 are a prerequisite for effective adaptive management and ensuring new technologies are used appropriately. Such monitoring provides significant returns on investment.

Pontederia crassipes (© Dinesh Valke).

6.8 Gaps identified in the book *Biological invasions in South Africa*

In the second report, key findings from the book *Biological invasions in South Africa* (Van Wilgen et al. 2020) were highlighted together with the implications of these findings. These, naturally, touched on information required for this report, management and governance issues, as well as broader issues not included in the scope of this report. An update is provided here based on the experience of the report authors and the information contained in this report (Table 6.2).

6.9 Suggestions for additional work or extensions to the scope of the report

Gaps in the scope of the report were identified by external reviewers and the Reference and Advisory Committee (RAC) of this report (summarised below):

- More comprehensively consider the regulatory and institutional impediments to managing biological invasions in South Africa.
- Undertake a comprehensive review of indicators nationally and globally (post the publication of the IPBES IAS Assessment).
- The contribution of work on biological invasions to human capacity development in the biodiversity sector, including through postgraduate research, other skills development (e.g., training courses), and secondary and tertiary courses.
- The social benefits created through investments in work on and control of biological invasions, including number of jobs created and value-added products.
- The potential impact of invasions and the costs of ineffective (or a lack of) interventions, i.e., both a projection of likely future impacts and an evaluation of what would have happened if different interventions had been implemented (i.e., counter-factuals).
- Improved presentation of impacts and management in economic terms.
- The resources available to practitioners, managers and land-owners (e.g., relevant books, identification charts, apps, websites, etc.); including the development and uptake of effective tools or guidelines for management (e.g., of herbicides).
- An evaluation of public awareness and perceptions of biological invasions, their management, and how these change over time.
- Review of commercial forests and authorisation in view of climate change, where water security has become a more impactful issue.
- An assessment of communities of practice and the degree to which there is integrated governance.
- An evaluation of needs and issues with regard to taxonomy and nomenclature, linking with workflows on the species list and the proposed formation of a national committee to make decisions on native or alien status in South Africa.
- Consider native taxa that have modified through breeding (e.g., plants in horticulture) and that might become weedy and/or cross with wild-type native organisms of the same taxa and 'contaminate' the gene-pool (perhaps in concert with a report on GMOs).

Table 6.2. Key findings and implications of the book on biological invasions in South Africa (Van Wilgen et al. 2020) as identified in the second report, with an update based on recent events. For the full wording of the key finding and implications see Table S6.2.

Key finding	Update (2020–2022)
South Africa is a global leader in invasion science. South Africa has a relatively small and well-connected community of academics, researchers embedded in management agencies, managers and policy-makers, who, by-and-large, share common goals.	The DST-NRI Centre of Excellence in Invasion Biology was due to stop receiving core funding from the DST-NRI in 2023. If the CIB or a similar inter-institutional body is not present, there is a risk to South Africa maintaining its global competitiveness in the discipline and ability to address the issues in the report.
There is no overarching policy to guide the current (comprehensive) regulations.	A white paper on 'The Conservation and Sustainable Use of South Africa's Biodiversity' has been published, which includes a policy objective that focuses specifically on biological invasions, although this is not comprehensive and only addresses one aspect of the issue (the focus is largely on biodiversity). The DFFE has drafted a national strategy on biological invasions but this has not, as of October 2023, gone for public comment.
The process for listing species under national regulations was not transparent and has been contested.	A detailed process is now in place, although it is not yet fully functional (see Section 4.1).
In a few notable cases control measures have been contested, reducing the effectiveness of interventions.	The mechanisms used to engage stakeholders were not reviewed in this report, though it is not clear if such processes are consistently documented.
Biological control remains the most cost-effective and sustainable method for gaining control of alien plant invasions.	Biological control continues to be highly effective with data continuing to show significant returns on investment. Additional processes have been developed to aid prioritisation.
Certain dimensions of the invasion problem have been poorly researched.	The decision by the DSI-NRI to stop funding the CIB suggests that research on biological invasions might become more applied and focus less on research gaps. There is research on some under-studied areas [e.g., understanding forest pathology through the lens of invasion science (Paap et al. 2022)], but much remains to be done.
The substantial impacts that invasions can and do have on water resources, rangeland productivity, the ability to control damaging wildfires and on biodiversity were confirmed.	Significant work is still needed to close the loop between monitoring, reporting and adaptive management; but the development of workflows and collation of information (particularly on economic estimates) means that information on impacts is becoming synthesised in a more standardised manner.
Funding cycles and elections mean most policy and management decisions are incentivised to focus on the short-term (one to five years).	The Kunming-Montreal GBF developed through the CBD will run until 2030 with a vision for 2050. South Africa's draft national strategy on biological invasions is to run over five to ten years providing an opportunity for longer-term strategic thinking.

