

# Factsheets for indicators used to report on the status and management of biological invasions in South Africa

v20260602

These factsheets are based on the guidelines of the Biodiversity Indicators Partnership (Biodiversity Indicators Partnership, 2011), with the addition of explicit sections on how to define the confidence interval for each metric, and the properties of the indicators (see Appendix 1).

These indicators are used as part of the report series "The status of biological invasions and their management in South Africa". For the latest version of the report see <http://dx.doi.org/10.5281/zenodo.7414803> for general details see <http://iasreport.sanbi.org.za>

Much of the information on how the indicators are scored and how confidence levels are calculated are inherited from the metadata to the list of alien taxa for South Africa <https://doi.org/10.5281/zenodo.7433112> or from workflows associated with the national status report on biological invasions <https://doi.org/10.5281/zenodo.7433129>

There are several additional facilitating mechanisms that are vital for successful interventions, specifically: accessibility of data and information; research; organisational, infrastructure, and human capacity; and public awareness and engagement. Indicators for these are not included as they are not currently used for measuring outcomes or outputs of the interventions themselves.

Suggested citation for this document:

SANBI and CIB (2026) Factsheets for indicators used to report on the status and management of biological invasions in South Africa. v20260602. Part of the report series 'The Status of Biological Invasions and their Management in South Africa'. South African National Biodiversity Institute and Centre for Invasion Biology. <http://dx.doi.org/10.5281/zenodo.17739011>

For enquiries contact: [IAS.report.SANBI@gmail.com](mailto:IAS.report.SANBI@gmail.com) OR [invasives@sanbi.org.za](mailto:invasives@sanbi.org.za)

## Versions

Version	Description	Link
Not indicated on document	Paper outlining Indicators with factsheets included as supplementary material. Wilson et al. (2018) Indicators for monitoring biological invasions at a national level. Journal of Applied Ecology, 55, 2612–2620. doi: 10.1111/1365-2664.13251	<a href="http://dx.doi.org/10.1111/1365-2664.13251">http://dx.doi.org/10.1111/1365-2664.13251</a>
20260130	Factsheets as part of the draft report 'The status of biological invasions and their management in South Africa in 2025' sent for public comment 30 Jan–1 Mar 2026	<a href="http://dx.doi.org/10.5281/zenodo.17739011">http://dx.doi.org/10.5281/zenodo.17739011</a>
20260602	Factsheets as part of the report 'The status of biological invasions and their management in South Africa in 2025'	<a href="http://dx.doi.org/10.5281/zenodo.20507633">http://dx.doi.org/10.5281/zenodo.20507633</a>

# Table of contents

Factsheets for indicators used to report on the status and management of biological invasions in South Africa .....	1
Versions .....	1
Table of contents .....	2
1. <i>Rate of unregulated introduction of new species</i> .....	3
1.1. <i>Introduction pathway prominence</i> .....	7
1.2. <i>Introduction rates</i> .....	12
1.3. <i>Within-country pathway prominence</i> .....	16
1.4. <i>Within-country dispersal rates</i> .....	20
2. <i>Number of invasive species that have 'Major' impacts</i> .....	24
2.1. <i>Number and status of alien species</i> .....	27
2.2. <i>Extent of alien species</i> .....	31
2.3. <i>Abundance of alien species</i> .....	35
2.4. <i>Impact of alien species</i> .....	39
3. <i>Extent of area that suffers 'Major' impacts from invasions</i> .....	42
3.1. <i>Alien species richness</i> .....	44
3.2. <i>Relative invasive abundance</i> .....	48
3.3. <i>Impact of invasions</i> .....	51
4. <i>Level of success in managing invasions</i> .....	55
4.1. <i>Quality of the regulatory framework</i> .....	58
4.2. <i>Money spent</i> .....	61
4.3. <i>Planning coverage</i> .....	65
4.4. <i>Pathways treated</i> .....	69
4.5. <i>Species treated</i> .....	73
4.6. <i>Sites treated</i> .....	76
4.7. <i>Effectiveness of pathway treatments</i> .....	79
4.8. <i>Effectiveness of species treatments</i> .....	84
4.9. <i>Effectiveness of site treatments</i> .....	88
Appendix 1 Scoring indicator properties .....	91
Appendix 2 Linkages between indicators .....	<b>Error! Bookmark not defined.</b>
References .....	93

# 1. Rate of unregulated introduction of new species

## Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Pressure

Theory of Change (ToC): Outcome

## Use and interpretation

'1. Rate of unregulated introduction of new species' provides an indication of potential future biological invasions (i.e., species-based invasion debt). It is also a metric by which the effectiveness of biosecurity interventions should ultimately be measured.

Species which have been introduced following a proper detailed and independently assessed risk analysis are not included (Ivey et al. 2023; Wilson and Kumschick 2024)

## Potential for aggregation

This is a high-level indicator, already aggregated at a national level. There is the potential for use across broader regions (e.g., southern Africa).

## Possible reasons for trends

↑	The volume of trade and travel is increasing, resulting in more accidental introductions
	More deliberate illegal introductions
	Effective regulation of imports
	Changes in the number or intensity of surveys
↓	Better at-border incursion response efforts
	Saturation [if a country is saturated with alien taxa for a particular group then the rate of new introductions will be zero. However, globally there is little evidence of saturation (Seebens et al. 2017) except for very specific and historic pathways (Liebhold et al. 2017)]
	Changes in the number or intensity of surveys

## Implications for biodiversity management of change in the indicator

Unregulated introductions (illegal, intentional introductions and accidental introductions) indicate that prevention methods have not succeeded.

Unregulated introductions might manifest in a greater number of invasive taxa, and ultimately of the area that they occupy. This in turn would increase the magnitude and complexity of management needed to prevent impact.

## Units in which it is expressed

1.	Number of taxa (species) introduced per year
----	----------------------------------------------

## Description of source data

This information comes from mapping and monitoring projects (such as atlas projects for various taxonomic groups), as well as from periodic surveys and studies.

## Link to workflow

Process to source data covered by 'Workflow to check sources for new introductions', which details which data sources to check and how to process the data.

## Calculation procedure

1.	The number of new alien taxa observed per year is calculated, and an average over the past decade calculated. Taxa which were deliberately introduced are assessed, and if a formal detailed risk analysis that was subject to independent expert review was conducted and as a result their introduction was officially sanctioned, these taxa are not included. Data from 'occurrenceStatus',
----	-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

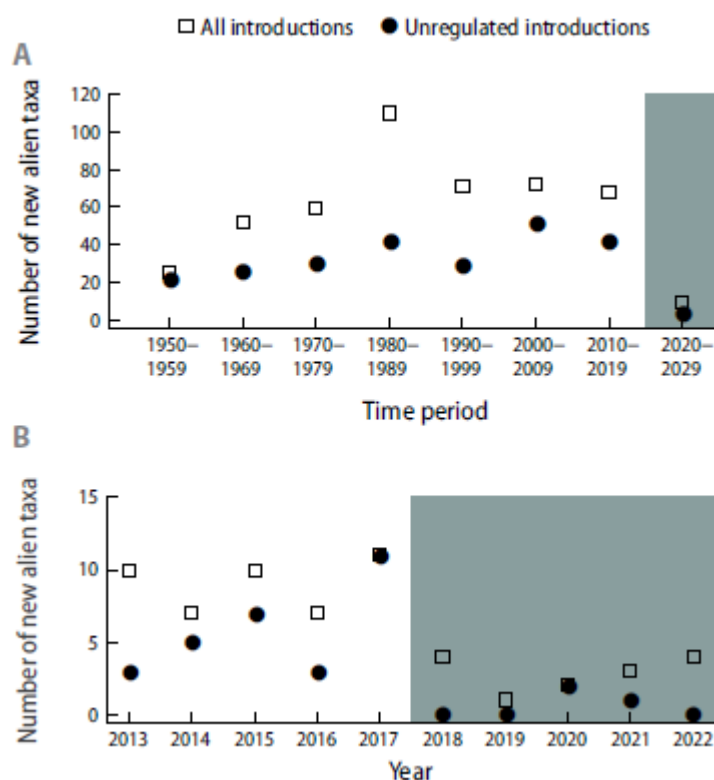
	'isNative', 'degreeOfEstablishment', 'eventDateIntroduction' in the list of alien taxa for South Africa database.
--	-------------------------------------------------------------------------------------------------------------------

### Guide for applying confidence levels

1.	High	There are good data and systems in place to detect new introductions, so the time between an introduction and it being detected will likely be < 5 years; the risk analysis process is transparent and documented in enough detail to allow proper assessment.
	Medium	The majority of introductions are detected within 10 years of probable date of introduction; and/or the risk analysis process is well laid out, though the actual process followed is not entirely clear.
	Low	It is likely there is a substantial delay between introduction and detections (such that the indicator will not be responsive). For example, if a large number of new detections are found without regular and routine monitoring (e.g. by a visiting international taxonomist) then it is likely the increase is not due to new introductions but to sampling effort; and/or the risk analysis process and decisions are not available for scrutiny.

### Most effective forms of presentation

Annual trends in the rates of new detections



**Indicator 1 Figure 1** Number of new alien taxa recorded in South Africa over time: A, over the last eight decades; B, during the last decade. These are alien taxa not previously found or known to be present. The low number of recent unregulated introductions (shaded in grey) likely reflects delays in detecting and reporting alien taxa. Ref: Figure 1.2, p 18, 2023 report.

### Limits to usefulness and accuracy

This indicator is sensitive to survey effort and the availability of sufficient taxonomists to confirm identification of species. The indicator is likely to always be an underestimate, given the difficulties of covering a large area, and of detecting less conspicuous species. A change can be an indication of better survey effort. Ideally an estimate of survey effort is needed (McGeoch et al. 2023).

New introduced species might pose little risk, and so ultimately not be of concern. Likewise, taxa introduced after risk analysis might still cause impacts.

It only looks at new species, but the introduction of new individuals can be problematic for several reasons (e.g. introduction to new sites, introduction of new genetic material).

### Updating the indicator

In South Africa the proposal is to work towards a dashboard of indicators, with updates at least annually if not in real-time.

### Closely related indicators

Depends upon	Links with	Required for
1.2. Introduction rates 2.1. Number and status of alien species	1.1. Introduction pathway prominence 4.4. Pathways treated 4.7. Effectiveness of pathway treatments 4. Level of success in managing invasions	None

### Additional information and comments

It includes reintroductions after species have been eradicated or died out from a region.

### Properties

Property	Response	Notes
Tested	Yes	The indicator has been proposed, tested, and applied to inform on range of situations (both PEIs and mainland South Africa).
Spatially explicit	Yes	The indicator provides information that can be linked to a specific spatial location (e.g., a site, region, and country) so that its features can be associated with that location.
Scalable	No	Needs to be evaluated at different scales.
Temporal	Yes	The indicator provides information that can be linked to a specific time periods.
Uncertainty appraisal	Qualitative	There are delays between when a new species is introduced, observed, and the observation is reported. These delays are impacted by search effort, as well as the detectability of the species.
Taxonomically representative	Yes	The indicator is applicable to all taxa.
Invasive alien species specific	Yes	The indicator is not relevant to native species that either evolved in the area, or spread through natural dispersal from areas in which they evolved.
Reproducible	Yes	The data required are accessible

Property	Response	Notes
Tested	Yes   No	
Spatially explicit	Yes   No	
Scalable	Yes   No	
Temporal	Yes   Partially   No	
Uncertainty appraisal	Qualitative   Quantitative   None	

Taxonomically representative	Yes   No	
Invasive alien species specific	Yes   Partially   No	
Reproducible	Yes   No	

## 1.1. *Introduction pathway prominence*

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Driver

Theory of Change (ToC): NA (as a driver)

### Use and interpretation

'1.1 *Introduction pathway prominence*' concerns the pathways that could facilitate the introduction of alien species to a country from another region. The indicator considers opportunities for introductions that the introduction pathway makes available (how active it is socio-economically), but does not take into account how many introductions these opportunities result in. Depending on the available data, the indicator can be used to answer three questions:

- What is the size of the pathway of introduction?;
- How prominent is the pathway of introduction relative to the other pathways?; and
- How does the size of the pathway of introduction vary across space and time?

### Potential for aggregation

This indicator was developed for use at a national level. However, as data might be available at larger (e.g. regions or continents) or smaller (e.g. provinces or districts) spatial scales, the indicator can also be used at a wide range of scales.

### Possible reasons for trends

↑ or ↓	Changes to the routes travelled by vessels that transport goods and people (e.g., due to the development of new, more favourable routes or political change)
	Changes to the amount or type of goods being imported or the number of people entering a country driven by political (e.g. trade agreements), socio-economic (e.g. consumer and travel trends) or environmental (e.g. droughts) factors.

### Implications for biodiversity management of change in the indicator

An increase in the size or relative prominence of a pathway could mean that there has been an increase in the likelihood that alien organisms could be introduced through this pathway. However, this is not always the case, and various factors (e.g. the phytosanitary policies of the exporting nations and the size of the pool of potential invaders) will influence the strength of this link.

Trends could lead to changes in the pathways that are prioritised for management and, as a consequence, to changes in the allocation of biosecurity resources (money and personnel).

### Units in which it is expressed

1.1.1	Five categories demonstrating the size of each pathway with pathways split along the CBD pathway categorisation (CBD 2014). <ul style="list-style-type: none"><li>• Not known</li><li>• Pathway not present</li><li>• Minor</li><li>• Moderate</li><li>• Major</li></ul>
1.1.2	A ranked order of pathways in terms of their prominence.
1.1.3	Spatially explicit data that detail the amount, number and value of goods/ vessels/people moving into the country per pathway, with information on the sources, routes, destinations and timings.

### Description of source data

Online global or national databases containing trade or transport data run by national governments, intergovernmental or global organisations and companies [e.g. the FAOSTAT database of the Food and Agricultural Organisation of the United Nations (<http://www.fao.org/faostat/en/#data>)]. Yearly

data are often available, however, often not for the most recent years. Data can also be obtained from peer-reviewed journal articles and from the websites and reports of national governments, intergovernmental or global organisations and companies.

### Calculation procedure

See details in workflow '*Introduction pathway prominence*'.

1.1.1	Experts use collected data to categorise each pathway as: <ul style="list-style-type: none"> <li>• Not known</li> <li>• Pathway not present</li> <li>• Minor</li> <li>• Moderate</li> <li>• Major</li> </ul>
1.1.2	For each pathway the amount, number and value of imported goods or vessels is calculated. Pathways are then ranked.
1.1.3	As for 1.1.2., for different entry points and periods of time, no ranking.

### Link to workflow

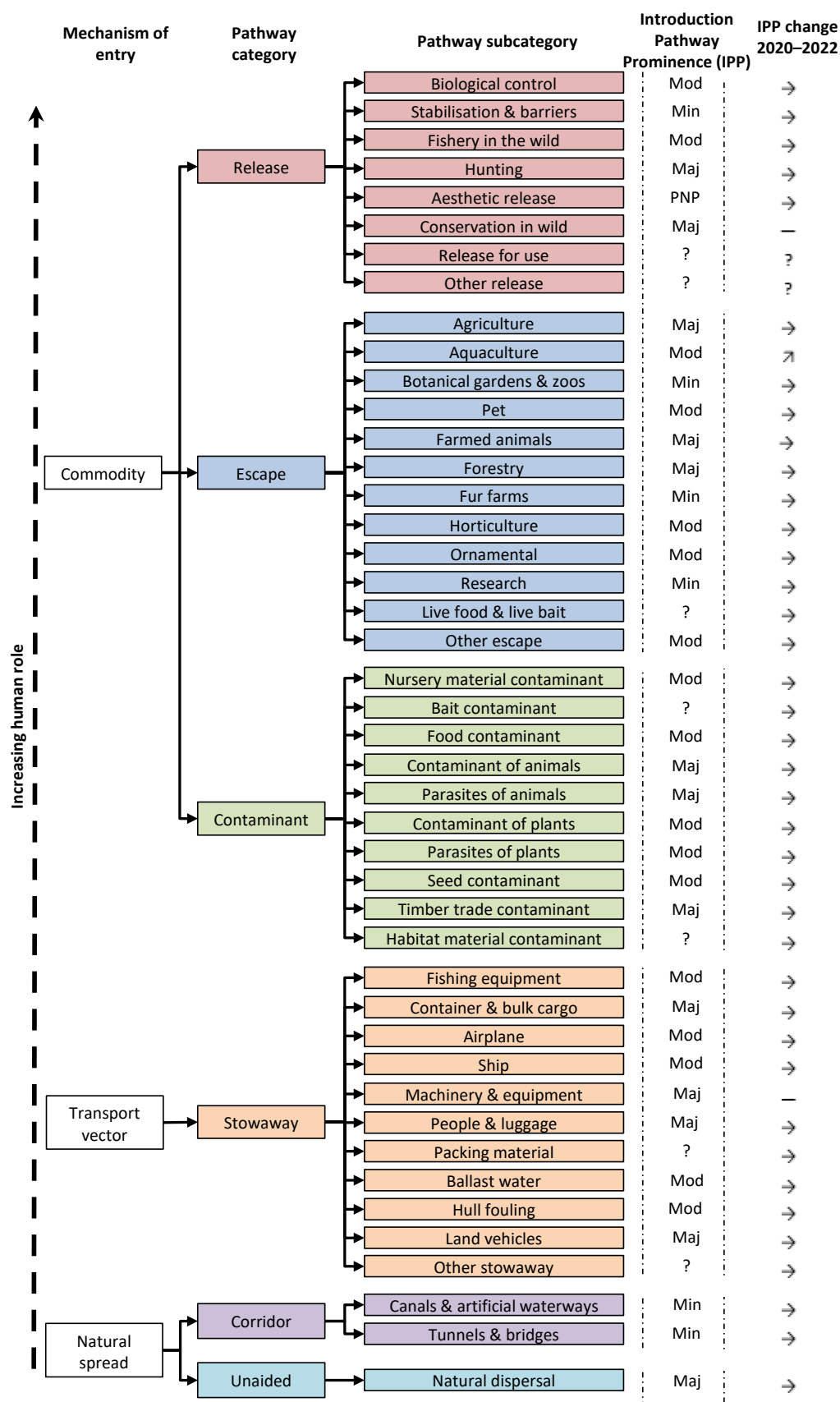
Calculation covered by '*Introduction pathway prominence*'. Workflow used to prepare, process, and plot the socio-economic data required to populate the indicator introduction pathway prominence

### Guide for applying confidence levels

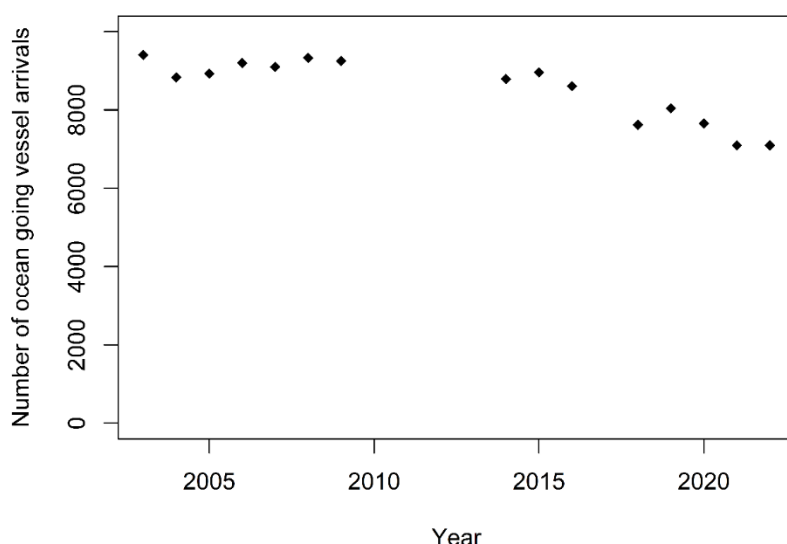
1.1.1	High	Data collated specifically on a particular pathway and recorded regularly (e.g. annually); and evaluated by at least three relevant experts with agreement in almost all cases.
	Medium	Data available across larger time-scales (e.g. decades), or have to be interpreted based on other data sources; and/or evaluation by one expert; and/or a few cases of disagreement with multiple experts
	Low	Few direct estimates of the data or estimated entirely based on expert opinion.
1.1.2	High	Data collated for all pathways in comparable units and recorded regularly (e.g. annually).
	Medium	Data available across larger time-scales (e.g. decades), or substantial interpretation across different data sources is required for comparisons.
	Low	Few direct estimates of the data or rank is based on expert opinion.
1.1.3	High	Regularly recorded, detailed data for every pathway with the destination of the vessels or imports and date of arrival.
	Medium	Data available across larger spatial (e.g. provinces) or temporal scales (e.g. decades), or have to be interpreted based on other data sources.
	Low	Errors in data apparent or clear that some data are inconsistently recorded.

### Most effective forms of presentation

1.1.1	A figure with the CBD pathway subcategories and for each pathway the assigned pathway size
1.1.2	A table with the CBD pathway subcategories and the rank of each pathway, or a figure demonstrating the size of the pathways, with the pathways ordered according to their rank
1.1.3	Maps or figures demonstrating spatial and temporal variation in pathway size



**Indicator 1.1.1 Figure 1**—Introduction pathway prominence for South Africa as of December 2022 and change 2020–2022. Adapted from Figure 1.1. in SANBI and CIB (2023).



**Indicator 1.1.3 Figure 1**— The number of ocean-going vessels arriving at South African ports (excluding fishing vessels) between 2003 and 2022. These data were used to assess the introduction pathway prominence of the ‘ship excluding ballast water or hull fouling’, ‘hull fouling’, and ‘ballast water’ pathways. These data were obtained from Transnet National Ports Authority (2017, 2019, 2023). Figure S1.15 in SANBI and CIB (2023).

#### Limits to usefulness and accuracy

Reliant on data provided by national and global databases, for which data quality might not be known. Data quality may vary between countries, leading to more accurate assessments for some countries than others. Databases that are infrequently updated might cause difficulties when estimating upward or downward trends, or will not be useful if updated less frequently than the indicator is updated. Data that are only available at regional or larger scales, will be unsuitable for national scale assessments. Useful measures of pathway prominence might not be available for all pathways, particularly for less specific pathways such as ‘other escape from confinement’, or will represent groups of related pathways (e.g. the ‘ornamental’ and ‘nursery material contaminant’ pathways). For some pathways there may be various types of data available, and this could lead to differing estimates. Often there is not a direct link between the data that are available and the pathway subcategories, such that it is difficult to aggregate or split data.

#### Updating the indicator

The indicator could be updated yearly or at coarser, but regular time intervals. At the least, the indicator should be updated as often as is required for reporting on the status of biological invasions.

#### Closely related indicators

Depends upon	Links with	Required for
	1.2. Introduction rates 1.3. Within-country pathway prominence A. Rates of introduction of new unregulated species	4.1 Quality of the regulatory framework 4.3. Planning coverage 4.4. Pathways treated 4.7. Effectiveness of pathway treatments 4. Level of success in managing invasions

#### Additional information and comments

For some pathways it might be difficult to access data. For example, some transport data are owned by companies and to gain access to the data or databases a fee is often required. Transport data can be commercially sensitive.

## Properties

Property	Response	Notes
Tested	Yes	The indicator has been proposed, tested, and applied to inform on range of situations (both PEIs and mainland South Africa)
Spatially explicit	Yes	The indicator provides information that can be linked to a specific spatial location (e.g., a site, region, and country) so that its features can be associated with that location.
Scalable	No	Would need to be evaluated at different scales
Temporal	Yes	Can be evaluated over different time periods
Uncertainty appraisal	Quantitative	Confidence estimates provided
Taxonomically representative	No	Does not take what is moved into account
Invasive alien species specific	No	While the introduction pathways facilitate introductions of alien taxa, they are not based on biological invasions per se
Reproducible	Partially	Most of the data required are accessible, but some are confidential trade data. A workflow has been developed, with some aspects automated. The evaluation of prominence is somewhat of an opinion

## 1.2. Introduction rates

### Type of indicator

DPSIR: Pressure

Theory of Change (ToC): Invasion-specific outcome

### Use and interpretation

'1.2. *Introduction rates*' considers the introduction of new alien species to a country from another region through each introduction pathway [i.e., from the introduction debt, Rouget et al. (2016)], a taxon can be ascribed to multiple pathways.

Depending on the available data, the indicator can be used to answer three questions:

- How many species have been introduced through each pathway;
- How has the number of species introduced through the pathway changed over time; and
- How has the number of individuals (of a specific species) introduced through the pathway varied over time and space (i.e. both propagule pressure and colonisation pressure)

The indicator is of particular use for measuring progress towards meeting Target 6 of the Global Biodiversity Framework (CBD 2022).

### Potential for aggregation

This indicator was developed for use at a national level, however, as the national level data can be aggregated, the indicator can also be used at larger spatial scales (e.g. regions or continents). For example, the number of species introduced through a pathway to different countries could be summed to get an indication of the importance of the pathway for a region or continent. As data could be available at both large (e.g. regions or continents) or small spatial scales (e.g. provinces or districts), the indicator can be used at a wide range of scales.

### Possible reasons for trends

↑ or ↓	Changes to what is imported based on political (e.g. changes to trade agreements), environmental, and socio-economic changes (like consumer trends and changes in travel trends)
	Changes to the biosecurity or policies (e.g. phytosanitary policies) of the importing and exporting nations
	Changes in the number or intensity of surveys
	The volume of trade and travel changes, resulting in changes to accidental introductions

### Implications for biodiversity management of change in the indicator

Upward or downward trends could lead to changes in the pathways that need to be prioritised for management and, as a consequence, to changes in the allocation of biosecurity resources (money and personnel).

### Units in which it is expressed

1.2.1	The total number of alien species introduced through each CBD pathway sub-category over all time (CBD 2014).
1.2.2	Five categories demonstrating changes over a recent period of time (e.g., in the past decade) in the number of species introduced through each pathway. <ul style="list-style-type: none"><li>• Not known</li><li>• No introductions</li><li>• Increase</li><li>• Decrease (if there were no introductions then specify)</li><li>• Minimal change (if there were no introductions then specify)</li></ul>
1.2.3	Number of individuals of each species introduced through the pathways and place and date of introduction

## Description of source data

Published peer-reviewed journal articles, alien species lists and databases. These could include local, national or global databases (e.g. the Global Invasive Species Database (<http://www.iucngisd.org/gisd/>), CABI Invasive Species Compendium (<http://www.cabi.org/isc/>)). Some alien species databases are regularly updated (every few years), however, this is not always the case.

## Link to workflow

Process to source data covered by 'Workflow to check sources for new introductions', which details which data sources to check and how to process the data.

## Calculation procedure

Information is extracted as part of the workflow 'Workflow to check sources for new introductions'.

