Peer review history for:

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HOW TO CITE:
The regulation of alien species in South Africa [peer review history]. S Afr J Sci. 2024;120(5/6), Art. #17002. https://doi.org/10.17159/sajs.2024/17002/peerreview

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Reviewer A: Round 1
Date completed: 03 March 2024
Recommendation: Accept / **Revisions required** / Resubmit for review / Decline
Conflicts of interest: None

Does the review fall within the scope of SAJS??
Yes/No
Is the review written in a style suitable for a non-specialist and is it of wider than only specialist interest?
Yes/No
Do the Title and Abstract clearly and accurately reflect the content of the review?
Yes/**No**
Does the review provide a significantly novel perspective or significant recent advances in the field?
Yes/No
Is the objective of the review concisely stated?
Yes/No
Is appropriate and adequate reference made to other work in the field?
Yes/No
Do current debates and points of contention receive appropriate coverage?
Yes/No/Not applicable
Are gaps in the literature adequately identified?
Yes/No/Not applicable
Does the review provide direction for future research?
Yes/No/Not applicable
Is the methodology and statistical treatment appropriate?
Not applicable/**Yes**/No/Partly/Not qualified to judge
Are the interpretations and recommendations aligned with the objective?
Yes/Partly/No
Please rate the manuscript on overall contribution to the field
Excellent/Good/Average/Below average/Poor
Please rate the manuscript on language, grammar and tone
Excellent/Good/Average/Below average/Poor
Is the manuscript concise and free of repetition and redundancies?
Yes/No
Is the supplementary material relevant and separated appropriately from the main document?
Yes/No/Not applicable
Please rate the manuscript on overall quality
Excellent/Good/Average/Below average/Poor
If accepted, would you recommend that the article receives priority publication?

Yes/No

Are you willing to review a revision of this manuscript?

Yes/**No**

Select a recommendation:

Accept / **Revisions required** / Resubmit for review / Decline

With regard to our policy on 'Publishing peer review reports', do you give us permission to publish your anonymised peer review report alongside the authors' response, as a supplementary file to the published article? Publication is voluntary and only with permission from both yourself and the author.

Yes/No

Comments to the Author:

Excellent contribution to the field. Very timely and useful precis of the history and the legislation underpinning attempts to control IASs in South Africa. A few asides on the difficulties of drawing in all the stakeholders (e.g. the trout affair) might be useful commentary to add (or make a subject for another paper on conflicts of interest).

[See Appendix 1 for Reviewer A's comments made directly on the manuscript]

Author response to Reviewer A: Round 1

Excellent contribution to the field. Very timely and useful precis of the history and the legislation underpinning attempts to control IASs in South Africa. A few asides on the difficulties of drawing in all the stakeholders (e.g. the trout affair) might be useful commentary to add (or make a subject for another paper on conflicts of interest).

AUTHOR: We are glad the reviewer appreciated the manuscript. The reviewer makes an important point in terms of stakeholders. We have added a short paragraph under the "Progress to date and issues to resolve", noting research in South Africa on the development of frameworks to engage stakeholders, conflicts, and the role of expert assessments. However, we recognise that the issue is simply too large to do justice in this manuscript, and agree that a separate commentary (e.g., on the trout affair) might be warranted.

Title Change from "The regulation of alien species in South Africa" to "The legislation with regards to regulation of alien species in South Africa"

AUTHOR: We consulted a colleague at the Department of Forestry, Fisheries and the Environment who is tasked with implementing the NEM:BA A&IS Regulations; and a colleague who is an expert on environmental legislation. Both preferred the shorter original title, felt the original title was an accurate reflection of the context, and said there was no technical issue with the original title. As such no change was made.

Page: 1 "and categorised."

AUTHOR: Changed

Page: 1 since?

AUTHOR: Added

Page: 1 use rather than usage.

AUTHOR: Changed

Page: 1 supporting what?

AUTHOR: Changed to "supplementary"

Page: 1 will

AUTHOR: Changed

Page: 4 confidence of what?

AUTHOR: Deleted, the confidence is in the scoring of partial, but this is confusing so simply deleted

Page: 5 Not clear why this is so.; Page: 5 clarify what is meant by this.; Page: 5

AUTHOR: Good points. In reviewing this section, it is not entirely clear to us why the 2007 lists were considered by the government as insufficient. So we've deleted the text, provided a link to Table S1 that provides a comparison between the features of the different lists, and flagged "It is not clear exactly why these lists were considered insufficient,"

Page: 6 It would be useful to emphasise here what is different about these vs the NEMBA list.

AUTHOR: Added NEM:BA here to make it clear that the A&IS Lists are more correctly the NEM:BA A&IS Lists. Checked throughout the document and ensured they are always referred to as the NEM:BA A&IS Lists to avoid confusion between the NEM:BA Lists and the A&IS Lists in future.

Page: 6 on; Page: 6 the same; Page: 6 as NEMBA

AUTHOR: Resolved by including the full title (the NEM:BA A&IS Lists)

Page: 7 “Authorised officials do not need a permit to do activities related to their duties.” No context given. What duties.

AUTHOR: Duties in terms of the NEM:BA or the National Environmental Management Act (clarification added)

Page: 7 perform

AUTHOR: Changed

Page: 7 “…before the NEM:BA came into force are exempt, as well as other species legally imported before the A&IS Regulations came into effect” Distinction between the two is not clear. see comment about in this regard.

AUTHOR: Dates provided to ensure clarity—the A&IS Regulations were promulgated under the NEM:BA.

Page: 7 Is this a repetition or referring to FW on offshore islands?

AUTHOR: Good point. Have reworded for clarity as the following given the actual wording in the regulations is more aligned to “release fresh-water fishes or fresh-water invertebrates species into discrete water-bodies in which they already occur” which is a distinct category. We’ve also re-ordered so it is clear that this does not refer to offshore islands.

Page: 7 “Prohibited lists were gazetted in 2014 and 2016, but removed from the 2020 listing (cf. Box 1).” Why?

AUTHOR: The detailed arguments had been set out in Box 1, but then removed to reduce the length of the manuscript. A putative reason was added back in to the main text “arguably as the evidence for why taxa were included on or excluded from the prohibited lists was not clearly set out”. However, we note that the rationale for the removal of the prohibited lists was not officially set out anywhere.

Page: 8 see footnote for typos.

AUTHOR: Footnote checked, and moved to the caption of Table S1 so more accessible.

Page: 8 “several taxonomic backbones” meaning what?

AUTHOR: Rephrased as “a national or international database of accepted scientific names (i.e., a taxonomic backbone)”

Page: 8 species'

AUTHOR: Corrected

Page: 8 “and in many other cases it is due to a slight difference in the formatting of species authorities or an update in the nomenclature.” not clear what this means.

AUTHOR: An example is provided to make this clearer.

Page: 8 Why is Clarias gariepinus on the list? Extra-limital? Columba livia misspelt.

AUTHOR: Yes Clarias gariepinus has formed native-alien populations, this is flagged in Table 3 row 1. Spelling of Columba livia corrected in Table S2, thanks for a great spot! This typo comes from the regulatory lists themselves (the 2014 and 2016 lists) and was corrected in the 2020 lists. It was only misspelt there, it was correct in all other instances in the manuscript and database.

Page: 8 Needs "status" above dates [in Table S2]. What does "various" mean?

AUTHOR: Changed to ‘2014 listing’ rather than adding status. A clarification was added to the caption to Table S2 “Where listings are complicated (e.g., different in different regions or there are lengthy prohibitions and/or exemptions) the listing is simply phrased here as “various”.”

Page: 8 taxa,

AUTHOR: The whole list was removed so this is preferred.

Page: 8 other

AUTHOR: Not needed given no change made above.

Page: 8 keep with body text.

AUTHOR: A page spacing issue that we assume will be addressed in layout.

Page: 9 why is this notable?

AUTHOR: Sentence rephrased and an explanation provided, “, which raises the question: If there is no

demand for permits should a taxon be listed as Category 2?"

Page: 9 Taxa vs Taxon, 2nd sentence in legend; column heading spacing and alignment need adjusting.

AUTHOR: Changes made to Table S3, although we disagree about the alignment, noting we will be happy with whatever changes are made during layout so it complies with SAJS formatting.

Page: 9 made by who?

AUTHOR: Rephrased, the changes are made by DFFE as the responsible authority for the NEM:BA A&IS Lists, but they are not specifically named here to avoid any impression of pointing fingers.

Page: 9 why not?

AUTHOR: Explanation added "(there was no requirement nor process for the rationale for changes to the NEM:BA A&IS Lists to be published)."

Page: 9 Inclusion of Table 3 in the preceding paragraph implies that this process has already been implemented.

AUTHOR: We presume this comment refers to Figure 3, the preceding reference has been changed to Figure 3b. The process for imports has already been implemented in part (given explicit provision in the regulations), but we decided not to go into too much detail here and hope that this is not overly confusing to readers.

Page: 9 Table or Fig.?

AUTHOR: Neither. We've renamed it as "Text" but would appreciate advice as to what it should be called.

Page: 10 set up

AUTHOR: Changed

Page: 10 when?

AUTHOR: The RARC first met 1 March 2023, date moved up from the following paragraph

Page: 10 points

AUTHOR: Changed

Page: 10 centred on

AUTHOR: Changed

Page: 10 addresses

AUTHOR: Change

Page: 11 Fig S1 should be included with the main text.

AUTHOR: We agree that Fig S1 is useful context for understanding, but is not, we believe, essential. Given the manuscript is on the long side, we did not add it back in to the main text.

Page: 12 Font change here?

AUTHOR: Font standardised, though we could not see any change, hopefully any residual issue will be addressed in layout?

Page: 12 the risk analyses were

AUTHOR: Paragraph edited for clarity

Page: 12 46 were recommended to have no substantive change to their listing.

AUTHOR: Paragraph edited for clarity

Page: 12 It is not clear how to read table 2.

AUTHOR: A sentence was added to the legend for clarity "The listings (on date of approval by ASRARP) are shown in the rows and the recommendations are shown in columns. Taxa for which the recommendation was to retain the listing are therefore in the main diagonal (e.g., 20 taxa were listed as 1b and are recommended to be kept as 1b)."

Page: 13 Therefore what category would/should it fall under? 3?

AUTHOR: Edited so the recommendation is explicit

Page: 14 such as?

AUTHOR: Good point. In looking over the delays between submission to acceptance of risk analyses carefully, while complex issues did sometimes lead to long times the longest delays were when "either the risk assessor or the ASRARP handling member became unavailable such that the analyses needed to be reassigned before it could be finalised"

Page: 14 amongst?

AUTHOR: Text changed to help risk assessors

Page: 14 All

AUTHOR: Change made

Page: 15 and

AUTHOR: Changed

Page: 15 How will this work with PIA

AUTHOR: This would need to be tested in a legal case we suspect, but would welcome some suggestion as to whether this issue needs to be discussed more in this manuscript or more broadly how we should address it going forward. We do, however, note that ASRARP members, if they are acting in good faith, are not individually liable for the recommendations of ASRARP and so there would seem to be no necessity to identify individuals?

Page: 16 should

AUTHOR: We used 'could' to avoid being prescriptive, there are advantages and disadvantages to specifying the RAAT and the RARC in the legislation.

Page: 16 to be

AUTHOR: Changed

Page: 24 contradictory. Rather "without risk of invasion"
Page: 24 ditto comment above.

AUTHOR: There is no such thing as zero risk, there will always be a risk of invasion. Rephrased to "acceptably low risk" for clarity

Page: 25 rather "intended" than known.

AUTHOR: Changed to "have been shown to", something stronger than intention is needed here we would argue.

Page: 25 why, if they allow possession but prohibit propagation?

AUTHOR: Category 3 has been defined in different ways in the past. We would argue that it is preferable to recategorise Category 3 taxa as 1a, 1b or 2 and be explicit about the exemptions and/or prohibitions rather than try again to have a Category 3 that is defined more tightly. This is partly on the basis that fewer categories are easier to deal with and that if the exemptions are clearly spelled out in the listing then there is less room for confusion. Text altered to make this clearer.

Page: 26 Not clear how to read this table

AUTHOR: A sentence was added to the legend for clarity "The listings (on date of approval by ASRARP) are shown in the rows and the recommendations are shown in columns. Taxa for which the recommendation was to retain the listing are therefore in the main diagonal (e.g., 20 taxa were listed as 1b and are recommended to be kept as 1b)."

Page: 27 Has "extra-limital" been deliberately avoided here? If so why?

AUTHOR: Rationale added to the proposal as per the reference cited, "The term "native-alien populations" is to be preferred to alternative terms (e.g., "extra-limital", "domestic exotic", "intra-country established alien species", and "home-grown exotic") for consistency."

Page: 27 This proposal should be amended to coincide with "Context Specific" in Table 1. Use the table 1 proposal here.

AUTHOR: Good suggestion, thank you, done.

Page: 28 or unidentified?

AUTHOR: Agreed, added.

Page: 28 what species? Its own? None of this sounds good in terms of altering an intact ecosystem.

AUTHOR: Rewritten focussing on the example of classical biological control.

Page: 28 this is confusing. Legal permission given but not used therefore not present?

AUTHOR: Good point, the phrasing of the issue simplified to "No list of alien taxa legally in the country"

Page: 28 How does this mesh with the NEMBA list. Many taxa are here legally as deliberate introductions but still invasive.

AUTHOR: Agree, a note on how this links to the NEM:BA A&IS Lists was added

Page: 28 therefore present illegally?

AUTHOR: Yes, rephrased

Page: 28 this is still happening.

AUTHOR: Agreed.

Page: 28 of alien taxa?

AUTHOR: Of alien taxa never present, not currently present but were before, currently present but not seen at a particular site, new naturalisations, or similarly of native-alien populations. Kept as is for simplicity.

Page: 28 = >3/yr!

AUTHOR: Yes

Page: 28 speed is of the essence. Compare the trout debacle with the eventual establishment of grey squirrels in Italy because of the delay caused by legal wrangling.

AUTHOR: Agreed, a topic for another paper.

Page: 28 listed or destroyed.

AUTHOR: Changed to "or earmarked for control"

Page: 29 This is tricky territory. Microorganisms introduced unknowingly as symbionts of biocontrol agents will be subject to restrictive legislation. see Venter et al. Water hyacinth and microbiota.

AUTHOR: Agreed, unwitting introductions of symbionts of biocontrol agents without an evaluation of the risks posed is concerning, it should at least be done with an appreciation of the likelihood and consequence of such introductions and legislation should balance such risks with the estimated benefits.

Page: 30 and species used for traditional medicine? See Wiiliams et al, 2021 South African Journal of Botany,

AUTHOR: Agreed, there are many such pathways some of which are more notable in South Africa, the focus on here is integrated governance though.

Page: 32 what is that?

AUTHOR: It is the program used to produce the figure, comment added to that effect.

Page: 33 Here the act and the regulations are treated as one entity. In the text this treatment varies. It would be useful in the text to precisely define what each refers to.

AUTHOR: In correcting references to the regulatory lists (NEM:BA A&IS) this issue is, we believe addressed. Links to the regulations and the act are provided.

Page: 35 this is a bit obscure. On what grounds should it not be? Or should be?

AUTHOR: Details on the process are provided in S1. Grounds for whether DFFE asks SANBI to consider an issue is not specified in the regulations. We have avoided speculating on the relationship and the decisions made in the text though in our experience this is largely down to DFFE wanting SANBI to prioritise on issues that directly and immediately affect how they work.

Page: 35 On what grounds would rejection happen?

AUTHOR: As per the figure legend "For full details of these processes…see S1". In S1 "DFFE is obliged to respond to applications to import a taxon within a set time-frame as specified in the regulations. However, as the requirements for such a report are specified in the regulations, there is a clear basis on which a report may be sent back to the importer without it being sent for further review…"

Page: 36 It would be interesting to know the shortest and longest times and why the long one took so much time.

AUTHOR: We've now noted in the text that the longest ones were due to assessors or ASRARP handling members moving on to something else and us having to reassign documents. Given the issues are procedural we haven't specified exact details. We also haven't provided the range as it is misleading. The shortest times for evaluation are on the basis that taxa are not valid and so should be relisted. This information can be sourced either from the supplementary material or extracted from the figures, so it is presented. But going into a lengthy explanation here seemed unwarranted (and incommensurate with the request to keep the manuscript length in check).

Reviewer B: Round 1
Date completed: 20 February 2024
Recommendation: Accept / Revisions required / Resubmit for review / Decline
Conflicts of interest: None

Does the review fall within the scope of SAJS??

Yes/No

Is the review written in a style suitable for a non-specialist and is it of wider than only specialist interest?

Yes/No

Do the Title and Abstract clearly and accurately reflect the content of the review?

Yes/No

Does the review provide a significantly novel perspective or significant recent advances in the field?

Yes/No

Is the objective of the review concisely stated?

Yes/No

Is appropriate and adequate reference made to other work in the field?

Yes/No

Do current debates and points of contention receive appropriate coverage?

Yes/No/Not applicable

Are gaps in the literature adequately identified?

Yes/No/**Not applicable**

Does the review provide direction for future research?

Yes/No/Not applicable

Is the methodology and statistical treatment appropriate?

Not applicable/Yes/No/Partly/Not qualified to judge

Are the interpretations and recommendations aligned with the objective?

Yes/Partly/No

Please rate the manuscript on overall contribution to the field

Excellent/**Good**/Average/Below average/Poor

Please rate the manuscript on language, grammar and tone

Excellent/**Good**/Average/Below average/Poor

Is the manuscript concise and free of repetition and redundancies?

Yes/No

Is the supplementary material relevant and separated appropriately from the main document?

