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A vision for global monitoring of biological invasions

Guillaume Latombe [a], Petr Pyšek [b,c], Jonathan M. Jeschke [d,e,f], Tim M. Blackburn [g,h,i], Sven Bacher [j], César Capinha [k], Mark J. Costello [l], Miguel Fernández [m,n], Richard D. Gregory [o], Donald Hobern [p], Cang Hui [q,r,s], Walter Jetz [t], Sabrina Kumschick [u,v], Chris McGrannachan [a], Jan Pergl [b], Helen E. Roy [w], Riccardo Scalera [x], Zoe E. Squires [a], John R.U. Wilson [u,v], Marten Winter [m], Piero Genovesi [y,z], Melodie A. McGeoch [a,*]

[a] School of Biological Sciences, Monash University, Melbourne 3800, Australia
[b] Department of Invasion Ecology, Institute of Botany, The Czech Academy of Sciences, CZ-252 43 Průhonice, Czech Republic
[c] Department of Ecology, Faculty of Science, Charles University in Prague, Viničná 7, CZ-128 44 Praha 2, Czech Republic
[d] Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Müggelseedamm 310, 12587 Berlin, Germany
[e] Freie Universität Berlin, Department of Biology, Chemistry, Pharmacy, Institute of Biology, Königin-Luise-Str. 1-3, 14195 Berlin, Germany
[f] Berlin-Brandenburg Institute of Advanced Biodiversity Research (BBIB), Altensteinstr. 34, 14195 Berlin, Germany
[g] Department of Genetics, Evolution & Environment, Centre for Biodiversity & Environment Research, UCL, Gower Street, London WC1E 6BT, UK
[h] Institute of Zoology, ZSL, Regent's Park, London NW1 4RY, UK
[i] School of Earth & Environmental Sciences and the Environment Institute, University of Adelaide, South Australia 5005, Australia
[j] Unit Ecology & Evolution, Department of Biology, University of Fribourg, Ch. du Musée 10, CH-1700 Fribourg, Switzerland
[k] CIBIO/InBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, Cátedra Infraestruturas de Portugal-Biodiversidade, Universidade do Porto, Campus Agrário de Vairão, 4485-661 Vairão, Portugal
[l] Institute of Marine Science, University of Auckland, P. Bag 92019, Auckland 1142, New Zealand
[m] German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Deutscher Platz 5e, 04103 Leipzig, Germany
[n] Instituto de Ecología, Universidad Mayor de San Andrés, Campus Universitario Cota-cota Calle 27, La Paz, Bolivia
[o] RSPB Centre for Conservation Science, RSPB, The Lodge, Sandy, Bedfordshire SG19 2DL, UK
[p] Global Biodiversity Information Facility Secretariat, Universitetsparken 15, 2100 Copenhagen, Denmark
[q] Centre for Invasion Biology, Department of Mathematical Sciences, Stellenbosch University, Matieland 7602, South Africa
[r] Mathematical and Physical Biosciences, African Institute for Mathematical Sciences, Cape Town 7945, South Africa
[s] Research School of Arid Environment and Climate Change, Lanzhou University, Lanzhou 730000, China
[t] Department of Ecology and Evolutionary Biology, Yale University, 165 Prospect Street, New Haven, CT 06520-8106, USA
[u] Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa
[v] Invasive Species Programme, South African National Biodiversity Institute, Kirstenbosch Research Centre, Claremont 7735, South Africa
[w] Centre for Ecology & Hydrology, Benson Lane, Crowmarsh Gifford, Oxfordshire OX10 8BB, UK
[x] IUCN SSC Invasive Species Specialist Group, Via Mazzola 38, 00142 Rome, Italy
[y] Institute for Environmental Protection and Research, Via V. Brancati 48, 00144 Rome, Italy
[z] IUCN SSC Invasive Species Specialist Group, Via V. Brancati 48, 00144 Rome, Italy

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A B S T R A C T

Managing biological invasions relies on good global coverage of species distributions. Accurate information on alien species distributions, obtained from international policy and cross-border co-operation, is required to evaluate trans-boundary and trading partnership risks. However, a standardized approach for systematically monitoring alien species and tracking biological invasions is still lacking. This Perspective presents a vision for global observation and monitoring of biological invasions. We show how the architecture for tracking biological invasions is provided by a minimum information set of Essential Variables, global collaboration on data sharing and infrastructure, and strategic contributions by countries. We show how this novel, synthetic approach to an observation system for alien species provides a tangible and attainable solution to delivering the information needed to slow the rate of new incursions and reduce the impacts of invaders. We identify three Essential Variables for Invasion Monitoring; alien species occurrence, species alien status and alien species impact. We outline how delivery of this minimum information set by joint, complementary contributions from countries and global community initiatives is possible. Country contributions are made feasible using a modular approach where all countries are able to participate and strategically build their contributions to a global information set over time. The vision we outline will deliver wide-ranging benefits to countries and international efforts to slow the

* Corresponding author.
E-mail address: melodie.mcgeoch@monash.edu (M.A. McGeoch).

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rate of biological invasions and minimize their environmental impacts. These benefits will accrue over time as global coverage and information on alien species increases.

1. Introduction

There has been renewed focus on global observation systems for up-to-date information on the state of biodiversity and the threats it faces (Larigauderie and Mooney, 2010; Pereira et al., 2013; Scholes et al., 2012; Tittensor et al., 2014). One of these threats is biological invasions, which have been shown to affect ecosystem services and decrease native species abundance through mechanisms such as predation, hybridization, competition and indirect effects (Simberloff et al., 2013). The worldwide number of alien species is large, with, for example, >13.000 naturalized vascular plant species (van Kleunen et al., 2015). In Europe alone there are >12.000 species of alien plants and animals, of which 15% are known to negatively impact biodiversity (Vilà et al., 2010). Globally, there are 1900 alien marine species (Pagad et al., 2015a). Prioritizing where to invest in action is a key part of effective policy and management (McGeoch et al., 2016), as emphasized by the Convention on Biological Diversity's (CBD) Strategic Plan for Biodiversity 2020 and associated Aichi Target 9 for biological invasions (UNEP, 2011).

A substantial increase in effort is needed to reduce the pressure of alien species on biodiversity and ecosystems (Tittensor et al., 2014), that includes globally integrated approaches to prioritize, manage and control them (McGeoch et al., 2016; van Kleunen et al., 2015). Biological invasions occur through a number of pathways, the most prominent being related to trade and transport (Hulme et al., 2008). The ongoing increase in volumes of trade and expansion of transport networks will continue to foster species movements beyond their native distributions (Seebens et al., 2015). Cross-border policy and co-operation is essential to slow the rate of new incursions, but accurate information on alien species distributions is required for the assessment of trans-boundary and trading partnership risks (Essl et al., 2015). As a result, monitoring and mapping species movements at various scales, from local to global, is essential for dealing with biological invasions on a global scale. A global monitoring system is particularly important for the effective management of biological invasions and, as we reveal in this Perspective, is now within reach (http://invasionevs.com/).

