



The regulation of alien species in South Africa

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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. In this paper, we review how the lists developed, changed over time, and how they have been implemented. As of March 2021, 560 taxa were listed under four broad regulatory categories, and between 2014 and 2020, almost 3000 permits were issued to regulate the continued use of listed taxa. The full lists of regulated taxa, permits issued, and corresponding regulations are available in the [Supplementary material](#). A proposed standardised, transparent, and science-informed process to revise the regulatory lists is also presented – as of 30 April 2024, risk analyses have been developed for 140 taxa using the Risk Analysis for Alien Taxa (RAAT) framework and reviewed by an independent scientific body [the Alien Species Risk Analysis Review Panel (ASRAP)] with input from taxon-specific experts. These recommendations are being considered by an interdepartmental 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, and ultimately facilitate efforts to reduce the harmful impacts of alien taxa.

Significance:

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.

Introduction

Biological invasions are a leading driver of global change.¹ There is increasing evidence that the scale, scope, and cost of problems caused by invasions will increase in the coming years.²⁻⁴ In response to this threat, regulatory frameworks 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.⁵ 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...”⁶. 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...”⁸. Lists of alien taxa are thus considered fundamental to how biological invasions are managed.^{9,10} Moreover, the World Trade Organisation (WTO) Agreement of 1995 recognised that restrictions on trade are warranted to ensure food safety and to protect the health of animals and plants. The WTO Agreement recommended that such restrictions “...should be based as far as possible on the analysis and assessment of objective and accurate scientific data”¹¹. The justification for restrictions, as codified in the Application of Sanitary and Phytosanitary Measures, typically takes the form of a risk analysis, which consists 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) ([Supplementary figure 1](#)).

South Africa, by virtue of its biogeographical and socio-economic history, has been both a global hotspot of biological invasions¹² and a pioneer in the science and management of biological invasions¹³. South Africa’s history of regulating alien taxa dates back to the 19th century, with at least 50 pieces of legislation passed since the *Xanthium Spinosum Act of 1861*.¹⁴ 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 20th century. In particular, the *Conservation of Agricultural Resources Act (CARA) of 1983* included several environmental weeds, guiding the management of invasive plants for over 30 years. South Africa is negatively impacted by invasive plants (and especially invasive trees)¹⁵, but also by invasive microbes, fungi, and animals (especially invasive freshwater fishes¹⁶)¹⁷. The promulgation of the *National Environmental Management: Biodiversity Act in 2004* (hereafter the NEM:BA) 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 A&S Regulations and Lists).

The NEM:BA A&S 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. “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.¹⁸ An evaluation of the overall quality of the current regulatory framework in South Africa, based on the indicators proposed by Wilson et al.¹⁹, categorised South Africa's current regulations as "partial" 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"²⁰. It is this process of listing that we review in this paper. Specifically, we: (1) review the development of the NEM:BA A&S Lists (Figure 1); (2) consolidate information on the lists²¹, the regulations²², and the processes used to develop the lists (Tables 1 and 2; Figures 1 and 3); (3) briefly evaluate the implementation of the lists (Table 2; Figure 2); (4) outline processes to provide scientific evidence to underpin changes to the lists (Figure 4); and (5) identify issues that need to be resolved (Box 1, Table 3).

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

The NEM:BA of 2004 envisaged that lists would be produced by 1 April 2007. However, the process took much longer. The then Department of Environmental Affairs and Tourism (DEAT) consulted various stakeholders and, based on expert opinion as informed by various global databases and sources, published the first draft lists in September 2007. It is not clear why these lists were considered insufficient (though cf. Supplementary table 1), but, from 2 April 2008 until 27 January 2009, the South African National Biodiversity Institute (SANBI), on behalf of the DEAT, chaired a task team to revise the lists. Experts in various taxonomic groups were consulted, workshops and meetings were held, and the nomenclature was checked. Revised draft lists published on 3 April 2009 are largely similar to the lists eventually promulgated in 2014. Nonetheless, the process was not finalised and a series of taxon-specific working groups was established with relevant experts. Separate meetings were held on freshwater fishes, mammals, plants, and reptiles, and additional meetings were 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 that took effect on 27 September 2016, and revised regulations and lists (without the prohibited list) were published on 18 and 25 September 2020, respectively. Following submissions from stakeholders regarding the listing of two invasive trout taxa, 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 NEM:BA A&S Regulations and Lists were published in South Africa's Government Gazette (See Figure 1 and Supplementary table 1 for details, with the documents themselves collated online²²). 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.

Categories and exemptions under the NEM:BA A&S Lists

The two principles that underlie the NEM:BA A&S Lists are that: (1) all harmful invasive or potentially harmful invasive taxa are to be listed; 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 an evaluation of risk management options).

