Ecological Indicators 91 (2018) 182–188

Contents lists available at ScienceDirect

Ecological Indicators

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

Original Articles

Plant invasions in Italy: An integrative approach using the European LifeWatch infrastructure database

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ARTICLE INFO

Keywords:
Abiotic factors
Biotic factors
Climate
LifeWatch
LTER-Italy network
Propagule pressure

ABSTRACT

By using the LifeWatch database – a European e-science infrastructure on native and alien plant occurrence collected from a wide set of Italian terrestrial sites – we estimated the occurrence of alien species in a cross-habitat framework in relation to propagule pressure (P), abiotic (A) and biotic (B) conditions. The research represents an example of macro-ecological assessment of invasion risk at national scale claimed by the recent European regulation (EU 1143/2014) on invasive alien species. Based on a large vegetation dataset, we estimated alien and native species richness across a set of 19 Italian terrestrial sites. By using a Generalized Linear Mixed Model, we investigated the relationship between the proportion of alien occurrence across sites and habitat types (EUNIS) at family level with PAB putative drivers derived from LifeWatch and other open access geographic databases. Our results support the full model as the best-fitting option, highlighting that plant invasion in the Italian terrestrial ecosystems is a function of the combination of PAB conditions. In the first step of the invasion process, the accessibility time from towns plays a major role. By contrast, the abiotic filter imposed by environmental condition (high temperatures and low precipitations) as well the competition with the native community (high species richness) may pose a limit to the settlement and spread of alien species. Because of the high availability of similar data on PAB conditions worldwide, this study represents an effective and easy tool to design appropriate biodiversity conservation policies focused on the prevention of alien spread.

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https://doi.org/10.1016/j.ecolind.2018.03.038
Received 21 October 2017; Received in revised form 15 March 2018; Accepted 16 March 2018

1. Introduction

Biological invasions have become a global issue constituting a major threat to biodiversity and requiring urgent solutions (Ehrenfeld, 2010; Early et al., 2016). Successful invasions are relatively rare (Williamson and Fitter, 1996) and depend on the interaction of several drivers, but once the species is established in a new area, it is difficult to eradicate or control it effectively. The most valuable method to reduce its impact is to prevent establishment or spread in the first place (Duncan et al., 2003; Early et al., 2016). Determining what makes habitats vulnerable to biological invasion is therefore among the most important targets in ecology (Chytrý et al., 2008). However, in order to manage invasive species, an understanding of the mechanisms that contribute to the success of the invaders is required (Pauchard and Shea, 2006). Many hypotheses have been formulated to explain successful biological invasion, most of which attribute it to the interplay between invasiveness (i.e. the biologically-related property of species to become established, spread to or become abundant in new communities) and invasibility (i.e. the susceptibility of habitats to the establishment or proliferation of invaders) (Colautti and MacIsaac, 2004). However, few studies have integrated these two aspects and most have instead generally focused on one single mechanism (Kueffer et al., 2013). Indeed, invasion success is due to a combination of factors and mechanisms, and it is likely to be context-dependent (Catford et al., 2009). There are high numbers of supported explanations for invasion success, but the main drivers thereof are usually tested in isolation (McGill et al., 2007), and consequently observations differ quite often among studies, sometimes showing opposite results (Lockwood et al., 2005). There is an increasing need for a synthetic approach in which as many drivers as possible are considered (Kueffer et al., 2013; Bazzichetto et al., 2018). Such an exhaustive approach has been proposed by Catford et al. (2009), in order to explain the invasion success of exotic species in a given site. The authors outline a wide range of non-exclusive drivers summarised into three major groups: propagule pressure, abiotic conditions of the invaded ecosystems and biotic characteristics (recipient community and invading species). They claim that the degree of invasion is driven by a combination of these three factors, even though their influence is unlikely to be equal and the incursion is usually interwoven with anthropogenically induced disturbances (Byers, 2002).

