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Developing and testing alien species indicators for Europe

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ABSTRACT

Alien species indicators provide vital information to the biodiversity policy sector on the status-quo and trends of biological invasions and on the efficacy of response measures. Applicable at different geographical scales and organizational levels, alien species indicators struggle with data availability and quality. Based on policy needs and previous work on the global scale, we here present a set of six alien species indicators for Europe, which capture complementary facets of biological invasions in Europe: (a) an combined index of invasion trends, (b) an indicator on pathways of invasions, (c) the Red List Index of Invasive Alien Species (IAS), (d) an indicator of IAS impacts on ecosystem services, (e) trends in incidence of livestock diseases and (f) an indicator on costs for alien species management and research. Each of these indicators has its particular strengths and shortcomings, but combined they allow for a nuanced understanding of the status and trends of biological invasions in Europe. We found that the scale and impact of biological invasions are steadily increasing across all impact indicators, although societal response in recent years has increased. The Red List Index is fit-for-purpose and demonstrates that overall extinction risks (here shown for amphibians in Europe) are increasing. Introduction pathway dynamics have changed, with some pathways decreasing in relevance (e.g., biological control agents) and others increasing (e.g., horticultural trade) providing a leverage for targeted policy and stakeholder response. The IAS indicators presented here for the first time on a continental basis serve as a starting point for future improvements, and as a basis for monitoring the efficacy of the recent EU legislation of IAS. This will need a better workflow for data collection and management. To achieve this, all main actors must work toward improving the interoperability among existing databases and between data holders.

1. Introduction

The human-mediated introduction of species into previously inaccessible regions has become a defining feature of global environmental change (Tittensor et al., 2014). Invasive alien species (IAS) are the subset of these species that poses a risk to biodiversity (Blackburn et al., 2014; CBD, 2002) and related ecosystem services (Vilá et al., 2010; EU, 2014), human, animal or plant health or the economy (Scalera, Genovesi, Essl, & Rabitsch, 2012). According to the most recent global analysis of the Red List (IUCN, 2012), IAS constitute the fifth most severe threat to amphibians, the fourth to reptiles, the third to birds and mammals, and the second to freshwater fish species (Vié, Hilton-Taylor, & Stuart, 2009).

Globally, the scale and impacts of biological invasions are increasing (Butchart et al., 2010; McGeoch, Chown, & Kalwij, 2006; McGeoch et al., 2010). In particular, increasing trade and delayed responses in establishment and spread of alien species (Essl et al., 2011) and other drivers of global change as climate change (Bellard et al., 2013; Walther et al., 2009) will likely foster future introductions of invasive organisms. In response to these increasing

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pressures, the European Union (EU) has recently adopted a dedicated legislation on IAS (EU, 2014), which aims to reduce the future impacts of alien species (Genovesi, Carboneras, Vilà, & Walton, 2015). To assess the scale and temporal trajectories of alien species impacts in Europe and to provide a baseline assessment for the future evaluation of EU IAS-policy, developing and testing indicators on alien species has become an urgent need.

Biodiversity indicators, and more specifically alien species indicators, are an integral part of the biodiversity policy sector and used for providing information on the trends, status-quo and likely future development of the drivers, pressures, status, impact and response that relate to the subject (Butchart et al., 2010; Genovesi, Butchart, McGeoch, & Roy, 2012a; Tittensor et al., 2014; Armon & Zenetos, 2015). In recent years, there was substantial progress in developing and applying alien species indicators. In particular, the Global Biodiversity Outlook 3 for the first time introduced an indicator based on the cumulative number of alien species to measure the global progress toward the 2010 biodiversity targets (Butchart et al., 2010). Subsequently, this indicator has been presented in detail by McGeoch et al. (2010). Within the Biodiversity Indicators Partnership (http://www.bipnational.net/) invasive alien species indicators are developed further to ensure that CBD-Aichi Target 9 ("By 2020, 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") can be monitored at the global level. Recently, a mid-term assessment was provided by Tittensor et al. (2014) for the Global Biodiversity Outlook 4 providing further evidence of the increasing pressure executed by IAS.