In the 2020 NEM:BA A&S Lists there are four categories of listing (Table 1). Category 1 is for taxa which require management: this category is sub-divided into 1a (nationwide 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

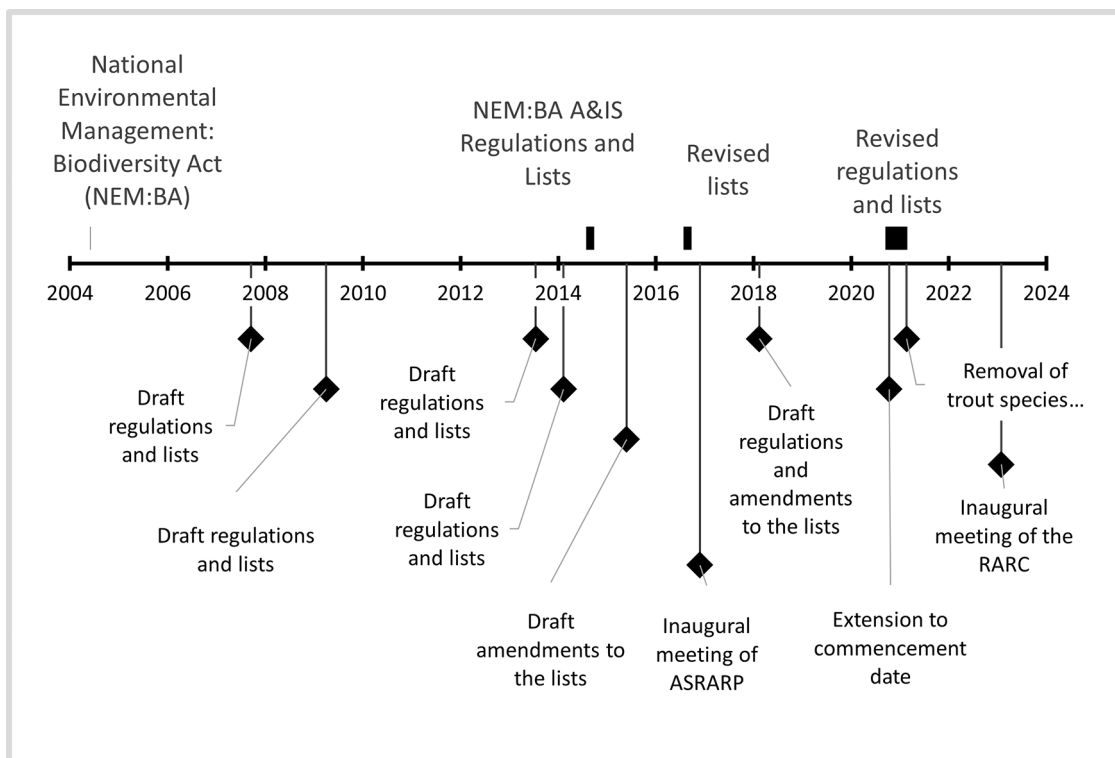


Figure 1: Timeline of the development of the Alien and Invasive Species Regulations under the *National Environmental Management: Biodiversity Act* (NEM:BA A&S Regulations). Full details of the lists and regulations are in Supplementary table 1. ASRARP is the Alien Species Risk Analysis Review Panel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

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 (ASRAP), noting that these proposed criteria would in some cases require a revision to the regulations and or the Act. A total of 560 valid taxa are considered here (see Supplementary table 2 for more details noting that the generic listings for all hybrids between native and alien species of amphibians, birds, mammals, and reptiles are not counted here).

Category	Number of taxa	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).	<ul style="list-style-type: none"> • 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 acceptably low risk of invasion; AND • nationwide eradication is deemed desirable and feasible based on a costed evaluation^(e.g. 23,24); 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.	<ul style="list-style-type: none"> • 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 acceptably low risk of invasion; AND • it is not desirable or feasible to attempt nationwide 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).
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 the specified area.	<ul style="list-style-type: none"> • 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 acceptably low risks); AND • permit conditions have been established that have been shown to reduce the risk of invasion to an acceptably low level and that can be readily implemented and monitored. Effective remedial control measures are available if there are any escapes with such measures specified in permits.
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. Taxa listed as Category 3 to be relisted as 1b with exempted activities (e.g. possession) to be explicitly specified in the regulatory lists. This is because Category 3 has been interpreted in several different ways and so it would be preferable to make the exemptions and prohibitions explicit in the listing itself.
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.	<p>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 NEM:BA A&IS Lists themselves. Regulation at the sub-national level is also needed 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).</p> <p>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.²⁵</p>

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.

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 (see Figure 3 in Henderson and Wilson²⁶)]. Moreover, the NEM:BA A&S Lists are not comprehensive lists of all invasive taxa in South Africa [there are more invasive plant taxa that are not listed than are listed; 435 vs. 338 plant taxa¹⁵].