While some countries have compiled alien species inventories and gathered information on the distribution of alien species within their country (*e.g.* Gereraas et al., 2012; Roy et al., 2014), systematic monitoring of alien species at multiple spatial scales that is comparable across borders remains lacking. In 2010, only 26% of countries reported national surveillance and monitoring activity, with a further 16% expressing an intention to implement or improve such activity (Fig. 1, Appendix A). Such monitoring can provide early warning of potential alien species both within a country and for neighboring countries. To achieve this, there is need for standardized variables and metrics to underpin a global observation system for alien species that can accommodate countries across a range of baseline knowledge levels and economic capabilities. To date, geographic variation in information and capacity and difficulties of keeping most inventories regularly updated, along with taxonomic gaps, have impeded globally harmonized monitoring of invasions (Bellard and Jeschke, 2016; Canhos et al., 2015; Jeschke et al., 2012; McGeoch et al., 2010; Pyšek et al., 2008, 2013). These inequalities have also significantly undermined the performance of indicators of alien species prevalence and impact, and increased their likelihood of delivering misleading outcomes for policy (Collen and Nicholson, 2014).

Clear direction is needed for national and international efforts to collect the data most essential to enable actions for reducing the negative consequences of biological invasions, and to avoid delivering unreliable information to policy makers and conservation agencies. The approach needs to be flexible enough to accommodate data with a range of precision and accuracy for multiple taxa, ecosystems and regions. It should also be supported by best-practice data infrastructure and biodiversity informatics (Costello and Wieczorek, 2014; Jetz et al., 2012; Katsanevakis and Roy, 2015).

Here, we used the concepts of Essential Variables (Nativi et al., 2015) and specifically Essential Biodiversity Variables (EBVs; Pereira et al., 2013; Kissling et al., 2015; Schmeller et al., 2015) as a springboard for identifying a minimum suite of variables essential for invasion monitoring. We present the elements required for a global observation and monitoring system for biological invasions, which include: (i) a minimum information set provided by three Essential Variables (that are either EBVs, attributes of EBVs, or constructed from multiple EBVs) as the basis for measuring and monitoring invasion (Fig. 2); (ii) delivery of this minimum information set by joint, complementary contributions from countries and global community initiatives; and (iii) a modular approach (Fig. 3) where all countries are able to participate at a basic level and strategically build their contributions over time. We outline how recent progress in data infrastructure and technology, and in classifying the impacts of alien species, together place such a system within reach.

2. Approach

2.1. The relationship between Essential Variables for Invasion Monitoring and Essential Biodiversity Variables

Essential Variables are the minimum information set needed for the study, reporting and management of scientific or societal phenomena (Nativi et al., 2015). Essential Biodiversity Variables (EBVs) are, more specifically, the minimum information set needed for the study, reporting and management of biodiversity change (Geijzendorffer et al., 2015; Pereira et al., 2013). The case of biological invasions is interesting, because (i) it is a scientific and societal phenomenon, as defined above, and (ii) invasive alien species are themselves part of biodiversity (both inside and outside of their historic geographic ranges), but (iii)

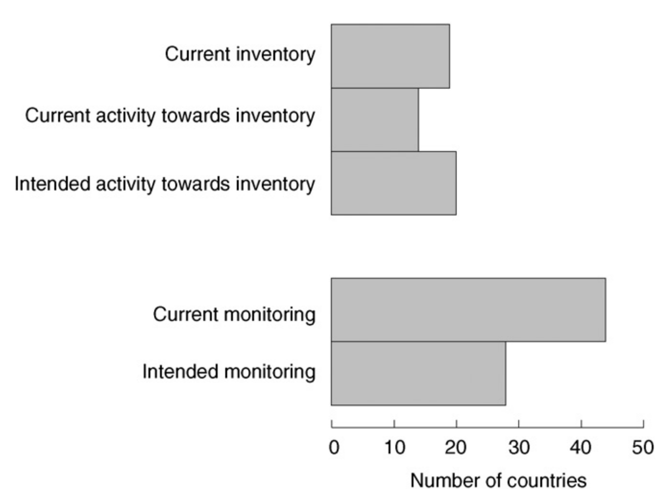

Fig. 1. The number of countries in 2010 ($n = 170$) reporting to have inventories and monitoring activities for alien species at different stages of development.

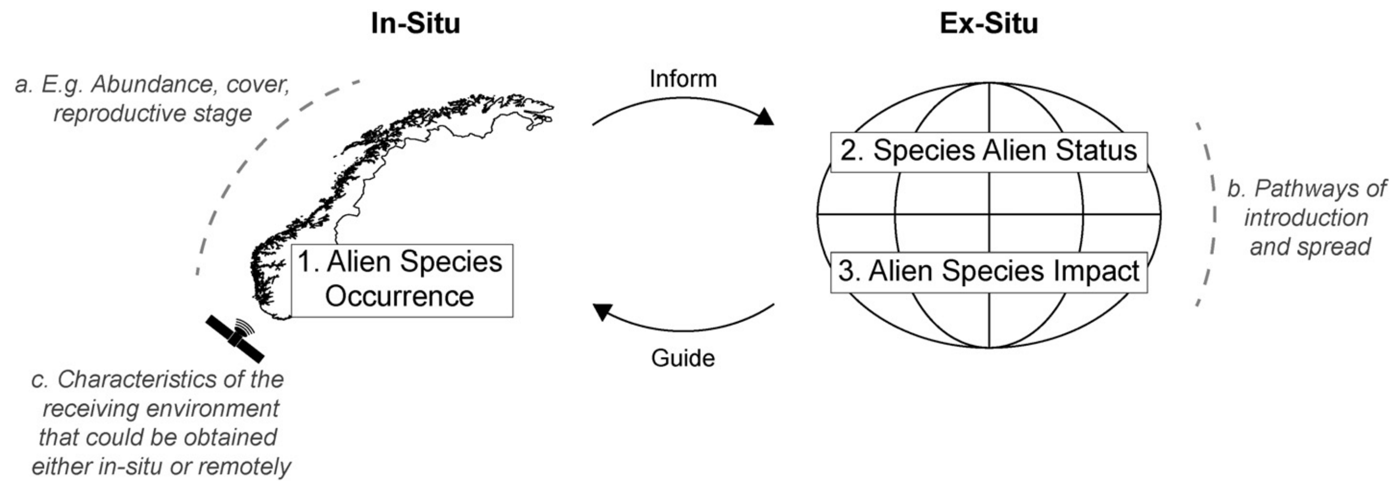

Fig. 2. The three Essential Variables for Invasion Monitoring, *i.e.* alien species occurrence, species alien status and alien species impact (in boxes). Alien species occurrence is the only Essential Variable that must be collected *in-situ* (Norway is given as an example; Gereraas et al., 2012), whereas species alien status and alien species impact may be derived from *ex-situ* sources (see text). Additional supplementary variables (a–c) are generated either *in-situ* or derived from *ex-situ* sources, potentially including remote sensing information. The priority of these supplementary variables will depend on the monitoring context.

they are also a driver of biodiversity change. In this sense they represent a valuable test case for the application of the EBV concept for the purpose of designing a biodiversity-related monitoring system. Importantly, the variables we identified are not all EBVs, and we have chosen to call them *Essential Variables for Invasion Monitoring* (or Essential Variables for short in this context), rather than EBVs. For each variable selected, we explain in some detail the relationship between the selected variable and EBVs.

2.2. Identification and selection process

To identify the variables that are necessary for invasion monitoring, we asked first, what are the variables that are most essential for invasion monitoring, and then examined the relationship between each of these and EBVs. We followed an expert elicitation process comprising three stages: preparation, elicitation and synthesis (Gregory et al., 2012). The preparation phase included framing the question and preparing the supporting documents to guide and capture the discussion and decisions. The expertise represented in the group (that included all authors of this article) spanned a wide range including the biology, ecology, analysis, modeling and policy regarding biological invasions. We worked in four pre-established groups designed as far as possible to balance the set of expertise amongst groups. The elicitation phase started with the provision and discussion of background information on Essential Variables and EBVs, as well as outlining and discussing the task, *i.e.* the identification of a set of Essential Variables for Invasion Monitoring. This phase then included structuring the elicitation and eliciting the judgment. To structure the elicitation, participants completed pre-prepared documents that required input on the variables required to study, report and manage biological invasions, along with their characteristics, such as temporal sensitivity and feasibility (similar to the approach adopted by Pereira et al., 2013). The variables were then ranked by importance. Each group was tasked with narrowing down their set of variables to a shortlist of three variables and a longer list including up to five additional variables based on the ranks. Each of the four groups completed this task independently.

