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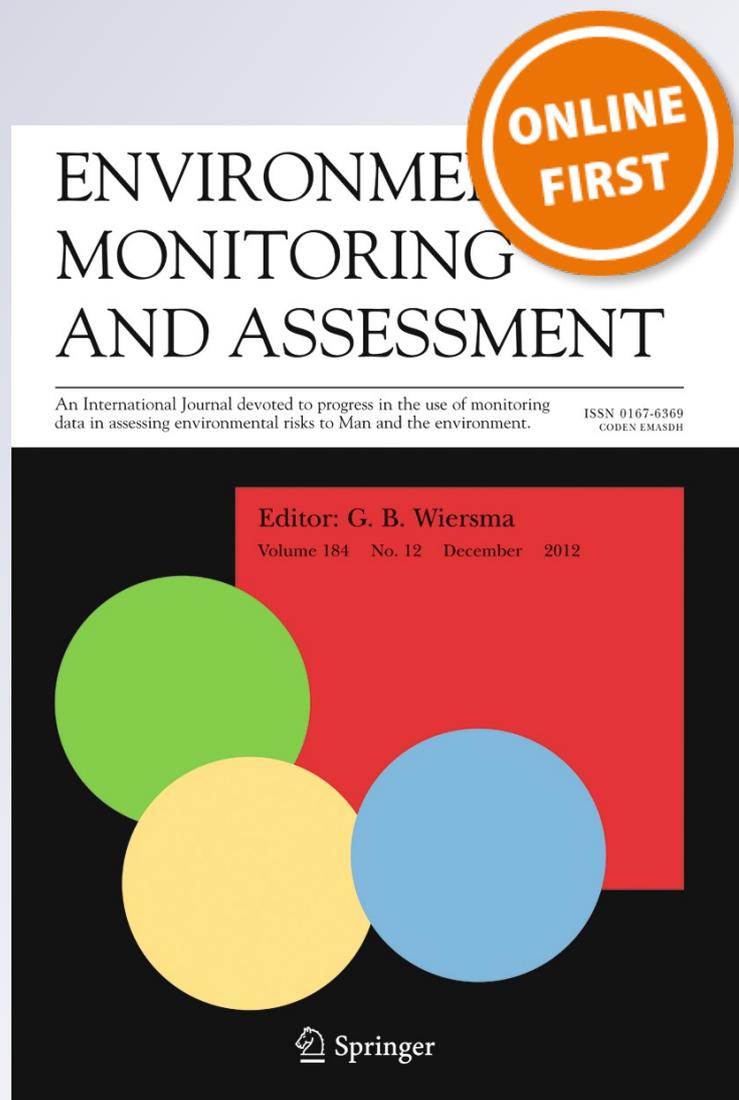
Environmental Monitoring and Assessment

An International Journal Devoted to Progress in the Use of Monitoring Data in Assessing Environmental Risks to Man and the Environment

ISSN 0167-6369

Environ Monit Assess

DOI 10.1007/s10661-012-3019-9



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Using species spectra to evaluate plant community conservation value along a gradient of anthropogenic disturbance

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Received: 24 June 2012 / Accepted: 20 November 2012
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Abstract The aim of this study was to assess the impact of anthropogenic disturbance on the partitioning of plant communities (species spectra) across a landcover gradient of community types, categorizing species on the basis of their biogeographic, ecological, and conservation status. We tested a multinomial model to generate species spectra and monitor changes in plant assemblages as anthropogenic disturbance rise, as well as the usefulness of this method to assess the conservation value of a given community. Herbaceous and arborescent communities were sampled in five Azorean islands. Margins were also sampled to account for edge effects.

Different multinomial models were applied to a data set of 348 plant species accounting for differences in parameter estimates among communities and/or islands. Different levels of anthropogenic disturbance produced measurable changes on species spectra. Introduced species proliferated and indigenous species declined, as anthropogenic disturbance and management intensity increased. Species assemblages of relevance other than economic (i.e., native, endemic, threatened species) were enclosed not only in natural habitats, but also in human managed arborescent habitats, which can positively contribute for the preservation of indigenous species outside remnants of natural areas, depending on management strategies. A significant presence of invasive species in margin transects of most community types will contribute to an increase in edge effect that might facilitate invasion. The multinomial model developed in this study was found to be a novel and expedient tool to characterize the species spectra at a given community and its use could be extrapolated for other assemblages or organisms, in order to evaluate and forecast the conservation value of a site.