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 perform their duties in terms of the NEM:BA or the *National Environmental Management Act*. Unless otherwise listed, species legally imported for agricultural purposes before the NEM:BA came into force (i.e. 2004) are exempt, as well as species legally imported before the NEM:BA A&S Regulations came into effect (i.e. 2014 or later depending on which version of the regulations was applicable). 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 freshwater fishes or freshwater invertebrates, release freshwater fishes or freshwater invertebrate species into discrete water bodies in which they already occur, and introduce a species to an offshore island. Some restrictions, however, remain, e.g. no permits will be issued for Category 2 alien plants within riparian areas. Permits can also be issued for any listed taxa 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 provide 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 in 2020, arguably as the evidence for the inclusion or exclusion of taxa was not clearly set out (Box 1).

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

In the 2020 NEM:BA A&S Lists, 560 taxa are listed as well as all hybrids between native and alien species of amphibians, birds, mammals, and reptiles (see [Supplementary table 1](#) for details of how this number was calculated). Of these, 13 taxa are only listed on the Prince Edward Islands. Of the remaining 547 taxa, 1 is an order (*Phasmida*), 2 are families (Dendrobatidae and Salviniaceae), 15 are genera, 1 taxon 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 mentioned in the listings of 18 taxa.²¹

As part of this paper, the name of each regulated taxon was aligned manually to a national or international database of accepted scientific names (i.e. a taxonomic backbone). Notably, almost half the listed regulated names (255 out of 560) do not correspond exactly to the name found in the relevant taxonomic backbone. In about a hundred cases, this is because the regulatory name includes one or more 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 [e.g. the Global Biodiversity Information Facility refers to the addax as '*Addax nasomaculatus* (Blainville, 1816)', but the NEM:BA A&S Lists of 2020 refers to the addax as '*Addax nasomaculatus* (de Blainville, 1816)']. A full list of proposed changes to the nomenclature of the regulatory lists is provided online.²¹

There have been few changes to the regulatory lists over time ([Supplementary table 2](#)). Excluding the removal of the prohibited list, the category under which 85 taxa are listed has changed since 2014 [including 20 taxa that are no longer listed and 11 taxa that were at one point not listed that are now listed]. There were also some notable changes between the draft lists and the promulgated lists. In the February 2014 draft lists, the whole family Cactaceae was listed, but, based on evidence of invasiveness in the country, only 37 cactus taxa were on 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 forms³⁰, i.e. spiny cacti that spread rapidly via clonal fragmentation³¹. 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.³²

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).³³ Permits have been issued for 268 different taxa; however, over half of all permits have been issued on five taxa – in decreasing order, *Kobus leche* subsp. *leche* (red lechwe), *Oreochromis niloticus* (tilapia), *Ctenopharyngodon idella* (grass carp), *Dama dama* (fallow deer), and *Psittacula krameri* (rose-ringed parakeet) – and half of the taxa have only had one permit issued for them (Figure 2b). No permits have been issued for 26 of the 124 taxa (i.e. ~20%) that have at some point been listed as Category 2 ([Supplementary table 3](#)), which raises the question: if there is no demand for permits should a taxon be listed as Category 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* (Siberian sturgeon); *Meriones unguiculatus* (Mongolian gerbil); and *Salmo salar* (Atlantic salmon). There have been other requests to import taxa (particularly reptiles), but these were rejected, often as the risk analyses were inconclusive or incomplete (cf. the process outlined in Figure 3). A separate process is in place for importing agricultural commodities and the inspection of plant products.^{34,35}

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.^{27,28}

Emergency response plan list: taxa identified as likely to be introduced, that pose an unacceptable threat, and that are a high priority for control. Contingency plans should be developed in advance so any incursions can be controlled immediately upon 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.²⁹

