Biol Invasions
https://doi.org/10.1007/s10530-020-02298-2

PERSPECTIVES AND PARADIGMS

A proposed unified framework to describe the management of biological invasions

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Received: 15 May 2019 / Accepted: 19 June 2020

Abstract Managing the impacts of invasive alien species (IAS) is a great societal challenge. A wide variety of terms have been used to describe the management of invasive alien species and the sequence in which they might be applied. This variety and lack of consistency creates uncertainty in the presentation and description of management in policy, science and practice. Here we expand on the existing description of the invasion process to develop an IAS management framework. We define the different forms of active management using a novel approach based on changes in species status, avoiding the need for stand-alone descriptions of management types, and provide a complete set of potential management activities. We propose a standardised set of management terminology as an emergent feature of this framework. We identified eight key forms of management: (1) pathway management, (2) interception, (3) limits to keeping, (4) secure keeping, (5) eradication, (6) complete reproductive removal, (7)

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Published online: 30 June 2020

containment and (8) suppression. We recognise four associated terms: prevention; captive management; rapid eradication; and long-term management, and note the use of impact mitigation and restoration as associated forms of management. We discuss the wider use of this framework and the supporting activities required to ensure management is well-targeted, cost-effective and makes best use of limited resources.

Keywords Terminology · Management · Prevention · Containment · Eradication · Removal · Keeping

Introduction

Managing the increasing environmental and socio-economic impacts from invasive alien species (IAS) is a great societal challenge for the twenty-first century. This is addressed by the Convention on Biological Diversity (CBD 2010) and the Sustainable Development Goals (UN 2015), which commit signatories to introduce measures that prevent the introduction and significantly reduce the impacts of IAS, and control or eradicate priority species. Management involves multiple actions at different stages in the invasion process (Wilson et al. 2017). Management is defined in the EU IAS Regulation as 'any lethal or non-lethal action aimed at the eradication, population control or containment of a population of an invasive alien species.' In the US, the legal definition of invasive species control is "eradicating, suppressing, reducing, or managing invasive species populations, preventing spread of invasive species from areas where they are present, and taking steps such as restoration of native species and habitats to reduce the effects of invasive species and to prevent further invasions". Thus, active management may prevent a potential IAS from entering a new area; if introduced, may remove it before it becomes widely established; and if it becomes widely established, may limit its impact by reducing spread and abundance. Management may also include impact adaptation without species intervention or environmental restoration after species removal.

To meet these targets, a shared understanding of the processes involved and their description is needed (Keller et al 2011). Papers that define and standardise the terminology used to describe the invasion process (Blackburn et al. 2011), the biogeographical status of alien species (Essl et al. 2018), pathways (Hulme et al. 2008), risks (Roy et al. 2018) and their impact (Blackburn et al. 2014; Jeschke et al. 2014; Bacher

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et al. 2018) all support this objective. By contrast, a range of studies, legislation and policy documents use diverse terms to describe the different elements of IAS management. These may be internally consistent, but there is a lack of consistency between them, creating uncertainty in the presentation and description of management amongst policy makers, researchers, stake-holders and managers.

The diverse terms currently in use to describe management can be a source of confusion. For example, 'containment' can either refer to the controlled keeping of an IAS under captive conditions (Scott 2005; Dobson et al. 2013), or reducing the spread of a population in the wild (Grice et al. 2010). 'Eradication' is a widely used term defined as the complete and permanent removal of a population (Bomford and O'Brien 1995). However, this definition does not cover situations where a population has been removed from an area, but there still is a need for the ongoing management of dormant life stages such as seeds (Klimešová and Klimeš 2007; Panetta 2015), or the continued influx of dispersing individuals from neighboring areas (Robertson et al. 2019). Some terms are often linked to advice on how they should be applied, such as 'rapid eradication, removal or response'. While good advice, many successful eradications have been of long-established species (Keitt et al. 2011) and do not fit this description. Appropriate terminology is influenced by spatio-temporal scale, for example eradication from an individual site might constitute spread reduction at larger scales. The terminology of management needs to include direct reference to scale if it is to be meaningfully interpreted. This needs to be flexible enough to include scales varying from the continental, to individual political entities, to particular sites and will also be reflected in the definition of 'borders'. Non-standard terminology or descriptions which do not specify a particular scale make the literature on IAS management difficult to interpret (McGeoch et al. 2010; Latombe et al. 2017). Terminology that does not cover all possible forms of management also risks excluding or under-valuing possible management approaches.