In the third phase, results were synthesized by first asking each group to report orally the outcome of their reflections, and to provide the short and long lists they produced. The same elicitation process was then repeated on the second day to refine the output. The second day started by presenting and discussing the lists summarizing the outcome from day one (Appendix B, Table B1). We then divided ourselves

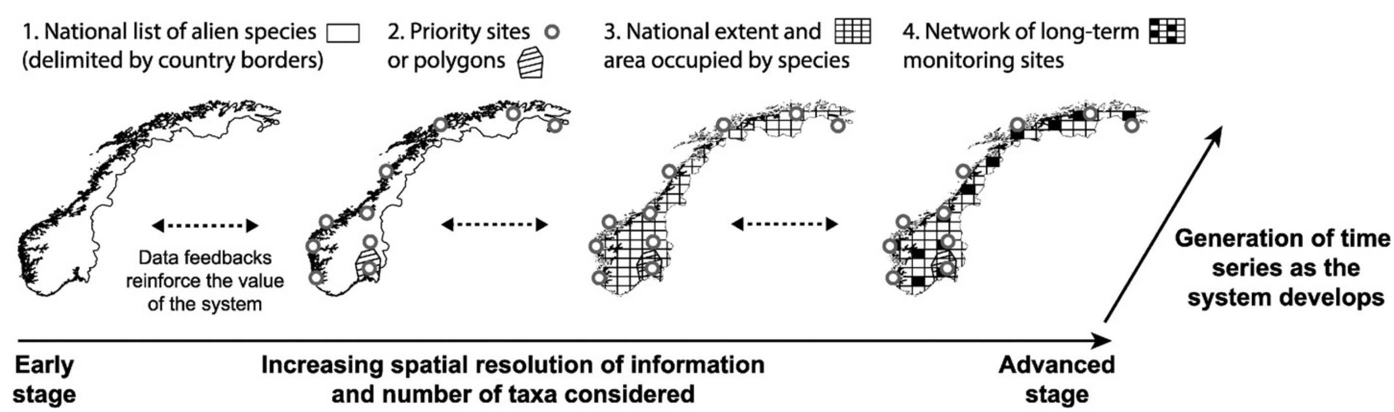

Fig. 3. Four stages of development of national observation and monitoring systems for alien species, that represent increases in spatial resolution of monitoring, using Norway for illustration. Steps 1 to 4 represent an efficient path for countries that are in the early stages of developing their national systems to follow. The approach accommodates countries across the current spectrum of data and resource availability and stages of monitoring system development. Data feedbacks (double-ended arrows) allow countries at different stages to share information, while they improve data quality, cover and taxonomic representation. These feedbacks reinforce the system as it develops. For example, new species detected at priority sites (stage 2) feed into the next update of the national list of alien species. Repeated observations at each level over time (y-axis on right) provide trends in the status of biological invasion, such as changing numbers of alien species on the national inventory, changes in range extent, and estimates of rates of spread. (Note that the position of demarcated sites and areas are for illustration only).

randomly into a new set of four groups with different composition, and each group was tasked with independently identifying three variables from the synthesized short lists from day 1. Each group reported the outcome orally and provided their final shortlists for further discussion (Appendix B, Table B2). At the end of this process, three variables considered essential for invasion monitoring emerged as a consensus amongst participants (the final shortlist), along with a series of supplementary variables (the final long list).

3. Essential Variables for Invasion Monitoring

The three Essential Variables are (i) the presence or absence (occurrence) of alien species over defined spatial units, (ii) information on the alien status of species within their current geographic ranges, and (iii) a measure of alien species impact (McGeoch and Squires, 2015; http://invasionevs.com) (Tables 1–2). As emphasized above, these Essential Variables for Invasion Monitoring are not all EBVs themselves, since their objective is to characterize change in the status and impact of biological invasions rather than biodiversity change *per se*. The rationale for the variables identified is provided below.

3.1. Alien species occurrence

Spatially explicit presence-absence records are the basic unit for quantifying the geography and movements of species and monitoring range expansion (McGeoch and Latombe, 2016). Quantifying the size, extent and nature of biological invasions globally at regular interval (at least every five years, preferably on an ongoing basis and collated every five years) will be facilitated significantly by the existence of harmonized occurrence data across countries for aliens from multiple taxonomic groups (McGeoch et al., 2010). The occurrence or 'occupancy' (Azaele et al., 2012) of alien species at any particular scale of interest provides the basis for quantifying several derived variables and indicators of invasion (Tables 1–2). Tracking the spread of alien species and evaluating the success of policies and management interventions is achieved by repeated measurement of occurrence records of alien species, which enables the assessment of their geographic distribution. Species occurrences, for alien and native species, are an instance of, and contribute directly to, the 'Species Distribution' EBV, which belongs to the 'Species Populations' class (Pereira et al., 2013).

3.2. Species alien status

Information on the geographic distribution of a species and its presence outside of its indigenous geographic range is an essential part of the knowledge needed to monitor alien species occurrence (McGeoch et al., 2012; Tables 1–2). A species must first be observed and identified during routine surveillance or by incidental observation, and later confirmed to be alien, to contribute data to national inventories of alien species and possibly trigger a risk assessment or actions to limit detrimental impacts. Thereafter, *a priori* knowledge of the presence of an alien species in a country is used, *inter alia*, to target monitoring and control strategies (Fig. 2).

Being able to confidently assign alien status to a species at national and subnational scales is not always straightforward, because the historical distribution of species is often poorly known, especially along range margins and at fine spatial scales. Sources of error in assigning a species alien or native status are multiple, and range from human and taxonomic error (such as misidentification or taxonomic uncertainty) to inadequate data resolution or accessibility (McGeoch et al., 2012). Yet, being able to confidently assign alien (or native) status to an individual species record is a key step to formulate appropriate responses and guide monitoring efforts for biological invasions. Information on species alien status is therefore an Essential Variable for the study, reporting and management of biological invasions.

Given a specific locality, the status of a species as either alien or native does not correspond to an EBV *per se* (Pereira et al., 2013). Rather, in the EBV framework, species alien status is considered to be an attribute, or information ancillary to the Species Distribution EBV. Nonetheless, the status of a species as alien or native at any point within its geographic distribution is included in the set of Essential Variables for Invasion Monitoring. This forms the essence of implementing sound policy and management actions (McGeoch et al., 2010). The need for adequately assessing this variable at a global level is reinforced by the fact that the prioritization and collation of data on the alien or native status of species are currently inadequate (McGeoch et al., 2012). Given the potential errors described above for assessing this status, this is a variable that requires regular, preferably continuous updates, however at a minimum every five years, along with the occurrence variable.

Table 1
The three Essential Variables for a global observation and monitoring system for biological invasions.