Yes/No/Not applicable

Please rate the manuscript on overall quality

Excellent/**Good**/Average/Below average/Poor

If accepted, would you recommend that the article receives priority publication?

Yes/No

Are you willing to review a revision of this manuscript?

Yes/**No**

Select a recommendation:

Accept / Revisions required / Resubmit for review / Decline

With regard to our policy on 'Publishing peer review reports', do you give us permission to publish your anonymised peer review report alongside the authors' response, as a supplementary file to the published article? Publication is voluntary and only with permission from both yourself and the author.

Yes/No

Comments to the Author:

This is a very important paper dealing with the regulation of alien species in South Africa. This impacts many economic sectors (agriculture, tourism, conservation, etc.), and on South African biodiversity as a whole. A brief history of the regulatory efforts in this regard are also included and are interesting. I believe that this paper is very important, and all the supplementary files are also of value. I have made a few minor edits to the main file. There is one comment in the abstract, which appears to suggest that plants are not included, but many exampled used in the text refer to plants. Hence, I suggest the authors may need to clarify that point.

[See Appendix 2 for Reviewer B's comments made directly on the manuscript]

Author response to Reviewer B: Round 1

This is a very important paper dealing with the regulation of alien species in South Africa. This impacts many economic sectors (agriculture, tourism, conservation, etc.), and on South African biodiversity as a

whole. A brief history of the regulatory efforts in this regard are also included and are interesting. I believe that this paper is very important, and all the supplementary files are also of value. I have made a few minor edits to the main file. There is one comment in the abstract, which appears to suggest that plants are not included, but many exampled used in the text refer to plants. Hence, I suggest the authors may need to clarify that point.

AUTHOR: We are glad the reviewer found the manuscript useful. The sentence flagged in the abstract was confusing as written and we've rephrased.

Page: 1 what about plants - many of the examples in the text are plants?

AUTHOR: Good point, sentence rephrased.

Page: 1 "Will"

AUTHOR: Corrected

Page: 6 "on"

AUTHOR: Corrected

Page: 8 Note: Rubus is a plant species aggregation

AUTHOR: We believe this refers to the first point about plants being listed (and so it has been addressed)

Page: 10 "a"

AUTHOR: Changed

Page: 11 "That"

AUTHOR: Sentence rephrased

Page: 13 "recommendation"

AUTHOR: Corrected

Page: 13 "through"

AUTHOR: Corrected

Page: 16 "Latter"

AUTHOR: Corrected (not change not tracked on the document as it was embedded in a citation)

Page: 1 what about plants - many of the examples in the text are plants?

AUTHOR: Good point, sentence rephrased.

Author comments for the Associate Editor

Thank you for the comments, the manuscript has been fully revised in line with the requirements specified.

With reference to our previous request that this paper is not published before the national status report on biological invasions is released, we are pleased to note the report was released on Friday 8 March 2024 (https://zenodo.org/records/8217182). We have updated the reference as required. The status report and its supplementary material can be accessed and cross-checked as needed.

Also as discussed, we plan to do a final update of the risk analyses completed at the last stage possible (i.e., if the manuscript is accepted before production) so that the paper will be as up-to-date as it can be (and avoid multiple updates). This largely concerns the supplementary material, with minor adjustments to the numbers in the main text and figures.

The revised manuscript is <5% longer than the originally submitted manuscript, and no figures or tables have been added.

We note that the reviewers agreed the manuscript was "concise and free of repetition and redundancies" and the "language, grammar and tone" was Good or Excellent, and so we have not attempted to further shorten the manuscript; and have rejected a few suggestions of the reviewers where doing so would increase the length. In addition to addressing the reviewers' comments we carefully rechecked the manuscript. One addition to the list of issues to address that was missed off the initial submission but raised again by colleagues in the meantime was "The pre-eminence of common names over scientific names". We have added a row to Table 3 on this.

The regulation of alien species in South Africa

Abstract

A key global change challenge is to significantly reduce the risks of alien taxa causing harmful impacts without compromising the rights of citizens. As part of efforts to address this challenge, South Africa promulgated comprehensive regulations and lists of alien taxa in 2014. This paper reviews how the lists were developed and have changed over time. As of March 2021, 560 taxa and all hybrids between native and alien species of amphibians, birds, mammals, and reptiles were listed. Almost 3000 permits have been issued for usage of 268 listed taxa with a steady rate of about 30 permits per month. The full lists of regulated taxa, permits issued, and corresponding regulations are available on-line as supporting files. A proposed standardised, transparent, and science-informed process to revise the regulatory lists is also presented—risk analyses have been developed for over 120 taxa using the Risk Analysis for Alien Taxa (RAAT) Framework and reviewed by an independent scientific body [the Alien Species Risk Analysis Review Panel (ASRARP)]. These recommendations are being considered by an inter-departmental governmental decision-making body established in March 2023 [the Risk Analysis Review Committee (RARC)]. Finally, key issues with the listing of alien taxa in South Africa that remain to be resolved are presented. As South Africa's regulatory framework continues to develop, the process of listing and regulating alien taxa will, we believe, become more transparent, consistent, and acceptable to stakeholders. Ultimately this well facilitate efforts to reduce the harmful impacts of alien taxa.

Significance of the main findings

The regulation of alien species is a major part of how South Africa addresses biological invasions. For this process to be effective, relevant stakeholders need to be engaged and involved. This paper outlines how species have been regulated in the past, provides regulatory lists in accessible formats, and analyses how the lists have changed over time. A transparent science-informed process to update the regulatory lists is presented and

progress to date reviewed. This process aims to engage interested and affected parties in efforts to preserve the benefits of alien species while reducing the harmful impacts of invasions.

[Tables and figures inserted at the end of the document.]

Introduction

Biological invasions are a leading driver of global change (1, 2). There is increasing evidence that the scale, scope, and cost of problems caused by invasions will increase in the coming years (3-5). In response to this threat, regulations and management need to focus on the pathways of introduction and spread, the sites that are or might be invaded, and on the taxa that form invasive populations (6). In 2010, through the Convention on Biological Diversity (CBD), the Aichi Biodiversity Target 9 specified that: "*By 2020, invasive alien species…are identified and prioritized, priority species are controlled or eradicated…*" (https://www.cbd.int/sp/targets/). To address this aspect of the target, many countries have developed checklists of alien taxa (7). The need for such lists is reinforced in Target 6 of the Kunming-Montreal Global Biodiversity Framework (GBF) that was agreed under the CBD in December 2022. The GBF tasks parties with "…*preventing the introduction and establishment of priority invasive alien species, reducing the rates of introduction and establishment of other known or potential invasive alien species by at least 50 per cent, by 2030, eradicating or controlling invasive alien species…*" (https://www.cbd.int/article/cop15-final-text-kunming-montreal-gbf-221222). Lists of alien taxa are thus crucial to developing effective regulatory frameworks to address biological invasions (8, 9). Similarly, the World Trade Organisation (WTO) Agreement of 1995 recognises that restrictions to trade are warranted to ensure food safety and to protect the health of animals and plants, recommending that such restrictions "…*should be based as far as possible on the analysis and assessment of objective and accurate scientific data…*" (https://www.wto.org/english/tratop_e/sps_e/spsund_e.htm). The justification for restrictions, as codified in the Application of Sanitary and Phytosanitary Measures, typically takes the form of a risk analysis, which is comprised of an assessment of the likelihood and consequence of an invasion (risk assessment), an evaluation of what measure can be taken to manage the risk (risk management), and efforts to clearly outline and communicate what the concerns are (risk communication) (cf. Figure S1).

South Africa, by virtue of its biogeographical and socio-economic history, has been both a global hotspot of biological invasions (10) and a pioneer in the science and management of biological invasions (11). South Africa's history of regulating alien taxa dates back to the nineteenth century, with at least 50 pieces of legislation passed since the Xanthium Spinosum Act of 1861 (12). Initially the impetus behind such legislation was to protect economic interests, but an increasing focus on reducing environmental degradation and limiting harmful impacts on biodiversity emerged in the late twentieth century. This culminated in the promulgation of the Conservation of Agricultural Resources Act (CARA) in 1983 which included a list of regulated environmental weeds. For over 30 years, the CARA list guided the management of invasive plants in the country. South Africa is also negatively impacted by invasive microbes, fungi, and animals (especially invasive freshwater fishes, 13). The promulgation of the National Environmental Management: Biodiversity Act in 2004 provided the framework for the first comprehensive regulatory lists of alien taxa—the Alien and Invasive Species Regulations and Lists of 2014 (hereafter the NEM:BA and the A&IS Regulations and Lists).

The NEM:BA A&IS Regulations and Lists were a milestone in how South Africa addresses biological invasions. However, in the decade since they were promulgated, several issues have emerged. Bennett and van Sittert (2019) (14) noted that "*Legislative and government efforts to manage IAPs* [Invasive Alien Plants] *have faltered because of the difficulty of engaging private landowners, competition* [sic] *local viewpoints and limited support for technical interventions by scientists and managers".* An evaluation of the overall quality of the current regulatory framework in South Africa based on the indicators proposed by Wilson et al. (2018) (15), categorised South Africa's current regulations as "*partial with medium confidence",* noting that "*…a process to evaluate the scientific evidence underpinning the lists of regulated alien species has been established…*", with the overall outlook that the "*…process of listing should become more dynamic and responsive to recommendations.*" (16). It is this process of listing that we review in this paper. Specifically, we: 1) review the

development of the NEM:BA A&IS Lists; 2) consolidate information on the lists, the regulations, and processes used to develop the lists (see links in Appendix 1); 3) briefly evaluate the implementation of the lists; 4) outline processes to provide scientific evidence to underpin changes to the lists; and 5) identify issues that need to be resolved.

The development of the NEM:BA A&IS Regulations and Lists

The NEM:BA of 2004 envisaged that lists would be produced by 1 April 2007. However, the process took much longer than this. The then Department of Environmental Affairs and Tourism consulted various stakeholders and, based on this expert opinion as informed by various global databases and sources, published the first draft lists in September 2007. The draft lists included two categories [listed (i.e., present in the country), and prohibited (i.e., not present in the country)] and so any potential benefits of listed alien taxa could not be retained; and the lists did not include taxon authorities potentially leading to confusion around the identity of taxa. The South African National Biodiversity Institute (SANBI) chaired a task team to revise the lists from 2 April 2008 until 27 January 2009. This included corresponding with experts in each taxonomic group, organising workshops and meetings, checking the nomenclature, and revising the lists. Revised draft lists were published on 3 April 2009 that are largely similar to the lists eventually promulgated in 2014. Nonetheless various concerns were still raised. To address these, experts were consulted via a series of taxon-specific working groups. Separate meetings were held on freshwater fishes, mammals, plants, and reptiles (and additional meetings held specifically to discuss trout invasions). However, the different working groups interpreted the proposed regulatory categories slightly differently (in particular category 3, see Table 1). After further draft lists were published in 2013 and 2014, the first regulations and lists were promulgated on 1 October 2014. Since then, revised lists were published taking effect on 27 September 2016, and revised regulations and lists (without the prohibited list) published on 18 and 25 September 2020 respectively. Following submissions from stakeholders regarding the listing of two invasive trout taxa [i.e., *Salmo trutta* (brown trout) and *Oncorhynchus mykiss* (rainbow

trout)], the promulgation of the latter lists was deferred to 1 March 2021, with the trout temporarily removed. In all, between 2007 and 2021, 15 documents pertaining to the A&IS Regulations and Lists have been published in South Africa's Government Gazette (see Figure 1 and Table S1 for details, with the documents themselves collated on-line see Appendix 1). A major remaining issue, as we discuss later, is that the evidence used to arrive at (and change) the lists was not clearly set out.

[Insert Figure 1]

Categories and exemptions under the A&IS Lists

The two principles that underly the A&IS Lists are that: 1) all harmful alien or potentially harmful alien taxa are to be listed under the NEMBA A&IS Regulations; and 2) provision, where appropriate, can be made to utilise taxa that are both beneficial and harmful. In practice this means that: 1) taxa that pose a high likelihood of causing significant harmful impacts (based on a risk assessment) are to be listed; and 2) the choice of listing category is based on the most suitable option for regulation (based risk management).

In the 2020 A&IS Regulations there are four categories of listing (Table 1). Category 1 is for taxa which require management: this is sub-divided into 1a (nation-wide eradication targets) and 1b (requiring compulsory control). Category 2 is for taxa which have benefits and can be allowed under specific permit conditions (outside of which Category 2 listed taxa are treated as Category 1b). Category 3 is similar to Category 1b except that keeping existing individuals is exempt (i.e., allowed without a permit). However, the interpretation of Category 3 varies somewhat across taxonomic groups. Existing Category 3 plants in people's gardens are allowed to remain, but not be replaced (i.e., breeding and trading are restricted), therefore over time such taxa are being phased out and will essentially end up being Category 1b. Category 3 birds, by contrast, are often highly abundant and widespread taxa which might be difficult to control due to their sheer numbers.

[Insert Table 1]

Notably, category 1a taxa are not more invasive than category 1b taxa, and category 1a and 1b taxa are not more invasive than category 2 or category 3 taxa [on average category 2 plant taxa are the most widespread (17)]. Moreover, the NEM:BA A&IS Lists are not comprehensive lists of all invasive taxa in South Africa [there are more invasive plant taxa that are not listed (435) than are listed (338) (18)].

Some general exemptions apply to all listed taxa. Dead specimens, plants used as biomass (i.e., firewood), and specimens moved for disposal (e.g., after control) are exempt. Authorised officials do not need a permit to do activities related to their duties. Unless otherwise listed, species legally imported for agricultural purposes before the NEM:BA came into force are exempt, as well as other species legally imported before the A&IS Regulations came into effect. Alien freshwater fish are also exempted in some situations (including catch and release in artificial dams and catching to eat).

For Category 2 listed taxa, permits can be applied to: import, possess, breed, convey, trade, spread (or allow to spread), release, move freshwater taxa between water-bodies, discharge water, catch and release fresh-water fishes or fresh-water invertebrates, introduce to an off-shore island, and release fresh-water fish or fresh-water invertebrates species into water-bodies. Some restrictions remain, e.g., no permits will be issued for alien plants within riparian areas. Permits can also be issued for research (including biological control) by a scientific institution, display by a zoological or botanical institution, and during a state inter-basin water transfer scheme.

Finally, the NEM:BA provides provision for a list of alien taxa that are not present in the country and that should be prevented from entry (termed a prohibited list). Prohibited lists were gazetted in 2014 and 2016, but removed from the 2020 listing (cf. Box 1).

[Insert Box 1]

The NEM:BA A&IS Lists and changes over time

In the 2020 NEM:BA A&IS Lists, 560 taxa are listed as well as all hybrids between native and alien species of amphibians, birds, mammals, and reptiles (see the footnote to Table S1 as to how this number was calculated). 13 of these taxa are only listed on the Prince Edward Islands. Of the remaining 547 taxa, one is an order (Phasmida), two are families (Dendrobatidae and Salviniaceae), 15 are genera, one is a species aggregation (*Rubus fruticosus* L. agg.), 506 are species, 12 are listed at the sub-specific level, and 10 at the variety level; and, regardless of the level at which the listing is, hybrids are explicitly listed for 18 species (Table 1; 19).

As part of this paper, the name of each regulated taxon was aligned manually to one of several taxonomic backbones. Notably, almost half the listed regulated names (255 out of 560) do not correspond exactly to the name found in a relevant taxonomic backbone. In around a hundred cases this is because the regulatory name includes synonyms (cf. Table 3) and in many other cases it is due to a slight difference in the formatting of species authorities or an update in the nomenclature. For a full list of proposed changes to the nomenclature of the regulatory lists see (19).

There have been few changes to the regulatory lists over time (Table S2). Excluding the removal of the prohibited list, the category under which 85 taxa are listed has changed since 2014 (Table S3). By comparison there were significant changes between the draft lists and the promulgated lists. In the February 2014 draft lists, the whole family Cactaceae was listed, but only 37 cactus taxa were in the final promulgated list. Research suggests this decision was proportionate—globally invasive cacti come from only 13 of 130 genera, and crucially from only 5 of 12 cactus growth forms (20), i.e., spiny cacti that spread rapidly via clonal fragmentation (21). Banning the whole family, including *Mammillaria* spp. that are popular in horticulture and none of which are invasive (as they are globose), is not warranted (22).

Permitting

There has been a steady stream of permits issued for restricted activities on listed alien taxa over time with 2906 permits issued as of December 2022 (Figure 2a). Permits have been issued for 268 different taxa, with over half of all permits issued on five taxa—*Kobus leche* subsp. *leche* (red lechwe), *Oreochromis niloticus* (tilapia), *Ctenopharyngodon idella* (grass carp), *Dama dama* (fallow deer), and *Psittacula krameri* (rose-ringed parakeet) (in decreasing order)— half of the taxa have only had one permit issued for them (Figure 2b). Notably, no permits have been issued for 26 of the 124 taxa that have at some point been listed as Category 2 (Table S3).

[Insert Figure 2]

There have also been ~10–20 permits issued to import taxa each year, around a quarter of which have been for research. Import permits have been issued for three taxa not recorded as legally in the country previously [*Acipenser baerii* Brandt, 1869; *Meriones unguiculatus* (Milne-Edwards, 1867); and *Salmo salar* Linnaeus, 1758]. There have been other requests to import taxa (particularly reptiles), but these were rejected as the risk analyses were often inconclusive or incomplete (cf. the process outlined in Figure 3). For a discussion on the separate process for importing agricultural commodities, and the inspection of plant products in South Africa see (23, 24).

