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A vision for global monitoring of biological invasions

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ABSTRACT

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

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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)

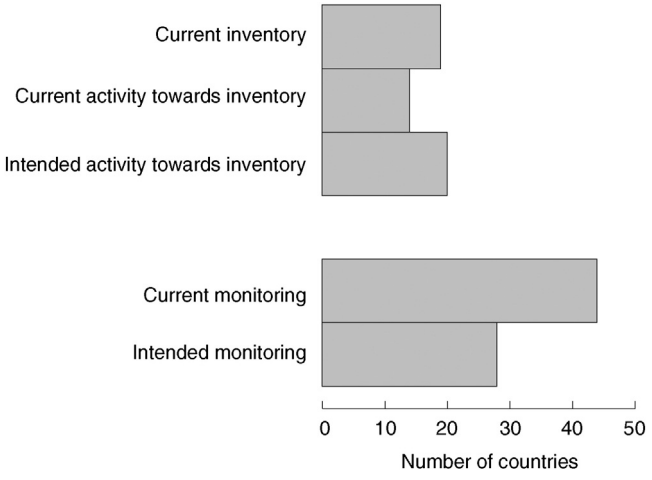

Fig. 1. The number of countries in 2010 ($n = 170$) reporting to have inventories and monitoring activities for alien species at different stages of development.

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