Propagule pressure is often the key driver of invasion and may reveal its idiosyncratic nature (Lockwood et al., 2005). Propagule pressure is defined as the number and frequency of propagules arriving at a site to which they are not native (Lonsdale, 1999), and is related with different factors, such as density of human population, numbers of visitors in nature reserves, proportion of urban or industrial land cover, land cover change, road density or the intensity of traffic and trade (Thuiller et al., 2005; Von der Lippe and Kowarik, 2007; Malavasi et al., 2014). Factors governing success also include an organism's ability to colonize and settle in specific abiotic conditions. An invasion will fail if the invading species cannot withstand the environmental filters and conditions of a site (Weiher and Keddy, 1995; Chytrý et al., 2008). Several hypotheses attribute invasion degree to environmental characteristics, together with a change in resource availability (Blumenthal, 2006); for example, when an increase in unused resources occurs, communities could be more susceptible to invasion (Melbourne et al., 2007). Generally, alien plants occurrence has a strong, significant relationship with water availability, and therefore climate, thereby increasing species richness when precipitation increases and the summer drought period becomes shorter (Martin-Fores et al., 2015). Moreover, an alien species entering a new area will gain or lose biotic interactions, which might promote or constrain invasion (Mitchell et al., 2006). Among these interactions, native richness is known to play a significant role in biotic resistance (Levine et al., 2004). Elton (1958) first forged the notion of biotic resistance to non-native invaders, defined as the degree of resistance offered by native communities, to explain the heavy invasion of species-poor systems such as island and anthropogenically disturbed areas. Higher native species richness is expected to reduce nutrient availability and intensify competition, predation, disease and parasites (Von Holle and Simberloff, 2005). In turn, these factors may reduce niche opportunities for invaders and play a role in biotic resistance (Shea and Chesson, 2002). However, the exact way in which native species richness influences alien invasion has not yet been clarified convincingly (Pauchard and Shea, 2006; Stohlgren et al., 2006; Carboni et al., 2013).

For many years, biological invasion studies were performed on single habitats or sites, or restricted to one or just a few species, and only with the recent compilations of large datasets of vegetation from all the major habitats of a country or large region, an increase in more extended studies has occurred (van Kleunen et al., 2015). Nonetheless, many of them are often confined to understanding different levels of invasion among habitats (Chytrý et al., 2009) by focusing on a single driver (Pyšek et al., 2010), species or taxonomical group (Feng et al., 2016; Taylor et al., 2016), while few have attempted to model invasion in a cross-habitat framework over a large set of taxonomic groups (Pyšek, and Chytrý, 2014; Bellard et al., 2016).

The impact of biological invasions has been a widespread problem in Europe, where it currently poses a major threat to both biodiversity conservation (DAISIE, 2009; EEC, 2014; Genovesi et al., 2015) and ecosystem functioning (Beninde et al., 2015), causing significant economic losses (Hulme et al., 2009). In response, the European commission proposed a strategy (EC, 2008) and a recent regulation on invasive alien species (EEC, 2014) that among others emphasizes prevention as one of the most cost-effective approaches. Still, the identification of different prevention actions depends on the national capacities to analyze and model species invasions and it should be favored by the existence of standardized open databases (DAISIE, 2009).

Based on this background, the challenge of this work is to apply an exhaustive synthetic approach whereby relative studies are placed within a robust, general theoretical framework proposed by Catford et al. (2009), in order to describe the context of plant invasion and to understand how the mechanisms relate to each other in such a macro-ecological environment. The here proposed analysis, developed using open data, sets a good example of macro-ecological assessment of invasion risk at national scale which is claimed by the recent regulation (EU) No 1143/2014 on invasive alien species (EEC, 2014; Genovesi et al., 2015; Beninde et al., 2015). In order to do this, we used the database assembled by LifeWatch, the e-Science and Technology European Infrastructure for Biodiversity and Ecosystem Research on native and alien plant occurrence (Basset and Los, 2012). LifeWatch aims to provide major contributions to addressing big environmental challenges by providing access through a pan-European distributed e-infrastructure to large sets of data, services and tools. The native and alien plant dataset is the result of systematically collating the species lists collected in a wide set of Italian terrestrial sites, including sites from the LTER-Italy network and the CONECOFOR ICP-Forest network. By using this dataset, we attempt to estimate the occurrence of plant alien species over a large set of taxonomic groups in a cross-habitat framework in relation to propagule pressure, abiotic and biotic conditions.

2. Materials and methods

2.1. Study area

In Italy, 13.4% of the national vascular flora is represented by non-native taxa (Celesti-Grapow et al., 2009). Their introduction and establishment may date back thousands of years, because of Italy's historical position at the centre of the main trade routes and a long history of human activity (Celesti-Grapow et al., 2009). Moreover, offering a wide range of environmental contexts, Italy represents a worthwhile model for study. To our knowledge, at the Italian national level, only Celesti-Grapow et al. (2009) have attempted to identify the main large-scale drivers of alien species invasion, albeit only accounting for