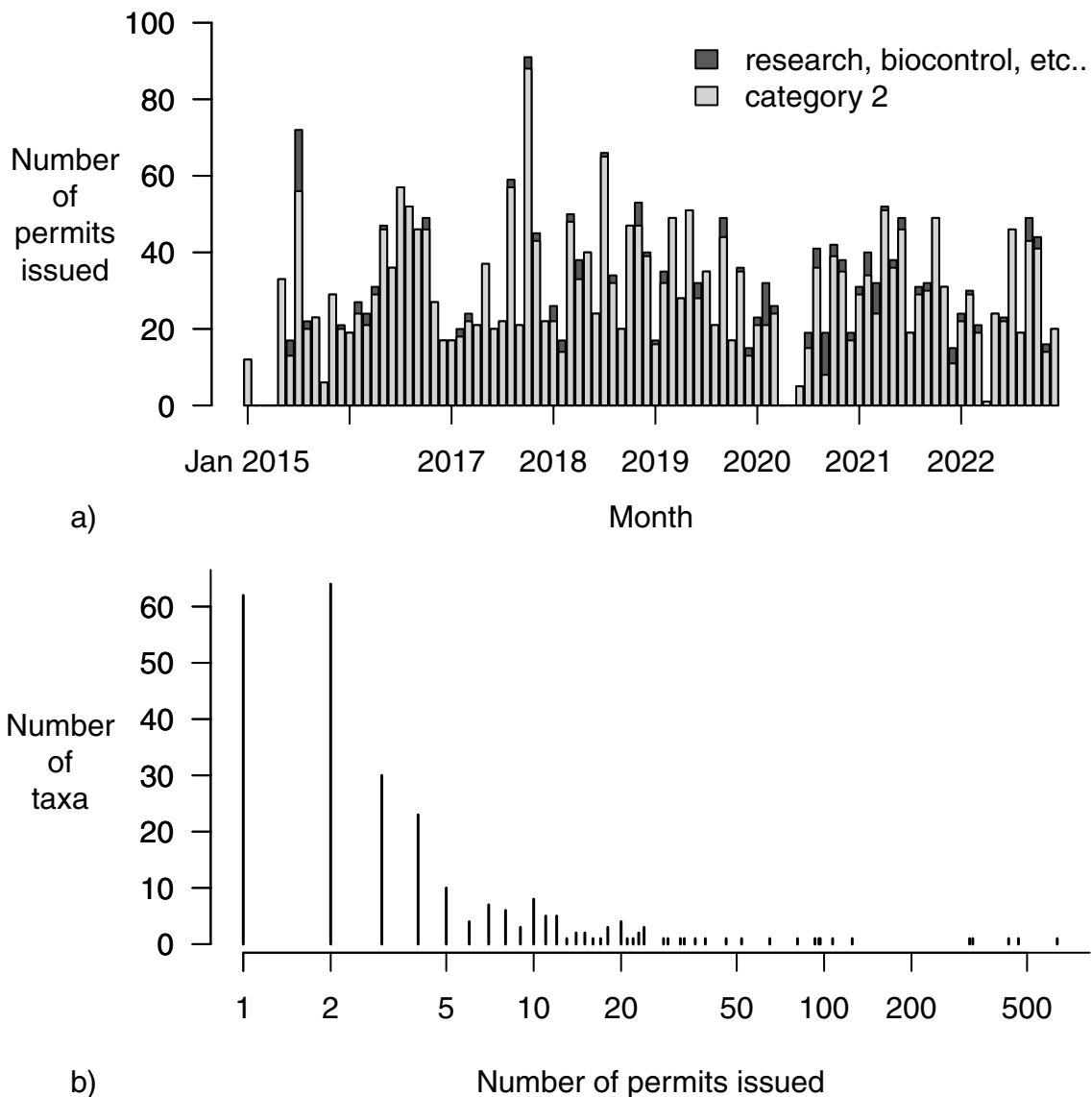


Figure 2: Permits issued for taxa listed under the *National Environmental Management: Biodiversity Act*, Alien and Invasive Species Regulations 2014–2022. a) The number of permits issued has not varied much over time, except for an initial slow start and a dip during the South African national lockdowns in response to COVID-19 in 2020. b) Most taxa have had only 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 South African Department of Forestry, Fisheries and the Environment (DFFE) to the South African National Biodiversity Institute (SANBI), as part of the national status report.^{17,33}

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 basis for specific changes was not made public, likely, in part, as the NEM:BA A&IS Regulations do not require the publication of the rationale for changes made to the lists. To improve transparency and the link to scientific evidence, a new process has been developed (summarised in Figure 3 and discussed in detail in [Supplementary material 1](#)).³⁶ The new process:

- has a clear evidence base – through the use of the Risk Analysis for Alien Taxa (RAAT) framework³⁷;
- engages with the scientific community – risk analyses produced using the RAAT framework are peer reviewed and subject to scrutiny by the Alien Species Risk Analysis Review Panel (ASRARP); and
- facilitates 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. The RARC’s first meeting was on 1 March 2023.

We discuss the first two of these points below, noting it is too early to review the performance of the RARC.

The Risk Analysis for Alien Taxa framework

The RAAT is centred on three questions that address the key aspects required of a risk analysis and that link to a mechanistic understanding of invasions ([Supplementary figure 1](#))³⁹:

- 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?

