Biological Conservation 179 (2014) 25–32

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

A simple, rapid methodology for developing invasive species watch lists

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ARTICLE INFO

Article history:
Received 5 May 2014
Received in revised form 12 August 2014
Accepted 20 August 2014
Available online 16 September 2014

Keywords:
Biological invasions
Biosecurity
Invasive elsewhere
Pre-border control
Propagule pressure
Risk assessment

ABSTRACT

Biosecurity schemes aim to prevent the introduction of species with a high invasion potential, without unduly restricting personal freedom and commercial activities. But invasive species risk assessments are time consuming, data intensive and expensive. Consequently, resource poor nations cannot implement these schemes. Here we develop a method for creating watch lists using the consistent predictors of invasion success—history of invasion, environmental suitability, and propagule pressure (measured respectively using the Global Invasive Species Database (GISD), environmental modelling, and tourism and trade data). We tested the approach for South Africa, at a national level for various taxa and at a provincial level for plants. Of 884 alien species listed in the GISD, 400 were potential invaders, with most occurring in high risk regions. When alien species in South Africa were evaluated there were many false-negatives (sensitivity of 32% for terrestrial and 40% for marine species), because the GISD is not comprehensive, but few false positives (specificity of 91% for terrestrial and 89% for marine species). The methodology was easy to apply at different political levels, but we found substantial overlaps between the national and provincial watch lists of plants. This simple technique is rapid, easily repeatable, flexible, transparent, works across taxa, and does not require substantial financial or scientific input. It can be used in any region of the world and at various political levels as an initial assessment of key threats. As such it may be an important step in developing biosecurity schemes for resource poor regions.

1. Introduction

Intentionally and unintentionally introduced alien organisms can become invasive and cause economic and ecological impacts (Pimentel et al., 2001; Simberloff et al., 2013). To prevent or lessen the negative impacts, management strategies are needed that can target species that pose substantial threats. However, many countries have severely limited resources to implement the required biosecurity policies (McGeoch et al., 2010).

Often the most cost-effective way to manage alien species is to prevent their introduction (Leung et al., 2002; Simberloff, 2006; Simberloff et al., 2013; Wittenberg and Cock, 2005), but under international agreements (e.g. the World Trade Organisation's Agreement on the Application of Sanitary and Phytosanitary Measures), any restrictions that prevent introductions should not unduly restrict trade (Mumford, 2002; Simberloff, 2006). Moreover, as only a few alien species have become invasive (Williamson and Fitter, 1996) (e.g. <1% of all tree and shrub species (Richardson and Rejmánek, 2011)), it is not feasible, desirable or necessary to prevent the introduction of all alien species (Mumford, 2002). Therefore, prevention strategies must focus on those with a demonstrably high potential impact.

To achieve this, pre-border invasive species risk assessments have been developed to evaluate introductions (Daehler et al., 2004; Kumschick and Richardson, 2013; Pheloung et al., 1999). Risk assessments, however, can be time-consuming, labour intensive and expensive. They are usually not suited for screening numerous species (McClay et al., 2010), are data intensive (Hayes and Barry, 2008), and for some taxa there are no methodologies in place (Kumschick and Richardson, 2013). As an example of the time and costs involved, the US National Research Council estimates that assessments for most planned introductions could take several years (Simberloff, 2005), while in Australia the annual cost of conducting such assessments might be as much as 300 000 Australian dollars (Keller et al., 2007). While there may still be a net economic benefit to their implementation (Keller et al., 2007), such slow evaluations delay trade (Simberloff, 2006).

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http://dx.doi.org/10.1016/j.biocon.2014.08.014
0006-3207/

Another widely used pro-active approach is to create watch lists that can be used to identify threats that require monitoring. These lists identify species with an invasion history that are absent from the study region but that could pose an invasion risk if introduced intentionally or unintentionally (e.g. 'black list–warning list' of Essl et al. (2011) and 'warn list' of Nehring and Klingenstein (2008)). Watch list methodologies are often less exhaustive than full pre-border risk assessments, for example the 'Alert list' of the Belgian Harmonia system is based on only three criteria (the taxon is absent from Belgium, present in neighbouring regions that are eco-climatically similar, and has the potential for a high environmental impact (Branquart, 2007)). Watch lists are important tools that can aid in decision making and the development of preventative strategies and contingency plans (Nehring and Klingenstein, 2008; Parrott et al., 2009), for example, they can be used to direct monitoring and inspection efforts to limit accidental introductions (Bacon et al., 2012). Additionally, watch lists can serve as a list with which to prioritise post-border assessments and control efforts (Nehring and Klingenstein, 2008; Parrott et al., 2009).

