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A South African perspective on the 2023 IPBES Thematic Assessment Report on Invasive Alien Species and their control

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Background: Biological invasions are a major threat to biodiversity and sustainable development. A global assessment of biological invasions released in 2023 by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), concluded that while invasions '…cause dramatic and, in some cases, irreversible changes…' they can be '…overcome through a context-specific integrated governance approach'.

Aim: Here we evaluate insights from the IPBES assessment in the context of South Africa and explore how these insights could inform the development of a national policy and strategy to address biological invasions.

Results: Trends and status of biological invasions in South Africa are similar to those seen globally, but there are some distinct local nuances. South Africa has: 1) a long history of invasions with negative impacts caused especially by invasive trees and freshwater fishes, whilst invasive marine invertebrates have transformed large parts of the coastline; 2) a long history of control (biological control was first implemented in 1913) with large-scale, state-run invasive species management programmes currently in place; 3) a comprehensive regulatory system (e.g., there is provision for beneficial invasive species to be used under permits); 4) relatively high levels of awareness and engagement (at least among some stakeholder groups); and 5) a well-connected community of practice.

Discussion: Efforts to limit introductions (intentional or unintentional) are difficult given South Africa's extensive and porous borders and the pressing need to increase trade and travel. Regulatory and implementation efforts aimed at prevention are improving, with the newly established Border Management Authority aiming to integrate biosecurity interventions at ports of entry. Such integrated governance is, we argue, needed more broadly if affected sectors, society groups and stakeholders are to be effectively included in decision-making and management. A more systematic flow of information from observation to action is essential, as is better feedback between research, policy and implementation at all scales. Biological invasions will continue to pose threats, but many of these can be effectively mitigated through focussed interventions. Co-ordinating such interventions in the context of other cross-cutting global change challenges and initiatives is a cost-effective way of protecting and improving livelihoods, human health, quality of life and biodiversity.

Keywords: biological invasions, invasion science, Science-policy interface, the Kunming-Montreal Global Biodiversity Framework (KM-GBF), IPBES IAS Assessment

Introduction

Biological invasions are a global issue with negative impacts on biodiversity and human well-being (Pyšek et al. 2020; Roy et al. 2024; WTO 1998). The introduction and spread of invasive species are facilitated directly and indirectly

by different drivers such as the increasing movement of goods and people around the world (Hulme 2021), land- and sea-use change, and climate change (Bellard et al. 2016). Rates of introduction are projected to continue to increase (Seebens et al. 2021). Because biological invasions transcend regional and national boundaries, international collaboration, including the co-ordination of responses and the sharing of insights and expertise, is essential for effective mitigation and management (Faulkner et al. 2020b; IPBES 2023a). Nonetheless, the negative impacts of biological invasions are felt and addressed primarily at local levels, whilst control and regulation efforts are typically decided upon by national jurisdictions (García-de-Lomas & Vilà 2015). Biological invasions are also facilitated by, and impact on, a wide range of sectors (IPBES 2023a), including agriculture (Paini et al. 2016) and human health (Mazza et al. 2014), making co-ordination amongst stakeholders essential. Despite these complexities, managing biological invasions has been shown to be amongst the most cost-effective conservation measures available (Langhammer et al. 2024; Roy et al. 2024).

Global policy is increasingly addressing the challenge of biodiversity loss and associated changes in ecosystem services. The fifteenth meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD) adopted the Kunming-Montreal Global Biodiversity Framework (KM-GBF) in December 2022. The framework resulted from a four-year consultative and negotiation process and includes 23 action-oriented targets for 2030 and four goals for 2050. Target six (6) focuses on biological invasions and calls on parties to the CBD to:

> '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.'
>
> (CBD 2023)

In parallel with activities of the CBD, member states of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) requested a thematic assessment report on biological invasions in 2014. The Thematic Assessment Report on Invasive Alien Species and their Control (hereafter the IPBES IAS Assessment) officially started in 2019 with co-chairs, coordinating lead authors, lead authors, fellows, review editors and contributing authors (Schwindt et al. 2024) ensuring inclusive and diverse views and contributions from across the world, including Indigenous Peoples and local communities (Nuñez et al. 2024). The IPBES guidelines for conducting such an assessment highlight the process as an iterative and collective critical evaluation of the state of knowledge by experts across several chapters, agreed upon in the scoping report (IPBES 2018b). The main findings of each chapter are then summarised in policy relevant key messages, incorporating less technical language, with links to the relevant evidence in the chapters. The Summary for Policymakers (SPM) is then reviewed and negotiated by member states before its approval (IPBES 2023a). The IPBES IAS Assessment was accepted and its summary for policy-makers approved during the 2023 IPBES Plenary in Bonn, Germany. The IPBES IAS Assessment was released on 4 September 2023 (IPBES 2023a).

South Africa made a significant contribution to the IPBES IAS Assessment. The 285 experts listed in the assessment came from 59 countries (Schwindt et al. 2024, Supplementary Table S1), 25 of which (close to 10%) included South Africa as one of their affiliations. Only the UK (39), the USA (35), and Australia (28) had more affiliates (Germany also had 25 listed affiliates). South Africa's significant contribution is not surprising – the country has a long history of being affected by and managing biological invasions and is a global leader in research and capacity building on biological invasions (Van Wilgen et al. 2020a).

South Africa also pioneered the production of national level reports on the status of biological invasions (Wilson et al. 2017). As mandated under the National Environmental Management: Biodiversity Act (Act no. 10 of 2004) and its Alien and Invasive Species Regulations [the NEM:BA A&IS Regulations first promulgated in 2014, and most recently updated in 2020 (Wilson & Kumschick 2024)], triennial reports have been produced, titled *The Status of Biological Invasions and their Management in South Africa in [2017, 2019 and 2022]* (Van Wilgen & Wilson 2018; Zengeya & Wilson 2020; 2023), hereafter 'the South African status report'.

Both the IPBES IAS Assessment and the South African status reports collate information from a broad range of sources and are intended to be policy relevant but not policy prescriptive. Both reports underwent two rounds of open public external review, although the IPBES IAS Assessment underwent an additional round of government review and a formal process for governmental approval at the IPBES Plenary. The major differences between the reports are in terms of structure and scope. The South African status reports are framed around a set of 20 indicators that address biological invasions from the perspective of pathways, species, sites and interventions (McGeoch et al. 2016; Wilson et al. 2018), with a concluding chapter on gaps (both knowledge gaps and gaps in what we are doing to address the problem). The IPBES IAS Assessment had chapters on status and trends, drivers, impacts, management and future options, with knowledge gaps identified

within each chapter. The IPBES IAS Assessment does not report on indicators per se, nor does it provide recommendations on which indicators to use. In terms of definitions, the IPBES IAS Assessment (while acknowledging the multi-faceted impacts of biological invasions) defined invasive species purely in terms of those taxa which cause negative impacts on biodiversity. This was because the assessment arises from the CBD and the assessment authors were constrained by the IPBES processes and definitions, including a scoping document agreed by IPBES prior to the assessment starting (IPBES 2018a). No such restrictions are placed on the South African status reports; a biogeographic definition of invasions is preferred (Box 1). Finally, the IPBES IAS Assessment was global whereas the South African status reports are national.

In 2023, South Africa adopted a White Paper on 'the Conservation and Sustainable Use of South Africa's Biodiversity' (Department of Forestry, Fisheries and the Environment 2023). The White Paper addresses invasive species through policy objective 1.4: 'Identify and manage harmful, and potentially harmful, invasive alien species, their potential and existing introduction pathways and biological invasions.' This has created a platform for South Africa's policy and regulations on biological invasions to respond to the KM-GBF, and specifically to implement Target 6 of the KM-GBF at a national level. Notably the focus of this White Paper (and the action paper that is being developed to facilitate it) is on the threat to biodiversity. However, South Africa still has a need for a policy and strategy that addresses all aspects of biological invasions, i.e., beyond the

Box 1. Terminology in biological invasions is fraught, but it need not be if terms are clearly defined

The issue of terminology continues to raise passions. Even at the final plenary of the IPBES IAS Assessment (after four years and three rounds of external review) the distinctions between 'alien species', 'invasive alien species' and 'biological invasions' were contested. This issue was resolved during a special lunch-time session (termed 'Friends of the Chair' that was open to all) a day before the assessment was approved. The outcome reflected a compromise. The term 'invasive alien species' was, for the purpose of the assessment, defined as 'A subset of established alien species that spread and have a negative impact on biodiversity, local ecosystems and species'. It was noted that invasive species might also have negative socio-economic impacts, but the stricture that impact must be on biodiversity was the result of IPBES emanating from the CBD. By contrast the South African status report uses the biogeographical definition for 'invasive alien species', i.e., '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', on the basis that definitions of impact are often subjective. The relevant South African legislation [i.e., the National Environmental Management: Biodiversity Act of 2004 (NEM:BA)] is more in line with the CBD definition, defining 'invasive alien species' as '…species whose establishment and spread outside of its natural distribution range, threaten ecosystems, habitats or other species or have demonstrable potential to threaten ecosystems, habitats or other species…'.

Three important points arose during the IPBES IAS Assessment and South African status report processes. First, definitions should be written out in full even if they are repeated from elsewhere (Latombe et al. 2019). Second, when referring to the process that needs to be managed, the term 'biological invasions' should be used, as the term is explicit in covering all stages (including interventions at- and pre-border) and all aspects (pathways, species and sites). This means that national strategies address the process 'biological invasions' rather than simply 'invasive alien species' (although for consistency with the CBD and Target 6 of the KM-GBF the later term was preferred for the title of South Africa's draft strategy). Third, and in line with the need to think holistically about the issue, attempts to address biological invasions should: a) consider both socio-economic and environmental impacts and threats, e.g. through the One Health (Ogden et al. 2019) and One Biosecurity concepts (Hulme 2020); and b) consider the interaction between invasions and other global change drivers (Hulme 2022).

Somewhat against the first recommendation a glossary is not included here, noting that the IPBES IAS Assessment, the South African status reports, and the NEM:BA use three slightly different definitions for 'invasive alien species'. The exact definitions of the terms should be read in the context of which of the three sources is being discussed.

Links to definitions

IPBES IAS Assessment: https://www.cbd.int/invasive/terms.shtml; https://www.ipbes.net/glossary-definitions.

NEM:BA: https://www.gov.za/documents/national-environmental-management-biodiversity-act-0 and the various version of the A&IS Regulations https://dx.doi.org/10.5281/zenodo.8160209.

South African status report: http://iasreport.sanbi.org.za/.

threat just to biodiversity. This is a key recommendation of the South African status reports (Zengeya & Wilson 2023). Since 2023, relevant government departments have engaged in developing a National Invasive Species Strategy and Action Plan (NISSAP). Given the launch of the IPBES IAS Assessment and the setting of Target 6 of the KM-GBF, it is an opportune time to reflect on what a policy and national strategy for South Africa should include. This paper aims to assist South Africa to meet its various obligations (international commitments, national imperatives and local needs); and aims to serve as a model for other countries and regions seeking to meet KM-GBF targets. This paper tries to specifically address the following:

- How do statements and proposals in the IPBES IAS Assessment resonate in South Africa?
- Is South Africa addressing the issues raised by the IPBES IAS Assessment?
- What should South Africa do to improve responses to biological invasions (particularly in the context of the proposed national strategy)?

Materials and methods

We undertook a qualitative synthesis based on expert review. We argue this approach is appropriate, if only in that it facilitated discussion, and forced us to be clear on our views and to identify assertions that can be resolved based on evidence and data. Insights were gleaned from the South African status reports, published literature and reports, and from the diverse backgrounds and expertise of us as authors. To capture the perspective of those who were directly involved in relevant processes, invitations to contribute were sent to: all those involved as experts in the IPBES IAS Assessment who listed South Africa as an affiliation (Supplementary Table S1); members of the South African delegation to the tenth session of the IPBES Plenary at which the IPBES IAS Assessment was approved; the chapter lead authors of the latest version of the South African status report (Zengeya & Wilson 2023); and the task team responsible for drafting South Africa's national strategy on biological invasions.