A lack of clarity over terminology can also impact on the effectiveness of legislation. For example, in Iceland, a non-English speaking nation, only two terms are available to describe the management of established species, útrýming (eradication), and stjórnun (all forms of intervention). These terms are used in Icelandic legislation which provides financial support for the management of American mink (*Neovison vison*) (Stefansson et al. 2016). However, the broad definition of stjórnun reduces its effectiveness, resulting in subsidies for local suppression by hunters at an estimated cost of over $21 m since 1958 (Robert Stefansson unpublished data). While complete eradication of the American mink is unlikely to be feasible in Iceland, more focused use of terminology to define specific management objectives (Bryce et al. 2011) might support a more cost-effective use of subsidies. Defining management terminology, typically produced in English, in ways that can readily be translated into other languages will be of broader benefit.

A range of other methods are widely used to support active management, but do not in themselves involve any form of intervention. These include public education, raising awareness, early detection, monitoring, risk analysis which includes risk assessment, risk management and risk communication; contingency planning and cost–benefit analysis. While important to support effective management, the terminology of these approaches is not considered further in this paper, which limits itself to forms of active intervention.

We see a need for a comprehensive and common terminology with agreed definitions for active IAS management, particularly when these terms are included in legislation, international policies and guidance, the scientific literature or used to define or disseminate best practice. In this paper we propose solutions to these problems. In particular, we:

(1) Provide examples of the key terms currently used to refer to the sequence of IAS management to illustrate the diversity of terms in use;
(2) Develop a novel IAS management framework compatible with the widely used invasion process framework of Blackburn et al. (2011); and
(3) Propose terms and definitions to describe the key elements of this framework.

Current use of terms

We reviewed legislation, guidance and scientific publications dealing with the management of IAS. From this, we identified examples describing terms

used and the recommended sequence of management actions to respond to IAS during the invasion process (Table 1). This review was not comprehensive, and other terms have undoubtedly been used to describe other forms of management. However, this selection was intended to highlight the differences in usage and the need for greater consistency. Many sources include terms describing supportive methods such as monitoring, detection or assessment throughout. Other reports restrict themselves to terms describing forms of direct intervention. There was a broad consensus in the literature that prevention formed the initial objective of management. Eradication was also a commonly used term, but used in a range of contexts including linkage to a rapid response, or as a separate term following this phase. A variety of other terms were used to describe the management of species where eradication is no longer practically feasible, including control, containment, removal, management, asset-based protection, suppression or long-term management. Mitigation often appeared at the end of this sequence, linked to terms such as rehabilitation or restoration, but also appeared as one of the initial management actions (McNeely et al. 2001). This variety of terms and sequence illustrates the problem based on a selection of the currently used terminology in policy and scientific documents.

A proposed IAS management framework

We used the invasion framework described by Blackburn et al. (2011) as a starting point, as it has become the standard framework to conceptualize the invasion process. This describes a series of barriers that a species must overcome if it is to become a successful invader. The description of these six barriers is supplemented by four further terms, describing the stages of the invasion process (a copy of this is included as a component of Fig. 2).

To define the possible management actions, we made two additions to this framework. Firstly, we produced descriptions of species status, including the status before and immediately after it progressed through each of the six barriers (Table 2). Secondly, we added reference to a defined 'area of interest' to contextualise the description. Blackburn et al. (2011) also categorised populations based on the route by which the species arrived at a particular status but without a spatial component, limiting its usefulness as the basis to describe management.

Table 1 A selection of the terms currently used to describe the management of IAS, arranged in chronological order, illustrating the diversity of terms and of their recommended sequence

Proposed sequence of actions	Source
Prevent—reduce—control	United Nations Convention on the Law of the Sea (1982)
Prevention—mitigation—eradication—containment—suppression	McNeely et al. (2001)
Prevention—early detection and rapid response—control and management—rehabilitation and restoration	U.S. Department of Agriculture and Forest Service (2004)
Prevention—early detection and eradication—control	Simberloff et al. (2005)
Prevention—rapid response/eradication—control/containment—restoration/mitigation	Hulme (2006)
Risk assessment—pathway and vector management—early detection and rapid response—eradication—mitigation and restoration	Pyšek and Richardson (2010)
Prevention—detection and early response—long-term management	Richardson and Blanchard (2011)
Prevention—eradication—containment—asset-based protection	IPAPF (2012)
Prevention—eradication—containment—control—mitigation	CBD (2010)
Prevention—early detection and rapid eradication—management	EU Regulation 1141/2014 (EU 2014)
Prevention—eradication—containment—resource protection	Harvey and Mazzotti (2014)
Prevention—removal—remediation—monitoring	van Wilgen et al. (2014)
Prevention—eradication—control—monitoring	Hawkins et al. (2015)
Prevention—eradication—complete removal—control	Robertson et al. (2017)