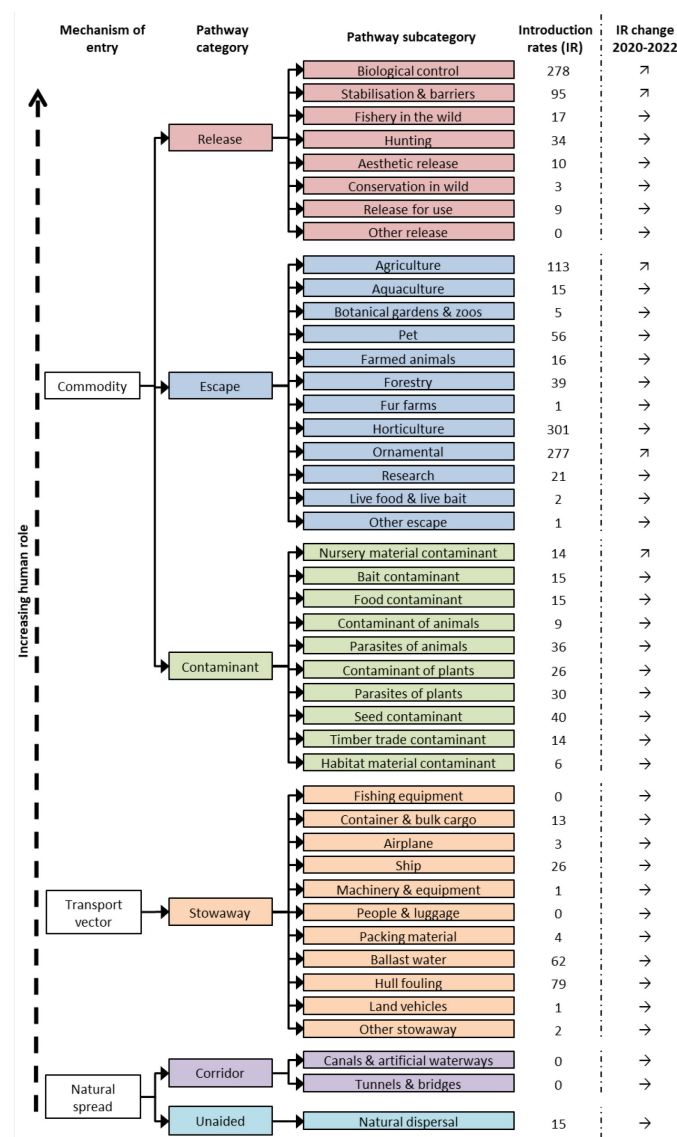
1.2.1.	For each pathway, calculate the total number of alien species introduced. The number and change from previous estimates is presented: <ul style="list-style-type: none"><li>• Increase (new introductions for the pathway recorded during the assessment period)</li><li>• No change (no new introductions for the pathway recorded during the assessment period)</li><li>• First estimate (new pathway that was not present in the previously)</li></ul> Data from 'occurrenceStatus', 'isNative', 'degreeOfEstablishment', 'pathway' in the list of alien taxa for South Africa database.
1.2.2.	For each pathway calculate the number of taxa introduced over the last decade and compare to the number introduced in the previous decade: <ul style="list-style-type: none"><li>• Not known (there have been introductions but not in the last decade, and the pathway or group of organisms typically introduced through the pathway is not well studied)</li><li>• No introductions (no introductions in the last two full decades and the pathway or group of organisms typically introduced through the pathway is well studied)</li><li>• Increase (increase of <math>\geq 5</math> species over the last decade)</li><li>• Decrease (decrease of <math>\geq 5</math> species over the last decade)</li><li>• Minimal change (increase or decrease of <math>&lt; 5</math> species over the last decade)</li></ul> Data from 'occurrenceStatus', 'isNative', 'degreeOfEstablishment', 'eventDateIntroduction' in the list of alien taxa for South Africa database.
1.2.3.	For each entry point and period of time, calculate the number of individuals of each species introduced through each of the pathways

## Guide for applying confidence levels

1.2.1.	High	Direct evidence of the introduction pathway for most alien species and the species can easily be assigned to the pathway subcategories
	Medium	Pathway of introduction for most species can be inferred as the species appeared when and where a single pathway was in operation and there is no other explanation. Species can easily be assigned to pathway subcategories
	Low	Pathway of introduction is inferred for most species based on information on species traits and information from other regions or species cannot easily be assigned to the pathway subcategories. Data are not available for many species, qualitative estimates or based on expert opinion
1.2.2.	High	Specific records exist for each pathway of all the introductions per year
	Medium	Species introductions can be inferred from data on numbers of alien species introduced with knowledge of likely introduction dates (in the order of several years)
	Low	The change in rate is from expert opinion, or data are not available for many species
1.2.3.	High	Detailed, regularly recorded records exist for each introduction for all pathways on the point of introduction and number of individuals introduced
	Medium	Data available across larger spatial (e.g. provinces) or temporal scales (e.g. decades), or have to be interpreted based on other data sources
	Low	Based on expert opinion

## Most effective forms of presentation

1.2.1.	A figure demonstrating the number of alien species introduced through each pathway, and change since previous assessment
1.2.2.	A table with the CBD pathway subcategories and for each pathway the assigned change in introductions (i.e. Increase, decrease, minimal change, no introductions and not known)
1.2.3.	Maps or figures demonstrating spatial and temporal variation in the number of individuals introduced through a pathway



**Indicator 1.2.1 Figure 1**—Number of alien taxa introduced to South Africa through the pathways of introduction through all time, and change from the previous assessment. Adapted from Figure 1.1. in SANBI and CIB (2023).

### Limits to usefulness and accuracy

Difficulties associated with categorising species into the CBD pathway subcategories could lead to inaccuracies, these difficulties could be due to the similarity of some of the pathway subcategories, or as data are not of sufficient detail to make the designations. If pathway and date of introduction information are not available for many species, upward or downward trends in this indicator might be inaccurate. Trends may be influenced by the frequency or intensity of surveys for alien species. It does not consider whether such introductions are desirable or not. If the risk of an introduction was assessed and deemed acceptable prior to introduction, then that species is likely of less concern than accidental or unregulated intentional introductions.

## Updating the indicator

The indicator should be regularly updated as data on alien species introductions becomes available, or as often as is required for reporting on the status of biological invasions.

## Closely related indicators

Depends upon	Links with	Required for
5. Number and status of alien species	1.1. Introduction pathway prominence 1.4. Within-country dispersal rates	4.1 Quality of the regulatory framework 4.3. Planning coverage 4.4. Pathways treated 4.7. Effectiveness of pathway treatments A. Rates of introduction of new unregulated species 4. Level of success in managing invasions

## Additional information and comments

Species might use multiple pathways. Yearly data might be available on alien species introductions, but this temporal scale might be too fine to calculate introduction trends.

It would be useful to record large inter-annual variations in the numbers of introductions per pathway sub-category, but this is not explicitly dealt with here.

The cut-off is in terms of absolute numbers of species, but relative measures could also be used.

## Properties

Property	Response	Notes
Tested	Yes	The indicator has been proposed, tested, and applied to inform on range of situations (both PEIs and mainland South Africa)
Spatially explicit	Yes	The indicator provides information that can be linked to a specific spatial location (e.g., a site, region, and country) so that its features can be associated with that location
Scalable	No	Needs to be evaluated at different scales
Temporal	Yes	The indicator is linked to a specific time periods
Uncertainty appraisal	Qualitative	Confidence estimates provided. There are delays between when a new species is introduced, observed, and the observation is reported. These delays are impacted by search effort, as well as the detectability of the species. Introduction pathways are often not known with certainty
Taxonomically representative	Yes	The indicator provides information that can be linked to taxonomic information. Can be applied to all taxa
Invasive alien species specific	Yes	The indicator is not relevant to native species that either evolved in the area, or spread through natural dispersal from areas in which they evolved
Reproducible	Yes	The data required are accessible

### 1.3. *Within-country pathway prominence*

#### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Driver

Theory of Change (ToC): NA (as a driver)

#### Use and interpretation

'1.3 *Within-country pathway prominence*' concerns the pathways that facilitate the movement of alien species from one part of a country to another. The indicator considers opportunities for within-country movement that the pathway makes available (how active it is socio-economically), but does not take into account how many alien species movements these opportunities result in. Depending on the available data, the indicator can be used to answer three questions:

- What is the size of the pathway?;
- How prominent is the pathway relative to the other pathways?; and
- How does the size of the pathway vary across space and time?

#### Potential for aggregation

This indicator was developed for use at a national level. However, as data might be available at large (e.g. regions or continents) or small (e.g. provinces or districts) spatial scales, the indicator can be used at a wide range of scales.

#### Possible reasons for trends

↑ or ↓	Changes to the routes travelled by vessels that transport goods and people, due to the development of new, more favourable routes or to local socio-economic changes (e.g. in the demand for certain products or travel trends) driven by socio-economic or environmental factors
	Changes to the number of people or the amount or type of goods being transported within the country driven by socio-economic or environmental factors

#### Implications for biodiversity management of change in the indicator

An increase in the size or relative prominence of a pathway could mean that there has been an increase in the likelihood that alien organisms are being dispersed within the country through this pathway. However, this might not be the case as various factors (e.g. the number and type of alien species introduced to the country) will influence the strength of this link.

Similarly, a downward trend in this indicator could mean that there has been a decrease in the likelihood that alien organisms are being moved around the country through a given pathway.

Upward or downward trends could lead to changes in the pathways that are prioritised for management and, as a consequence, to changes in the allocation of resources (money and personnel).

#### Units in which it is expressed

1.3.1.	Five categories demonstrating the size of each pathway with pathways split along the CBD pathway categorisation (CBD 2014). <ul style="list-style-type: none"><li>• Not known</li><li>• Pathway not present</li><li>• Minor</li><li>• Moderate</li><li>• Major</li></ul>
1.3.2.	A ranked order of pathways in terms of their prominence.
1.3.3.	Spatially explicit vectors that detail the amount, number and value of goods or vessels moving around the country per pathway, with information on the sources, routes, destinations and timings.

## Description of source data

Online global or national databases containing trade or transport data run by national governments, intergovernmental or global organisations and companies (e.g. the FAOSTAT database of the Food and Agricultural Organisation of the United Nations (<http://www.fao.org/faostat/en/#data>)). Yearly data are often available, however, often not for the most recent years. Data can also be obtained from peer-reviewed journal articles and the websites and reports of national governments, intergovernmental or global organisations and companies. Spatial data on transportation networks.

## Calculation procedure

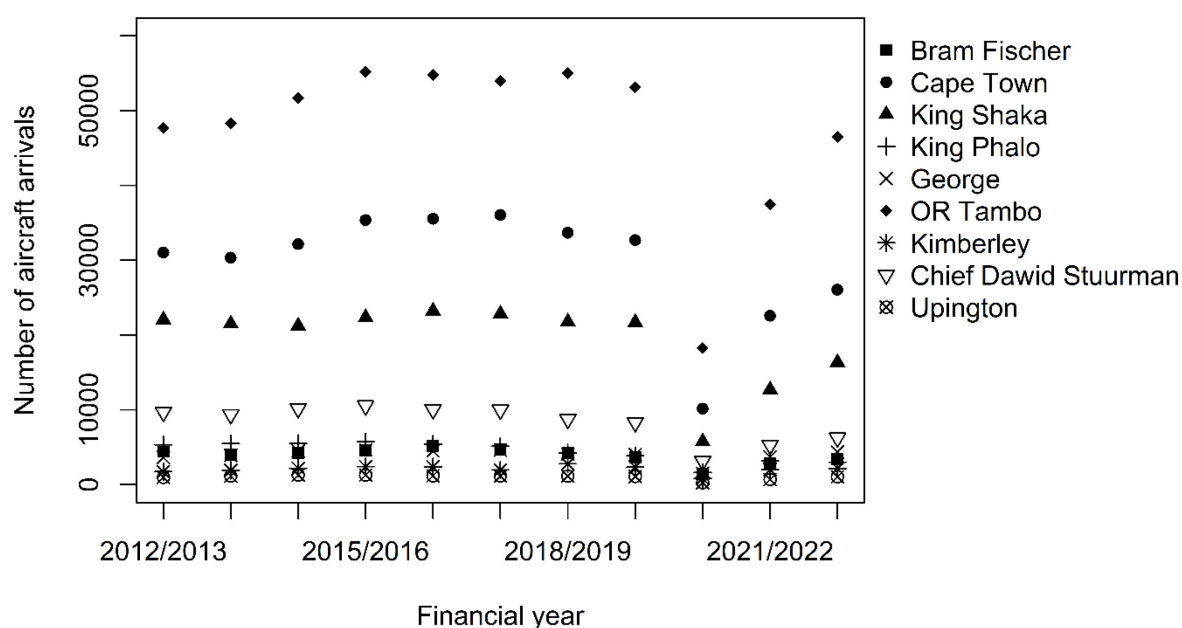
1.3.1.	Experts use collected data to categorise each pathway as: <ul style="list-style-type: none"><li>• Not known</li><li>• Pathway not present</li><li>• Minor</li><li>• Moderate</li><li>• Major</li></ul>
1.3.2.	For each pathway the amount, number and value of transported goods or vessels is calculated. Pathways are then ranked.
1.3.3.	As for 1.3.2., for different routes and periods of time, no ranking

## Guide for applying confidence levels

1.3.1.	High	Data collated specifically on a particular pathway and recorded regularly (e.g. annually). Evaluated by at least three relevant experts with agreement in almost all cases
	Medium	Data available across larger time-scales (e.g. decades), or have to be interpreted based on other data sources and/or evaluation by one expert; and/or a few cases of disagreement with multiple experts
	Low	Few direct estimates of the data or estimated entirely based on expert opinion.
1.3.2.	High	Data collated for all pathways in comparable units and recorded regularly (e.g. annually).
	Medium	Data available across larger time-scales (e.g. decades), or substantial interpretation across different data sources is required for comparisons.
	Low	Few direct estimates of the data or rank based on expert opinion.
1.3.3.	High	Regularly recorded, detailed data for every pathway with the destination of the vessels or goods and date of arrival.
	Medium	Data available across larger spatial (e.g. provinces) or temporal scales (e.g. decades), or have to be interpreted based on other data sources.
	Low	Errors in data apparent or clear that data are inconsistently recorded.

## Most effective forms of presentation

1.3.1.	A figure with the CBD pathway subcategories and for each pathway the assigned pathway size.
1.3.2.	A table with the CBD pathway subcategories and the rank of each pathway, or a figure demonstrating the size of the pathways, with the pathways ordered according to their rank.
1.3.3.	Maps or figures demonstrating spatial and temporal variation in pathway size.



**Indicator 1.3.3 Figure 1**—Number of domestic flight arrivals at South African airports every financial year from 2012/2013 to 2022/2023. Data were obtained from Airports Company South Africa. Figure S1.20 from SANBI and CIB (2023).

#### Limits to usefulness and accuracy

Reliant on data provided by national and global databases, for which data quality might not be known. Data quality might vary between countries leading to more accurate assessments for some countries than others. Databases that are infrequently updated might cause difficulties when estimating upward or downward trends, or will not be useful if updated less frequently than the indicator is updated. Data that are only available at regional or larger scales, will be unsuitable for national scale assessments. Useful measures of pathway prominence might not be available for all pathways, particularly for less specific pathways such as ‘other escape from confinement’, or will represent groups of related pathways (e.g. the ‘ornamental’ and ‘nursery material contaminant’ pathways). For some pathways there may be various types of data available, and this could lead to differing estimates.

#### Updating the indicator

The indicator could be updated yearly or at coarser, but regular time intervals. At the least, the indicator should be updated as often as is required for reporting on the status of biological invasions.

#### Closely related indicators

Depends upon	Links with	Required for
None	1.1. Introduction pathway prominence 1.4. Within-country dispersal rates	4.1 Quality of the regulatory framework 4.4. Pathways treated 4.3. Planning coverage 4.7. Effectiveness of pathway treatments 1. Rate of unregulated introduction of new species 4. Level of success in managing invasions

#### Additional information and comments

For some pathways it might be difficult to access data. For example, some transport data are owned by companies and to gain access to the data or databases a fee is often required. Transport data can be commercially sensitive.

#### Properties

<b>Property</b>	<b>Response</b>	<b>Notes</b>
Tested	Yes	The indicator has been proposed, tested, and applied for the PEIs. For mainland South Africa a lack of within-country socio-economic data has prevented testing
Spatially explicit	Yes	The indicator provides information that can be linked to a specific spatial location (e.g., a site, region) so that its features can be associated with that location
Scalable	No	Would need to be evaluated at different scales
Temporal	Yes	Can be evaluated over different time periods
Uncertainty appraisal	Qualitative	Estimates of confidence provided
Taxonomically representative	Yes	Does not take what is moved into account
Invasive alien species specific	No	While the within-country pathways facilitate introductions of alien taxa, they are not based on biological invasions per se
Reproducible	No	Most data required are not accessible. The evaluation of prominence is somewhat of an opinion

## 1.4. *Within-country dispersal rates*

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Pressure

Theory of Change (ToC): Invasion-specific outcome

### Use and interpretation

'1.4 *Within-country dispersal rates*' considers the number of alien species dispersing within a country through each of the pathways. Depending on the available data, the indicator can be used to answer three questions:

- How many species have dispersed through the pathway?;
- How has the number of species dispersing through the pathway changed over time?; and
- How has the number of individuals (of a specific species) dispersing through the pathway varied over time and space?

The indicator is of particular use for measuring progress towards meeting Target 6 of the Global Biodiversity Framework (CBD 2022).

### Potential for aggregation

This indicator was developed for use at a national level, however, as the national level data can be aggregated, the indicator can also be used at larger spatial scales (e.g. regions or continents). For example, the number of species dispersing through a pathway within different countries could be summed to get an indication of the importance of the pathway for dispersal in a region or continent. As data could be available at both large (e.g. regions or continents) and small spatial scales (e.g. provinces or districts), the indicator can be used at a wide range of scales.

### Possible reasons for trends

↑ or ↓	Environmental and socio-economic changes (like changes to consumer or travel trends)
	The number or intensity of surveys
	Changes to within-country biosecurity

### Implications for biodiversity management of change in the indicator

Upward or downward trends could lead to changes in the pathways that are prioritised for management and, as a consequence, to changes in the allocation of resources.

### Units in which it is expressed

1.4.1.	The total number of alien species native-alien populations dispersing through each pathway over all time, with pathways split along the CBD pathway categorisation (CBD 2014).
1.4.2.	Five categories demonstrating changes over a recent period of time (e.g. in the past decade) in the number of species dispersing through each pathway. <ul style="list-style-type: none"><li>• Not known</li><li>• No dispersal</li><li>• Increase</li><li>• Decrease (if there was no dispersal then specify)</li><li>• Minimal change (if there was no dispersal then specify)</li></ul>
1.4.3.	Number of individuals of each species dispersing through the pathways and place and date of arrival

### Description of source data

Published peer-reviewed journal articles, alien species lists and databases. These could include local, national or global databases (e.g. the Global Invasive Species Database (<http://www.iucngisd.org/gisd/>), CABI Invasive Species Compendium (<http://www.cabi.org/isc/>)).

Some alien species databases are regularly updated (every few years), however, this is not always the case.

### Calculation procedure

1.4.1.	For each pathway, calculate the total number of alien species that have dispersed through the pathway. The number and change from previous estimates is presented: <ul style="list-style-type: none"> <li>• Increase (new introductions for the pathway recorded during the assessment period)</li> <li>• No change (no new introductions for the pathway recorded during the assessment period)</li> <li>• First estimate (new pathway that was not present in the previously)</li> </ul>
1.4.2.	For each pathway and time period, calculate the total number of alien species dispersing through the pathway over the last decade and compare to the number introduced in the previous decade: <ul style="list-style-type: none"> <li>• Not known (there have been dispersal events but not in the last decade, and the pathway or group of organisms typically dispersing through the pathway is not well studied)</li> <li>• No dispersals (no dispersal events in the last two full decades and the pathway or group of organisms typically introduced through the pathway is well studied)</li> <li>• Increase (increase of <math>\geq 5</math> species over the last decade)</li> <li>• Decrease (decrease of <math>\geq 5</math> species over the last decade)</li> <li>• Minimal change (increase or decrease of <math>&lt; 5</math> species over the last decade)</li> </ul>
1.4.3.	For each period of time, calculate the number of individuals of each species dispersing through each of the pathways, and map the various routes followed

### Guide for applying confidence levels

1.4.1.	High	Direct evidence of the dispersal pathway for most alien species and the species can easily be assigned to the pathway subcategories
	Medium	Pathway of dispersal for most species can be inferred as the species appeared when and where a single pathway was in operation and there is no other explanation. Species can easily be assigned to pathway subcategories
	Low	Pathway of dispersal is inferred for most species based on information on species traits and information from other regions or species cannot easily be assigned to the pathway subcategories. Data are not available for many species, qualitative estimates or based on expert opinion
1.4.2.	High	Specific records exist for each pathway for all the dispersal events per year
	Medium	Inferred from data on numbers of alien species with knowledge of likely dispersal dates (in the order of several years)
	Low	The change in rate is from expert opinion, or data are not available for many species
1.4.3.	High	Detailed, regularly recorded records exist for each dispersal event for all pathways on the point of introduction and number of individuals dispersing
	Medium	Data available across larger spatial (e.g. provinces) or temporal scales (e.g. decades), or have to be interpreted based on other data sources
	Low	Based on expert opinion

### Most effective forms of presentation

1.4.1.	A figure demonstrating the number of alien species dispersing through each pathway, and change since previous assessment
1.4.2.	A table with the CBD pathway subcategories and for each pathway the assigned trend in the number of species dispersing through the pathway (i.e. increase, decrease, minimal change, no dispersal and not known)
1.4.3.	Maps or figures demonstrating spatial and temporal variation in the number of individuals dispersing through a pathway

**Indicator 1.4.1 Table 1** — Number of native-alien populations, and number of taxa with native-alien populations introduced through the pathways of dispersal. From Table S1.4 in SANBI and CIB (2023).

Pathway of Introduction		Number of populations	Number of taxa
Release	Biological control	1	1
	Stabilisation and barriers	0	0

Pathway of Introduction		Number of populations	Number of taxa
	Fishery in wild	7	4
	Hunting	1	1
	Aesthetic release	20	11
	Conservation in wild	9	7
	Release for use	0	0
	Other release	6	2
Escape	Agriculture	1	1
	Aquaculture	4	4
	Botanical gardens & zoos	0	0
	Pet	3	2
	Farmed animals	0	0
	Forestry	4	3
	Fur farms	0	0
	Horticulture	0	0
	Ornamental	21	16
	Research	1	1
	Live food and live bait	0	0
	Other escape	0	0
Contaminant	Nursery material contaminant	13	8
	Bait contaminant	0	0
	Food contaminant	0	0
	Contaminant of animals	0	0
	Parasite of animals	0	0
	Contaminant of plants	9	6
	Parasite of plants	0	0
	Seed contaminant	0	0
	Timber trade contaminant	0	0
Stowaway	Habitat material contaminant	7	5
	Fishing equipment	0	0
	Container & bulk cargo	0	0
	Airplane	0	0
	Ship excluding ballast water or hull fouling	3	2
	Machinery & equipment	0	0
	People & luggage	0	0
	Packing material	0	0
	Ballast water	1	1
	Hull fouling	1	1
	Land vehicles	4	2
	Other stowaway	0	0
Corridor	Canals & artificial waterways	8	4
	Tunnels & bridges	0	0
Unaided	Natural dispersal	3	2
Unknown		10	9

### Limits to usefulness and accuracy

Poor data quality (e.g. no direct evidence of the dispersal pathway) might lead to the inaccurate designation of the pathways of dispersal. Difficulties associated with categorising species into the CBD pathway subcategories could lead to inaccuracies, these difficulties could be due to the similarity of some of the pathway subcategories, or as data are not of sufficient detail to make the designations. If pathway and date of introduction information are not available for many species, upward or downward trends in this indicator might be inaccurate. Trends may be influenced by the frequency or intensity of surveys for alien species.

A positive value will not necessarily be undesirable (e.g. for biological control agents), as the redistribution of effective and safe biological control agents is desirable.

Species might use multiple pathways, and this indicator does not distinguish between alien species that pose a risk.

### Updating the indicator

The indicator should be regularly updated as data on the dispersal of alien species becomes available, or as often as is required for reporting on the status of biological invasions.

#### Closely related indicators

Depends upon	Links with	Required for
5. Number and status of alien species	1.2. Introduction rates 1.3. Within-country pathway prominence	4.1 Quality of the regulatory framework 4.3. Planning coverage 4.4. Pathways treated 4.7. Effectiveness of pathway treatments. 1. Rate of unregulated introduction of new species 4. Level of success in managing invasions

#### Additional information and comments

None.

#### Properties

Property	Response	Notes
Tested	No	Both for mainland South Africa and PEIs the number of taxa dispersing through the pathways could not be determined. The number of native-alien populations in South Africa introduced through each of the pathways has been calculated
Spatially explicit	Yes	The indicator provides information that can be linked to a specific spatial location (e.g., a site, region) so that its features can be associated with that location
Scalable	No	Needs to be evaluated at different scales
Temporal	Yes	The indicator is linked to a specific time periods
Uncertainty appraisal	Qualitative	Confidence levels provided. There are delays between when a new species disperses, is observed at the location, and the observation is reported. These delays are impacted by search effort, as well as the detectability of the species. Dispersal pathways are often not known with certainty
Taxonomically representative	Yes	The indicator provides information that can be linked to taxonomic information, and is applicable to all taxa
Invasive alien species specific	Yes	The indicator is not relevant to native species that either evolved in the area, or spread through natural dispersal from areas in which they evolved
Reproducible	Partially	The data required are not available

## 2. Number of invasive species that have ‘Major’ impacts

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Impact

Theory of Change (ToC): Invasion-specific outcomes

### Use and interpretation

Alien species that have been reported to have a Major (**MR**) or Massive (**MV**) impact in a country under either the EICAT or SEICAT are those that are of significant current concern to that country; the implication is that species-specific control efforts are currently needed to reduce the impacts of invasions (e.g., a national species-specific management programme). While species that have Moderate (**MO**) impacts are considered ‘harmful’ by the IUCN (2020), they have not been reported to cause losses in native species or activities in a particular country; and so may be of less immediate concern. The total number of alien species that have been reported to have a Major (**MR**) or Massive (**MV**) impact thus provides an indication of the current size and complexity of the species-specific responses needed. An increase in the ‘Number of invasive species that have ‘Major’ impacts’ indicates an increase in consequences and management complexity (as the number of species grows, so too will the range of impacts).

Importantly the focus is on the most recent records of impact at each site within the country, and does not consider impact elsewhere, i.e., in different countries (see calculation procedure).

### Potential for aggregation

This is a high-level indicator aggregated across all the taxa found in the country. It can be split up into different functional or taxonomic groups and aggregated to larger spatial scales.

