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Sampling alien species inside and outside protected areas: Does it matter?

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HIGHLIGHTS

- We examine patterns of alien species richness inside and outside protected areas.
- Alien species richness is lower in protected areas due to lower human activities.
- Can we reach conclusions about non-protected regions by monitoring protected areas?
- Yes, we can, if the anthropogenic activity is accounted for.

GRAPHICAL ABSTRACT

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ABSTRACT

Data of alien species presences are generally more readily available in protected than non-protected areas due to higher sampling efforts inside protected areas. Are the results and conclusions based on analyses of data collected in protected areas representative of wider non-protected regions? We address this question by analysing some recently published data of alien plants in Greece. Mixed effects models were used with alien species presences in 8.25 × 8.25 km cells as dependent variable and the percentage of protected area, as well as the agricultural and artificial land cover types richness (as indicators of human presence) as independent variables. In addition, the spatial cross-correlation between the percentage of protected area and alien species richness was examined across scales. Results indicated that the percentage of protected area per cell is a poor predictor of alien species richness. Spatial analysis indicated that cells with higher percentage of protected areas have slightly less alien species than cells with lower percentage of protected areas. This result is likely to be driven by the overall negative correlation between habitat protection and anthropogenic activities. Thus, the conclusions deduced by data deriving from protected areas are likely to hold true for patterns of alien species in non-protected areas when the human pressures are accounted for.

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1. Introduction

Alien species are non-native taxa introduced by human agency to areas beyond their natural distribution and bio-geographical barriers (Falk-Petersen et al., 2006). Some alien species may become invasive, with important impacts on biodiversity, human health, and ecosystem services, through competition, predation, toxicity, transmission of pathogens, and the disruption of ecosystem functions (Vilà et al., 2011; Mazza et al., 2014; Katsanevakis et al., 2014). With the human population being higher than ever before and increasing, together with unprecedented rates of mobility of humans and goods, the human assisted movement of living individuals or propagules beyond their natural distributions and across biogeographical barriers (Richardson et al., 2011) has been accelerating (Seebens et al., 2017). Biological invasions are at the forefront of research in many disciplines such as ecology, conservation, epidemiology and food security (Giakoumi et al., 2016; He et al., 2017; Katsanevakis et al., 2014; Silva et al., 2009).

Protected areas are not immune to being invaded by alien species, and the risks can be high when this happens (McKinney, 2002; van Wilgen et al., 2016). Although management measures in protected areas and the expected increase of biodiversity and improvement of ecosystem functioning could control biological invasions, according to the ‘biotic resistance’ and ‘diversity-stability’ hypotheses (Jeschke, 2014), a number of studies has reported the opposite pattern, i.e. a positive correlation between alien and native species, according to the ‘acceptance’ hypothesis (Bjarnason et al., 2017; McKinney, 2002).

To protect its habitats and species diversity, the European Union (EU) has created the Natura 2000 network of protected areas, which is one of the world's most extensive networks of conservation areas (Evans, 2012). Alien species are generally better monitored in protected than non-protected areas due to existing monitoring frameworks and greater investment of monitoring and conservation efforts in such areas. Thus, rich datasets are more likely to be found in networks of protected areas than in unprotected areas - see e.g. (Dimitrakopoulos et al., 2017; Foxcroft et al., 2017; Rose and Hermanutz, 2004).

A recent paper (Dimitrakopoulos et al., 2017), investigated potential factors that influence alien plant species richness in the Natura 2000 sites in Greece. The main conclusions of that study were that native plant species richness and human population density have a positive effect on alien plant species presence. These findings are generally in agreement with a recent study examining hypotheses of vascular plant species invasibility in Crete and 49 surrounding islets (Bjarnason et al., 2017). The latter study examined alien species patterns in the Cretan area representing ~6.4% of the area of Greece (with ~24.5% of the Cretan area being protected), while (Dimitrakopoulos et al., 2017) covered plant species throughout Greece but only in Natura areas, a ~16.3% of the area of Greece. How different would the patterns of alien plant species richness in Greece as recorded by (Dimitrakopoulos et al., 2017) be outside protected areas? Are results and conclusions based on analyses of data collected in protected areas representative of the wider region? We herein investigate this question by analysing some recently published data of alien plants in Crete and surrounding islets as a case study.

