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Developing a framework of minimum standards for the risk assessment of alien species

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Running title: Minimum standards for risk assessment

Abstract

1. Biological invasions are a threat to biodiversity, society and the economy. There is an urgent need to provide evidence-based assessments of the risks posed by invasive alien species

(IAS) to prioritise action. Risk assessments underpin IAS policies in many ways: informing legislation; providing justification of restrictions in trade or consumer activities; prioritising surveillance and rapid response. There are benefits to ensuring consistency in content of IAS risk assessments globally and this can be achieved by providing a framework of minimum standards as a checklist for quality assurance.

2. From a review of existing risk assessment protocols, and with reference to the requirements of the EU Regulation on IAS (1143/2014) and international agreements including the World Trade Organisation, Convention on Biological Diversity and International Plant Protection Convention, coupled with consensus methods, we identified and agreed upon 14 minimum standards (attributes) a risk assessment scheme should include.

3. The agreed minimum standards were: 1. Basic species description; 2. Likelihood of invasion; 3. Distribution, spread and impacts; 4. Assessment of introduction pathways; 5. Assessment of impacts on biodiversity and ecosystems; 6. Assessment of impact on ecosystem services; 7. Assessment of socio-economic impacts; 8. Consideration of status (threatened or protected) of species or habitat under threat; 9. Assessment of effects of future climate change; 10. Completion possible even when there is a lack of information; 11. Documents information sources; 12. Provides a summary in a consistent and interpretable form; 13. Includes uncertainty; 14. Includes quality assurance. In deriving these minimum standards, gaps in knowledge required for completing risk assessments and the scope of existing risk assessment protocols were revealed, most notably in relation to assessing benefits, socio-economic impacts and impacts on ecosystem services but also inclusion of consideration of climate change.

4. *Policy implications*: We provide a checklist of components that should be within invasive alien species risk assessments and recommendations to develop risk assessments to meet these proposed minimum standards. Although inspired by implementation of the European Union Regulation on invasive alien species, and as such developed specifically within a European context, the derived framework and minimum standards could be applied globally.

Keywords: consensus methods, invasive alien species, management, prioritisation, European Union, risk assessment, biological invasions, legislation, socio-economic impacts, biodiversity impacts

Introduction

Invasive alien species (IAS) are considered one of the greatest threats to biodiversity through their interactions with other drivers of change (Tittensor *et al.* 2014; Bellard, Cassey & Blackburn 2016; Early *et al.* 2016; Seebens *et al.* 2017). Several international agreements (including those within the Convention on Biological Diversity and the International Plant Protection Convention) recognise the negative impacts of IAS (Turbelin, Malamud & Francis 2016) and reflect the growing concerns of policy-makers, scientists, stakeholders and society. As the number of IAS arriving in new regions escalates (Seebens *et al.* 2017) there is an increasing need for robust analysis of risks to inform prioritisation of management. Risk analysis is a broad term encompassing both risk assessment (technical and objective process of evaluating biological or other scientific and economic evidence to identify potential IAS and determine the level of invasion risk associated with a species or pathway) and risk management (Genovesi *et al.* 2010a; Benke, Steel & Weiss 2011; Heikkilä 2011). There can be considerable confusion with respect to the definitions and delimitations of the terms in use to describe risk analysis and associated processes such as risk assessment (Roy *et al.* 2014), however broadly risk assessment can be defined as "the evaluation of entry, exposure and consequence" (Vanderhoeven *et al.* 2017). The inclusion of entry or introduction within a risk assessment framework ensures relevance to pre- and post-border management (McGeoch *et al.* 2016).

Risk assessment is essential for underpinning many components of IAS policy, for example EU Regulation No 1143/2014, and decision-making including prevention (to inform legislation and justify restrictions, such as on trade and/or consumer activities), early detection (warning) and rapid response (prioritising action and guiding surveillance) and long-term control (prioritising species for control and monitoring) (Beninde *et al.* 2015; Genovesi *et al.* 2015; Tollington *et al.* 2015). Additionally risk assessments are required to justify measures that may affect trade without infringing the rules and disciplines of the World Trade Organisation (WTO) (Shine *et al.* 2010) and for communicating with other sectors such as those with conservation remits (Pergl *et al.* 2016). Therefore, there is a need for a framework to ensure risk assessments generate consistent and comparable outcomes to enable information exchange (Brunel *et al.* 2010) and prioritisation of IAS at multiple scales ensuring strategic and effective responses globally (McGeoch *et al.* 2016).