Focussing primarily on the Summary for Policymakers (IPBES 2023a) of the IPBES IAS Assessment (IPBES 2023b), we identified four key elements relevant to South Africa:

- The 22 key messages in the Summary for Policymakers (p. 12–17 of the IPBES IAS Assessment's SPM; see Table 2 and Supplementary Table S2 for the results).
- The six identified management objectives, and eleven management actions (Table SPM.1 in the IPBES IAS Assessment; see Supplementary Table S3 for the results).
- The seven strategic actions, four properties of governance systems that support integration, and the twelve options for strengthening governance (Figure SPM.7 and Table SPM.2 in the IPBES IAS Assessment; see Table 3 for the results).
- The synthesis of knowledge and data gaps (Appendix 2 and Table SPMA.1 in the IPBES IAS Assessment; see Supplementary Table S4 for the results).

In each case we evaluated how these elements resonate for South Africa using a semi-quantitative scale developed for this purpose (Table 1A). Each evaluation was also ascribed one of four levels of confidence as per the IPBES guidelines (IPBES 2018b) (Table 1B).

Throughout the process, we identified recommendations for South Africa's draft national strategy. As noted in the most recent South African status report, the issue of biological invasions on mainland South Africa is significantly different from that on South Africa's sub-Antarctic islands (the Prince Edward Islands, cf. Box 2), with different stakeholders involved. Therefore, we decided to evaluate the Prince Edward Islands separately and plan to conduct a similar exercise at a later stage.

A draft outline was circulated to a core group (those directly involved in the South African status report or leading the draft national strategy) for discussion (January–February 2024). This led to the focus on the five key elements of the IPBES IAS Assessment listed above and how they should be scored. From here, all five elements were shared online with a request for input (March–April 2024). Of the 71 people invited, 36 indicated that they wished to be involved further. Sections of the document were also discussed in person as part of a two-day workshop on drafting the national strategy (March 2024). A further round of online commenting was held (April–May 2024), complemented by four online sessions where each of the five key elements were discussed and edited in plenary (each session was ~ 3 hours with between 11 and 24 participants). Based on these discussions and the emerging insights, a draft of the full manuscript was compiled and posted online for comments and input, with specific tasks allocated (May–June 2024). An online session was held to identify the actions needed to fill in gaps. The manuscript was then completed, circulated for comment in sequence (June–August 2024), with a final version made available for approval by authors (August 2024). To provide a comparison and a less directly biased overview, we invited two Brazilian experts on biological invasions and their management and regulation in the Americas (one of whom acted as a review editor for the IPBES IAS Assessment and the other was a contributing author to the IPBES IAS Assessment, both of whom were on sabbatical in South Africa at the time) to review the draft and provide an external perspective (Box 3).

Table 1. How statements and proposals in the IPBES IAS Assessment were scored in terms of whether they resonate for South Africa

A) A semi-quantitative scale was developed. We did not use a specific elicitation exercise or workshop, but rather discussed responses iteratively. The authors were encouraged to express differences of opinion and provide supporting evidence.

B) The level of confidence was assigned to the degree of resonance as per IPBES guidelines (IPBES 2018b). The level of confidence was based on the views of us as authors and how we perceive the views of other stakeholders in South Africa. For example, if we felt a statement in the IPBES IAS Assessment perfectly captured the situation in South Africa, but the data in support of such an assertion was largely lacking (e.g., there were only a few case studies), the scoring would be 'Completely agree' with a confidence of 'Established but incomplete'.

Table 1A.

Degree of resonance	Description
Completely agree	The experience in South Africa is the same as that outlined in the IPBES IAS Assessment
Largely agree	The experience in South Africa is the same as that outlined in the assessment with a few exceptions (fewer than a quarter of cases)
Somewhat similar	The experience in South Africa is, in many situations, the same as that outlined in the assessment, but there are also many exceptions (in the range a quarter to three-quarters of situations)
Different	The large majority of situations in South Africa are different to that outlined or suggested in the assessment
Not applicable	The topic is not relevant to South Africa

Table 1B.

Level of confidence in the scoring of the degree of resonance	Description
Well established	The quality and quantity of evidence is robust and there is a high level of agreement
Established but incomplete	The quality and quantity of evidence is low, but there is a high level of agreement
Unresolved	The quality and quantity of evidence is high, but there is a low level of agreement
Inconclusive	The quality and quantity of evidence is low and there is a low level of agreement
Not applicable	There is no resonance with which to be confident about

Results

The key messages

Most of the 22 key messages of the IPBES IAS Assessment resonated strongly with what we perceive the situation in South Africa to be – 14 were scored as 'completely agree', five as 'largely agree', two were 'somewhat similar', and one was 'different' (Table 2). The differences from the global assessment are that: 1) South Africa has shown significant progress with managing and regulating biological invasions (e.g., Wilson & Kumschick 2024) (cf. key message A5); 2) the available evidence does not suggest that rates of introduction have increased drastically over the past few decades (Faulkner 2023) (cf. key message B2); and 3) there are few examples of successful nationwide eradications to date (Davies et al. 2020b; Wilson et al. 2013) (cf. key message C3). Despite a system in place to regularly report on biological invasions in the country (Zengeya & Wilson 2023) and a recent comprehensive academic review (Van Wilgen et al. 2020a), the evidence base was scored as low in many cases (6 key messages scored as 'inconclusive'; 11 as 'established but incomplete'; only 5 as 'well established'). Notably, no key messages were scored as 'unresolved'. We feel that there is, with a few exceptions (Zengeya et al. 2017), general agreement among all stakeholders on the need for interventions in situations where the quality and quantity of evidence of impacts or threats is high.

Managing biological invasions

There were more differences between how we scored the objectives and actions for managing biological invasions in South Africa and how these were scored in the IPBES IAS Assessment (Table S3):

1. While prevention efforts have improved recently with the integration of biosecurity functions at ports of entry into the Border Management Authority, South Africa's geographical position means that prevention is inherently more challenging than on islands or for countries with borders that are fewer, shorter or that align with major biogeographical breaks (e.g., mountain ranges). South Africa has a substantial land border (4 862 km) that it shares with six other nations (Faulkner et al. 2017).
2. Physical methods of control were scored as being relatively ineffective in the IPBES IAS Assessment but are routinely and sometimes effectively used in South Africa (Van Wilgen et al. 2023a). Much of the physical control in South Africa might be considered

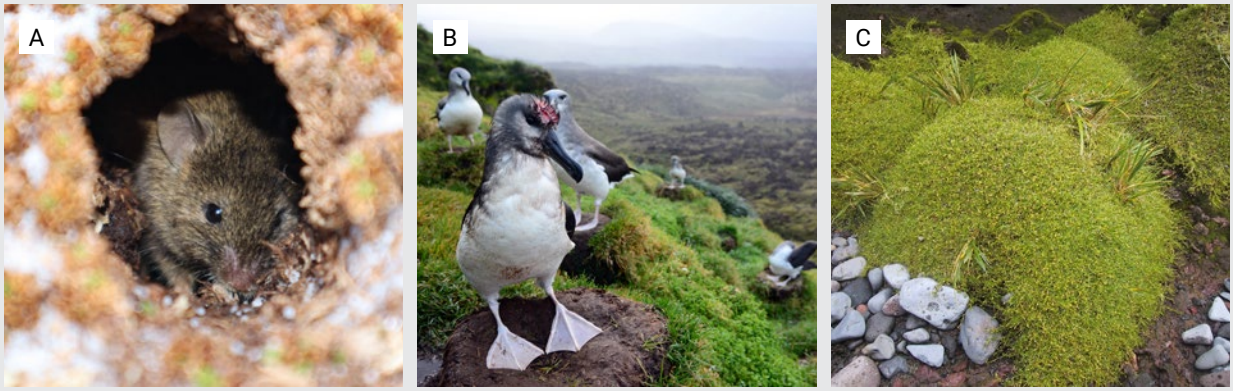
Box 2. South African islands and invasions

Islands are particularly threatened by biological invasions. The IPBES IAS Assessment states: 'On islands, invasive alien species are a major cause of biodiversity loss' (background message A3) and 'Eradication has been successful and cost effective for some invasive alien species, especially when their populations are small and slow-spreading in isolated ecosystems such as islands' (background message C19). South Africa has few inshore and freshwater islands but possesses two sub-Antarctic islands (Prince Edward Island and Marion Island, collectively called the Prince Edward Islands or PEIs).

The PEIs were declared a Special Nature Reserve in 1995 (De Villiers & Cooper 2008). Tourism is prohibited, with the PEIs set aside for conservation and science. Nonetheless alien species have been, and continue to be, introduced, albeit all invasive species were introduced before 1995, after which strict biosecurity measures were introduced (Department of Environmental Affairs 2010). The PEIs have only one regular access point – a government-owned research vessel transports people, food and cargo to and from the island once a year (Greve et al. 2017). About 80 people at a time can stay on Marion Island, and Prince Edward is visited no more than once every four years by a maximum of 10 people (Department of Environmental Affairs 2010) [by comparison there were > 3 million international arrivals at South African airports in 2022 (Faulkner 2023)]. The intentional introduction of taxa to the PEIs, as well as the importation of fresh produce, is prohibited. Clothes and cargo are checked for propagules prior to and upon landing at the islands. The pathways for the introduction of alien species are therefore very limited [there are only ten potentially active pathways], and most pathways are effectively managed. However, despite clear biosecurity guidelines and enforcement, introductions continue, highlighting that more can still be done. For example, systematically recording all detections and identifying them to species level could assist with pinpointing breaches in biosecurity (Fernández Winzer et al. 2025).

Approximately 45 alien species are currently present on the PEIs, with 25 considered invasive. These include invertebrates, plants, a mammal and a fungus, with no alien birds, reptiles, amphibians or marine taxa detected to date (Greve et al. 2020). The house mouse (*Mus musculus*) causes the most detrimental impacts (Box 2 Figure 1) (Greve et al. 2017), and an eradication plan is being developed (https://mousefreemarion.org/). Feral cats have already been eradicated from Marion Island (Bester et al. 2002). Thirteen species are regulated and require management on the PEIs; however, not all are being managed, and some unregulated species are being controlled. Close communication and collaboration among researchers and managers will likely do much to assist such control efforts.

Given how distinct the issue of biological invasions is on the PEIs when compared to the rest of South Africa, it is recommended that regulation and management be tailored to the specific needs of the PEIs (Fernández Winzer et al. 2023; Wilson & Kumschick 2024). This should perhaps be reflected as a separate subgoal or discrete set of actions in the national strategy, with most day-to-day decisions informed by the PEIs Management Plan itself. See Fernández Winzer et al. (2025) for a recent review of invasions on the islands, including most of the information herein.



Box 2 Figure 1. Two invasive species with harmful impacts on the Prince Edward Islands: A, the house mouse (*Mus musculus*) has caused a 'Massive' impact, damaging native flora like this *Azorella selago* cushion (into which the mouse has burrowed), and preying upon invertebrates and birdlife, like this Grey-headed Albatross (B). Birds on these islands did not evolve with predators and do not defend themselves when attacked; C, the invasive plant *Sagina procumbens* (light green) dominates some areas of Marion Island, in this case overgrowing the native grass *Polypogon magellanicus*. Photographs: A, Stefan Schoombie; B, Ben Dilley; C, Peter le Roux.

Box 3. South Africa as a model for invasive species management and governance –perspectives from Brazilian experts on biological invasions

South Africa has been a reference for Brazilian researchers, practitioners and policymakers in terms of relevant scientific production, construction and implementation of public policies, and management of invasive species. Although Brazil and South Africa have similarities in some aspects of historical colonisation and exploitation, past and current socioeconomic problems and environmental conditions; the success of South Africa in addressing biological invasions is likely due to different factors, with one that stands out. In simple terms, it seems that the 'knowing-doing' gap is less in South Africa than in Brazil.