Table 2 Descriptions of status of species, populations and individuals at the point at which they overcome the different barriers to successful invasion described by Blackburn et al. (2011). These also include reference to a defined 'area of interest' in each case

Barrier to successful invasion (see Fig. 2)	Species, population or individual status after passing through barrier	Description of individual or population status in the area of interest
	No risk	Species not present in the area of interest, and not posing a risk of entry
Geography	In transit	Species not present in the area of interest, but posing a risk of entry
Captivity or cultivation[a]	In captivity/cultivation	Individuals or populations present in the area of interest, but only under controlled conditions
Survival	Surviving in the wild	Individuals surviving in the area of interest, but not successfully reproducing
Reproduction	Reproducing in the wild	Populations surviving and successfully reproducing in the area of interest, but not spreading
Dispersal	Spreading in the wild	Population surviving, reproducing and spreading within the area of interest, but is not yet widespread
Environment	Widespread	Population widespread and abundant throughout the area of interest

[a]Not all species will pass through this category, many will go from 'In transit' straight to 'Surviving in the wild' especially those species introduced as a stowaway or contaminant (see Blackburn et al. 2011)

Different forms of management can then be described by the effects they have on species status. Considering species status prior to management along with its desired status after management produces a matrix (Fig. 1) which describes 21 potential changes in species status and seven cases where management may maintain a species at a particular status. These 28 possible management actions, each described by a separate element of the matrix, are thus an emergent feature of the Blackburn et al. framework.

This long list of management actions can then be summarised down to eight more generic terms to provide a pragmatic and consistent set of descriptions. In some cases, these terms apply to only a single element of the matrix, such as Interception, in others the same management term applies to a range of elements, such as Eradication.

We mapped these management alternatives and their associated terms onto the invasion framework from Blackburn et al. (2011) (Fig. 2). Four further terms (Prevention, Captive Management, Rapid Eradication and Long-term Management) were also added to reflect the wider management groupings commonly used in legislation and guidance documents. These definitions are based on changing species status. However, there are cases where management may focus on the impacts associated with the presence of a species rather than the species itself, or deal with the environmental consequences of the removal of a species. To recognise these forms of active management that are not related to changing species status, we added two further terms, Impact Adaptation and Restoration.

Comparison with existing terminology and actions

This novel approach based on changes in species status has a number of advantages over previous definitions of individual management terms. The different forms of management are defined by the start- and end-points of the changes in species status, rather than requiring stand-alone definitions of their own. This obviates the need for complex definitions of often overlapping management terms, which has led to many of the current problems of interpretation. This approach also brings an element of completeness, as all possible changes in species status are included. In this section, we describe each management term used in our framework and compare it with other terms used in the literature. Table 3 provides a published example of each form of management.

Desired Species Status After Management

Species Status In the Invasion process

	7 Wide-spread	6 Spreading in the wild	5 Reproducing in the wild	4 Surviving in the wild	3 In Captivity/ Cultivation	2 In Transit	1 No Risk
1 No Risk							Pre-border Pathway Management
2 In Transit						Interception	Pre-border Pathway Management
3 In Captivity/ Cultivation					Secure Keeping	Limits to Keeping	Multiple Methods Required
4 Surviving in the wild				Complete Reproductive Removal	Eradication	Eradication	Multiple Methods Required
5 Reproducing in the wild			Containment	Complete Reproductive Removal	Eradication	Eradication	Multiple Methods Required
6 Spreading in the wild		Suppression	Suppression	Complete Reproductive Removal	Eradication	Eradication	Multiple Methods Required
7 Wide-spread	No Management	Suppression	Suppression	Complete Reproductive Removal	Eradication	Eradication	Multiple Methods Required