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Keywords Anthropogenic disturbance · Bayesian inference · Biodiversity · Multinomial model · Species spectra

Introduction

Biodiversity has been indicated as a key factor maintaining ecosystem function (Chapin et al. 2000; Bolger

2001; Naeem et al. 2009), while land use change has been considered to be one of the greatest threats to biological diversity (Western 2001; Castro et al. 2010; Hawksworth and Bull 2010; Laliberté et al. 2010). Islands may be particularly prone to biodiversity loss due to the high rate of endemism and the potential release of competitors when invasive species are introduced (Whittaker and Fernández-Palacios 2007; Chane-ton et al. 2002). In models of possible biodiversity loss through the year 2100, land use change, fragmentation, and homogenization have been shown to have a high potential impact on biodiversity (Sala et al. 2000; Western 2001; Brook et al. 2008; Castro et al. 2010; Hawksworth and Bull 2010), namely on islands (Caujapé-Castells et al. 2010; Kueffer et al. 2010).

In this study, we aim to estimate the partitioning of plant species categorized on the basis of their biogeographic, ecological, and conservation status (henceforth referred to as species spectra) across two spatial land-cover gradients. In addition, we intend to determine if the use of a multinomial model within the framework of Bayesian inference could be useful to generate species spectra and estimate changes in the partitioning of plant species across community typologies. This new methodological approach may be a practical tool to detect changes in the ecological, economic, and social attributes of ecosystems and a clear estimator of biodiversity in the mosaic of existing habitat types. Expedient methodologies for this purpose have been previously attempted although for a limited number of ecosystem typologies (Herrick et al. 2006). Although it is assumed that native plant species disappear as a consequence of anthropogenic habitat disturbance (Chane-ton et al. 2002; Didham et al. 2007; Flynn et al. 2009), empirical evidence is mostly available for single or restricted groups of herbaceous ecosystems (Chane-ton et al. 2002; Bassa et al. 2011; Rao et al. 2011) and environmental gradients (Sherman et al. 2008). Comprehensive field work on the effects of fragmentation and human disturbance in the distribution of species, across a broad gradient of representative habitat types, under different levels of anthropogenic management and disturbance (i.e., anthropogenic gradient), is rare, albeit its increasing interest (Flynn et al. 2009; Laliberté et al. 2010; Panitsa et al. 2011).

Using plant communities with two different vegetation structures (herbaceous and arborescent) along a gradient of anthropogenic influence, we tested the hypothesis that different levels of anthropogenic

disturbance generate measurable changes on species spectra. Both marginal and core areas of these communities were surveyed in order to account for edge effects. The Azores are a good model system for this type of study due to differences in the level of conservation of indigenous plant communities on the different islands and because of the robust information already available on biodiversity (Borges et al. 2010; Silva et al. 2010).

Materials and methods

Study site

The Azores (36°35′–39°43′ N, 24°45′–31°17′ W), one of the Macaronesian archipelagos, is located over 615 km across the Mid-Atlantic ridge, comprising nine volcanic islands and several small islets, forming three main groups, on a WNW–ESE alignment, along the tectonic lines. The topography of the islands is characterized by the presence of large catchments, ravines, and seasonal water streams. Several native plant communities existed prior to human settlement, including coastal and wetland vegetation, meadows, and different types of scrub and forest (Hortal et al. 2006; Cardoso et al. 2007). The Azorean islands are recognized worldwide as important conservation hotspots (Dias et al. 2007) with 14 % of its territory protected (UNESCO World Heritage Sites, Biosphere Reserves and Natura 2000 Network).

Community selection

Communities were selected to represent a gradient of increasing anthropogenic influence and management intensity. A total of eight community types, divided between herbaceous and arborescent ecosystems were selected to represent the most comprehensive range of plant communities as possible (Table 1).

Island selection

Islands were selected on the basis of the relative proportion of land allocated to agriculture and relatively pristine habitats, aiming to cover all possible combinations, i.e., (1) São Miguel, with high level of agricultural development vs. low level of pristine habitats; (2) Terceira, with high level of agricultural development vs. high level of pristine habitats; (3) Pico, with low agricultural development vs. high level of pristine habitats, UNESCO World

Table 1 Description and characteristic plant species per community type within a given ecosystem, depicting an increasing level of anthropogenic influence and management intensity