### Possible reasons for trends

↑	Impacts of existing alien species have increased over time
	Newly introduced alien species start having impact
	Better documentation of impacts
↓	Species are brought under effective control such that their impacts decrease
	The magnitude of a recorded impacts was overscored (e.g., alien species shown to be a passenger rather than a driver of the impact)
	There has been a change in the system such that the impact of a species is no longer so severe (e.g., the climate has changed and become less suitable for the species)

### Implications for biodiversity management of change in the indicator

A genuine increase would usually mean a greater cost of biological invasions to society. However, it is likely that many changes to the scoring of this indicator will be based on improved knowledge.

Linking the indicator to action (e.g., mandating all taxa with an **MR** or **MV** impact require a national-management plan) would ensure that impact records will be more likely to result in action.

### Units in which it is expressed

2.	Number of species
----	-------------------

### Description of source data

Published literature on impacts, and published EICAT and SEICAT reports for the country. Note the IUCN’s EICAT database hosted on the GISD focusses on impact at a global level, it is necessary to download the detailed data on impact records to confirm that a given impact was recorded in a given country.

### Calculation procedure

2.	<p>Species are assessed through the EICAT and SEICAT schemes specifically for the country (e.g., <i>impactEICATSouthAfrica</i> and <i>impactSEICATSouthAfrica</i>). However, unlike scoring EICAT using the IUCN scheme, the score can decrease as well as increase. Historically, a species might have been recorded to have had a Major (MR) or Massive (MV) impact at a site; but if a genuine reduction in the magnitude of impact has been recorded, the overall impact for that species might now be lower than MR and should be scored as such. The assumption, however, is that unless there is clear evidence to the contrary, the impact is scored as the greatest ever recorded at any site within the country.</p> <p>The number of species that currently have 'Major' or 'Massive' impacts in any impact mechanism are added up.</p>
----	----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

### Guide for applying confidence levels

Three different aspects to the confidence level can be evaluated:

- 1) the degree to which species in a country have been assessed using EICAT or SEICAT;
- 2) the degree to which there are data available to assign an EICAT or SEICAT magnitude to each species in a country; and
- 3) the confidence by which an EICAT or SEICAT magnitude has been assigned to each species in a country, e.g., based on EICAT and SEICAT guidelines (note there would need to be some way of aggregating such confidence levels).

The only aspect with potentially irreducible uncertainty is the third aspect (e.g., the impact might be on the border between two impact magnitudes). Given there are also substantial technical difficulties in combining confidence levels, the following only considers aspects one and two.

Confidence level can be applied either to all invasive species or to a specific subset.

2.	High	For at least 90% of invasive species ( <i>IntroductionStatus</i> ='Invasive'): the impact has been assessed (using both EICAT and SEICAT) AND there are impact data (i.e., not DD) (see indicator 2.4.1)
	Medium	For 50–90% of invasive species ( <i>IntroductionStatus</i> ='Invasive'): the impact has been assessed (using both EICAT and SEICAT) AND there are impact data (i.e., not DD) (see indicator 2.4.1)
	Low	For <50% of invasive species ( <i>IntroductionStatus</i> ='Invasive'): the impact has been assessed (using both EICAT and SEICAT) AND there are impact data (i.e., not DD) (see indicator 2.4.1)

### Most effective forms of presentation

Trend over time as a line graph, with the species added and removed flagged.

The example is shown below.

**Indicator 2. Table 1** Number of invasive species that have at least 'Major' impacts in South Africa. Adapted from pXVI SANBI and CIB (2023).

Head-line Indicator	Trend	Confidence	Notes
2. Number of invasive species that have 'Major' impacts	↗	low (many taxa still need to be assessed)	The impact of 36 invasive species has been assessed in a manner similar to that of the IUCN's EICAT scheme. Of these, <b>19 invasive species</b> are reported to cause Major or Massive impacts in mainland South Africa. No invasive species were recorded to have MR or MV impacts under SEICAT.

### Limits to usefulness and accuracy

This indicator depends on regular and ongoing surveys and documentation of impacts. The indicator is likely to always be an underestimate given the difficulties of covering a large area and of detecting less conspicuous invasive species and their impacts, as well as the resources required to document **MR** and **MV** impacts. On the other hand, recovery from high impacts (after control, for example) is rarely studied, which makes it difficult for the indicator to decrease at any stage.

### Updating the indicator

See '2.4. Impact of alien species' and the workflows 'Alien taxa impact assessment' and 'Tracking data sources and adding data as published'. In essence need a process for sourcing data on impacts and for conducting, updating, and collating impact assessments themselves. Currently these processes are not in place.

### Closely related indicators

Depends upon	Links with	Required for
2.1. Number and status of alien species 2.4. Impact of alien species 4.8. Effectiveness of species treatments	3. Extent of area that suffers 'Major' impacts from invasions 4. Level of success in managing invasions	None

### Additional information and comments

A species which has a **MR** impact based on one mechanism or that affects one native species will be rated as of more concern than a species which has a **MO** impact based on several impact mechanisms or that affect several native species.

### Properties

Property	Response	Notes
Tested	Yes	A value was derived for the Prince Edward Islands, South Africa's sub-Antarctic Islands (Fernández Winzer et al. 2025). Four species have caused MR or MV impacts, this is known with medium confidence (out of 25 invasive species, 14 have been assessed all of which have data on impact magnitude). This was not explicitly measured over time. Current values for South Africa are misleading as few impact assessments have been performed.
Spatially explicit	Yes	The impacts need to be recorded within the country.
Scalable	Yes	Information on where impacts were recorded can be used to define recorded impact magnitude at whichever scale; in practice the smaller the area the less information will be available.
Temporal	Partially	Information is available as to when impacts were first recorded, although it is hard to relate this to the point at which impacts occurred at a particular magnitude. Impacts are rarely studied over time.
Uncertainty appraisal	Quantitative	The confidence level is presented as a qualitative value (low, medium, or high), but is based on a quantitative value (the proportion of invasive species in a region that have an assessed impact magnitude)
Taxonomically representative	Yes	The indicator can be used for specific taxonomic groups with the intention that EICAT and SEICAT can be applied to any alien taxon.
Invasive alien species specific	Yes	EICAT and SEICAT methodologies focus on impacts in the alien ranges.
Reproducible	Partially	The indicator relies on published evidence and follows accepted standardised protocols for impact classification. However, there could be differences between assessors in the interpretation of available evidence or the use of the protocols, therefore it is deemed somewhat reproducible.

## 2.1. Number and status of alien species

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): State

Theory of Change (ToC): Invasion-specific outcomes

### Use and interpretation

The basis for constructing lists of alien taxa for a country.

Such information is important for biosecurity to be able to target species which are not yet present and to identify threats based on what is already in the country. If the status is known this can be used to estimate the establishment part of the invasion debt, i.e., how many alien taxa are likely to establish in future.

Gives an indication of the effectiveness of species-focused control measures.

### Potential for aggregation

Can be presented per taxonomic group or aggregated across all species. Can be used at a variety of spatial scales, depending on the scale at which data are available.

### Possible reasons for trends

↑	[in numbers] New alien species are introduced
	[in numbers] Alien species that were already introduced were detected for the first time
	[in statuses] Alien species exiting a lag phase, i.e., there was a mechanistic reason preventing establishment or invasion that has been lifted
	[in statuses] Alien species had sufficient time in a country for populations to build up and spread and so exhibit invasive potential
	[in statuses] Establishment or invasion detected for the first time
↓	[in numbers] Eradication
	[in numbers or statuses] Populations unintentionally wiped out (e.g., removal of habitat)
	[in numbers or statuses] Populations naturally die and collapse
	[in statuses] Effective management (though typically management will not impact the degreeOfEstablishment)
↑ or ↓	[in numbers or statuses] Taxonomic revisions

### Implications for biodiversity management of change in the indicator

The detection of a new alien species should trigger an evaluation and potentially an incursion response. If status increases, it might indicate a need to reassess the invasive risk of an alien taxa and potentially precipitate an incursion response.

For taxa which are no longer in the country, biosecurity resources can be reallocated to controlling other targets or to preventing future introductions.

### Units in which it is expressed

2.1.1.	Number of invasive species
2.1.2.	<p>Number of alien species in one of three categories corresponding to: <i>IntroductionStatus</i></p> <ul style="list-style-type: none"> <li>• presentAsAlienNotEstablished</li> <li>• EstablishedNotInvasive</li> <li>• Invasive</li> </ul> <p>Additional terms are available to address native-alien populations</p> <ul style="list-style-type: none"> <li>• EstablishedNotInvasive:NativeAlienPopulations</li> <li>• Invasive:NativeAlienPopulations</li> </ul>
2.1.3.	<p>Number of alien species in one of 12 categories: <i>degreeOfEstablishment</i> (adapted from Groom et al. 2019; based on Blackburn et al. 2011)</p> <ul style="list-style-type: none"> <li>• A0: Not introduced</li> </ul>

	<ul style="list-style-type: none"> <li>• A1: No longer present</li> <li>• B1: captive</li> <li>• B2: cultivated</li> <li>• B3: released</li> <li>• C0: failing</li> <li>• C1: casual</li> <li>• C2: reproducing</li> <li>• C3: established</li> <li>• D1: colonising</li> <li>• D2: invasive</li> <li>• E: widespreadInvasive</li> </ul> <p>Introduced but not established corresponds to B1–C2 Established but not invasive corresponds to C3–D1 Invasive corresponds to D2–E</p>
--	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

### Description of source data

Data are analysed from South Africa's list of alien taxa, for the latest version see: <https://doi.org/10.5281/zenodo.7433102>. Data sources used in the list of alien taxa are collated here: <https://zenodo.org/10.5281/zenodo.17185376>

### Calculation procedure

See 'Introduction status and degreeOfEstablishment' workflow, a subroutine of the 'Adding alien taxa and enrichment data to the species list' workflow.

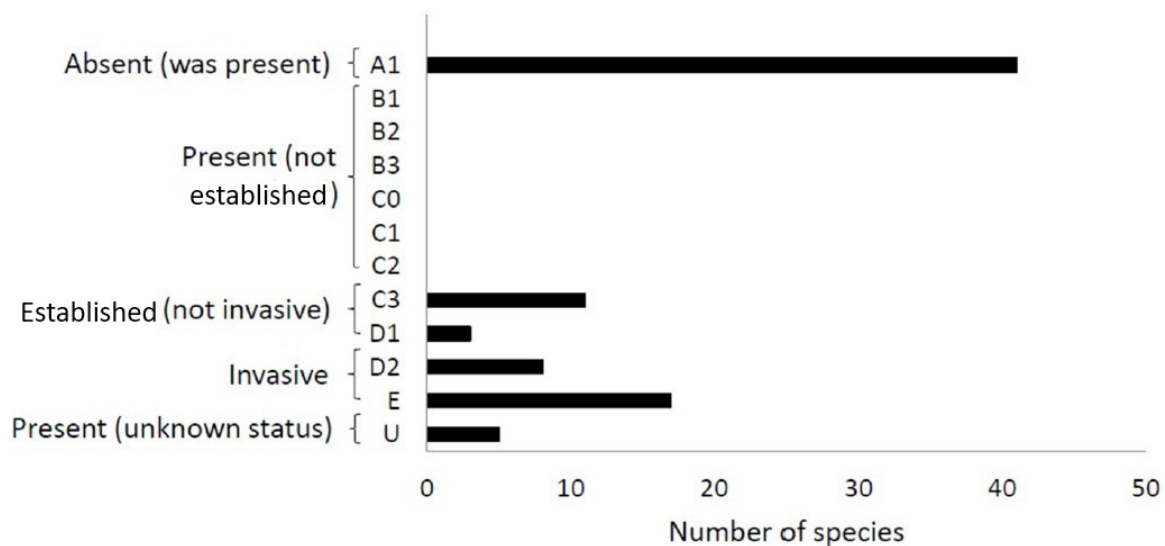
2.1.1.	The total number of taxa in South Africa's list of alien taxa for which <i>occurrenceStatus</i> = 'present' AND <i>IntroductionStatus</i> = 'Invasive' If native-alien populations are included can also include <i>IntroductionStatus</i> = 'Invasive:NativeAlienPopulations'
2.1.2.	The total number of taxa in each category of <i>IntroductionStatus</i>
2.1.3.	The total number of taxa in each category of <i>degreeOfEstablishment</i>

### Guide for applying confidence levels

2.1.1.	High	At a taxon level, there is strong evidence the taxon is alien (see <i>isNativeConfidence</i> ) it is present (see <i>occurrenceStatusConfidence</i> ) AND it is invasive ( <i>IntroductionStatusConfidence</i> ). How confidence levels are to be aggregated, e.g., for how many taxa should the confidence be High for the overall confidence to be High has not been determined.
	Medium	At a taxon level, there is evidence the taxon is alien (see <i>isNativeConfidence</i> ) it is present (see <i>occurrenceStatusConfidence</i> ) AND it is invasive ( <i>IntroductionStatusConfidence</i> )
	Low	<i>isNativeConfidence</i> and <i>occurrenceStatusConfidence</i> need to be at least medium otherwise the taxon should not be included in a list; as such for low confidence <i>IntroductionStatusConfidence</i> must be low. Either scoring is interpreted from distribution data in an atlas project or similar listing project OR invasiveness is based on expert opinion only with no clear indication of last field observation.
2.1.2.	High	Inherited from <i>IntroductionStatusConfidence</i>
	Medium	Inherited from <i>IntroductionStatusConfidence</i>
	Low	Inherited from <i>IntroductionStatusConfidence</i>
2.1.3.	High	Inherited from <i>degreeOfEstablishmentConfidence</i>
	Medium	Inherited from <i>degreeOfEstablishmentConfidence</i>
	Low	Inherited from <i>degreeOfEstablishmentConfidence</i>

### Most effective forms of presentation

2.1.1.	As a number
2.1.2.	In a bar chart
2.1.3.	As a table, or as a bar chart (can be plotted as a bar chart noting changes)



**Indicator 2.1.3 Figure 1** The degree of establishment of alien taxa recorded as having at some point been introduced to the Prince Edward Islands. Adapted from Fernández Winzer et al. (2025).

#### Limits to usefulness and accuracy

It can be highly sensitive to search effort and taxonomy, so for under-studied taxonomic groups, the number of alien species in a country will be a function of how much material has been collected and whether taxonomists have worked on it.

Assumes an equivalency between species, e.g., one alien tree species is the same as one mite species.

It relies on species being well defined concepts.

It does not encapsulate invasion at lower than the level of a whole organism, e.g., at the gene level (Petit 2004).

There can be inconsistencies in the use of the terminology, e.g. in some databases the definition of “invasive” requires populations to be found in “natural” areas or that a negative impact of some sort has been recorded.

#### Updating the indicator

Should be done on an on-going basis as new detections are made and new instances of establishment or invasions are noted. However, it might be necessary for a specific effort to be made to update records according to the *degreeOfEstablishment*, and guidelines for scoring different taxa are still needed.

#### Closely related indicators

Depends upon	Links with	Required for
2.2. Extent of alien species (for 5.3) 2.3. Abundance of alien species (for 5.3)	None	1.2. Introduction rates 1.4. Within-country dispersal rates 2.2. Extent of alien species 2.3. Abundance of alien species 2.4. Impact of alien species 3.1. Alien species richness 3.2. Relative invasive abundance 3.3. Impact of invasions 4.1 Quality of the regulatory framework 4.2. Money spent 4.3. Planning coverage

		4.4. Pathways treated 4.5. Species treated 4.7. Effectiveness of pathway treatments 4.8. Effectiveness of species treatments 4.9. Effectiveness of site treatments 1. Rate of unregulated introduction of new species 2. Number of invasive species that have 'Major' impacts 3. Extent of area that suffers 'Major' impacts from invasions 4. Level of success in managing invasions
--	--	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

### Additional information and comments

At a basic level, the metric is the number of invasive species rather than number of alien species. This is because for many groups only invasive species will be known with any level of accuracy (they tend to be much more detectable). However, it does require additional information that taxa are actually invasive.

Species which are both native and alien to a region (i.e., that form native-alien populations) need to be dealt with consistently. Whether they are included or not should be specified clearly whenever a metric for *2.1 Number and status of alien species* is specified.

Similarly, it is important to specify whether taxa for which *isNative* is scored as *Cryptogenic* are included.

Should link to various databases, e.g., the Global Register of Introduced and Invasive Species, that provide checklists of alien species in a country.

While regulatory lists can provide some indication of alien species, it is often difficult to trace these to verified physical records, and they might be the result of some prioritisation exercise (so are only a subset of species that have undesirable impacts).

### Properties

Property	Response	Notes
Tested	Yes	Explicitly for the Prince Edward Islands, more data collection is needed for a South Africa wide evaluation
Spatially explicit	Yes	Presence and invasive status are for a particular region
Scalable	No	Why presence and invasive status in one part of a region will imply presence and invasive status in a broader region, it is not directly possible to scale down
Temporal	Partially	The numbers are at a given point in time and so it would be possible to track over time as invasions progress
Uncertainty appraisal	Qualitative	Uncertainty levels are given for classifying specific taxa, but not, as yet, for the overall indicator
Taxonomically representative	Yes	Can be used for different groups, although the species concept is less reliable for some taxa
Invasive alien species specific	Yes	Explicitly refers to the introduction-establishment-invasion continuum
Reproducible	Yes	Based on specific lists of alien taxa that if FAIR, the values can readily be recalculated

## 2.2. Extent of alien species

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): State

Theory of Change (ToC): Invasion-specific outcome

### Use and interpretation

Provides an indication of how widespread alien species are and provides information that can be used for metrics of how invaded sites are and where impacts might be occurring.

Species that are more widespread or that are increasing in range might be considered to be of greater concern (Parker et al. 1999), though there can often be a weak link between extent and impact across species (Hulme 2012).

### Potential for aggregation

Can provide an overall picture of which alien species are the most widespread. Can be split along taxonomic or functional lines to provide an indication of which are the most widespread alien taxa.

### Possible reasons for trends

↑	Greater survey effort
	Species dispersing (either naturally or particularly through human-mediated within-country dispersal at broader spatial scales)
↓	Populations die out through natural means, e.g. stochastic climatic events and directional shifts in climate
	Populations are extirpated by effective control
↑ or ↓	Errors in reporting

### Implications for biodiversity management of change in the indicator

Provides an indication of the area over which management interventions are needed for a given species. Declines (or a relative reduction in spread rates) can indicate the effectiveness of control interventions.

### Units in which it is expressed

The unit are all estimates of extent of occurrence (EOO) at a particular spatial scale with a specified resolution

2.2.1.	Number of large-scale national subdivisions (provinces, primary catchments or bioregions as appropriate) occupied per species
2.2.2.	Number of finer-scale national subdivisions (quarter-degree grid cells or hectads) occupied per species
2.2.3.	Range size for each species (e.g. km <sup>2</sup> or ha) for a specific alpha hull value

### Description of source data

Data are analysed from South Africa's list of alien taxa, for the latest version see: <https://doi.org/10.5281/zenodo.7433102>. Data originate from atlas projects or distribution surveys, with occurrences extracted from such data published by GBIF or as part of SAPIA (the Southern African Plant Invaders Atlas) if such data is not incorporated into GBIF.

### Calculation procedure

See 'Adding alien taxa and enrichment data to the species list' workflow.

2.2.1.	The total number of taxa in South Africa's list of alien taxa in each category of <i>RangeBroadAdmin</i> or <i>RangeBroadEcol</i> , broken down by taxonomic group or family as appropriate.
2.2.2.	Values in <i>RangeQDGC</i> are extracted and collated accordingly.
2.2.3.	Values in <i>RangeExact</i> are extracted and collated accordingly taking <i>RangeExactType</i> into account. The values for <i>RangeExact</i> are based on a technique is applied to observation data in a GIS using an

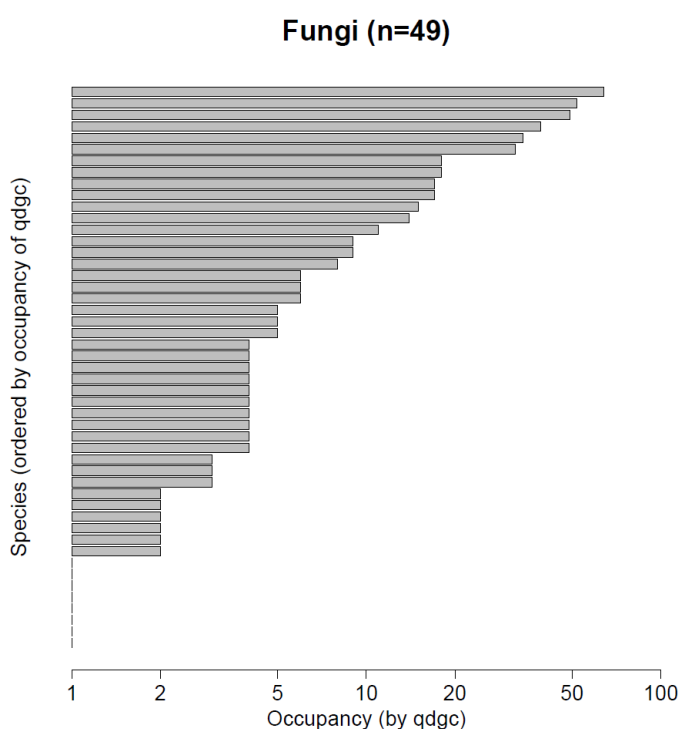
	appropriate projection. In some cases a convex hull approach might be sufficient, but might need to use an alpha-hull approach for species with disjunct distributions (likely for many aliens).
--	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

### Guide for applying confidence levels

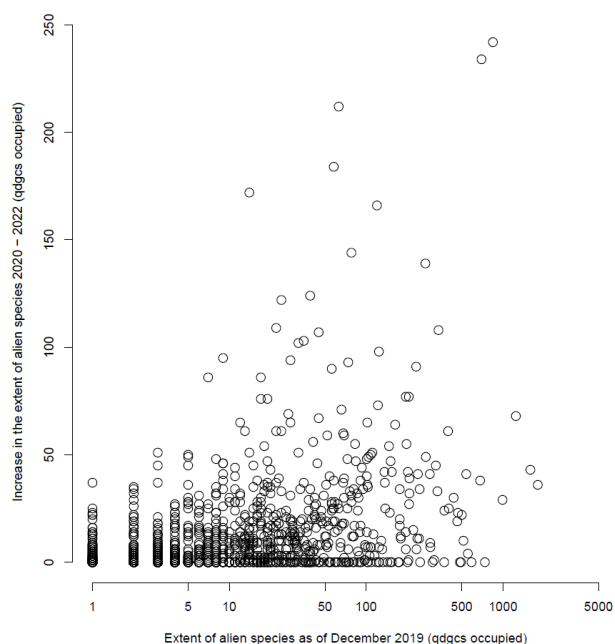
2.2.1.	High	Inherited from <i>RangeBroadAdminConfidence</i> and <i>RangeBroadEcolConfidence</i> :  Included in a formal verified atlas or mapping project based on recent surveys with adequate ground-truthing. There is some indication that there have been surveys at sites where the taxon is not recorded as present.
	Medium	Data from an atlas project, though it is not explicit that sites where it is not recorded as present would have been recorded/some sites might not have been surveyed.
	Low	Interpreted from expert opinion
2.2.2.	High	Inherited from <i>RangeQDGCCConfidence</i> (wording <i>RangeBroadAdminConfidence</i> )
	Medium	Inherited from <i>RangeQDGCCConfidence</i>
	Low	Inherited from <i>RangeQDGCCConfidence</i>
2.2.3.		Inherited from <i>RangeExactConfidence</i>
	High	Data based on a project within the last decade specifically designed to map the range of the taxon in question, with search effort explicit and sufficient to determine where taxa are and where they are not. Might include citizen science component for easily identified taxa. Appropriate statistical technique used to estimate total range size (particular if disjunct distributions).
	Medium	Data from atlas project or general mapping project with indication of sampling effort, but data not complete or not recent (e.g., >10 years old).
	Low	No absence data, no clear statistical methodology for estimating range size, or very broad estimate.

### Most effective forms of presentation

2.2.1.	Bar chart showing frequency distribution of range per taxon; plot of how ranges have changed over time
2.2.2.	As for 2.2.1.
2.2.3.	As for 2.2.1.



**Indicator 2.2.2 Figure 1** The distribution in broad-scale range sizes of alien fungal taxa in South Africa. Range sizes are plotted on a log scale (qdgcs is quarter-degree grid cell). Data are from GBIF. Based on Figure 2.2 in SANBI and CIB (2023).



**Indicator 2.2.2 Figure 2** The increase in the recorded extent of 2402 alien species in South Africa (December 2019 vs. December 2022) at the scale of a quarter-degree grid cell (qdgcs). The possibility that taxa are no longer present in a qdgcs is not assessed (and so no taxa can have decreased extent). Data are from SAPIA (accessed 17 March 2020) and GBIF (accessed 26 August 2023). Occupancy is plotted on a log scale (i.e., the x-axis) and change in occupancy is on a linear scale. Based on Figure 2.3 in SANBI and CIB (2023).

### Limits to usefulness and accuracy

An alien taxon might be present at a site but restricted to particular environments (in some cases human influenced), or at very low density, so the indicator does not map directly to impact.

The accuracy of the data will depend on large-scale repeated surveys.

Often need to assume absences, and in many databases these are not recorded.

If a taxon is present historically at a site it is not clear what is needed to show it is no longer present (and so metrics can go down as well as up).

### Updating the indicator

This can be done ad hoc but ideally should be linked to set survey frequency or at least with respect to repeat surveys.

### Closely related indicators

Depends upon	Links with	Required for
5. Number and status of alien species	None	1.4. Within-country dispersal rates 5. Number and status of alien species 2.3. Abundance of alien species 2.4. Impact of alien species 3.1. Alien species richness 3.2. Relative invasive abundance 3.3. Impact of invasions 4.1 Quality of the regulatory framework 4.2. Money spent

		4.3. Planning coverage 4.4. Pathways treated 4.5. Species treated 4.6. Sites treated 4.7. Effectiveness of pathway treatments 4.8. Effectiveness of species treatments 4.9. Effectiveness of site treatments 1. Rate of unregulated introduction of new species 2. Number of invasive species that have 'Major' impacts 3. Extent of area that suffers 'Major' impacts from invasions 4. Level of success in managing invasions
--	--	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

### Additional information and comments

At a finer-scale it can be important to consider presence in ecologically relevant sub-divisions, e.g. habitats or vegetation types.

The abundance can be used in concert with the extent to look at dynamics across scales, e.g. Kunin (1998). Such area-occupancy curves can be used to explore mechanisms affecting dispersal dynamics (Veldtman et al. 2010; Donaldson et al. 2014).