- An evaluation of the human capacity (and potentially other resources) to address invasions available at different levels of government.
- A suite of indicators could be developed and used to monitor and analyse the social dimensions, e.g., types of stakeholders along with their reactions to and perceptions of the situation and their response to management interventions.

In a few cases the existing indicators are appropriate to capture these issues, although the issues have either not been evaluated to date or there is a lack of data. In many other cases, these issues cannot be captured by the current set of indicators. The report needs to provide a balance between ensuring there is a focus on biological invasions (as per the remit) and looking at invasions in the broader context (without replicating other reporting processes). Moreover, extending the report scope will both extend the resources required (e.g., total cost to produce the report) and the expertise needed to achieve this (e.g., economists and social scientists). This will be an important challenge for the next comprehensive report, and an important focus for the planned stakeholder consultation.

6.10 The way forward

The next comprehensive report will need to fully examine these gaps. Several other sources of gaps or methods to identify gaps were flagged and will form a core part of future reports. Gaps were also identified as part of the IPBES IAS Assessment (Box 0.1). However, as all the chapters of the assessment were only made public in October 2023, these gaps could not be assessed during this report cycle. It is also planned to have broader stakeholder consultation as part of the initiation of the next comprehensive report to determine how this report is, and can be, used (cf. a recent end-user survey was conducted as part of South Africa's National Biodiversity Assessment to identify topics that should be the focus of future assessments). This is recognised as a major short-coming of the reporting process to date. Finally, implementing the indicators over the three reports has uncovered a number of issues. For example, the high-level indicator **Rate of unregulated introduction of new species** is based on the observed rate of introductions and does not consider the rate of detection (Wilson et al. 2018), which will result in misleading patterns (Box 1.1). The report will need to look at indicators that are adopted as part of the Kunming-Montreal Global Biodiversity Framework (GBF) (Box 0.2), as well as those being developed through the sTWIST project (Box 1.1). The explicit intention is for these reports to directly report on South Africa's progress in addressing Target 6 the GBF and facilitate reporting on other targets. Ensuring the information contained in this report is of value at local, national, and international levels will remain the key impetus for these reports.

Phytolacca americana (© Agnieszka Kwiecień).

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Acacia saligna (© Zeynel Cebeci).

Links to supplementary material and appendices

Copies of the files will be permanently available at the links below:

- This report is available at https://dx.doi.org/10.5281/zenodo.8217182
- Supplementary Material is available at http://dx.doi.org/10.5281/zenodo.8217189
- Appendix 1. Species level pathway data http://dx.doi.org/10.5281/zenodo.8217192
- Appendix 2. The species list http://dx.doi.org/10.5281/zenodo.8217197
- Appendix 3. Metadata for the species list http://dx.doi.org/10.5281/zenodo.8217211
- Appendix 4. Workflows http://dx.doi.org/10.5281/zenodo.8217222
- Appendix 5. Pathways change tracker http://dx.doi.org/10.5281/zenodo.8217224
- Appendix 6. A database of permits issued under the NEM:BA A&IS Regulations 2014–2022 https://dx.doi.org/10.5281/zenodo.8229321
- Appendix 7. The species list for the Prince Edward Islands http://dx.doi.org/10.5281/zenodo.8217229
- Appendix 8. Metadata for the species list for the Prince Edward Islands http://dx.doi.org/10.5281/zenodo.8217230

Pinus pinaster (© Krzysztof Ziarnek).

Biological invasions are a major threat to South Africa's biodiversity, economy and sustainable development. This report is part of South Africa's commitment to alleviating these impacts. It is a comprehensive national-scale assessment with contributions from 28 experts from 16 institutions. Drafts of the report were available for comment in two substantive rounds of review, with over 600 comments received from 19 institutions. The report is based on a suite of 20 indicators that provide details on: 1) the pathways along which alien species are introduced and move around the country; 2) the status and impacts of over 3 500 alien species, at least a third of which are invasive; 3) the degree to which sites are invaded and impacted; 4) the effectiveness of the full range of interventions that South Africa has used to address the problem (the South Africa government has invested over 1.5 billion ZAR 2020–2022); and 5) the status and management of invasions on the Prince Edward Islands (South Africa's sub-Antarctic territories). This report is, thus, a key reference source for policymakers and managers working to reduce the negative impacts of biological invasions while retaining the benefits alien species provide where this is possible and desirable.

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