Essential Variables for Invasion Monitoring				
Origin	Essential Variable	Observations on which it is based	Collated as	Examples for derived supplementary variables and indicators
In-situ data	1. Alien species occurrence (McGeoch and Latombe, 2016)	Taxonomically verified species presence or absence records at a locality with a geographic co-ordinate, or in a prescribed area, management or geopolitical unit or site	A matrix of alien species occurrences (presence and where possible absence) by particular locations	Requiring Essential Variables 1 and 2: – Alien species area of occupancy – Alien species inventories for countries and sites – Number of alien species per site, area or geopolitical unit – Trends in numbers of alien species – Propagule pressure or invasion rate – Status of species along the introduction–naturalization–invasion continuum (Blackburn et al., 2011) – An alert system for new incursions – Model-based predictions of which species are candidates for future incursion
Ex-situ information	2. Species alien status (McGeoch et al., 2012)	Knowledge of the historical geographic range of the species that is commonly available in flora and fauna volumes, its historical absence from the introduced range, or genotypic difference from local populations	Categorical Alien/Native for each species record from which the introduced range of the species can be extracted	
	3. Alien species impact (Blackburn et al., 2014)	An objective, transparent and repeatable system for classifying alien taxa in terms of the current and maximum realized impact globally of their detrimental effect on any recipient ecosystem	Alien taxa categorized into one of five 'impact' categories by applying the standardized classification system (Hawkins et al., 2015)	– Number and identity of species in each impact category at a site or in an area of interest – Trends in alien species with the most severe impacts – Lists of priority species for policy and management

Table 2
Characteristics of the three Essential Variables for Invasion Monitoring, including alien species observation, and their relationships with EBVs.

Essential Variable for Invasion Monitoring	Related EBV[a] class and EBVs	Measurement and scalability	Temporal sensitivity[b]	Feasibility	Associated information	Relevance to Aichi Target 9[c] and long-term monitoring of biological invasion
Alien species occurrence	Species populations, distributions. The relevant EBV is Species Distribution[d], and the distribution of alien species forms an instance thereof.	Records of species presence or absence, scalable by increase in resolution of record from country to georeferenced point locality	1 to 5 years	Data are available for many species and many of these have some global and country-specific coverage, but distribution information remains coarse or riddled by observer bias (Jetz et al., 2012). For alien species, data quality can be improved using the systematic approach proposed here, supported by GIASIP initiative, species registries (*e.g.* Canhos et al., 2015; Essl et al., 2015; Jeschke et al., 2012; van Kleunen et al., 2015), citizen science and new technologies (Essl et al., 2015)	– Spatiotemporally explicit records or predictions in the form of sites or areas occupied – Taxonomic information, including nomenclature and species identity	Target refers to the identification and prioritization of alien species, the fundamental basis of which is determined by the presence of such species in a locality or associated with a pathway
Species alien status	Ancillary to species populations, distributions[e]	Categorical, yes/no, alien or indigenous (Jetz et al., 2012)	Fixed over ecological timescales with historical distribution as a baseline	Well known for many of the species currently considered to be the worst invaders, less well known for many smaller, and more narrowly distributed alien species. This variable needs to be underpinned by sound taxonomy (Katsanevakis and Roy, 2015). Molecular tools are increasingly able to support identification of species and the provenance of populations (Chown et al., 2015).	– Associated geographic position. – Indigenous geographic range	Target refers to identification of alien species
Alien species impact	Ecosystem function and species traits, involving multiple EBVs[f]	Species classified based on the magnitude of their impacts assessed against 10 standard impact mechanisms	5 to 10 years	Theoretically well understood and widely appreciated, although not straightforward to measure. Recently proposed impact classification scheme EICAT (Hawkins et al., 2015) provides a solution for comparative, broad, taxonomic and geographic assessment	Information on mechanisms by which taxa have deleterious effects, including traits such as trophic level, species interactions, physical and chemical properties and processes	Target refers to prioritization of alien species, which requires an impact assessment and classification scheme that facilitates comparisons across species

[a] Essential Biodiversity Variable (EBV) (Pereira et al., 2013).
[b] Inherent responsiveness of the variable to change. The timescale at which the variables should be reassessed must therefore be lower than the temporal sensitivity.
[c] Aichi Target 9 of the Strategic Plan for Biodiversity 2011–2020 (Conference of Parties to the Convention on Biological Diversity) states: Invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.
[d] The EBV 'Species Distribution' includes species presence–absence records over sets of defined spatial units, and over a specified time, and aims to cover entire species ranges. The Essential Variable for Invasion Monitoring 'alien species occurrence' forms a natural subset of information provided by the Species Distribution EBV, and the value of this information will increase over time as the numbers of species and their taxonomic ranges, temporal detail and spatial detail become more comprehensive.
[e] The status of a species as either native or alien within any particular locality or region is considered ancillary information to the Species Distribution EBV. However, in the context of biological invasions it is the essential basis upon which appropriate policy and management decisions are taken (McGeoch et al., 2010), and prioritization of the collection and collation of these data is needed (McGeoch et al., 2010).
[f] Composed of information from multiple EBVs, this Essential Variable for Invasion Monitoring is not strictly 'observation' based, but can rather be considered a derived variable or indicator within the EBV framework (Pereira et al., 2013).

3.3. Alien species impact

Understanding the impact of an alien species on the environment is critical for prioritizing efforts to prevent future introductions and to contain the spread of the most harmful species (Blackburn et al., 2014), *i.e.* those that have a substantial impact on biodiversity and/or ecosystems. This concept of impact underpins many different lists (such as the Invasive Alien Species Indicator — http://academic.sun.ac.za/iasi/ and the Global Register of Introduced and Invasive Species — http://www.griis.org/) currently used to report on biodiversity targets and inform policies for the management of biological invasions (McGeoch et al., 2010). An assessment of the realized or potential impact of an alien species was thus the third Essential Variable identified (Tables 1–2). A recently proposed scheme for the classification of alien species into five impact classes across taxa and environments, based on the magnitude and potential reversibility of their deleterious environmental impacts (Blackburn et al., 2014), has international support, notably through the IUCN and the Global Invasive Alien Species Information Partnership (GIASIP) (UNEP, 2014). This scheme, called the *Environmental Impact Classification for Alien Taxa* (EICAT), is supported by a framework and guidelines to facilitate consistent and comparable application by users (Hawkins et al., 2015) and also evaluates the mechanisms through which impact occurs. With evidence that now supports comparative quantification of impact across taxa (Kumschick et al., 2015), the scheme is being used to collate information on the environmental impacts of alien species globally (*e.g.* McGeoch et al., 2015a). This development provides a standardized approach and platform for delivering the third Essential Variable for Invasion Monitoring.

The 'alien species impact' variable is not itself an EBV, but is rather generated from information on various EBVs. It is therefore a composite, higher-level variable derived from multiple EBVs, such as population abundance or ecosystem structure, generated by collating direct observations in a semi-quantitative, analytical process (Blackburn et al., 2014). By regularly (at least every five years, as for the other two variables, and every two years once the scheme is in common and widespread usage) quantifying the magnitude and the reversibility of the impact at a scale defined by the impact classes from the EICAT scheme, alien species impact can eventually be used as an indicator of the change caused by biological invasions.

Alien species impact is an Essential Variable for Invasion Monitoring because the distinction it makes between the impact of different alien species is necessary for studying and reporting biological invasions, and for further potential prioritization and management purposes (McGeoch et al., 2016). Although the current and future impacts of biological invasions in specific locations are context-dependent (determined for example by the species richness or existing management measures; Hulme et al., 2013), their quantification requires extensive assessments and predictions across multiple environmental variables (Rouget et al., 2016). In the absence of detailed information, the maximum impact observed elsewhere and the mechanisms through which maximum impact occurs (as estimated using EICAT) provide an efficient way of estimating the potential future impact of alien species (Hawkins et al., 2015).