At both international and regional levels, as well as among countries, there is huge variation in how the risks posed by alien species are assessed and this in part depends on the context and objectives of the risk assessment. The available risk assessment schemes vary widely in approach, objective, implementation, environments and taxa covered (Verbrugge, Leuven & van der Velde 2010), and the majority are based on qualitative methods, even though the need to develop quantitative approaches has been recognised (Genovesi *et al.* 2010b; Essl *et al.* 2011; Leung *et al.* 2012). Major hurdles preventing the use of a robust quantitative risk assessment method are the lack of data (Kulhanek, Ricciardi & Leung 2011), high taxonomic, geographic and impact specificity of available methods (Gallardo *et al.* 2016) and challenges in interpretation and communication (Biosecurity New Zealand 2006).

Here we provide guidelines which, to our knowledge, are the first to include comprehensive standards that risk assessments of alien species across a wide range of taxonomic groups should fulfil within an environmental context. From a review of existing risk assessments coupled with

consensus methods, we derived a set of minimum standards with which a risk assessment method should include. The process of deriving the minimum standards revealed gaps in the scope of existing protocols and so we provide recommendations for further developing these to meet the proposed minimum standards.

Selection of risk assessment methods to derive the preliminary list of minimum standards

To identify the most relevant risk assessment protocols, we followed a sequential step-wise process:

1. A literature search for IAS risk assessment schemes used worldwide and their applications was performed using the internet and scientific literature databases (Thomson Reuters Web of Science, Google Scholar), which were investigated through combinations of relevant keywords: risk analysis, risk assessment, invasive alien species, non-native, biological invasions, black list, pathways, uncertainty, biosecurity;
2. The lists of references in these publications were cross-checked for additional relevant publications;
3. The publications were filtered by examination of the abstracts and "material and methods" sections, resulting in 70 papers providing original risk assessment methods and their applications being retained for further consideration. This involved the collation of risk and impact assessment protocols from which to derive criteria for the development of minimum standards; and
4. The list of 70 publications was further reduced by elimination of those in which an existing risk assessment scheme was not modified but simply applied to a different geographic region (e.g. countries or other regions) or specified taxonomic group or groups. Some schemes were excluded because of their high specificity to a geographic region or taxonomic group. The selection process identified 33 publications (Supplementary information 1) representing 29 different risk assessment schemes (noting that some risk

assessments were reported in multiple publications but within the context of specific taxonomic groups or environments).

Preliminary list of attributes derived from risk and impact assessment protocols

The risk assessment schemes and their protocols are diverse and consequently include many attributes for consideration as potential minimum standards. We reviewed the selected risk assessments, alongside requirements documented within the EU Regulation No 1143/2014 and international agreements including WTO, Convention on Biological Diversity and the International Plant Protection Convention, to compile a preliminary list of attributes (Supplementary information 2) for subsequent evaluation through a consensus workshop.

Consensus workshop

Consensus methods (Sutherland *et al.* 2011) were employed during a two-day workshop to distil the critical components of risk assessments that, through expert opinion and consensus, were agreed as essential to achieve overarching assessment of the risk of an IAS, regardless of the specific approach taken and with relevance across taxa, environments and geographic regions.

The experts

The described minimum standards were derived in the context of the EU Regulation "On the prevention and management of the introduction and spread of invasive alien species" (European Union 2014). Thus, they have been designed for underpinning IAS policy implementation on a continental scale, but they will arguably be informative for developing IAS policies globally. Given the EU focus of the underlying policy, 35 European experts from 17 European countries contributed to the development of the minimum standards in a transparent, collaborative and objective manner. Of these, 30 attended the consensus workshop and the remaining five were involved in the pre- and post-consultation. The experts represented a breadth of expertise across taxonomic groups (all taxa,

excluding microorganisms), environments (freshwater, marine and terrestrial), impacts (environmental, socio-economic and health) and disciplines (ecological scientists, plant health, economists, conservation practitioners, policy-makers, risk assessors).