### Properties

Property	Response	Notes
Tested	Yes	Has been used for the status report
Spatially explicit	Yes	Refers to extent at a particular spatial scale
Scalable	Yes	Can be upscaled and downscaled easily depending on the resolution
Temporal	Partially	Given the difficulties in recording absences after a presence was recorded, while values can be tracked over time, there is likely some error there
Uncertainty appraisal	Quantitative	Minimum coordinate uncertainty included in the calculation procedure
Taxonomically representative	Yes	Can be displayed for particular groups (e.g., Indicator 2.2.2 Figure 1)
Invasive alien species specific	Yes	IAS specific in the sense that it can be calculated only for alien taxa, though of course it can also be calculated for native taxa
Reproducible	Yes	A workflow has been developed based on information and workflows from the B-Cubed project ( <a href="https://b-cubed.eu">https://b-cubed.eu</a> ) to track the extent of alien species. Estimates can be recalculated using the workflow

## 2.3. Abundance of alien species

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Impact

Theory of Change (ToC): Invasion-specific outcomes

### Use and interpretation

Provides an indication of how many individuals there are of particular species. Can be used as part of prioritisation efforts for species-specific control measures.

### Potential for aggregation

Can be split into taxonomic groups.

### Possible reasons for trends

↑	Population growth
	More survey work
↓	Population decline
↑ or ↓	Changes in survey method or models used to estimate abundance

### Implications for biodiversity management of change in the indicator

Core outcome variable for the effectiveness of species-based interventions. Changes could lead to the reallocation of resources.

### Units in which it is expressed

2.3.1.	Categorical measure of abundance per species per locality in one of five categories: <ul style="list-style-type: none"><li>• not known</li><li>• absent</li><li>• rare</li><li>• occasional</li><li>• abundant</li></ul>
2.3.2.	Number of individuals for mobile organisms or condensed area occupied for sessile organisms
2.3.3.	Abundance estimates divided into appropriate stage or age cohorts. At a basic level numbers of individuals which are reproductive or not.

### Description of source data

Field or remotely sensed observations, some representative sub-sampling of populations that are then used to extrapolate total population estimates (e.g. mark-recapture), or direct counts of individuals.

### Calculation procedure

2.3.1.	If <i>organismQuantityCategorical</i> =T then refer to <i>organismQuantityCategoricalSource</i> and extract the relevant data
2.3.2.	Values in <i>organismQuantityExact</i> are extracted and collated accordingly taking <i>organismQuantityExactType</i> into account, as necessary referring back to <i>organismQuantityExactSource</i> to extract the relevant data
2.3.3.	If <i>organismQuantityDetailed</i> =T then refer to <i>organismQuantityDetailedSource</i> and extract the relevant data

### Guide for applying confidence levels

2.3.1.	High	Inherited from <i>organismQuantityCategoricalConfidence</i>  Recent survey, technique used well documented, and several people confirming the value obtained (e.g., included in a formal verified atlas or mapping project based on recent surveys with adequate ground-truthing).
--------	------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

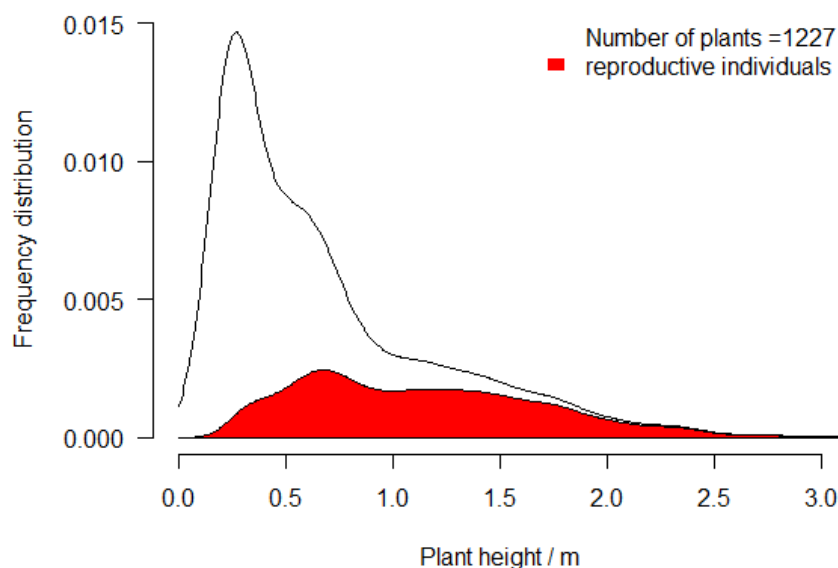
	Medium	Data from an atlas project or recent survey but only one person.
	Low	Interpreted from expert opinion, or no clear basis for the value given, or over 10 years ago.
2.3.2.	High	Inherited from <i>organismQuantityExactConfidence</i> Accurate and recent population census, using appropriate statistical techniques.
	Medium	Estimation based on sampling that uses assumptions and makes extrapolations
	Low	Expert opinion.
2.3.3.	High	Evaluate each <i>organismQuantityDetailedSource</i> using the scoring for 2.3.1 and 2.3.2 as guidelines
	Medium	Evaluate each <i>organismQuantityDetailedSource</i> using the scoring for 2.3.1 and 2.3.2 as guidelines
	Low	Evaluate each <i>organismQuantityDetailedSource</i> using the scoring for 2.3.1 and 2.3.2 as guidelines

### Most effective forms of presentation

2.3.1.	Bar chart of different species / tables
2.3.2.	Frequency histogram of different species / tables
2.3.3.	Size distribution graphs for each taxon, with indications of which individuals are reproductively active.

Taxon	Abundance
<i>Sagina procumbens</i>	0.90 (mean % cover)
<i>Poa annua</i>	0.39 (mean % cover)
<i>Agrostis stolonifera</i>	0.10 (mean % cover)
<i>Cerastium fontanum</i>	0.07 (mean % cover)
<i>Poa pratensis</i>	0.04 (mean % cover)
<i>Mus musculus</i>	1 760 000 (total number of individuals)

**Indicator 2.3.2 Table 1.** Abundance of selected alien plants and vertebrates on Marion Island adapted from Fernández Winzer et al. (2025). The estimate for mice is for lowland elevations (below 300 m a.s.l.) (McClelland et al. 2018; Fig. 3b); noting densities up to ~ 230 mice/ha. The annual peak density of mice experienced a 430% increase over the thirty-year period from 1979–1980 to 2008–2011.



**Indicator 2.3.3 Figure 1** Size frequency distribution from established populations of *Genista monspessulana* in South Africa in 2012 (Geerts et al. 2013). Data are pooled from several sites, and roughly a tenth of the total population estimate (~10,000 plants) were measured. In addition, *G. monspessulana* was estimated to have a seed-bank of several million.

#### Limits to usefulness and accuracy

Without stage-structured information, coarse numbers can be a bit misleading as there might be a large number of juveniles and few reproductively active adults (so population growth will at least initially be slow).

As for extent, abundance does not necessary map on to impact.

#### Updating the indicator

Can be updated after individual surveys, might be part of annual progress reports.

#### Closely related indicators

Depends upon	Links with	Required for
2.1. Number and status of alien species 2.2. Extent of alien species	None	2.1. Number and status of alien species 2.4. Impact of alien species 3.1. Alien species richness 3.2. Relative invasive abundance 3.3. Impact of invasions 4.1 Quality of the regulatory framework 4.2. Money spent 4.3. Planning coverage 4.5. Species treated 4.6. Sites treated 4.8. Effectiveness of species treatments 4.9. Effectiveness of site treatments 1. Rate of unregulated introduction of new species 2. Number of invasive species that have 'Major' impacts 3. Extent of area that suffers 'Major' impacts from invasions 4. Level of success in managing invasions

#### Additional information and comments

The abundance can be used in concert with the extent to look at dynamics across scales, e.g. Kunin (1998). Such area-occupancy curves can be used to explore mechanisms affecting dispersal dynamics (Veldtman et al. 2010; Donaldson et al. 2014).

#### Properties

Property	Response	Notes
Tested	Yes	There are few data collated to date at the national South Africa level, but information has been collated for the Prince Edward Islands
Spatially explicit	Yes	The abundance measures are explicitly over a particular region
Scalable	?	NA
Temporal	Partially	Data on abundance will be collected at a specific time and so time series can be generated provided there is repeat similar sampling
Uncertainty appraisal	?	Depends. If sampling has been consistent, it is likely that quantitative measure of uncertainty in abundance estimates can be calculated
Taxonomically representative	Yes	Has flexibility to look at different life forms (sessile vs. non-sessile in particular)
Invasive alien species specific	Yes	IAS specific in the sense that it can be calculated only for alien taxa, though of course it can also be calculated for native taxa
Reproducible	Partially	Set workflows are still to be developed to facilitate this, noting that in some cases the information is stored in papers and may require work to store it in a format that can be readily used here



## 2.4. Impact of alien species

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Impact

Theory of Change (ToC): Invasion-specific outcomes

### Use and interpretation

Identify which alien species are causing the largest negative impacts.

Helps identify which types of impacts are most common (i.e., the impact mechanisms).

If the current impact level is less than the maximum impact level ever recorded this provides an indication that any interventions to reduce impacts might have been successful.

### Potential for aggregation

Can be scaled up, i.e., if impact is 'Massive' at a local scale it will be 'Massive' at a global scale.

However, in scaling down an assumption might be that impacts should only be considered where they were recorded and as such most sites will have no impacts recorded.

### Possible reasons for trends

↑	Increases in the extent and abundance of alien species (with per capita impact staying the same)
	Impacts accruing over time due to lagged biodiversity responses (Essl et al. 2015)
↓	Mitigation or management is effective in reducing impacts
↑ or ↓	Improved reporting or attribution of impacts

### Implications for biodiversity management of change in the indicator

There might be a change in which species should be prioritised for management. If the impact of a species declines, then it might be indicative of successful management.

### Units in which it is expressed

2.4.1.	<p>Categorical factor with eight levels. For each species, a single value should be given which is the maximum current recorded impact in the region. The impact will be the maximum of either the Environmental Impact Classification of Alien Taxa (EICAT) or Socio-economic Impact Classification of Alien Taxa (SEICAT) schemes (IUCN 2020; Bacher et al. 2018) across all mechanisms and constituents of human wellbeing.</p> <ul style="list-style-type: none"><li>• NE   Not evaluated</li><li>• NA   No alien populations in the region</li><li>• DD   Data deficient</li><li>• MC   Minimal Concern</li><li>• MN   Minor</li><li>• MO   Moderate</li><li>• MR   Major</li><li>• MV   Massive</li></ul>
2.4.2.	<p>Same eight levels as above, but three values are provided: the maximum global impact, the maximum impact ever recorded in South Africa, and the current maximum impact.</p>

### Description of source data

Published literature on impacts of alien species.

### Calculation procedure

See details in the workflow '*Alien taxa impact assessment*'

2.4.1.	See IUCN (2020) for EICAT and Bacher et al. (2018) for SEICAT. The current maximum recorded impact might be different from the maximum ever recorded.
--------	-------------------------------------------------------------------------------------------------------------------------------------------------------

	Information extracted from <i>impactEICATSouthAfrica</i> and <i>impactSEICATSouthAfrica</i> for each taxon, in both cases these are a single value with the maximum in a region.
2.4.2.	Information will need to be extracted from both <i>impactEICATSouthAfricaSource</i> and <i>impactSEICATSouthAfricaSource</i> on the full ranges of impacts; and information from <i>impactEICATSource</i> and <i>impactSEICATSource</i> updated based on the latest international sources. Need to ensure additional information on date and locations of impact (at least for South Africa) are included as well.

### Guide for applying confidence levels

2.4.1.	High	Inherited from <i>impactEICATSouthAfricaConfidence</i> and <i>impactSEICATSouthAfricaConfidence</i> , based on published guidelines [IUCN (2020) for EICAT; Bacher et al. (2018) for SEICAT]; see also Probert et al (2020) in particular Table 3. Approximate probability of the impact being correct is 90%
	Medium	As for 2.4.1. High, except approximate probability of the impact being correct is 65–75%
	Low	As for 2.4.1. High, except approximate probability of the impact being correct is 35%
2.4.2.	High	As for 2.4.1., with global values inherited from <i>impactEICATConfidence</i> etc.
	Medium	As for 2.4.1., with global values inherited from <i>impactEICATConfidence</i> etc.
	Low	As for 2.4.1., with global values inherited from <i>impactEICATConfidence</i> etc.

### Most effective forms of presentation

2.4.1.	A histogram or table of species per category.
2.4.2.	A histogram showing which mechanisms are most frequently recorded for a given group at a given level of impact.

**Indicator 2.4.2 Table 1** Selected alien species for which impact has been recorded in South Africa. The data in this section of the table are from Jansen and Kumschick (2022), noting the study also looked at global impacts for these taxa (not shown here). Adapted from Table S2.4 in SANBI and CIB (2023). The confidence in each of these estimates is not shown here.

scientificName	Impact mechanism	impactEICAT SouthAfrica	impactEICAT	impactSEICAT SouthAfrica	ImpactSEICAT
<i>Acacia baileyana</i>	Competition  Changes to ecosystem functioning	Major	Major	Data Deficient	Data Deficient
<i>Acacia cyclops</i>	Changes to ecosystem functioning	Major	Major	Data Deficient	Data Deficient
<i>Acacia dealbata</i>	Indirect impacts through species interactions	Major	Major	Minor	Minor
<i>Acacia decurrens</i>	Not recorded	Data Deficient	Moderate	Minimal Concern	Minor
<i>Acacia longifolia</i>	Competition	Major	Major	Minor	Minor
<i>Acacia mearnsii</i>	Competition  Changes to ecosystem functioning  Indirect impacts through species interactions  Threats to safety	Major	Major	Minor	Minor
<i>Acacia melanoxylon</i>	Not recorded	Minimal concern	Major	Data Deficient	Minor
<i>Acacia saligna</i>	Competition  Changes to ecosystem functioning  Indirect impacts through species interactions	Major	Major	Data Deficient	Data Deficient

### Limits to usefulness and accuracy

Dependent on the availability of published assessments of impact. As such it will normally represent an observed minimum, and underestimate impacts. It only represents observed historical impact and not necessarily current actual impact.

There are currently no set methods to distinguish between current maximum and maximum ever recorded, but this will be essential if a decrease in this indicator is to be documented (e.g., as a result of effective or permanent control, cf. indicator 4.8 *Effectiveness of species treatments*).

### Updating the indicator

Can be updated as new studies are published.

### Closely related indicators

Depends upon	Links with	Required for
2.1. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species 3.2. Relative alien abundance	4.1. Quality of the regulatory framework 4.2. Money spent 4.5. Species treated	2. Number of invasive species that have 'Major' impacts 3. Extent of area that suffers 'Major' impacts from invasions 4. Level of success in managing invasions 3.3. Impact of invasions 4.3. Planning coverage 4.5. Species treated 4.8. Effectiveness of species treatments 4.9. Effectiveness of site treatments

### Properties

Property	Response	Notes
Tested	Yes	Has been used at a national South African level and global level though noting much data still needs to be collated as most taxa have not been evaluated to date
Spatially explicit	Yes	The impact refers to the maximum across a specified region
Scalable	No	While impact measures can be scaled up, given impacts are frequently context dependent, extrapolating impacts to lower spatial resolutions is unwise
Temporal	Partially	The impact is assigned the year when the study was conducted; though noting it will not be clear at what point the actual impact reached this level
Uncertainty appraisal	Qualitative	Both EICAT and SEICAT have guidance for evaluating qualitative uncertainty for specific impact assessments (linked to cut-offs), however it is not clear how these uncertainties propagate when comparisons are made across multiple taxa. The uncertainty measures in this indicator rather refer to the extent to which the EICAT and SEICAT guidelines and frameworks were demonstrably followed
Taxonomically representative	Yes	The indicator can be used for any alien taxon and aggregated for specific taxonomic groups
Invasive alien species specific	Yes	EICAT and SEICAT are specific to alien taxa
Reproducible	Partially	The indicator relies on published evidence and follows accepted standardised protocols for impact classification. However, there could be differences between assessors in the interpretation of available evidence or the use of the protocols, therefore it is deemed somewhat reproducible

### 3. Extent of area that suffers 'Major' impacts from invasions

*Note: in trying to apply this indicator in practice it is clear further development is needed to define the indicator and outline calculation procedures for it to be fit for purpose. As such what is listed is below should be regarded as under development.*

#### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Impact

Theory of Change (ToC): Invasion-specific outcomes

#### Use and interpretation

The extent of invaded area that suffers 'Major' impacts (with definitions of impact magnitude intended to correspond to those of the ICAT schemes) gives an indication of the overall extent of impacts of biological invasions. Invaded areas are expected to deliver fewer or diminished ecosystem services and/or to support lower levels of biodiversity.

#### Potential for aggregation

This is a high-level indicator, already aggregated at a national level.

#### Possible reasons for trends

↑	Growth of populations of alien species with negative impacts
	Spread of alien species with negative impacts to previously un-invaded areas
	Increase in the impacts over time (e.g., accumulated effects and crossing of impact thresholds)
↓	Control measures reducing the invaded cover or abundance
↑ or ↓	Reassessments of extent of invasions and attribution of impacts

#### Implications for biodiversity management of change in the indicator

Increases in the extent of the invaded area that suffers 'Major' impacts would indicate increasing pressure on biodiversity and the delivery of ecosystem services. Given that the resources required to manage the problem will almost certainly be insufficient to control all sites effectively, sites would need to be prioritised and managed accordingly.

#### Unit in which it is expressed

3.	Area or proportion of the country
----	-----------------------------------

#### Description of source data

Assigning values to this indicator requires the assessment of the impact of invasions at fine scales across the whole country, and aggregation to a national level. Currently in South Africa, this is only possible for alien plants at the scale of quarter-degree grid cells, where species presence and abundance are recorded. Even then, estimates are coarse as invasions recorded within grid cells do not necessarily cover the entire grid cell.

#### Calculation procedure

3.	Data on indicator 3.3. Impact of invasions is used, and the total area with 'Major' impacts calculated
----	--------------------------------------------------------------------------------------------------------

#### Guide for applying confidence levels

3.	High	As per indicator 3.3.
	Medium	As per indicator 3.3.
	Low	As per indicator 3.3.

#### Most effective forms of presentation

A map showing areas that have 'Major' impacts; a single figure stating the proportion of the area of the country assessed as having 'Major' impacts.

This indicator was scored in the first status report (SANBI and CIB 2018), as 1.4% with low confidence. The information was based on the only available estimate of condensed cover alien plants in South Africa. It was not rescored in subsequent reports as there was insufficient confidence in the value. It was not assessed in the study of the Prince Edward Islands (Fernández Winzer et al. 2025).

### Limits to usefulness and accuracy

The sites currently experiencing 'Major' impacts might not be those that should be prioritised for management. For example, returns on investment might be greater at sites where there are currently low levels of invasion or that are responsible for higher rates of spread (i.e., to prevent future invasions and impacts).

### Updating the indicator

Monitoring both of levels of invasion at a site and of outcomes broader than invasions (e.g., water flow) is required.

### Closely related indicators

Depends upon	Links with	Required for
2.1. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species 2.4. Impact of alien species 3.1. Alien species richness 3.2. Relative invasive abundance 3.3. Impact of invasions 4.6. Sites treated 4.9. Effectiveness of site treatments	2. Number of invasive species that have 'Major' impacts 4. Level of success in managing invasions	None

### Additional information and comments

Will be important to link this indicator to other data on biodiversity and ecosystem functioning.

The impacts that occur need not to be at the same location as where the invasions are found, e.g., reduction in water availability due to invasions at the top of a catchment.

### Properties

Property	Response	Notes
Tested	No	An initial estimate was provided in the first status report (SANBI and CIB, 2018) but then not reassessed
Spatially explicit	Yes	The intention is that the indicator will be presented as a map
Scalable	Yes	Depends on the resolution of the distribution data, but can be readily recalculated for different parts of a larger region
Temporal	Yes	It is in theory feasible to track over time
Uncertainty appraisal	None	Currently no evaluation of uncertainty is provided
Taxonomically representative	Yes	The indicator focusses on sites rather than taxa and so would be classed as taxonomically representative as per the guidelines
Invasive alien species specific	Yes	The indicator specifically refers to invasions
Reproducible	No	The data needed are not currently available

### 3.1. Alien species richness

#### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): State

Theory of Change (ToC): Invasion-specific outcomes

#### Use and interpretation

This is an indicator of the number of alien species at a particular site. Higher numbers of invasive species indicate the number of issues to be addressed, while higher numbers of all alien species indicate a higher risk of invasion, as a proportion of these species can be expected to become invasive over time. The indicator can be used at a range of scales to track invasion debt.

#### Potential for aggregation

This indicator is expressed at a particular spatial scale (for example a country, a province, or a municipality; or at primary, secondary or tertiary catchment scales) and can be aggregated upwards from data collected at finer scales.

#### Possible reasons for trends

↑	More introductions and spread of alien species around the region
↓	Extirpation of alien species from a region or failed to establish self-sustaining populations and disappeared locally
↑ or ↓	Changes to taxonomy or survey efforts might affect values

#### Implications for biodiversity management of change in the indicator

As alien species richness increases, the number of species that need to be managed increase. As resources to manage all species over the whole site would probably be limiting, species would need to be prioritised in terms of potential impacts on biodiversity.

If the invasion stage is known, it can also be used to identify potential hotspots of future establishment.

#### Units in which it is expressed

3.1.1.	The total number of invasive species per large-scale national sub-division.
3.1.2.	The total number of invasive species per finer-scale national sub-division.
3.1.3.	The number of alien species in different stages of the Unified Framework per finer-scale national sub-division

#### Description of source data

Records of alien species distribution at scales suitable for upward aggregation. In South Africa, the prominent example is the Southern African Plant Invaders Atlas (SAPIA), in which presence and absence are recorded at the scale of quarter-degree grid cells (QDGCs), and these can be examined at higher spatial scales.

#### Calculation procedure

See 'Adding alien taxa and enrichment data to the species list' workflow.

3.1.1.	A count of invasive species within a large-scale national subdivision.
3.1.2.	A count of invasive species within a finer-scale national subdivision.
3.1.3.	A count of alien species at different stages of the Unified Framework within a finer-scale national subdivision.

#### Guide for applying confidence levels

3.1.1.	High	Based on recent (within the past 5 years) data from across the entire site, populations are formally recorded as invasive.
--------	------	----------------------------------------------------------------------------------------------------------------------------

	Medium	Based on recent data from surveys that cover portions of all or most habitat types within the site and/or there is documentation that some populations are invasive.
	Low	Based on older data (collected more than five years ago), or data gathered from some, but not all, habitat types within the site.
3.1.2.	High	Based on data in which at least 80% of the finer-scale units have been surveyed over the past five years.
	Medium	Based on data in which at least 40% of the finer-scale units have been surveyed over the past five years.
	Low	Based on data in which less than 40% of the finer-scale units have been recently surveyed, or where data from finer-scale units are older than five years
3.1.3.	High	As for 3.1.2., with confidence level for alien species status from 2.1.3.
	Medium	As for 3.1.2., with confidence level for alien species status from 2.1.3.
	Low	As for 3.1.2., with confidence level for alien species status from 2.1.3.

### Most effective forms of presentation

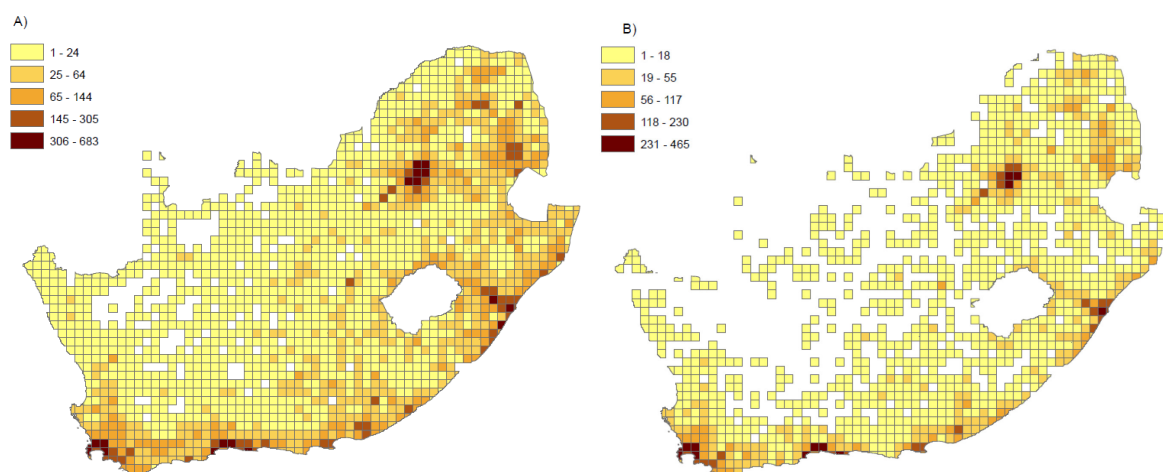
3.1.1.	A table or map of invasive species richness per large-scale national subdivision.
3.1.2.	A table or map of invasive species richness per finer-scale national subdivision.
3.1.3.	Tables or maps of alien species at different stages of the Unified Framework within finer-scale national subdivisions.

**Indicator 3.1.1. Table 1** Alien terrestrial and freshwater plant species richness per province. The values are based on records available from GBIF (<https://www.gbif.org/>) and the Southern African Plant Invaders Atlas (SAPIA) for continental South Africa. Adapted from Table 3.1a SANBI and CIB (2023).

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

**Indicator 3.1.2. Table 1** Invasive species in protected areas in South Africa. Adapted from Table 3.1e SANBI and CIB (2023) and excludes biocontrol agents and marine species.

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



**Indicator 3.1.2. Figure 1** A) Alien species richness of plants in South Africa per quarter-degree grid cell (qdegc) as of December 2022, and B) the change in these values since December 2019. Adapted from Figure 3.1 SANBI and CIB (2023).

#### Limits to usefulness and accuracy

Large sites would have to be covered on a regular basis to detect trends.

The indicator works well for highly visible taxa (terrestrial plants, birds), but not for others.

In some cases it is not clear if records represent invasive populations or presence within captivity or cultivation.

#### Updating the indicator

Can in theory be updated dynamically, but likely only done for reports on status, e.g. three years at a national level for South Africa. This would be useful for highly visible taxa, but for other taxa a longer period between updates would be more appropriate.

#### Closely related indicators

Depends upon	Links with	Required for
2.1. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species	None	3.3. Impact of invasions 4.1 Quality of the regulatory framework 4.3. Planning coverage 4.5. Species treated 4.8. Effectiveness of species treatments 4.9. Effectiveness of site treatments 3. Extent of area that suffers 'Major' impacts from invasions 4. Level of success in managing invasions

#### Additional information and comments

The indicator at lower levels does not make a distinction between records of invasive populations and alien populations. Most data, however, are collected on invasive populations (e.g. excluding plants in people's gardens).