Proposed improvements to the process

The changes to the 2014 lists made in 2016 and 2020 were based on either a risk assessment or expert opinion, but the reasons for the changes were not made public. To improve transparency and the link to scientific evidence, a new process has been developed (summarised in Figure 3 and discussed in detail in S1 see also (25)). The new process:

- has a clear evidence base—through the use of the Risk Analysis for Alien Taxa (RAAT) framework (26);

- engages with the scientific community—risk analyses produced using RAAT are peer-reviewed and subject to scrutiny by the Alien Species Risk Analysis Review Panel (ASRARP); and
- is step up to facilitate integrated governance—an inter-governmental Risk Analysis Review Committee (RARC) was established to assist the Minister of the Department of Forestry, Fisheries and the Environment (DFFE) with the evaluation of proposals to change the NEM:BA A&IS Lists.

We discuss the first two of these below, noting that the RARC met for the first time 1 March 2023, and so it is too early to review its performance.

[Insert Figure 3]

The Risk Analysis for Alien Taxa (RAAT) Framework

The RAAT is composed of three core questions that address the key aspects required of a risk analysis and that link to a mechanistic understanding of invasions (27; Figure S1):

- What is the likelihood that the taxon will become invasive in South Africa?
- What are the likely negative environmental and socio-economic consequences if the taxon were to become invasive?
- What options are available to manage the taxon to ensure that any benefits derived can be sustainably retained?

We believe RAAT represents an important advance. Of 14 minimal standards proposed for risk assessments by (28), RAAT fully addressed 12 of them. RAAT does not currently assess effects of future climate change (the intention is for risk analyses to be valid for around a decade or so), and only indirectly considers the status (threatened or protected) of taxa or habitats under threat. In addition to the criteria of (28), RAAT also considers environmental and socio-economic benefits of the taxon under assessment and evaluates risk management options (i.e., RAAT results in a risk analysis rather than simply a risk

assessment, Figure S1). The process is also transparent. Assessors are required to ensure there is robust evidence that listed taxa are present in the country, and to systematically collate and present evidence of impact or threat to justify listing. This means stakeholders and decision makers can see how the evidence used influenced the recommendations. Finally, there is a formal review process to ensure consistency, quality, and to engage with relevant experts (see the section on ASRARP below).

The RAAT framework has not, as yet, been evaluated in terms of the accuracy of its classification of risk into low, medium, and high. This is mostly because analyses have, to date, focussed on invasive and high-risk taxa.

The Alien Species Risk Analysis Review Panel (ASRARP)

ASRARP was set up by the DFFE and SANBI in 2016 as an independent scientific advisory panel to review documents pertaining to the risk of alien taxa, specifically with reference to potential imports and listings (cf. Figure 3 and S1). ASRARP also assists in reviewing guidelines for risk analyses and changes made to the A&IS Regulations (see S2 for the current terms of reference).

ASRARP (since July 2018) has been composed of *ex officio* SANBI members and independent members. Independent members are experienced academics, researchers, or those involved in relevant industries from across the country, that attend ASRARP in their personal capacities and can be remunerated for their time. In compliance with the A&IS Regulations on risk assessment practitioners, such members are registered as professional scientists with the South African Council for Natural Scientific Professions (SACNASP).

Panel members handle the review of risk analyses, and for each risk analysis solicit at least two external reviews (including ideally one international) that focus on errors and omissions. Risk analyses and reviews are then presented at at least one ASRARP meeting; with recommendations passed back to the assessors for revision. Conflicts of interest are

declared, and it is understood that ASRARP members are not individually liable for the recommendations if such were made in good faith.

There have been 27 meetings of ASRARP as of 6 November 2023, with the inaugural meeting held on 29 November 2016 (Figure 1). ASRARP has gone through essentially five terms (including the current one) in line with DFFE funding cycles. Prior to 2018, various government and provincial officials attended ASRARP Meetings in *ex officio* capacity, but by the 4th meeting a decision was taken to clearly separate the scientific advisory panel from decision makers. The second term was short, Jan 2018–March 2018, with 10 members; the third term ran 16 July 2018–31 March 2020 with 15–19 members; the fourth term 18 May 2020–31 March 2022 with 23–26 members; and the current fifth term began 3 June 2022 and is due to run until 31 March 2025 and consists of nine members. The hiatuses between terms were due to delays in finalising fund agreements between DFFE and SANBI and inefficiencies in advertising and reconstituting the panel. Meetings are now held quarterly. Initially meetings were in person but since the COVID-19 pandemic they have been online (Figure 4). Since July 2018, 38 people have attended ASRARP meetings (excluding guests)—29 independent members and 12 *ex officio* SANBI staff, with some people serving in different roles at different times (Table S4).

Progress to date and issues to resolve

As of 1 November 2023, risk analyses have been completed on 122 taxa, although 16 of these were not listed at the time the risk analysis was approved by ASRARP (Table S5). Of the 106 regulated taxa that have been subject to a risk analysis (19 % of all regulated taxa), 46 recommended no substantive change to the listings (~57 %, cf. Table 2). It is unsurprising that almost half of all risk analyses evaluated to date have recommended a change to listing. Taxa for which it was felt that a change to the listing was likely warranted and taxa for which the listing was contentious were prioritised. As risk analyses focus on less

controversial taxa there are likely to be fewer cases of the recommendations of the risk analyses differing from the current regulatory listing.

Examples of taxa where there was a recommended change to the listing include: *Sasaella ramosa* (dwarf bamboo). This taxon is currently listed as category 3 under the synonym *Sasa ramosa*. However, the taxa is not formally recorded as present in the country, and the risk of invasion was scored low. The recommendation was to delist. By contrast *Phyllostachys aurea* (fishpole bamboo) is not currently listed but is recorded to have naturalised in South Africa, is invasive in other parts of the world, and requires costly management especially in forested areas. The recommended was to list *Phyllostachys aurea* as category 1b (29). *Iris pseudacorus* (yellow flag iris) was listed as a national eradication target (Category 1a). However, naturalised populations have been recorded at 24 localities across four provinces; plants are present in many people's gardens; and individual populations are very hard to control (30). Therefore, the recommendation was for the species to be listed as Category 1b and options for biological control explored. *Kobus ellipsiprymnus* subsp. *defassa* (Defassa waterbuck) is currently listed as Category 2 (i.e., can be kept under permit). Given the potential for hybridisation with the native *K. e.* subsp. *ellipsiprymnus* (common waterbuck), it was recommended that the listing of Category 2 is inappropriate and *K. e.* subsp. *defassa* should no longer be bred in South Africa.

Importantly these recommendations are provisional and need to be discussed both within government (through the RARC), with interested and affected stakeholders (e.g., the horticultural and game industries), and though wider public consultation (e.g., through publishing the lists for public comment).

[Insert Figure 4]

[Insert Table 2]

As with similar processes (e.g., submission of manuscripts to peer-reviewed journals), the review process takes time (Figure S2). As of November 2023, most risk analyses are

reviewed within six months, but 20 % have taken longer than a year (particularly when there were complex issues).

A risk analysis training course was developed in 2018 to build capacity. As of July 2023, 18 courses have been run, two of which were refresher courses developed upon revision of the risk analysis framework to v1.2 in 2020 (Kumschick et al. 2020; Figure 4). As of 6 November 2023, 46 course participants have received a course certificate, which—beside attending the course—requires a risk analysis is developed using RAAT, reviewed and accepted by ASRARP, and ultimately submitted to the DFFE.

During the implementation of the regulatory lists and following discussion at ASRARP several issues have come to light that still need to be resolved. These are summarised in Table 3.

[Insert Table 3]

Discussion and conclusions

The regulation of alien taxa in South Africa can be described as a gradual move from focussing on weeds, to broader efforts to limit damage to people and nature caused by alien plants, to a comprehensive and innovative regulatory framework that seeks to limit the harmful impacts of alien taxa without unduly reducing benefits to South Africans. The current NEM:BA A&IS Lists thus provides a foundation needed for South Africa to meet its commitment to Target 6 of the GBF by 2030. We believe that the proposed process will make the system more proportionate, accountable, consistent, transparent, and targeted [Annex B of Better Regulation Task Force (31)]. The process also aims to make the regulation of alien taxa in South Africa credible, legitimate, and acceptable.

- Proportionate: the NEM:BA A&IS Regulations and Lists recognise that many alien taxa provide benefits, and exemptions are provided for. There is an attempt to balance a precautionary approach (e.g., on imports where prevention is desirable)

against a pragmatic or in some cases ethical one, (e.g., phasing taxa out). Provisions allow for research on biological invasions to continue and so on-going projects have not been jeopardised (cf. 32). The cost of the regulations (both to the government and to society) has not, however, been estimated.

- Accountable: all lists are subject to government scrutiny and published for public scrutiny before promulgation. With the development of the RAAT framework and use of the risk analyses, the evidence that informs decisions is clear and the standards and criteria for judging regulations are set out. For the regulations in general, but also specifically for permitting, complaints and appeals processes are set out in the regulations, and the criteria for judging the performance of regulators and enforcers is partly set out (e.g., response times).
- Consistent: by working across taxa and realms, ASRARP helps ensure risk analyses are consistent. Moreover, the RARC is intended to ensure governmental work is "joined-up". As the process and time-lines for making changes become clearer, affected stakeholders (e.g., the horticultural industry) will have a greater certainty as to what might happen when.
- Transparent: the lists are available to all, and, with the development of the RAAT framework, the process to derive the lists will be clearer. A principle aim of the risk analyses is to ensure information is in a usable accessible form, although the DFFE has requested that risk analyses not be placed in the public domain until the RARC has had a chance to consider them. The names of the assessors who completed risk analyses are, however, redacted (in part as the product is the result of the work of both the assessors and ASRARP).
- Targeted: the regulations have been modified over time based on experience (cf. 33), although more information on monitoring the effectiveness of the regulations appears warranted.

- Credibility: the original lists were developed with many of the top academics working on biological invasions in the country in consultation with affected stakeholders. The RAAT framework incorporates existing schemes for impact assessment [(34; the later adopted by the UN following COP decision 15/27 on Invasive Alien Species (Annexes I to VI), 35)], and the pathway classification used by CBD (36). Risk analyses are routinely reviewed by national and international experts as well as working groups at the science-policy-management interface of biological invasions (37, 38).
- Legitimate: the development of the regulations is mandated in South African legislation, i.e., NEM:BA. More broadly the regulations address both national imperatives and international obligations on biodiversity conservation (CBD) and trade (WTO). Neither the RAAT framework, ASRARP nor the RARC are explicitly mentioned in the regulations, though they ~~could~~ be in future. Training courses are not yet registered with the SACNASP, but again this is likely desirable in future.
- Acceptable: the measures put in place try to preserve the benefits of alien species while reducing the harmful impacts of invasions. Any regulation of biodiversity is inimical to some ethical perspectives (39), but a clear distinction should be made between the rationale for regulation and evaluating the ethics of particular management interventions (37).

In summary, we believe that, while many issues still need to be resolved (Table 3), the regulation of alien species in South Africa has many desirable features. The challenge, as with many conservation issues, will continue to be to equitably balance the rights of the current with the rights of future generations. This will, we believe, require continued discussions, partnerships, and collaborations between scientists, policy-makers, implementers, and those affected by the regulations.

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Appendix 1 Links to accompanying on-line databases and list of on-line supplementary material

List of regulated taxa: this database outlines the taxa listed in 2014, 2016, and 2020 versions of the National Environmental Management: Biodiversity Act Alien and Invasive Species Lists as well as those proposed for listing in the 2009, 2013, 2014, 2015, and 2018 draft lists published in the Government Gazette. Changes in the lists over time and a link between the regulatory names used and the valid scientific name are also presented. The database will be updated when revisions of (or proposals to revise) the lists are published (19), https://dx.doi.org/10.5281/zenodo.7638966.

List of permits issued: The list of permits issued in terms of the National Environmental Management: Biodiversity Act Alien and Invasive Species Regulations to conduct activities on listed alien taxa 2014–2022. This database is based on data owned by the DFFE and made available to SANBI as part of the national status report on biological invasions process. The database is stored on-line and will be updated periodically (40), https://dx.doi.org/10.5281/zenodo.7947508

Notices in the South Africa Government Gazette relevant to the National Environmental Management: Biodiversity Act, Alien and Invasive Species Regulations and Lists: The original notices from 2007 to 2021 in pdf format. See Table S1 for an analysis of these and suggestions for how to reference the documents. https://dx.doi.org/10.5281/zenodo.8160209

Table S1: Regulations and notices published in South Africa's Government Gazette in terms of the National Environmental Management: Biodiversity Act, Alien and Invasive Species Regulations and Lists (NEM:BA A&IS).

Table S2: Taxa for which the regulatory listing has changed over time.

Table S3: Taxa listed as category 2 for which permits have been issued.

Table S4: Current and previous members of the Alien Species Risk Analysis Review Panel (ASRARP).

Table S5: Risk analyses submitted by the South African National Biodiversity Institute (SANBI) to the Department of Forestry, Fisheries, and the Environment (DFFE) following review by the Alien Species Risk Analysis Review Panel (ASRARP).

Figure S1: Aspects of risk addressed by the Risk Analysis for Alien Taxa (RAAT) framework.

Figure S2: The time taken to review risk analyses by ASRARP.

S1: The process for making regulatory decisions concerning alien taxa in South Africa (under the National Environmental Management: Biodiversity Act, Alien and Invasive Species Regulations of 2014 as amended 2020) as understood by the authors.

S2: Terms of reference for the Alien Species Risk Analysis Review Panel (ASRARP) vApril 2022.

Box 1 Potential lists of taxa not present in South Africa

One of the most effective ways to address biological invasions is to prevent introductions (1). This can be done in various ways, e.g., prohibiting the import of taxa; identifying risks and putting specific surveillance in place; and developing contingency plans so any incursions detected can be eradicated. For each of these a list of taxa can be developed noting the merit of such a list should be defined by its utility.

Prohibited list: taxa that are not allowed to be introduced (deliberately or accidentally). No import or other permits will be granted for these taxa.

Watch list: taxa that are likely to arrive and pose an unacceptable threat. Active surveillance can improve how quickly incursions are detected, and a watch list can therefore provide priorities for setting up surveillance efforts. Various methods have been used to develop such lists (41), including horizon scanning (42).

Emergency Response Planning: taxa prioritised for contingency planning where incursion response plans are set up to ensure an emergency response plan can be initiated rapidly on detection.

Finally, given the number of potential new introductions, it is often impractical to manage taxon by taxon. Instead it is preferable to look at the risks posed by particular pathways and implement pathway-specific regulations and control measures (43).

Table 1 The regulatory categories of the National Environmental Management: Biodiversity Act (NEM:BA) Alien and Invasive Species (A&IS) Regulations and Lists of 2020. The regulatory definitions are précised, with the omitted sections referring to particular actions that must be undertaken. The proposed criteria for the different categories are based on the authors' experience developing the Risk Analysis for Alien Taxa (RAAT) framework and discussions at the Alien Species Risk Analysis Review Panel (ASRARP), noting that these proposed criteria would in some cases require a revision to the regulations and or the act.

Category	Number of taxa[1]	Regulatory definition (précised)	Proposed criteria / approach
1a	53	Category 1a species must be combatted or eradicated. A person in control of a 1a species must immediately take steps to combat or eradicate the species and allow authorised officials to inspect a property and to monitor, assist with or implement the combatting or eradication (in accordance with an Invasive Species Management Programme if one is in place).	• Present in the country as an alien taxon; AND • poses a high risk; AND • any benefits provided can be provided by other taxa or such benefits cannot be maintained with an acceptable risk of invasion; AND • nation-wide eradication is deemed desirable and feasible based on a costed evaluation (e.g., 44, 45); AND • a national eradication plan has been developed and is being implemented.
1b	259	Category 1b species must be controlled. A person in control of a 1b species must control the species (in accordance with an Invasive Species Management Programme if one is in place), and allow authorised officials to inspect a property and to monitor, assist with or implement the control.	• Present in the country as an alien taxon; AND • poses a high risk; AND • any benefits provided can be provided by other taxa or such benefits cannot be maintained with an acceptable risk of invasion; AND • it is not desirable or feasible to attempt nation-wide eradication, although the extirpation of some populations might be warranted; AND • a taxon-specific national management plan has been developed and is being implemented (in certain cases, such a plan might simply indicate that control is not cost-effective at present).

[1]Of 560 valid taxa. This does not include generic listings for all hybrids between native and alien species of amphibians, birds, mammals, and reptiles, see the footnote to Table S2 for further details.

Category	Number of taxa[1]	Regulatory definition (précised)	Proposed criteria / approach
2	75	Category 2 species are treated as 1b species except in cases where a permit has been issued. Permits may be issued to persons to carry out restricted activities within a specified area (specified either in the regulations or in the issued permit), with permit holders required to ensure they adhere to the permit conditions, often with the goal that there is no spread to areas outside of the specified area.	• Present in the country as an alien taxon; AND • poses a high risk; AND • has significant socio-economic benefits which cannot be supplied by other taxa (either native taxa or alien taxa which pose acceptable risks); AND • permit conditions have been established that are known to reduce the risk of invasion to an acceptable level and that can be readily implemented and monitored with effective remedial control measures available and specified in permits if there are any escapes.
3	51	Category 3 species are regarded and managed as 1b species except that specimens may be kept without a permit providing there is no further propagation, movement, or trade, and category 3 plant species may not be kept in riparian areas.	Category 3 to be removed as unnecessary. If specific activities, types of taxa, or specific sites are to be exempt, these are specified in the regulations. If exemptions are highly complicated or would require maps, details are to be outlined in taxon-specific national management plans.
Prohibited	0	NA (cf. the 2014 and 2016 regulations and lists).	See Box 1
Context-specific	122	This is not a formal definition but arises as the regulations list some taxa in multiple categories (e.g., 1b in one province and not listed in other provinces). Moreover, specific exemptions may be indicated (e.g., existing plantations of some forestry species are exempt, noting that the listed taxon may not spread outside the existing plantation). The 13 taxa listed only on the Prince Edward Islands (PEIs) are included in this category (no taxon is listed on both the PEIs and mainland South Africa).	No taxon is to be listed in multiple categories. Details of sites to be prioritised for control should be outlined in taxon-specific national management plans rather than specifying different listing categories for different sites in the A&IS Lists themselves. This would require regulation at the sub-national level to address taxa which are native to one part of South Africa but pose a high risk as an invasive taxon in another part of the country (cf. Table 3). A separate list to be created and maintained for the PEIs as the risk and management options differ from the mainland. Such a list should include all alien taxa present on the PEIs, with management goals specified in the PEIs Management Plan (cf. 46).