Preliminary consultation

The preliminary consultation phase involved the provision of a preliminary list of risk assessment attributes to all contributing experts two weeks before the workshop. Experts were asked to rank the importance of each as a minimum standard on a scale of 1–5 (low to high importance, respectively). Experts were also asked to provide additional attributes that were not included within the preliminary list of attributes.

The workshop

The two-day workshop was held in Brussels (27-28 March 2014). Participants contributed to discussions on each attribute for the preliminary list in relation to key themes of the risk assessment process: introduction, establishment and dispersal, environmental and socio-economic impacts. The discussions were consolidated through a voting process during which experts were asked to express agreement or disagreement with inclusion of each attribute as a minimum standard. In most cases, the participants were in unanimous agreement, but where there was substantial divergence in opinion, further discussion was invited to explore the basis of disagreement. In most cases, this led to re-wording of the minimum standard and subsequent consensus from the group. Therefore, the preliminary long list of attributes was modified substantially.

Minimum standards derived by consensus

The annotated list of 14 minimum standards finally agreed upon is as follows:

1. Description (taxonomy, invasion history, distribution range (native and introduced), geographic scope, socio-economic benefits)

The description of the species should provide sufficient information to ensure the risk assessment can be understood without reference to additional documentation. This is essential for decision-makers to ensure they have rapid access to the relevant information for their needs.

2. Likelihood of introduction, establishment, spread and magnitude of impact

The risks of introduction, establishment, spread and impact are the four main components of alien species risk assessments. The risks of introduction and establishment are usually expressed as "likelihood", dispersal as "likelihood", "rate" or "rapidity" and impact as both "likelihood" and "magnitude" of a detrimental effect. This minimum standard is relevant for full risk assessments and only in part (spread and magnitude of impact) for assessments which consider impact alone. Assessors should use the best available evidence but transparently document where information may be lacking. It may take into account extrinsic factors, such as pathways and propagule pressure.

3. Description of the current and potential distribution, spread and magnitude of impact

The description of current and potential distribution within the invaded range coupled with information on spread capacity and the magnitude of impact contributes to the classification of an alien species as invasive or not. This minimum standard expands descriptively on the previous minimum standard, providing an overview of documented information, and is critical for both full risk assessments and impact assessments.

4. Inclusion of multiple pathways and vectors of introduction and spread both intentional and unintentional

Information on the mode of introduction including pathway information (CBD 2014) is essential for informing IAS management strategies. All pathways of entry and spread should be considered for a given species, and pathway categories should be clearly defined and sufficiently comprehensive to ensure interoperability with other assessments.

5. Assessment of environmental impacts with respect to biodiversity (and ecosystem) patterns and processes

Environmental impact should consider negative effects on biodiversity (genetic and species) as well as on the structure and function (processes) of natural or semi-natural ecosystems (e.g. habitat diversity and complexity, succession, food-web dynamics, nutrient and energy cycles).

6. Assessment of adverse impacts with respect to ecosystem services

The assessment of adverse impacts to ecosystem services was acknowledged as difficult because empirical evidence is often sparse and such an assessment requires an agreed list and/or classification of ecosystem services. The Common International Classification of Ecosystem Services (CICES) (http://cices.eu/), although still a work in progress, is currently commonly endorsed as the preferred classification system. However, while further progress is made on common classification of ecosystem services it is foreseen that assessment would be at qualitative and descriptive level to meet this minimum standard.

