THE EFFECTS SPECIES-AREA RELATIONSHIP IN PLANT SPECIES RICHNESS: A META-ANALYSIS

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Abstract - The species-area relationship is an important phenomenon in ecology. I performed a meta-analysis to determine if the plant species richness varies with the size of the ecosystem. The analysis involved Pearson correlation and regression analysis using R. The results suggest that species richness in islands increase with the habitat size; however, this is not the case in fragments, contrary to what is taken for granted in the literature. Differences in fragments are probably because the type of land between patches limited the species sensibility to fragment area. By focusing on species- area relationship between island and fragments, I might be able to determine different patterns of species distribution in relation to habitat size. This in turn may also give us the opportunity to develop conservation strategies more focused on the type of land instead of the effect of habitat area alone.

Keywords: plants, species area relationship, path/island size, biogeography, species richness.

Resumen - La relación especie-área es un fenómeno importante en la ecología. Llevé a cabo un meta-análisis para determinar si la riqueza de especies de plantas varía con el tamaño del ecosistema. El análisis envolvió correlación de Pearson y regresión lineal utilizando R. Los resultados sugieren que la riqueza de especies en islas aumenta con el tamaño del hábitat, sin embargo, este no es el caso en fragmentos, contrario a lo que se da por sentado en la literatura. Las diferencias en los fragmentos se deben probablemente a que el tipo de tierra entre parcelas limita la sensibilidad de la especie al área de fragmentación. El estudio de la relación área-especie en islas y fragmentos, permite determinar diferentes patrones de distribución de especies en relación con el tamaño del hábitat. Esto, a su vez, también nos puede dar la oportunidad de desarrollar estrategias de conservación más centradas en el tipo de tierra en lugar del efecto del área del hábitat únicamente.

Palabras clave: plantas, relación especies área, tamaño de isla/parcela, biogeografía, riqueza de especies.

Introduction

The relation between the species richness and the habitat size is one of the most important phenomena in ecology (He & Legendre, 2002). It has been proposed that

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species can survive better in large islands than in small islands because large ecosystems can decrease the extinction rate (Buckley et al., 1982; MacArthur & Wilson, 1967) and contains more habitats (MacArthur & Wilson, 1967). There are several studies that show that species richness increases as the habitat increase (Hu et al., 2011; Picton, 1979) because species have more opportunities to persist under different environmental conditions. In addition, there are studies that suggest that the same island theory can be applied to evaluate the species richness in fragments (Cook et al., 2002).

Fragmentation is one of the greater reasons of species decline around the world (Myers, 2004) and causes alteration in community structures, loss of species diversity and elimination of taxa (Paciencia & Prado, 2005). Studies suggest that species cannot survive in small fragments, only generalist species can have the opportunity to survive (Alvarenga & Porto, 2007) and for that reason, bigger fragments should be established (Pineda & Halfer, 2004). Supporting the hypothesis that fragments and islands will have more species diversity as they increase in size; and the positive species-area effect observed in fragments could be attributed to species movement from disturbance area (Tscharntke et al., 2002). However, there are studies that debate this hypothesis and their results show a negative effect and an increase in species local extinction (Debuse et al., 2007). The objective of this study is to evaluate the species-area relationship in island and fragments and to determine if there is a positive species-relationship effect in both scenarios. I hypothesize is that the plants species richness will increase as habitat size increase. There are meta-analysis involving species-area relationships in fragments and island but with the objective to evaluate two different methods in the same datasets (Matthews et al., 2015). However, they do not evaluate the differences or similarities between species-area relationships in fragments and archipelagos. To our knowledge, this is the first meta-analysis, which compares the species-area relationships in fragments and small islands to explore if both show increase in plant richness as the habitat area increase that is important to develop specific conservation and management strategies.