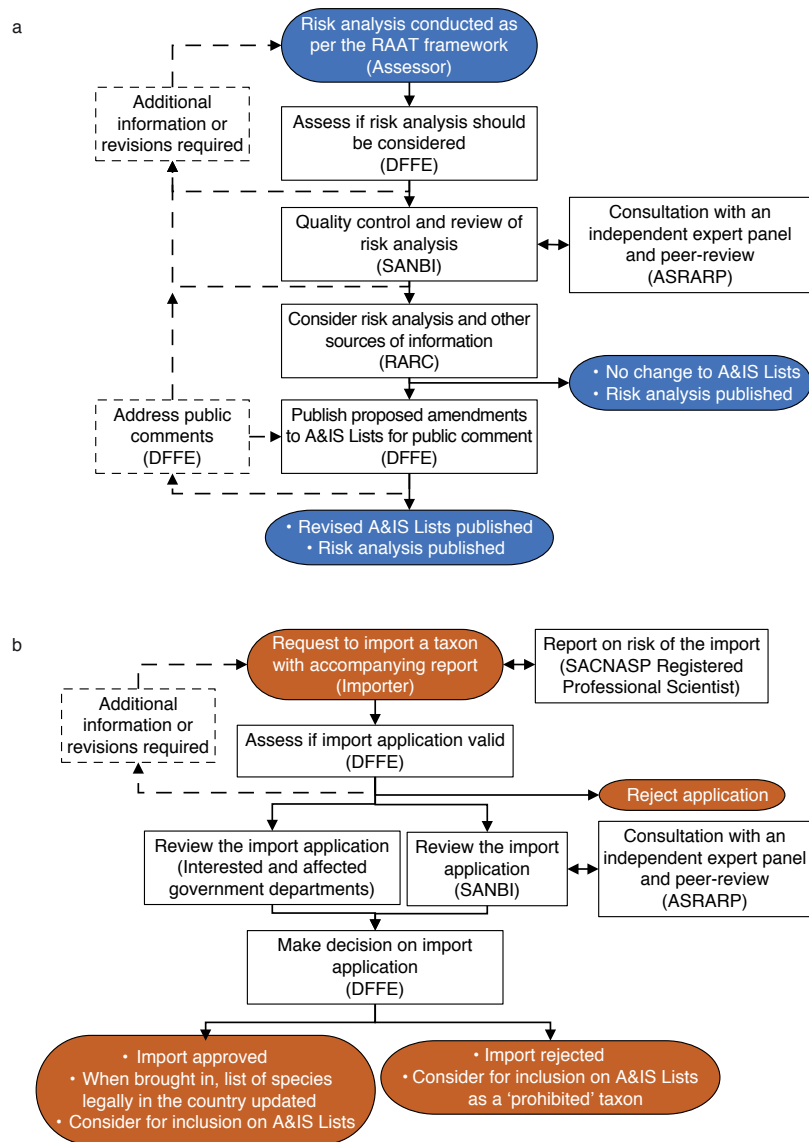


Figure 3: How decisions are made with regard to: a) evaluating and potentially changing the listing of a taxon; and b) requesting an import permit. Please note these diagrams are the authors' interpretation of the situation and have no legal basis. The NEM:BA A&IS Lists are the Alien and Invasive Species Lists published under the *National Environmental Management: Biodiversity 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 information³⁸ see Supplementary material 1.

We believe the RAAT framework represents an important advance. Of 14 minimal standards for risk assessments for alien taxa⁴⁰, the RAAT framework fully addresses 12. The framework does not currently assess the 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 minimum standards⁴⁰, the RAAT framework also considers environmental and socio-economic benefits of the taxon under assessment and evaluates risk management options (i.e. results in a risk analysis rather than simply a risk assessment, Supplementary figure 1). 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 recommendations were influenced by the available evidence. Finally, there is a formal review process to ensure consistency and 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. We feel the RAAT approach is nonetheless preferable as it sets out the arguments as to why a taxon should be (or does not need to be) listed, and therefore provides a clear basis for which someone can contest a listing.

The Alien Species Risk Analysis Review Panel

The ASRARP was initiated 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 (see Figure 3 for the outline and Supplementary material 1 for more details).⁴¹ ASRARP also assists in reviewing guidelines for risk analyses and changes made to the A&IS Regulations (see Supplementary material 2 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, who serve on ASRARP in their personal capacities and can be remunerated for their time. In accordance with the NEM:BA A&IS Regulations on risk assessment practitioners, independent members must be 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 review) that focus on errors and omissions. Risk analyses and reviews are then presented in 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 29 meetings of ASRARP as of April 2024, 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 fourth meeting, a decision was taken to clearly separate the scientific advisory panel from decision-makers. The second term was short, Jan 2018–March 2018; the third term ran from 16 July 2018 to 31 March 2020; the fourth term from 18 May 2020 to 31 March 2022; and the current fifth term began on 3 June 2022 and is due to run until 31 March 2025 (the hiatuses between terms were due to delays in finalising funding 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. Since July 2018, 39 people (excluding guests) have attended ASRARP meetings: 29 independent members, 5 as *ex officio* SANBI staff, and 9 as part of the secretariat, with some people serving in different roles at different times (see Supplementary table 4).

Progress to date and issues to resolve

As of 30 April 2024, risk analyses approved by ASRARP have been completed for 140 taxa (Supplementary table 5) – 17 on taxa not listed at the time of approval, and 123 on regulated taxa. Almost half of the risk analyses on regulated taxa recommended a substantive change to the listing (54 of 123, cf. Table 2). This is because taxa were prioritised for risk analyses if it was felt a change to the listing was likely warranted or the listing was contentious. As risk analyses are completed on less controversial taxa, there are likely to be fewer cases of the recommendations differing from the current listing.