#### Properties

Property	Response	Notes
Tested	Yes	Is included in national status reports for South Africa
Spatially explicit	Yes	Values are for a particular region
Scalable	Yes	Depending on the resolution of the underlying data it can be scaled up
Temporal	Yes	Have seen values change over time

Property	Response	Notes
Uncertainty appraisal	None	There are broad qualitative confidence levels given, but the uncertainty in each evaluation is not formally measured. Minimum coordinate uncertainty is included in the calculation procedure
Taxonomically representative	Yes	Can work for different taxa
Invasive alien species specific	Yes	Although it can also be for native taxa
Reproducible	Yes	A workflow has been developed based on information and workflows from the B-Cubed project ( <a href="https://b-cubed.eu">https://b-cubed.eu</a> ) to track the extent of alien species. Data can be downloaded and the estimates can be recalculated using the workflow

## 3.2. *Relative invasive abundance*

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): State

Theory of Change (ToC): Invasion-specific outcomes

### Use and interpretation

This indicator measures the degree to which a site is invaded by considering the combined abundance of all invasive populations present relative to the abundance of indigenous and invasive organisms. *Relative invasive abundance* is a useful indicator of the degree of stress on an ecosystem, and it can be used at a range of spatial scales.

### Potential for aggregation

Can be split into taxonomic groupings.

### Possible reasons for trends

↑	Decreases in native abundance (not related to invasions)
	Increases in invasions (spread and population growth)
	Invasions leading to increases in native abundance
↓	Vice versa for ↑ (though more likely due to active interventions, e.g., control of invasions and restoration of natives)

### Implications for biodiversity management of change in the indicator

Increases in area in low-level categories should be accompanied by decreases in high-level categories, and vice-versa, providing a means for assessing the effectiveness of control measures.

Management would presumably seek to reduce the *relative invasive abundance* at high priority sites. If trends indicate that management is not effective, it would inform decisions about the prioritisation and allocation of scarce funds to sites where they would be more effectively used.

### Units in which it is expressed

3.2.	The proportion of the abundance (measured as cover, biomass, or number of individuals depending on the taxonomic group under consideration) that is invasive expressed at six levels for a given spatial unit <ul style="list-style-type: none"><li>• not known</li><li>• invasive-free</li><li>• minor</li><li>• moderate</li><li>• extensive</li><li>• dominant</li></ul>
3.2.	A quantitative estimate of the percentage abundance that is invasive for a given spatial unit

### Description of source data

The relative invasive abundance would be assessed for particular sites. The data required would depend on the basis of measurement chosen. For example, the use of plant cover could be derived from mapping exercises, or from remote sensing; estimating numbers of individuals would require a population census; and estimating biomass would require physical sampling or remote sensing. Ideally these kinds of data should be assembled during the development of management plans, and tracked through regular monitoring of progress towards management goals.

### Calculation procedure

3.2.1.	Basic information for this indicator should be collected at the scale of management units, for example protected areas or tertiary or quaternary catchments. Each unit is assigned to a single
--------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

	<p>category of relative abundance based on the proportion of the abundance of alien species to indigenous species, as follows:</p> <ul style="list-style-type: none"> <li>• Invasive-free: No invasive populations occur at the site.</li> <li>• Minor: Invasive plants cover &lt; 2% of the area that is covered by plants; or invasive species make up &lt; 2% of the biomass of the entire community; or populations of invasive animals make up &lt; 2% of all individual animals at the site.</li> <li>• Moderate: Invasive plants cover 2–10% of the area covered by plants, or invasive species make up 2–10% of the biomass of the area; populations of invasive animals make up 2–10% of all individual animals at the site.</li> <li>• Extensive: Invasive plants cover 10–50% of the area covered by plants, or invasive species make up 10–50% of the biomass of the area; populations of invasive animals make up 10–50% of all individual animals at the site.</li> <li>• Dominant: Invasive plants cover &gt; 50% of the area covered by plants, or invasive species make up &gt; 50% of the biomass of the area; populations of invasive animals make up &gt; 50% of all individual animals at the site.</li> </ul>
3.2.2.	As above, but with a quantitative estimate

### Guide for applying confidence levels

3.2.1.	High	Cover estimates are based on mapping or the use of remote sensing that samples > 80% of the area of the site; biomass estimates are made on the basis of sampling a representative set of habitats, and extrapolated on the basis of reliable habitat maps; population estimates are made on the basis of sampling that covers > 80% of the area of the site.
	Medium	Cover estimates are based on mapping or the use of remote sensing that samples 20–80% of the area of the site; biomass estimates are made on the basis of limited sampling, and/or extrapolated on the basis of coarse habitat subdivisions; population estimates are made on the basis of sampling that covers 20–80% of the area of the site.
	Low	All estimates are based on local knowledge of the area concerned, or on limited sampling that covers < 20% of the area of the site.
3.2.2.	High	As for 3.2.1.
	Medium	As for 3.2.1.
	Low	As for 3.2.1.

### Most effective forms of presentation

3.2.1.	Bar chart, map, or table
3.2.2.	Bar chart or map

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

**Indicator 3.2.1. Table 1** Estimates of relative invasive abundance in South Africa's protected areas based on percentage plant cover. Adapted from Table 3.2 SANBI and CIB (2023)

### Limits to usefulness and accuracy

This indicator requires detailed mapping. It is thus most likely to be used at smaller spatial scales. It will nevertheless be useful for assessing the levels of invasion in particular types of areas, for example protected areas.

It requires information on indigenous abundances as well, and, when dealing with coverage data, the total coverage might either be much greater than 100% (i.e., overlapping canopies), or less than 100% (i.e. bare rock).

The impact of different levels of relative abundance will also vary. An understory shrub at 50% coverage might have much lower impacts than a vine that overtops and smothers vegetation which is also at 50% coverage.

### Updating the indicator

This indicator would be assessed at the scale for which management plans are available, and where goals are set to achieve reductions in the relative abundance of alien species. Monitoring and updating of the database on which this indicator is based should be continuous, as management is ongoing, likely as part of annual planning updates.

### Closely related indicators

Depends upon	Links with	Required for
2.1. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species	None	2.4. Impact of alien species 3.3. Impact of invasions 4.3. Planning coverage 4.7. Effectiveness of pathway treatments 4.8. Effectiveness of species treatments 4.9. Effectiveness of site treatments 2. Number of invasive species that have 'Major' impacts 3. Extent of area that suffers 'Major' impacts from invasions 4. Level of success in managing invasions

### Additional information and comments

The data can be linked to other GIS layers to look at possible interactions, e.g. with human footprint.

Rather than broad taxonomic groups, it can be important to consider functional groups, or function itself, e.g. what proportion of photosynthesis in a given region is due to alien species (and how has this changed post-invasion).

### Properties

Property	Response	Notes
Tested	Yes	Used for status report
Spatially explicit	Yes	Refers to a particular region
Scalable	Yes	Potentially scalable though need both this value and overall extent of area
Temporal	Yes	Has been used for several periods over time
Uncertainty appraisal	??	NA
Taxonomically representative	Yes	Can be used for different types of organisms based on different units (e.g., cover, number of individuals, or biomass)
Invasive alien species specific	Yes	Explicitly requires information on alien taxa (as well as native taxa)
Reproducible	Partially	Depending on the data source it can be easily added to a workflow, but if the underlying data are based on expert evaluations of an area it will be harder to reproduce

### 3.3. Impact of invasions

*Note: in trying to apply this indicator in practice it is clear further development is needed to define the indicator and outline calculation procedures for it to be fit for purpose. As such what is listed is below should be regarded as under development.*

#### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Impact

Theory of Change (ToC): Invasion-specific outcomes

#### Use and interpretation

This indicator assesses the impact on the delivery of selected ecosystem services or on biodiversity of invasions at a site. It should focus on those ecosystem services that are important in the context of the site concerned (e.g., water resources in dry regions, livestock production in rangelands, and biodiversity in protected areas). The indicator provides information useful to prioritise sites for management interventions. At a more advanced level, the value of impacts can be expressed in monetary terms and so used for calculations of costs and benefits of control.

Intention is to estimate current impacts rather than future impacts.

#### Potential for aggregation

Impacts on ecosystem services that are made at finer scales can be aggregated upwards at larger scales.

#### Possible reasons for trends

↑	Physiological or competitive consequences of invasions. For example, displacement of plants that are able to conserve water with species that are less efficient water users can reduce streamflow and deplete groundwater resources; and unpalatable or thicket-forming species can displace palatable grass species in rangelands, reducing the livestock carrying capacity.
	Increases in the spread of alien species with negative impacts
	Accrual of impact over time.
↓	Vice versa for ↑ (though more likely due to active interventions, e.g., control of invasions)
↑ or ↓	Improved monitoring and attribution

#### Implications for biodiversity management of change in the indicator

The size and value of impacts would be important factors to consider when allocating scarce management resources to address and hopefully reduce, or slow the growth of, negative impacts. Management resources should be directed to those sites where attractive returns on management interventions could be realised (potentially, but not necessarily) including sites where the impacts are greatest.

#### Units in which it is expressed

3.3.1.	Factor with five levels of impact. The intention is that the magnitude is to correspond to those intended for the ICAT Schemes. <ul style="list-style-type: none"> <li>• Not known</li> <li>• Minor (~no changes in activities are recorded but the activities are less effective)</li> <li>• Moderate (~the impacts are of a magnitude that there are changes in activity size, but the activity is still carried out)</li> <li>• Major (the impacts are of a magnitude that some activities stop at the site)</li> <li>• Massive (the impacts are of a magnitude that activities permanently stop at the site)</li> </ul>
3.3.2.	The reduction caused by the invasions expressed quantitatively in the units in which the ecosystem service is measured (for example, water yield expressed in m <sup>3</sup> per ha, rangeland carrying capacity in livestock units per ha, and biodiversity intactness).

3.3.3.	Monetary values (in net present value) of the reduction in the relevant ecosystem service or biodiversity indicators.
--------	-----------------------------------------------------------------------------------------------------------------------

### Description of source data

The use of this indicator requires data on the spatial distribution and magnitude of ecosystem services, and on the impact of invasions on that service. While the magnitude of a wide range of ecosystem services can be assessed, good information on the impacts of invasions on those services is not easily obtained, as relatively few studies have been conducted.

### Calculation procedure

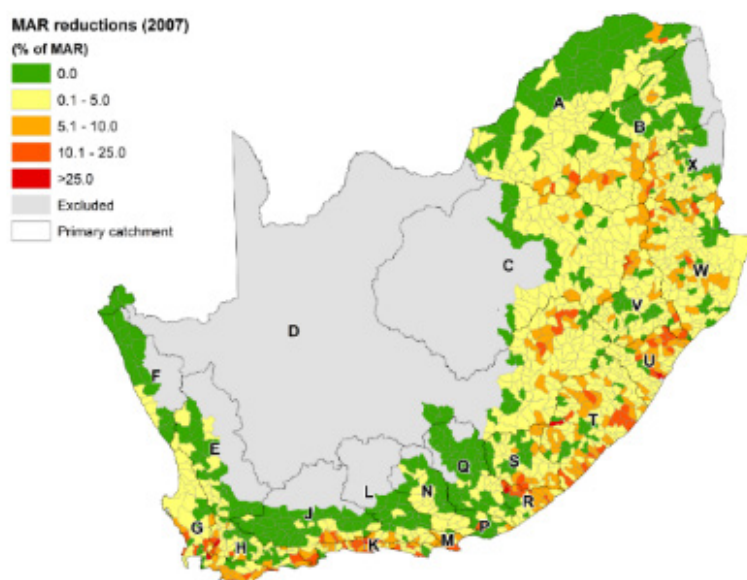
3.3.1.	Select which ecosystem services are of concern. For South Africa it is biodiversity, water availability, pastureland Define the impact levels for that service Map services at appropriate scales. Model the impact of current invasions on these services. Map estimates impacts
3.3.2.	As for 3.3.1., but where the data are of sufficient resolution and models of sufficient reliability that a quantitative percentage can be obtained rather than a broad range.
3.3.3.	Conversion of ecosystem services to monetary values in which the value of sustainable yields (of water, livestock, or harvested products) are estimated for the scale concerned.

### Guide for applying confidence levels

3.3.1.	High	Based on well documented impacts of particular alien species combined with quantitative information on relative alien species abundance with a medium or high level of confidence (see 3.2.1.)
	Medium	Based on well documented impacts of particular alien species combined with qualitative information on relative invasive abundance (see 3.2.1.)
	Low	Based on expert opinion
3.3.2.	High	Based on levels of ecosystem services that have been measured and quantified across the region; and on robust studies that quantify the impact of invasions on these services
	Medium	Based on levels of ecosystem services that have been measured for representative parts of the region, with well tested spatial models used to extrapolate to the whole region.
	Low	Based on estimates of ecosystem services derived from spatial modelling, and/or on modelled estimates of the impact of alien species on these services.
3.3.3.	High	Based on direct valuation of measured and quantified ecosystem goods and services at the site concerned.
	Medium	Based on indirect estimations of the market value of modelled levels of ecosystem services (for example, by comparison to values for similar services estimated elsewhere).
	Low	Based on market values of ecosystem services derived from expert opinion.

### Most effective forms of presentation

3.3.1.	Spatially (on maps) or graphically by means of bar graphs showing trends over time or under different scenarios of invasion.
3.3.2.	As for 3.3.1.
3.3.3.	Tables



**Indicator 3.3.2 Figure 1** Estimates of the reductions in mean annual run-off (MAR) due to invasive alien plants in the quaternary catchments of South Africa. Capital letters refer to primary catchments. The quaternary catchments that were completely excluded are shown in grey; many others were only partially mapped; the Kruger National Park was also excluded. Data from Le Maitre et al. (2016), figure taken from Figure 5.3 (SANBI and CIB, 2018).

#### Limits to usefulness and accuracy

The degree to which this indicator can be used is constrained by limited spatial information on a wide range of ecosystem services (although information on some of the more important services is available at a range of scales), accurate distribution maps for biological invasions, and studies that have accurately quantified impacts, and on which models can be based.

Even if extent or abundance of invasions do not change over time, biophysical thresholds can be crossed leading to ecosystem level impacts (Suding & Hobbs, 2009), understanding these thresholds is difficult but essential to evaluate impacts (and the potential for such impacts to be reduced).

Mapping ecosystems services is easier for some services (for example water or timber extraction, or livestock or fish production) than for others (for example aesthetic or cultural values).

#### Updating the indicator

The indicator can be updated based on updates to estimates of ecosystem service against a counter-factual of no invasions.

#### Closely related indicators

Depends upon	Links with	Required for
2.1. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species 2.4. Impact of alien species 3.1. Alien species richness 3.2. Relative invasive abundance	4.1 Quality of the regulatory framework 4.2. Money spent 4.3. Planning coverage	4.3. Planning coverage 4.8. Effectiveness of species treatments 4.9. Effectiveness of site treatments 2. Number of invasive species that have 'Major' impacts 3. Extent of area that suffers 'Major' impacts from invasions 4. Level of success in managing invasions

#### Additional information and comments

The choice of what to measure in terms of the impact of invasions will be influential and the importance of different impacts will be context dependent. A Minor reduction in biodiversity in a biodiversity hotspot might be much more important than a Massive reduction elsewhere; similarly providing the cost of an invasion in absolute terms might hide profound societal inequities.

### Properties

Property	Response	Notes
Tested	No	Some aspects of the indicator have been tested (e.g., water flow)
Spatially explicit	Yes	Impacts should be mapped out
Scalable	Yes	Potentially
Temporal	Yes	Potentially
Uncertainty appraisal	Qualitative	More information is needed
Taxonomically representative	Yes	Focus is on sites rather than taxa, but all alien taxa can cause the impacts
Invasive alien species specific	No	The impacts need not be specifically due to alien species
Reproducible	No	Current information not readily accessible to calculate impacts and workflows are not in place

## 4. Level of success in managing invasions

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Response

Theory of Change (ToC): Output (direct result of activities)

### Use and interpretation

The degree of success achieved by control measures will vary from place to place, and this indicator is intended to provide an assessment of overall control effectiveness across all projects. High levels of effectiveness would indicate that control measures are appropriate and that the goals of management are realistic and achievable. Low levels of effectiveness would indicate inefficiencies in management, or unrealistic expectations and goals, or both. It should trigger a thorough examination of the component projects with a view to re-allocating national-level resources to projects where the goals are more likely to be achieved, or to re-defining more-realistic goals.

### Potential for aggregation

This is a high-level indicator, already aggregated at a national level.

### Possible reasons for trends

There are a plethora of reasons for trends, a few are highlighted here.

↑	Strong public and community support and engagement
↓	A lack of understanding of the ecology of target species (e.g., Shackleton et al. 2016)
	Bureaucratic inefficiencies
↑ or ↓	Ability of managers to assess the magnitude and complexity of the problem leading to appropriate or unrealistic goal-setting
	The extent to which best-practice control measures are adhered to
	Unforeseen fluctuations in funding
	Unforeseen events (fires, floods, droughts)

### Implications for biodiversity management of change in the indicator

Change to management approaches would be required if the indicator suggests high levels of inefficiency. This would be in line with the philosophy of adaptive management, where the methods employed could be improved, or the funding could be moved to new sites or species where success would be more likely, or the goals of management could be changed.

### Units in which it is expressed

4.	% efficacy or broad category
----	------------------------------

### Description of source data

Data would be sourced from regular monitoring of progress towards the goals listed in formal management plans.

### Calculation procedure

4.	<p>First the proportion of pathways, species, and sites that require management and where a plan is in place is calculated (see indicators 14, 15, 16 and 17).</p> <p>Second for pathways, species, or areas treated, treatments are assessed based on their effectiveness (see indicators 18, 19, and 20) and scored as:</p> <ul style="list-style-type: none"><li>• Counter-productive. -100%</li><li>• None / ineffective / not known. 0%</li><li>• Partial. 20%</li><li>• Effective or Permanent. 100%</li></ul> <p>Then the proportion which are treated are multiplied with the proportion that are effective to give an overall percentage success for pathways, species and sites.</p>
----	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

	Finally the percentage efficacy of pathway, species, and site interventions are averaged to give an overall figure.
--	---------------------------------------------------------------------------------------------------------------------

### Guide for applying confidence levels

4.	High	All the relevant indicators are assessed with at least medium confidence
	Medium	All the relevant indicators are assessed but some with low confidence
	Low	Some of the relevant indicators are not assessed, so assumptions are made/the analysis is not complete, or all of the relevant indicators are assessed with low confidence.

### Most effective forms of presentation

4.	% (that at maximum will be 100%, but can be negative if interventions are on balance exacerbating invasions)
----	--------------------------------------------------------------------------------------------------------------

For the Prince Edward Islands (based on Fernández Winzer et al. 2025), “The proportion of pathways that require management and where a plan is in place equals 90%, the same proportion but for species is 26% and 100% for sites. Some management actions have been successful, and species are being monitored to confirm eradication. The distribution of some other taxa has remained stable (in some cases, due to taxa being controlled). However, a few taxa have increased in extent. So overall ... the level of success is partial. If successful, the ‘Mouse-free Marion’ Project would be a significant achievement, and although less pressing, other eradications would lead to an improvement in this indicator”

The indicator was scored for continental South Africa in the first report as 5.5% [Average of pathway success (15.8%), species success (0.65%), and area success (0.0005%)], but given very few data on the effectiveness of control of invasions (at specific sites in particular), an estimate was not given in other reports.

### Limits to usefulness and accuracy

This indicator will be limited to the area for which management plans are available. Currently, South African legislation requires all protected areas to develop management plans, and that would provide a useful starting point. Ideally, management plans should also be developed for sites where substantial funding is being expended on control of invasive alien species. The assessment of management effectiveness would be dependent on (1) setting goals for management progress; and (2) regular monitoring of progress towards those goals.

### Updating the indicator

In South Africa the proposal is to work towards a dashboard of indicators, with updates at least annually if not in real-time.

### Closely related indicators

Depends upon	Links with	Required for
1.1. Introduction pathway prominence 1.2. Introduction rates 1.3. Within-country pathway prominence 1.4. Within-country dispersal rates 2.1. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species 2.4. Impact of alien species 3.1. Alien species richness 3.2. Relative invasive abundance 3.3. Impact of invasions 4.1 Quality of the regulatory framework	1. Rate of unregulated introduction of new species 2. Number of invasive species that have ‘Major’ impacts 3. Extent of area that suffers ‘Major’ impacts from invasions	None

4.2. Money spent 4.3. Planning coverage 4.4. Pathways treated 4.5. Species treated 4.6. Sites treated 4.7. Effectiveness of pathway treatments 4.8. Effectiveness of species treatments 4.9. Effectiveness of site treatments		
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	--	--

### Additional information and comments

If there is permanent control, the value might need to be removed from the calculation at some point, as those taxa would no longer need to be managed (so wouldn't come in under pathways, species, and sites treated). Ironically, however, this could lead to a decrease in the indicator. This will need to be resolved.

### Properties

Property	Response	Notes
Tested	No	Remains to be regularly measured and evaluated
Spatially explicit	Yes	Refers to a particular area
Scalable	No	Will not be easily disaggregated across regions
Temporal	Yes	Providing data are available and interventions monitored, temporal trends can be evaluated
Uncertainty appraisal	Quantitative	The intention is for uncertainty in the different aspects to be evaluated and combined to give an overall range estimate
Taxonomically representative	Yes	Works across all taxa
Invasive alien species specific	Yes	Specifically designed for biological invasions
Reproducible	No	At present there are insufficient data to calculate values

## 4.1. Quality of the regulatory framework

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Response

Theory of Change (ToC): Input

### Use and interpretation

- What regulatory framework is in place to manage biological invasions?
- What is the level of completeness of this regulatory framework? and
- What mechanisms are in place to enable its implementation, update, review and appeal?

At a country level, this indicator provides an assessment of the degree to which authorities are able to regulate the cultivation or use of alien species, their transport or trade, and to what extent citizens are required to take steps to control problematic invasive alien species. Voluntary agreements should also be considered as relevant here.

### Potential for aggregation

This indicator would assess the quality of the regulatory framework at a national level, and there would be no need for aggregation. Can be evaluated at lower spatial administrative levels.

### Possible reasons for trends

↑ or ↓	Regulations are enacted or updated
	New voluntary agreements reached
	Policy framework changes

### Implications for biodiversity management of change in the indicator

Increases or decreases in the quality of the regulatory framework would affect the ability of managers to address the negative effects of invasive alien species.

### Units in which it is expressed

4.1.1.	Factor with four levels at a national level: <ul style="list-style-type: none"><li>• <i>None</i> (there are no regulations (or voluntary agreements) on biological invasions)</li><li>• <i>Partial</i> (regulations are enacted and have clear mechanisms for implementation and enforcement, but only cover some of the aspects of the problem)</li><li>• <i>Substantial</i> (regulations are enacted dealing with most aspects of the problem and/or responsibilities are mostly clearly assigned/most mechanisms for implementation, update, review and appeal are clear)</li><li>• <i>Complete</i> (comprehensive legislation governs biological invasions in a holistic way, with responsibilities clearly assigned and clear mechanisms for implementation, update, review and appeal).</li></ul>
4.1.2.	As for 4.1.1., but for a range of different administrative entities, and incorporating an evaluation of inter-agency co-operation

### Description of Source Data

Gazetted legislation applicable to biological invasions; and published codes of conduct.

### Calculation Procedure

See also the workflow '*The permit database*'

4.1.1.	Assessments by experts on the quality of legislation based on completeness (covers all aspects of pathways, species and sites); mechanisms for implementation; update; and review and appeal processes
4.1.2.	As for 4.1.1., at different administrative levels and incorporating an evaluation of inter-agency co-operation

## Guide for applying confidence levels

4.1.1.	High	Assessment of regulation quality provided by an independent team of experts that includes both invasion scientists and members of the legal profession
	Medium	Assessment of regulation quality provided by either an independent or semi-independent team. The team includes invasion scientists or members of the legal profession but not both
	Low	Assessment provided by a team who either come from the institution responsible for developing or enforcing the regulations and/or do not contain assessors qualified in invasion science or law
4.1.2.	High	As for 4.1.1.
	Medium	As for 4.1.1.
	Low	As for 4.1.1.

## Most effective forms of presentation

4.1.1.	Table providing a breakdown of coverage of the regulatory framework across all aspects of the problem, on which the assignment to one of the levels is based
4.1.2.	As for 4.1.1.

**Indicator 4.1.1. Table 1** The quality of the regulations pertaining to biological invasions in South Africa as assessed by SANBI and CIB (2020), Table S5.5.

Aspect of regulations	Aspect of biological invasions		
	Pathways	Species	Sites
Is there a mandate for management interventions?	Partial	Partial	Partial
Is there provision for enforcement of non-compliance?	Partial		
Is there a requirement for regular assessment of performance, and review?	Partial		Partial

## Limits to usefulness and accuracy

Politically sensitive indicator, might be slow to change in response to pressures.

## Updating the indicator

Will be updated in response to the legislative process (e.g. amendments or new regulations).

## Closely related indicators

Depends upon	Links with	Required for
1.1. Introduction pathway prominence 1.2. Introduction rates 1.3. Within-country pathway prominence 1.4. Within-country dispersal rates 2.1. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species 3.1. Alien species richness	2.4. Impact of alien species 3.3. Impact of invasions 4.2. Money spent	4.3. Planning coverage 4.4. Pathways treated 4.5. Species treated 4.6. Sites treated 4.7. Effectiveness of pathway treatments 4.8. Effectiveness of species treatments 4.9. Effectiveness of site treatments 4. Level of success in managing invasions

## Additional information and comments

Can be a long process to change or amend regulations involving public consultations and changes have to be gazetted to take effect.

## Properties

Property	Response	Notes
Tested	Yes	Values for South Africa were discussed
Spatially explicit	No	?
Scalable	No	Not easy to evaluate at provincial level or otherwise at present

<b>Property</b>	<b>Response</b>	<b>Notes</b>
Temporal	Partially	Evaluations are done and can change over time
Uncertainty appraisal	None	No uncertainty measure is formally presented
Taxonomically representative	Yes	Refers to all taxa
Invasive alien species specific	Yes	Specific to biological invasions
Reproducible	No	Much of the information is not in the public domain until presented in the status report

## 4.2. Money spent

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Response

Theory of Change (ToC): Input (resources)

### Use and interpretation

Indicator that measures the monetary inputs into the management of biological invasions. It provides a basis on which to estimate one of the main indicators of the outcome of management interventions, namely return on investment.

### Potential for aggregation

This indicator can be aggregated across any spatial scale for all of the management interventions at that scale.