In South Africa, cooperative programmes in the 1970s and 80s brought together academics, government officials, researchers and managers (Huntley 1987); these were expanded upon by long-term programmes established by the democratic government in the late 1990s onwards, such as Working for Water, Working for Wetlands and Working on Fire. The connection between the urgent need of management of biological invasions for the availability of natural resources that are fundamental for human well-being was crucial for the understanding of the threats posed by invasive species to nature and human livelihoods. Those programmes also provided vast environmental and social benefits, including the clearing of thousands of hectares invaded by alien trees based on the creation of jobs for disadvantaged people (Van Wilgen & Wannenburgh 2016) and poverty alleviation. Therefore, public awareness about invasive species and the engagement of South African citizens in management activities (e.g., volunteer groups) is more prominent than in other countries, especially in the Fynbos Biome in the Western Cape (Jubase et al. 2021).

The Brazil Ministry of Environment published the second National Invasive Alien Species Strategy in 2018, the result of collaborative construction by governmental, research and civil society organisations. However, no central coordination has been established, so despite the willingness of many to contribute, only a few agenda items have moved forward with funding from a Global Environmental Facility project targeting the conservation of endangered species. A national list was compiled but is not officially published; the layout of an early detection, rapid response programme was conceived, but not implemented; and other valuable information was made available by the government, but there is no work towards the fulfilment of the Kunming-Montreal Global Biodiversity Framework (KM-GBF). A few of the 26 Brazilian states have advanced with the publication of official lists, regulations and management, though mostly only for protected areas. Restrictions on the use of herbicides to control invasive species hinders the efficiency of work done in natural areas, while there is great need for the use of additional techniques such as biological control, so far only developed for agriculture, and the use of aerial spraying from helicopters for areas of high risk to people. Brazil has committed to restore 12 million hectares of land by 2030, but restoration initiatives cannot make progress due to the difficulty in managing invasive African grasses without proper chemical control. Therefore, South Africa provides important learning opportunities for Brazil, and much of the work in progress can be quite inspirational in terms of proving that it is possible to achieve significant results for biodiversity and human well-being. Also, the collaboration between scientists and policymakers is unique and remarkable, a key factor for the prevention of new introductions and to mitigate negative impacts by invasive species, as set in Target 6 of the KM-GBF. For a recent assessment of biological invasions in Brazil see Dechoum et al. (2024); and for a call for more collaboration between the countries on biological invasions see Measey et al. (2019).

'integrated' control by others (e.g., cut-stump herbicides are often used when clearing invasive trees to prevent resprouting), but labour costs are often lower, and there are some long-term and well-established initiatives in place to address multiple socio-economic objectives, e.g., the Working for Water Programme (Van Wilgen et al. 1998; Van Wilgen et al. 2022a).

3. Possibly for some of the same reasons that physical control is relatively successful, we scored ecosystem restoration as easier in South Africa than globally (Table S3).
4. Finally, and perhaps most noticeably, there is a great deal of uncertainty in South Africa in terms of the effectiveness of most interventions. Efficacy is rarely measured. Without a feedback loop between the outcomes of interventions and decision-makers, adaptive management is not possible, and the goal of reducing biological invasions might not be met. The exception to this is that biological control interventions are often well researched, understood and highly effective.

Strategies and governance

In terms of strategies and governance, we strongly concur with a key conclusion of the IPBES IAS Assessment (key

message D) – integrated governance should be improved at all levels (Table 3). Greater collaboration and coordination is needed: with neighbouring countries, across disciplines, among and between local, provincial and national government departments, and with various stakeholder groups. The recent establishment of South Africa's Border Management Authority that integrates biosecurity for animals, plants, the environment and humans with the regulation of the movement of people at ports of entry under a single command, is a notable step forward in this regard.

Whilst it will be difficult to achieve, greater flexibility is needed to ensure that management decisions are made at the most appropriate level and that proactive interventions are incentivised. A focused long-term approach that empowers relevant institutions to implement the measures necessary for the control and management of biological invasions would ensure critical decisions can be made timeously. It would also ensure interventions can adapt to changing threats and respond to successes and failures. This would require flexibility in decision-making. At the same time, much of what South Africa is doing needs to be systematised, i.e., interventions and analyses should be repeatable, and progress and successes should be tracked and shared. Monitoring of outcomes in terms of the status of invasions and feedback loops are needed to ensure that management can respond to what is happening on the ground (Ntshotsho et al. 2015). Several specific initiatives have been proposed to improve integrated governance including: stakeholder mapping, a legal review and meetings and fora to increase collaboration between all stakeholders as part of an active community of practice; with some collaborative governance programmes having been initiated (e.g., Angelstam et al. 2017; Canavan et al. 2021; Foxcroft & McGeoch 2011; Ivey et al. 2024). We also need to consider integrated governance from the perspective of the regulated community and how to leverage support (e.g., through integrated corporate governance, companies could reflect their contributions towards prevention and management of biological invasions).

Gaps

We found it generally difficult to apply the scoring used in the IPBES IAS Assessment to evaluate how addressing a gap would improve management and understanding (Table S4). Some gaps at a global level (e.g., comparatively incomplete inventories of invasive alien species in Africa and Central Asia) were not as applicable to South Africa (South Africa has relatively good inventories when compared with many countries around the world). Many of the identified actions to fill gaps (e.g., the need for systems to track the effectiveness of interventions) have already been identified as part of the South African status reports (e.g., Wilson et al. 2023) and are under consideration in the draft national strategy. There also appears to be a need to integrate global and national needs. Nonetheless, the process helped us develop some specific actions that should be considered (e.g., the need to support general surveys of alien invertebrates and microorganisms, the need to promote transdisciplinary work and draw more on integrative social-ecological systems thinking and the need for actions to improve participation of communities in decision-making). Finally, there are a range of valuable South African specific databases and knowledge products (e.g., on research, policy, compliance and enforcement and management best practice). Consolidating such information so it is findable, accessible, inter-operable and reusable (i.e., FAIR; Wilkinson et al. 2016) as well as better co-ordination between the various organisations that collect and curate data will be essential if governance is to be integrated (Table 3).

Discussion

South Africa is a significant contributor to global knowledge and policy on biological invasions (Pinto et al. 2022; Van Wilgen et al. 2020a) and many authors affiliated to South Africa were involved in the IPBES IAS Assessment (Table S1). As such, it is not surprising that, in our opinion, much of the IPBES IAS Assessment resonated strongly with South African issues and priorities. Going through the exercise of comparing the IPBES IAS Assessment with the situation in South Africa provided a useful cross-check for developing South Africa's national strategy and action plan. It also: served to strengthen our view that certain actions are key to improving how biological invasions are understood and addressed (through integrated governance in particular); highlighted where South Africa differs from other countries (Box 3); and helped us identify actions that need to be prioritised (e.g., continued funding for biological control and research across different taxa and realms, and a move towards more adaptive management). We discuss these below.

Invasive trees, invasive freshwater fishes and a substantially modified coastline

In South Africa, invasive trees (Richardson et al. 2020b) and invasive freshwater fishes (Weyl et al. 2020) are particularly problematic and rocky parts of the western and southern coastlines have been substantially modified by marine invasive species (Robinson et al. 2020; Figure 1, 2). Relative to elsewhere in the world, South Africa (especially the mainland) is much less affected by invasive vertebrates (Measey et al. 2020), and no offshore marine invaders have been recorded to date (Zengeya & Wilson 2023). There are also relatively few examples of highly damaging terrestrial arthropod invasions (Janion-Scheepers & Griffiths 2020) and plant pathogens, although the recent invasion of the polyphagous shot-hole borer (*Euwallacea fornicatus*) along with its fungal symbiont *Fusarium*

Table 2. The 22 key messages from the IPBES IAS Assessment and how the authors felt they resonate with the South African situation

The key messages are taken verbatim from the IPBES IAS Assessment (IPBES 2023a). The resonance for South Africa (RSA) was evaluated as per Table 1, combining both our evaluation of the degree of resonance and our confidence in that evaluation. The focus is on mainland South Africa and the immediate offshore environment (including islands); cf. Box 2. The corresponding paragraphs for each key message in the IPBES IAS Assessment are further broken down in Table S2.

Key message	Resonance for RSA	Rationale	RSA references
A1. People and nature are threatened by invasive alien species in all regions of Earth	Largely agree (established but incomplete)	While the key message is appropriate at a global scale, as in other regions in the world, at local scales in South Africa there are sites where there are few, if any, invasions. Most remote sites are not heavily invaded, and no invasive off-shore marine taxa have been recorded to date (although such sites are not well sampled).	Zengeya et al. (2023a)
A2. Invasive alien species cause dramatic and, in some cases, irreversible changes to biodiversity and ecosystems, resulting in adverse and complex outcomes across all regions of Earth, including local and global species extinctions	Largely agree (established but incomplete)	Significant changes to ecosystem functions caused by invasive species have been observed in many parts of South Africa. The evidence of impacts on extinctions are less clear, although invasive species have been implicated in the extinction of seven plant species and some population extirpations have been recorded. Observed impacts are of greater magnitude in some environments than others.	Skowno et al. (2019); Van der Colff et al. (2023); Van Wilgen et al. (2022b)
A3. The economy, food security, water security and human health are profoundly and negatively affected by invasive alien species	Completely agree (established but incomplete)	Economy: the monetary cost of the damage caused has been estimated at ZAR 52.7 billion between 1960 and 2023 (in 2022 values). Food security: there are substantial negative impacts on agriculture through imported pests and diseases (though not systematically estimated). An estimate of the negative impacts on rangeland and grazing activities at the scale of South Africa has been made. Water security: invasive plants have caused substantial reductions in water flows with important consequences. For example, it was estimated that if there had been no invasive trees in the water catchment of the City of Cape Town, day zero during the 2015–2018 drought would have been delayed by 60 days. Human health: biological invasions have various negative impacts on human health, but information has not been well consolidated to date. More research is needed. Fire: there has been a notable increase in fire intensity caused by invasive plants. Tree invasions have often exacerbated recent fires (e.g., the devastating fire in 2017 in the Garden Route). Note: This key message is not intended to downplay the positive impacts that can accrue from invasive species – it is important to consider positive and negative impacts separately before they are compared.	De Wit et al. (2001); Kraaij et al. (2018); Le Maitre et al. (2016); Le Maitre & Gorgens (2003); McCulloch-Jones et al. (2024); O'Connor & Van Wilgen (2020); Wise et al. (2012)

Table 2. The 22 key messages from the IPBES IAS Assessment and how the authors felt they resonate with the South African situation* (continued)

Key message	Resonance for RSA	Rationale	RSA references
A4. Invasive alien species can add to marginalisation and inequity, including, in some contexts, gender- and age-differentiated impacts	Completely agree (inconclusive)	The impact on rural communities has been explicitly evaluated in some studies with indications that it can have significant negative impacts. But gender- and age-differentiated impacts have rarely been assessed. Rural communities often adapt to invasions or co-opt invasive species (e.g., for firewood and the medicinal trade). Such adaptation would likely reduce marginalisation, but the overall impact is not known, and so the confidence level is scored as inconclusive. More research is needed.	Ngorima & Shackleton (2019); Ruwanza & Thondhlana (2022); Yessoufou et al. (2021, 2022)
A5. Overall, policies and their implementation have been insufficient in managing biological invasions and preventing and controlling invasive alien species	Somewhat similar (established but incomplete)	South African regulations addressing biological invasions date back to 1861. Comprehensive regulations were promulgated in 2014 and revised in 2016 and 2020. They are being implemented although more evaluations of their effectiveness are needed. The quality of the regulatory framework was scored as 'partially adequate' by the South African status report. The 'Conservation and Sustainable Use of South Africa's Biodiversity' White Paper addresses part of the issue of biological invasions, though impacts on agriculture and health are not part of its remit. A strategy for implementing the regulations is being developed. The resources for effective implementation or ensuring compliance are inadequate. Overall, there is a need for better integration of policies (e.g., those on animal pests and diseases with those on biological invasions), noting the current lack of an overarching policy.	Lukey & Hall (2020); Van Wilgen et al. (2022a, 2023a), Wilson & Kumschick (2024)
B1. Many human activities facilitate the transport, introduction, establishment and spread of invasive alien species	Completely agree (well established)	This has been and is still true for South Africa.	Faulkner et al. (2016), Faulkner (2023)
B2. The threats from invasive alien species are increasing markedly in all regions of Earth, with the current unparalleled high rate of introductions predicted to rise even higher in the future	Different (inconclusive)	In South Africa, pathways, particularly those relating to intentional introductions, are much better regulated than in the past and arguably than in other countries. There have not been dramatic recent increases compared to historical introductions for many pathways (e.g., trees for forestry and freshwater fishes for angling); though information on unintentional introductions and illegal deliberate introductions is not available and will be difficult to obtain. Without better estimates of search effort, it is difficult to be confident in estimates of introduction rates (hence scored as inconclusive). The data that are available suggest similar rates over the past few decades. There has been a long history of introductions to the country resulting in invasions. This arguably has led to relatively high levels of awareness and appreciation of invasions in policy and industry sectors; and many potential invaders have already been introduced.	Faulkner (2023)