Key

Management Term	Management Objective
Pre-Border Pathway Management	Reduce the uptake of the species and its transport outside the area of interest
Interception	Intercept the species on first entry into the area of interest
Limits to Keeping	Limit the keeping or cultivation of the species within the area of interest
Secure Keeping	Ensure the security of species held in captivity/cultivation within the area of interest
Eradication	Remove the entire population from the area of interest – with no immediate risk of re-invasion
Complete Reproductive Removal	Remove the reproductive population from the area of interest– but with remaining risk of re-invasion or further reproduction if not managed
Containment	Limit the spread of a reproducing population within the area of interest
Suppression	Reduce the distribution or abundance of a population within the area of interest
Multiple Methods Required	No single management approach available to achieve this change, multiple methods required
No Management	No management undertaken to reduce the distribution or abundance of the population in the area of interest

◀**Fig. 1** Matrix of the possible changes in species status following management at different stages in the invasion process. The rows describe the different categories of species status' in the invasion process, ranging from 'no risk' to 'widespread, derived from Table 2′. The columns represent the desired change (or maintenance) of status to be achieved following management. The elements of the matrix describe the appropriate form of management to achieve such a change. The colours represent related management types, defined in the associated key

Pre-border pathway management

To reduce the uptake of the species and its transport outside the area of interest. This can be defined as changing status from In Transit to No Risk, or maintaining a species as No Risk, with the objective of preventing or reducing the uptake or transport of individuals. Pathway Management is already widely recognised as a key element of IAS management (Hulme et al. 2008). These include measures to reduce the uptake of individuals, such as requirements for clean shipping materials and packaging prior to the shipment of goods; regulations such as The Ballast Water Management Convention (Werschkun et al. 2014) or the management of horticultural supply chains (Hulme et al. 2018).

Interception

To intercept individuals when they first enter into the area of interest. This can be defined as maintaining status as In Transit. This includes established processes of surveillance of imports and border inspections to intercept new arrivals. Accepted definitions include 'the detection of a pest during inspection or testing of an imported consignment' and 'the refusal or controlled entry of an imported consignment due to failure to comply with phytosanitary regulations' (FAO 2018).