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Table 2 Recommendations of the Alien Species Risk Analysis Review Panel (ASRARP) based on 122 risk analyses conducted as of 6 November 2023. For changes to nomenclature see (19). In 20 cases there was a recommendation to re-evaluate taxa (usually within five years) as the evidence was equivocal or there was specific research or monitoring that should be carried out to inform the recommendation. Of the five taxa flagged for delisting, one was found not to be a valid taxon, one was native to a part of South Africa, one is a hybrid for which both parental taxa are already listed (and so the listing is not needed), and two were found to pose a low invasion risk. See Table S5 for further details.

		Recommendation for listing					
		1a	**1b**	**2**	**Context-specific**	**Prohibit**	**Do not list**
Listing under NEM:BA A&IS lists (on date of approval)	**1a**	13	5	0	0	1	1
	1b	0	20	0	0	0	0
	2	3	10	24	0	1	1
	3	0	2	0	0	0	1
	Context-specific	0	9	10	3	0	2
	Not listed	3	7	4	0	1	1

Table 3 Issues identified during discussion around the regulation of the alien taxa in South Africa with proposed solutions. These issues are largely based on discussions held at the Alien Species Risk Analysis Review Panel (ASRARP) or while the authors have been developing and implementing the Risk Analysis for Alien Taxa (RAAT) framework.

Issue	Description	Proposal	Examples	Key reference(s)
Taxa which have both alien and native populations within the Republic of South Africa	The regulations define nativity in terms of the whole of South Africa. However, there can be species which are native to one part of the country that form alien populations in another part of the country, i.e., "...*populations that result from the human-mediated dispersal of individuals of a species beyond a biogeographical barrier to a point beyond that species' native range, but that is still within the same political entity as parts of the species' native range*""	Taxa which are native to some parts of the country but alien in others (i.e., have native-alien populations) should only be regulated in the provinces where they are not native; and so should not be included in the NEM:BA A&S Lists which are at a national level.	132 such populations from 77 native species have been formally categorised in the country. Three of these taxa are currently listed under the A&IS Regulations [*Clarias gariepinus* (African sharptooth catfish), *Hyperolius marmoratus* (painted reed frog), and *Sclerophrys gutturalis* (guttural toad)]	(47)
Listing of taxa at provincial or other geographical levels other than national	Certain alien taxa are not a threat to the whole country and therefore only warrant listing in certain regions of the country, for example provinces. However, there are no border controls between provinces, and therefore control of movement and enforcement is more difficult.	There is provision in the NEMBA for provincial lists (70.1b, 70.2). Local ordinances could be used to handle such cases.	*Metrosideros excelsa* (New Zealand Christmas tree) is currently only listed in the Overstrand District of the Western Cape	(19)
International introductions	Biological invasions are inherently an international issue and taxa that are introduced to South Africa need to consider the risks of invasions to neighbouring countries and vice versa.	Assessors and decision-makers should consider threats to neighbouring countries and not allow such taxa to be introduced	Biological control releases evaluated by the National Biological Control Release Application Review Committee routinely consider the threat biocontrol agents could have to the flora and fauna of other Africa countries.	(48, 49)

Issue	Description	Proposal	Examples	Key reference(s)
Declaring taxa as absent	Some taxa were added to the list but are subsequently believed to be absent from the country. This can be because a taxon was present but there is strong evidence that it is no longer present either because it was deliberately eradicated from South Africa or the population was lost.	A protocol for declaring taxa absent is under development and would provide a rationale for removing taxa from the lists.	*Tetrapygus niger* (the Chilean black urchin) was found in aquaculture dams used for oyster production on the West Coast of South Africa. Oyster production was stopped at the dams and surveys of the dams and the neighbouring coast found no evidence of the urchins remaining.	(45, 50)
Evaluating positive impacts	The evaluation of positive impacts and benefits in risk analyses is important as it gives an indication of the uses of the taxa and potential conflicts of interest. However, there has often been discussion as to what constitutes a "significant" benefit, and stakeholders might differ in their perceptions of benefits.	International frameworks have recently been developed to assess positive impacts on the environment, and similar frameworks for socio-economic benefits are in development. These should be incorporated into the risk analysis process once they are more established.	A taxon can be regarded as having a 'Major' positive impact if it causes an increase (or prevents a decrease) in species occupancy through local or subpopulation reestablishment (or extinction prevention).	(51, 52)
List of taxa legally in the country or that are not present	Many of the exemptions to the regulations depend on knowledge of which taxa are legally present in the country, and similarly which are not here legally. However, such lists have not been systematically curated.	A list of alien taxa legally in the country needs to be compiled and curated. This would require digitisation of historical import records; an assessment of whether a taxon for which an import permit was issued was actually been imported; and an assessment of whether a taxon is still present in the country.	Many agricultural and forestry taxa were introduced over a century ago for various uses and are widely used. These taxa might have been introduced in compliance with any regulations that applied at the time.	see Box 1
How to respond to new detections	Taxa can, of course, be accidentally or illegally introduced. The A&IS Regulations do not specify what should happen to such taxa on detection—they are not automatically listed.	A detection should ideally rapidly trigger an incursion response, including the activation of an emergency response plan, and a process (supported by a risk analysis) to consider listing.	Over the period 2013–2022, 32 new alien taxa were either illegally or accidentally introduced	(46)

Issue	Description	Proposal	Examples	Key reference(s)
Listing of taxa at levels other than the species level	Some taxa are listed at levels above (e.g., genus or family) or below (e.g., sub-species and variety) the species level. Risks and impacts can vary across taxa but most information in the literature is available at the species level.	Listing should generally be done at the species level. Exceptions could be if the whole taxonomic entity is alien to the country and considered of high risk. If entities below the species level are to be listed, it should be feasible in practice to distinguish between entities.	The order Phasmida (stick insects) is listed, despite some taxa being native to the country, and that many taxa likely pose a low risk.	(53)
Co-invasions	Multiple taxa can be introduced together, and in some cases only the combination of the taxa makes them of high risk.	A decision needs to be made whether all involved taxa are listed, and if they are to be listed separately or as a complex.	*Euwallacea fornicatus* (the polyphagous shot-hole borer) and a symbiotic fungus, *Fusarium euwallaceae*, were introduced together. Both the fungus and the beetle are required for there to be an invasion and for trees to be killed.	(54)
Taxa that are too widespread for effective control	Some alien taxa, specifically certain small mammals and birds, are distributed across South Africa. In such cases effective control might not be possible.	Listing such taxa is still important to avoid further introductions. In certain cases, simple bans on imports could be instituted without the mandate to control the taxa actively otherwise.	There are several notable invasive rats in South Africa including *Rattus norvegicus, R. rattus,* and *R. tanezumi*, these are only currently listed on off-shore islands, but are a pest on the mainland as well.	(55)
Suitability of risk analysis framework for micro-organisms / diseases	The RAAT framework, as many frameworks in invasion science, was not specifically designed to be applied to micro-organisms, and there might be unique issues when assessing such organisms.	A separate process is in place for human health and animal diseases which could possibly be implemented, but such protocols do not necessarily reflect or cover threats to biodiversity at large.	Rinderpest was detected for the first time in South Africa in 1896 killing an estimated 2.5 million domestic cattle in southern Africa and an unknown number of game.	(56)

Issue	Description	Proposal	Examples	Key reference(s)
Dealing with agricultural vs. environmental vs. health issues	NEM:BA focuses on biodiversity, but the impacts of many invasive taxa cut across multiple domains. It is not clear if all alien pests, pathogens, and weeds should be included on the NEM:BA A&IS Lists; or only those found outside of cultivated regions. There is a need to harmonise relevant legislation.	The cross-sectoral and inter-departmental RARC should be able to address some of the issue, but the impact of agricultural pests and weeds on biodiversity is understudied. The One Biosecurity approach is potentially useful.	The import of plants is variously addressed under NEM:BA, the Agricultural Pests Act of 1983, and the Plant Improvement Act of 1976.	(57, 58)
Regulation after successful biological control	Taxa that are under permanent biological control might warrant a change in listing as no other control measures are required to prevent harmful impacts and so arguably their risk is no longer high.	A protocol is needed to determine how biocontrol and other successful control efforts should affect the listing of alien taxa.	At least 17 taxa are considered to have been brought under permanent control by the release of classical biological control agents.	(59, 60)
Inclusion of synonyms in regulatory listings	In ~100 cases the listed taxon includes a synonym. Presumably this was based on the desire to reduce confusion due to changes in the nomenclature. However, the choice of which taxa to include synonyms for and which synonyms to include was not clear.	Keep the regulatory name verbatim as the taxonomic backbone and add a separate column to the regulations that specifies common synonyms. This would ensure the lists are 'tidy' (sensu, 61), easier to work with, and links to previously used names are retained.	*Acacia paradoxa* DC. (= *A. armata* R.Br.) could be simply listed as *Acacia paradoxa* DC.	(19)
Inclusion of regulatory groupings	The regulations are split into several lists based on either a quasi-taxonomic grouping or on a combination of the quasi-taxonomic grouping and the realm in which the organism is found. Several taxa, however, are found in more than one realm.	A single 'tidy' list would allow for greater interoperability in the listing. Information on groupings could be retained as a different column that could allow for sorting and for multiple values to be incorporated.	Amphibian | Bird | Freshwater fish | Marine fish | Freshwater invertebrates | Marine invertebrates | Terrestrial invertebrates | Mammal | Microbe | Marine plants | Terrestrial and freshwater plants | Reptile	(62)

Issue	Description	Proposal	Examples	Key reference(s)
The same process is used for the Prince Edwards Islands (PEIs) as for mainland South Africa	Currently the NEM:BA A&IS Lists do not have a separate list or regulatory processes for the PEIs. However, the risks and management options are substantially different from the mainland. Management in practice will be defined by the PEI Management Plan.	Taxa to be managed on the PEIs should be listed in a separate process to that of the NEM:BA A&IS Regulations. For each alien taxon present on the PEIs a decision should be taken to: a) implement management with the goal of eradication; b) implement maintenance management with the goal of reducing harmful impacts; or c) to not manage the alien population given it is not cost-effective to do so. Any new alien taxon found should be exterminated and a sample taken for identification purposes.	Of the 13 taxa present in the PEIs listed under the NEM:BA A&IS Regulations, nine have been subjected to some form of management. An additional two taxa which are not listed have been subject to management.	(46)
Demonstrating the effectiveness of the regulations	It is not always clear if the regulations are being adhered to, and ultimately whether adhering to permit conditions is sufficient to keep invasions in check.	An increased focus on targeted monitoring and evaluation of interventions will allow the regulations to become more adaptive and responsive.	Various studies have evaluated the awareness of the regulations and how the lists have guided action. While there has been significant uptake and engagement with the permitting system (Figure 2), information on the degree to which those who need permits are applying for permits or simply ignoring the regulations, is needed.	(63-65)

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Figure 1 Time-line of the development of the Alien and Invasive Species Regulations under the National Environmental Management: Biodiversity Act (NEM:BA A&IS Regulations). Full details of the lists and regulations are in Table S1. ASRARP is the Alien Species Risk Analysis Review Panel (an independent body) and the RARC is the Risk Analysis Review Committee (a governmental decision-making body). For related process concerning the development of risk analyses see Figure 4. This figure was produced using a template from Vertex42.

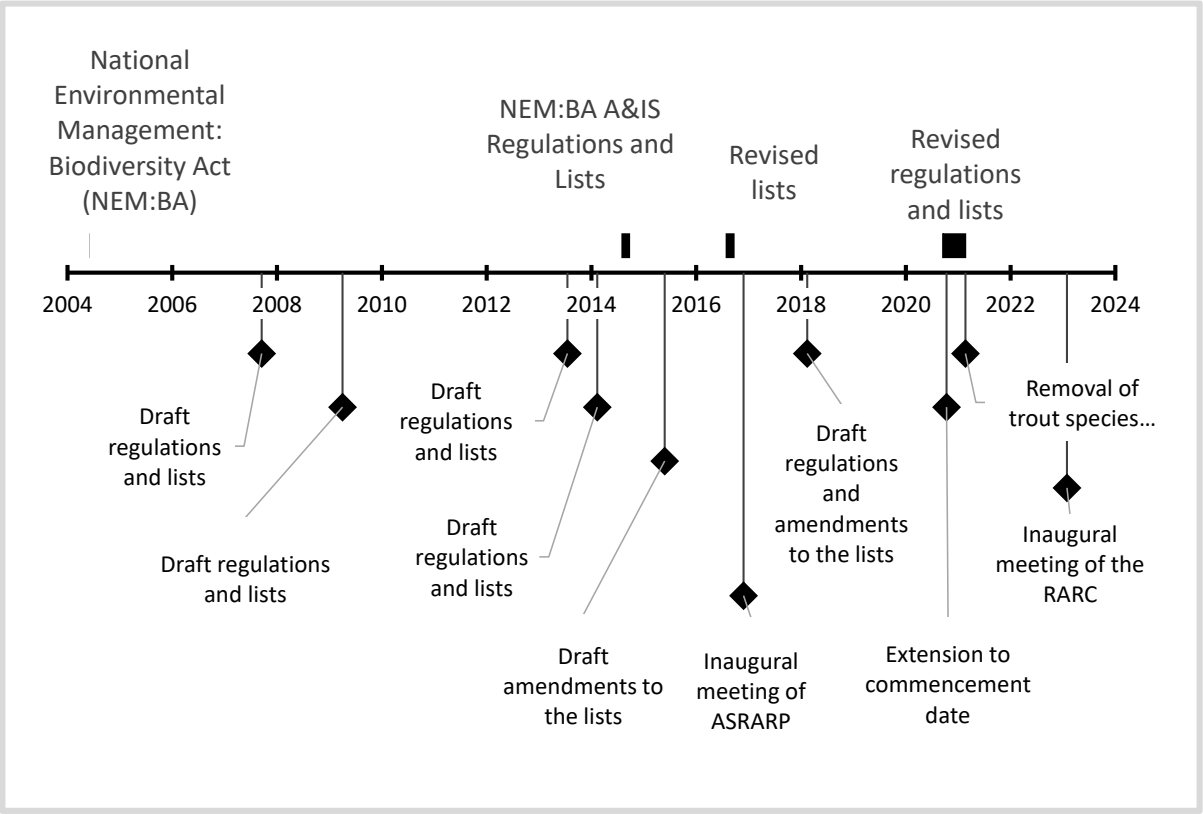
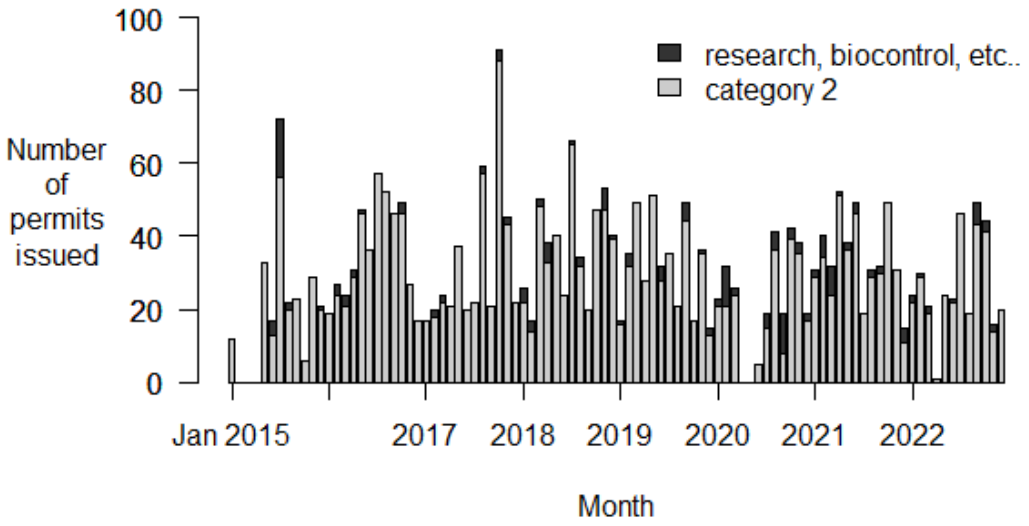
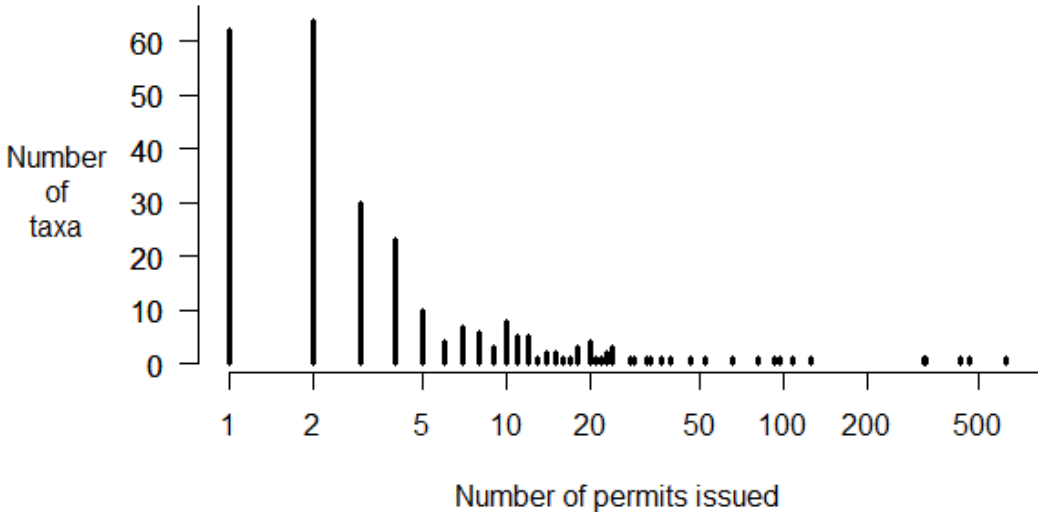


Figure 2 Permits issued for taxa listed under the National Environmental Management: Biodiversity Act, Alien and Invasive Species Regulations 2014–2022. a) The number of permits issued has not varied much over time, except for an initial slow start and a dip during the South African national lockdowns in response to COVID-19 in 2020. b) Most taxa have only had a few permits issued, with permits issued predominately on a handful of taxa. Information on permits declined was not collated here as it can be misleading (e.g., permits can be declined based on how the application is submitted, and such declined permits can be issued subsequently once applicants comply with the requirements). These figures are based on information provided by the Department of Forestry, Fisheries and the Environment (DFFE) to the South African National Biodiversity Institute (SANBI) as part of the national status report and are redrawn from (33).

