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MS31 List of indicators and data sets to be used in the case study II “Biological invasions in South Africa”

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Summary

South Africa has set up a process of reporting on the state of biological invasions every three years (<https://iasreport.sanbi.org.za/>). Biodiversity monitoring requires access to rapid, reliable, and repeatable monitoring data that can be used to inform policy, decision-making, and interventions. The South Africa's status report on biological invasions is one of four case studies for the Biodiversity Building Blocks for Policy (B-Cubed) project (<https://b-cubed.eu/>). The overarching objective of the B-Cubed project is to develop pipelines to improve the integration of biodiversity data into data cubes that are then used as the basis for models and indicators to monitor biodiversity status and change. The data cubes, models and indicators developed under the B-Cubed project will feed into South Africa's status report on biological invasions and show the usefulness of the B-Cubed project from an end-user perspective (South African National Biodiversity Institute). The B-Cubed project will provide information on indicators that are used to monitor biological invasions and the information will help address three of the six identified key gaps in previous reports on invasive alien species in South Africa (alignment of indicators; mobilization of spatial data; mobilization of impact data), will assist with the automation and standardization of the process and improve how reports are communicated (i.e., including workflows and dashboards).

List of abbreviations

BODATSA	Botanical Database of Southern Africa
EICAT	Environmental Impact Classification for Alien Taxa
FAIR	Findability, Accessibility, Interoperability, and Reusability of digital assets
GBIF	Global Biodiversity Information Facility
POWO	Plants of the World Online
SAPIA	Southern African Plant Invaders Atlas
SEICAT	Socio-economic impact classification of alien taxa
WoRMS	World Register of Marine Species
WP4	Work Package 4
WP5	Work Package 5





1. Data sets

Work Package 6 (WP6) – Use Cases aims to validate the relevance, usability, and impact of B-Cubed developments through a series of representative case studies. Each use case contributes to assessing:

- a) the capacity of B-Cubed indicators to capture key aspects of biodiversity relevant to the specific context;
- b) the ability of B-Cubed workflows to deliver tailored outputs aligned with the spatial, temporal, and thematic requirements of stakeholders;
- c) effective strategies for communicating outputs in a policy-relevant and user-friendly manner.

This milestone presents the initial list of datasets and indicators identified for Case Study II: Biological Invasions in South Africa, which will be used to support the evaluation of B-Cubed components in alignment with the objectives of WP6. This case study will use datasets on the occurrence of alien taxa in South Africa that were developed as part of the process to compile a national report on the status of biological invasions and their management in the country. A list of alien species for South Africa was used to retrieve these occurrence records from the Global Biodiversity Information Facility (GBIF, <https://www.gbif.org/>). This list of alien species is the result of a process to consolidate and standardise information on the presence of alien taxa in South Africa from various sources. These data sources vary from government reports, peer-reviewed papers, grey-literature, atlasing projects, and online databases (see Zengeya et al. 2025a). We acknowledge that not all documented occurrence records of all the alien species in South Africa are yet reflected on the GBIF platform. As a result, the occurrence dataset was also complimented with local datasets, such as the Southern African Plant Invaders Atlas (SAPIA).

1.1. Taxonomic groups

The list currently includes all alien species that have evidence to document their presence in South Africa as of December 2022. It covers 6 211 taxa from five kingdoms: Plantae (3 845 taxa), Animalia (2209), Fungi (131 taxa), Chromista (19 taxa), Protozoa (2 taxa), and bacteria (4 taxa). The number of species on the list is expected to increase with future updates. Taxonomic information is based on several backbones (Faulkner in press, Zengeya et al. 2025a). For plant taxa, the nomenclature was first checked against the Botanical Database of Southern Africa (BODATSA), and if the information was not available, the Plants of the World Online database was used (POWO; <https://powo.science.kew.org/>). The nomenclature of non-plant taxa was checked against the Global Biodiversity Information Facility taxonomic backbone (GBIF; <https://doi.org/10.15468/39omei>). However, for many taxa, other user-defined taxonomic backbones were used. For example, plant taxa not found in BODATSA and POWO were checked against the International Plant Name Index (IPNI; <https://www.ipni.org/>) and names of animal taxa not found on GBIF were checked against Nemaplex (<http://nemaplex.ucdavis.edu/>) for nematodes, the World Register of Marine Species (WoRMS; <https://www.marinespecies.org/>) for marine taxa, and published lists in other cases (e.g., for biological control agents released on plants, Zachariades 2021).