For example, *Sasaella ramosa* (dwarf bamboo) is currently listed as Category 3 under the synonym *Sasa ramosa*. However, the taxon 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 recommendation was to list *Phyllostachys aurea* as Category

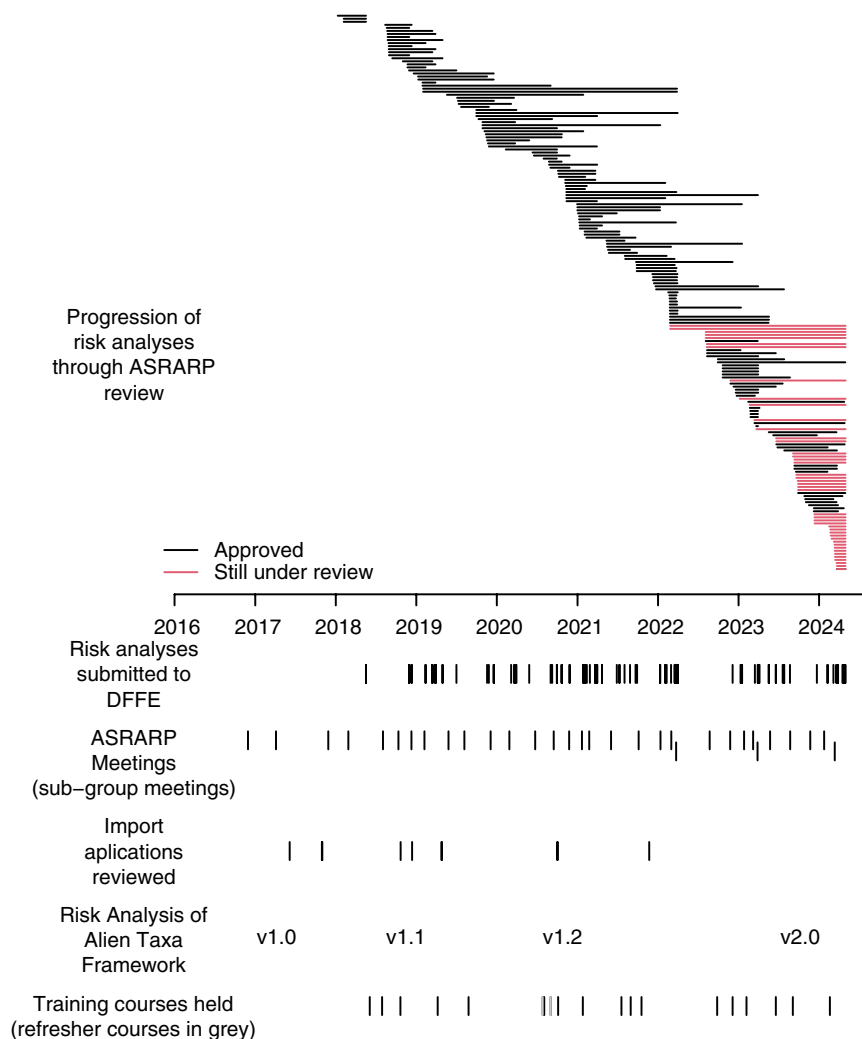


Figure 4: Progress developing risk analyses on alien taxa and activities of the Alien Species Risk Analysis Review Panel (ASRARP) as of 30 April 2024. Each horizontal line represents a risk analysis that has been developed for a specific taxon, with the length of the line indicating the time the risk analysis had been under review with ASRARP.

1b.⁴² *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.⁴³ 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 *K. e.* subsp. *defassa* should no longer be kept in South Africa and the taxon relisted as Category 1a.

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

As with similar processes (e.g. submission of manuscripts to peer-reviewed journals), the review process takes time (Figure 4, Supplementary figure 2). As of 30 April 2024, most submitted risk analyses were reviewed, revised, and approved by ASRARP within 6 months, but ~20% took longer than a year. The longest delays were

when either the assessor or the ASRARP handling member became unavailable during the process; in such cases, risk analyses needed to be reassigned before they could be finalised.

A risk analysis training course was developed in 2018 to help assessors complete risk analyses. As of 30 April 2024, 19 courses have been run, 2 of which were refresher courses developed upon revision of the risk analysis framework to v1.2 in 2020. As of 30 April 2024, 52 course participants have received a course certificate, which requires – in addition to attending the course – that a risk analysis is developed using the 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. One of the most difficult issues is how to draw in all stakeholders. The need for consultation is intended to be integral throughout the development, revision, and implementation of the NEM:BA A&IS Regulations and Lists (cf. Supplementary material 1). A framework to help with such engagement has been developed⁴⁴; however, conflicts often arise⁴⁵, and, in some cases, a formal process to reach an agreement, e.g. a scientific assessment⁴⁶, might be needed.