Table 2. The 22 key messages from the IPBES IAS Assessment and how the authors felt they resonate with the South African situation* (continued)

Key message	Resonance for RSA	Rationale	RSA references
B3. The ongoing amplification of drivers of change in nature may substantially increase the number of invasive alien species and their impacts in the future	Completely agree (inconclusive)	Expect similar mechanisms will operate in South Africa, though there is a very high level of uncertainty and some drivers are likely to be much more important in (or even unique to) the African context.	Van Wilgen et al. (2023b)
B4. The magnitude of the future threat from invasive alien species is difficult to predict because of complex interactions and feedback among direct and indirect drivers of change in nature	Completely agree (inconclusive)	Expect similar complexities, particularly given the diversity of environmental, socio-economic and climatic conditions seen in South Africa; and uncertainty particularly around future rainfall. There have been few explicit studies though. Estimates of invasion debt have shown the potential for problems.	Rouget et al. (2016); Shackleton et al. (2020); Van Wilgen et al. (2020a, 2020); Wilson et al. (2020)
C1. The number and impacts of invasive alien species can be reduced through management of biological invasions	Largely agree (established but incomplete)	South Africa has management structures in place across the different stages of invasion. However, the funding does not match the scale of the problem, and thus it has not been possible to get on top of all invasions. There is evidence that: invasions can be controlled at local scales; impacts have been reduced through classical biological control for some species; water flows have been improved by removing pines, wattles and eucalypts; and there is an increasing understanding of the negative impacts. However, for most invasive species and invaded sites, invasions continue to grow. Saying that, some impacts might be difficult or impossible to reduce even with management, and often the effectiveness of management is not measured in terms of impact reduction, so data are not available in many cases.	Coetzee et al. (2021); Henderson & Wilson (2017); Hill et al. (2020); Le Maitre et al. (2020); Paterson et al. (2021); Van Wilgen et al. (2022a, 2022b)
C2. Prevention and preparedness are the most cost-effective options and thus crucial for managing the threats from invasive alien species	Largely agree (established but incomplete)	With significant land borders, South Africa relies on biosecurity of neighbouring countries. In some cases, it will be very difficult to prevent accidental introductions (or natural spread) without severely affecting trade. In this sense prevention is not always feasible (and so not cost effective). An assessment of the returns of investment of funding prevention and preparedness for South Africa would be very useful. Inspections are occurring at the border; however, there is insufficient staff capacity to cover all goods and modes of transport. Efforts are being made to improve this through risk-based inspections at ports of entry. Furthermore, efforts are being made to manage pathways such as the breakbulk cargo. Efforts have been made to develop a national watchlist, though a formal watchlist has not been adopted to date. No approved contingency plans for environmental threats are available. Deliberate legal introductions are being addressed. All new imports require a formal application supported by a risk analysis.	Faulkner et al. (2017); Faulkner (2023); Kumschick et al. (2020); Wilson et al. (2013)

Table 2. The 22 key messages from the IPBES IAS Assessment and how the authors felt they resonate with the South African situation* (continued)

Key message	Resonance for RSA	Rationale	RSA references
		Plant pests are regulated in terms of the Agricultural Pests Act no. 36 of 1983 and Control Measures R.110 of 27 January 1984, with the aim of providing for measures by which agricultural pests may be prevented and combated; and for matters connected therewith. The South African Emergency Plant Pest Response Plan (SAEPPRP) provides guidelines for an efficient and timely reaction to the identification, mitigation and detection of an emergency plant pest incursion in South Africa. During a plant pest emergency, this protects and maintains production and business continuity in unaffected areas, prevents the establishment and spread before the pest population becomes established, and facilitates efficient and timely communication between local, national and international government agencies, academia and professionals in the plant industry. Given the massive volumes of data generated, pest detection techniques are critical to pest early warning systems. The implementation of awareness campaign programmes is essential for detection of incursions and for securing community members' and role actors' cooperation during pest control efforts.	
C3. Eradication has been successful, especially for small and slow-spreading populations of invasive alien species in isolated ecosystems	Somewhat similar (well established)	There has been only one documented nationwide eradication on the mainland [that of the Mediterranean snail (*Otala punctata*) in 1989] though several attempts are ongoing. Nationwide coordinated efforts were initiated in 2008 and there are currently around 42 eradication attempts. Numerous eradication targets have been brought down to 'low levels' some of which may already have been eradicated (e.g., *Sporobolus alterniflorus*) and the extirpation of some populations has been declared for various sites. However, protocols to formally declare eradication have not yet been established. Given variations in life histories we suspect some widespread conspicuous invaders will be easier to eradicate than small populations of other invaders. Various taxa have been eradicated (or at least extirpated) from in-shore islands (e.g., rabbits from Robben Island).	Davies et al. (2020b); Herbert & Sirgel (2001); Riddin et al. (2016); Wilson et al. (2013)
C4. Containment and control can be an effective option for invasive alien species that cannot be eradicated for various reasons from terrestrial and closed water systems, but most attempts in marine and connected water systems have been largely ineffective	Largely agree (established but incomplete)	In contrast to the IPBES statement there have been some notable successes with classical biological control containing and controlling invasive aquatic species in connected water systems. There have been some successes in extirpating invasive fishes in discrete catchment sections. There has been no successful management of invasive species in marine ecosystems. Various techniques have been used to manage agricultural insect pests. Sterile Insect Technique (SIT) is mostly used, establishing areas of low pest prevalence (ALPP) or pest-free areas (PFA). This requires effective communication, coordination and active participation from the farmers and stakeholders in the target area. In South Africa, FruitFly Africa (FFA) is an SIT company that works in collaboration with stakeholders such as HORTGRO (pome- and stone-fruit), Canning Fruit Producers Association, Raisins SA, South African Table Grape Industry, Agricultural Research Council and the Department of Agriculture (DoA).	Davies et al. (2020b); Hill & Coetzee (2017)

Table 2. The 22 key messages from the IPBES IAS Assessment and how the authors felt they resonate with the South African situation* (continued)

Key message	Resonance for RSA	Rationale	RSA references
C5. The recovery of ecosystem functions and nature's contributions to people can be achieved through adaptive management, including ecosystem restoration in terrestrial and closed water systems	Completely agree (established but incomplete)	There have been a few notable cases of successful restoration following clearing of extensive stands of invasive plants. However, projects to clear invasive plants typically do not include dedicated ecosystem restoration – systems are left to restore passively. For some invasions this seems to be sufficient and systems show significant recovery even after long periods of invasions (e.g., pine invasions). In other cases, abiotic thresholds have been crossed requiring active restoration (e.g., wattle invasions). The success of restoration thus depends on the context, including the nature of the invasions and the timing and type of interventions. Investments in ecosystem restoration have increased over time. However, barriers to restoration remain unaddressed in many instances (including re-invasion, secondary invasions and soil legacy effects). There is a need to scale-up restoration efforts with investments made to match the problem. Restoration projects could also do more to align with international standards and guidelines and best practice. Tracking of progress through monitoring is essential and national reporting should be emphasised and streamlined.	Holmes et al. (2020); Nsikani et al. (2018)
C6. Engagement and collaboration with stakeholders and Indigenous Peoples and local communities improve outcomes of management actions for biological invasions	Completely agree (inconclusive)	There is a broad consensus that engagement is crucial for management to be effective. However, as few studies have explicitly evaluated the impact of such engagements in South Africa, the evidence is weak. Sometimes communities have adapted, and invasive species have become important commodities (e.g., fruits of cacti) and part of the local culture. Attempting to shift such practices would require an offer of alternatives but is not always practical or desirable. It is important to identify situations where invasive species can be a (net) benefit if managed (i.e., invasives are well contained in agricultural areas and controlled effectively outside designated growing areas). Similarly, it is important to identify when and where conflicts are likely (e.g., if benefits cannot be preserved without undue threat to the broader environment).	Shackleton et al. (2007, 2011); Zengeya et al. (2017)
D1. Through a complementary set of strategic actions, integrated governance can limit the global problem of invasive alien species throughout the biological invasion process and at local, national and regional scales	Completely agree (established but incomplete)	There have been few specific analyses of the importance of governance or the value of integrated governance in South Africa, although we as authors were unanimous that a lack of co-ordination limits the effectiveness with which biological invasions are managed. The Border Management Authority is a potential example of integrated governance (in this case co-ordinating preventative actions at ports of entry). The BMA was established in 2020 and became operational in 2023, and so monitoring of progress is needed to confirm its value. There are some other examples of integration (e.g., intergovernmental meetings on biocontrol releases and the Risk Analysis Review Committee) but the impact of these has not been evaluated and in most cases different organisations have different mandates. South Africa does not yet have a formally adopted strategy, but one is in development. This will help to formalise what is happening and to assist with co-ordination. There are also regional initiatives through the Southern African Development Community (SADC). The White Paper on Biodiversity includes biological invasions, but there is no overarching policy (i.e., guidelines or principles that guide decision-making) specifically on biological invasions. Such a policy would help move integrated governance forward.	Van Wilgen et al. (2023a); Wilson & Kumschick (2024)

Table 2. The 22 key messages from the IPBES IAS Assessment and how the authors felt they resonate with the South African situation* (continued)

Key message	Resonance for RSA	Rationale	RSA references
D2. The threat of invasive alien species could be reduced with closer collaboration and coordination across sectors and countries to support the management of biological invasions	Completely agree (well established)	Closer coordination across countries is particularly important for South Africa as it shares a 4 862 km long land border with six countries (Botswana 1 840 km, Lesotho 909 km, Mozambique 491 km, Namibia 967 km, Eswatini 430 km, Zimbabwe 225 km), with 71 official ports of entry. There are sector specific co-ordination actions in some cases, such as the forestry industry (Forest Invasive Species Network for Africa) and citrus industry. However, roles and responsibilities are not always clear. The control of biological invasions relies on other sectors for whom invasions are seen as a minor issue (e.g., the Departments of Health and Transport). Cross-cutting approaches offer promise (e.g., One Biosecurity and One Health) but are not widely implemented yet. International co-ordination is outlined in various multilateral agreements (e.g., the International Plant Protection Convention and World Trade Organization Agreements) but co-ordination at the national level is less clear. Collaboration with private landowners is key as biological invasions occur on public and private land. There is a need to provide guidance on best practice to achieve this. There is also a need to harmonise regulations (e.g., the issuing of permits under the Agricultural Pest Act and the NEM:BA A&IS Regulations).	Faulkner et al. (2017, 2020b); Faulkner (2023)
D3. The Kunming-Montreal Global Biodiversity Framework provides an opportunity for national governments to develop or update aspirational, ambitious and realistic approaches to prevent and control invasive alien species	Completely agree (inconclusive)	The Kunming-Montreal Global Biodiversity Framework (KM-GBF) is influencing the development of the national strategy and how the South African status reports are structured. The KM-GBF also forms the basis for setting up local, national and regional targets. There is an important opportunity for funding via the Global Biodiversity Framework Fund specifically on biological invasions, this would be useful to stimulate greater subregional collaboration.	Zengeya & Wilson (2023)
D4. Preventing and controlling invasive alien species can strengthen the effectiveness of policies designed to respond to other threats to biodiversity and contribute to achieving several Sustainable Development Goals	Completely agree (established but incomplete)	The interaction between biological invasions and other drivers of change (such as climate change) are well recognised in South Africa. Strategic interventions that tackle biological invasions are occurring through projects following the principle of Ecosystem-based Disaster Risk Reduction (Eco-DRR). These projects are designed to help communities to adapt to the impacts of climate change (e.g., drought, fire and floods) and sustain human livelihoods (including through policy development and the involvement of the private sector).	Graziosi et al. (2020); Paini et al. (2016); Sileshi et al. (2019)