1.2. Temporal and spatial scale

Spatial: Mainland South Africa and inshore islands [a separate list is curated for the Prince Edward Islands, South Africa's sub-Antarctic territories (Fernández Winzer et al. 2024, 2025)]. The spatial scale can be disaggregated further into a number of large-scale national subdivisions





(provinces, primary catchments or bioregions as appropriate), finer-scale national subdivisions (quarter-degree grid cells or hectads), and at a finer scale, the range for each species (e.g., in km² or ha).

Temporal: Sources published or available up to 31 December 2022, with sources dating from 1906 (Theobald 1906). Some alien taxa were introduced to South Africa prior to European colonisation in the second half of the 17th century, but the majority were introduced since then (Faulkner et al. 2020). Currently, the list of alien species in South Africa is updated every three years, in line with the legal requirement to produce a triennial report on the status of biological invasion and their management, but it is expected that, in the future, the process will be automated and updates released as new information becomes available with detailed assessments of broad issues being regularly published, or as needs arise (Zengeya et al. 2025b).

2. Indicators to be used

2.1. Indicators to be used

The national report on the status of biological invasions and their management is based on a suite of 20 indicators (Wilson et al. 2018). These indicators explicitly consider biological invasions in terms of 1) pathways – how alien species are introduced and move around the country; 2) species – the status and impacts of alien species; 3) sites – the degree to which sites are invaded and impacted; and 4) interventions – the effectiveness of the full range of interventions that South Africa has used to address the problem (Figure 1).

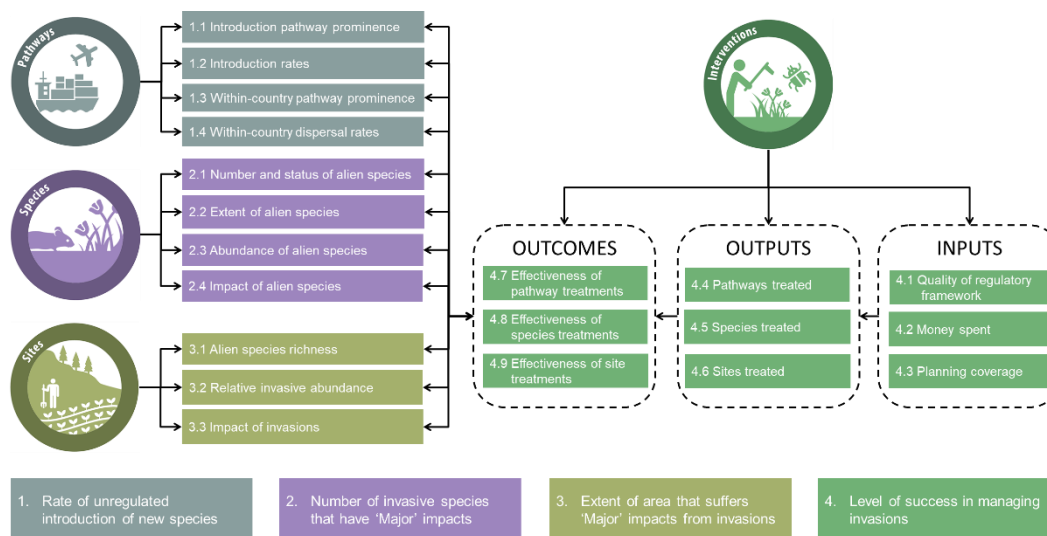


Figure 1. The indicator framework for the national status report on biological invasions and their management in South Africa.

The B-Cubed project will help address three of the six identified key gaps in the previous reports on invasive alien species (alignment of indicators; mobilisation of spatial data; mobilisation of impact data); and assist the automation and standardisation of the process and how reports are communicated (i.e., including workflows and dashboards). There are five indicators that have a





direct link to the B-Cubed project: *number and status of alien species* (i.e., whether they are known to be present in South Africa and their stage of invasion); the *extent of alien species* (at national, provincial, biome or other scales); the *impact of alien species* (the degree to which alien species have impacts) and the *impact of invasions* (combined impact of invasive species at a site).