### Possible reasons for trends

↑ or ↓	Changes in political or economic conditions, resulting in changes to the budget invested to address biological invasions.
--------	---------------------------------------------------------------------------------------------------------------------------

### Implications for biodiversity management of change in the indicator

Increased allocation can lead to an increased amount of resources to undertake interventions and decreased allocation can lead to a decrease in the number of interventions implemented. Decreases will also lead to the need for prioritisation, and for conservation triage, so that sufficient resources can be allocated to priority sites to achieve the goals of management.

### Units in which it is expressed

4.2.1.	Annual government expenditure at a national scale
4.2.2.	Annual government expenditure separated into expenditure on the relevant components of pathways, species, and sites
4.2.3.	As for 4.2.2., including expenditure by private individuals/organisations, and detailed accounts of the sources of funding

### Description of source data

Records of expenditure from various government departments. Reports of money spent by private individuals/organisations.

### Calculation procedure

See details in workflow '*Money spent*'

4.2.1.	Addition of expenditure from different sources to obtain a total. When compared over multiple years, it would be useful to inflate annual totals to net present values in the current year. This would facilitate meaningful comparisons, especially in countries that experience relatively high levels of inflation.
4.2.2.	As for 4.2.1., split into different units.
4.2.3.	As for 4.2.1., split into different units.

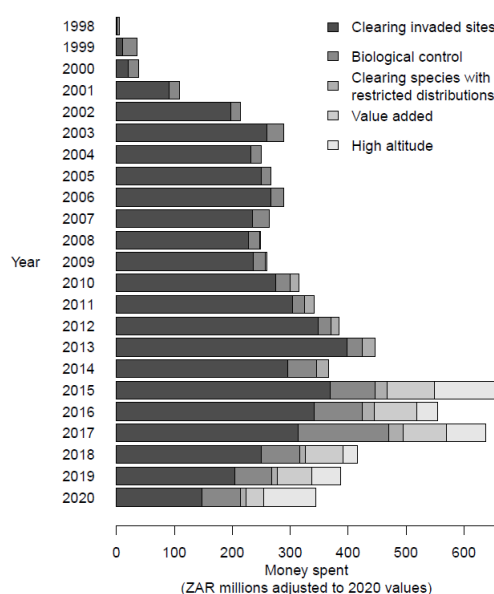
### Guide for applying confidence levels

4.2.1.	High	Records of expenditure on biological invasions are available from all participating agencies
	Medium	Records of expenditure from all participating agencies do not differentiate clearly between expenditure on biological invasions and other activities, leading to the need for assumptions

	Low	Records of expenditure are available for some, but not all participating agencies, and/or records do not differentiate clearly between expenditure on biological invasions and other activities
4.2.2.	High	Records of expenditure are available from all participating agencies, with clear breakdowns of expenditure into projects that can be assigned easily to relevant components of pathways, species and sites
	Medium	Records of expenditure are available from all participating agencies, but they do not differentiate clearly between expenditure on biological invasions and other activities, and/or they do not differentiate between expenditure on pathways, species and sites, leading to the need for assumptions
	Low	Records of expenditure are available for some, but not all participating agencies, and/or it is very difficult to ascribe known expenditure to different aspects of biological invasions
4.2.3.	High	As for 4.2.2., but with the additional requirement that records are available for money spent by private individuals/companies
	Medium	As for 4.2.2., but with the additional requirement that records are available for money spent by private individuals/companies
	Low	As for 4.2.2., but with the additional requirement that records are available for money spent by private individuals/companies

### Most effective forms of presentation

4.2.1.	Graphic presentation of annual expenditure over time
4.2.2.	Tables of expenditure per component; with graphical summary of how this has changed over time
4.2.3.	As for 4.2.2.



**Indicator 4.2.1. Figure 1** Amount spent per year (including overheads and adjusted to 2020 ZAR values) on invasive plant control operations. Data from van Wilgen et al. 2022 based on Figure S4.2 SANBI and CIB (2023).

**Indicator 4.2.2. Table 1** Money reported as having been spent on the management of biological invasions in South Africa by different organisations between 2020 and 2022. The amounts are totalled for three years in ZAR and unadjusted for inflation. Inputs from various organisations and many stakeholders, particularly in the private sector, were not available. Some of the money spent by implementing agencies may also have been reported by the Department of Forestry, Fisheries and the Environment's (DFFE's) Working for Water Programme. Extract from Table 4.1 SANBI & CIB (2023)

Organisation	Money spent on	Money spent	Notes
Agricultural Research Council	Biological control research	104 495 930	ZAR 69 700 073 from the DFFE and ZAR 34 795 857 from the ARC.
Buffalo City (East London)	Protected areas within the municipal boundaries	9 151 000	This includes other activities such as clearing of vegetation along road verges
Cape Nature	31 protected areas in the Western Cape Province	9 299 189	Most of this money came from the Working for Water programme and so there may be some double counting
Centre for Biological Control, Rhodes University	Biological control research and implementation	82 000 000	ZAR 59 million from Working for Water; ZAR 15 million from the DST-NRF via the South African Research Chairs Initiative; ZAR 8 million from other sources. The bulk is spent at Rhodes University, but part of the funding is distributed to the Universities of Cape Town, Witwatersrand, KwaZulu/Natal, Mpumalanga, and Fort Hare
City of Cape Town	Management of invasive species in municipal protected areas & Mass-rearing of biological control agents	106 007 412	The City of Cape Town is the only municipality that reported that they were actively controlling the polyphagous shot-hole borer ( <i>Euwallacea fornicatus</i> )
City of Ekurhuleni (Gauteng)	Management of aquatic ecosystems	17 700 000	Funding has been expended mostly on <i>Pontederia crassipes</i> (water hyacinth), <i>Arundo donax</i> (giant reed), and <i>Nymphaea mexicana</i> (yellow water lily) invading aquatic ecosystems

### Limits to usefulness and accuracy

Government expenditure data will be hard to collate as expenditure will be in multiple departments some of which will not view the costs as relevant to invasions or separate these from other costs (human health in particular).

Contributions from the private sector, and private landowners are unlikely to be readily available, are difficult to estimate, but could be substantial. The indicator is therefore likely to be an underestimate of inputs.

Information is not often split down into pathways, species, or site; although data spent clearing particular taxa in a particular area can be available.

### Updating the indicator

This indicator could be updated annually

### Closely related indicators

Depends upon	Links with	Required for
None (though ultimately of course all aspects of pathways, species, and sites could come into the calculation) e.g., 5. Number and status of alien species; 2.2. Extent of alien species and 2.3. Abundance of alien species	2.4. Impact of alien species 12. Impact of invasions 4.1 Quality of the regulatory framework 4.3. Planning coverage 4.4. Pathways treated 4.5. Species treated 18. Areas treated	4.7. Effectiveness of pathway treatments 4.8. Effectiveness of species treatments 21. Effectiveness of site treatments 4. Level of success in managing invasions

### Additional information and comments

None

## Properties

Property	Response	Notes
Tested	Yes	Values have been noted, but gaps are remaining
Spatially explicit	Yes	Spending in some cases can be mapped out
Scalable	?	Possible?
Temporal	Yes	Values are usually reported each financial year end
Uncertainty appraisal	None	There isn't uncertainty ascribed to these values
Taxonomically representative	Yes	Can apply to any taxa
Invasive alien species specific	Yes	Resources are specifically on controlling invasions, although such data might not always be disaggregated
Reproducible	Partially	A workflow has been developed although obtaining information is not always easy

### 4.3. Planning coverage

#### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Response

Theory of Change (ToC): Input

#### Use and interpretation

Adequate levels of planning are an essential input into the management of biological invasions. This indicator gauges the level of planning input, which should include the setting of goals, and monitoring and assessment of progress towards those goals. The degree to which management interventions are covered by adequate planning provides a basis for explaining the degree to which outputs and outcomes are achieved.

#### Potential for aggregation

Plans are drawn up for individual pathways, species and sites, and can be aggregated across the components that require management. For example, ballast water management plans for individual harbours, or passenger, luggage and cargo monitoring plans for individual airports.

#### Possible reasons for trends

↑	Improvements in management plans
	Allocating additional resources to planning to allow for greater scope
↓	Funding cuts
↑ or ↓	Changes in regulatory requirements

#### Implications for biodiversity management of change in the indicator

A lack of planning, or inadequate planning, could lead to major inefficiencies in management, as a result of uncertainty relating to the goals of management, the allocation of funding to various activities, as well as a lack of clarity regarding progress towards goals.

#### Units in which it is expressed

4.3.1.	The proportion of each component (pathways, species, and sites) that have a regulatory requirement for a management plan and that have a management plan in place.
4.3.2.	As for 4.3.1., but including an assessment of the quality of plans as gauged against a minimum set of criteria for adequate plans.
4.3.3.	The presence and quality of management plans for each component (pathways, species, and sites) that have been ranked in terms of their priorities

#### Description of source data

Management plans developed by authorities responsible for the management of various aspects of biological invasions, and regulations.

#### Calculation procedure

4.3.1.	<p>The number of pathways, species, and sites requiring management is taken to be pre-determined by any existing regulatory framework.</p> <p>Each component is then assessed as to whether a plan is in place.</p> <p>From this an overall percentage is determined (average of % in place for pathways, species, and sites).</p> <p>For species the information can be sourced from <i>RegulatoryListing</i> potentially checked against the latest version of the regulations (cf. Wilson 2025).</p>
4.3.2.	<p>For the advanced metric, each plan needs to be assessed with respect to the degree to which the plan meets a minimum set of criteria (e.g., Department of Environmental Affairs 2015). Each plan should be placed into one of three categories, as follows:</p>

	<ul style="list-style-type: none"> <li>• Adequate: Information required in terms of all of the criteria is included, and is of excellent standard;</li> <li>• Partially adequate: Information for most required criteria (&gt;50%) is included, and is of an adequate to good standard; and</li> <li>• Inadequate: Information required in terms of the criteria is almost entirely lacking from the plan.</li> </ul>
4.3.3.	<p>First a risk assessment is conducted for each component of pathways, alien species, and sites to determine where management is needed (regardless of resource constraints).</p> <p>Second for those components where management is needed, the proportion that have plans in place is determined.</p> <p>Finally, plans that are in place are assessed in terms of their quality.</p>

### Guide for applying confidence levels

4.3.1.	High	Plans are explicit as to their coverage with details such that gaps can be identified. Comparison across plans is easy as plans are curated in transferable formats. Guidelines meet international best-practice standards and reviewed externally and cover all relevant situations.
	Medium	The coverage and gaps in the plans can be inferred from details of what is covered, and/or the comparison across plans is made difficult by a variety of formats.
	Low	Coverage based on expert opinion
4.3.2.	High	Plans are produced in enough detail to allow assessment of their quality and the assessment is conducted by someone experienced in project management of biological invasions
	Medium	Plans are produced in enough detail to allow assessment of their quality or the assessment is conducted by someone experienced in project management or biological invasions (not both)
	Low	Quality of plans difficult to assess and assessor not suitably experienced
4.3.3.	High	As for 4.3.2 with some evaluation of the confidence in the assessments conducted
	Medium	As for 4.3.2 with some evaluation of the confidence in the assessments conducted
	Low	As for 4.3.2 with some evaluation of the confidence in the assessments conducted

### Most effective forms of presentation

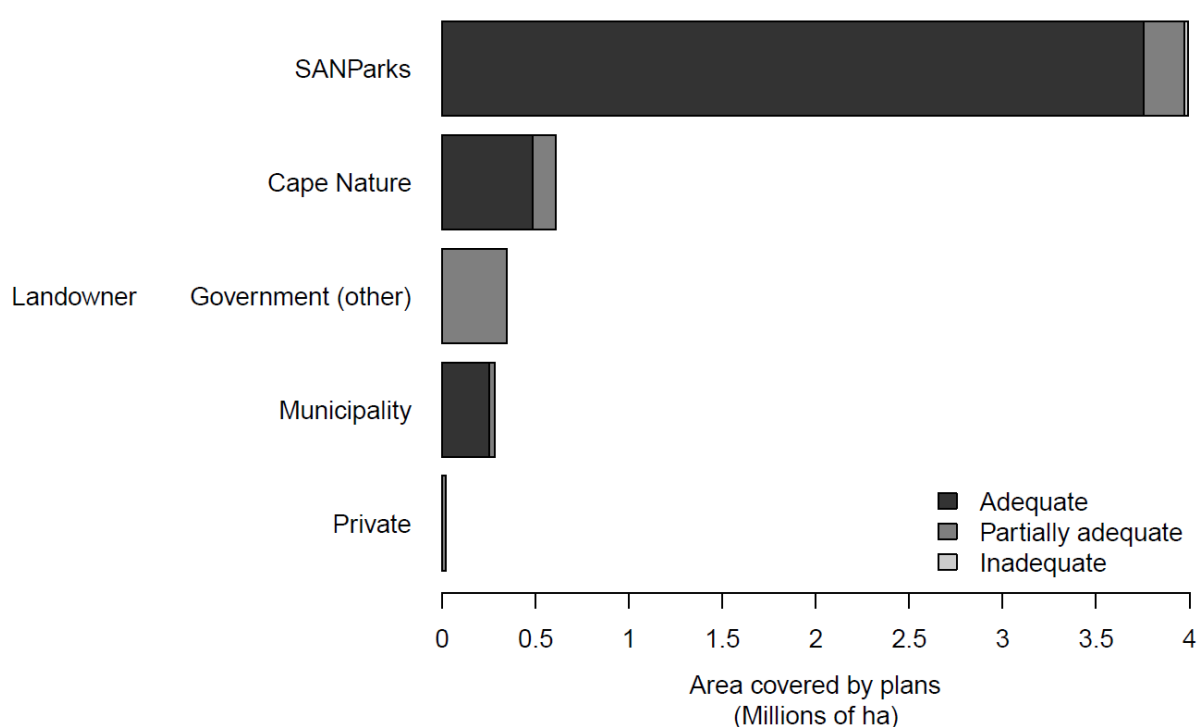
4.3.1.	Bar diagrams showing the proportion of pathways, species or sites for which management plans have been prepared. Numbers above the bars indicate the number of pathways, species, and sites being managed.
4.3.2.	Bar charts or tables
4.3.3.	Bar charts or tables

**Indicator 4.3.1 (Pathways)** The following notes are from SANBI and CIB (2023) p56 “No formally approved management plans for pathways have been developed by DFFE, and there is no requirement for pathway management plans under the NEM:BA A&IS Regulations. However, management is in place for 39 of 44 pathways. Therefore, it is assumed that plans are in place for those pathways... In addition, ballast water management plans have been developed, but not implemented, thus 40 pathways are assumed to have plans in place (see Supplementary Material S4.8).”

**Indicator 4.3.2 (Species) Table 1** Assessment of the adequacy of existing species management plans according to the degree to which they meet six criteria. Extract from Table S4.6 of SANBI and CIB (2023).

scientificName	Regulatory category	Goal	Extent of invasion	Ecology of species	Historic control measures	Control measures	Indicators of success	Assessed category
<i>Acacia fimbriata</i>	1a	Yes	Yes	No	Yes	Yes	Yes	Partially adequate
<i>Acacia paradoxa</i>	1a	Yes	Yes	Yes	Yes	Yes	Yes	Adequate

<i>Acacia stricta</i>	1a	Yes	Yes	No	Yes	Yes	Yes	Partially adequate
<i>Aloysia gratissima</i>	Not listed	Yes	Yes	Yes	Yes	Yes	No	Partially adequate
<i>Anigozanthos flavidus</i>	Not listed	Yes	Yes	Yes	Yes	Yes	Yes	Adequate
<i>Asphodelus fistulosus</i>	Not listed	Yes	Yes	Yes	Yes	Yes	Yes	Adequate
<i>Billardiera heterophylla</i>	1a	Yes	Yes	Yes	Yes	Yes	Yes	Adequate
<i>Cylindropuntia pallida</i>	1a	Yes	Yes	No	Yes	Yes	Yes	Partially Adequate



**Indicator 4.3.2 (Sites) Figure 1** The area of South Africa covered by management plans for biological invasions as reported by SANBI and CIB (2023) Figure 4.1.

#### Limits to usefulness and accuracy

This indicator does not measure whether, or how well or comprehensively, the plans are actually implemented. This could limit usefulness, as effective implementation is an important output. There might also be implementation without plans in place.

At a basic level assumes that the regulatory requirements are an appropriate indication of actual need. At a more advanced level does not take into account the fact that the planning might be appropriate given the resource constraints, i.e. prioritised things are well covered.

#### Updating the indicator

Potentially annually, linking to annual plans of operation.

#### Closely related indicators

Depends upon	Links with	Required for
--------------	------------	--------------

1.1. Introduction pathway prominence 1.2. Introduction rates 1.3. Within-country pathway prominence 1.4. Within-country dispersal rates 2.1. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species 2.4. Impact of alien species 3.1. Alien species richness 3.2. Relative invasive abundance 3.3. Impact of invasions 4.1 Quality of the regulatory framework	4.2. Money spent	4.4. Pathways treated 4.5. Species treated 4.6. Sites treated 4.7. Effectiveness of pathway treatments 4.8. Effectiveness of species treatments 4.9. Effectiveness of site treatments 4. Level of success in managing invasions
------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	------------------	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

### Additional information and comments

Might need to weight the planning coverage by how important it is to have a plan in place, i.e. that given financial constraints, priority pathways, species, or sites should be covered by plans in preference to other components.

### Properties

*Tested*

*Spatially explicit*

*Not scalable*

*Temporal*

*No uncertainty*

*?*

*Taxonomically representative*

*IAS specific*

*Somewhat reproducible*

Property	Response	Notes
Tested	Yes	While much information is missing, planning coverage has been assessed
Spatially explicit	Yes	Plans are specified for a given region
Scalable	No	Plans are only applicable to the planning area specified
Temporal	Yes	In most cases plans specify the date and can be tracked over time
Uncertainty appraisal	None	None
Taxonomically representative	Yes	Plans can be for any taxa
Invasive alien species specific	Yes	Plans are specifically for aspects of biological invasions
Reproducible	Partially	A certain amount of the work involves expert assessment of the plans for their quality, so it is not completely reproducible or at least automated

## 4.4. Pathways treated

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Response

Theory of Change (ToC): Activity

### Use and interpretation

'4.4. Pathways treated' concerns the management of pathways that could facilitate the introduction of new alien species to a country or the dispersal of alien species within the country after introduction. The indicator is concerned with pathway-focused control measures and provides an indication of the degree to which pathways are being managed (including aspects like inspection, and enforcement).

### Potential for aggregation

Developed for use at a national level, however, as the national level data can be aggregated, the indicator can also be used at larger spatial scales (e.g. regions or continents). For example, information on the total amount of goods or vessels entering different countries or moving within countries, and the amount subjected to a management intervention, could be used to get an indication of the proportion of the goods or vessels for different pathways that are subjected to management at a regional or continental scale. As data could be available at larger (e.g. regions or continents) spatial scales, the indicator can be used at these scales.

### Possible reasons for trends

↑ or ↓	Political (e.g. changes to trade agreements), environmental and socio-economic changes (like consumer trends), as well as changes to the biosecurity (e.g. change to resources such as funds or personnel) or policies (e.g. phytosanitary policies) of the importing nation.
--------	-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

### Implications for biodiversity management of change in the indicator

An upward trend in this indicator demonstrates that there has been an increase in the proportion of pathways or goods and vessels that are subjected to a management intervention.

A downward trend in this indicator demonstrates that there has been a decrease in the proportion of pathways or goods and vessels that are subjected to a management intervention.

Downward trends are not necessarily undesirable, and might reflect the reallocation of resources to more high priority pathways. Similarly, upward trends could reflect the allocation of resources to many low priority pathways rather than a small number of high priority pathways.

Upward or downward trends could lead to changes in the allocation of resources for biosecurity (money and personnel), and the pathways to which these resources are allocated (e.g. increase allocation to high priority pathways).

### Units in which it is expressed

4.4.1.	Factor with five categories based on the degree to which the pathway sub-categories are subjected to a management intervention. <ul style="list-style-type: none"><li>• Not known</li><li>• None</li><li>• Partial</li><li>• Substantial</li><li>• Complete</li></ul>
4.4.2.	Proportion of vectors that are subjected to a management intervention per pathway sub-category.
4.4.3.	As for 4.4.2., with an assessment of the quality of the interventions.

### Description of source data

Global or national databases containing trade data run by national governments, intergovernmental or global organisations and companies. Yearly data are often available, however, often not for the most recent years. Data can also be obtained from peer-reviewed journal articles and from the websites and reports of national governments, intergovernmental or global organisations and companies.

Detailed data on management interventions will need to be obtained from the relevant government departments.

#### Calculation procedure

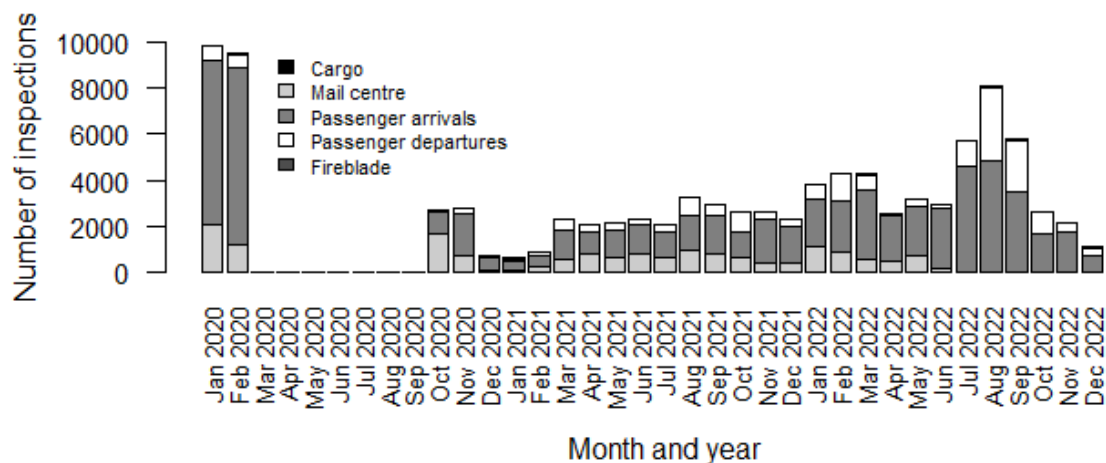
4.4.1.	For each pathway sub-category determine if management interventions are needed (as per indicator 14) and are in place, then categorise as follows: <ul style="list-style-type: none"> <li>• Not known</li> <li>• None (pathway sub-category is not managed)</li> <li>• Partial (&lt; 75% of the pathway sub-category has some management)</li> <li>• Substantial (&gt;75% of the pathway sub-category has some management)</li> <li>• Complete (100% of pathway sub-category is managed)</li> </ul>
4.4.2.	For each pathway sub-category, calculate the proportion of the goods or vessels that are subjected to a management intervention using information on the amount of goods or vessels and the amount that are subjected to regulation or inspections.
4.4.3.	As above, with the interventions assessed against set standard operating criteria: <ul style="list-style-type: none"> <li>• Not known;</li> <li>• Inadequate (less than half the criteria addressed);</li> <li>• Partially adequate (more the half the criteria addressed)</li> <li>• Adequate (all criteria met).</li> </ul>

#### Guide for applying confidence levels

4.4.1.	High	Detailed data on all of the interventions in place and the pathways to which they are relevant
	Medium	Inferred from the types of introductions and/or the vectors that are managed or interpreted from other data sources
	Low	Qualitative estimate or based on expert opinion
4.4.2.	High	Detailed data on the total number of imports or vessels per pathway and the number that have been subjected to a management intervention
	Medium	Inferred from the types of introductions and/or the vectors that are managed or interpreted from other data sources
	Low	Qualitative estimate or based on expert opinion
4.4.3.	High	Detailed data on the proportion of imports or vessels that are managed per pathway with enough information to assess the quality of interventions, and assessment of interventions carried out by a relevant expert
	Medium	Inferred from the types of introductions and/or the vectors that are managed and some information on how interventions are carried out
	Low	Qualitative estimates or based on expert opinion

#### Most effective forms of presentation

4.4.1.	A table or bar chart showing the proportion of pathways treated
4.4.2.	A table or bar chart showing the proportion of pathways treated
4.4.3.	A figure demonstrating the proportion treated to different levels



**Indicator 4.3.3 Figure 1** The number of inspections performed at OR Tambo International Airport by DFFE between January 2020 and December 2022. Figure S4.3 SANBI and CIB (2023).

### Limits to usefulness and accuracy

Reliant on data provided by governments and found in national and global databases. Data quality might not be known and may vary between countries, leading to more accurate assessments for some countries than others. Databases that are infrequently updated might cause difficulties when estimating upward or downward trends, or will not be useful if updated less frequently than the indicator is updated. Data that are only available at regional or larger scales, will be unsuitable for national scale assessments. Useful measures of the amount of goods and vessels might not be available for all pathways, particularly for less specific pathways such as ‘other escape from confinement’. For some pathways there may be various types of data available, and this could lead to differing estimates.

### Updating the indicator

The indicator could be updated yearly or at coarser, but regular time intervals. At the least, the indicator should be updated as often as is required for reporting on the status of biological invasions.

### Closely related indicators

Depends upon	Links with	Required for
1.1. Introduction pathway prominence 1.2. Introduction rates 1.3. Within-country pathway prominence 1.4. Within-country dispersal rates 5. Number and status of alien species 2.2. Extent of alien species (required for within-country dispersal rates) 4.1 Quality of the regulatory framework (needed for planning coverage) 15: Planning coverage	14 Money spent 4.5. Species treated 18. Areas treated 1. Rate of unregulated introduction of new species	4.7. Effectiveness of pathway treatments 4. Level of success in managing invasions

### Additional information and comments

The level of treatment required should be proportionate to the rate of introduction and thus should not be consistent across pathways. For some pathways it might be difficult to access data. For example, some transport data are owned by companies and to gain access to the data or databases a fee is often required.

Some pathways might not need treatment (see indicator 4.3).

### Properties

Property	Response	Notes
Tested	Yes	Tested for mainland South Africa and PEIs, although as pathways managed for mainland South Africa it is difficult to get information and assessment is largely based on the knowledge of experts
Spatially explicit	Yes	Management is given region (e.g., South Africa) or site (e.g., port)
Scalable	No	Only applicable to the specific region
Temporal	Yes	In some cases the dates of activities are recorded and thus can be tracked over time
Uncertainty appraisal	Qualitative	Confidence estimates provided. Often the exact pathway the activity is related to is unclear (e.g., number of inspections of plant products)
Taxonomically representative	Partially	Applicable to all taxa
Invasive alien species specific	Yes	Activities are specifically for pathways that facilitate biological invasions
Reproducible	Partially	A certain amount of the work involves expert knowledge, as what is done is not transparently documented

## 4.5. Species treated

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Response

Theory of Change (ToC): Activity

### Use and interpretation

Output indicator that provides an indication of the degree to which alien species that need to be managed are being managed.