7. Assessment of adverse socio-economic impacts

Assessment of adverse socio-economic impacts by alien species should cover a range of possible socio-economic consequences, encompassing relevant economic sectors and aspects of human health, including broader wellbeing. As per the general nature of risk assessments, the assessment

should focus on the negative/adverse impacts to inform decision makers of the potential risks, with possible socio-economic benefits of IAS outlined qualitatively in the general description (cf. minimum standard 1). Recently a standardised method for classifying alien taxa in terms of the magnitude of their impacts on human well-being, based on the capability approach from welfare economics has been developed (Bacher *et al.* 2017). A systematic assessment of IAS socio-economic impacts, such as SEICAT, would require a common list and/or classification of documented impacts (and it should be noted that it is also essential to include potential but so far undocumented impacts). Here, a preliminary classification is provided (Supplementary Information 3), which builds on the current, commonly-identified socio-economic consequences, i.e. loss of biodiversity and degradation of ecosystems and related services.

8. Status (threatened or protected) of species or habitat under threat

Threatened species and habitats are those that are "critically endangered"," endangered" or "vulnerable" according to the Red Lists relevant for the assessment area (www.iucnredlist.org/technical-documents/categories-and-criteria) (Keith *et al.* 2013). It is feasible that any impact on a threatened species or habitat could be more critical, or perceived as being more critical, than on species and habitats of "least concern" because threatened species and habitats of specific conservation concern may be (or perceived to be) less resilient in the face of biological invasions (Stohlgren *et al.* 1999). However, when severely threatened by an IAS, a common species or habitat may also eventually become designated as threatened, and this highlights the importance of regular review of risk assessments. Useful sources to look for species potentially affected include the: European Alien Species Information Network (EASIN, http://easin.jrc.ec.europa.eu/); Global Invasive Species Database (GISD, www.iucngisd.org/gisd/); CABI-Invasive Species Compendium (www.cabi.org/isc/); Global Register of Introduced and Invasive Species (GRIIS, http://griis.org/); European Network on Invasive Alien Species (NOBANIS, www.nobanis.org/); and/or DAISIE database (www.europe-aliens.org/).

9. Possible effects of climate change in the foreseeable future

Alien species may be in the process of establishing or expanding when they are first assessed, and so it is essential to consider not only the current situation but also predictable changes in the foreseeable future (where the time-scale should be clearly defined and appropriate to the specific IAS under assessment). Alien species may benefit from climate change, and therefore risk assessments should take possible effects into account. For instance, climate change can alter patterns of human transport, changing the propagule pressure of species with the potential to become invasive (Hellmann *et al.* 2008). Climate change may also prolong the optimal climatic conditions for successful colonization or provide conditions that are closer to the climatic optimum of IAS (Walther *et al.* 2009). Additionally, climate change may increase the rate of spread and extend suitable areas for IAS, which might offer new opportunities for repeat introductions via corridors and unaided introductions (so increasing propagule pressure). Extreme events such as floods, tsunamis and strong winds may directly help IAS spread and indirectly open new areas for colonisation. One approach to investigate the potential consequences of climate change for IAS is to revisit components of the risk assessment in the light of predicted climate changes (Supplementary Information 4).

10. Data limitations

The best available evidence should be used throughout the risk assessment process. There may be a paucity of information on some species, but it is essential that risk assessment can still proceed, with precautionary approaches applied where appropriate, to enable decision-makers to undertake risk management. Therefore, it is critical that that the range of sources, including expert opinion, are accompanied by a statement indicating the assessor's confidence level in the quality and reliability of the data/information (see minimum requirement 13). Additionally, risk assessments should be reviewed regularly and revised when new data and/or information becomes available.

11. Information sources

The information sources should be well documented and supported with references to the scientific literature (peer-reviewed publications). If this is lacking, then it may also include other sources ("grey literature" and expert opinion). In all cases, confidence levels should be assigned to the information sources (see minimum requirement 13).

12. Summary of the different components of the risk assessment in a consistent and interpretable form and an overall summary

Many risk assessments are divided into related component sections corresponding to invasion stages such as introduction, establishment, spread and impact alongside an overall summary. Both the individual questions (protocols) and the system summarizing risks should be consistent and unambiguous. The summary information could be as a nominal scale (for example low, medium, high risk) or numerical scale (1 = low risk to 5 = high risk). It is important that clear interpretation guidance or definitions of the summaries are provided for each component of the risk assessment so that decision-makers can rapidly refer to the most pertinent aspects for their needs.