As we outline below, these three variables are generated *in-situ* by countries, or provided *ex-situ* by international initiatives and partnerships (Table 1, Fig. 2). Several indicators of invasion trends may then be derived from repeated measurements of these variables over time (*e.g.* McGeoch et al., 2016).

4. Supplementary variables

The three Essential Variables outlined above provide the information essential for a global observation system for biological invasions. The expert elicitation process did identify a number of other important variables in the different short and long lists, such as abundance, pathways, and characteristics of the receiving environment. The need for the information delivered by these supplementary variables was however considered to be more context-dependent and objective-specific than the three Essential Variables for Invasion Monitoring, and this list is therefore not exhaustive (Table 3; Fig. 2; Appendix B, Table B1).

The supplementary variables for invasion monitoring (which themselves in most cases are made up of a combination of EBVs or are variables derived from EBVs; Table 3) complement the three Essential Variables in three different ways. First, they enable prioritizing sites where variables should be recorded *in-situ*. For example, the value of the receiving environment enables the identification of sites of high conservation value, and identifying pathways of introduction enables identification of sites of high risk of invasion (McGeoch et al., 2016). Second, supplementary variables such as abundance and body size provide information valuable for assessing and quantifying local risk and impact that can contribute to EICAT assessments. Third, the supplementary variables may be combined with the three Essential Variables for a variety of applications, such as estimating the cost of management actions and predicting the future state of invasion. In some cases, supplementary variables may also be used to derive or estimate Essential Variables (*e.g.* occurrence can be recovered from cover and abundance data) (Table 3). These supplementary variables can be obtained either *in-situ* from direct observation measures, or from *ex-situ* sources, such as globally available databases (UNEP, 2014) or remote sensing data (O'Connor et al., 2015; Pettorelli et al., 2016; Skidmore et al., 2015). In summary, information on these supplementary variables forms a key part of monitoring or management programs already in place under many local contexts and in some national monitoring and reporting schemes (*e.g.* Allen et al., 2009; Stokes et al., 2006), and they provide valuable information complementary to the information delivered by the three Essential Variables for Invasion Monitoring we identified.

5. Building country contributions

The global measurement of Essential Variables, including EBVs, requires international cooperation amongst scientists and research infrastructures to implement common data standards and monitoring practices (Schmeller et al., 2015). Some initiatives and projects, such as Biodiversity Observation Networks (Wetzel et al., 2015) and GLOBIS-B, funded by the European Commission (Kissling et al., 2015), have been effectively implemented to this end. Similarly, to maximize the value of investment in monitoring biological invasions, the information generated from monitoring schemes must as far as possible enable assessments of the status of biological invasions to be comparable across local, national and international scales. An important outcome of identifying this set of Essential Variables for Invasion Monitoring is that only the first variable, alien species occurrence, must be truly generated *in-situ* and delivered by countries (Table 1; Fig. 2). The other two Essential Variables consist of information that is to a large extent transferrable across countries and can be delivered *ex-situ*, by information partnerships, global databases and intergovernmental initiatives (*e.g.* Katsanevakis and Roy, 2015; van Kleunen et al., 2015).

This insight simplifies the message to countries and organizations responsible for monitoring and lightens the burden on countries for data delivery. For example, occurrence data (that constitute the first Essential Variable) are readily scalable (Azaele et al., 2012) and well-suited to

Table 3
Supplementary variables that complement or can be derived from the three Essential Variables for observing and monitoring alien species, with *in-situ* variables collected by countries and *ex-situ* variables provided by international initiatives and partnerships, in the form of globally available databases or remote sensing data. *Ex-situ* remote sensing data for use in research and projection is already available in the form of climate and land cover data layers.

Origin	Variable	Comment	How it complements Essential Variable-based monitoring
In-situ	Cover, abundance or biomass[a] and body size or reproductive stage	Possible to estimate some variables with alien species occurrence data and life-history information (McGeoch et al., 2010), but otherwise requires *in-situ* measurement (Nativi et al., 2015). Variables such as cover and biomass, or any species traits, are EBVs.	Used to calibrate realized local impact, and to estimate costs of management action
Ex-situ	Pathways of introduction and spread	Pathway information is often transferable and can be obtained from external information resources (Essl et al., 2015). Fine-scale occurrence data (Table 1) can also be used to inform this variable (Pagad et al., 2015b). Pathways can be inferred from multiple EBVs.	Used to target and prioritize sites at which occurrence should be measured, or should be monitored more intensively
In-situ	Value of the receiving environment	Such as biodiversity value measured, for example, as native or threatened species presence or richness. This variable may also be derived from multiple EBVs.	Used to target and prioritize sites at which occurrence should be measured, or should be monitored more intensively
In-situ or ex-situ	Characteristics of the receiving environment	Including habitat characteristics and climate (Roy et al., 2015). Can either be obtained *in-situ* from direct field observation, or using *ex-situ* remote sensing data (Pettorelli et al., 2016).	Used to estimate future potential invasions and their associated impacts; can be combined with information on pathways

[a] Although this information could be obtained *in-situ*, remote technology, such as remote sensing, may enable obtaining it *ex-situ* (Pettorelli et al., 2016; Pyšek et al., 2013; Skidmore et al., 2015). It is also often possible (such as with adequate or targeted alien species occurrence data) to estimate it from existing information sources (Costello et al., 2015; McGeoch et al., 2010).

incremental increases in resolution as observation and monitoring activities increase over time (Fig. 3). Even at the earliest stages of data gathering, alien species occurrence data at coarse scale can be combined with information generated from the other two Essential Variables to inform country actions and feed into global reports (Blackburn et al., 2014).

A modular development of national observation and monitoring systems for alien species from early to advanced stages, corresponding to an increase in the spatial (and potentially temporal) resolution of occurrence data collected, will enable the collation of information across countries at different stages of development (McGeoch and Squires, 2015). Countries build from coarse-scale listing of alien species in selected taxa (early foundation; McGeoch et al., 2012) toward higher spatial resolution data that are taxonomically more comprehensive. Using such a modular approach, the information obtained from countries already at advanced stages, such as Norway (Gereraas et al., 2012; Norwegian Biodiversity Information Centre, http://www.biodiversity.no; although they themselves may not have followed this trajectory historically), can be simplified and combined with information from countries in the early stages (Fig. 3).

To contribute to global invasion monitoring, a country need at first only deliver a national species inventory of aliens present in any part of the country, starting with the best-studied taxa (Fig. 3.1). The Parties to the CBD have identified the need for such inventories, and, although only 11% of countries reported having a national inventory of alien species in 2010, 20% of countries were conducting, or intended to compile a national inventory (Fig. 1; Appendix A). The number of countries and regions with inventories for various taxa, management and policy purposes is increasing (Canhos et al., 2015; UNEP, 2014). More detailed information on the status and distribution of alien species at national levels will facilitate the optimization of management actions and over time incrementally and strategically build on this foundation (van Kleunen et al., 2015).

National systems can be further developed to target fine-scale observations at priority sites or polygons within countries (Fig. 3.2), such as high conservation value areas or sites for early detection of new incursions (McGeoch et al., 2016). In practice, countries reporting national monitoring activities sometimes restrict such activity to industrial sectors such as agriculture and forestry, or to protected areas (Appendix A). In the next stage, these alien occurrence observations can be scaled up to contribute to data on national distributions for selected taxa, starting at fairly coarse resolution or, for example, providing an estimate of the spatial extent (Fig. 3.3). Finally, an advanced observation and monitoring system will include a network of long-term monitoring sites at which alien species occurrence is recorded at regular intervals enabling countries to evaluate and respond to trends in alien species occurrence over time and evaluate the effectiveness of any management actions (Fig. 3.4).