Table 2: Recommendations of the Alien Species Risk Analysis Review Panel (ASRARP) based on 140 risk analyses conducted as of 30 April 2024. 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. 27 taxa were listed as 1b and are recommended to be kept as 1b). Details of changes to the nomenclature are in Wilson²¹. In 26 cases there was a recommendation to re-evaluate taxa (usually within 5 years) as the evidence was equivocal or there was specific research or monitoring that should be carried out to inform the recommendation. Of the six 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 three were found to pose a low invasion risk. See Supplementary table 5 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	16	5	0	0	1	1
	1b	0	27	0	0	0	0
	2	4	11	25	0	1	2
	3	0	2	0	0	0	1
	Context-specific	0	11	11	3	0	2
	Not listed	3	8	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&IS Lists which are at a national level. 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.	132 such populations from 77 native species have been formally categorised in the country. Three of these taxa are currently listed under the NEM:BA A&IS Regulations: <i>Clarias gariepinus</i> (African sharp-toothed catfish), <i>Hyperolius marmoratus</i> (painted reed frog), and <i>Sclerophrys gutturalis</i> (guttural toad).	Nelufule et al. ⁴⁷

...Table 3 continues on next page



Table 3 continued...

Issue	Description	Proposal	Examples	Key reference(s)
Listing of taxa at geographical levels other than national (e.g. provincial)	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.	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. There is provision in the NEM:BA for provincial lists (70.1b, 70.2). Local ordinances could also be used to handle such cases. Moreover, regulation at the sub-national level is needed 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 (see above).	<i>Metrosideros excelsa</i> (New Zealand Christmas tree) is currently only listed in the Overstrand District of the Western Cape	Wilson ²¹
Spread between South Africa and other countries	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 when considering applications to allow taxa to be introduced.	Biological control releases evaluated by the National Biological Control Release Application Review Committee routinely consider the threat biocontrol agents could pose to the flora and fauna of other Africa countries.	Ivey et al. ³⁸ , Faulkner et al. ⁴⁸
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. The taxon might also have been initially misidentified.	A protocol for declaring taxa absent is under development and would provide a rationale for removing taxa from the lists.	<i>Tetrapygyus niger</i> (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.	Mabin et al. ⁴⁹ , Matthys 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.	Classical biological control agents have arguably had 'major' positive impacts on biodiversity in South Africa.	Vimercati et al. ^{51,52} , Paterson et al. ⁵³
No list of alien taxa legally in the country	Many of the exemptions to the regulations depend on knowledge of which taxa are legally present in the country and which are present but were introduced illegally. However, no such list has been systematically curated and made publicly available (please note, many taxa regulated under the NEM:BA A&IS Lists will have originally been legally and deliberately introduced).	A list of alien taxa legally in the country needs to be compiled and curated. This will require digitisation of historical import records; an assessment of whether a taxon for which an import permit was issued was actually 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 still 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 NEM:BA A&IS Regulations do not specify what should happen to such taxa on detection – they are not automatically listed or earmarked for control.	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 (or at least detected for the first time).	Wilson et al. ²³ , Faulkner et al. ⁵⁴
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 high risk. If entities below the species level are to be listed, it is important that entities can be distinguished in practice.	The order Phasmida (stick insects) is listed, despite some taxa being native to the country, and that many taxa likely pose a low risk.	Datta et al. ⁵⁵

Table 3 continued...

Issue	Description	Proposal	Examples	Key reference(s)
Co-invasions	Multiple taxa can be introduced together, and in some cases only the combination of the taxa makes them high risk.	A decision needs to be made on whether all involved taxa are listed, and if they are to be listed separately or as a complex.	<i>Euwallacea fornicatus</i> (the polyphagous shot-hole borer) and a symbiotic fungus, <i>Fusarium euwallaceae</i> , were introduced together. Both the fungus and the beetle are required for an invasion to occur and for trees to be killed.	Paap et al. ⁵⁶
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 <i>Rattus norvegicus</i> , <i>R. rattus</i> , and <i>R. tanezumi</i> – these are only currently listed on off-shore islands, but are a pest on the mainland as well.	Bastos et al. ⁵⁷
Suitability of risk analysis framework for microorganisms / diseases	The RAAT framework, as many frameworks in invasion science, was not specifically designed to be applied to microorganisms, 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, and killed an estimated 2.5 million domestic cattle in southern Africa and an unknown number of game.	Van Helden et al. ⁵⁸
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&S Lists; or only taxa that have negative impacts on biodiversity. There is a need to harmonise relevant legislation.	The cross-sectoral and inter-departmental RARC should be able to address some of the issues, 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 <i>Agricultural Pests Act of 1983</i> , and the <i>Plant Improvement Act of 1976</i> .	Rambauli et al. ⁵⁹ , Hulme ⁶⁰
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.	Prinsloo and Uys ⁶¹ , Zachariades ⁶²
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 ⁶³), easier to work with, and retain links to previously used names.	<i>Acacia paradoxa</i> DC. (= <i>A. armata</i> R.Br.) could be simply listed as <i>Acacia paradoxa</i> DC.	Wilson ²¹
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	Department of Environment, Forestry and Fisheries ⁶⁴
The same process is used for the Prince Edward Islands (PEIs) as for mainland South Africa	Currently the NEM:BA A&S 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 PEIs Management Plan.	Taxa to be managed on the PEIs should be listed in a separate process to that of the NEM:BA A&S Regulations. For each alien taxon present on the PEIs, a decision should be taken to: (1) implement management with the goal of eradication; (2) implement maintenance management with the goal of reducing harmful impacts; or (3) not manage the alien population if 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&S Regulations, 9 have been subjected to some form of management. An additional two taxa which are not listed have been subject to management.	Fernández Winzer et al. ²⁵