Table 2. The 22 key messages from the IPBES IAS Assessment and how the authors felt they resonate with the South African situation* (continued)

Key message	Resonance for RSA	Rationale	RSA references
		Achieving Sustainable Development Goals requires coordination of relevant pieces of legislation in South Africa when responding to invasive species [e.g., including the Agricultural Pests Act, 1983 (Act no. 36 of 1983) and its associated regulations, namely, Control Measures R.110 of 27 January 1984 as amended, Regulations R.111 of 27 January 1984 as amended, Government Notice R.1013 of 26 May 1989 as amended]. The Agricultural Pests Act mandates the National Plant Protection Organisation of South Africa to regulate plants, plant products and other regulated articles when imported into South Africa. The Fertilizers, Farm Feeds, Agricultural Remedies, and Stock Remedies Act of 1947 (Act no. 36 of 1947) governs the registration of pest control operators, sterilising facilities, agricultural remedies, farm feeds and stock remedies. The importation, sale, purchase, disposal and use of farm feeds, fertilisers, agricultural and stock remedies are all governed by this Act. Additionally, it allows for pest registration in emergencies such as detection of new pests or diseases.	
D5. Open and interoperable information systems will improve the coordination and effectiveness of the management of biological invasions, within and across countries	Completely agree (well established)	There are multiple organisations in South Africa that work across different mandates and collect different types of data. Initiatives are in place to develop interoperable and open information systems (e.g., a list of alien species linked to the South African status reports). We still need data pipelines and workflows to go from observation to action. Many records on alien species in the country have been digitised, but more still needs to be done. The South African status report has started working on several of these, e.g., permits issued and information on regulated alien species are available. Notable information systems include the Southern African Plant Invaders Atlas (SAPIA) and the government's Water Information Management System (WIMS). SAPIA was valuable for a wide range of stakeholders who were interested in managing invasive plants, but information was held in a proprietary format and not readily accessible. Increasingly iNaturalist is providing similar functions. WIMS provides valuable information on management actions, but the information can be very hard for external people to use (i.e., lacking in interoperability).	Kraaij et al. (2017); MacFadyen et al. (2022); McConnachie et al. (2012); Van Wilgen et al. (2023a), Wilson (2024); Wilson & Kumschick (2024); Zengeya et al. (2023b)
D6. Public awareness, commitment and engagement, and capacity building, are crucial for the prevention and control of invasive alien species	Completely agree (established but incomplete for public awareness; well-established capacity building)	Public awareness, commitment and engagement: there are lots of initiatives (e.g., through the Working for Water programme, Weed Buster Week) but these are not systematically monitored so it is difficult to judge their effectiveness. The awareness of some key sectors (nurseries) has been shown in some instances to be low, and in other sectors (pet trade) where there is awareness, there is disagreement with management. If activities are linked more closely to outcomes, the efficacy of interventions will likely improve.	Byrne et al. (2020); Davies et al. (2020a); Jubase et al. (2021); Novoa et al. (2017); Potgieter et al. (2024); Shivambu et al. (2022); Weaver et al. (2021)

Table 2. The 22 key messages from the IPBES IAS Assessment and how the authors felt they resonate with the South African situation* (continued)

Key message	Resonance for RSA	Rationale	RSA references
		The National Invasive Alien Species Awareness & Advocacy Support Project developed a toolkit that can be built upon. iNaturalist has facilitated and engaged people to help monitor biological invasions in the country. Hack groups have assisted with in-field control, these are very active groups often locally based and run (e.g., 'Friends of …' groups and Botanical Societies). The work is not always well co-ordinated, and data could potentially be productively shared and activities tracked. However, a careful balance must be struck between bureaucracy and motivating volunteers. Capacity-building: student projects can assist with detecting and managing biological invasions. Biological invasions are included in the school curriculum and various outreach initiatives have been set up.	
D7. There is compelling evidence for immediate and sustained action to manage biological invasions and mitigate the negative impacts of invasive alien species	Completely agree (well established)	South Africa has well over a century of experience of the impacts of biological invasions, of research into understanding them, and of using various management techniques to alleviate the impacts. The challenge remains to continue to engage with government and civic society to ensure immediate and sustained actions continue to be funded and resourced.	Van Wilgen et al. (2020c)

euwallaceae seems set to change this (De Wit et al. 2022; Paap et al. 2018). Despite some no invasions [e.g., rinderpest, Van Helden et al. (2020)], information on invasive pests and pathogens of animals has not been as well collated into databases on invasions as it has been in other regions globally.

There has been some success in using teams of people to clear invasive trees (Fill et al. 2017; McConnachie et al. 2016), and in extirpating freshwater fishes in isolated water bodies (Weyl et al. 2014). There has also been substantial success in using biological control to manage invasive cacti, some trees and shrubs, and floating aquatic plants (Coetzee et al. 2021; Impson et al. 2021; Paterson et al. 2021). However, the ubiquitous and connected nature of the marine environment means that there is little that can be done in coastal settings once invaders have established, and so the focus must be on vigilance and pathway management to prevent incursions.

Relatively high levels of awareness and engagement?

During our discussions, we disagreed about the levels of general awareness around biological invasions in South Africa. Shackleton et al. (2020) argued that, '*certain sectors of society are more knowledgeable regarding invasions, such as elites, and those living in rural areas who are likely to be more in contact with invasions and their impacts*'. However, absolute levels of knowledge are often low, e.g., Coka et al. (2024) found that 23% of rural villagers in the Eastern Cape (former Transkei region) knew *Acacia dealbata* was an invasive species. Studies that have monitored awareness come to differing conclusions (Cronin et al. 2017; Shackleton et al. 2015a), but from our experiences, stories about biological invasions appear regularly in newspapers and online; and some studies indicate both government officials and the public are often aware of invasive species and their impacts (Byrne et al. 2020). In discussions with international colleagues who are experts in biological invasions, levels of awareness are less than in New Zealand but greater than in much of the Americas (Box 3), Asia and other African countries. There is also broad agreement among researchers, practitioners and policy-makers as to the desirability of raising awareness about impacts and management (Van Wilgen et al. 2020a). What is clear is that efforts to raise awareness (amongst the public or specific stakeholders) have rarely been monitored in terms of their outcomes. This topic deserves much more focussed research effort so that the intended outcomes are specified and progress tracked. Systematic interdisciplinary research and monitoring (including through collaborations with social scientists and economists) could profoundly improve our understanding of the perceptions of stakeholders and facilitate management (Novoa et al. 2018), e.g., by ensuring awareness activities are tailored to particular stakeholders.

Figure 1. Biological invasions are a significant threat to biodiversity and sustainable development in South Africa. A, South Africa has had a long-history of the introduction and invasion of cacti, but classical biological control has been used to effectively control invasions for over a century (Kaplan et al. 2017; Paterson et al. 2021). The image is of *Cylindropuntia fulgida* (boxing-glove cactus) invading in the Northern Cape, a species that has been a recent target for successful biological control (Klein et al. 2020); B, substantial sections of the South African coastline have been transformed by the invasive mussel, *Mytilus galloprovincialis*; currently there are no control options to address existing marine invasions and so prevention is the only current option to limit future marine invasions (Robinson et al. 2020); C, a farm labourer clearing *Neltuma* spp. (prosopis) trees in the Northern Cape; this helps to reduce spread and impacts from invasions with the wood later used on the farm or sold for fuelwood to help cover control costs (Shackleton et al. 2014, 2015b); D, pines (*Pinus* spp.) are among the most damaging invasive species severely impacting water run-off, but they also provide shade in recreational areas and are still important forestry species in South Africa; various methods have been developed to address these conflicts of interest, with the goal of limiting negative impacts while preserving benefits where possible (Van Wilgen & Richardson 2012; Zengeya et al. 2017); the picture shows historically planted pines on the slopes of Table Mountain; E, workers from the Working for Water (WfW) Programme clearing invasive shrubs in the Table Mountain National Park; the South African government has invested significant resources to control invasions through job creation (WfW in particular) (Van Wilgen & Wannenburgh 2016); while there is evidence of significant reductions in invasions in some cases, better monitoring of outcomes is needed to ensure management is effective in meeting both the social and environmental goals of the programme (Van Wilgen et al. 2022a). Photos: A, T. Xivuri; B, D, T. Robinson; C, R. Shackleton; E, B.W. van Wilgen.

Table 3. Reflections by the authors on how the: A. seven strategic actions, B. four properties and C. 12 options to strengthen efforts to address biological invasions proposed in the IPBES IAS Assessment are or could be adopted in the South African context

The recommendations are from key message D25 (Figure SPM.7) and key message D28 (Table SPM.2) of the SPM of the IPBES IAS Assessment (IPBES 2023a), a current prognosis is detailed, and some key actions for a proposed national strategy identified. The focus is on mainland South Africa and the immediate offshore environment (cf. Box 2).

Table 3A.

Recommended strategic action	Current status	Proposed actions for a national strategy
1. Enhance coordination and collaboration across international and regional mechanisms	South Africa actively contributes to many multilateral environmental agreements it is party to [e.g., IPBES and as part of the Regional Plant Protection Organisation (RPPO)]. The SADC Secretariat has flagged the need for a regional approach on biological invasions (including through the SADC Biodiversity Strategy), noting existing substantial collaboration in science and for biocontrol between SADC and other African countries. There are several industry specific partnerships between African countries to monitor alien species (e.g., the Forest Invasive Species Network for Africa for forestry pests; and the SADC Plant Protection Technical Committee). Notably, the SADC Seed Centre, with technical assistance from the SADC Seed Committee and National Plant Protection Organizations (NPPOs), helps member states: document current policies and how they affect seed exchange; organise technical reviews to improve standards and procedures; ensure new initiatives comply with regional and international agreements; design and support initiatives to garner political support for rationalising and harmonising regulations; help establish databases to provide links to important documents and current national regulations; help with the issuance of permits (including the quantity of seed involved) and to resolve disputes; and keep informed about important issues through the SADC Food Agriculture and Natural Resources (FANR) website and other channels. The SADC Seed Centre closely collaborates with the NPPOs and facilitates the holding of regional meetings to discuss the following topics: the creation and revision of phytosanitary guidelines and procedures for seed; the identification and recommendation of more effective methodologies for use in the phytosanitary system(s) for seed; and the creation of techniques for technical support and monitoring of the existing system(s).	Several proposed actions were codified in Figure 5 of Faulkner et al. (2017), these are built on below: Facilitate the Border Management Authority to collaborate with neighbouring countries on compliance & enforcement / border control issues. Encourage joint symposia and researcher and student exchanges (including attending already established scientific meetings). Establish flagship projects (based on shared invasive species) as models for regional collaboration. Incentivise collaboration with other biodiverse countries in Africa and beyond. Share technology and approaches leading to the development of international agreements over biosecurity requirements.