Temporal information is an important attribute of each occurrence record, specifically as monitoring advances. Date of first record of an alien species at a specific locality, as well as absence records as they accumulate, will provide invaluable information for monitoring the dynamics of alien species. For example, in cases where an alien species has been eradicated, an early presence record may be followed by an absence record at a later date. Attributing alien status and temporal information to such species also enables the tracking of invasion history and is invaluable for implementing prevention measures against such invaders that have been shown to establish outside of their native range.

For many countries, the efficiency of invasion monitoring can be improved by inclusion into pre-existing biodiversity monitoring schemes. Countries may capitalize on citizen science (Crall et al., 2010), as well as emerging online and remote technologies in data capture (O'Connor et al., 2015; Pettorelli et al., 2016; Skidmore et al., 2015) to improve records of invasions (Table 2). For all countries the goal should be to provide at regular intervals (at least every five years) alien species occurrence data corresponding to their maximum level of resolution, be it for the national inventory, priority sites, spatial extent, or the national distribution of occurrence of a priority set of taxa (Table 2).

6. Global delivery of information

Recent advances have been made in understanding global and regional patterns in the naturalization of alien taxa, and in biodiversity informatics for global environmental problems, including biological invasions (*e.g.* Capinha et al., 2015; McGeoch et al., 2015b; van Kleunen et al., 2015). Digital infrastructure for big data on Essential Variables is under development (Canhos et al., 2015; Jetz et al., 2012; Nativi et al., 2015). The Global Biodiversity Information Facility (GBIF) and Ocean Biogeographic Information System (OBIS) are international infrastructures for organizing data of species presences in space and time (Costello et al., 2013, 2015). Map of Life (MOL) integrates a variety of species distribution data types, including inventories, with the goal of providing best-possible species range information (Jetz et al., 2012). This data infrastructure provides the platforms necessary for deriving standardized alien species occurrence data.

The Global Invasive Alien Species Information Partnership (GIASIP), initiated in 2012, already delivers a freely accessible mechanism for sharing and integrating data, including an Information Gateway that can accommodate all Essential Variables for monitoring biological invasions (UNEP, 2014). Knowledge products such as the recently launched Global Register of Introduced and Invasive Species (GRIIS; http://www.griis.org/) provide a home for, and access to, verified national inventories (UNEP, 2014). This register links the species name and geographic reference to the country or site of occurrence with primary data sources. It includes over 120 verified national inventories, made available through the Partnership (UNEP, 2014).

The World Register of Introduced Marine Species (WRIMS; Pagad et al., 2015a) adds alien and invasive status to the geographic occurrence of species in the World Register of Marine Species (WoRMS; Costello et al., 2013). The species taxonomy is managed by WoRMS editors and WRIMS editors concentrate on the geographic distribution. The development of WRIMS found numerous instances of unjustified reporting of species as alien in the scientific literature and online resources. This emphasizes the difficulty of quality assurance of data on alien species and how to prevent perpetuation of erroneous information. Other online resources, such as AquaNIS (http://www.marine-vectors.eu/Core_pages/Alien_species_database) and EASIN (http://easin.jrc.ec.europa.eu/) in Europe, and NEMESIS (http://invasions.si.edu/nemesis/browseDB/intro.html) in USA, have a regional focus.

The Global Invasive Species Database (GISD), managed by the IUCN Species Survival Commission Invasive Species Specialist Group (ISSG), contains information on the ecology of alien species. In particular, it contains information on the mechanisms through which alien species impact native communities, with which the EICAT scheme is aligned (Hawkins et al., 2015), and it will also be the repository for completed EICAT assessments.

The combination of infrastructures for storing alien species occurrence and alien impact mechanisms and intensity will eventually provide the possibility of deriving more extensive, localized predictions of impact. Up-to-date range information of alien species can be combined with latest maps on the distribution of impact-related environmental or biotic granularity (*e.g.* the impact in specific habitats, or in relation to prey or host species) for a more detailed and dynamic spatial prediction of potential impacts.

The continued increase in online resources illustrates government and science responses to the threat of alien species. However, none of these resources are complete and expert validation is a continuous cost. Experts are reluctant to spend time repeatedly validating the same information across multiple repositories. Because alien species most often originate from countries other than those in which they have a negative environmental impact, a shared global infrastructure for data management and interpretation is optionally positioned to provide a comprehensive, cost-effective, and sustainable solution (Costello et al., 2014).

7. Conclusion: the road ahead

There is now substantial momentum behind countries delivering information on alien species, with significant progress in the range, quality and scope of information sources, supporting tools, data infrastructure and information systems. Along with the focus on a small set of Essential Variables, a spirit of cooperation and knowledge exchange, and a modular approach to countries delivering information on alien species, the necessary building blocks for a global observation and monitoring system are in place. This system enables contributions from countries across the economic development spectrum.

The approach we outline here provides clear direction and highlights benefits for national and international efforts to collect the data most essential to enable actions to reduce the negative consequences of biological invasions. It is also flexible enough to accommodate data with a range of precision and accuracy for multiple taxa, ecosystems and countries. The system further provides a much-needed platform for improving the performance of indicators of alien species prevalence and impact, and the delivery of reliable information for policy, such as for the Convention on Biological Diversity's Strategic Plan for Biodiversity, 2011–2020 (UNEP, 2011). Once baselines on the status of biological invasions in countries have been achieved, maintaining and updating these over suitable intervals (Table 2) is not an insubstantial task. This task now becomes tangible with the direction provided by Essential Variables for Invasion Monitoring with the information and data management resources now accessible. Ongoing commitment to the vision for a global observation and monitoring system for biological invasions by Parties to the CBD, and scientific support from bodies such as Group on Earth Observations Biodiversity Observation Network (GEO BON) and the IUCN Species Survival Commission Invasive Species Specialist Group (ISSG), provides a strategic and realistic opportunity to launch such a system by 2020.

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Appendix A

Here we present information on existing national inventories of alien species, or related activities, provided by countries to the CBD through the 4th National Reports (Table A1; see Table A1 for detailed explanation of each column). We used 170 of the 4th National Reports submitted to the Convention on Biological Diversity by 30 March 2009, reporting information and measures taken for the implementation of the Convention, to assess progress toward the 2010 Biodiversity Targets. Each of the 4th National Reports was read to identify any reference to inventory or monitoring activity for alien species.

In 2010, only 11% of countries had a national inventory. In addition, 26% of them reported conducting national monitoring activities, and only 8% were implementing actions to create a national inventory (Fig. 1, Table A1). Examination of the national reports revealed information gaps and information management needs, impeding a globally harmonized monitoring scheme. For example, alien species monitoring and control initiatives are sometimes restricted to certain industrial sectors, such as agriculture and forestry, or may be restricted to protected areas. Some countries also relied heavily on regional databases rather than direct assessments.

The Global Invasive Alien Species Information Partnership (GIASIP; http://giasipartnership.myspecies.info/en) was initiated subsequent to 2010 (2012), and now provides national lists of alien species for 250 countries, regions and territories (see text, Section 6. Global delivery of information, for details).

Table A1
Summary of information extracted from 4th National Reports (2010) to the Convention on Biological Diversity. See Table A2 for a detailed description of the information in each column.