Code	Habitat types	Description	Characteristic plant species
Herbaceous ecosystem gradient			
MED	Natural meadows	Dominated by indigenous taxa, with low management intensity and low anthropogenic influence	<i>Holcus rigidus</i> , <i>Festuca</i> spp., <i>Deschampsia foliosa</i> , <i>Leontodon</i> spp., <i>Tolpis azorica</i>
SNP	Semi-natural pasture (high altitude)	Dominated by non-indigenous taxa, but including several indigenous taxa, with low management intensity and low anthropogenic influence	<i>Holcus lanatus</i> , <i>Agrostis castellana</i> , <i>Polytrichum commune</i> , <i>Ranunculus repens</i>
SNPL ^a	Semi-natural pasture (low altitude)	Dominated by annual populations of <i>Daucus carota</i> with low management intensity and low anthropogenic influence	<i>Daucus carota</i> , <i>Sporobolus indicus</i> , <i>Briza minor</i> , <i>Lotus subbiflorus</i>
PAS	Artificial pasture	Dominated by introduced taxa, with high management intensity and high anthropogenic influence	<i>Lolium perenne</i> , <i>Bromus willdenowii</i> , <i>Trifolium repens</i> , <i>Poa</i> spp., and many weeds
COR	Crop	Dominated by introduced taxa, with high management intensity, high anthropogenic influence, pesticide and fertilizer use	<i>Zea mays</i> , many agricultural weeds and ruderal plants
Arborescent ecosystem gradient			
NAT	Natural forest	Dominated by indigenous taxa, with low management intensity and low anthropogenic influence	<i>Laurus azorica</i> , <i>Juniperus brevifolia</i> , <i>Erica azorica</i> , <i>Ilex perado</i> , <i>Morella faya</i>
INV	Exotic woodland	Dominated by non-indigenous taxa, with low to medium management intensity and medium anthropogenic influence	<i>Pittosporum undulatum</i> , <i>Acacia melanoxylon</i> , <i>Eucalyptus globulus</i> , <i>Pinus pinaster</i> , <i>Solanum mauritianum</i>
CRY	Production forest	Dominated by introduced taxa, with high management intensity and high anthropogenic influence	Monocultural stands of <i>Cryptomeria japonica</i>
ORC	Orchard	Dominated by introduced taxa, with medium management intensity and medium anthropogenic influence	<i>Citrus sinensis</i> , <i>Mallus domestica</i> , <i>Prunus</i> spp. and many other crop, weed, ornamental, or ruderal species

^a SNPL replaced MED habitats in two of the sampled islands (Santa Maria and Terceira) due to the lack of sampling areas for the latter habitat type in these islands

Heritage cultural landscapes; (4) Flores, with low agricultural development vs. high level of pristine habitats, UNESCO Biosphere Reserve; and (5) Santa Maria, with low agricultural development, low level of pristine habitats with relevant uniqueness value.

Sampling

To obtain a representative sample of the plant species richness for a given community type, 100×100 m geo-referenced plots were selected following the methodology of Silva and Smith (2006) and Lourenço et al. (2011). Plots were sampled by walking along two parallel 100-m transects within each plot. All plant taxa

were recorded and identified to species level as presence-absence taxa. Marginal areas (usually hedgerows) were also sampled in order to assess possible differences in the partitioning of plant species, specie spectra, between margin and core areas. For each plant community type there were two replicate sites, per island, for a total of 80 sampling sites (i.e., 2 sites×8 community types×5 islands) and 160 transects. Field work was concentrated in the summer season of 2009 to avoid seasonal effects.

Species classification

Species categories were used to differentiate changes in species composition across habitats (Table 2). Although

Table 2 Criteria used to assign plant species to the different species categories

Species category	Ecological criteria	Social criteria	Economic criteria	References	
Indigenous spp.	Endemic	Endemic to one or more islands of Azores resulting from speciation events (neo-endemics) or extinction of the mainland populations (paleo-endemics)	Occurring in a particular ecological or social context with informative scientific value and/or social interest	Vicarious value (welfare obtained via indirect consumption (for example, books and documentaries)	a, c, g
	Native	Native to one or more islands of Azores	Natural heritage Scientific, educational, medicinal, religious, artistic, spiritual value	Cultural value attached to the species reflecting in economic revenues	a, b, c
	Top and threatened	Keystone in biotic dynamic of habitat (for example, trophic webs, pollination) with priority for conservation Endemic to one or more islands of Macaronesia 15–30 % of known global population in the area	Recreational and aesthetic relevance for part or all the region Value for at least one interest group (for example NGO, European directives, or lists) Species of high social value to mainstream community in relevant distribution area	Structural to maintain recreational and economic revenues within the distribution area Vicarious value (welfare obtained via indirect consumption through, for example, books and documentaries)	a, b, c, d, e, g
Introduced spp.	Cultivated or casual	Area of occupancy ≤ 5 % of island area Unique or shared role (with one or two other species) Monospecific stands with reduction of diversity Modification of biotic webs Disruption or modification of natural landscape	Considerable social value to human populations of at least one island due to direct or indirect benefits	New food sources available for dairy or meat animals Production of grain, forage	f
	Naturalized	Introduced spp. with self-supporting populations	Many species considered as ruderal, weeds in agriculture and many species used in pastures as forage	Some have negative impact (agricultural weeds) others positive impact (forage species)	a, f
Invasive	Introduced (actively or passively) and uncontrolled dispersal Modification of trophic webs in presence areas	Block trails and cause allergies	Reduction of recreational, economic and aesthetic revenues within the distribution area		f, h