Method

I searched Google scholar and JSTOR abstracting services for relevant habitat island studies and datasets. The following keywords were selected for literature review: plants/ species area relationship/ path size/ island/ biogeography/ species richness. First, the tittles and abstract were reviewed; then survey of plant species and habitat size was carried out meeting the exclusion and inclusion criteria. Inclusion criteria for studies included (i) the relationship between species richness and area, (ii) a table with the number of species per area (ha), (iii) and the study had to be done exclusively in plant species. Papers showing numbers of species per total area or do not followed the criteria mentioned above were excluded. After papers selection, the data extraction was carried out following data normalization. The area (ha) was converted to m^2 and the log of area to facilitate the data analysis. Data analysis involved Pearson correlation and regression methods using ggplot R package to calculate the association between variables and for hypothesis testing. The number of species was counted in different ranges of habitat area (ha). The bigger habitat

was 2628.63ha and the smallest was 0.008ha (Table 1).

Table 1

Data on the islands (Puerto Rico, Shetland and Ireland) and fragments (Brazil and Sweden) analyzed

Taxa	Species richness (range)	Area range (ha)	Log10 (Area) (range)	Type of ecosystem	Source
Plants	0-71	0.03-99.58	2.5-6.0	Small island off Shetland Mainland	Kohn & Walsh (1994)
Plants	13-113	0.008-3.24	1.90-4.51	Lakes islands in western Ireland	Roden (1998)
Plants	12-33	1.60- 3.33	4.20-5.52	Subtropical Moist Forest in PR	Galanes & Thomlinson (2008)
Plants	10-55	22.98-2628.63	5.36-7.42	Fragments northeast in Brazil	Silva & Porto (2009)
Plants	42-78	0.5-13.6	3.70-5.13	Fragments in Södermanland in southern Sweden	Kiviniemi & Eriksson (2002)

Note. ha= hectare. Species richness is the number of species represented in a region.

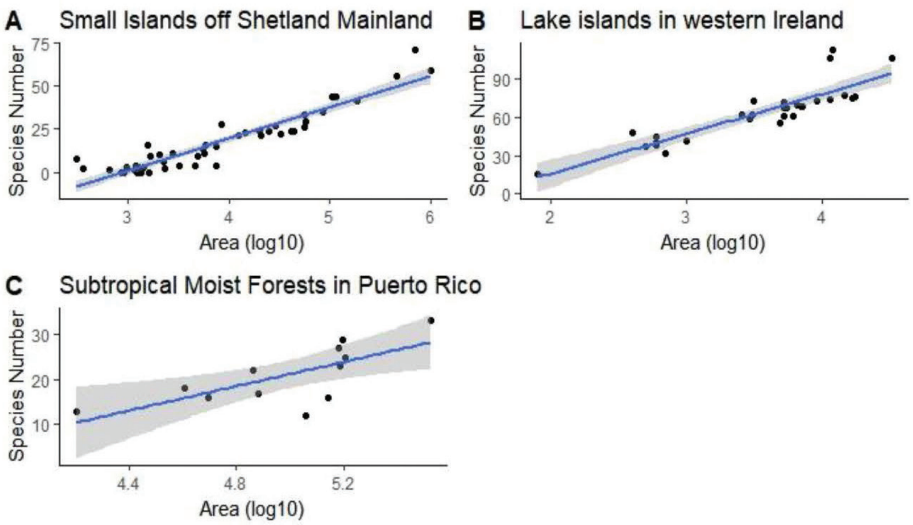

Figure 1. Plant species-area for islands. Lineal regression model used to estimate the best straight line (with shaded 95% confidence interval) to predict plant species richness prevalence using log area prevalence as explanatory variable on (A) Small islands off Shetland Mainland (R^2= 0.87, P< 2.2e-16), (B) Lake islands in western Ireland (R^2= 0.77, p=4.517e-10) and (C) Subtropical moist forest in Puerto Rico (R^2= 0.51, p=0.009289).