Table 3. Reflections by the authors on how the: A. seven strategic actions, B. four properties and C. 12 options to strengthen efforts to address biological invasions proposed in the IPBES IAS Assessment are or could be adopted in the South African context (continued)

Table 3A. (continued)

Recommended strategic action	Current status	Proposed actions for a national strategy
2. Develop and adopt effective and achievable national implementation strategies	A National Invasive Species Strategy and Action Plan (NISSAP) is under review by South African governmental structures (October 2025), and due to go for public consultation and approval in 2026.. There is provision for all regulated taxa to have national plans developed (a few drafted but not formally approved). Biological invasions are highlighted in other implementation strategies (e.g., the Biodiversity and Ecosystems Sector Climate Change Response Strategy). The White Paper on Biodiversity sets out intentions for the environment sector (noting that some actions are captured here, e.g., on pathways, but not elsewhere). A Plant Health Bill is in draft (replacing the Agricultural Pest Act).	Identify and outline responsibilities for each proposed action in the NISSAP, detailing indicative time-lines and resources and specifying how progress will be monitored. Identify people/bodies with responsibilities and mandates to co-ordinate and separately oversee the activities of the NISSAP. Draft, approve and implement national management plans for priority taxa. Cross-check that NISSAP covers aspects identified in the White Paper. Ensure implementation strategies and working groups focus on specific targets and co-ordinate across responsible agencies (e.g., One Health, as a broad concept).
3. Share efforts, commitments and understanding of the specific roles of all actors	Mandates are set out in legislation emanating from the Constitution (national, provincial and municipal government departments and entities); and international commitments are set out in the CBD and multilateral environmental agreements. The responsibility for the management and regulation of biological invasions sits sometimes with a government department, but it is a minor issue for that department [e.g., Transport (hull fouling) and Health (invasive wasps)]. In other cases, there might be no champion, expertise or continuity. A newly created intra-departmental Alien and Invasive Species Forum was established by the DFFE to facilitate integrated governance and is to cover all issues of biological invasions. The intention is for it become interdepartmental. In terms of interaction with scientists, there were Management and Research Partnership meetings (MAREP) organised by the DFFE as part of Working for Water, but these have not happened for at least the last decade. The National Symposium on Biological Invasions is one mechanism. NGOs are very active and work closely with communities. Traditional landowners similarly play vital roles. There are some examples of structures for such roles (e.g., the uMzimvubu partnership in the Eastern Cape). In contrast, in some cases the roles have not been clear or there have been overlaps between mandates.	Expand the forum on biological invasions to include other entities (although with the focus specifically on the issue of biological invasions). Set up a broader inter-agency One Biosecurity Forum to address animal, environmental, human and plant health issues. Map mandates and roles onto activities. Facilitate working groups, communities of practice and steering groups.

Table 3. Reflections by the authors on how the: A. seven strategic actions, B. four properties and C. 12 options to strengthen efforts to address biological invasions proposed in the IPBES IAS Assessment are or could be adopted in the South African context (continued)

Table 3A. (continued)

Recommended strategic action	Current status	Proposed actions for a national strategy
	There have been steering committees formed on detection of new threats and working groups on various taxa or invasions. Annual co-ordination meetings are held on biological control.	
4. Improve policy coherence	There is no cross-cutting policy on biological invasions that talks to all the different elements of the issue. A White Paper on Biodiversity is in place (but this only covers the remit of DFFE). The Inter-Governmental Relations Act is also in place but has not been implemented with regard to biological invasions. The Biodiversity Lekgotla (linked to the Kunming-Montreal Global Biodiversity Framework) introduced the idea of a Biodiversity Indaba for policy coherence.	Conduct a legal review of the regulatory framework (aimed at repealing, replacing, filling gaps or aligning). Establish and utilise mechanisms to interact with SADC partners.
5. Engage broadly across governmental sectors, industry, the scientific community, Indigenous Peoples and local communities, and the wider public	There are various initiatives to raise awareness (e.g., roadshows), but it is not always clear whose responsibility it is to engage (particularly across sectors). All legislative changes, however, involve discussions with stakeholders and include formal processes for public comment. Some studies have estimated levels of engagement, but these have been piecemeal and with varying results. Without a systematic evaluation it is difficult to be sure of the current status. It is also not clear what level of awareness would be desirable.	Map stakeholders to identify who should be targeted, for what reason and how. Review awareness raising activities to learn from existing cases across the country. Develop mechanisms to promote stakeholder engagement and collaboration (Novoa et al. 2018). Set up systems for the co-design and co-implementation of management. Acknowledge and address conflicts and power dynamics among stakeholders, including through a better understanding of different value systems and conflicts (Mukwada et al. 2016). Incentivise social scientists to work on biological invasions. Develop and implement a biosecurity awareness campaign targeting stakeholders who produce and trade in products based on alien species and those involved in pathways that facilitate accidental introductions.

Table 3. Reflections by the authors on how the: A. seven strategic actions, B. four properties and C. 12 options to strengthen efforts to address biological invasions proposed in the IPBES IAS Assessment are or could be adopted in the South African context (continued)

Table 3A. (continued)

Recommended strategic action	Current status	Proposed actions for a national strategy
6. Support, fund and mobilise resources for innovation, research and environmentally sound technology	There is a long history of research and technology development in South Africa but this is somewhat under threat due to declining funding. A national centre of research excellence of biological invasions received direct government support up until 2023 (becoming funded by a specific university thereafter). Primary research on biocontrol was previously well supported but governmental funds have been reduced and delayed.	Develop a technical tertiary qualification (that allows for part-time study) on the management of biological invasions. Develop a series of short courses teaching relevant skills. Fund and support research and capacity building. Build/develop more public-private partnerships. Identify and develop novel funding mechanisms (e.g., crowd sourcing and tax incentives).
7. Support information systems, infrastructures and data sharing	The South African status report is one mechanism to consolidate data, but there are continuing issues of data access, awareness and data curation. For example, South Africa's list of alien species exists only as a static database produced triennially, risk analyses are produced but not in public domain yet, the digitisation of historical paper records is not complete, the mapping of invasions is partial and not consolidated, and records on inputs (e.g., money spent) are not accessible or in an interoperable format. Data-sharing agreements are lacking between organs of state. This is exacerbated by a lack of cooperative governance, with poor alignment of mandates and poor communication.	Provide training on data management. Move to on-line dashboards for species lists. Develop workflows and data pipelines. Publication of risk analyses in support of changes to regulatory lists. Develop consistent maps of presence of alien species across freshwater, marine and terrestrial systems to facilitate application of regulatory measures.

Table 3B.

Recommended property	Current status	Proposed actions for a national strategy
1. Robust institutions that maintain performance through sustained investment and commitment	South Africa has several strong well-established and robust governmental institutions, public entities and public universities with many civic societies and organisations. However, it seems probable that the fiscus will continue to decline. The DFFE is the lead organisation for many activities (under NEM:BA) but funding is typically on three-year cycles, with little guarantee of continuity.	Explore the role of private actors to assist with funding, keeping issues of sustainability in mind. Look critically at options to extract value from control operations (e.g., value addition and value chain, biomass harvesting). Explore other financing mechanisms (payment for ecosystems services and tax incentives)

Table 3. Reflections by the authors on how the: A. seven strategic actions, B. four properties and C. 12 options to strengthen efforts to address biological invasions proposed in the IPBES IAS Assessment are or could be adopted in the South African context (continued)

Table 3B. (continued)

Recommended property	Current status	Proposed actions for a national strategy
	The Department of Agriculture (DoA), the Department of Science and Innovation (DSI), and Innovation Africa @ University of Pretoria have partnered to create the National Biosecurity Hub. A fundamental component of the STI Decadal Plan 2021–2031 and the White Paper on Science, Technology, and Innovation (2019–2020), the Hub contributes to the research, development and innovation necessary to revitalise the agricultural sector. To protect the country from newly emerging sanitary and phytosanitary (SPS) threats that compromise food security, the establishment, upkeep and financing of a strong national biosecurity system also fosters trade partner confidence, which expands market access and creates jobs throughout the value chain.	
2. Responsive governance that adapts to different and changing contexts	There is provision for emergency changes to the NEM:BA A&IS Regulations to be made, but none have been implemented to date. Emergency plant pest response plans are, however, in place and have been implemented. In general, the situation is typified by decisions being made at a very high level (for example director generals are held financially responsible for most issues); with implementation further delayed by unsuitable supporting bureaucratic functions (e.g., supply chain management). In most cases contracts are fixed and inflexible. There is also typically inadequate monitoring of outcomes. As a result, it is very hard for government or their implementing agents to do adaptive management. Governance is mostly reactive rather than proactive.	Investigate ways of devolving decision-making to lower and local levels (e.g., clear aliens in response to fires at a local level). Develop emergency response plans both for agricultural issues and threats to other sectors (e.g., biodiversity). Outline co-ordination mechanisms for emergency response plans including all affected sectors. Establish regular active general surveillance. Monitor outcomes and develop feedback loops to ensure management can respond to what is happening on the ground. Develop and prioritise watch lists for surveillance activities.

Table 3. Reflections by the authors on how the: A. seven strategic actions, B. four properties and C. 12 options to strengthen efforts to address biological invasions proposed in the IPBES IAS Assessment are or could be adopted in the South African context (continued)

Table 3B. (continued)

Recommended property	Current status	Proposed actions for a national strategy
3. Effective implementation that results in the achievement of goals and targets	Current goals and targets for management are not clearly specified and so the progress to address biological invasions is unclear. Similarly, a lack of monitoring of outcomes means progress cannot be tracked. Monitoring focuses on inputs (and in a few cases outputs, e.g., area cleared). By contrast, the goals and targets of biocontrol are specified, and high efficacy has been demonstrated in some cases. For bureaucratic reasons, eradication attempts are often based on the same clearing approach as for widespread invaders, more flexibility is needed. Some protected areas have been evaluated and some control has been shown to be effective. Exercises have been undertaken to prioritise management interventions but these have rarely been acted upon.	Set priorities and goals. Develop a clear monitoring framework. Establish and implement reporting mechanisms. Align goals and mandates between institutions. Link different clearing approaches (best practice) to activities and goals. Establish and implement medium to longer term plans.
4. Equitable and inclusive governance that is fair to all people, communities, and institutions affected by and responsible for the problem	The processes of public government are in place, with mechanisms for three levels of governance and consultation. The system has, at least on paper, all these properties (though in consequence decision-making can be slow). There are several good examples of partnerships (e.g., the uMzimvubu partnership in the Eastern Cape). The NEM:BA A&IS Regulations try to uphold the various rights enshrined in the Constitution by balancing commercial needs vs local community or individual needs. For example, exemptions are specified and provision for permits can be made.	Establish risk management measures and processes to evaluate them so risks are reduced without unduly limiting people's rights. Setup consultation processes (e.g., stakeholder forums and information groups) with specific timelines to ensure decisions are reached. Routinely run stakeholder identification exercises to ensure affected parties become participants in decision-making. Measure the positive impacts both of invasions and interventions and evaluate against costs. Explore options to ensure communities benefit in situations where the risk is minimised and mitigate the risks outside of those cases.

Table 3. Reflections by the authors on how the: A. seven strategic actions, B. four properties and C. 12 options to strengthen efforts to address biological invasions proposed in the IPBES IAS Assessment are or could be adopted in the South African context (continued)

Table 3C.