Number and status of alien species

This indicator provides the basis for constructing lists of alien species for a country. The process of documenting and tracking changes in the status of alien species has been substantially improved through the development of workflows to ensure analyses are properly documented and repeatable (Zengeya et al. 2025a). This will facilitate tracking of alien species status (e.g., naturalised but not invasive; invasive) over time, information that should feed into management planning and facilitate regulatory decisions. 6 197 taxa have been assessed for presence in South Africa, of which there is evidence that 3 802 taxa are present, the presence of 1 639 taxa is doubtful, and 739 are recorded as absent (Zengeya et al. 2025a). Over half of the alien taxa recorded as present are plants, in line with the view that South Africa is a hotspot for plant invasions

Link to B-Cubed project outputs or indicators: B-Cubed is creating a species occurrence cube format for a range of analyses to indicate trends and predictively model the future of biodiversity under different scenarios. It is documenting the workflows and scripts that are used to generate the cubes, ensuring that they are interoperable with other data cubes, particularly those that include environmental variables. Occurrence cubes could be used to track changes in the number of alien species in South Africa (or other smaller scales e.g., biomes) and their status over time.

Challenges/issues: Need to establish a baseline. A list of alien taxa in South Africa has been produced as part of the process to compile the national status reports on biological invasions (Zengeya et al. 2025a). The development of documented and repeatable workflows ensures it is clear why taxa are included on the list and facilitates reviews and updates. Data are intended to be tidy and adhere to FAIR data principles and biodiversity information standards (Darwin Core). However, several key data sources still need to be verified and integrated into the list (particularly species in captivity or cultivation), and many alien species are yet to be detected and documented. As data are captured and collated, the list will increase in length and content. This means that the list is not yet a complete baseline of the knowledge of alien taxa presence in South Africa. The aim is for the list to become comprehensive and dynamic, allowing the number and status of alien taxa to be tracked over time, and informing management planning and regulatory decisions.

Extent of alien species

The indicator provides an indication of how widespread alien species are and information that can be used for other indicators e.g., impacts. The majority of alien species are localized and only a few are widespread. However, the potential for spread is large, and many species are spreading. Citizen science platforms and the digitization of historical records have increased knowledge of the distribution of some alien taxa, but there is a decline in active surveillance for plants (i.e., hiatus of SAPIA).

Link to B-Cubed project outputs or indicators: Occurrence cubes could be used to track changes in the extent of alien species in South Africa. For example, changes in the number of quarter degree grid cells occupied by the species.





Challenges/issues: Data on the distribution and abundance of alien species need to be collected, collated and integrated into national and global databases to facilitate the planning of interventions. Occurrence data are mainly from GBIF, with additional data from local atlassing projects e.g., (SAPIA) is used to populate this indicator. However, a hiatus of SAPIA in 2020 means there is a decline in active surveillance for alien plants. SAPIA provided standardized data on the distribution of alien plants through collating submissions from experts and through dedicated roadside surveys across the country. The active surveillance effort of SAPIA allowed for trends in the extent of plant invasions to be reliably evaluated over time. Various remote sensing techniques continue to offer great promise in addressing some of these issues, but no tangible results that can be used in the report. Ensuring the long-term sustainability of structured surveillance efforts and integrating these with historical data and citizen science observations will support management planning and facilitate regulatory decisions.

Impact of alien species

This indicator helps to identify which alien species are causing the largest negative impacts and the types of impact mechanism that are most common. The negative impacts of invasive species on biodiversity and people's livelihoods are known to be substantial, in particular those of trees and freshwater fishes. However, the impacts of only a few taxa (36) have been assessed using formal assessment methods such as Environmental Impact Classification for Alien Taxa (EICAT; Blackburn et al. 2014) and Socio-economic impact classification of alien taxa (SEICAT; Bacher et al. 2018).

Link to B-Cubed project outputs or indicators: Occurrence cubes could be used to visualize the impact of alien taxa and individual species in a given area.

Challenges/issues: There is need for more studies and assessments on the impact of invasive species. Improved impact assessment methodologies have aided in identifying highly impactful species. There is ongoing development of frameworks and models assessing potential impacts and risks posed. There is additional progress developing standards and assessing alien taxa at a global level. However, these methodologies have only been applied to very few alien taxa found in South Africa to date.

Impacts of invasions

This indicator assesses the combined impact of all invasive species at a particular site on the delivery of selected ecosystem services, or on biodiversity. It should have a focus on those ecosystem services that are important in the context of the site concerned (for example on water resources in dry regions, livestock production in rangelands, or biodiversity in protected areas) and can be used to prioritise sites for management interventions.

Link to B-Cubed project outputs or indicators: Occurrence cubes could be used to visualize the impact of all invasive species at a particular site on the delivery of selected ecosystem services, or on biodiversity.