Country	National inventories of alien or invasive alien species						Surveillance and monitoring activity	
	National Inventory although may be incomplete	Rely on/use regional database/depend on global databases (outsourced)	Some lists accessible but not comprehensive	Estimates/counts of alien species present in the country	Current activity toward a national inventory	Intended/proposed activity toward a national inventory	Current surveys/surveillance/monitoring	Intended/proposed national surveys/surveillance/monitoring
Afghanistan	0	0	0	0	0	0	0	0
Albania	0	0	0	0	0	0	0	0
Algeria	0	0	0	1	1	1	1	0
Angola	0	0	0	1	0	0	0	0
Antigua and Barbuda	0	0	0	0	0	0	0	0
Argentina	0	0	1	1	0	0	0	0
Armenia	0	0	0	0	0	1	1	0
Australia	1	0	0	1	1	0	1	0
Austria	1	0	0	0	0	0	1	0
Azerbaijan	0	0	0	1	0	0	0	0
Bahamas	0	0	1	1	0	0	0	0
Bahrain	0	0	0	0	0	0	0	0
Bangladesh	0	0	0	0	0	1	0	1

Table A1 (*continued*)

Country	National inventories of alien or invasive alien species						Surveillance and monitoring activity	
	National Inventory although may be incomplete	Rely on/use regional database/depend on global databases (outsourced)	Some lists accessible but not comprehensive	Estimates/counts of alien species present in the country	Current activity toward a national inventory	Intended/proposed activity toward a national inventory	Current surveys/surveillance/monitoring	Intended/proposed national surveys/surveillance/monitoring
Barbados	0	0	0	0	0	1	0	1
Belarus	0	0	1	1	1	0	1	0
Belgium	1	0	1	0	0	0	1	0
Belize	0	0	0	0	0	0	0	0
Benin	0	0	1	0	0	0	0	0
Bhutan	0	0	0	1	0	0	0	0
Bosnia and Herzegovina	0	0	0	0	0	1	0	0
Botswana	0	0	1	0	0	0	1	0
Brazil	1	0	0	0	0	0	0	0
Brunei Darussalam	0	0	0	0	0	0	0	0
Bulgaria	1	0	0	1	0	0	1	1
Burkina Faso	0	0	1	0	0	0	0	0
Burundi	0	0	0	0	0	0	0	0
Cambodia	0	0	0	1	0	1	0	1
Cameroon	0	0	0	1	0	0	0	1
Canada	1	0	0	1	0	0	1	0
Cape Verde	0	0	0	1	0	0	0	0
Central African Republic	0	0	0	0	0	0	0	0
Chad	0	0	0	0	0	0	0	0
Chile	0	1	1	1	0	0	0	0
China	1	0	0	1	0	0	1	0
Colombia	0	0	1	1	0	0	0	0
Comoros	0	0	0	0	0	0	0	0
Cook Islands	0	0	1	1	0	0	1	1
Costa Rica	0	0	0	1	1	0	0	0
Côte d'Ivoire	0	0	0	0	0	0	0	0
Croatia	0	0	1	0	0	1	0	1
Cuba	0	0	0	1	1	0	0	0
Cyprus	0	0	0	1	0	0	0	0
Czech Republic	1	0	0	1	0	0	1	0
Democratic People's Republic of Korea	1	0	0	1	0	1	0	1
Democratic Republic of the Congo	0	0	0	0	0	0	0	0
Denmark	0	1	0	1	0	0	0	0
Djibouti	0	0	0	0	0	0	0	0
Dominica	0	0	0	0	0	0	0	0
Dominican Republic	0	0	0	1	0	0	1	0
Ecuador	0	0	1	1	0	0	1	0
El Salvador	0	1	0	1	0	0	0	0
Equatorial Guinea	0	0	0	0	0	0	0	0
Eritrea	0	0	0	0	0	0	0	1
Estonia	0	0	1	1	0	0	0	0
Ethiopia	0	0	0	0	0	0	0	0
Fiji	0	0	0	0	0	1	1	0
Finland	0	1	1	0	0	1	0	0
France	0	0	1	0	1	0	0	0
Georgia	0	0	1	1	0	0	1	0
Germany	0	0	0	1	0	0	0	0
Ghana	0	0	0	0	0	0	0	0
Grenada	0	0	0	0	0	0	0	0
Guatemala	0	1	1	0	0	0	0	0
Guinea	0	0	0	0	0	0	0	0
Guinea-Bissau	0	0	0	0	0	0	0	0
Guyana	0	1	0	0	0	0	0	0
Honduras	0	0	0	0	0	1	0	0
Hungary	1	0	0	0	0	0	1	0
India	0	0	1	1	0	0	0	0
Indonesia	0	0	0	1	0	0	1	0
Iran (Islamic Republic of)	0	0	0	0	0	0	0	0
Iraq	0	1	0	0	0	0	0	0

(continued on next page)

Table A1 (*continued*)

Country	National inventories of alien or invasive alien species						Surveillance and monitoring activity	
	National Inventory although may be incomplete	Rely on/use regional database/depend on global databases (outsourced)	Some lists accessible but not comprehensive	Estimates/counts of alien species present in the country	Current activity toward a national inventory	Intended/proposed activity toward a national inventory	Current surveys/surveillance/monitoring	Intended/proposed national surveys/surveillance/monitoring
Ireland	0	0	0	1	0	0	0	1
Israel	0	0	1	0	0	0	1	0
Italy	0	0	1	1	1	0	1	0
Jamaica	1	0	0	1	0	0	0	0
Japan	0	0	0	1	0	0	0	0
Jordan	0	0	0	0	0	0	0	0
Kazakhstan	0	1	0	0	0	0	0	0
Kenya	0	0	0	1	0	0	0	0
Kiribati	0	0	0	0	0	0	0	1
Kyrgyzstan	0	0	1	1	0	0	0	0
Lao People's Democratic Republic	0	0	0	0	0	0	0	0
Latvia	0	1	0	0	0	0	0	0
Lebanon	0	0	0	0	0	0	0	0
Lesotho	1	0	0	0	0	0	1	0
Liberia	0	1	0	0	0	0	0	0
Liechtenstein	0	0	1	0	0	0	0	0
Lithuania	0	0	0	1	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0
Madagascar	0	0	0	0	0	0	0	0
Malawi	0	0	0	1	0	0	0	0
Malaysia	0	0	0	0	0	1	0	0
Maldives	0	0	0	0	0	0	0	0
Mali	0	0	0	0	0	0	0	0
Malta	0	0	1	1	1	1	1	1
Mauritania	0	0	0	0	0	0	0	0
Mauritius	0	0	1	1	0	0	1	0
Mexico	1	0	0	1	0	0	0	0
Micronesia (Federated States of)	0	1	1	1	0	1	1	0
Monaco	0	0	0	0	0	0	0	0
Mongolia	0	0	1	0	0	0	0	1
Montenegro	0	0	1	0	0	1	0	0
Morocco	0	0	0	0	0	0	0	0
Mozambique	0	0	0	0	0	1	0	0
Myanmar	0	0	0	1	0	0	1	0
Namibia	1	0	0	0	0	0	0	0
Nepal	0	0	1	0	0	0	0	0
Netherlands	1	0	0	1	0	0	0	0
New Zealand	1	0	0	0	0	0	1	1
Nicaragua	0	0	0	0	0	0	0	0
Niger	0	0	0	0	0	0	0	0
Nigeria	0	0	0	0	0	0	0	0
Niue	0	0	0	1	0	0	0	0
Norway	1	0	0	1	0	0	0	0
Oman	0	0	0	0	0	0	0	0
Pakistan	0	0	0	0	0	0	0	0
Panama	0	0	1	0	0	0	0	1
Papua New Guinea	0	0	0	0	0	0	0	0
Peru	0	0	0	0	1	0	1	0
Philippines	0	1	1	0	0	0	0	0
Poland	0	0	1	0	1	0	1	0
Portugal	1	0	0	1	0	0	0	0
Republic of Congo	0	0	0	0	0	0	0	0
Republic of Korea	0	0	0	1	0	0	1	1
Republic of Moldova	0	0	0	1	0	0	0	0
Romania	0	0	0	0	0	0	0	0
Russian Federation	1	0	0	0	0	1	1	1
Rwanda	0	0	0	0	0	0	0	0
Saint Lucia	0	0	0	0	0	0	0	1
Saint Vincent and the Grenadines	0	0	0	0	0	0	0	0
Samoa	0	0	0	0	0	0	1	1
Sao Tome and Principe	0	0	0	0	0	0	0	0