Recommended option	Proposed actions for a national strategy
Coordination and resourcing 1. Enhance multilateral coordination and collaboration to support the integrated governance of biological invasions	*This is defined here at an international level noting there were differing views on what 'multilateral' means in this context* Support the development and implementation of a regional biological invasions strategy and action plan (this is a CBD COP decision and outcome of SADC joint session held June 2023 / ministerial joint session of ministers of natural resource management, wildlife and tourism). Identify taxa that occur across national borders, engage relevant departments/units from affected countries, co-develop a strategy to manage each taxon, explore means of funding and implement an agreed-upon strategy using relevant tools and monitoring arrangements. Specifically establish joint research and control projects within SADC and working groups on shared issues including classical biological control. Identify specific funding proposals. Identify potential points of conflict across different multilateral agreements. Consider options to integrate management of biological invasions with other global change drivers, by considering land degradation and different perspectives (e.g., under UNFCCC and CBD, ocean acidification and carbon markets). Interact and where possible align with international efforts guided by IPBES, IPCC and others on biological invasions. Explore whether the ideas specified in the sections below should also be done at an international level.
Coordination and resourcing 2. Engage broadly across affected and responsible parties	Stakeholder mapping (e.g., plot amount of interest vs amount of influence, and network analysis) at different scales. Build public-private partnerships (e.g., the Greater Cape Town Water Fund) Incorporate local/indigenous knowledge, perspectives and rights in the strategy development (cf. Box 4). Where feasible and relevant, translate communication material into the most appropriate languages. Develop protocols to ensure consent of use of knowledge or access to land. Identify and address the need for working groups on particular taxa or issues. There are existing working groups for specific taxa in the country; however, not all taxa are covered. There may be a need to increase the number of working groups to cover more taxa and strengthen existing ones by bringing more organisations on board. Share management plans and pool funding, e.g., implementing agencies could share their management plans, review them together, explore opportunities for working together on pathways, species or sites of interest, and allow for pooling of funding where possible. Create a platform for private landowners that are interested in managing invasions on their property to enhance collaboration and/or provide guidance on best practice.

Table 3. Reflections by the authors on how the: A. seven strategic actions, B. four properties and C. 12 options to strengthen efforts to address biological invasions proposed in the IPBES IAS Assessment are or could be adopted in the South African context (continued)

Table 3C. (continued)

Recommended option	Proposed actions for a national strategy
	Continue with existing outreach activities and roadshows to explain the NEM:BA A&IS Regulations. Conduct targeted engagements with the public to develop a sense of shared responsibility, with clearly defined roles and responsibilities.
Coordination and resourcing 3. Build capacity to enable strategic actions	Explore options for funding to build on existing expertise. The South African government has previously provided significant resources, but the fiscus is declining. It is vital to ensure the continuity of core funding if other funding sources are to be leveraged. Set up relevant postgraduate courses (e.g., on risk analysis, biocontrol). Set up specific training courses for technical skills (e.g., herbicide application). Fund postgraduate degrees. Identify and implement novel funding sources to promote control (e.g., debt for nature swaps, public-private partnerships, crowdsourcing).
Policy 4. Share efforts, commitments and understanding of the specific roles of all	Develop a policy on all aspects of biological invasions (going beyond the White Paper on Biodiversity). Ensure the NISSAP has a broad interdepartmental support process for developing, reviewing and implementing the strategy. Conduct awareness raising activities (e.g., roadshows and information sessions) to clarify what needs to be done by whom.
Policy 5. Strengthen compatibility of relevant regulatory instruments	Undertake a legal review and based on that rationalise regulatory instruments. Enforce legislation by building capacity for compliance monitoring by the Border Management Authority, and administrative and criminal enforcement by Environmental Management Inspectors. Review the list of invasive species informed by current science.
Policy 6. Use national strategy and planning for invasive alien species to achieve policy implementation	Finalise the development of the NISSAP and integrate action items identified into the Annual Performance Plans of relevant departments/units.

Table 3. Reflections by the authors on how the: A. seven strategic actions, B. four properties and C. 12 options to strengthen efforts to address biological invasions proposed in the IPBES IAS Assessment are or could be adopted in the South African context (continued)

Table 3C. (continued)

Recommended option	Proposed actions for a national strategy
Policy 7. Support, fund and mobilise resources for innovation, research and environmentally sound technology	Increase the integration of biological invasions and their management in the National Development Plan so that it is seen as a potential driver of economic development. Identify and implement novel funding sources to promote control (e.g., debt for nature swaps, public-private partnerships, crowdsourcing). Fund the Centre for Invasion Biology, the Centre for Biological Control, and consider other inter-institutional research-based agencies that can support the achievement of the national strategy. Build public-private partnerships (e.g., the Greater Cape Town Water Fund). Explore options to use biological invasions as a demonstration to highlight the application of a technology (e.g., remote sensing, gene drive). Consider investment platforms and market incentives/mechanisms, being careful to avoid perverse incentives.
Policy 8. Support information systems, infrastructures and open and equitable access to information on invasive alien species	Develop, update, collate and curate factsheets on pathways of introduction and spread, alien species and invaded sites. Maintain a central information clearing website and email circular (e.g., through www.invasives.org.za). Encourage open-access publishing by relevant journals and include funding for publications in grants as needed. Develop an integrated biosecurity data system that is accessible and interoperable. Use the South African status reports to link with data provision systems.
Research, information and technology 9. Invest in information systems for invasive alien species for information-sharing within and across countries	*Within country* Set up an information portal where details regarding research, policy, compliance and enforcement can be sourced (similar to a clearing house mechanism). Integrate the South African list of alien species with the Global Register of Introduced and Invasive Species. *Across countries* Develop and share generic protocols for data on biological invasions and work with neighbouring countries and other collaborators to facilitate such processes.

Table 3. Reflections by the authors on how the: A. seven strategic actions, B. four properties and C. 12 options to strengthen efforts to address biological invasions proposed in the IPBES IAS Assessment are or could be adopted in the South African context (continued)

Table 3C. (continued)

Recommended option	Proposed actions for a national strategy
Research, information and technology 10. Maintain up-to-date information on necessary and enabling indicators	Develop, document (e.g., using factsheets), regularly review and update biological invasion indicators as part of the South African status reports. Ensure indicators used in South Africa are compatible with indicators used for reporting to multilateral environmental agreements (e.g., the CBD). Move from a triennial national report to on-line dashboard of status (with broader reports roughly every decade). Develop data pipelines and workflows so that it is easy to move from observation to action.
Research, information and technology 11. Monitor policy and management effectiveness and resourcing levels	Use case studies/systems to develop and test different systematic monitoring approaches. Develop best management practice guidelines and run workshops to share techniques across groups. Regularly review and update guidelines based on field experiences. Develop pathways, species and site-based management plans to allow for monitoring of effectiveness.
Research, information and technology 12. Develop new solutions through research and technology	Undertake research responding to current trends relevant to prevention and management of biological invasions. Fund environmental management focused start-ups. Scan other environmental management literature. Move from technology and tools to application (e.g., gene drive, herbicides, remote sensing and eDNA). Support initiatives that promote innovation and product development in the field of biological invasions (e.g., innovation expositions). Look for opportunities for piggy-backing on techniques developed elsewhere. Systematically incorporate future thinking tools (e.g., environmental scanning, driver mapping, horizon scanning and scenario planning) into strategies and action plans.

A key cross-cutting issue for the IPBES IAS Assessment (referred to in four of the 22 key messages) is the importance of 'Indigenous Peoples and local communities' (IPLC) and 'Indigenous and Local Knowledge' (ILK). The roles of IPLCs and the value of ILK was felt to be very important in the South African context, but the terminology used locally sometimes differs from that used by the IPBES. It will be important to keep the sentiment without forcing the use of a specific framework and terms (Box 4).

A vibrant community of practice

Arguably South Africa's community of invasion scientists, managers and practitioners is neither too small that major issues are not addressed nor too large that they cannot regularly meet as a group. There is a sufficient diversity of practitioners with some turnover of both scientific and managerial staff so that there is institutional memory and willingness to continue group discussions over long periods of time (e.g., Davies et al. 2020a). This community of practice hits a Goldilocks zone, small enough to be intimate, connected, collaborative and continue over time without too much irrelevant bureaucracy, but not so small that it relies on a few individuals (Foxcroft et al. 2020).

South Africa is well placed in terms of specific governmental institutions that focus on directed applied research and coordination (e.g., the Agricultural Research Council, the Council for Scientific and Industrial Research and the South African National Biodiversity Institute). The government department in charge of fundamental research values applied research, and the departments in charge of environmental affairs and agriculture recognise the importance of foundational research, providing support to scientists through research grants and postgraduates through various bursary schemes.

Invasion science, as a discipline, allows for training in a real-world problem that cuts across different sectors and in which a tangible difference can be made by individual students. For almost two decades (2004–2022), the South African government funded a world-leading institute with the aim of conducting research, education and training, coordinating networking, information brokerage and service provision relating to biological invasions (the Centre for Invasion Biology, Richardson et al. 2020a). Similarly, a research centre dedicated to biological control research, training and implementation has provided vital support to managers across the country (the Centre for Biological Control, Byrne et al. 2020). Ensuring such initiatives continue will be crucial if the national strategy is to be effective.

Various methods are used to increase interactions, including joint attendance and participation in voluntary fora and conference series where researchers and managers are regularly exposed to each other's challenges (Foxcroft et al. 2020). There is an annual National Symposium on Biological Invasions that regularly has an attendance of over one hundred delegates including researchers, academics and policy- and decision-makers from various government departments. Government officials are also encouraged to attend training [e.g., short courses in biological control and risk analysis have been developed and led by academics and staff of research institutions (Byrne et al. 2020; Wilson & Kumschick 2024)] or to register for post-graduate qualifications. Other initiatives that have been in place are management and research planning fora. Some have run their course, but others have been ongoing for many years, including working groups on cacti, grasses and invasive animals (Davies et al. 2020a; Kaplan et al. 2017; Visser et al. 2017).

A substantial existing knowledge base but one that can be rapidly expanded

Biological invasions have been reasonably well-documented in protected areas (Van Wilgen & Herbst 2017), as well as across the whole country for plants (Henderson & Wilson 2017). There has also been a growing use of citizen science platforms (e.g., iNaturalist) to facilitate monitoring and reporting in South Africa (Potgieter et al. 2024; Zengeya & Wilson 2023). There is still a need, however, for inventories of cultivated aliens and cultivated areas (this was notably outside the scope of the IPBES IAS Assessment). Angling, arboreta, botanical gardens, horticulture, the pet trade and zoos often use alien taxa and information on these need to be incorporated into our thinking (Cheek et al. 2022; Glen 2002; Vezi et al. 2024; Wondafrash et al. 2021). Pathway-specific risk assessments and management plans are also needed.

Importantly, there is still much to be gained from more interdisciplinary and transdisciplinary research – much of the research on biological invasions is still driven by a core group of ecologists (Abrahams et al. 2019). For example, arguably social and gender issues as outlined in the IPBES approach are not adequately addressed [though studies have looked at the value of overt targets for gender and the need to consider social redress in interventions (Hough & Prozesky 2012, 2013; Sadan 2005; Van Koppen et al. 2011)]. It will be important to ensure the proposed national strategy elicits contributions from the social sciences and incorporates discourses from different perspectives.