13. Uncertainty (Confidence)

For many biological invasions, there may be a lack of information and a high degree of uncertainty surrounding the risk assessment, simply because the species may not have been the subject of previous study, and this may be both for the species' native and introduced ranges. Alternatively, there may be information available but the assessor may still have a level of uncertainty with respect to the interpretation of the information into a response to a risk assessment question. Therefore, it is essential that the answers provided within risk assessments are accompanied by an uncertainty ranking (e.g. certainty or confidence level) from the assessor (Baker *et al.* 2008). The Intergovernmental Panel on Climate Change (Mastrandrea *et al.* 2010) provides a framework for a

consistent approach to treatment of uncertainties whereby confidence is considered as a function of evidence and agreement. Evidence relates to the type, amount, quality and consistency of the data (D'hondt *et al.* 2015).

14. Quality assurance

It is important that the quality of the risk assessment is assured. There are many possible approaches to quality assurance, from peer-review after the risk assessment has been conducted through to the involvement of a panel of experts invited to review the risk assessment in a collaborative manner to ensure that it is 'fit for purpose' (Mumford *et al.* 2010). Eliciting multiple expert opinions and their associated confidence-levels provides the possibility of deriving the degree of agreement between experts (Vanderhoeven *et al.* In review).

It is important to note that while all the minimum standards are relevant for risk assessments, covering pre-invasion and post-invasion processes, while most but not all are also relevant to impact assessments. Specifically the minimum standards that include assessment or description of entry (namely 2. Likelihood of invasion; 3. Distribution, spread and impacts; 4. Assessment of introduction pathways; Figure 1) would not be comprehensively considered within an impact assessment.

Conclusions and Recommendations

It is essential that risk assessments are repeatable, reliable and robust if they are to underpin IAS policy and decision-making. The minimum standards described here were developed within the context of the EU Regulation on IAS but have applicability to risk assessments worldwide. The 14 minimum standards provide a checklist against which a risk assessment scheme can be evaluated within the context of the process of invasion and management approaches (Figure 1). However, the process of deriving the minimum standards revealed gaps in the scope of risk (and impact) assessments (Table 1) and the knowledge required for completing them. This was most notable in

relation to the assessment of impacts on ecosystem services, socio-economic activities and the likely impact that future, predicted changes in climate could have on the species under assessment. However, we suggest checklists for ensuring a structured approach to these broad themes with regard to the threat posed by the species under assessment. Our study provides a starting point for the inclusion of these relevant perspectives within risk assessments, but further interdisciplinary work is required to inform a more robust risk assessment framework. It is anticipated that such frameworks will emerge over the next few years, and SEICAT (Bacher *et al.* 2017) is an encouraging development in this regard.

Of the 29 risk assessment protocols reviewed, three were considered to be nearly compliant: GB Non-Native Risk Assessment, EPPO Pest Risk Assessment and Harmonia^{+}, but even these required modifications to meet fully the minimum standards. Indeed, all three of these risk assessment protocols have by now been enhanced to meet the minimum standards – demonstrating the utility of this approach. Furthermore, at least one further protocol, the Aquatic Species Invasiveness Screening Kit (AS-ISK) has ensured consistency with the minimum standards (Copp *et al.* 2016). An additional component was included to provide background information on the species alongside questions on potential socio-economic impacts and those on ecosystem services. Furthermore, additional six questions were added to enable the assessor to consider how forecasted changes in climate are likely to influence the risks of introduction, establishment, dispersal and impact of a species (Copp *et al.* 2016).

Lack of empirical evidence is perhaps the greatest constraint to ensuring risk assessment are sufficiently reliable, however expert opinion can provide complementary information. Additionally, there are a number of impact assessment schemes that do not comply because they do not consider the introduction phase of the invasion process but still have utility in providing structured frameworks to inform the content on impacts within a full risk assessment.