References: (a) Borges et al. 2010, (b) Martín et al. 2008, (c) Martín et al. 2010, (d) Silva et al. 2010, (e) Pellant et al. 2005, (f) Silva et al. 2008, (g) Marsh et al. 2007; Silva and Smith 2004

criteria to define taxa categories may vary depending on the biodiversity aspects in analysis (e.g., conservation, restoration, or stability), taxa categories often have similar requirements (Hilty and Merenlender 2000). In addition, assigning species to a given category based solely on ecological criteria do not reflect its overall importance (Eaton et al. 2005; Panitsa et al. 2011), hence, ecological criteria representing functional and structural attributes of a given taxon were combined with social and economic criteria as a strategy to most effectively discriminate the importance of a given species, based on published data. In addition, we suggest the term species spectra to discern the partitioning of plant species present in a given community type, according to their biogeographic, ecological, and conservation status (see Table 2 for bibliographical support), as follows:

1. Indigenous species (i.e., those that arrived or originated on the islands, in the absence of human influence)—those that are not unique to the islands (native), those that are unique to the islands (endemic), and those that were considered by humans as priority for conservation (top and threatened).
2. Introduced species (i.e., those that were accidentally or deliberately introduced by human activities)—those that still depend on humans to spread (cultivated and casual), those that are fully established, with self-sustainable populations (naturalized), and those that have a negative impact on conservation since they have established and spread into natural habitats (invasive).

Statistical analysis

Multinomial distributions have been used to model different events in ecology, namely in population age structure (McCarthy 2007) and in capture–recapture methods (King et al. 2010), but also in other areas (Boender et al. 1987; Vasko et al. 2000; Griffith and Tenenbaum 2002; Kazembe and Namangale 2007; Calvo 2009). We opted to analyze our data using Bayesian inference with the application WinBUGS (Spiegelhalter et al. 2003), since it provides the possibility of estimating the probabilities of each species category in each community type, and was shown to be an adequate tool for data analysis in ecology (McCarthy 2007; Kéry 2010; King et al. 2010). It also allows building different models, in order to determine

the possible differences in parameter estimates for different communities and/or islands. Each species spectrum is represented by a multinomial random variable. In the latter there are S species, each of which may lay in six different categories, with a certain probability, p_i , that we want to estimate. We used the Dirichlet distribution as a prior for the multinomial parameters, since it is the conjugate of the probabilities of the multinomial model (Gelman et al. 1995; McCarthy 2007; King et al. 2010). This distribution has been successfully used in different Bayesian applications (Pritchard et al. 2000, Huelsenbeck and Ronquist 2001); hence, it has the potential to be used in other modeling approaches, namely in those devoted to ecological studies.

The following models were calculated, both for arborescent and herbaceous communities: (1) Islands model, allowing different parameters for each Island; (2) Habitats model, allowing different parameters for each plant community; (3) Islands *versus* Habitats model, allowing different parameters for different Island/Habitat combinations; and (4) community Core area versus Margin model

Besides estimating the different probabilities of each species category (i, j) for each Island/Habitat (p_i), we also calculated, as derived quantities, the differences in probability estimates (d_i) among Islands, among Habitats (k) or among Habitat's Core area and Margin (see annex I for WinBUGS code). In all cases we used three chains and updated the model a number of times that was clearly sufficient to reach convergence, by using normally accepted criteria (King et al. 2010), including analysis of trace plots, the Brooks–Gelman–Rubin diagnostic, and the magnitude of Monte Carlo error, as provided by WinBUGS. To estimate model parameters we only considered the estimates obtained after convergence. We used Deviance Information Criteria (DIC) as a measure of model complexity and fit (Spiegelhalter et al. 2002). In general, we found that updating the model 100,000 times and using the last 30,000 updates to estimate model parameters and DIC was clearly sufficient to assure chain convergence. We give an example of the models used (annex I), namely when comparing species spectra in habitats of the herbaceous ecosystems gradient.

We must stress that using this type of relatively simple model within a Bayesian framework, allowed obtaining more comprehensive, intuitive, and interpretable results than using more common statistical procedures (i.e., MANOVA and discriminant analysis), also

tested by the authors. The present analysis does not demand that the data to follow the usual parametric tests assumptions (i.e., normality, homoscedasticity) (Zuur et al. 2007), and avoids the need to use previous data transformation and the use of post hoc tests after ANOVA. Furthermore, in Bayesian inference, all the parameters are considered as random variables, thus uncertainty is included at all components of the models (Gelman et al. 1995).

Results

A total of 348 plants were identified to species level and assigned to a species category, which composed the species spectra at a given sampled community, along the gradient of anthropogenic disturbance. We chose to discriminate results by arborescent and herbaceous communities in order to facilitate their interpretation, as these are not common to these landcover typologies.