Integrated governance

We agree strongly with the plea in the IPBES IAS Assessment for more focus on integrated governance. For example, provincial legislation on keeping pets differs

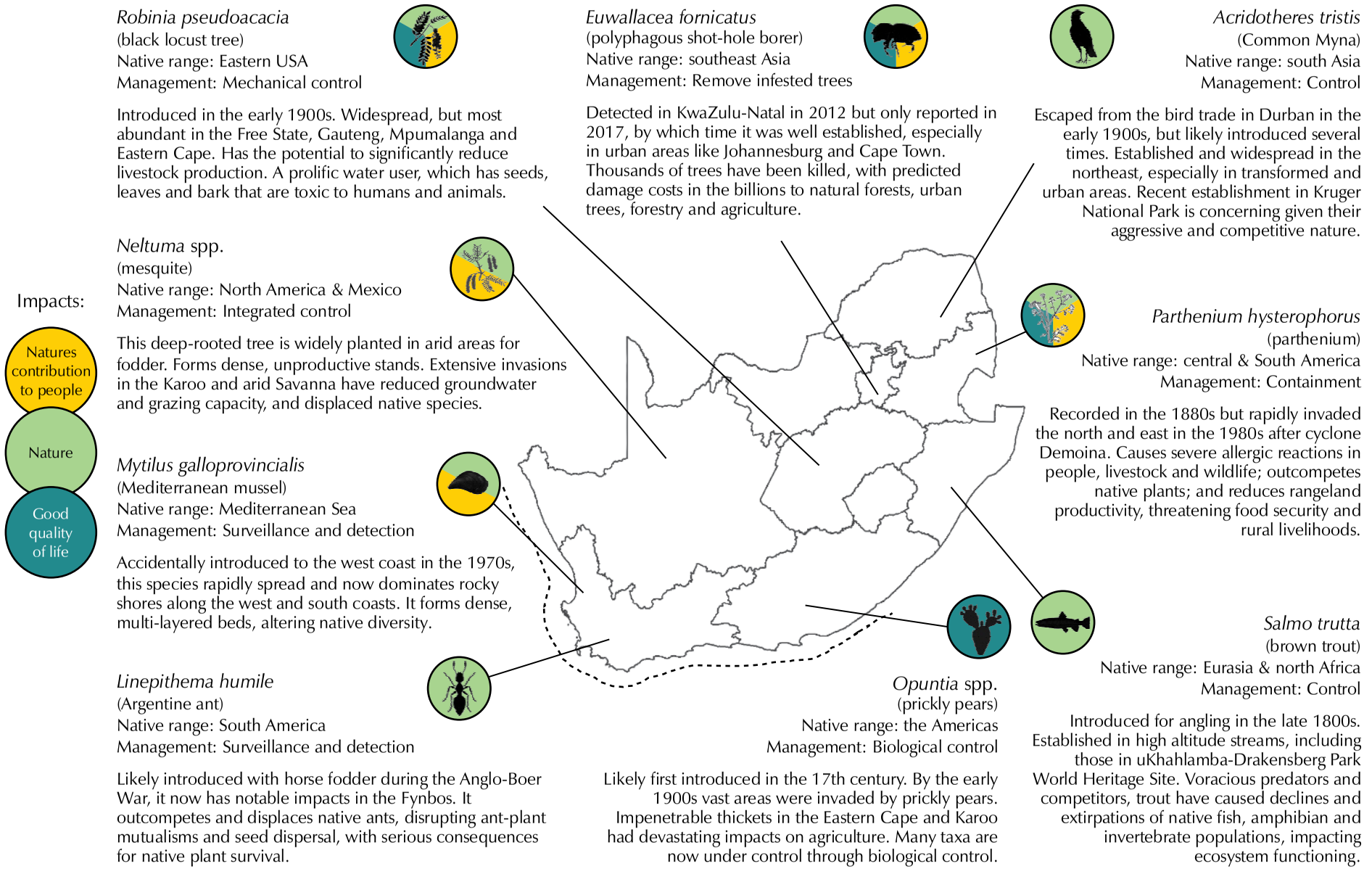


Figure 2. Selected damaging invasions across South Africa. The nomenclature is as per the species list of the South African status reports. The affected sectors are indicated by colours: yellow is on nature's contribution to people; green is on nature; and teal is on good quality of life [cf. Figures SPM.2 and SPM.3 in IPBES (2023a)].

throughout the country with some provinces allowing many alien pets, while others ban most (Nelufule et al. 2020). We often have the tools, frameworks and knowledge necessary to address biological invasions, and in many cases these have been adapted specifically to the South African context. We argue for a greater focus on how we implement. Improvements to project management (e.g., supply chain management) could greatly increase the effectiveness of control projects funded by the government. It will be important to focus management on where and when it is needed most, and ensure monitoring is sufficient to allow for management to be adaptive.

Humans are both the cause of and solution to biological invasions. Effective management requires co-ordination across different mandates, sectors (e.g., agriculture, health and transport) and scales (local to national). Several promising cross-cutting approaches have been identified with links to biological invasions, including One Health (Ogden et al. 2019) and One Biosecurity (Hulme 2020). The challenge (in particular for the national strategy) is to improve coordination while limiting bureaucracy to that which is needed. We believe there is room both for a forum dedicated to biological invasions (for those who work directly on the issue) and for a broader inter-agency One Biosecurity Commission (that brings together those working on animal, environmental, human and plant health; cf. the Presidential Climate Commission https://www.climatecommission.org.za/ established in Sep. 2020).

Box 4. Indigenous and Local Knowledge (ILK) and Indigenous Peoples and local communities (IPLCs) terminology in the South African context

In the parlance of IPBES, Indigenous and Local Knowledge (ILK) refers to 'knowledge and know-how accumulated across generations, which guide human societies in their innumerable interactions with their surrounding environment'. The collective term for stakeholders that hold and provide ILK are Indigenous Peoples and local communities (IPLCs). IPLCs are, 'typically, ethnic groups who are descended from and identify with the original inhabitants of a given region, in contrast to groups that have settled, occupied or colonized the area more recently' (IPBES 2022). Using ILK and other forms of knowledge, IPLCs have shaped the ecologies, conservation initiatives and resource economies of vast regions of the world – IPLC either control, use, manage or co-administer an estimated ~38 million km^2 or 25–28% of the world's land area (McElwee et al. 2020). Crucially these lands are less invaded than other areas, potentially due to active custodianship by IPLCs (Seebens et al. 2024).

In 2004 South Africa adopted an indigenous knowledge systems policy, with the then Department of Science and Technology as the custodian. Terms such as Indigenous Knowledge Systems (IKS) and Traditional Knowledge (TK) are widely used to refer to the knowledge, skills, practices and technologies developed by indigenous and local communities (often in practice synonymous with the term 'rural communities'). The literature in South Africa also recognises groupings such as indigenous communities, local communities, traditional communities and traditional knowledge holders. The aim is to include those who have a distinct cultural identity and a deep connection to their ancestral lands, including those that have lived in a particular area for a long period of time with their own knowledge systems and practices related to the natural environment. These terms are often used in policies, legislation and academic discourse in South Africa to recognise and respect the role of ILK in biodiversity conservation and sustainable development.

Several instruments exist currently to protect the input of IKS and TK such as NEM:BA, the indigenous knowledge systems policy and Protection, Promotion, Development, and Management of Indigenous Knowledge Act (IK Act, 2019), drawing on methods such as stakeholder engagements, public participation processes and citizen science. As examples, IKS are engaged through Community-Based Natural Resource Management (CBNRM) programmes as intervention points to assist with management of invasive species. Similarly, rural livelihoods affected by the impact of invasive species on ecosystem services, such as grazing or water supplies (Yapi et al. 2018), are best understood by engaging with the community. IKS contribute to local development, however traditional knowledge holders are often excluded from decision-making processes. IKS should be seen as a natural resource which guides decisions and informs how land is used, e.g., by farmers and agricultural households.

In summary, while the concepts of ILK and IPLC, as defined by IPBES, are recognised and contribute to biodiversity conservation and management in South Africa, given the diversity of definitions and associated groups, care should be taken to ensure that all stakeholders are represented and to avoid the misinterpretation and misalignment of information. As argued elsewhere in this paper, IPBES concepts and definitions should, we believe, be interpreted and adapted to the local context if they are to be of most value.

Biological invasions do not respect administrative borders, and all agreed on the need for greater collaboration with neighbouring countries, the Southern African Development Community (SADC) and Africa more generally. It will be vital for Africa to share experiences and collectively address biological invasions (Faulkner et al. 2017), particular in light of the African Continental Free Trade Area that was established in 2019 (Faulkner et al. 2020a).

Resourcing and where to from here

The amount of resources invested to address biological invasions in South Africa is substantial but declining (McCulloch-Jones et al. 2024; Van Wilgen et al. 2022a).

There is a specific and substantial value proposition in preventing and controlling biological invasions. This needs to be made more strongly. A greater investment of resources in proactive management would do much to limit future biological invasions (McCulloch-Jones et al. 2024) especially in the context of environmental biosecurity (Early et al. 2016). Substantial returns on investment have, however, also been made by treating existing widespread invasions, especially through clearing trees in water source areas (McConnachie et al. 2012; Stafford et al. 2019) and classical biological control (McConnachie et al. 2003; Van Wilgen & De Lange 2011). Since 2022, national government funding for biocontrol has not been forthcoming even though South Africa has a long and successful history of research and implementation in this area (Hill et al. 2020). This suggests the need to both improve how the case for safe and effective biological control is made to the South African government and to diversify funding options, for example, with more public-private partnerships (Ivey et al. 2024; Martin et al. 2018). We advocate strongly that funds to improve human health, agricultural productivity and food security, livelihoods and the economy can be highly effective if invested in addressing biological invasions.

There are, as always, challenges that could severely limit management options in future. A ban on herbicides would remove essential tools for control (integrated control linking mechanical removal with chemical control is imperative for many invasive trees); the push for commercialisation has the potential to open up new introduction pathways; and perverse incentives to address climate change through afforestation using alien species has led to widespread damaging invasions (Bond et al. 2019).

During our discussions, and as flagged by many parties during consultations, much more integration and collaboration with neighbouring countries are urgently needed if biological invasions are to be effectively addressed. Although South Africa was well represented in the IPBES IAS Assessment, several concerns were expressed at the IPBES plenary (during which the assessment was approved) pertaining to data gaps and low representation of experts from developing countries. South Africa's draft national strategy recognises this. Opportunities for funding through the Global Biodiversity Framework Fund and various international initiatives could provide valuable sources of seed funding to facilitate greater integration of efforts within SADC and Africa more broadly.

This paper is a selected view by a selected group in response to a particular initiative (the IPBES IAS Assessment). The South African status report provided background information but was not explicitly reviewed here. This paper also does not explicitly review the historical context [for a broad review of biological invasions in South Africa see Van Wilgen et al. (2020a)]. Key sectors from South Africa did not contribute to the IPBES IAS Assessment (and so were not included as authors of this paper), in particular microbiologists, fungal biologists and human health specialists; a more diverse range of viewpoints would be extremely valuable. A much broader analysis using a range of tools from futures thinking (including environmental scanning, driver mapping, horizon scanning and scenario planning) would also provide significant insights for the national strategy and action plan (Hulme 2025). Nonetheless, we believe this paper provides an important perspective linking international best practice and insights (the IPBES IAS Assessment) to national needs (the draft national strategy).

Conclusion

The IPBES IAS Assessment is a landmark report at the science-policy interface on biological invasions that, we argue, provides guidance for South Africa to deal with biological invasions. The IPBES IAS Assessment provides compelling evidence of the need for immediate and urgent control of invasive species, serving as a baseline to monitor progress towards Target 6 of the Kunming-Montreal Global Biodiversity Framework. Nonetheless, given the focus of the IPBES IAS Assessment (global and holistic), the key messages and gaps will likely not wholly resonate for any specific country. We encourage readers in South Africa and other countries to go beyond the key messages from the IPBES IAS Assessment and contextualise and scrutinise the findings based on what is important for their region or country. This opinion paper hopefully provides insights both for how South Africa can contribute to the implementation of CBD Article 8h and to Target 6 of the KM-GBF, what South Africa's national strategy should include, and, ultimately, how South Africa can be protected from the harm caused by biological invasions for the benefit of the environment and human well-being.

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Competing interests

Most of the authors are involved in management and research on biological invasions in South Africa. Several of the authors contributed to the IPBES IAS Assessment (see legend to Table S1).

Authors' contributions

Conceptualisation (JRUW, KTF, LFW, EJMcC-J, SM, BWvW, TAZ); project administration (JRUW); visualisation [CC (Figure 1); EJMcC-J, KTF, RB (Figure 2)]; writing – original draft [JRUW, KTF, LFW, EJMcC-J, SM, DMR, TBR, SK, NT, FT, SJR, BWvW, TAZ; JRUW (Box 1); KTF, LFW, MG, PClR (Box 2); MSD, SRZ (Box 3); RB, SJR (Box 4)]; writing – review and editing (all). All authors have read and agreed to the published version of the manuscript.

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Supplementary Material

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Table S1. IPBES IAS Assessment experts and countries of affiliation

Table S2. The key message paragraphs from the IPBES IAS Assessment and the corresponding South African situation

Table S3. Objectives and actions for managing biological invasions with details of the South African situation

Table S4. Knowledge and data gaps identified in the IPBES IAS Assessment in the context of South Africa