2. Methods

2.1. Dataset

A dataset derived from digitising a plant atlas of the spatial distribution of native and alien vascular plant species from Crete and 49 surrounding islets (i.e. the Cretan area) was used (Chilton and Turland, 2008; Turland et al., 1993). These data have been fully described in (Bjarnason et al., 2017; Daliakopoulos et al., 2017) for addressing different questions. In brief the dataset was gridded in 162 square cells of 8.25 × 8.25 km. Coastal and inland cells have unequal land area; all inland cells have a total land area of $8.25 \times 8.25 = 68.0625$ km^2 while coastal cells and islets have smaller land areas (part of the cell is covered by the sea). In order to account for this effect, the total area of each cell was normalized by the area of inland cells. Each location (cell) in the study area was extensively surveyed for 10 years, up to three times each year, therefore the dataset is very reliable and species absences are likely to be real absences and not sampling artefacts (Chilton and Turland, 2008; Turland et al., 1993). From the full plant dataset, alien species ($N_{alien} = 78$) were defined (D'Agata et al., 2009).

The percentage of the area of each cell that is protected (i.e. included in the Natura 2000 network) was calculated, based on the distribution of protected areas (EEA, 2010). Almost a fourth of the total Cretan area is within the Natura 2000, including all Cretan protected areas. Land cover data within each cell were classified using level three (the most detailed level) of the CORINE land cover classification system (EEA, 2010). The land cover data of the Cretan area included 29 land cover types, of which 9 were agricultural, 7 were artificial, and 13 were natural. The agricultural, artificial, and natural land cover richness per cell was calculated as the number of these land cover types present on each cell respectively. Agricultural and artificial habitat types richness were used as indicators of human presences and pressures.

Climatic variables were derived from WorldClim (Hijmans et al., 2005) for the Cretan area. The original spatial resolution of the climatic data was 1 km with a temporal resolution of one month. The data were spatially re-scaled to 8.25 km in order to match with the grid size resolution of the plant atlas and temporally averaged per annum. The climatic variables used were: mean annual precipitation in mm year^{-1} and mean annual temperature in °C per cell.

2.2. Statistical analyses

Linear mixed effects models (Pinheiro and Bates, 2000) were used to investigate the relationship between alien species richness (dependent variable) and (i) the percentage of each cell in the Natura 2000 protected area network, (ii) the agricultural and (iii) the artificial land cover types richness within the cell, (iv) the mean annual precipitation, and (v) the mean annual temperature per cell (independent variables). The model also included the unique cell identity as a random effect to account for the fact that some coastal cells have unequal surface area than continental cells, and that there are also other underlying factors within each cell such as geographic and soil factors that are not accounted for in this analysis. In general, fixed effects account for the mean and random effects for the variance in the variables; see e.g. (Moustakas et al., 2013) for a similar rationale. Initially, agricultural and artificial habitat richness was compared with agricultural and artificial habitat cover as predictor variables of alien species richness; the former gave lower AIC values and was thereafter used in all analyses (see Supplement for details). Model selection was conducted using the AIC with maximum likelihood estimation (Pinheiro and Bates, 2000). Any deletion that did not increase AIC scores by >2 was deemed to be justified (Burnham and Anderson, 2002). We ended up with the same model either by applying AIC or comparative F-tests. Inspection of residual plots for constancy of variance and heteroscedasticity indicated that the model was well behaved in all cases. Sequentially fixed effects were plotted with 95% confidence intervals. The analysis was performed using the ‘nlme’ and ‘effects’ packages in R (R Development Core Team, 2017).

We analysed the spatial cross-correlation between cells regarding alien species richness and the percentage of protected area using a multivariate spline cross-correlogram (Bjørnstad and Falck, 2001), in order to examine whether alien species richness increases with increased protected area. Spatial cross-correlogram estimates the spatial dependence at discrete distance classes. The region-wide similarity forms the reference line (the zero-line); the x-intercept is thus the distance at which objects are no more similar than that expected by-chance-alone across the region. This analysis examines in a spatially-explicit manner the correlation between two variables across scales