Table A1 (*continued*)

Country	National inventories of alien or invasive alien species						Surveillance and monitoring activity	
	National Inventory although may be incomplete	Rely on/use regional database/depend on global databases (outsourced)	Some lists accessible but not comprehensive	Estimates/counts of alien species present in the country	Current activity toward a national inventory	Intended/proposed activity toward a national inventory	Current surveys/surveillance/ monitoring	Intended/proposed national surveys/surveillance/ monitoring
Senegal	0	0	0	0	0	0	0	0
Serbia	0	0	0	1	0	0	0	0
Seychelles	0	0	0	0	0	0	0	0
Singapore	0	0	0	0	0	0	1	0
Slovakia	0	0	1	0	0	0	0	1
Slovenia	0	0	0	1	0	0	0	1
Solomon Islands	0	1	0	1	0	0	0	0
South Africa	0	0	0	1	0	0	0	1
Spain	0	0	1	1	1	0	1	0
Sri Lanka	0	0	0	1	0	0	0	0
Sudan	0	0	0	0	0	0	0	0
Suriname	0	0	0	0	0	0	0	0
Swaziland	0	0	1	0	0	0	0	0
Sweden	0	1	0	1	0	0	1	0
Switzerland	0	0	1	1	0	0	1	1
Syrian Arab Republic	0	0	0	0	0	0	0	0
Tajikistan	0	0	0	1	0	0	0	0
Thailand	0	0	1	1	0	0	0	1
The former Yugoslav Republic of Macedonia	0	0	0	0	0	0	1	0
Timor-Leste	0	1	0	1	0	0	0	0
Togo	0	0	0	0	0	0	0	0
Tonga	0	0	0	0	0	0	0	0
Trinidad and Tobago	0	0	0	1	0	0	1	0
Tunisia	0	0	0	1	1	0	1	0
Turkey	0	0	0	1	0	0	0	1
Turkmenistan	0	1	0	1	0	0	1	1
Tuvalu	0	0	0	0	0	0	0	0
Uganda	0	0	1	0	0	0	1	0
Ukraine	0	0	1	0	0	0	1	0
United Kingdom of Great Britain and Northern Ireland	0	0	0	1	1	0	1	0
United Republic of Tanzania	0	0	0	0	0	0	0	0
Uruguay	0	0	1	0	1	1	0	0
Venezuela (Bolivarian Re-public of)	0	0	0	1	0	1	1	1
Viet Nam	0	0	1	0	0	0	0	0
Yemen	0	0	0	0	0	1	0	1
Zambia	0	0	0	0	0	0	0	0
Zimbabwe	0	0	1	0	0	0	1	0
Sum	19	16	41	67	14	20	44	28
Sample size	170	170	170	170	170	170	170	170
Proportion	0.11	0.09	0.24	0.39	0.08	0.12	0.26	0.16

Table A2
Descriptions of the columns of Table A1.

Category	Interpretation
National Inventory although may be incomplete	Scored as a 1 if a country clearly states or provides evidence of a national inventory for alien species. An inventory may be restricted to certain taxa (*e.g.* plants or vertebrates).
Rely on/use regional database/depend on global databases (outsourced)	Scored as a 1 if a country has evidently mentioned or provided species lists from a regional or global database (*e.g.* Nobanis; ISSG, DAISIE).
Some lists accessible but not comprehensive	Any lists of alien species (excluding regional/global lists) that are provided/mentioned in the report, that are not explicitly part of an alien species national inventory. This includes lists pertaining to specific taxonomic groups (*e.g.* plants).
Estimates/counts of alien species present in the country	Scored as a 1 if the report mentions an estimated or realized number of alien species within the country. This may be restricted to certain taxa (*e.g.* estimates of fish species).

(continued on next page)

Table A2 (*continued*)

Category	Interpretation
Current activity toward a national inventory	Scored as a 1 when a country directly states or gives evidence that activity toward a national inventory is currently in progress.
Intended/proposed activity toward a national inventory	Scored as a 1 when a country directly states or gives evidence that activity toward a national inventory is intended/proposed.
Current surveys/surveillance/monitoring	Scored as a 1 when a country gives direct evidence/examples of current national surveys, surveillance or monitoring activities of alien species.
Intended/proposed national surveys/surveillance/monitoring	Scored as a 1 when a country gives direct evidence/examples of proposed or intended national surveys, surveillance or monitoring activities of alien species.

Appendix B. Outputs from the elicitation process

Table B1
List of variables and metrics collated across groups after Day 1, categorized by whether they relate to either native or alien species, the impacts of alien species or attributes of the broader community or ecosystem.

Category	Variable
Native species	Richness
	Change in conservation status of species threatened by alien species
	Number of native species impacted by aliens
	Biomass[a]
	Number of locally extinct
Alien species	Alien species identity
	Richness (number of alien species)
	Biomass (or as a proportion of native biomass)
	Range size
	Rate of spread
	Functional group
	Number of alien species with high impact[a]
	Number and identity of invasive alien species[a]
	Rates of naturalization (number of new species over time)[a]
	Propagule pressure (number of individuals
Invasion impact	Number or percentage of RedList threatened species impacted by alien species
	Proportion of alien species per magnitude of impact (EICAT)
	Change in impact (or impact category in EICAT) over time
	Sum of impact scores (Nentwig et al., 2010)
	Number of alien species with high impact[a]
Community/ecosystem/environment	Food web structure
	Community stability (temporal turnover)
	Community evenness[a]
	Vulnerability of a region to invasion[a]
	Impact on ecosystem function[a]
	Change in total biomass due to invasion[a]
	Change in functional or phylogenetic diversity or trophic structure due to invasion[a]

[a] Variables placed on long-lists rather than on any short list.

Table B2
List of variables and metrics collated across the shortlists of groups after Day 2, categorized by whether they relate to either alien species, the impacts of alien species or attributes of the broader community or ecosystem. The Essential Variables were distilled from this list by discussion, and remaining variables considered important were distilled as 'supplementary variables' (see text).

Category	Variable
Alien species	Presence (occupancy) of alien species (site-specific species list)
	Identity of alien species (species list), classification as alien or native
	Biomass or abundance
	Functional group of each species
	Number and rate of introductions
	Richness (identity) of aliens per site
Invasion impact	Impact on biodiversity (impact scores)
	Sum of impact scores
Community/ecosystem/environment	Densities of vectors (roads, people, entry points)
	Risk activities (*e.g.* pet traders, horticulture, botanic gardens)

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