Challenges/issues: The impact of invasions on water resources, rangeland productivity and biodiversity are severe. These negative impacts have not recently been reassessed, and workflows are required to improve the applicability and repeatability of the methods.





Alien species richness

This is an indicator of the number of alien species at a particular site. A higher number of invasive species indicates the number of issues experienced while higher numbers of alien species indicate a higher risk of invasions. Invasions are distributed across the country including in protected areas. Most alien species are found along the coast and around major urban centers. This is likely because some species are commensal with humans, urban areas are often sites of first introduction, and there is greater sampling around urban areas (in particular, iNaturalist observations).

Link to B-Cubed project outputs or indicators: Occurrence cubes could be used to visualize the the richness of alien species in a given area. For example, changes in the number of quarter degree grid cells occupied by the species.

Challenges/issues: Data on the distribution and abundance of alien species need to be collected, collated and integrated into national and global databases to facilitate the planning of interventions. Occurrence data are much more comprehensive for terrestrial and freshwater plants and for birds than for other taxa. There is a lack of robust and reliable monitoring systems that track the distribution and abundance of alien species that are required to facilitate the planning of interventions.

2.2.WP4/WP5 developments applied

WP4 integrates species occurrence cubes with climate change and land use change scenarios through existing models to project past, present and future biodiversity. It creates exemplar workflows for modelling with biodiversity data cubes, demonstrating how biodiversity data can be used to create policy-relevant forecasts and current estimates. In South Africa, a national report on the status of biological invasions, by definition, should focus on what the current state is, but this is often largely a function of historical events and processes (Figure 2). Given that the report will form the baseline for predictions of how problems will evolve under different scenarios, that is, invasion debt, indicators need to be responsive to changes. We propose forecasted indicators (*introduction debt*; *establishment debt*; *spread debt*; and *impact debt*) – as over time, invasion debt can result in new introductions, new invasions, more area invaded and greater impacts (Rouget et al. 2018; Wilson et al. 2018). The challenge is to develop models and techniques that can help improve decision-making and allow for adaptative management at various scales. The products from WP4 (e.g., suitability cube, dissimilarity cube, network invasibility cube) can be used to inform on the invasion debt in South Africa and this will be trailed and documented in the deliverable report for the case study. The products are however, not yet integrated into the indicator framework that is used to inform the national status report (Figure 1) and will be flagged for potential inclusion in the future when the indicator framework is revised and updated.



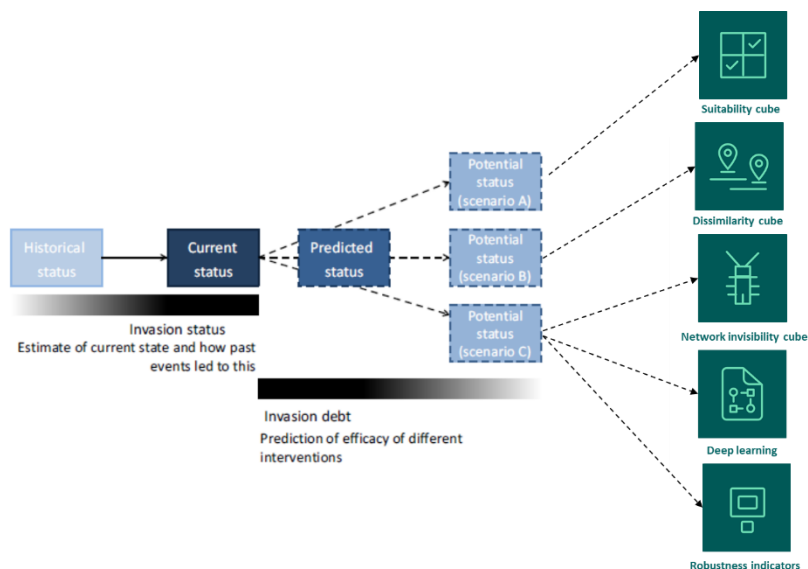


Figure 2. The concept of invasion debt (*introduction debt*; *establishment debt*; *spread debt*; and *impact debt*) and how products from WP4 (e.g., suitability cube, dissimilarity cube, network invisibility cube) can be used to inform on the invasion debt in South Africa