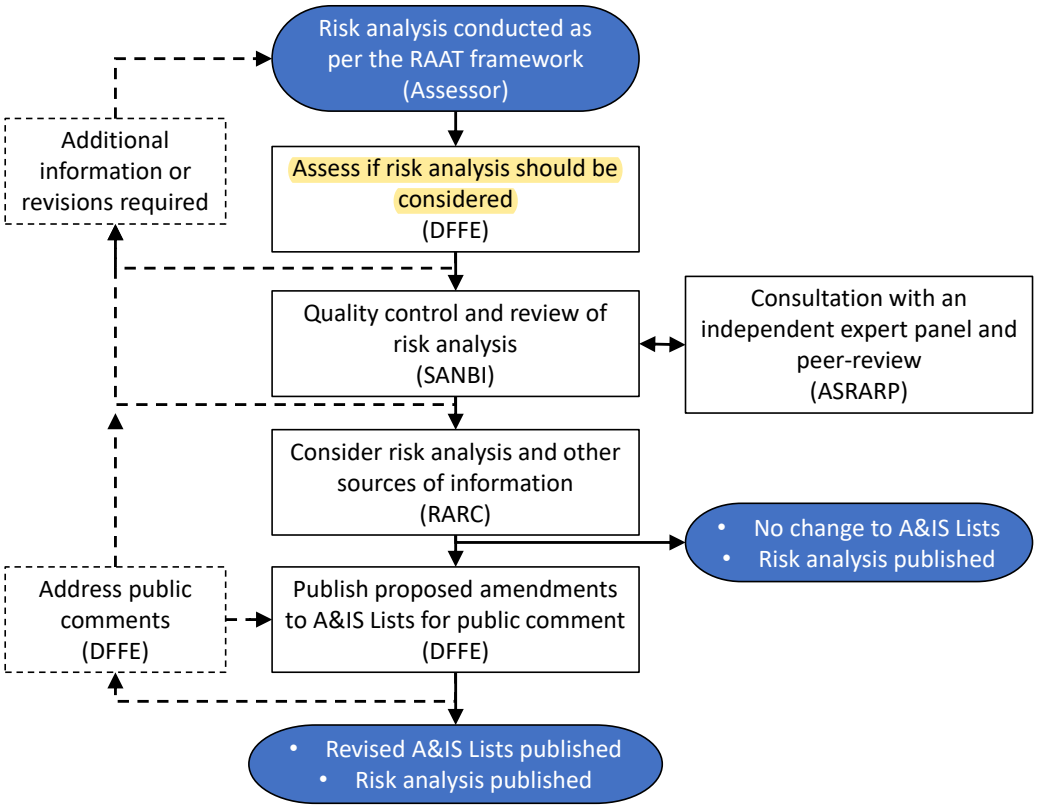


a)



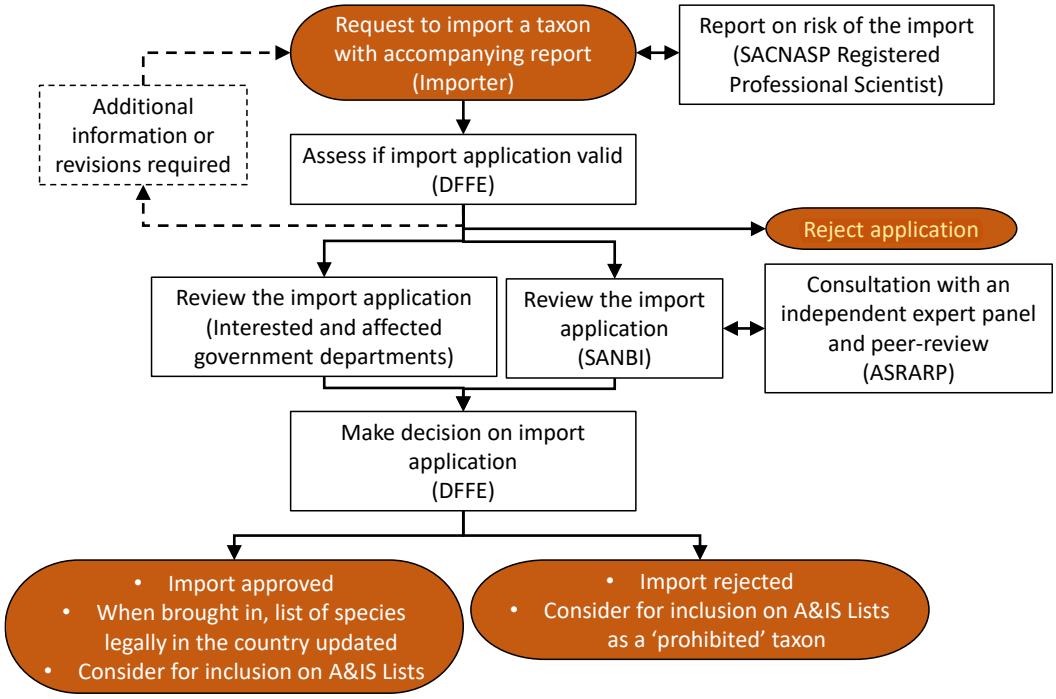
b)

Figure 3 How decisions are made with regard to: a) evaluating and potentially changing the listing of a taxon; and b) requesting an import permit. Please note these diagrams are the authors' interpretation of the situation and have no legal basis. A&IS Lists are the Alien and Invasive Species Lists published under the National Environmental Biodiversity: Management Act of 2004; ASRARP is the Alien Species Risk Analysis Review Panel; DFFE is the Department of Forestry, Fisheries and the Environment; RAAT is the Risk Analysis for Alien Taxa framework; RARC is the Risk Analysis Review Committee; and SANBI is the South African National Biodiversity Institute. For full details of these processes and the separate process to import biological control agents based on information in (49) see S1.


Risk analysis conducted as per the RAAT framework (Assessor)
Additional information or revisions required
Assess if risk analysis should be considered (DFFE)
Quality control and review of risk analysis (SANBI)
Consultation with an independent expert panel and peer-review (ASRARP)
Consider risk analysis and other sources of information (RARC)
No change to A&IS Lists
Risk analysis published
Address public comments (DFFE)
Publish proposed amendments to A&IS Lists for public comment (DFFE)
Revised A&IS Lists published
Risk analysis published

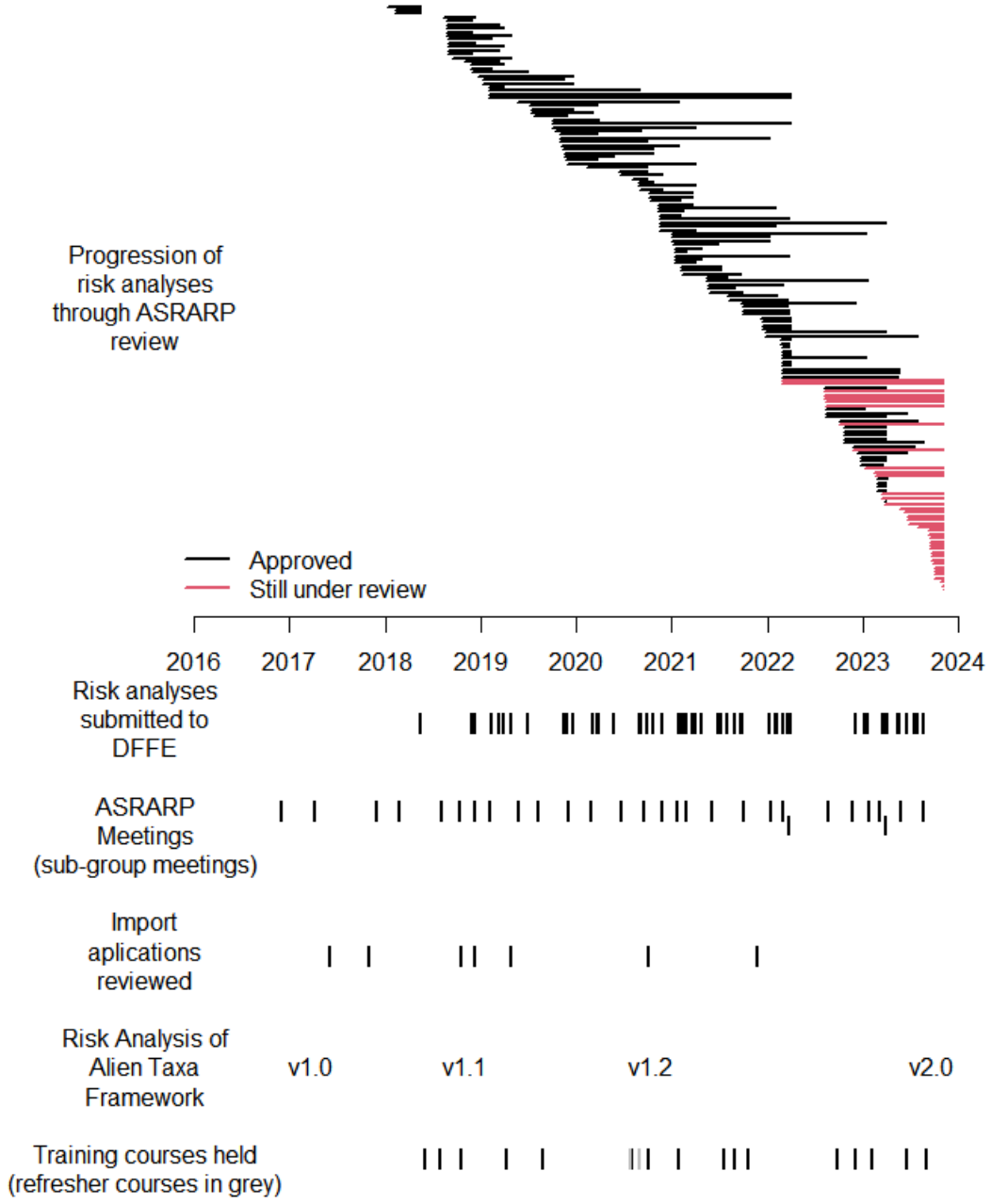
52 a)

53


Request to import a taxon with accompanying report (Importer)
Report on risk of the import (SACNASP Registered Professional Scientist)
Additional information or revisions required
Assess if import application valid (DFFE)
Reject application
Review the import application (Interested and affected government departments)
Review the import application (SANBI)
Consultation with an independent expert panel and peer-review (ASRARP)
Make decision on import application (DFFE)
Import approved
When brought in, list of species legally in the country updated
Consider for inclusion on A&IS Lists
Import rejected
Consider for inclusion on A&IS Lists as a 'prohibited' taxon

54 b)

Figure 4 Progress developing risk analyses on alien taxa and activities of the Alien Species Risk Analysis Review Panel (ASRARP) as of 6 November 2023. Each horizontal line represents a risk analysis that has been developed for a specific taxon, with the length of the line indicating the time the risk analysis had been under review with ASRARP.



The regulation of alien species in South Africa

Abstract

A key global change challenge is to significantly reduce the risks of alien taxa causing harmful impacts without compromising the rights of citizens. As part of efforts to address this challenge, South Africa promulgated comprehensive regulations and lists of alien taxa in 2014. This paper reviews how the lists were developed and have changed over time. As of March 2021, 560 taxa and all hybrids between native and alien species of amphibians, birds, mammals, and reptiles were listed. Almost 3000 permits have been issued for usage of 268 listed taxa with a steady rate of about 30 permits per month. The full lists of regulated taxa, permits issued, and corresponding regulations are available on-line as supporting files. A proposed standardised, transparent, and science-informed process to revise the regulatory lists is also presented—risk analyses have been developed for over 120 taxa using the Risk Analysis for Alien Taxa (RAAT) Framework and reviewed by an independent scientific body [the Alien Species Risk Analysis Review Panel (ASRARP)]. These recommendations are being considered by an inter-departmental governmental decision-making body established in March 2023 [the Risk Analysis Review Committee (RARC)]. Finally, key issues with the listing of alien taxa in South Africa that remain to be resolved are presented. As South Africa's regulatory framework continues to develop, the process of listing and regulating alien taxa will, we believe, become more transparent, consistent, and acceptable to stakeholders. Ultimately this well facilitate efforts to reduce the harmful impacts of alien taxa.

what about plants - many of the examples in the text are plants?

will

Significance of the main findings

The regulation of alien species is a major part of how South Africa addresses biological invasions. For this process to be effective, relevant stakeholders need to be engaged and involved. This paper outlines how species have been regulated in the past, provides regulatory lists in accessible formats, and analyses how the lists have changed over time. A transparent science-informed process to update the regulatory lists is presented and

progress to date reviewed. This process aims to engage interested and affected parties in efforts to preserve the benefits of alien species while reducing the harmful impacts of invasions.

[Tables and figures inserted at the end of the document.]

Introduction

Biological invasions are a leading driver of global change (1, 2). There is increasing evidence that the scale, scope, and cost of problems caused by invasions will increase in the coming years (3-5). In response to this threat, regulations and management need to focus on the pathways of introduction and spread, the sites that are or might be invaded, and on the taxa that form invasive populations (6). In 2010, through the Convention on Biological Diversity (CBD), the Aichi Biodiversity Target 9 specified that: "*By 2020, invasive alien species…are identified and prioritized, priority species are controlled or eradicated…*" (https://www.cbd.int/sp/targets/). To address this aspect of the target, many countries have developed checklists of alien taxa (7). The need for such lists is reinforced in Target 6 of the Kunming-Montreal Global Biodiversity Framework (GBF) that was agreed under the CBD in December 2022. The GBF tasks parties with "…*preventing the introduction and establishment of priority invasive alien species, reducing the rates of introduction and establishment of other known or potential invasive alien species by at least 50 per cent, by 2030, eradicating or controlling invasive alien species…*" (https://www.cbd.int/article/cop15-final-text-kunming-montreal-gbf-221222). Lists of alien taxa are thus crucial to developing effective regulatory frameworks to address biological invasions (8, 9). Similarly, the World Trade Organisation (WTO) Agreement of 1995 recognises that restrictions to trade are warranted to ensure food safety and to protect the health of animals and plants, recommending that such restrictions "…*should be based as far as possible on the analysis and assessment of objective and accurate scientific data…*" (https://www.wto.org/english/tratop_e/sps_e/spsund_e.htm). The justification for restrictions, as codified in the Application of Sanitary and Phytosanitary Measures, typically takes the form of a risk analysis, which is comprised of an assessment of the likelihood and consequence of an invasion (risk assessment), an evaluation of what measure can be taken to manage the risk (risk management), and efforts to clearly outline and communicate what the concerns are (risk communication) (cf. Figure S1).

South Africa, by virtue of its biogeographical and socio-economic history, has been both a global hotspot of biological invasions (10) and a pioneer in the science and management of biological invasions (11). South Africa's history of regulating alien taxa dates back to the nineteenth century, with at least 50 pieces of legislation passed since the Xanthium Spinosum Act of 1861 (12). Initially the impetus behind such legislation was to protect economic interests, but an increasing focus on reducing environmental degradation and limiting harmful impacts on biodiversity emerged in the late twentieth century. This culminated in the promulgation of the Conservation of Agricultural Resources Act (CARA) in 1983 which included a list of regulated environmental weeds. For over 30 years, the CARA list guided the management of invasive plants in the country. South Africa is also negatively impacted by invasive microbes, fungi, and animals (especially invasive freshwater fishes, 13). The promulgation of the National Environmental Management: Biodiversity Act in 2004 provided the framework for the first comprehensive regulatory lists of alien taxa—the Alien and Invasive Species Regulations and Lists of 2014 (hereafter the NEM:BA and the A&IS Regulations and Lists).