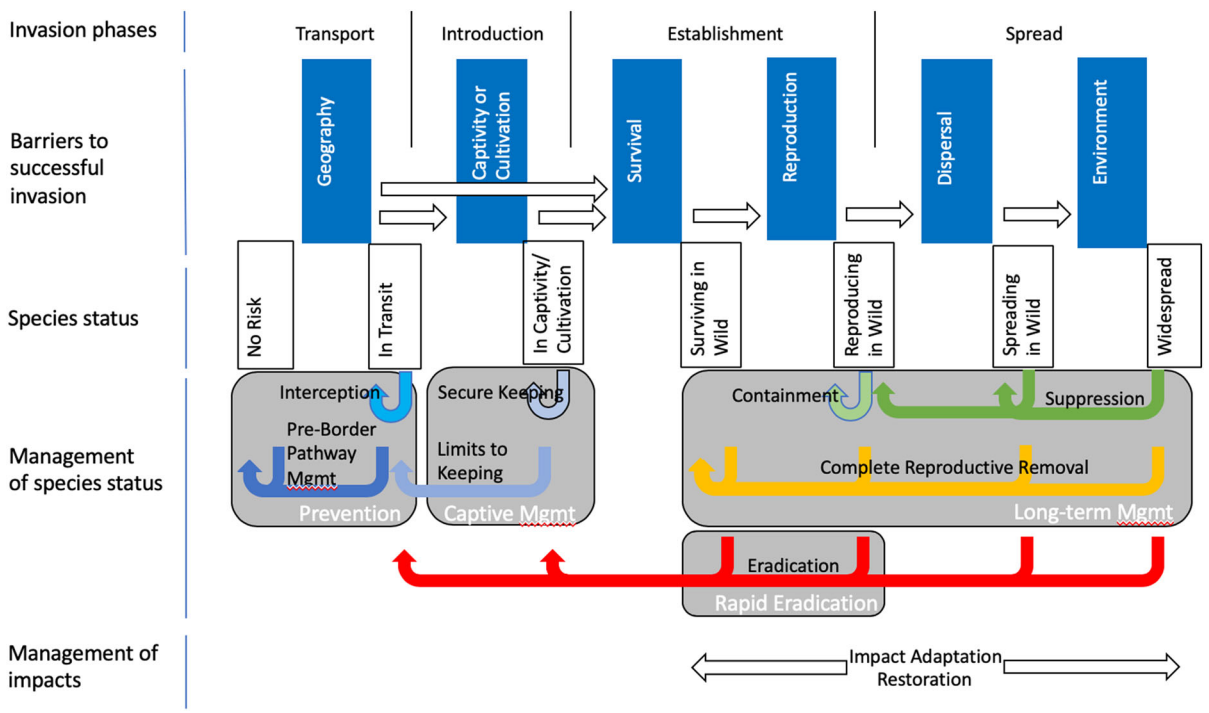

Fig. 2 Illustration of the possible management actions during a biological invasion. The barriers to successful invasion described by Blackburn et al. (2011) are represented by blue bars. The descriptions of species status from Table 2 are presented as white boxes. The different forms of management and their associated changes in species status from Fig. 1 are represented by coloured arrows, labelled with the eight management terms. Four groups of related management terms are represented by grey boxes with white labels

Table 3 Example publications illustrating each of the management types described in Fig. 1

Management type	References	Notes
Pre-border pathway management	Novoa et al. (2015)	Assesses the risks posed by the introduction of potentially invasive cacti in South Africa, including recommendations for legislation
Interception	Kenis et al. (2007)	Presents data on alien insect species introductions in Europe to identify the main source countries and pathways of introduction, with recommendations for pathway management
Limits to keeping	Keller and Lodge (2007)	Provides evidence of the risks posed by the sale of live aquatic taxa in North America, recommending the removal of known and likely invasive species from trade, and reductions in the number of contaminant organisms
Secure keeping	Cassey and Hogg (2015)	Describes escapes and thefts of invasive species from zoos in Australia, recommending biosecurity and licensing methods to reduce the risks
Eradication	Anderson (2005)	Describes the eradication of the invasive marine alga *Caulerpa taxifolia* from California using coverings and chemical treatments
Complete reproductive removal	Bryce et al. (2011)	Describes the removal of American mink from North-East Scotland using traps. Although populations remain on land neighbouring the managed area, ongoing monitoring and removal prevents the re-establishment of breeding individuals
Containment	Grice (2006)	Identifies weed pest species that should be targeted for containment in Australia. Examines the factors affecting the feasibility of containment; proposes and evaluates the prospects for effective containment under different circumstances
Suppression	Panzacchi et al. (2007)	Describes the cost-effectiveness of the wide-scale suppression of coypu *Myocastor coypus* populations in Italy through trapping and shooting

Prevention

This is the overarching term to describe Pre-border Pathway Management and Interception. This primary stage of management has been described as 'stop invasions before they happen, either by preventing high-risk species from entering the country or by intercepting individuals at the border' (van Wilgen et al. 2014).

Limits to keeping

To limit the keeping or cultivation of individuals of the species within the area of interest. This can be defined as changing status from In Captivity/Cultivation to In Transit or No Risk. For example, the EU regulation provides the basis for listing Species of Union Concern and prohibits them being kept, bred, transported, sold, used or exchanged, allowed to reproduce, grown or cultivated, or released into the environment (EU 2014). In general, if all captive individuals are removed, then the only remaining risk of entry arises from individuals In Transit.

Secure keeping

To ensure the security of individuals held in captivity/cultivation within the area of interest. Defined as maintaining status as In Captivity/Cultivation. Related terms include time–limited quarantine—the official confinement of regulated articles, pests or beneficial organisms for inspection, testing, treatment, observation or research (FAO 2018). Other examples include the ongoing management of biological collections such as zoos or gardens, or the holding of species under other controlled conditions (Cassey and Hogg 2015, EU 2015).

Captive Management

This is the overarching term to describe Limits to Keeping and Secure Keeping. These actions are rarely explicit in the current descriptions of IAS management (Table 1).

Eradication

To remove the entire population from the area of interest—with no immediate risk of re-invasion. This

can be defined as reducing status from either Surviving, Reproducing, Spreading or Widespread, to In Captivity/Cultivation or In Transit. Bomford and O'Brien (1995) provide a widely used definition of this term 'The complete and permanent removal of all wild populations from a defined area by a time-limited campaign', which is compatible with its use in this framework.