...Table 3 continues on next page

Table 3 continued...

Issue	Description	Proposal	Examples	Key reference(s)
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 is needed on the degree to which those who need permits are applying for permits or simply ignoring the regulations.	Cronin et al. ⁶⁵ , Shackleton and Shackleton ⁶⁶ , Keet et al. ⁶⁷
The pre-eminence of common names over scientific names	Table 1 in the NEM:BA A&S Lists specifies “Where the scientific name of any listed species changes or there is a spelling error in the scientific name, the common name of the species takes precedence and determines whether a particular species is listed or not.” However, common names are highly variable and very often not unique.	The scientific name takes legal precedence. The scientific names are checked against appropriate national and international taxonomic databases and updated periodically. If the nomenclature has changed, the scientific name is taken to be that of the revised nomenclature. If taxa are split or merged, the new taxa inherit the highest level of risk assigned to any corresponding taxa before the revision until such time as risk analyses specifically for the new taxa can be conducted.	Electric eels are listed as a single species, but in 2019 the group was split into three species. There is no evidence yet that the lineages differ in potential invasiveness. The species <i>Sus scrofa</i> includes both domestic pigs and wild boar. Given the potential for the domesticated form to revert, the common names can be misleading.	Patterson et al. ⁶⁸ , de Santana et al. ⁶⁹

Discussion and conclusions

The regulation of alien taxa in South Africa can be described as a gradual move from focusing 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 all alien taxa without unduly reducing benefits to South Africans. The current NEM:BA A&S Lists thus provide 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.⁷⁰ The process also aims to make the regulation of alien taxa in South Africa credible, legitimate, and acceptable.

- **Proportionate:** the NEM:BA A&S 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 ongoing projects have not been jeopardised (cf. Pietrzyk-Kaszyńska et al.⁷¹). The cost of the regulation (both to the government and to society) has not, however, been estimated.
- **Accountable:** all lists are subject to review by different government entities 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. The 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, the ASRARP helps ensure risk analyses are consistent. Moreover, the RARC is intended to ensure governmental work is ‘joined-up’. As the process and timelines for making changes become clearer, affected stakeholders (e.g. the horticultural industry) will have greater certainty as to what might happen and 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. The risk analyses also ensure information is in a usable and 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 NEM:BA A&S Regulations and Lists have been modified over time based on experience¹⁷, although more information on monitoring the effectiveness of the regulations appears warranted.
- **Credible:** 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^{72,73} – the first of which has been adopted by the UN following COP decision 15/27 on Invasive Alien Species (Annexes I to VI), and the pathway classification used by the CBD⁷⁴. Risk analyses are routinely reviewed by national and international experts as well as working groups at the science–policy–management interface of biological invasions.^{75,76}
- **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, although they could be in future. Training courses are not yet registered with SACNASP, but this is likely to be desirable in future.
- **Acceptable:** measures have been put in place to try to preserve the benefits of alien species while reducing the harmful impacts of invasions. Any regulation of biodiversity is inimical to some ethical perspectives⁷⁷, but a clear distinction should be made between the rationale for regulation and evaluating the ethics of particular management interventions⁷⁵.

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

generation with the rights of future generations. This will, we believe, require continued discussions, partnerships, and collaborations between scientists, policymakers, implementers, and those affected by the regulations.

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Competing interests

Both authors, through their roles with the South African National Biodiversity Institute (SANBI), were involved in setting up and running many of the processes outlined in the manuscript, specifically the Alien Species Risk Analysis Review Panel and the Risk Analysis of Alien Taxa framework. J.R.U.W. primarily, and S.K. to a lesser degree, have been involved in the analysis of this process as part of the report 'The status of biological invasions and their management in South Africa in 2022'¹⁷.

Authors' contributions

J.R.U.W.: Conceptualisation, methodology, validation, data collection, sample analysis, data analysis, and led the writing. S.K.: Conceptualisation, methodology, validation, assisted with writing.

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