### Potential for aggregation

Can be aggregated across taxonomic groups.

### Possible reasons for trends

↑	Increase in available funds
	Funding spread across more species
	Improvement in control techniques allow new taxa to be targeted
↓	Decrease in funding
	A decision to focus available funds on fewer species
	Loss in availability control techniques (e.g., a herbicide used previously is found to be highly hazardous and banned)
↑ or ↓	Changes in the total number of alien species

### Implications for biodiversity management of change in the indicator

Managing a higher proportion of alien species could be interpreted as advantageous, but it could also signal a dilution of scarce funds, leading to less effective management per species, an undesirable output. At advanced levels of this indicator, it would therefore be necessary to examine whether the level of funding is adequate to make a difference. Changes then will more closely correspond to changes in desired levels.

### Units in which it is expressed

4.5.1.	Proportion (of all regulated species that are being subjected to a management intervention)
4.5.2.	Five categories for the degree to which populations of an alien species identified as requiring management are actually being managed <ul style="list-style-type: none"><li>• Not known</li><li>• None</li><li>• Partial</li><li>• Substantial</li><li>• Complete</li></ul>
4.5.3.	As for 4.5.1. with each intervention (per population or relevant site) assessed as <ul style="list-style-type: none"><li>• Not known</li><li>• Inadequate</li><li>• Partially adequate</li><li>• Adequate</li></ul>

### Description of source data

Species-specific management plans, including funds allocated per species; estimates of the amount of funding needed to achieve control, usually from research projects.

### Calculation procedure

See details in the workflow '*Species treated*'.

4.5.1.	The proportion of those taxa for which <i>RegulatoryListing</i> is one of (1a   1b   2   3   Context-specific) for which <i>speciesTreated</i> = T. Can be broken down into <i>regulatoryGrouping</i> or similar.
--------	-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

4.5.2.	As for 4.5.1. with an assessment of the degree to which populations of an alien species are being managed as: <ul style="list-style-type: none"> <li>• Not known</li> <li>• None (no populations are managed)</li> <li>• Partial (&lt; 75% of populations have some management)</li> <li>• Substantial (&gt;75% of populations have some management)</li> <li>• Complete (100% of populations have some management)</li> </ul>
4.5.3.	As for 4.5.1., with the quality of the implementation assessed against standard criteria (e.g. all individuals/stages addressed, and best practice followed) as: <ul style="list-style-type: none"> <li>• Not known (there is no monitoring and reporting in place)</li> <li>• Inadequate (none of the criteria are adequately fulfilled)</li> <li>• Partially adequate (not all of the criteria are adequately fulfilled)</li> <li>• Adequate (all criteria fulfilled)</li> </ul>

### Guide for applying confidence levels

4.5.1.	High	Management plans readily available, up-to-date, with progress reports that are less than two years old. List of invasive species known with high confidence.
	Medium	Not clear if all management plans obtained, and/or the majority of management plans are not up-to-date. Progress report available but somewhat out of date (e.g. 2–5 years old). Alternatively, the list of invasive species known with medium confidence.
	Low	Over 50% of management plans are out of date, with the last progress report greater than 5 years ago, with no indication that the plan has been wrapped up. Alternatively, the list of invasive species known with low confidence.
4.5.2.	High	As for 4.5.1., in addition with detailed reporting on populations treated and not treated (e.g. >90%)
	Medium	As for 4.5.1., in addition with some direct data indicating coverage
	Low	As for 4.5.1., in addition with the level of coverage extrapolated from some data
4.5.3.	High	As for 4.5.1., in addition there has been a reliable (e.g. peer-reviewed) assessment of the adequacy of the treatments for almost all (>90%) species
	Medium	As for 4.5.1., in addition there has been a reliable (e.g. peer-reviewed) assessment of the adequacy of the treatments for most (50–90%) species
	Low	As for 4.5.1., in addition there has been a reliable (e.g. peer-reviewed) assessment of the adequacy of the treatments for less than half of high priority species

### Most effective forms of presentation

4.5.1.	Proportion for different taxonomic groups
4.5.2.	Bar chart
4.5.3.	Bar chart

**Indicator 4.5.1 Table 1** The number of alien species listed under the NEM:BA A&IS Regulations that were subjected to management interventions between 2020 and 2022 broken down into the different groups. Adapted from Table 4.4 in SANBI and CIB (2023). Roughly a third of all listed taxa were subject to management.

Group	1a	1b	2	3	Context-specific	Not listed	Number listed	Proportion listed that are managed
Plants (freshwater, terrestrial, and marine)	16	113	12	10	25	59	383	46%
Birds	1	0	1	0	0	1	14	14%
Freshwater fish	0	0	0	0	1	1	28	4%
Mammals	0	0	0	0	1	0	42	2%
Microbes	0	0	0	0	0	0	7	0%
Invertebrates (freshwater, terrestrial, and marine)	0	2	0	0	0	75	53	4%

Amphibians	0	1	0	0	0	0	6	17%
Reptiles	0	0	0	0	0	0	29	0%

### Limits to usefulness and accuracy

This output indicator simply measures the number of species that are being managed, unless the indicator is at an advanced level that includes an assessment of the quality of the control measures. At this advanced level, accuracy will depend on an understanding of what represents appropriate standards of control.

### Updating the indicator

Can potentially be linked to annual reports, but will likely only be done as part of national reporting cycles (e.g. 3 years for South Africa).

### Closely related indicators

Depends upon	Links with	Required for
2.1. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species 3.1. Alien species richness 4.1 Quality of the regulatory framework 4.3. Planning coverage	2.4. Impact of alien species 4.2. Money spent 16 Pathways treated 4.6. Sites treated	4.8. Effectiveness of species treatments 2. Number of invasive species that have 'Major' impacts 4. Level of success in managing invasions

### Additional information and comments

The species that need to be treated might include species that are not introduced yet (i.e. pre-border). In general the treatments should be with the goal of either prevention, eradication, containment, and impact reduction.

### Properties

Property	Response	Notes
Tested	Yes	Values are reported
Spatially explicit	?	NA
Scalable	?	NA
Temporal	?	NA
Uncertainty appraisal	?	NA
Taxonomically representative	Yes	Can be for any types of taxa
Invasive alien species specific	Yes	Management is specifically regarding alien taxa
Reproducible	Yes	Relies on sources and updates some of which are manual, however a workflow has been developed

## 4.6. Sites treated

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Driver-Pressure-State-Impact-Response

Theory of Change (ToC): Activity

### Use and interpretation

Output indicator that provides an indication of the area over which alien species control operations took place.

### Potential for aggregation

Can be aggregated from sites with management plans to larger spatial scales.

### Possible reasons for trends

↑	Increase in available funds
	Management shifts from densely-invaded areas to less densely invaded areas
↓	A decrease in funding
	A decision to focus available funds on more densely invaded areas
↑ or ↓	The number of times an area needs to be treated before the management can move to new areas. Some areas require numerous follow-up treatments (for example to remove seedlings after felling mature plants), and this will slow the rate at which new areas can be treated.

### Implications for biodiversity management of change in the indicator

Sites treated is an output indicator that can be used to gauge the proportion of the problem that is being addressed. This, in turn, provides an idea of whether or not the invasion can be reduced to an acceptable level within a reasonable timeframe. However, sites treated is not an indicator of success, as the outcome of treatment is not assessed.

### Units in which it is expressed

4.6.1.	The proportion of sites that need to be managed that are being managed
4.6.2.	As for 4.6.1., with the quality of the implementation of each management plan assessed as: <ul style="list-style-type: none"><li>• Not known</li><li>• Inadequate</li><li>• Partially adequate</li><li>• Adequate</li></ul>

### Description of source data

Management plans from government institutions, non-governmental organisations and private landowners

### Calculation procedure

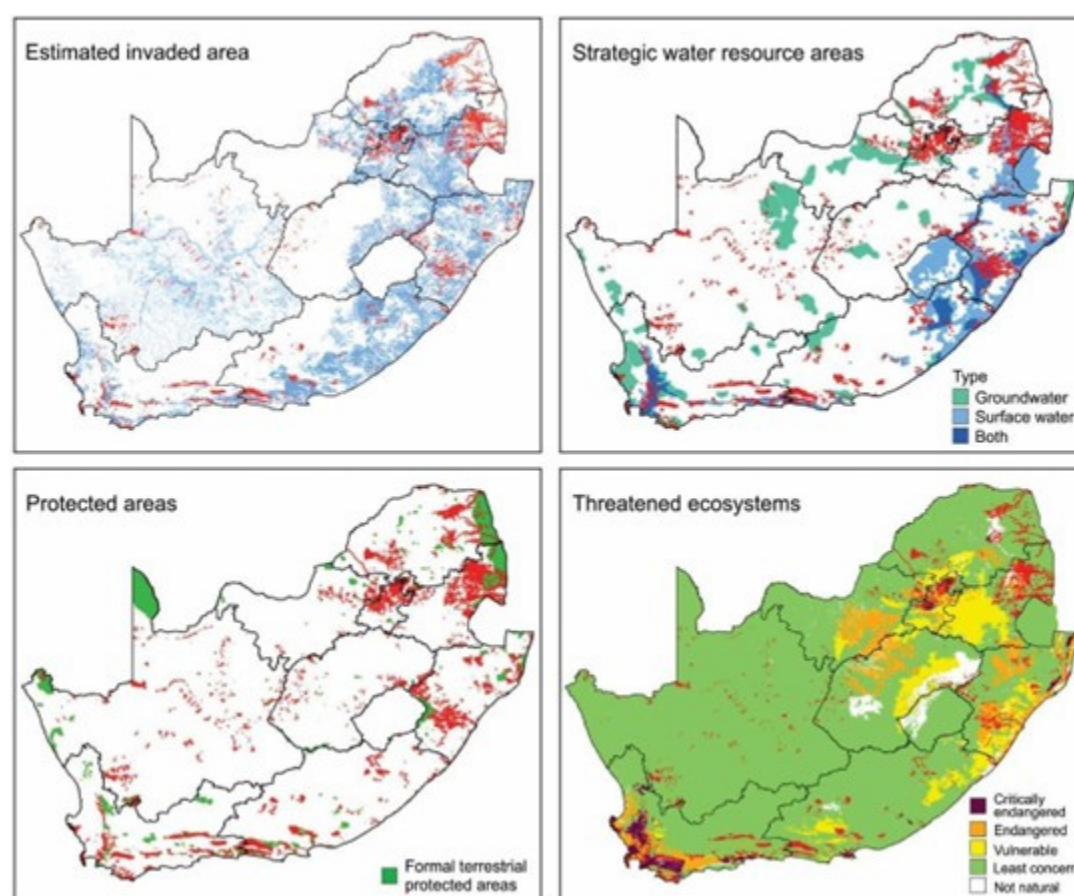
4.6.1.	The sites requiring management is calculated (as per indicator 4.1), and then the proportion where management plans are being implemented is assessed.
4.6.2.	As for 4.6.1., with the quality of the implementation of each management plan assessed against standard criteria (e.g. funding sufficient to reach goal of effective control; all sites addressed; introduction and dispersal pathways considered; and best practice followed) as: <ul style="list-style-type: none"><li>• No plan in place;</li><li>• Inadequate (none of the criteria are adequately fulfilled);</li><li>• Partially adequate (not all of the criteria are adequately fulfilled);</li><li>• Complete (all criteria fulfilled);</li></ul>

### Guide for applying confidence levels

4.6.1.	High	Management plans readily available, up-to-date, with progress reports that are less than two years old. Areas requiring management known with high confidence.
	Medium	Not clear if all management plans obtained, and/or the majority of management plans are not up-to-date. Progress report available but somewhat out of date (e.g. 2–5 years old). Alternatively, the area requiring management is known with medium confidence.
	Low	Over 50% of management plans are out of date, with the last progress report greater than 5 years ago, with no indication that the plan has been wrapped up. Alternatively, the area requiring management is known with low confidence.
4.6.2.	High	As for 4.6.1., and assessment based on clear goals in management plans, and on regular and verifiable monitoring of progress
	Medium	As for 4.6.1., and assessment based on irregular monitoring of progress
	Low	As for 4.6.1., and assessment based on expert local knowledge

### Most effective forms of presentation

4.6.1.	Maps of different sites, displayed according to appropriate administrative or biogeographical units.
4.6.2.	Bar chart



**Indicator 4.6.1 Figure 1** Comparison of areas within South Africa where plant invasions were subjected to treatment by Working for Water (shaded red in all panels) with estimated invaded area (shaded blue, top left); strategic water source areas (top right); protected areas (bottom left); and threatened ecosystems (bottom right). From Figure S4.4 in SANBI and CIB (2023) based on data from van Wilgen et al. (2022). See also p63 SANBI and CIB (2023) “...between 1998 and 2020...site treatments reached a relatively small proportion (~14%) of the estimated invaded area. About 72% of treatments were at sites that met at least one criterion for being a priority site for control (i.e., a Strategic Water Source Area, a protected area or an endangered or critically endangered ecosystem; see Supplementary Material S4.13 for more details).”

### Limits to usefulness and accuracy

Relies on the availability of reports on monitoring and evaluation of control operation.

### Updating the indicator

Annually, in line with annual project reporting.

### Closely related indicators

Depends upon	Links with	Required for
2.2. Extent of alien species 7. Abundance of alien species 4.1 Quality of the regulatory framework 4.3. Planning coverage	4.2. Money spent 4.4. Pathways treated 4.5. Species treated	4.9. Effectiveness of site treatments 3. Extent of area that suffers 'Major' impacts from invasions 4. Level of success in managing invasions

### Additional information and comments

It does not examine whether these treatments were effective.

### Properties

Property	Response	Notes
Tested	Yes	Indicator has been used
Spatially explicit	Yes	Should be a map of where sites have been treated
Scalable	Yes	If information is spatial can look at different scales
Temporal	Yes	Information should provide dates when
Uncertainty appraisal	None	No explicit uncertainty measure
Taxonomically representative	Yes	Refers to sites rather than species, but should not be sensitive to different taxonomic groups
Invasive alien species specific	Yes	Specific to controlling biological invasions
Reproducible	Partially	Information in various sources work is needed to easier to reproduce

## 4.7. Effectiveness of pathway treatments

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Response

Theory of Change (ToC): Output

### Use and interpretation

'4.7 Effectiveness of pathway treatments' concerns the effectiveness of managing pathways that facilitate the introduction of alien species to a country from another region, and the dispersal of alien species within a country after introduction. The indicator is concerned with the outcomes of pathway-focused control measures and in particular, the degree to which pathway treatments are reducing the rate of introduction and within-country dispersal of alien species. Depending on the available data, the indicator can be used to answer two questions:

- What proportion of pathways that require management are effectively managed?;
- What is the return on investment for pathway-focused control measures?

### Potential for aggregation

Although this indicator was developed for use at a national level it can be used at a wide range of spatial scales, depending on the scale at which data are available (e.g. regions or continents).

### Possible reasons for trends

↑ or ↓	Changes to the rate at which alien species are being introduced to the country or dispersing within the country
	Changes to the policies of the country or the resources available for biosecurity (funds and personnel), and how these resources are allocated

### Implications for biodiversity management of change in the indicator

Upward or downward trends could lead to changes in the resources allocated to pathway-focused control measures, and could influence the pathways that are managed.

### Units in which it is expressed

4.7.1.	<p>Number of pathways in seven categories of control effectiveness</p> <ul style="list-style-type: none"><li>• Not known</li><li>• None: There was no intervention</li><li>• Counter-productive: The intervention has exacerbated the problem.</li><li>• Ineffective: The intervention did not change the invasion.</li><li>• Partial: Somewhat effective intervention</li><li>• Effective: The treatment has reduced the problem to below a desired management threshold. On-going control is required.</li><li>• Permanent: The problem has been reduced to a sustainably low level (or zero), and so no on-going management is required.</li></ul> <p>AND</p> <p>An assessment of any negative impacts of control.</p>
4.7.2.	<p>Quantitative measure of impact on introduction pathway prominence, introduction rates, within-country pathway prominence, and within-country dispersal rates</p> <p>AND</p> <p>A formal environmental and social assessment of non-target effects of the interventions</p>
4.7.3.	<p>Return on investment expressed as a ratio of the amount spent on control to the value of avoided cost of impact.</p> <p>AND</p> <p>Include non-target impacts as costs</p>

### Description of source data

Reports on monitoring and evaluation of control interventions obtained from the relevant government departments. Information on the rate at which alien species are being introduced to the country and dispersing within the country obtained from assessments of the status of the introduction pathways and within-country dispersal pathways and data from interventions (e.g. interception data).

For more advanced metric, economic costings and back-casts from the relevant government departments, as well as estimates of avoided costs from models.

#### Calculation procedure

4.7.1.	<p>Data on control effectiveness from published reports, data on rates of introduction or expert opinions are used to categorise the effectiveness of treatment for each pathway as:</p> <ul style="list-style-type: none"> <li>• Not known</li> <li>• None: there is evidence that no interventions were applied to the assessed pathway (over the relevant time period)</li> <li>• Counter-productive: Evidence that there are more introductions or spread;</li> <li>• Ineffective: There is no discernible change in the rate of introductions or within-country dispersal or there is evidence that illegal/accidental introductions continue despite interventions</li> <li>• Partial: Rates of introduction and dispersal have decreased or there is some evidence that the treatments are effective</li> <li>• Effective: Rates of introduction and dispersal are below an explicitly defined management threshold or illegal introductions do not occur, management is continuing.</li> <li>• Permanent: Active management is no longer required, as there are no more introductions or dispersal</li> </ul> <p>AND</p> <p>Expert assessment informed by data collected on any collateral damage (e.g. details of legal claims and reports of direct non-target damage to native species and damage to ecological infra-structure, with such data ideally collected in the region of interest).</p>
4.7.2.	<p>A counter-factual model is produced that is used to project values with and without control interventions. Using this a percentage change in relevant indicators (e.g. introduction rates) is calculated.</p> <p>AND</p> <p>An impact assessment (both environmental and social) is conducted as per standard guidelines for the relevant country.</p>
4.7.3.	<p>Estimates of the costs of control are calculated for different management scenarios with the models used in the calculation of 4.7.2. together with quantitative estimates of the impact of the introductions or dispersal combined to give a ratio. Ratio &gt; 1 where cost of control is less than the value of impacts avoided through effective control or negative; &lt;1 where control costs exceed the value of impacts avoided through effective control.</p> <p>AND</p> <p>The costs of non-target impacts are included in costs of control.</p>

#### Guide for applying confidence levels

4.7.1.	High	There has been a published peer-reviewed quantitative assessment of the degree of control achieved.
	Medium	There is a report that is based on monitoring data.
	Low	Expert opinion.
4.7.2.	High	As 4.7.1., in addition, the models used are published in peer-reviewed journals and have been extensively tested in similar situations.
	Medium	As 4.7.1., in addition, the models used are published in peer-reviewed journals, but only recently or this is one of only a few examples of their implementation.
	Low	As 4.7.1., in addition, the models used have not been published.
4.7.3.	High	As 4.7.2.
	Medium	As 4.7.2.
	Low	As 4.7.2.

## Most effective forms of presentation

4.7.1.	A table with number of pathways in different categories
4.7.2.	A box-plot showing the degree to which different interventions have reduced specific indicators of biological invasions
4.7.3.	A table

Indicator 4.7.1 Table 1 – Effectiveness of pathway treatments per pathway. Adapted from SANBI and CIB (2023)

Pathway of Introduction		Effectiveness of pathway treatments
Release	Biological control	Effective
	Stabilisation and barriers	None/ineffective
	Fishery in wild	Effective
	Hunting	Effective
	Aesthetic release	Permanent
	Conservation in wild	Partial
	Release for use	Not known
	Other release	Not known
Escape	Agriculture	None/ineffective
	Aquaculture	Effective
	Botanical gardens & zoos	Not known
	Pet	None/ineffective
	Farmed animals	Effective
	Forestry	Not known
	Fur farms	Effective
	Horticulture	None/ineffective
	Ornamental	Not known
	Research	Not known
	Live food and live bait	Not known
	Other escape	None/ineffective
Contaminant	Nursery material contaminant	None/ineffective
	Bait contaminant	None/ineffective
	Food contaminant	None/ineffective
	Contaminant of animals	None/ineffective
	Parasite of animals	None/ineffective
	Contaminant of plants	None/ineffective
	Parasite of plants	None/ineffective
	Seed contaminant	None/ineffective
	Timber trade contaminant	None/ineffective
	Habitat material contaminant	None/ineffective
Stowaway	Fishing equipment	None/ineffective
	Container & bulk cargo	None/ineffective
	Airplane	Not known
	Ship excluding ballast water or hull fouling	Not known
	Machinery & equipment	Not known
	People & luggage	Not known
	Packing material	Not known
	Ballast water	None/ineffective
	Hull fouling	None/ineffective
	Land vehicles	Not known
Corridor	Other stowaway	None/ineffective
	Canals & artificial waterways	Not known
Unaided	Tunnels & bridges	None/ineffective
	Natural dispersal	Not known

## Limits to usefulness and accuracy

Relies on accurate and up to date data obtained from various government departments, and data are at present only available for a limited number of pathways. Poor data quality (e.g. poor estimates of rate of introduction or cost-benefit ratio) might lead to an inaccurate assessment.

## Updating the indicator

The indicator could be updated yearly or at coarser, but regular time intervals. At the least, the indicator should be updated as often as is required for reporting on the status of biological invasions.

## Closely related indicators

Depends upon	Links with	Required for
1.1. Introduction pathway prominence 1.2. Introduction rates 1.3. Within-country pathway prominence 1.4. Within-country dispersal rates 2.1. Number and status of alien species 4.1 Quality of the regulatory framework (needed for planning coverage) 4.2. Money spent 4.3. Planning coverage 4.4. Pathways treated	1. Rate of unregulated introduction of new species 4.8 Effectiveness of species treatments 4.9 Effectiveness of site treatments	4. Level of success in managing invasions

## Additional information and comments

Return on investment is not relevant if there is no control and there should have been, this is dealt with in the quality of the planning framework. Return on investment is only relevant if measured using an indicator that is related to control outcomes (e.g. rate of introductions rather than some metric of how many inspections were carried out).

## Properties

*Tested*

.

*Spatially explicit*

*Not scalable*

*Temporal*

*Qualitative uncertainty*

*Somewhat taxonomically representative*

*IAS specific*

*Somewhat reproducible*

Property	Response	Notes
Tested	Yes	Tested for mainland South Africa and PEIs, although as effectiveness of management for pathways is not estimated and assessment is largely based piecemeal information determined based on recently published data and data obtained from management agencies
Spatially explicit	Yes	Management is for a given region (e.g., South Africa) or site (e.g., port)
Scalable	No	Only applicable to the specific region
Temporal	Yes	Rates of introduction, and activities can be tracked over time, but currently not available
Uncertainty appraisal	Qualitative	There will be uncertainties in rates of introduction that will impact estimates. Confidence levels are provided
Taxonomically representative	Partially	Applicable to all taxa
Invasive alien species specific	Yes	Specifically for pathways that facilitate biological invasions

<b>Property</b>	<b>Response</b>	<b>Notes</b>
Reproducible	Partially	A certain amount of the work involves expert opinion, as effectiveness is not estimated by management agencies

## 4.8. Effectiveness of species treatments

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Response

Theory of Change (ToC): Output

### Use and interpretation

Outcome indicator of the number of alien species that require management brought under different degrees of control, based in part on that developed for assessing the efficacy of classical biological control programmes (Klein 2011). This indicator could inform the allocation of future management and research resources.

### Potential for aggregation

Can be aggregated across different taxonomic groups.

### Possible reasons for trends

↑	The development of improved management techniques
	The adoption and implementation of effective best-practice control measures
	Increased funding or other resources
↓	Reductions in resources for control
	Changes away from effective treatments
	More species start to require management

### Implications for biodiversity management of change in the indicator

If the number of species brought under effective control increases, then scarce funds could be freed up for controlling additional species.

### Units in which it is expressed

4.8.1.	<p>Number of species in seven categories of control effectiveness</p> <ul style="list-style-type: none"><li>• Not known</li><li>• None: There was no intervention</li><li>• Counter-productive: The intervention has exacerbated the problem.</li><li>• Ineffective: The intervention did not change the invasion.</li><li>• Partial. Somewhat effective intervention</li><li>• Effective. The treatment has reduced the problem to below a desired management threshold. On-going control is required.</li><li>• Permanent. The problem has been reduced to a sustainably low level (or zero), and no on-going management is required.</li></ul> <p>AND</p> <p>An assessment of any negative impacts of control.</p>
4.8.2.	<p>Quantitative measure of impact on population size, extent or impact due to control</p> <p>AND</p> <p>A formal impact assessment of the interventions</p>
4.8.3.	<p>Return on investment expressed as a ratio of the amount spent on control to the value of avoided cost of impact.</p> <p>AND</p> <p>Non-target impacts as costs</p>

### Description of source data

This indicator is determined using data on the number of species management plans obtained from literature, academic and government institutions, and on the success of such management obtained from literature, academic and government institutions.

### Calculation procedure

4.8.1.	<p>Values are sourced from <i>speciesTreatedEffect</i></p> <p>Data on control effectiveness from published reports and sources or expert opinions are used to categorise the control effectiveness for each species as:</p> <ul style="list-style-type: none"> <li>• Not known</li> <li>• None: there is evidence that no interventions were applied to the assessed species (over the relevant time period)</li> <li>• Counter-productive: There is evidence that control has led to further spread; has caused increases in abundance; and/or has made subsequent treatments more difficult without reducing the invasion;</li> <li>• Ineffective: There is no discernible change to the rate at which the extent of the invasion or the abundance of the species are increasing despite interventions.</li> <li>• Partial: Rate of increase in extent or abundance has slowed.</li> <li>• Effective: Extent or abundance is decreasing or has ended up below a management threshold, management is continuing.</li> <li>• Permanent: There is no more active management and despite this the population remains below the management threshold.</li> </ul> <p>AND</p> <p>Expert assessment informed by data collected on any collateral damage (e.g. details of legal claims and reports of direct non-target damage to native species and damage to ecological infra-structure, with such data ideally collected in the region of interest).</p>
4.8.2.	<p>A counter-factual model is produced that is used to project values with and without control interventions. Using this a percentage change in relevant indicators (e.g. population size after a given time) is calculated.</p> <p>AND</p> <p>An impact assessment is conducted as per standard guidelines for the relevant country.</p>
4.8.3.	<p>Estimates of the costs of control are calculated for different management scenarios with the models used in the calculation of 4.8.2. together with a quantitative estimate of the impact of the invasions combined to give a ratio. &gt; 1 where cost of control is less than the value of impacts avoided through effective control or negative; &lt; 1 where control costs exceed the value of impacts avoided through effective control, or where control is ineffective and delivers little or no benefit</p> <p>AND</p> <p>The costs of non-target impacts are included in costs of control.</p>

### Guide for applying confidence levels

4.8.1.	High	Inherited from <i>speciesTreatedEffectConfidence</i>
	Medium	There has been a published peer-reviewed quantitative assessment of the degree of control achieved.
	Low	Expert opinion.
4.8.2.	High	As for 4.8.1., in addition, the models used are published in peer-reviewed journals and have been extensively tested in similar situations.
	Medium	As for 4.8.1. in addition, the models used are published in peer-reviewed journals, but only recently or this is one of only a few examples of their implementation.
	Low	As for 4.8.1., in addition, the models used have not been published.
4.8.3.	High	As for 4.8.2.
	Medium	As for 4.8.2.
	Low	As for 4.8.2.