Differences in species spectra along the anthropogenic gradient of disturbance (arborescent communities)

The model comparing overall species spectra between islands (Fig. 1) showed similar plant distribution patterns. Conversely, species spectra at the community level showed differential species spectra (Fig. 2) and a low DIC (i.e., high model fit) than the islands model (Fig. 1). There was a significant decrease in the global contribution of indigenous species (i.e., native, endemic, top, and threatened) from less to more anthropogenically

influenced community types, particularly in native forest. Casual and cultivated species, as well as naturalized plants, were mainly found in orchards. Exotic woodland presented a larger contribution of invasive plants.

Differences in species spectra along the anthropogenic gradient of disturbance (herbaceous communities)

The model comparing the species spectra between islands (Fig. 3) showed a similar species distribution pattern for all islands, a comparable result to that obtained for arborescent communities, but with a lower DIC (i.e., larger fit). Some particularities were detected, namely an accentuated higher contribution of naturalized species in the species spectra and a slightly lower contribution of indigenous plants in Terceira and Santa Maria islands.

The model comparing different communities showed very sharp differences (Fig. 4), and the lowest DIC obtained in the analyses (largest fit). There was an increase in the global contribution of indigenous species (i.e., native, endemic, top, and threatened) from more to less anthropogenically influenced communities. Pasture appeared dominated by naturalized species, while corn showed the largest contribution of casual and cultivated plants. Semi-natural pastures at different elevations showed considerable differences in species composition.

Differences in species spectra between community core area and margin (arborescent communities)

The relationship between community core area and margin in the partitioning of plant species differed among

Fig. 1 Species spectra for arborescent communities in five Azorean islands. Results from a multinomial model using WinBUGS. Different letters indicate that the probability of a difference between two islands is different from zero. The multinomial parameters were estimated by performing 100,000 model updates, and using only the last 30,000 for three chains (DIC=1,088.790)

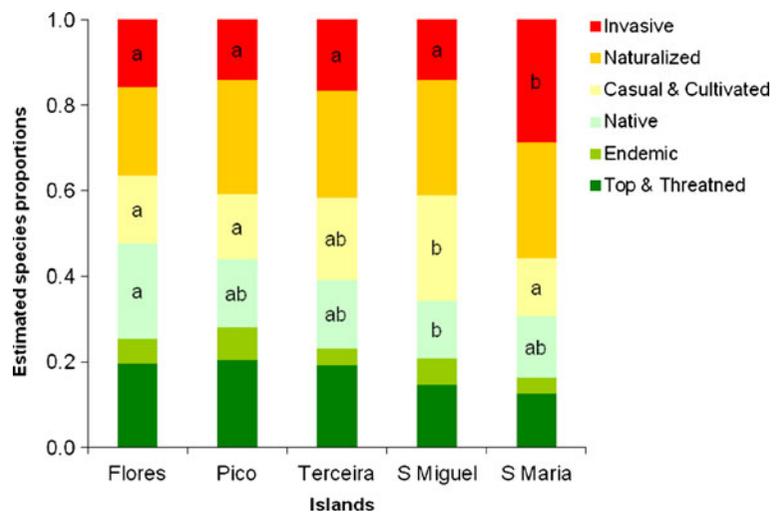
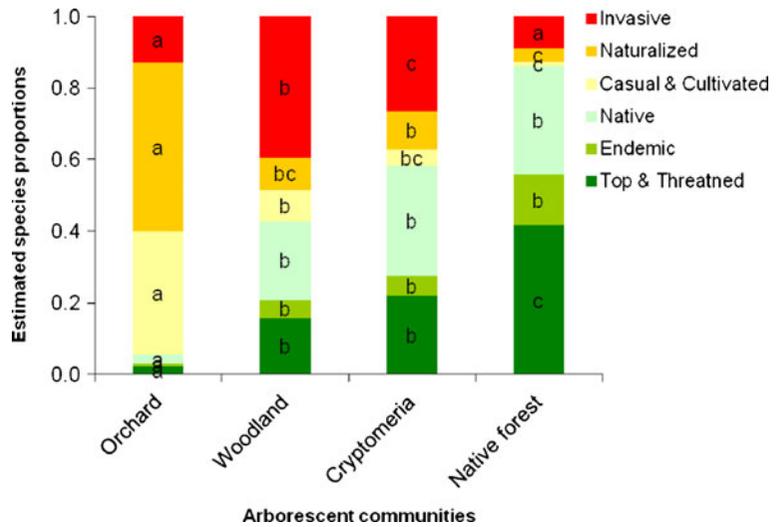


Fig. 2 Species spectra for four community types along a gradient of anthropogenic disturbance. Results from a multinomial model using WinBUGS. *Different letters* indicate that the probability of a difference between two habitats is different from zero. The multinomial parameters were estimated by performing 100,000 model updates, and using only the last 30,000 for three chains (DIC=527.362)



arborescent communities (Fig. 5). Namely, there was a larger contribution of naturalized species in the margin of both exotic woodland and production forest with anthropogenic influence. In orchards, there was a larger contribution of casual, cultivated, and naturalized species at the core area than at the margin. In natural forest, there was a prevalence of indigenous species at the core area while naturalized and invasive species dominated the margins.