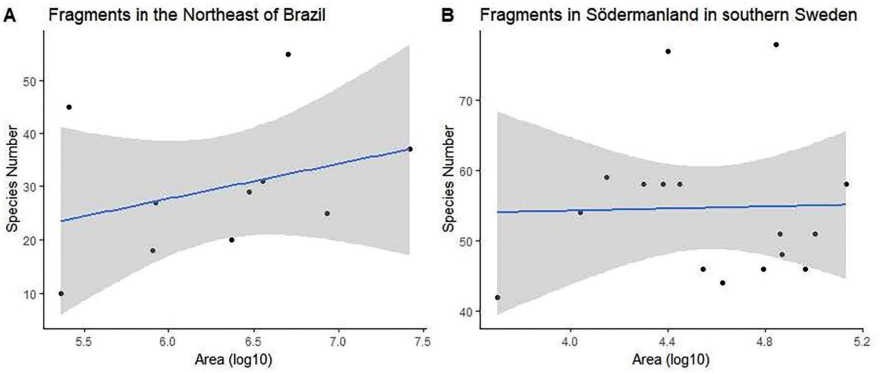

Figure 2. Plant species-area for fragments. Lineal regression model used to estimate the best straight line (with shaded 95% confidence interval) to predict plant species richness prevalence using log area prevalence as explanatory variable on (A) fragments in the northeast of Brazil (R= 0.11, p=0.3605) and (B) fragments in Sodermanland in southern Sweden (R^2= 0.0007, p=0.9198).

Results

I included five studies containing tables meeting the inclusion criteria. Data of the number of species occurring in study plots of different size revealed greater plant species richness in islands as they increase in size. Kohn & Walsh's (1994) study on small island off Shetland Mainland, showed a strong positive correlation between species richness and habitat area with a correlation coefficient= 0.9351824 (R^2=0.8746, p-value < 2.2e-16; Figure 1A). Roden's (1998) study performed in Lake islands in Ireland, demonstrated a significant association between species and habitat area with a R^2= 0.7686 (Cor= 0.8766767, p-value=4.517e-10; Figure 1B). The data extracted from the Galanes & Thomlinson's (2008) study in Puerto Rico also describe an association between species richness and habitat area in islands (Cor= 0.7126767, R2=0.5079, p-value= 0.009289; Figure 1C). Interestingly this was not the case in the studies performed in fragments. Silva & Porto's (2009) study carried out in Brazil fragments, showed a non-significant positive correlation (Cor=0.3243819, R^2= 0.1052, p-value- 0.3605; Figure 2A). Similarly, the pattern in fragments from southern Sweden (Kiviniemi & Eriksson, 2002) showed a weak positive lineal regression with a R^2=0.9198 (Cor= 0.02740266, p-value= 0.0007; Figure 2B).

Discussion

The meta-analysis results showed different patterns in the species-area relationship, some were expected, and others were not. Perhaps our most interesting result was that the plant species-area relationships in fragments were different to the observed in islands. The last one mentioned is supported by literature that shows similar patterns, that is, that species richness increase has the habitat size increase (Whithead & Jone, 1969). This suggest that large islands can support more habitats, in other words, the species richness will depend on the area-habitat relationship, the area will determine the quantity of habitat types and the habitats will determine the species diversity (Kohn & Walsh, 1994). On the other hand,

the claim that weak area effects are observed in fragments is strongly supported by this study. This no significant positive correlation in fragments could be explained by the land separating the fragments that reduce the sensibility of species to patch area (Prugh et al., 2008). In addition, a small island carved from a large one will lose biodiversity regardless the number of habitats preserved after the division (Soule et al., 1992). Weak species-area relationships in fragments have been found in other studies, which by the contrary of Soule and collaborators suggest that the number of species will be compensated due to many patches different in size and forms (Hu et al., 2012). For the reasons mentioned above, it is evident that there are still some gaps to understand species diversity in fragments that should be attended to improve species conservation strategies.

Conclusions

The relationship between the species richness and habitat area is considered almost a law in ecology. Many authors propose that the species diversity increase as the habitat area increase. There are studies that show that the called *biogeography theory* applies to islands and fragments, whereas there are other studies who demonstrated that fragments do not follow the theory. The results in this meta-analysis suggest that the number of species is strongly related to the area in islands, but this is not the case in fragments where the species-area relationships were not significant. This has multiple implications in conservation biology; in the case of island habitat, loss can be a direct result of loss of area and species diversity. In fragments, the habitat between fragments can limit the species sensibility to fragment area. It is important to understand the fragmentation to protect the species diversity in fragments.

Future studies should considerate the occurrence of species to estimate the probability of extinction, and the junction of multiple factors as altitude, size, area, form, secondary vegetation, and the edge effect to better understand species diversity. There are studies showing no significant relationship between species and the distant from the edge, which suggest that the edge effect is not lineal, and should be in consideration for future studies.

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