### Most effective forms of presentation

4.8.1.	A table with the number of species in different categories
4.8.2.	A box-plot showing the degree to which different interventions have reduced specific indicators of biological invasions
4.8.3.	A table

**Indicator 4.8.1 Table 1** The number of invasive species in different categories of control effectiveness that were subjected to management interventions between 2020 and 2022. Based on Table 4.6 in SANBI and CIB (2023)

Group	Category of control effectiveness					Total
	Permanent	Effective	Partially effective	Ineffective	Not evaluated	
Plants	12	34	10	9	170	235
Birds	0	1	0	1	1	3
Freshwater fish	0	0	1	1	0	2
Mammals	0	1	0	0	0	1
Invertebrates	5	5	13	2	52	77
Amphibians	0	0	0	0	1	1
Reptiles	0	0	0	0	0	0
Microbes	0	0	0	0	0	0
Total	17	41	24	13	224	319

#### Limits to usefulness and accuracy

Relies on accurate and to update data obtained from species management and control plans that are at present only available for limited number of species

#### Updating the indicator

Annually

#### Closely related indicators

Depends upon	Links with	Required for
5. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species 2.4. Impact of alien species 3.1. Alien species richness 3.2. Relative invasive abundance 4.1 Quality of the regulatory framework (needed for planning coverage) 4.2. Money spent 15: Planning coverage 4.5. Species treated	None	4. Level of success in managing invasions

#### Additional information and comments

None

#### Properties

Property	Response	Notes
Tested	Yes	For a few taxa, particularly those under classical biological control, it is possible to evaluate the effectiveness of species treatments based on long-standing metrics and analyses
Spatially explicit	Yes	The effectiveness is for a particular area
Scalable	No	Effectiveness might change depending on the spatial context and so it is not advised to assume effectiveness can be scaled up
Temporal	Partially	The date at which effectiveness is recorded can be measured, but things change over time

<b>Property</b>	<b>Response</b>	<b>Notes</b>
Uncertainty appraisal	None	The level of uncertainty is fairly crude at present
Taxonomically representative	Yes	The indicator is not specific to a given taxon
Invasive alien species specific	Yes	The indicator is not specific to controlling biological invasions
Reproducible	Partially	In most cases that scoring is based on published accounts that should be repeatable

## 4.9. Effectiveness of site treatments

### Type of indicator

Driver-Pressure-State-Impact-Response (DPSIR): Response

Theory of Change (ToC): Output

### Use and interpretation

Outcome indicator that assesses the effectiveness of site-focused control measures.

### Potential for aggregation

Data at smaller spatial scales can be aggregated to larger scales.

### Possible reasons for trends

↑	The development and implementation of more effective treatment technologies
	More strategic application of existing technologies
	Increased funding and other resources
	A decrease in the area requiring treatment (i.e., positive feedbacks are likely)
↓	Vice versa for ↑

### Implications for biodiversity management of change in the indicator

Increases imply that management is decreasing the size of future problems. In this instance resources could be directed to other sites.

### Units in which it is expressed

4.9.1.	<p>Number of sites in seven categories of control effectiveness</p> <ul style="list-style-type: none"> <li>• Not known</li> <li>• None: There was no intervention</li> <li>• Counter-productive: The intervention has exacerbated the problem.</li> <li>• Ineffective: The intervention did not change the invasion.</li> <li>• Partial. Somewhat effective intervention;</li> <li>• Effective. The treatment has reduced the problem to below a desired management threshold. On-going control is required;</li> <li>• Permanent. The problem has been reduced to a sustainably low level (or zero), and no on-going management is required.</li> </ul> <p>AND</p> <p>An assessment of any negative impacts of control.</p>
4.9.2.	<p>Quantitative measure of control on relative invasive abundance or alien species richness</p> <p>AND</p> <p>Conduct a formal impact assessment of the interventions</p>
4.9.3.	<p>Return on investment expressed as a ratio of the amount spent on control to the value of avoided cost of impact.</p> <p>AND</p> <p>Include non-target impacts as costs</p>

### Description of source data

This indicator is determined using data on the number of sites that have species monitoring, control and eradication plans; and species status reports that were obtained from literature, academic and government institutions.

### Calculation procedure

4.9.1.	<p>Data on control effectiveness from published reports and sources or expert opinions are used to categorise control effectiveness at sites as:</p> <ul style="list-style-type: none"> <li>• Not known;</li> </ul>
--------	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

	<ul style="list-style-type: none"> <li>• None: there is evidence that no interventions were applied to the assessed site (over the relevant time period)</li> <li>• Counter-productive: Evidence that relative invasive abundance is increasing as a result of the intervention;</li> <li>• Ineffective: There is no discernible change in the degree to which relative invasive abundance is increasing despite interventions;</li> <li>• Partial: The relative invasive abundance has decreased;</li> <li>• Effective: The relative invasive abundance has decreased to below a management threshold, management is continuing;</li> <li>• Permanent: There is no more active management, despite this relative invasive abundance remains below a management threshold.</li> </ul> <p>AND</p> <p>Expert assessment informed by data collected on any collateral damage (e.g. details of legal claims and reports of direct non-target damage to native species and damage to ecological infrastructure, with such data ideally collected in the region of interest).</p>
4.9.2.	<p>A counter-factual model is produced that is used to project values with and without control interventions. Using this a percentage change in relevant indicators (e.g. relative invasive abundance) is calculated.</p> <p>AND</p> <p>An impact assessment is conducted as per standard guidelines for the relevant country.</p>
4.9.3.	<p>Estimates of the costs of control are calculated for different management scenarios with the models used in the calculation of 20.2 together with quantitative estimates of the impact of the invasions combined to give a ratio. &gt; 1 where cost of control is less than the value of impacts avoided through effective control or negative; &lt;1 where control costs exceed the value of impacts avoided through effective control, or where control is ineffective and delivers little or no benefit</p> <p>AND</p> <p>The costs of non-target impacts are included in costs of control.</p>

### Guide for applying confidence levels

4.9.1.	High	There has been a published peer-reviewed quantitative assessment of the degree of control achieved.
	Medium	There is a report that is based on monitoring data.
	Low	Expert opinion.
4.9.2.	High	As for 4.9.1., in addition, the models used are published in peer-reviewed journals and have been extensively tested in similar situations.
	Medium	As for 4.9.1., in addition, the models used are published in peer-reviewed journals, but only recently or this is one of only a few examples of their implementation.
	Low	As for 4.9.1., in addition, the models used have not been published.
4.9.3.	High	As for 4.9.2.
	Medium	As for 4.9.2.
	Low	As for 4.9.2.

### Most effective forms of presentation

4.9.1.	A table with number of sites in different categories
4.9.2.	A box-plot showing the degree to which different interventions have reduced specific indicators of biological invasions
4.9.3.	A table

**Indicator 4.9.1 Table 1** A summary list of the condensed hectares of invasive plants per protected area cluster managed by Cape Nature over the period 2018 to 2021. Confidence in these figures is medium. Adapted from Table S4.12 of SANBI and CIB (2023).

Protected Area cluster	Protected Area extent (ha)	Invaded area in 2018 (ha)	Invaded area in 2021 (ha)	Change	Effectiveness of site treatments
Anysberg	83 530.92	1 679.85	1 158.60	Slight decrease	Partial
Cederberg	66 811.65	382.56	1 345.58	Slight increase	Partial

Protected Area cluster	Protected Area extent (ha)	Invaded area in 2018 (ha)	Invaded area in 2021 (ha)	Change	Effectiveness of site treatments
Dassen Island	737.81	18.70	17.52	Slight decrease	Partial
De Hoop	34 017.09	8 514.80	9 614.26	Moderate increase	Partial
De Mond	1 592.79	21.00	21.94	Slight increase	Partial
Driftsands	507.03	23.29	8.30	Moderate increase	Ineffective
Dyer Island	290.04	NA	0	No data	Not known
Gamkaberg	39 996.80	54.18	44.23	Slight decrease	Partial
Ganzekraal	6 239.81	1 306.21	1 583.40	Moderate increase	Partial
Geelkrans	1 294.93	483.38	603.93	Moderate increase	Partial
Goukamma	2 605.17	1 000.25	814.04	Moderate decrease	Partial
Grootvadersbosch	33 586.38	6 501.05	3 751.47	Moderate decrease	Partial
Groot-Winterhoek	27 330.36	368.75	471.41	Slight increase	Partial
Hottentots-Holland	32 775.79	8 757.01	12 532.24	Major increase	Partial
Jonkershoek	15 399.20	4 431.46	1 164.80	Major decrease	Effective

### Limits to usefulness and accuracy

Relies on accurate and up to date data obtained from management and control plans for each site. Such data are, at present, only available for limited number of sites.

### Updating the indicator

In line with reporting processes.

### Closely related indicators

Depends upon	Links with	Required for
2.1. Number and status of alien species 2.2. Extent of alien species 2.3. Abundance of alien species 2.4. Impact of alien species 3.1. Alien species richness 3.2. Relative invasive abundance 3.3. Impact of invasions 4.2. Money spent 4.1 Quality of the regulatory framework 4.3. Planning coverage 4.6. Sites treated	None	3. Extent of area that suffers 'Major' impacts from invasions 4. Level of success in managing invasions

### Additional information and comments

None.

### Properties

Property	Response	Notes
Tested	Yes	Values are available for a limited number of sites
Spatially explicit	Yes	The effectiveness will be for particular sites
Scalable	No	It will not be easy to sum up values across different sites
Temporal	Yes	Data should be updated over time
Uncertainty appraisal	None	No uncertainty measure is available
Taxonomically representative	Yes	The indicator is site specific
Invasive alien species specific	Yes	The indicator is specific to biological invasions
Reproducible	No	A workflow is needed with clear data sources

## Appendix 1 Scoring indicator properties

Indicators were compared with the eight properties identify by Vicente et al. (2022) as being important for indicators on biological invasions, noting some of the phrasing is changed for ease of use.

Property	Responses	Notes
<i>Tested</i>	<p><i>Yes</i>—the indicator has been proposed, tested, and applied to inform on range of situations</p> <p><i>No</i>—the indicator is being proposed and defined for the first time and has not yet been tested or applied to any situation</p>	Information derived from an indicator which has already been tested and applied in a range of situations and contexts will, in principle, be more reliable than that from an indicator which has been proposed but not yet validated. The original term for this property was ‘Established’ the term ‘Tested’ is preferred here as established is a stage in the biological invasions process.
<i>Spatially explicit</i>	<p><i>Yes</i>—the indicator provides information that can be linked to a specific spatial location (e.g., a site, region, and country) so that its features can be associated with that location</p> <p><i>No</i>—the indicator does not provide information that can be linked to a spatial location</p>	Spatially explicit information enables trends to be mapped for all indicators be they pathways, species, sites, or interventions. Linking the data that underpin indicators to specific places makes an indicator more valuable to local, national, or regional management, and possible to disaggregate to application at finer scales.
<i>Scalable</i>	<p><i>Yes</i>—the indicator is calculated through a hierarchy of nested spatial grains, i.e., scalable up or down</p> <p><i>No</i>—the indicator is not calculated over different spatial grains and does not provide clear indication on how to calculate it beyond the scale for which it was created</p>	Scalability enables the application of the indicator at the relevant spatial extent, a robust indicator should be reproducible at multiple, distinct spatial scales. Scalability allows data collected for indicators at national scale to be meaningfully aggregated for use at international scales (and vice versa).
<i>Temporal</i>	<p><i>Yes</i>—the indicator includes a temporal dimension (is expressed as a trend), being calculated for a particular time, and is periodically updated</p> <p><i>Partially</i>—the indicator is not specifically designed to have a temporal dimension (be expressed as a trend), but it provides clear indication that it can be repeated in future if data are collected for this purpose</p> <p><i>No</i>—the indicator is not designed to be recalculated in future nor does it provide clear indication that would allow calculation of a trend</p>	The availability of information that is linked to a date and duration relevant to informing on the status and trends of IAS. The indicator should be designed so that it can be recalculated over time to support the monitoring of IAS-relevant change.
<i>Uncertainty appraisal</i>	<p><i>Quantitative</i>—the indicator reports a quantitative measure of uncertainty</p> <p><i>Qualitative</i>—the indicator reports a qualitative measure of uncertainty</p> <p><i>None</i>—no uncertainty measure is reported with the indicator</p>	The presentation of measurements of uncertainty for informing on IAS trends and status represents a key aspect of any evaluation approach, with implications for implementation and reproducibility. This provides scientists and decision makers with information on the degree of confidence in the indicator message.

<b>Property</b>	<b>Responses</b>	<b>Notes</b>
<i>Taxonomically representative</i>	<p><i>Yes</i>—the indicator is presented as a general indicator that can be, by design, applied to any taxa</p> <p><i>Partially</i>—the indicator is designed or applied to a particular taxon or group but provides clear indication that it can be transferred to other taxa</p> <p><i>No</i>—the indicator is specifically designed for a particular taxon or group and it does not clearly indicate whether it can be transferred to other taxa</p>	To address a range of policy or decision-support requirements, the information provided by an indicator should be applicable to a range of IAS taxonomic groups.
<i>Invasive alien species specific</i>	<p><i>Yes</i>—the indicator has been calculated using IAS specific data and not proxy data that can be used to infer on IAS. This property is particularly relevant for Pressure indicators</p> <p><i>No</i>—the indicator is proposed and calculated using proxy data on IAS</p>	Sound measurement of progress toward preventing and controlling IAS requires indicators that use (IAS) species data (Note: this property is not applicable to some indicator types).
<i>Reproducible</i>	<p><i>Yes</i>—the data necessary to populate the indicator are accessible and available for public use and indications on how to calculate the indicator are provided</p> <p><i>Partially</i>—data necessary to populate the indicator is not explicitly indicated as accessible, yet indications on how to calculate the indicator and get the necessary data are provided</p> <p><i>No</i>—the data are not available for public use nor they contain explicit instructions to calculate it</p>	Reproducibility is essential for any communication, scientific and political goal, as it allows availability, repeatability, standardization, and archiving in support of information harmonisation, integration, use, and transparency.

## References

- Bacher S, Blackburn TM, Essl F, Genovesi P, Heikkilä J, Jeschke JM, Jones G, Keller R, Kenis M, Kueffer C, Martinou AF, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Roy HE, Saul W-C, Scalera R, Vilà M, Wilson JRU, Kumschick S (2018) Socio-economic impact classification of alien taxa (SEICAT). *Methods in Ecology and Evolution* 9: 159–168. doi:10.1111/2041-210X.12844
- Biodiversity Indicators Partnership (2011) Guidance for national biodiversity indicator development and use. UNEP World Conservation Monitoring Centre, Cambridge, U.K., 40 pp. [https://www.bipindicators.net/system/resources/files/000/002/191/original/Framework\\_Brochure\\_UK\\_0311\\_LOWRES\\_%281%29.pdf](https://www.bipindicators.net/system/resources/files/000/002/191/original/Framework_Brochure_UK_0311_LOWRES_%281%29.pdf)
- Blackburn TM, Pyšek P, Bacher S, Carlton JT, Duncan RP, Jarošík V, Wilson JRU, Richardson DM (2011) A proposed unified framework for biological invasions. *Trends in Ecology & Evolution* 26: 333–339. doi:10.1016/j.tree.2011.03.023
- Convention on Biological Diversity (2014) Pathways of introduction of invasive species, their prioritization and management. Secretariat of the Convention on Biological Diversity, Montreal, 18 pp. Available from: <https://www.cbd.int/doc/meetings/sbstta/sbstta-18/official/sbstta-18-09-add1-en.pdf>.
- Convention on Biological Diversity (2022) Kunming-Montreal Global Biodiversity Framework: draft decision submitted by the President. Secretariat of the Convention on Biological Diversity, Montreal, 1–14 pp.
- Department of Environmental Affairs (2015) Monitoring, control & eradication plans: guidelines for species listed as invasive in terms of section 70 of national environmental management: Biodiversity act, 2004 (act no. 10 of 2004) (NEM:BA) and as required by Section 76 of this Act. South African Government, 14 pp.
- Donaldson JE, Richardson DM, Wilson JRU (2014) Scale-area curves identify artefacts of human use in the spatial structure of an invasive tree. *Biological Invasions* 16: 553–563. doi:10.1007/s10530-013-0602-0
- Essl F, Dullinger S, Rabitsch W, Hulme PE, Pyšek P, Wilson JRU, Richardson DM (2015) Historical legacies accumulate to shape future biodiversity in an era of rapid global change. *Diversity and Distributions* 21: 534–547. doi:10.1111/ddi.12312
- Evans T, Kumschick S, Blackburn TM (2016) Application of the Environmental Impact Classification for Alien Taxa (EICAT) to a global assessment of alien bird impacts. *Diversity and Distributions* 22: 919–931. doi:10.1111/ddi.12464
- Fernández Winzer L, Greve M, le Roux PC, Faulkner KT, Wilson JRU (2025) Using indicators to assess the status of biological invasions and their management on islands—the Prince Edward Islands, South Africa as an example. *Biological Invasions* 27: article 108 (130 pages). doi:10.1007/s10530-024-03463-7
- Geerts S, Botha PW, Visser V, Richardson DM, Wilson JRU (2013) Montpellier broom (*Genista monspessulana*) and Spanish broom (*Spartium junceum*) in South Africa: an assessment of invasiveness and options for management. *South African Journal of Botany* 87: 134–145. doi:10.1016/j.sajb.2013.03.019
- Groom Q, Desmet P, Reyserhove L, Adriaens T, Oldoni D, Vanderhoeven S, Baskauf SJ, Chapman A, McGeoch M, Walls R, Wiczorek J, Wilson JRU, Zermoglio PFF, Simpson A (2019) Improving Darwin Core for research and management of alien species. *Biodiversity Information Science and Standards* 3: e38084. doi:10.3897/biss.3.38084
- Hawkins CL, Bacher S, Essl F, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Vilà M, Wilson JRU, Genovesi P, Blackburn TM (2015) Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). *Diversity and Distributions* 21: 1360–1363. doi:10.1111/ddi.12379
- Henderson L, Wilson JRU (2017) Changes in the composition and distribution of alien plants in South Africa: an update from the Southern African Plant Invaders Atlas (SAPIA). *Bothalia: African Biodiversity and Conservation* 47: a2142. doi:10.4102/abc.v47i2.2172
- Hulme PE (2012) Weed risk assessment: a way forward or a waste of time? *Journal of Applied Ecology* 49: 10–19
- IUCN (2020) IUCN EICAT Categories and Criteria. The Environmental Impact Classification for Alien Taxa (EICAT) First edition. IUCN, Gland, Switzerland and Cambridge, UK, 49 pp. doi:10.2305/IUCN.CH.2020.05.en
- Ivey PJ, Hill MP, Zachariades C (2021) Advances in the regulation of weed biological control in South Africa. *African Entomology* 29: 1060–1076, 1017. doi:10.4001/003.029.1060
- Jacobs LEO, Richardson DM, Lepschi BP, Wilson JRU (2017) Quantifying errors and omissions in the listing of alien species: *Melaleuca* in South Africa as a case-study. *NeoBiota* 32: 89–105. doi:10.3897/neobiota.32.9842
- Jansen C, Kumschick S (2022) A global impact assessment of *Acacia* species introduced to South Africa. *Biological Invasions* 24: 175–187. doi:10.1007/s10530-021-02642-0

- Kunin WE (1998) Extrapolating species abundance across spatial scales. *Science* 281: 1513–1515. doi:10.1126/science.281.5382.1513
- Le Maitre DC, Forsyth GG, Dziki S, Gush MB (2016) Estimates of the impacts of invasive alien plants on water flows in South Africa. *Water Sa* 42: 659–672. doi:10.4314/wsa.v42i4.17
- Liebholt AM, Brouwerhoff EG, Kimberley M (2017) Depletion of heterogeneous source species pools predicts future invasion rates. *Journal of Applied Ecology* 54: 1968–1977 doi:10.1111/1365-2664.12895
- McClelland GTW, Altwegg R, Van Aarde RJ et al (2018) Climate change leads to increasing population density and impacts of a key island invader. *Ecological Applications* 28:212–224. doi:10.1002/eap.1642
- McGeoch MA, Buba Y, Arlé E, Belmaker J, Clarke DA, Jetz W, Li R, Seebens H, Essl F, Groom Q, García-Berthou E, Lenzner B, Meyer C, Vicente JR, Wilson JR, Winter M (2023) Invasion trends: An interpretable measure of change is needed to support policy targets. *Conservation Letters* 16: e12981. doi:10.1111/conl.12981
- Parker IM, Simberloff D, Lonsdale WM, Goodell K, Wonham M, Kareiva PM, Williamson MH, Von Holle B, Moyle PB, Byers JE, Goldwasser L (1999) Impact: toward a framework for understanding the ecological effects of invaders. *Biological Invasions* 1: 3–19. doi:10.1023/a:1010034312781
- Petit RJ (2004) Biological invasions at the gene level. *Diversity and Distributions* 10: 159–165. doi:10.1111/j.1366-9516.2004.00084.x
- Probert AF, Volery L, Kumschick S, Vimercati G, Bacher S (2020) Understanding uncertainty in the Impact Classification for Alien Taxa (ICAT) assessments. *Neobiota* 62: 387–405. doi:10.3897/neobiota.62.52010
- Robinson TB, Alexander ME, Simon CL, Griffiths CL, Peters K, Sibanda S, Miza S, Groenewald B, Majiedt P, Sink KJ (2016) Lost in translation? Standardising the terminology used in marine invasion biology and updating South African alien species lists. *African Journal of Marine Science*: doi: 10.2989/1814232X.1812016.1163292
- Rouget M, Robertson MP, Wilson JR, Hui C, Essl F, Rentería JL, Richardson DM (2016) Invasion debt—quantifying future biological invasions. *Diversity and Distributions* 22: 445–456. doi:10.1111/ddi.12408
- SANBI and CIB. 2018. *The status of biological invasions and their management in South Africa in 2017*. South African National Biodiversity Institute, Kirstenbosch and DST-NRF Centre of Excellence for Invasion Biology, Stellenbosch. pp.398. doi: 10.5281/zenodo.17697754
- SANBI and CIB 2020. *The status of biological invasions and their management in South Africa in 2019*. South African National Biodiversity Institute, Kirstenbosch and DSI-NRF Centre of Excellence for Invasion Biology, Stellenbosch. pp.71. doi: 10.5281/zenodo.3947613
- SANBI and CIB. 2023. *The status of biological invasions and their management in South Africa in 2022*. South African National Biodiversity Institute, Kirstenbosch and DSI-NRF Centre of Excellence for Invasion Biology, Stellenbosch. pp. 122. doi: 10.5281/zenodo.8217182
- Seebens H, Blackburn TM, Dyer EE, Genovesi P, Hulme PE, Jeschke JM, Pagad S, Pysek P, Winter M, Arianoutsou M, Bacher S, Blasius B, Brundu G, Capinha C, Celesti-Grappow L, Dawson W, Dullinger S, Fuentes N, Jager H, Kartesz J, Kenis M, Kreft H, Kuhn I, Lenzner B, Liebholt A, Mosena A, Moser D, Nishino M, Pearman D, Pergl J, Rabitsch W, Rojas-Sandoval J, Roques A, Rorke S, Rossinelli S, Roy HE, Scalera R, Schindler S, Stajero K, Tokarska-Guzik B, van Kleunen M, Walker K, Weigelt P, Yamanaka T, Essl F (2017) No saturation in the accumulation of alien species worldwide. *Nature Communications* 8. doi:10.1038/ncomms14435
- Shackleton RT, Le Maitre DC, van Wilgen BW, Richardson DM (2016) Identifying barriers to effective management of widespread invasive alien trees: *Prosopis* species (mesquite) in South Africa as a case study. *Global Environmental Change* 38: 183–194
- Suding KN, Hobbs RJ (2009) Threshold models in restoration and conservation: a developing framework. *Trends in Ecology & Evolution* 24: 271–279. doi:10.1016/j.tree.2008.11.012
- van Wilgen BW, Forsyth GG, Le Maitre DC, Wannenburgh A, Kotzé JD, van den Berg E, Henderson L (2012) An assessment of the effectiveness of a large, national-scale invasive alien plant control strategy in South Africa. *Biological Conservation* 148: 28–38. doi:10.1016/j.biocon.2011.12.035
- Veldtman R, Chown SL, McGeoch MA (2010) Using scale-area curves to quantify the distribution, abundance and range expansion potential of an invasive species. *Diversity and Distributions* 16: 159–169. doi:10.1111/j.1472-4642.2009.00632.x
- Vicente JR, Vaz AS, Roige M, Winter M, Lenzner B, Clarke DA, McGeoch MA (2022) Existing indicators do not adequately monitor progress toward meeting invasive alien species targets. *Conservation Letters* 15: e12918. doi:10.1111/conl.12918

- Wilson JR (2025) A list of taxa currently and historically regulated under South Africa's National Environmental Management: Biodiversity Act, Alien & Invasive Species Regulations. v1.1(20250325). doi:10.5281/zenodo.15082537
- Wilson JRU, Caplat P, Dickie I, Hui C, Maxwell BD, Nuñez MA, Pauchard A, Rejmánek M, Richardson DM, Robertson MP, Spear D, Webber BL, van Wilgen BW, Zenni RD (2014) A standardized set of metrics to assess and monitor tree invasions. *Biological Invasions* 16: 535–551 doi:10.1007/s10530-013-0605-x
- Wilson JRU, Ivey P, Manyama P, Nänni I (2013) A new national unit for invasive species detection, assessment and eradication planning. *South African Journal of Science* 109: Art. #0111, 0113 pages. doi:10.1590/sajs.2013/20120111
- Wilson JRU, Faulkner KT, Rahlao SJ, Richardson DM, Zengeya TA, van Wilgen BW (2018) Indicators for monitoring biological invasions at a national level. *Journal of Applied Ecology* 55: 2612–2620. doi:10.1111/1365-2664.13251
- Wilson JRU, Kumschick S (2024) The regulation of alien species in South Africa. *South African Journal of Science* 120: 14 pages. doi:10.17159/sajs.2024/17002