Differences in species spectra between community core area and margin (herbaceous communities)

The relationship between community core area and margin in the partitioning of plant species differed among herbaceous communities (Fig. 6). A large contribution of naturalized species was observed at the

core area of pasture. Invasive species were prevalent at the margin of corn.

The two latter models, for Figs. 5 and 6, showed larger DIC values (lower fit), which is to be expected since the number of estimated parameters doubled (i.e., core and margin) in relation to the community core devoted models, clearly penalizing the former models.

Discussion

Changes of species spectra in community types along a gradient of anthropogenic disturbance

One important result of this study was the empirical confirmation that different levels of anthropogenic

Fig. 3 Species spectra for herbaceous communities in five Azorean islands. Results from a multinomial model using WinBUGS. *Different letters* indicate that the probability of a difference between two islands is different from zero. The multinomial parameters were estimated by performing 100,000 model updates, and using only the last 30,000 for three chains (DIC=706.113)

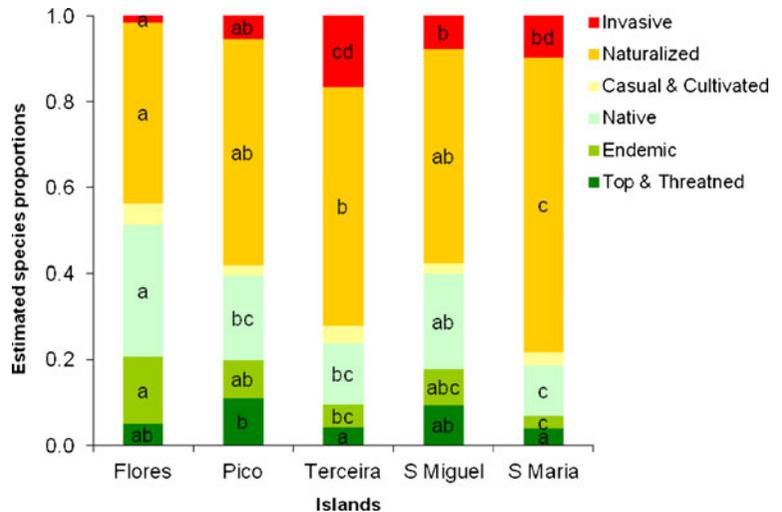
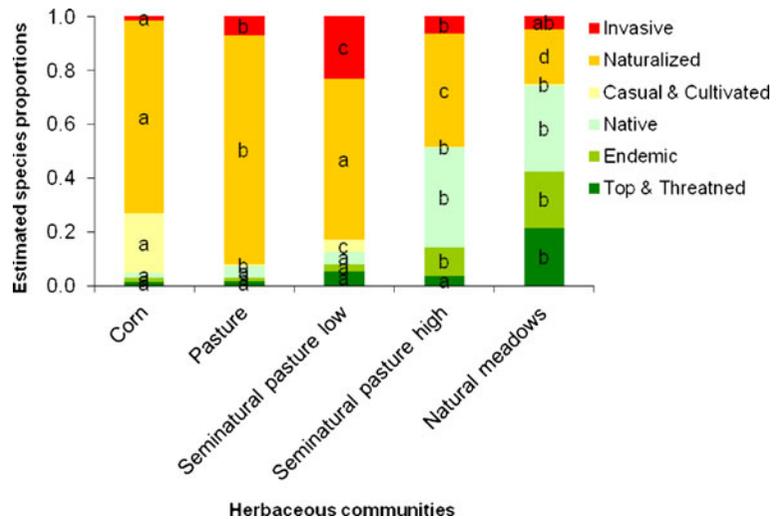


Fig. 4 Species spectra for five community types along a gradient of anthropogenic disturbance. Results from a multinomial model using WinBUGS. *Different letters* indicate that the probability of a difference between two habitats is different from zero. The multinomial parameters were estimated by performing 100,000 model updates, and using only the last 30,000 for three chains (DIC=383.567)



disturbance and management intensity correlate with measurable changes in the partitioning of plant species in both herbaceous and arborescent community types. Overall, a significant relationship between anthropogenic action and the decrease of indigenous species diversity (i.e., native, endemic, top, and threatened plants), and conversely an increase in introduced species diversity (i.e., invasive, naturalized, casual, and cultivated plants), was found. Differences were evident when comparing

the species spectra at the community level, but not at the island level, i.e., community landcover type influenced the partitioning of plant species (alpha diversity) although the overall richness of plants per island (gamma diversity) was not significantly different. This result corroborates recent studies on the contribution of local alpha and beta diversity, shaping the broader scale diversity of islands with distinct sizes, where the overall insular diversity (gamma diversity) is mainly influenced