The NEM:BA A&IS Regulations and Lists were a milestone in how South Africa addresses biological invasions. However, in the decade since they were promulgated, several issues have emerged. Bennett and van Sittert (2019) (14) noted that "*Legislative and government efforts to manage IAPs* [Invasive Alien Plants] *have faltered because of the difficulty of engaging private landowners, competition* [sic] *local viewpoints and limited support for technical interventions by scientists and managers".* An evaluation of the overall quality of the current regulatory framework in South Africa based on the indicators proposed by Wilson et al. (2018) (15), categorised South Africa's current regulations as "*partial with medium confidence"*, noting that "*…a process to evaluate the scientific evidence underpinning the lists of regulated alien species has been established…*", with the overall outlook that the "*…process of listing should become more dynamic and responsive to recommendations.*" (16). It is this process of listing that we review in this paper. Specifically, we: 1) review the

development of the NEM:BA A&IS Lists; 2) consolidate information on the lists, the regulations, and processes used to develop the lists (see links in Appendix 1); 3) briefly evaluate the implementation of the lists; 4) outline processes to provide scientific evidence to underpin changes to the lists; and 5) identify issues that need to be resolved.

The development of the NEM:BA A&IS Regulations and Lists

The NEM:BA of 2004 envisaged that lists would be produced by 1 April 2007. However, the process took much longer than this. The then Department of Environmental Affairs and Tourism consulted various stakeholders and, based on this expert opinion as informed by various global databases and sources, published the first draft lists in September 2007. The draft lists included two categories [listed (i.e., present in the country), and prohibited (i.e., not present in the country)] and so any potential benefits of listed alien taxa could not be retained; and the lists did not include taxon authorities potentially leading to confusion around the identity of taxa. The South African National Biodiversity Institute (SANBI) chaired a task team to revise the lists from 2 April 2008 until 27 January 2009. This included corresponding with experts in each taxonomic group, organising workshops and meetings, checking the nomenclature, and revising the lists. Revised draft lists were published on 3 April 2009 that are largely similar to the lists eventually promulgated in 2014. Nonetheless various concerns were still raised. To address these, experts were consulted via a series of taxon-specific working groups. Separate meetings were held on freshwater fishes, mammals, plants, and reptiles (and additional meetings held specifically to discuss trout invasions). However, the different working groups interpreted the proposed regulatory categories slightly differently (in particular category 3, see Table 1). After further draft lists were published in 2013 and 2014, the first regulations and lists were promulgated on 1 October 2014. Since then, revised lists were published taking effect on 27 September 2016, and revised regulations and lists (without the prohibited list) published on 18 and 25 September 2020 respectively. Following submissions from stakeholders regarding the listing of two invasive trout taxa [i.e., *Salmo trutta* (brown trout) and *Oncorhynchus mykiss* (rainbow

trout)], the promulgation of the latter lists was deferred to 1 March 2021, with the trout temporarily removed. In all, between 2007 and 2021, 15 documents pertaining to the A&IS Regulations and Lists have been published in South Africa's Government Gazette (see Figure 1 and Table S1 for details, with the documents themselves collated on-line see Appendix 1). A major remaining issue, as we discuss later, is that the evidence used to arrive at (and change) the lists was not clearly set out.

[Insert Figure 1]

Categories and exemptions under the A&IS Lists

The two principles that underly the A&IS Lists are that: 1) all harmful alien or potentially harmful alien taxa are to be listed under the NEMBA A&IS Regulations; and 2) provision, where appropriate, can be made to utilise taxa that are both beneficial and harmful. In practice this means that: 1) taxa that pose a high likelihood of causing significant harmful impacts (based on a risk assessment) are to be listed; and 2) the choice of listing category is based on the most suitable option for regulation (based on risk management).

In the 2020 A&IS Regulations there are four categories of listing (Table 1). Category 1 is for taxa which require management: this is sub-divided into 1a (nation-wide eradication targets) and 1b (requiring compulsory control). Category 2 is for taxa which have benefits and can be allowed under specific permit conditions (outside of which Category 2 listed taxa are treated as Category 1b). Category 3 is similar to Category 1b except that keeping existing individuals is exempt (i.e., allowed without a permit). However, the interpretation of Category 3 varies somewhat across taxonomic groups. Existing Category 3 plants in people's gardens are allowed to remain, but not be replaced (i.e., breeding and trading are restricted), therefore over time such taxa are being phased out and will essentially end up being Category 1b. Category 3 birds, by contrast, are often highly abundant and widespread taxa which might be difficult to control due to their sheer numbers.

[Insert Table 1]

Notably, category 1a taxa are not more invasive than category 1b taxa, and category 1a and 1b taxa are not more invasive than category 2 or category 3 taxa [on average category 2 plant taxa are the most widespread (17)]. Moreover, the NEM:BA A&IS Lists are not comprehensive lists of all invasive taxa in South Africa [there are more invasive plant taxa that are not listed (435) than are listed (338) (18)].

Some general exemptions apply to all listed taxa. Dead specimens, plants used as biomass (i.e., firewood), and specimens moved for disposal (e.g., after control) are exempt. Authorised officials do not need a permit to do activities related to their duties. Unless otherwise listed, species legally imported for agricultural purposes before the NEM:BA came into force are exempt, as well as other species legally imported before the A&IS Regulations came into effect. Alien freshwater fish are also exempted in some situations (including catch and release in artificial dams and catching to eat).

For Category 2 listed taxa, permits can be applied to: import, possess, breed, convey, trade, spread (or allow to spread), release, move freshwater taxa between water-bodies, discharge water, catch and release fresh-water fishes or fresh-water invertebrates, introduce to an off-shore island, and release fresh-water fish or fresh-water invertebrates species into water-bodies. Some restrictions remain, e.g., no permits will be issued for alien plants within riparian areas. Permits can also be issued for research (including biological control) by a scientific institution, display by a zoological or botanical institution, and during a state inter-basin water transfer scheme.

Finally, the NEM:BA provides provision for a list of alien taxa that are not present in the country and that should be prevented from entry (termed a prohibited list). Prohibited lists were gazetted in 2014 and 2016, but removed from the 2020 listing (cf. Box 1).

[Insert Box 1]

The NEM:BA A&IS Lists and changes over time

In the 2020 NEM:BA A&IS Lists, 560 taxa are listed as well as all hybrids between native and alien species of amphibians, birds, mammals, and reptiles (see the footnote to Table S1 as to how this number was calculated). 13 of these taxa are only listed on the Prince Edward Islands. Of the remaining 547 taxa, one is an order (Phasmida), two are families (Dendrobatidae and Salviniaceae), 15 are genera, one is a species aggregation (*Rubus fruticosus* L. agg.), 506 are species, 12 are listed at the sub-specific level, and 10 at the variety level; and, regardless of the level at which the listing is, hybrids are explicitly listed for 18 species (Table 1; 19).

Note: Rubus is a plant species aggregation

As part of this paper, the name of each regulated taxon was aligned manually to one of several taxonomic backbones. Notably, almost half the listed regulated names (255 out of 560) do not correspond exactly to the name found in a relevant taxonomic backbone. In around a hundred cases this is because the regulatory name includes synonyms (cf. Table 3) and in many other cases it is due to a slight difference in the formatting of species authorities or an update in the nomenclature. For a full list of proposed changes to the nomenclature of the regulatory lists see (19).

There have been few changes to the regulatory lists over time (Table S2). Excluding the removal of the prohibited list, the category under which 85 taxa are listed has changed since 2014 (Table S3). By comparison there were significant changes between the draft lists and the promulgated lists. In the February 2014 draft lists, the whole family Cactaceae was listed, but only 37 cactus taxa were in the final promulgated list. Research suggests this decision was proportionate—globally invasive cacti come from only 13 of 130 genera, and crucially from only 5 of 12 cactus growth forms (20), i.e., spiny cacti that spread rapidly via clonal fragmentation (21). Banning the whole family, including *Mammillaria* spp. that are popular in horticulture and none of which are invasive (as they are globose), is not warranted (22).

Permitting

There has been a steady stream of permits issued for restricted activities on listed alien taxa over time with 2906 permits issued as of December 2022 (Figure 2a). Permits have been issued for 268 different taxa, with over half of all permits issued on five taxa—*Kobus leche* subsp. *leche* (red lechwe), *Oreochromis niloticus* (tilapia), *Ctenopharyngodon idella* (grass carp), *Dama dama* (fallow deer), and *Psittacula krameri* (rose-ringed parakeet) (in decreasing order)— half of the taxa have only had one permit issued for them (Figure 2b). Notably, no permits have been issued for 26 of the 124 taxa that have at some point been listed as Category 2 (Table S3).

[Insert Figure 2]

There have also been ~10–20 permits issued to import taxa each year, around a quarter of which have been for research. Import permits have been issued for three taxa not recorded as legally in the country previously [*Acipenser baerii* Brandt, 1869; *Meriones unguiculatus* (Milne-Edwards, 1867); and *Salmo salar* Linnaeus, 1758]. There have been other requests to import taxa (particularly reptiles), but these were rejected as the risk analyses were often inconclusive or incomplete (cf. the process outlined in Figure 3). For a discussion on the separate process for importing agricultural commodities, and the inspection of plant products in South Africa see (23, 24).

Proposed improvements to the process

The changes to the 2014 lists made in 2016 and 2020 were based on either a risk assessment or expert opinion, but the reasons for the changes were not made public. To improve transparency and the link to scientific evidence, a new process has been developed (summarised in Figure 3 and discussed in detail in S1 see also (25)). The new process:

- has a clear evidence base—through the use of the Risk Analysis for Alien Taxa (RAAT) framework (26);

- engages with the scientific community—risk analyses produced using RAAT are peer-reviewed and subject to scrutiny by the Alien Species Risk Analysis Review Panel (ASRARP); and
- is step up to facilitate integrated governance—an inter-governmental Risk Analysis Review Committee (RARC) was established to assist the Minister of the Department of Forestry, Fisheries and the Environment (DFFE) with the evaluation of proposals to change the NEM:BA A&IS Lists.

[a]

We discuss the first two of these below, noting that the RARC met for the first time 1 March 2023, and so it is too early to review its performance.

[Insert Figure 3]

The Risk Analysis for Alien Taxa (RAAT) Framework

The RAAT is composed of three core questions that address the key aspects required of a risk analysis and that link to a mechanistic understanding of invasions (27; Figure S1):

- What is the likelihood that the taxon will become invasive in South Africa?
- What are the likely negative environmental and socio-economic consequences if the taxon were to become invasive?
- What options are available to manage the taxon to ensure that any benefits derived can be sustainably retained?

We believe RAAT represents an important advance. Of 14 minimal standards proposed for risk assessments by (28), RAAT fully addressed 12 of them. RAAT does not currently assess effects of future climate change (the intention is for risk analyses to be valid for around a decade or so), and only indirectly considers the status (threatened or protected) of taxa or habitats under threat. In addition to the criteria of (28), RAAT also considers environmental and socio-economic benefits of the taxon under assessment and evaluates risk management options (i.e., RAAT results in a risk analysis rather than simply a risk

assessment, Figure S1). The process is also transparent. Assessors are required to ensure there is robust evidence that listed taxa are present in the country, and to systematically collate and present evidence of impact or threat to justify listing. This means stakeholders and decision makers can see how the evidence used that influenced the recommendations. Finally, there is a formal review process to ensure consistency, quality, and to engage with relevant experts (see the section on ASRARP below).

The RAAT framework has not, as yet, been evaluated in terms of the accuracy of its classification of risk into low, medium, and high. This is mostly because analyses have, to date, focussed on invasive and high-risk taxa.

The Alien Species Risk Analysis Review Panel (ASRARP)

ASRARP was set up by the DFFE and SANBI in 2016 as an independent scientific advisory panel to review documents pertaining to the risk of alien taxa, specifically with reference to potential imports and listings (cf. Figure 3 and S1). ASRARP also assists in reviewing guidelines for risk analyses and changes made to the A&IS Regulations (see S2 for the current terms of reference).

ASRARP (since July 2018) has been composed of *ex officio* SANBI members and independent members. Independent members are experienced academics, researchers, or those involved in relevant industries from across the country, that attend ASRARP in their personal capacities and can be remunerated for their time. In compliance with the A&IS Regulations on risk assessment practitioners, such members are registered as professional scientists with the South African Council for Natural Scientific Professions (SACNASP).

Panel members handle the review of risk analyses, and for each risk analysis solicit at least two external reviews (including ideally one international) that focus on errors and omissions. Risk analyses and reviews are then presented at at least one ASRARP meeting; with recommendations passed back to the assessors for revision. Conflicts of interest are

declared, and it is understood that ASRARP members are not individually liable for the recommendations if such were made in good faith.

There have been 27 meetings of ASRARP as of 6 November 2023, with the inaugural meeting held on 29 November 2016 (Figure 1). ASRARP has gone through essentially five terms (including the current one) in line with DFFE funding cycles. Prior to 2018, various government and provincial officials attended ASRARP Meetings in *ex officio* capacity, but by the 4th meeting a decision was taken to clearly separate the scientific advisory panel from decision makers. The second term was short, Jan 2018–March 2018, with 10 members; the third term ran 16 July 2018–31 March 2020 with 15–19 members; the fourth term 18 May 2020–31 March 2022 with 23–26 members; and the current fifth term began 3 June 2022 and is due to run until 31 March 2025 and consists of nine members. The hiatuses between terms were due to delays in finalising fund agreements between DFFE and SANBI and inefficiencies in advertising and reconstituting the panel. Meetings are now held quarterly. Initially meetings were in person but since the COVID-19 pandemic they have been online (Figure 4). Since July 2018, 38 people have attended ASRARP meetings (excluding guests)—29 independent members and 12 *ex officio* SANBI staff, with some people serving in different roles at different times (Table S4).

Progress to date and issues to resolve

As of 1 November 2023, risk analyses have been completed on 122 taxa, although 16 of these were not listed at the time the risk analysis was approved by ASRARP (Table S5). Of the 106 regulated taxa that have been subject to a risk analysis (19 % of all regulated taxa), 46 recommended no substantive change to the listings (~57 %, cf. Table 2). It is unsurprising that almost half of all risk analyses evaluated to date have recommended a change to listing. Taxa for which it was felt that a change to the listing was likely warranted and taxa for which the listing was contentious were prioritised. As risk analyses focus on less

controversial taxa there are likely to be fewer cases of the recommendations of the risk analyses differing from the current regulatory listing.

Examples of taxa where there was a recommended change to the listing include: *Sasaella ramosa* (dwarf bamboo). This taxon is currently listed as category 3 under the synonym *Sasa ramosa*. However, the taxa is not formally recorded as present in the country, and the risk of invasion was scored low. The recommendation was to delist. By contrast *Phyllostachys aurea* (fishpole bamboo) is not currently listed but is recorded to have naturalised in South Africa, is invasive in other parts of the world, and requires costly management especially in forested areas. The recommended was to list *Phyllostachys aurea* as category 1b (29). *Iris pseudacorus* (yellow flag iris) was listed as a national eradication target (Category 1a). However, naturalised populations have been recorded at 24 localities across four provinces; plants are present in many people's gardens; and individual populations are very hard to control (30). Therefore, the recommendation was for the species to be listed as Category 1b and options for biological control explored. *Kobus ellipsiprymnus* subsp. *defassa* (Defassa waterbuck) is currently listed as Category 2 (i.e., can be kept under permit). Given the potential for hybridisation with the native *K. e.* subsp. *ellipsiprymnus* (common waterbuck), it was recommended that the listing of Category 2 is inappropriate and *K. e.* subsp. *defassa* should no longer be bred in South Africa.

Importantly these recommendations are provisional and need to be discussed both within government (through the RARC), with interested and affected stakeholders (e.g., the horticultural and game industries), and though wider public consultation (e.g., through publishing the lists for public comment).

[Insert Figure 4]

[Insert Table 2]

As with similar processes (e.g., submission of manuscripts to peer-reviewed journals), the review process takes time (Figure S2). As of November 2023, most risk analyses are

reviewed within six months, but 20 % have taken longer than a year (particularly when there were complex issues).

A risk analysis training course was developed in 2018 to build capacity. As of July 2023, 18 courses have been run, two of which were refresher courses developed upon revision of the risk analysis framework to v1.2 in 2020 (Kumschick et al. 2020; Figure 4). As of 6 November 2023, 46 course participants have received a course certificate, which—beside attending the course—requires a risk analysis is developed using RAAT, reviewed and accepted by ASRARP, and ultimately submitted to the DFFE.

During the implementation of the regulatory lists and following discussion at ASRARP several issues have come to light that still need to be resolved. These are summarised in Table 3.

[Insert Table 3]

Discussion and conclusions

The regulation of alien taxa in South Africa can be described as a gradual move from focussing on weeds, to broader efforts to limit damage to people and nature caused by alien plants, to a comprehensive and innovative regulatory framework that seeks to limit the harmful impacts of alien taxa without unduly reducing benefits to South Africans. The current NEM:BA A&IS Lists thus provides a foundation needed for South Africa to meet its commitment to Target 6 of the GBF by 2030. We believe that the proposed process will make the system more proportionate, accountable, consistent, transparent, and targeted [Annex B of Better Regulation Task Force (31)]. The process also aims to make the regulation of alien taxa in South Africa credible, legitimate, and acceptable.

- Proportionate: the NEM:BA A&IS Regulations and Lists recognise that many alien taxa provide benefits, and exemptions are provided for. There is an attempt to balance a precautionary approach (e.g., on imports where prevention is desirable)

against a pragmatic or in some cases ethical one, (e.g., phasing taxa out). Provisions allow for research on biological invasions to continue and so on-going projects have not been jeopardised (cf. 32). The cost of the regulations (both to the government and to society) has not, however, been estimated.