There is a clear need to develop harmonised approaches to ensure effective risk assessment of alien species to provide an evidence-base for informing decision-making and so ultimately conservation action. Although information gaps and lags in provision of empirical evidence for assessing IAS as they arrive within a new region are inevitable, it is essential that the process of assessing the threat posed by an alien species is transparent and robust. Furthermore, communication and information exchange are essential for enabling a global response to IAS and as such the minimum standards described here provide an acceptable and practical check list which would achieve the aspired outcome.

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Authors' contributions

HER, WR, RS, AS and FE developed the ideas following European Commission tender specification. HER, BG, PG, WR, RS, AS and FE designed the approach, implemented and coordinated the methods for information gathering including the workshop and led the writing of the manuscript. All authors contributed to the consensus approach as experts and critically reviewed the drafts giving final approval for publication.

Data accessibility

No primary data was generated through this study. The summary of attributes (including the name of the method, study type (original or further development of an existing method), geographic and taxonomic scope to which the method has been applied, total number of questions, types of question, output and associated reference) of selected risk assessments and associated information is provided within Supplementary information 1.

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Figure 1: Minimum standards mapped against the stages of invasion and management strategies. (Grey arrows = minimum standards which are relevant only to a full risk assessment; Black arrows = minimum standards which are relevant to both impact and full risk assessments).

Table 1: Screening of selected risk and impact assessment protocols against the proposed minimum standards: 1. Basic species description and brief overview; 2. Likelihood of invasion; 3. Distribution, spread and impacts; 4. Assessment of introduction pathways; 5. Assessment of impacts on biodiversity and ecosystems; 6. Assessment of impact on ecosystem services; 7. Assessment of socio-economic impacts; 8. Consideration of status (threatened or protected) of species or habitat under threat; 9. Assessment of effects of future climate change; 10. Completion possible even when there is a lack of information; 11. Documents information sources; 12. Provides a summary in a consistent and interpretable form; 13. Includes uncertainty; 14. Includes quality assurance. For details of citations see Supplementary Information 1. Note that the proposed minimum standards 2 and 4 would not be relevant for an assessment pertaining to impact only.

Name	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	Number of minimum standard compliances	References
A Unified Classification of Alien Species Based on the Magnitude of their Environmental Impacts	No	No	Partly	No	✓	No	No	✓	No	Partly	No	✓	✓	Partly	4	(Blackburn et al. 2014)
Australian freshwater fish model	Partly	Partly	Partly	Partly	✓	No	Partly	No	No	Partly	No	✓	✓	Partly	3	(Bomford 2006; Bomford and Glover 2004)
Australian reptile and amphibian model	Partly	Partly	Partly	Partly	✓	No	Partly	No	No	Partly	No	✓	✓	Partly	3	(Bomford et al. 2005)
Australian and New Zealand Bird and Mammal risk assessment	Partly	Partly	Partly	Partly	✓	No	Partly	No	No	Partly	No	✓	✓	Partly	3	(Bomford 2008)

Name	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	Number of minimum standard compliances	References
Invasive Species Environmental Impact Assessment Protocol (ISEIA)	No	No	✓	No	✓	No	No	✓	No	✓	✓	✓	No	✓	7	(Branquart 2007)
EPPO prioritization process for invasive alien plants	Partly	Partly	Partly	Partly	✓	No	✓	No	No	✓	✓	✓	✓	✓	7	(EPPO 2012)
EPPO Decision-support scheme for quarantine pests	✓	✓	✓	✓	✓	No	✓	✓	No	✓	✓	✓	✓	✓	12	(EPPO, 2011)
Trinational Risk Assessment for Aquatic Alien Invasive Species (CEC)	✓	Partly	Partly	✓	✓	✓	✓	✓	No	✓	✓	✓	✓	✓	11	(CEC 2009)
Fish Invasiveness Screening KIT (FISK) (with uncertainty and predictive power improvements)	Partly	Partly	Partly	No	Partly	No	No	No	No	✓	✓	Partly	✓	✓	4	(Copp et al. 2005; Copp et al. 2009)
European Non-native Species in Aquaculture Risk Assessment Scheme (ENSARS)	✓	✓	✓	✓	✓	✓	✓	✓	No	✓	✓	✓	✓	✓	13	(Copp et al. 2008)