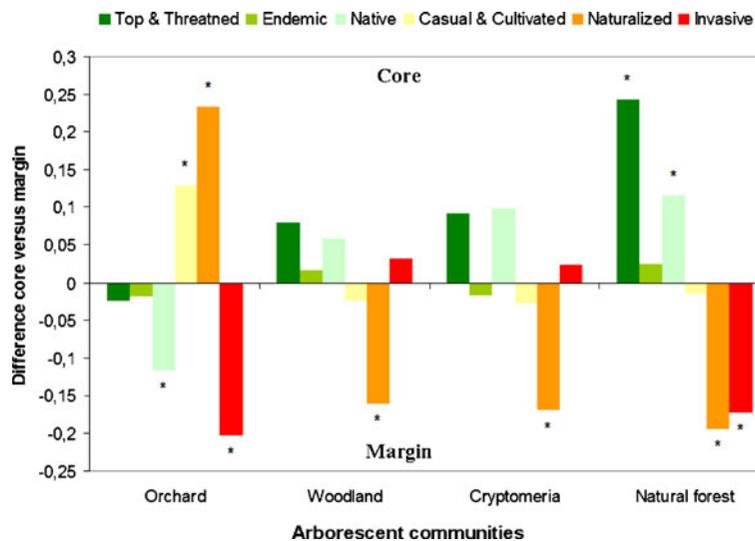


Fig. 5 Comparisons between species spectra of core and margin in four arborescent community types along a gradient of anthropogenic disturbance. Results from a multinomial model using WinBUGS. Positive values indicate larger proportion on core; negative values indicate larger proportion on margin;

asterisks the probability of a difference between core and margin is different from zero. The multinomial parameters were estimated by performing 100,000 model updates, and using only the last 30,000 for three chains (DIC=1,047.370)

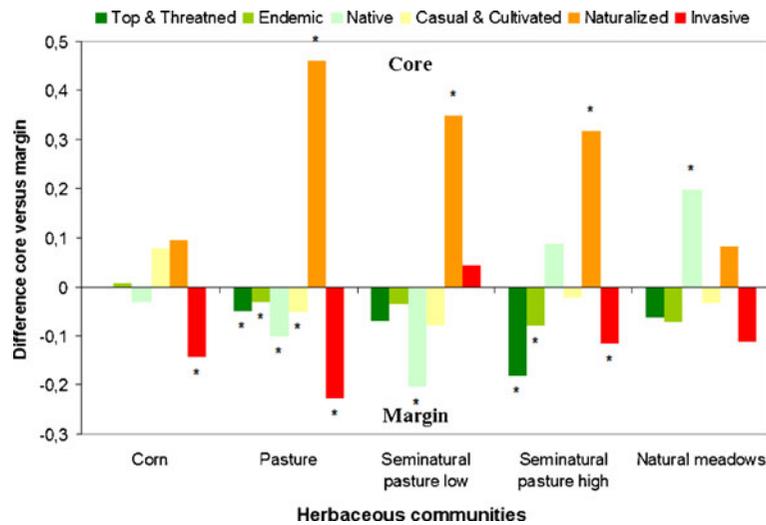


Fig. 6 Comparisons between species spectra of core and margin in five herbaceous community types along a gradient of anthropogenic disturbance. Results from a multinomial model using WinBUGS. Positive values indicate larger proportion on core; negative values indicate larger proportion on margin;

asterisks the probability of a difference between core and margin is different from zero. The multinomial parameters were estimated by performing 100,000 model updates, and using only the last 30,000 for three chains (DIC=920.021)

by unique species richness variation at small local scales (beta diversity) but not alpha diversity (Sfenthourakis and Panitsa 2012).

The robustness of these findings is grounded in a comprehensive evaluation within a large panel of eight key community types, and in the use of species categories defined according not only to ecological criteria but to a combination of ecological and functional attributes of a given taxon combined with social and economic impact, aiming to more judiciously discern the importance of a given species.

The methodology presented herein empirically ascertained different plant partitioning patterns for each community type, and detected considerable differences in species composition between community core and margin areas. These differences depended upon plant community type and anthropogenic influence. The significant impact of anthropogenic action in the decrease of native species richness was more evident in herbaceous habitats, where species of endemic nature (i.e., native and threatened) declined more abruptly in the gradient as human action and management intensity increased. Cultivated and naturalized species, tolerant to herbivory and thus capable of displacing species of native or endemic nature, dominated intensely managed herbaceous community types. These findings corroborate previous reports on the impact of disturbance in species partitioning and species

turnover from indigenous to invasive species, mainly in herbaceous community types (Chañeton et al. 2002; Seabloom et al. 2003; Tracy and Sanderson 2004; O'Connor 2005; Collinge 2009; Rao et al. 2011), incorporating arborescent communities in the analyses. The latter communities also presented a significant, although less abrupt, decline in species of indigenous nature as anthropogenic influence increased.