- Accountable: all lists are subject to government scrutiny and published for public scrutiny before promulgation. With the development of the RAAT framework and use of the risk analyses, the evidence that informs decisions is clear and the standards and criteria for judging regulations are set out. For the regulations in general, but also specifically for permitting, complaints and appeals processes are set out in the regulations, and the criteria for judging the performance of regulators and enforcers is partly set out (e.g., response times).
- Consistent: by working across taxa and realms, ASRARP helps ensure risk analyses are consistent. Moreover, the RARC is intended to ensure governmental work is "joined-up". As the process and time-lines for making changes become clearer, affected stakeholders (e.g., the horticultural industry) will have a greater certainty as to what might happen when.
- Transparent: the lists are available to all, and, with the development of the RAAT framework, the process to derive the lists will be clearer. A principle aim of the risk analyses is to ensure information is in a usable accessible form, although the DFFE has requested that risk analyses not be placed in the public domain until the RARC has had a chance to consider them. The names of the assessors who completed risk analyses are, however, redacted (in part as the product is the result of the work of both the assessors and ASRARP).
- Targeted: the regulations have been modified over time based on experience (cf. 33), although more information on monitoring the effectiveness of the regulations appears warranted.

- Credibility: the original lists were developed with many of the top academics working on biological invasions in the country in consultation with affected stakeholders. The RAAT framework incorporates existing schemes for impact assessment [(34; the latter later adopted by the UN following COP decision 15/27 on Invasive Alien Species (Annexes I to VI), 35)], and the pathway classification used by CBD (36). Risk analyses are routinely reviewed by national and international experts as well as working groups at the science-policy-management interface of biological invasions (37, 38).
- Legitimate: the development of the regulations is mandated in South African legislation, i.e., NEM:BA. More broadly the regulations address both national imperatives and international obligations on biodiversity conservation (CBD) and trade (WTO). Neither the RAAT framework, ASRARP nor the RARC are explicitly mentioned in the regulations, though they could be in future. Training courses are not yet registered with the SACNASP, but again this is likely desirable in future.
- Acceptable: the measures put in place try to preserve the benefits of alien species while reducing the harmful impacts of invasions. Any regulation of biodiversity is inimical to some ethical perspectives (39), but a clear distinction should be made between the rationale for regulation and evaluating the ethics of particular management interventions (37).

In summary, we believe that, while many issues still need to be resolved (Table 3), the regulation of alien species in South Africa has many desirable features. The challenge, as with many conservation issues, will continue to be to equitably balance the rights of the current with the rights of future generations. This will, we believe, require continued discussions, partnerships, and collaborations between scientists, policy-makers, implementers, and those affected by the regulations.

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Appendix 1 Links to accompanying on-line databases and list of on-line supplementary material

List of regulated taxa: this database outlines the taxa listed in 2014, 2016, and 2020 versions of the National Environmental Management: Biodiversity Act Alien and Invasive Species Lists as well as those proposed for listing in the 2009, 2013, 2014, 2015, and 2018 draft lists published in the Government Gazette. Changes in the lists over time and a link between the regulatory names used and the valid scientific name are also presented. The database will be updated when revisions of (or proposals to revise) the lists are published (19), https://dx.doi.org/10.5281/zenodo.7638966.

List of permits issued: The list of permits issued in terms of the National Environmental Management: Biodiversity Act Alien and Invasive Species Regulations to conduct activities on listed alien taxa 2014–2022. This database is based on data owned by the DFFE and made available to SANBI as part of the national status report on biological invasions process. The database is stored on-line and will be updated periodically (40), https://dx.doi.org/10.5281/zenodo.7947508

Notices in the South Africa Government Gazette relevant to the National Environmental Management: Biodiversity Act, Alien and Invasive Species Regulations and Lists: The original notices from 2007 to 2021 in pdf format. See Table S1 for an analysis of these and suggestions for how to reference the documents. https://dx.doi.org/10.5281/zenodo.8160209

Table S1: Regulations and notices published in South Africa's Government Gazette in terms of the National Environmental Management: Biodiversity Act, Alien and Invasive Species Regulations and Lists (NEM:BA A&IS).

Table S2: Taxa for which the regulatory listing has changed over time.

Table S3: Taxa listed as category 2 for which permits have been issued.

Table S4: Current and previous members of the Alien Species Risk Analysis Review Panel (ASRARP).

Table S5: Risk analyses submitted by the South African National Biodiversity Institute (SANBI) to the Department of Forestry, Fisheries, and the Environment (DFFE) following review by the Alien Species Risk Analysis Review Panel (ASRARP).

Figure S1: Aspects of risk addressed by the Risk Analysis for Alien Taxa (RAAT) framework.

Figure S2: The time taken to review risk analyses by ASRARP.

S1: The process for making regulatory decisions concerning alien taxa in South Africa (under the National Environmental Management: Biodiversity Act, Alien and Invasive Species Regulations of 2014 as amended 2020) as understood by the authors.

S2: Terms of reference for the Alien Species Risk Analysis Review Panel (ASRARP) vApril 2022.

Box 1 Potential lists of taxa not present in South Africa

One of the most effective ways to address biological invasions is to prevent introductions (1). This can be done in various ways, e.g., prohibiting the import of taxa; identifying risks and putting specific surveillance in place; and developing contingency plans so any incursions detected can be eradicated. For each of these a list of taxa can be developed noting the merit of such a list should be defined by its utility.

Prohibited list: taxa that are not allowed to be introduced (deliberately or accidentally). No import or other permits will be granted for these taxa.

Watch list: taxa that are likely to arrive and pose an unacceptable threat. Active surveillance can improve how quickly incursions are detected, and a watch list can therefore provide priorities for setting up surveillance efforts. Various methods have been used to develop such lists (41), including horizon scanning (42).

Emergency Response Planning: taxa prioritised for contingency planning where incursion response plans are set up to ensure an emergency response plan can be initiated rapidly on detection.

Finally, given the number of potential new introductions, it is often impractical to manage taxon by taxon. Instead it is preferable to look at the risks posed by particular pathways and implement pathway-specific regulations and control measures (43).

Table 1 The regulatory categories of the National Environmental Management: Biodiversity Act (NEM:BA) Alien and Invasive Species (A&IS) Regulations and Lists of 2020. The regulatory definitions are précised, with the omitted sections referring to particular actions that must be undertaken. The proposed criteria for the different categories are based on the authors' experience developing the Risk Analysis for Alien Taxa (RAAT) framework and discussions at the Alien Species Risk Analysis Review Panel (ASRARP), noting that these proposed criteria would in some cases require a revision to the regulations and or the act.

Category	Number of taxa[1]	Regulatory definition (précised)	Proposed criteria / approach
1a	53	Category 1a species must be combatted or eradicated. A person in control of a 1a species must immediately take steps to combat or eradicate the species and allow authorised officials to inspect a property and to monitor, assist with or implement the combatting or eradication (in accordance with an Invasive Species Management Programme if one is in place).	• Present in the country as an alien taxon; AND • poses a high risk; AND • any benefits provided can be provided by other taxa or such benefits cannot be maintained with an acceptable risk of invasion; AND • nation-wide eradication is deemed desirable and feasible based on a costed evaluation (e.g., 44, 45); AND • a national eradication plan has been developed and is being implemented.
1b	259	Category 1b species must be controlled. A person in control of a 1b species must control the species (in accordance with an Invasive Species Management Programme if one is in place), and allow authorised officials to inspect a property and to monitor, assist with or implement the control.	• Present in the country as an alien taxon; AND • poses a high risk; AND • any benefits provided can be provided by other taxa or such benefits cannot be maintained with an acceptable risk of invasion; AND • it is not desirable or feasible to attempt nation-wide eradication, although the extirpation of some populations might be warranted; AND • a taxon-specific national management plan has been developed and is being implemented (in certain cases, such a plan might simply indicate that control is not cost-effective at present).

[1]Of 560 valid taxa. This does not include generic listings for all hybrids between native and alien species of amphibians, birds, mammals, and reptiles, see the footnote to Table S2 for further details.

Category	Number of taxa[1]	Regulatory definition (précised)	Proposed criteria / approach
2	75	Category 2 species are treated as 1b species except in cases where a permit has been issued. Permits may be issued to persons to carry out restricted activities within a specified area (specified either in the regulations or in the issued permit), with permit holders required to ensure they adhere to the permit conditions, often with the goal that there is no spread to areas outside of the specified area.	• Present in the country as an alien taxon; AND • poses a high risk; AND • has significant socio-economic benefits which cannot be supplied by other taxa (either native taxa or alien taxa which pose acceptable risks); AND • permit conditions have been established that are known to reduce the risk of invasion to an acceptable level and that can be readily implemented and monitored with effective remedial control measures available and specified in permits if there are any escapes.
3	51	Category 3 species are regarded and managed as 1b species except that specimens may be kept without a permit providing there is no further propagation, movement, or trade, and category 3 plant species may not be kept in riparian areas.	Category 3 to be removed as unnecessary. If specific activities, types of taxa, or specific sites are to be exempt, these are specified in the regulations. If exemptions are highly complicated or would require maps, details are to be outlined in taxon-specific national management plans.
Prohibited	0	NA (cf. the 2014 and 2016 regulations and lists).	See Box 1
Context-specific	122	This is not a formal definition but arises as the regulations list some taxa in multiple categories (e.g., 1b in one province and not listed in other provinces). Moreover, specific exemptions may be indicated (e.g., existing plantations of some forestry species are exempt, noting that the listed taxon may not spread outside the existing plantation). The 13 taxa listed only on the Prince Edward Islands (PEIs) are included in this category (no taxon is listed on both the PEIs and mainland South Africa).	No taxon is to be listed in multiple categories. Details of sites to be prioritised for control should be outlined in taxon-specific national management plans rather than specifying different listing categories for different sites in the A&IS Lists themselves. This would require regulation at the sub-national level to address taxa which are native to one part of South Africa but pose a high risk as an invasive taxon in another part of the country (cf. Table 3). A separate list to be created and maintained for the PEIs as the risk and management options differ from the mainland. Such a list should include all alien taxa present on the PEIs, with management goals specified in the PEIs Management Plan (cf. 46).

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Table 2 Recommendations of the Alien Species Risk Analysis Review Panel (ASRARP) based on 122 risk analyses conducted as of 6 November 2023. For changes to nomenclature see (19). In 20 cases there was a recommendation to re-evaluate taxa (usually within five years) as the evidence was equivocal or there was specific research or monitoring that should be carried out to inform the recommendation. Of the five taxa flagged for delisting, one was found not to be a valid taxon, one was native to a part of South Africa, one is a hybrid for which both parental taxa are already listed (and so the listing is not needed), and two were found to pose a low invasion risk. See Table S5 for further details.

		Recommendation for listing					
		1a	**1b**	**2**	**Context-specific**	**Prohibit**	**Do not list**
Listing under NEM:BA A&IS lists (on date of approval)	**1a**	13	5	0	0	1	1
	1b	0	20	0	0	0	0
	2	3	10	24	0	1	1
	3	0	2	0	0	0	1
	Context-specific	0	9	10	3	0	2
	Not listed	3	7	4	0	1	1

Table 3 Issues identified during discussion around the regulation of the alien taxa in South Africa with proposed solutions. These issues are largely based on discussions held at the Alien Species Risk Analysis Review Panel (ASRARP) or while the authors have been developing and implementing the Risk Analysis for Alien Taxa (RAAT) framework.

Issue	Description	Proposal	Examples	Key reference(s)
Taxa which have both alien and native populations within the Republic of South Africa	The regulations define nativity in terms of the whole of South Africa. However, there can be species which are native to one part of the country that form alien populations in another part of the country, i.e., "...*populations that result from the human-mediated dispersal of individuals of a species beyond a biogeographical barrier to a point beyond that species' native range, but that is still within the same political entity as parts of the species' native range*""	Taxa which are native to some parts of the country but alien in others (i.e., have native-alien populations) should only be regulated in the provinces where they are not native; and so should not be included in the NEM:BA A&S Lists which are at a national level.	132 such populations from 77 native species have been formally categorised in the country. Three of these taxa are currently listed under the A&IS Regulations [*Clarias gariepinus* (African sharptooth catfish), *Hyperolius marmoratus* (painted reed frog), and *Sclerophrys gutturalis* (guttural toad)]	(47)
Listing of taxa at provincial or other geographical levels other than national	Certain alien taxa are not a threat to the whole country and therefore only warrant listing in certain regions of the country, for example provinces. However, there are no border controls between provinces, and therefore control of movement and enforcement is more difficult.	There is provision in the NEMBA for provincial lists (70.1b, 70.2). Local ordinances could be used to handle such cases.	*Metrosideros excelsa* (New Zealand Christmas tree) is currently only listed in the Overstrand District of the Western Cape	(19)
International introductions	Biological invasions are inherently an international issue and taxa that are introduced to South Africa need to consider the risks of invasions to neighbouring countries and vice versa.	Assessors and decision-makers should consider threats to neighbouring countries and not allow such taxa to be introduced	Biological control releases evaluated by the National Biological Control Release Application Review Committee routinely consider the threat biocontrol agents could have to the flora and fauna of other Africa countries.	(48, 49)

Issue	Description	Proposal	Examples	Key reference(s)
Declaring taxa as absent	Some taxa were added to the list but are subsequently believed to be absent from the country. This can be because a taxon was present but there is strong evidence that it is no longer present either because it was deliberately eradicated from South Africa or the population was lost.	A protocol for declaring taxa absent is under development and would provide a rationale for removing taxa from the lists.	*Tetrapygus niger* (the Chilean black urchin) was found in aquaculture dams used for oyster production on the West Coast of South Africa. Oyster production was stopped at the dams and surveys of the dams and the neighbouring coast found no evidence of the urchins remaining.	(45, 50)
Evaluating positive impacts	The evaluation of positive impacts and benefits in risk analyses is important as it gives an indication of the uses of the taxa and potential conflicts of interest. However, there has often been discussion as to what constitutes a “significant” benefit, and stakeholders might differ in their perceptions of benefits.	International frameworks have recently been developed to assess positive impacts on the environment, and similar frameworks for socio-economic benefits are in development. These should be incorporated into the risk analysis process once they are more established.	A taxon can be regarded as having a ‘Major’ positive impact if it causes an increase (or prevents a decrease) in species occupancy through local or subpopulation reestablishment (or extinction prevention).	(51, 52)
List of taxa legally in the country or that are not present	Many of the exemptions to the regulations depend on knowledge of which taxa are legally present in the country, and similarly which are not here legally. However, such lists have not been systematically curated.	A list of alien taxa legally in the country needs to be compiled and curated. This would require digitisation of historical import records; an assessment of whether a taxon for which an import permit was issued was actually been imported; and an assessment of whether a taxon is still present in the country.	Many agricultural and forestry taxa were introduced over a century ago for various uses and are widely used. These taxa might have been introduced in compliance with any regulations that applied at the time.	see Box 1
How to respond to new detections	Taxa can, of course, be accidentally or illegally introduced. The A&IS Regulations do not specify what should happen to such taxa on detection—they are not automatically listed.	A detection should ideally rapidly trigger an incursion response, including the activation of an emergency response plan, and a process (supported by a risk analysis) to consider listing.	Over the period 2013–2022, 32 new alien taxa were either illegally or accidentally introduced	(46)

Issue	Description	Proposal	Examples	Key reference(s)
Listing of taxa at levels other than the species level	Some taxa are listed at levels above (e.g., genus or family) or below (e.g., sub-species and variety) the species level. Risks and impacts can vary across taxa but most information in the literature is available at the species level.	Listing should generally be done at the species level. Exceptions could be if the whole taxonomic entity is alien to the country and considered of high risk. If entities below the species level are to be listed, it should be feasible in practice to distinguish between entities.	The order Phasmida (stick insects) is listed, despite some taxa being native to the country, and that many taxa likely pose a low risk.	(53)
Co-invasions	Multiple taxa can be introduced together, and in some cases only the combination of the taxa makes them of high risk.	A decision needs to be made whether all involved taxa are listed, and if they are to be listed separately or as a complex.	*Euwallacea fornicatus* (the polyphagous shot-hole borer) and a symbiotic fungus, *Fusarium euwallaceae*, were introduced together. Both the fungus and the beetle are required for there to be an invasion and for trees to be killed.	(54)
Taxa that are too widespread for effective control	Some alien taxa, specifically certain small mammals and birds, are distributed across South Africa. In such cases effective control might not be possible.	Listing such taxa is still important to avoid further introductions. In certain cases, simple bans on imports could be instituted without the mandate to control the taxa actively otherwise.	There are several notable invasive rats in South Africa including *Rattus norvegicus, R. rattus,* and *R. tanezumi*, these are only currently listed on off-shore islands, but are a pest on the mainland as well.	(55)
Suitability of risk analysis framework for micro-organisms / diseases	The RAAT framework, as many frameworks in invasion science, was not specifically designed to be applied to micro-organisms, and there might be unique issues when assessing such organisms.	A separate process is in place for human health and animal diseases which could possibly be implemented, but such protocols do not necessarily reflect or cover threats to biodiversity at large.	Rinderpest was detected for the first time in South Africa in 1896 killing an estimated 2.5 million domestic cattle in southern Africa and an unknown number of game.	(56)