Name	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	Number of minimum standard compliances	References
Harmonia^{+} and Pandora^{+}: risk screening tools for potentially invasive organisms	Partly	✓	✓	✓	✓	No	✓	✓	No	✓	✓	✓	✓	✓	11	(D'hondt et al. 2014)
EFSA PLH scheme for PRA	Partly	✓	✓	✓	✓	✓	No	Partly	Partly	✓	✓	✓	✓	✓	10	(EFSA Panel on Plant Health 2011)
GABLIS	✓	No	Partly	✓	✓	No	No	✓	✓	✓	✓	✓	✓	Partly	9	(Essl et al. 2011)
Full Risk Assessment Scheme for Non-native Species in Great Britain (GB NNRA)	Partly	✓	✓	✓	✓	No	✓	✓	✓	✓	✓	✓	✓	✓	12	(Baker et al. 2008)
Alien Species in Norway - with the Norwegian Black List 2012	Partly	No	✓	✓	✓	No	No	✓	✓	✓	✓	✓	✓	✓	10	(Gederaas et al. 2013; Sæther et al. 2010; Sandvik et al. 2013)

Name	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	Number of minimum standard compliances	References
Risk analysis and prioritisation (Ireland and Northern Ireland)	Partly	Partly	Partly	Partly	✓	No	✓	No	✓	✓	✓	✓	✓	✓	8	(Kelly et al. 2013)
Quantitative Risk Assessment for alien fishes	Partly	Partly	Partly	✓	✓	No	Partly	No	No	✓	No	✓	No	✓	5	(Kolar and Lodge 2002)
A conceptual framework for prioritization of invasive alien species for management according to their impact	✓	No	Partly	No	✓	Partly	✓	✓	No	Partly	✓	✓	✓	✓	8	(Kumschick et al. 2012)
Generic Impact-Scoring System (GISS)	Partly	No	Partly	No	✓	No	✓	✓	No	Partly	✓	✓	✓	✓	7	(Kumschick and Nentwig 2010; Nentwig et al. 2010)
Biopollution Index	No	No	Partly	No	✓	No	No	No	No	Partly	✓	✓	No	No	3	(Olenin et al. 2007)
Chinese WRA	Partly	✓	✓	✓	✓	Partly	Partly	No	No	✓	✓	✓	No	✓	8	(Ou et al. 2008)

Name	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	Number of minimum standard compliances	References
US Weed Ranking Model	Partly	No	Partly	No	✓	No	Partly	No	✓	✓	No	Partly	No	No	3	(Parker et al. 2007)
Australian WRA	Partly	No	Partly	Partly	✓	No	✓	No	No	✓	No	✓	Partly	✓	5	(Pheloung et al. 1999)
Freshwater Invertebrates Scoring Kit (FI-ISK)	Partly	Partly	Partly	No	Partly	No	No	No	No	✓	✓	Partly	✓	✓	4	(Tricarico et al. 2010)
Expert System for screening potentially invasive alien plants in South African fynbos	Partly	Partly	No	No	Partly	No	No	No	No	✓	No	Partly	✓	No	2	(Tucker and Richardson 1995)
Invasive Ant Risk Assessment	Partly	Partly	Partly	✓	✓	No	✓	No	No	✓	No	No	✓	No	5	(Ward et al. 2008)
Classification key for Neophytes	Partly	Partly	No	No	✓	No	No	No	No	No	No	No	No	No	1	(Weber and Gut 2004)
Climate-Match Score for Risk-Assessment Screening	No	Partly	Partly	No	No	No	No	No	No	No	✓	No	Partly	No	1	(van Wilgen et al. 2009)
Assessment of risk of establishment for alien amphibians and reptiles	No	Partly	Partly	No	No	No	No	No	No	No	✓	No	Partly	No	1	(van Wilgen and Richardson 2012)