The cosmopolitan presence of invasive species in core areas of the sampled communities, especially in arborescent habitats, denotes the need for management options aiming to halt their spread and competition with endemic species for resources. Bassa et al. (2011) emphasize that anthropogenic action can increase free space and decrease competition with established vegetation, however, a proper management of the species assemblages is underlined. Arborescent habitats, being mostly perennial, and harboring a large number of invasive species capable of colonizing surrounding habitats may translate into unforeseen negative biological implications for adjacent ecosystems or endemic plant and animal communities (see review by Crooks, 2002; Didham et al., 2007). However, we also found that human managed arborescent habitats (i.e., exotic woodlands and production forests) provide conditions to harbor native and endemic plant assemblages in considerable number, hence, we show that these stands are capable of maintaining

populations of species with relevance other than economic, thus with the potential for combining economic return with biodiversity preservation. Connectivity between unmanaged natural areas and managed arborescent community types may be the key to integrate agrofields into semi-natural areas and indigenous vegetation and is strongly recommended in the scientific literature (Crooks 2002; Lindborg and Eriksson 2004; Hilty et al. 2006; Lindenmayer and Fischer 2006; Noss and Daly 2006).

The effects of boundaries in the partitioning of plant species has been the focus of increasing attention due to the impacts, and species dynamics, with adjacent fields (Dunning et al. 1992; Boatman 1994; Schippers and Joenje 2002). Positive edge effects in the preservation of perennial species with conservation value have been reported (Boutin and Jobin 1998; Bassa et al. 2011). However, although the effect of the surrounding landscape in the partitioning of species may vary according to habitat type (Weibull and Östman 2003), we found that invasive species established abundantly throughout most margins of all the community types surveyed in this study, independently of the degree of anthropogenic influence. Since invasive species are prone to rapid growth and high seed production, due to their biology and cosmopolitan preferences, anthropogenic disturbance may affect the growth of species in marginal patches boosting seed reproduction and spread. This result is important for the design of conservation strategies since margins can both work as refuge for indigenous species and as a corridor for the spread of invasive plants that may translate into unforeseen negative effects in adjacent ecosystems (see review by Crooks 2002; Didham et al. 2007). This agrees with Boatman (1994) for the direct correlation between anthropogenic management intensity and invasive species pool enclosed in marginal areas. Endemic species present an opposing pattern of distribution in arborescent and herbaceous communities, being mainly found in the core or in the margin, respectively. Thus, arborescent anthropogenically influenced communities can provide conditions to harbor indigenous plants, with relevance other than economic, outside remnants of fragmented natural forest.

Conclusions

The use of a multinomial model within the framework of Bayesian inference, aiming to empirically assess

changes in the partitioning of plant species as anthropogenic influence rise, revealed to be an effective statistical tool to monitor changes in plant distribution patterns and provide an assessment of the conservation value of a given site, community, or ecosystem based on the ecological, social, and economical attributes of a given species. The methodology allowed to demonstrate the potential value of arborescent habitats for the conservation of indigenous species with importance other than economical, and hence an important alternative to manage these species outside remnants of pristine forest. The important role of margins in the distribution of species of invasive nature was also discriminated. The latter could strongly influence the dissemination of invasiveness depending on management strategies.

The methodology developed herein could be used to produce species spectra for other plant community types in order to evaluate their conservation value, along the gradient now established or along other types of ecological gradients. In addition, it would be possible to use this gradient to study community changes, or species spectra, in other organisms, namely arthropods and eventually birds, for which a considerable amount of information is increasingly available. Moreover, the possibility of extending this type of analysis to extensive databases like the Global Biodiversity Information Facility in order to evaluate conservation status of land areas and to support the selection of priority sites for control of invasive species, or the restoration of native plant communities, is also valuable. Finally, this approach could also be used in a more comprehensive study of plant community composition, extending species partitioning to other species traits like life form or other types of functional groups.

Cohesive management approaches to landscape management and ecologically sound restoration strategies, taking into consideration the methodology developed in this study, may provide an alternative tangible approach to determine critical zones for conservation and intervention in anthropogenic modified landscapes, preserving remnants of biodiversity which otherwise will continue in an unidirectional path towards senescence.

Acknowledgments We thank Mr. Roberto Resendes and Mr. João Moniz for field assistance as well as Eng. Dina Gonçalves and Dr. Pedro Rodrigues for technical support. We also thank the Forest Service of Pico, Flores, and Santa Maria Islands for logistic assistance and lab space as well as CITA-A at Terceira Island. This work was supported by a grant from the Fundo Regional Ciência e Tecnologia, Regional Government of the

Azores and PROEMPREGO and the research project “PRO-BIO, Profiling Reliable Organisms as Bioindicators: an integrated approach for island systems” financed by FLAD (Fundação Luso-Americana para o Desenvolvimento).

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