Issue	Description	Proposal	Examples	Key reference(s)
Dealing with agricultural vs. environmental vs. health issues	NEM:BA focuses on biodiversity, but the impacts of many invasive taxa cut across multiple domains. It is not clear if all alien pests, pathogens, and weeds should be included on the NEM:BA A&IS Lists; or only those found outside of cultivated regions. There is a need to harmonise relevant legislation.	The cross-sectoral and inter-departmental RARC should be able to address some of the issue, but the impact of agricultural pests and weeds on biodiversity is understudied. The One Biosecurity approach is potentially useful.	The import of plants is variously addressed under NEM:BA, the Agricultural Pests Act of 1983, and the Plant Improvement Act of 1976.	(57, 58)
Regulation after successful biological control	Taxa that are under permanent biological control might warrant a change in listing as no other control measures are required to prevent harmful impacts and so arguably their risk is no longer high.	A protocol is needed to determine how biocontrol and other successful control efforts should affect the listing of alien taxa.	At least 17 taxa are considered to have been brought under permanent control by the release of classical biological control agents.	(59, 60)
Inclusion of synonyms in regulatory listings	In ~100 cases the listed taxon includes a synonym. Presumably this was based on the desire to reduce confusion due to changes in the nomenclature. However, the choice of which taxa to include synonyms for and which synonyms to include was not clear.	Keep the regulatory name verbatim as the taxonomic backbone and add a separate column to the regulations that specifies common synonyms. This would ensure the lists are 'tidy' (sensu, 61), easier to work with, and links to previously used names are retained.	*Acacia paradoxa* DC. (= *A. armata* R.Br.) could be simply listed as *Acacia paradoxa* DC.	(19)
Inclusion of regulatory groupings	The regulations are split into several lists based on either a quasi-taxonomic grouping or on a combination of the quasi-taxonomic grouping and the realm in which the organism is found. Several taxa, however, are found in more than one realm.	A single 'tidy' list would allow for greater interoperability in the listing. Information on groupings could be retained as a different column that could allow for sorting and for multiple values to be incorporated.	Amphibian | Bird | Freshwater fish | Marine fish | Freshwater invertebrates | Marine invertebrates | Terrestrial invertebrates | Mammal | Microbe | Marine plants | Terrestrial and freshwater plants | Reptile	(62)

Issue	Description	Proposal	Examples	Key reference(s)
The same process is used for the Prince Edwards Islands (PEIs) as for mainland South Africa	Currently the NEM:BA A&IS Lists do not have a separate list or regulatory processes for the PEIs. However, the risks and management options are substantially different from the mainland. Management in practice will be defined by the PEI Management Plan.	Taxa to be managed on the PEIs should be listed in a separate process to that of the NEM:BA A&IS Regulations. For each alien taxon present on the PEIs a decision should be taken to: a) implement management with the goal of eradication; b) implement maintenance management with the goal of reducing harmful impacts; or c) to not manage the alien population given it is not cost-effective to do so. Any new alien taxon found should be exterminated and a sample taken for identification purposes.	Of the 13 taxa present in the PEIs listed under the NEM:BA A&IS Regulations, nine have been subjected to some form of management. An additional two taxa which are not listed have been subject to management.	(46)
Demonstrating the effectiveness of the regulations	It is not always clear if the regulations are being adhered to, and ultimately whether adhering to permit conditions is sufficient to keep invasions in check.	An increased focus on targeted monitoring and evaluation of interventions will allow the regulations to become more adaptive and responsive.	Various studies have evaluated the awareness of the regulations and how the lists have guided action. While there has been significant uptake and engagement with the permitting system (Figure 2), information on the degree to which those who need permits are applying for permits or simply ignoring the regulations, is needed.	(63-65)

19

Figure 1 Time-line of the development of the Alien and Invasive Species Regulations under the National Environmental Management: Biodiversity Act (NEM:BA A&IS Regulations). Full details of the lists and regulations are in Table S1. ASRARP is the Alien Species Risk Analysis Review Panel (an independent body) and the RARC is the Risk Analysis Review Committee (a governmental decision-making body). For related process concerning the development of risk analyses see Figure 4. This figure was produced using a template from Vertex42.

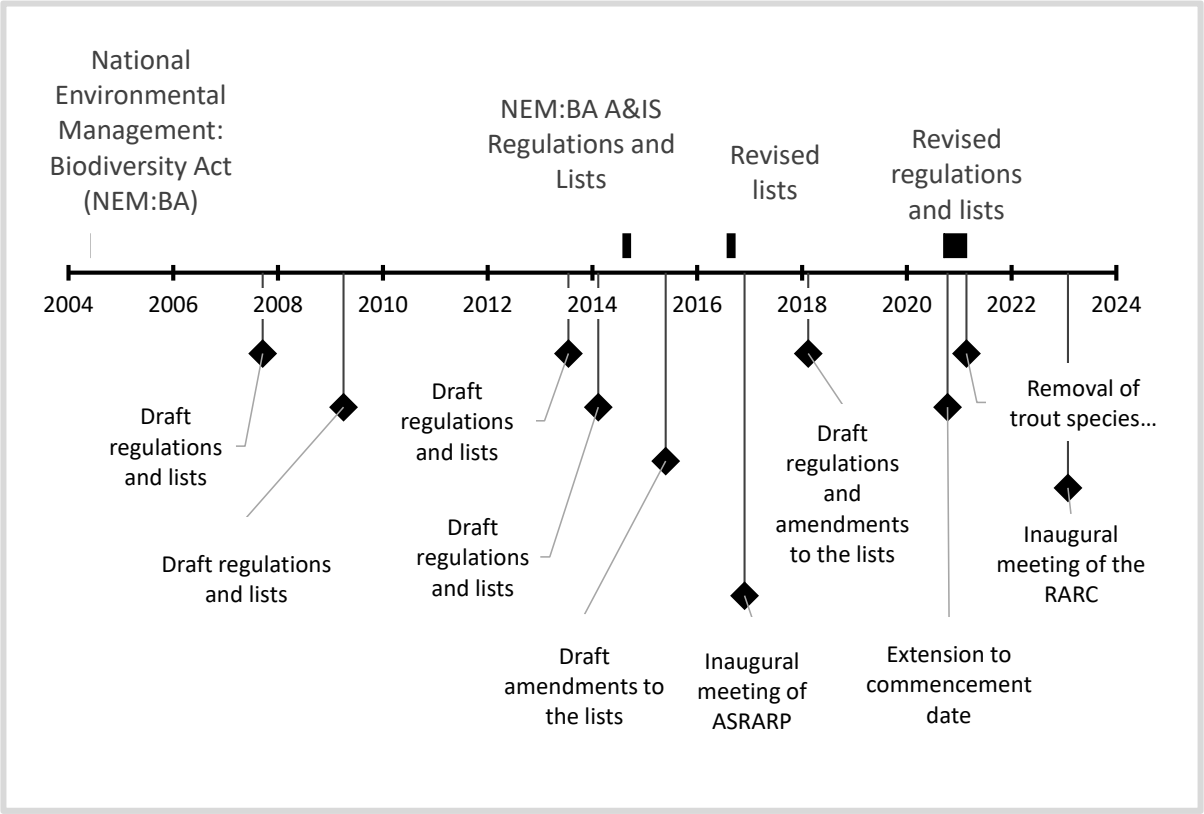
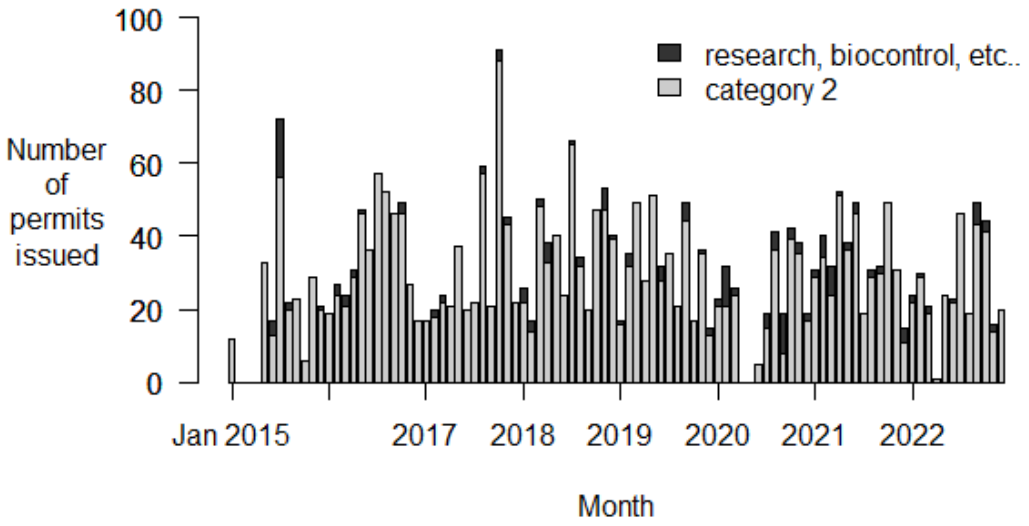
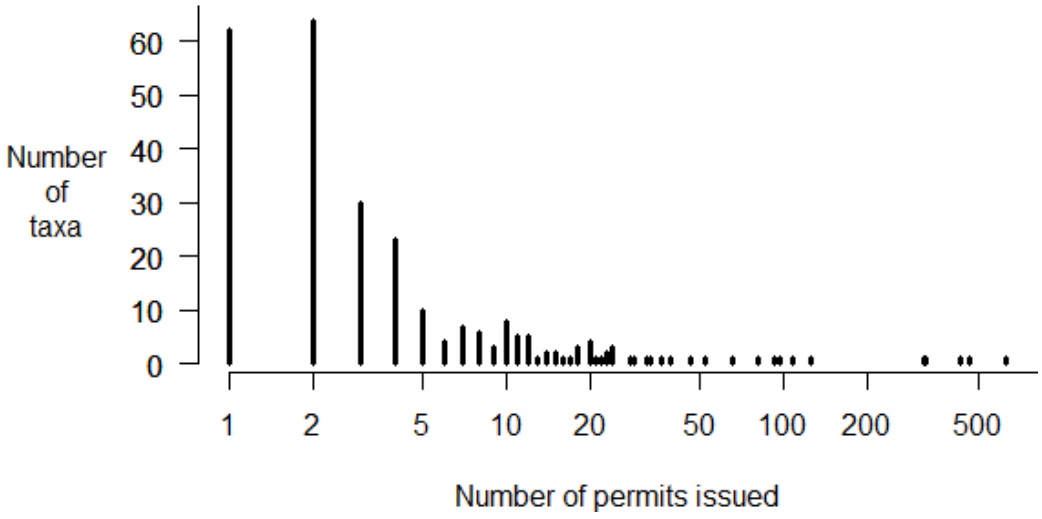


Figure 2 Permits issued for taxa listed under the National Environmental Management: Biodiversity Act, Alien and Invasive Species Regulations 2014–2022. a) The number of permits issued has not varied much over time, except for an initial slow start and a dip during the South African national lockdowns in response to COVID-19 in 2020. b) Most taxa have only had a few permits issued, with permits issued predominately on a handful of taxa. Information on permits declined was not collated here as it can be misleading (e.g., permits can be declined based on how the application is submitted, and such declined permits can be issued subsequently once applicants comply with the requirements). These figures are based on information provided by the Department of Forestry, Fisheries and the Environment (DFFE) to the South African National Biodiversity Institute (SANBI) as part of the national status report and are redrawn from (33).

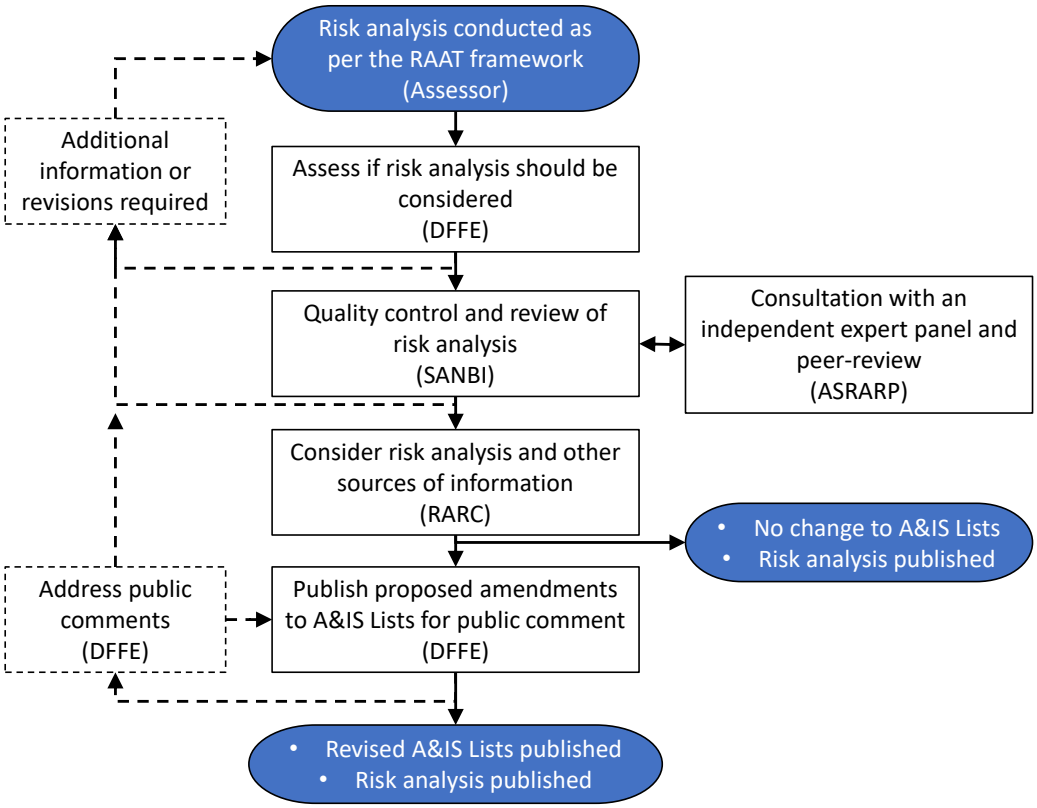


a)



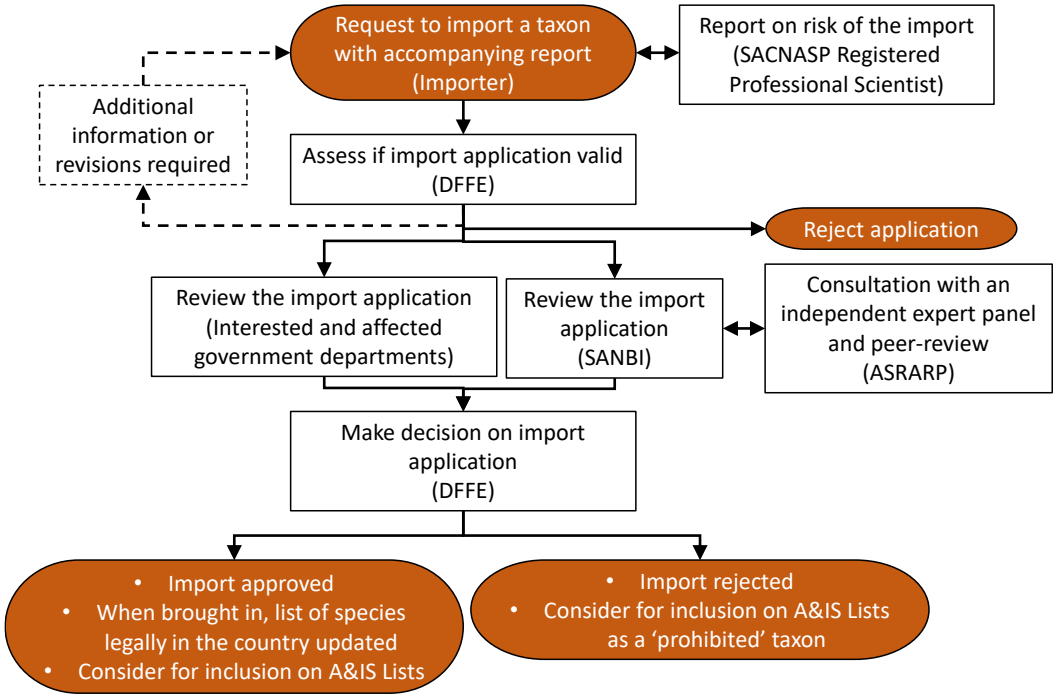
b)

Figure 3 How decisions are made with regard to: a) evaluating and potentially changing the listing of a taxon; and b) requesting an import permit. Please note these diagrams are the authors' interpretation of the situation and have no legal basis. A&IS Lists are the Alien and Invasive Species Lists published under the National Environmental Biodiversity: Management Act of 2004; ASRARP is the Alien Species Risk Analysis Review Panel; DFFE is the Department of Forestry, Fisheries and the Environment; RAAT is the Risk Analysis for Alien Taxa framework; RARC is the Risk Analysis Review Committee; and SANBI is the South African National Biodiversity Institute. For full details of these processes and the separate process to import biological control agents based on information in (49) see S1.


Risk analysis conducted as per the RAAT framework (Assessor)
Additional information or revisions required
Assess if risk analysis should be considered (DFFE)
Quality control and review of risk analysis (SANBI)
Consultation with an independent expert panel and peer-review (ASRARP)
Consider risk analysis and other sources of information (RARC)
No change to A&IS Lists
Risk analysis published
Address public comments (DFFE)
Publish proposed amendments to A&IS Lists for public comment (DFFE)
Revised A&IS Lists published
Risk analysis published

52 a)

53


Request to import a taxon with accompanying report (Importer)
Report on risk of the import (SACNASP Registered Professional Scientist)
Additional information or revisions required
Assess if import application valid (DFFE)
Reject application
Review the import application (Interested and affected government departments)
Review the import application (SANBI)
Consultation with an independent expert panel and peer-review (ASRARP)
Make decision on import application (DFFE)
Import approved
When brought in, list of species legally in the country updated
Consider for inclusion on A&IS Lists
Import rejected
Consider for inclusion on A&IS Lists as a 'prohibited' taxon

54 b)

Figure 4 Progress developing risk analyses on alien taxa and activities of the Alien Species Risk Analysis Review Panel (ASRARP) as of 6 November 2023. Each horizontal line represents a risk analysis that has been developed for a specific taxon, with the length of the line indicating the time the risk analysis had been under review with ASRARP.