WP4 will also provide the conditions for reliable estimates on national or regional species status and trends from GBIF data. The task will explore the conditions that determine the reliability of models, trends and status by comparing aggregated cubes with structured monitoring schemes. These conditions relate to both data quality and species characteristics (such as abundance, detection probability and spatial and temporal dynamics). Examples of taxa where systematic monitored data are available will be selected for comparison. The workflows from B-Cubed project will be applied to both sets of data. In that way the separate and combined datasets can be analyzed in the same framework. For Flanders, long term monitoring programs will be selected (such as birds, plants and dragonflies). For South-Africa, invasive bird data based on atlassing projects will be used to assess the contribution of such to trend estimation. The results of this task will help to substantiate rules of thumb about the conditions under which national or regional species status and trends can be reliably calculated from aggregated occurrence data. The results of this task will be further used in task 5.4.

WP5 is creating reproducible and sustainable workflows to calculate indicators and their uncertainty, as well as to evaluate the quantity and quality of biodiversity observations in order to identify data gaps. It is also to deploy software packages allowing others to apply the provided workflows and indicators and to develop their own workflows. Case study II on biological invasions in South Africa will trial the application of some general biodiversity variables and indicators (Task 5.2), indicators on impacts of alien taxa (Task 5.3) and measures to assess and mitigate uncertainty in data and indicators (Task 5.4) (Figure 3). The indicators for phylogenetic diversity are not yet integrated into the indicator framework that is used to inform the national status report and will be flagged for potential inclusion in the future.



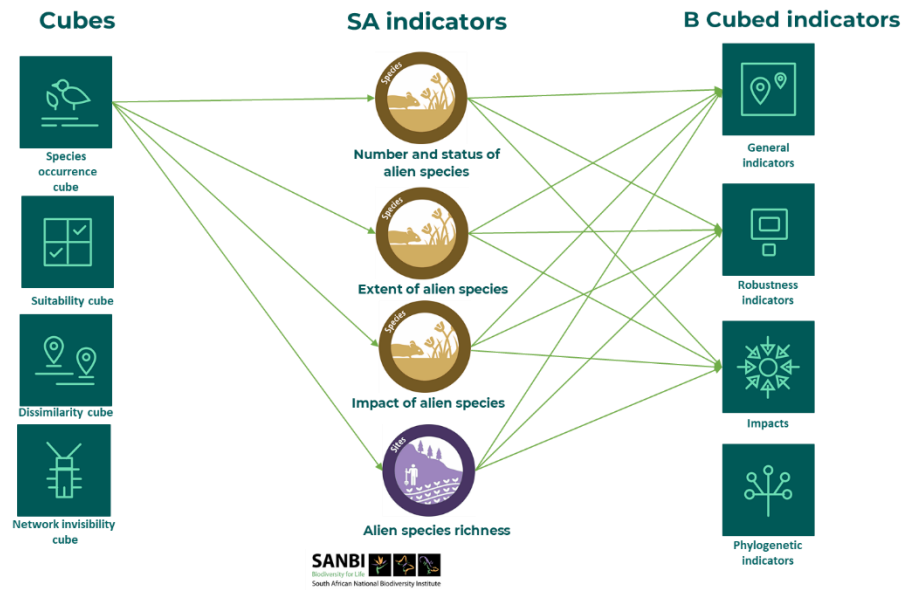


Figure 3. A summary of the products from the B-cubed project that will be applied in the case study on biological invasions in South Africa

3. Policy question(s)

Biological invasions are a major threat to South Africa's biodiversity, economy, and sustainable development. The national status report on biological invasions and their management is a part of South Africa's commitment to alleviating these impacts (Zengeya and Wilson 2023). It is a comprehensive national-scale assessment, is one of a few such national assessments in the world that focuses specifically on biological invasions and is an important part of South Africa's global leading position on the issue. This report provides valuable insights into how South Africa can reduce the negative impacts of biological invasions on ecosystems, the economy, and people while retaining the benefits alien species provide where this is possible and desirable. It collates foundational information essential for researchers of the topic and an assessment of interventions that is vital for policymakers and managers. Data cubes, models and indicators developed under the B-Cubed project will feed into these status reports on biological invasions for South Africa. The case study will show the usefulness of the B-Cubed project from an end-user perspective (SANBI). This project will provide information on indicators that are used to monitor biological invasions and the information will help address three of the six identified key gaps in the last status report on invasive alien species (alignment of indicators; mobilisation of spatial data; mobilisation of impact data); and assist the automation and standardisation of the process and with how reports are communicated (i.e., including workflows and dashboards).





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