In Europe, a set of IAS indicators corresponding to the 'Driving Forces-Pressures-State-Impacts-Responses' (DPSIR) framework was developed within the 'Streamlining European Biodiversity Indicators 2010′ process (EEA, 2012). Subsequently, Rabitsch, Essl, Genovesi and Scalera (2012) proposed the development of a set of indicators to measure progress toward both the Aichi biodiversity targets, and the targets adopted in Europe within the EU Biodiversity Strategy to 2020 (EC, 2011). Building on these preceding initiatives, we test the applicability of six alien species indicators which capture complementary facets of biological invasions in Europe: (a) a combined index of invasion trends, (b) an indicator on pathways of invasions, (c) a Red List Index of IAS, (d) an indicator of IAS impacts on ecosystem services, (e) trends in incidence of livestock diseases and (f) an indicator on costs for alien species management and research. We hence discuss the suitability of these indicators in relation to the following questions: (i) What are their specific strengths and constraints? (ii) Does the indicator answer the posed policy question? (iii) Can the indicator be applied in a European and global context? and (iv) What are the gaps in data coverage and which avenues allow for closing these?

2. Material and methods

2.1. Combined index of invasion trends

This trend indicator provides information on accumulation rates of alien species in Europe over time. To ensure a broad taxonomic coverage, we used data on the year of first observation records from five groups: mammals (Genovesi, Carnevali, Alonzi, & Scalera, 2012b; P. Genovesi, unpubl.), marine metazoans (VECTORS project, S. Olenin, unpubl.), terrestrial arthropods (Roques et al., 2010 with updates in 2012), vascular plants (data until 2005, J. Pergl, unpubl.), and bryophytes (Essl, Steinbauer, Dullinger, Mang, & Moser, 2013). Whereas records on arthropods and mammals only included established species, records on the other groups also included casuals and species with unknown invasion status. To calculate the relative increases in species numbers from 1900 onwards, we standardized the numbers of alien species recorded in Europe in 1900 for each taxonomic group to one. Then, we calculated for each taxonomic group the relative increase in alien species from the year 1900 to 2010 in decadal increments. According to Butchart et al. (2010) we calculated the geometric mean of these taxonomic indices, i.e., each taxonomic group contributes equally to this index, irrespective of the large differences in species numbers for which the year of first record is known: mammals ($n = 38$ species), marine metazoans ($n = 662$ species), arthropods ($n = 1424$ species), vascular plants ($n = 3660$ species) and bryophytes ($n = 87$ species).

2.2. Indicator on pathways of invasions

The contribution of specific pathways to invasions often changes substantially over time due to consumer behavior, fashion and economic trends (Nentwig, 2007; Kowarik & von der Lippe, 2007; Rabitsch et al., 2013; Essl et al., 2015). Despite on-going efforts toward harmonized definitions (CBD, 2014; Hulme et al., 2008), a standard pathway terminology has not yet been adopted by the many different alien species data sources. We evaluated the pathway indicator for Europe using data from an updated version of the DAISIE-database (www.europe-aliens.org; as of September 2012), to demonstrate trends in the most important pathways (Horticulture/Ornamentals, Stored product pests, Biological control, Forestry, Unknown) of alien terrestrial arthropod species in Europe. We exemplarily selected arthropod species because of the large number of species, and recent updates of pathway assignments and time of first records in Europe.

2.3. The Red List Index of IAS

The Red List Index (RLI) of IAS permits to calculate overall rates at which species impacted by IAS are moving toward or away from extinction. This indicator was originally developed by Butchart et al. (2007, 2010) and calculated from the number of species in each Red List category and the number of species which were changing categories between Red List assessments. It can only be applied when at least two comprehensive Red List assessments are available. Unfortunately, the IUCN European Red Lists currently have only one data point in time and can therefore not be used for calculating a European RLI for the time being. Therefore, we used the global IUCN Red List assessments and selected amphibians as model group. Many amphibian species are in particularly strong decline worldwide (e.g., Hof, Araújo, Jetz, & Rahbek, 2011; Sodhi et al., 2008), and the proportion of species facing extinction risk is the highest of all vertebrate groups (IUCN, 2012; Stuart et al., 2004). In addition, amphibians are known to be particularly affected by IAS and associated pathogens and diseases (Hof et al., 2011). We extracted a complete list of native European amphibian species from the IUCN database (IUCN, 2012) and compared their Red List assessments of the years 2004 and 2009. We then used the "Major threats" described in the assessments to check if IAS are hold responsible for the deterioration of the status of the native species. For calculations we used the freely available 'RLI-Calculator' (http://www.birdlife.org/action/science/indicators/rli.html) to analyze changes in the RLI.

2.4. Indicator of IAS impacts on ecosystem services

Ecosystem services are the direct and indirect contributions of ecosystems to human wellbeing (TEEB, 2010). Depending on the applied definition, these include provisioning, regulating, and cultural services that directly affect people and the supporting services needed to maintain other services. To develop and test a measure of the impact of IAS on ecosystem services in Europe we analyzed