Rapid eradication

This is a specific form of Eradication, where the population is managed before it has begun to spread. This term is widely used (Table 1) and highlights a management priority. However, it is not a specific form of management in itself—'rapid' constitutes good advice rather than describing a change in status. Rapid Eradication does not cover all forms of Eradication, which has also been applied to species that have been long and widely established in an area. This is particularly the case for mammals (Keitt et al. 2011; Robertson et al. 2017) although the opportunities vary widely between taxa.

Complete reproductive removal

To remove the entire reproductive population from the area of interest—but with remaining risk of re-invasion or further reproduction if not managed, or the remaining presence of non-breeding forms. This can be defined as reducing status from either Reproducing, Spreading or Widespread to Surviving, or maintaining status as Surviving. Management of this sort requires an on-going effort to maintain the area clear in the face of dormant life stages such as seeds, or the continued influx of new individuals from neighbouring areas. This term does not feature explicitly in most of the existing descriptions of IAS management (Table 1) but is needed as there are a growing number of large-scale control programs (Bryce et al. 2011; Robertson et al. 2017) where the removal is not complete or permanent as required by the current definition of eradication (Bomford and O'Brien 1995; Robertson et al. 2019). However, the area of interest is effectively kept clear of the species, so it is different from Suppression. This form of management is likely to increase as more widespread species are managed at large scales.

Containment

To limit the spread of a reproducing population within the area of interest. This can be defined as maintaining status as Reproducing. This term is already widely used, for example 'Any action aimed at creating barriers which minimises the risk of a population of an invasive alien species dispersing and spreading beyond the invaded area' (EU 2014), or 'Application of phytosanitary measures in and around an infested area to prevent spread of a pest' (FAO 2018).

Suppression

To reduce the distribution or abundance of a population within the area of interest. It can be defined as changing status from either Spreading or Widespread to either Reproducing or Spreading respectively with the objective of reducing the distribution or abundance of a population. Synonyms include reduction, control or population control, or '…Action…with the aim of keeping the number of individuals as low as possible so that …its invasive capacity and impacts…. are minimised' (Population control, EU 2014). Reproducing populations remain after Suppression, so any management will typically need to be repeated indefinitely to maintain its effect. However, some forms of biological control can achieve effective suppression without ongoing management inputs and have particular value. Suppression is a widely used form of management, but its objectives in terms of the degree of suppression or the reduction of impact need to consider the context specific IAS density vs impact relationship (Norbury et al. 2015) if its effectiveness is to be assessed.

Long-Term Management

This is the overarching term which includes Containment, Suppression and Complete Reproductive Removal. This form of management requires the on-going input of management if the desired outcome is to be achieved and maintained.

No management

For populations that are already widespread in an area and where there is no objective to reduce their abundance or extent, then no management is

undertaken (Maintaining species status as Widespread). If a Widespread population is managed, then its abundance or distribution will be reduced—forming part of Suppression. No Management is synonymous with the concepts of 'Tolerance' or 'Acceptance'. Even with No Management of the species, its impacts may still be reduced through Impact Adaptation.

When considering management to change the status of a species to be No Risk, in many cases no single method was considered able to achieve this, these cases were classed as Multiple Methods Required. For example, Eradication of a species from a particular area would need to be accompanied by effective Pathway Management to remove all risk of it returning. This is not to say that species cannot be managed to achieve this outcome, just that this would require multiple steps.

By being directly linked to the status of the population before and after management, these terms relate to the direct management of the species. However, management may also be motivated and directed to reduce the impact of an existing species, or one that has been removed from an area. We recognise two further terms, Impact Adaptation and Restoration. They are included here for completeness although they do not refer to changes in species status.

Impact adaptation

No change in the status of the species, but forms of management to reduce associated impacts. This includes payments to compensate for impact caused, changes in human behaviour to avoid situations where the impact might occur, operation of hatcheries or nurseries for native species, selection of resistant genotypes of species that may be impacted, control of nutrient inputs, placing protective covers or deterrents on young trees vulnerable to grazing, responding to increased erosion risk by mechanically stabilising habitats. These may also occur alongside the other direct forms of species management described here.

Restoration

The management of the environment following the change in the status of an IAS. Related terms describing different forms and intensities of management include regeneration, revegetation, replacement, rehabilitation and remediation of a habitat favouring native communities (van Andel and Aronson 2012), with definitions including 'restoring ecosystems following the removal of invasive species' (van Wilgen et al. 2014) and 'restore or rehabilitate degraded areas to their proper ecological function […] after invasive species removal' (USDA 2004).