Unfortunately, the methods and criteria used in developing watch lists are often not transparent and decisions are based solely on expert opinion. Here we aim to develop a transparent, simple, rapid, and inexpensive watch list methodology suitable for resource poor regions that is based on sound scientific principles and that could be used for the initial assessment of a wide range of taxa. We test the methodology using South Africa as a case study. The resultant methodology can be used in any region of the world and at various political levels for the rapid initial assessment of potential future invasive species.

2. Methodology

2.1. Concept and criteria

Our approach relies on three well-tested criteria: history of invasion, environmental suitability and propagule pressure (Fig. 1). To achieve our aim the evaluation criteria had to be applicable to many taxa and only readily available data could be utilised. Consequently, a history of invasion and environmental match were selected, as these criteria are consistent predictors of invasion success across taxa (Hayes and Barry, 2008; Hulme, 2012; Kolar and Lodge, 2001), and the data required (invasive species lists, occurrence records and environmental data) are readily available. Propagule pressure was additionally selected as this criterion is often a key determinant of establishment success (Hayes and Barry, 2008; Kolar and Lodge, 2001; Lockwood et al., 2005). The use of these three criteria for the identification of potentially invasive species is well established (e.g. Locke, 2009; Thuiller et al., 2005) and the resultant watch list includes any alien species that has not yet been introduced but that meets all three of these criteria (Fig. 1). Finally, as propagule pressure data are not available for most species, we used a readily available proxy (trade and tourism data) for propagule pressure and developed three thresholds for this criterion.

2.2. Watch list methodology

The proposed procedure for developing a watch list is set out in Fig. 2: (1) obtain a global list of invasive species; (2) filter out species already present in the target region (native species or alien species already introduced); (3) gather distribution data from the remaining species' native and invasive ranges; (4) use the distribution data to determine whether the target region is environmentally suitable or not; and (5) determine if there is propagule pressure from any region where the species occurs to the target region. We demonstrate this approach for South Africa.

2.2.1. Obtain a global list of invasive species

To identify species with a history of invasion, the Global Invasive Species Database (GISD) was accessed online (http://www.issg.org/database/welcome/) and taxonomic information for all listed species was extracted. Information on organism type and environment were additionally obtained from the database and were used to classify each species as either 'marine' (exclusively inhabits estuarine or marine environments) or 'terrestrial' (includes freshwater species).

2.2.2. Filter out species present in the target region

Species in the GISD that are already present in South Africa were identified using databases and references (Plants of Southern Africa: an online checklist version 3.0 (Morris and Glen, 1978); Wells et al., 1986; South African Plant Invaders Atlas 2012 (Henderson, 1998); CABI, 2013; Faulkner, unpublished data) as well as a literature search in Google Scholar (using the name of each species and "South Africa"). Species recorded as present in South Africa were removed from the GISD list, resulting in a list of candidate species ('candidate list').

2.2.3. Gather distribution data from the native and introduced ranges

For each candidate species, occurrence data from the native and introduced ranges were obtained from the Global Biodiversity Information Facility (GBIF, http://www.gbif.org/). Records with missing or incomplete coordinate data were excluded, and marine and terrestrial data were classified as appropriate. Species without any GBIF records were classified as 'requiring further study'.

2.2.4. Determine whether the target region is environmentally suitable

The level of complexity required of environmental matching techniques was evaluated using two simple climate matching techniques for terrestrial species and a third, more complex, published technique (Richardson and Thuiller, 2007). Additionally, for marine species a classification of the world's oceans was utilised.

Firstly, the Köppen–Geiger climate classification (Kottek et al., 2006) was employed to identify terrestrial locations that have similar climate zones to those present in mainland South Africa. As the Köppen–Geiger classification is relatively coarse, we secondly used a more stringent method based on the bioclimatic envelopes of the biomes found in South Africa (based on the classification of Olson et al. (2001)). South African biome data (truncated at the South African borders, but including Lesotho) were rasterized at a 10 min $\times$ 10 min grid resolution and converted into point data. The terrestrial areas of the world with climatic conditions similar to each biome present in South Africa were then identified using the climate envelope modelling method BIOCLIM (method equivalent to 'marginal bioclimate' (Carpenter et al., 1993)). We considered four climatic parameters (mean annual temperature, minimum temperature of the coldest month, maximum temperature of the hottest month and mean annual precipitation) from the WorldClim 10 min $\times$ 10 min data (Hijmans et al., 2005). These general climatic variables were selected so that the watch list methodology can be used for a wide range of taxa. To allow for more inclusive models (fewer omission errors), all predicted areas (percentiles 0–100) were included in the final prediction (see Fig. A1 in Appendix A). This analysis was performed in the open-source GIS software DIVA-GIS (version 7.5.0, http://www.diva-gis.org) to ensure that the methodology can be widely used.

The third method used for terrestrial taxa was based on a more complex method developed by Richardson and Thuiller (2007). Generalised additive models were used to identify regions of the world that are climatically analogous to the South African biomes