Discussion

A variety of authors have provided definitions for different forms of IAS management and the sequence in which they might best be applied (see Table 1). However, differences in interpretation, partly due to different schools in invasion biology dealing with different types of environments and taxa (Keller et al. 2011), have led to the use of a wide diversity of overlapping terms and definitions. This brings problems for common understanding, effective communication, awareness raising, meta-analyses and the development of indicators.

In this paper, we propose a novel approach, recognising that management can be described by detailing the start- and end-points of the desired changes in species status. Considering management in the context of the key barriers and stages of the invasion process (Blackburn et al. 2011) and the changing species status associated with each, the alternative forms of management then become emergent features of this existing framework.

This approach has the advantage that different forms of management are defined by the start- and end-point of changing species status, rather than requiring individual definitions of their own. Defining management terms based on changes in species status also supports their effective translation into other languages. This approach also brings an element of completeness, as all possible changes in species status are included in the descriptions. It ensures that the framework is comprehensive, describes distinct management outcomes and includes approaches such as Captive Management or Complete Reproductive Removal which may not be widely used or made explicit in other lists of IAS management, but need to be considered, for example if we are to classify and assess the frequency and effectiveness of different management types.

This approach defines IAS management based on the desired change in the status of the species. However, the motivation for management may be different. While management to prevent a species entering an area or becoming established may be driven by the precautionary principle, or by experience of its effects elsewhere; once a species has become widely established, it is likely that management will be motivated by the need to reduce impacts, rather than to manage the species.

Setting clear objectives for IAS management is important to assess success or failure, or to decide that the objective is not achievable. Some objectives are simple; for Interception we can assess if the species was effectively kept out. In others, objectives need greater refinement. When considering Suppression, by what degree should the extent or abundance of the species be reduced for this to be considered successful? The objectives of an action, and indicators to measure success, need to be carefully defined if the cost-effectiveness is to be meaningfully assessed. The framework also includes the need to define the spatio-temporal scale if management is to be usefully described. The removal of an invasive species from an enclosed water body may qualify as Eradication at the scale of the water body, but nationally only contribute to Suppression. The framework also contains a temporal dimension—some forms of management such as Eradication include a discrete end-point, while others such as Containment or Suppression require ongoing inputs. Species status will also change through time as invasion progress.

The framework describes discrete management terms. The management of an IAS may develop through time, undertaking a sequence of different management actions with limited objectives, but with cumulative effects. For example, the management of the Ruddy Duck (*Oxyura jamaicensis*) in the UK began with local Suppression, followed by Limits to Keeping and Complete Reproductive Removal. Given the continuing presence of mobile birds in neighbouring countries, further management is required before Eradication could be achieved (Robertson et al. 2015).

It is also worth emphasising the difference between the full matrix of 28 elements, which is an emergent feature of the invasion process, and our proposed summary of these down to eight management terms. For this summary stage, there is scope to produce other classifications, or to increase the number of sub-categories within the presented terms. However, we recommend that any further management terms are defined by reference to the start- and end-points of management rather than stand-alone definitions. The use and definition of various management terms are also embedded within existing advice and legislation and are unlikely to change in retrospect. However, a more complete and systematic approach to defining and classifying management is still needed, for example if the success and effectiveness of management are to be assessed in a systematic manner.

Effective management needs to be well-targeted, cost-effective and make best use of limited resources. This requires it to be embedded in a wider framework of supporting activities such as public education, risk awareness, detection, monitoring and risk assessment, contingency planning, cost–benefit analysis and risk management, all of which support and inform active management. In future it would be useful to map these supporting activities onto this management framework.

Acknowledgements This paper arose from a workshop of the Invasion Dynamics Network (InDyNet) in Berlin in 2018, funded by the Deutsche Forschungsgemeinschaft (DFG) Grant JE 288/8-1, which included a Mercator Fellowship for DLS. Additional support was received through DFG Grants JE 288/9-1 and JE 288/9-2 to JMJ, the G.E. Hutchinson Chair to DLS and the project "Capacity Building Neobiota" (Austrian Federal Ministry for Sustainability and Tourism) to WR. AN, PP and JP were supported by long-term research development project no. RVO 67985939, project 17-19025S and EXPRO grant 19-28807X (Czech Science Foundation). IJ was supported by the J. E. Purkyně Fellowship of the Czech Academy of Sciences. We also thank the referees for this paper for their critical and constructive comments.

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