Arthropod Article Report

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# Introduction

Oceanic islands are home to a large numbers of endemic species, which together with other native species, create unique communities (Whittaker et al, 2007). These communities are often more sensitive to the introduction of exotic and potential invasive species (Jager, 2007). Biological invasions are a major driver of biodiversity loss (Vitousek et al, 1996; Butchart et al 2010), with ecological and economic implications (Lockwood et al, 2007) and oceanic islands are especially sensitive to this process, and is where the most extinctions took place so far (Whittaker & FernÃ¡ndez-Palacios, 2007. Additionally, being isolated, many populations are unable to recover from past disturbance events, mainly driven by habitat loss and species introductions (Whittaker & FernÃ¡ndez-Palacios, 2007). Habitat loss is a complex processes with many variables to consider: isolation, matrix quality, patch area, shape complexity and edge effects (Didham, 2012). Edge effect defines as the exposure of a given fragmented community to the influence of the surrounding matrix (Cook et al, 2002). Many species avoid edges, and a high proportion edge area in a small habitat can devalue its conservation significance. Edges can change the capacity of fixation of a species, due to changes microclimate such as temperature, humidity, wind speed, etc (Tscharntke et al, 2002). The disruption of native ecosystems by landscape alterations is often a source of immigrant species and complex source-sink dynamics creating opportunities to higher turnover in non-native species (Matthews et al. 2019 ) . This process can alter the established biotic interactions, eventually providing new ecological opportunities for invaders (Didham, 2007). Native forest fragments in the Azores are characterized by hard edges, with abrupt changes from native habitats to anthropogenic habitats (Borges et al, 2006, 2008; Matthews et al. 2019). As such, it is likely to expect a constant arrival of non-native species into the native forest, via a source-sink effect (Matthews et al., 2019). However, the establishment of an exotic species implies overcoming several barriers: first, the successful arrival to the new territory (Diez et al, 2012) and then being able to reproduce and to disperse from that point. Invasion is considered successful when a species establishes a self-sustaining population, who can expand to new areas (Blackburn et al, 2011). Regarding Arthropod dispersal movements between native forest patches and the surrounding habitats in the Azores, two main types of arthropod dispersal trends were described: i) endemic and native species are dispersing from native habitats to human-altered habitats; and ii) many exotic species are dispersing to the native forest (Borges et al., 2008). In our study, we aim to understand and quantify the entry of exotic species into the Azorean native forest. The study of beta-diversity patterns, interpreted as the extent of change in a community composition (Whittaker, 1960), is a crucial tool for such task, since it aims to understand the processes that originate community variation (Carvalho et al., 2013). This variation can be originated in species composition (species being replaced by others), species richness (one community has more species than the other), or both. A considerable number of approaches have been proposed to study beta-diversity patterns, and recently it was proposed to partition the components that originate from underlying processes (Baselga, 2010, Carvalho et al., 2012). Carvalho and colleagues defended that beta values should be disentangled into algebraically comparable fractions, reflecting the replacement and richness-difference components in an ecologically meaningful way, which was also supported by Legende (2015). ( Initially, the analysis of such processes were mostly based on the number of taxa and distribution of abundances â Taxonomic Diversity (TD). However, this measure ignores the ecological functions provided by each species in an ecosystem and consequently the role of Functional Diversity (FD). For example, several species in an ecosystem can exhibit a small variation of traits, while few species may perform a large variation of those (VillÃ©ger et al., 2012, 2013). Functional diversity (FD) quantifies the components of biodiversity that influence how an ecosystem operates or functions (Tilman et al., 2001). (Desenvolver mais este tema)Both TD and FD, together with Philogenetic Diversity (PD), have been unified under a methodological and statistical framework for the study of spatial and temporal heterogeneity including its phylogenetic and functional components (Cardoso et al., 2014) along with a statistical package incorporating these innovations (Cardoso et al., 2015). Adding to the relatively well-documented ecological disturbance processes above described, the increasing rate of visitation of protected areas raises concerns as to whether recreation and tourism activities in protected areas can be sustainably managed (Monz et al., 2009). Several studies even suggest that perceived impacts by users can degrade the quality of visitorâs experience (Leung et al., 2013). In response to these concerns, a specialized field of study â recreation ecology â has emerged. Recreation ecology began in the early 1960s (Leung et al., 2013) and is commonly defined as the study of the impacts of outdoor recreation and nature-based tourism activities in natural or semi-natural environments. Modelling the relationship between use and ecological change stood as one of the most sought generalizations in this field. It is often generalized as a curvilinear, asymptotic relationship (Hammitt et al., 1987), largely due to research that focused on easily observable ecological responses and a limited set of variables, such as changes in vegetation cover (Queiroz et al, 2014(1)(2)). Despite recognition that speciesâ responses to perturbations are not random and that different species may be more or less sensitive to particular disturbance depending on their life-history traits. It is increasingly recognized that functional traits (i.e. components of an organismâs phenotype that influence ecosystem level processes) better predict the effects of human-disturbance ecosystem functioning than taxonomic species identity alone (Swenson, 2011).

Intensity of use is the variable most commonly studied in the past for obvious reasons, as it should be both directly related with impact and easily measurable. Yet, other variables of interest should be quantified for better-informed decisions. Recent proposals for modelling the relationship between use and impacts (Monz et al., 2009) are based on long-term studies and suggest that ecological change may be more dynamic and spatially diffuse than these generalizations imply (Kim, 2012). Consequently, future research could more directly model the useâresponse relationship through more sensitive methods of measurement and improved experimental designs focused on long term monitoring. Studies focusing on measurement of dispersal on seeds directly by humans demonstrated that they differ from wind dispersion, confirming that human-associated dispersal allows for seeds to spread to longer distances than the wind. The pattern of propagation is logarithmic, largely decreasing the amount of seeds as distance from the beginning of the trail increases (Whichmann et al., 2009). In the Azores, habitat and plant variables have a significant effect in the richness of arthropod endemic species (Florencio et al, 2016), which in turn are a surrogate group for the arthropod community in these forests (Procurar referÃªncia â jÃ¡ li isto). The source-sink process also explains the presence of non-indigenous species, by means of proximity of a certain point of the forest to its edge (Mathews et al., 2019).

Our hypothesis are: (1) human recreational activities affect the vegetation composition and structure, which in turn affect the spider community. Since this effect is expected to be amplified in the beginning of the trail, pairwise spatial beta taxonomic (TD) and functional (FD) diversity will decrease as the sampling sites go further into the trail; (2) The distance to the edge is a measure of scale for the source-sink effect, and therefore the closest the trail is to the edge, the more likely it is that pairwise spatial beta TD and FD variation is explained by non-human related factors. (3) Both distance to the beginning of the trail and edge distance explain the variation observed in pairwise spatial beta TD and FD values. Confirming or invalidating these relations will allow us to understand the current relevance of recreational activities on arthropod community dynamics (using spiders as indicators), aiding relevant information to where to prioritize efforts in management of the touristic pressure in the Azorean and Macaronesian native forests.

# Materials and Methods

## Study area

The Azorean archipelago is located in the North Atlantic Ocean, roughly between the coordinates 37Âº-40ÂºN and 25-31ÂºW longitude. It consists of nine volcanic islands separated into three groups: the western group (Flores and Corvo), the central group (Fail, Pico, S. Jorge, Graciosa and Terceira) and the eastern group (S. Miguel and S. Maria), in addition to small islets. The climate is temperate oceanic, strongly influenced by the surrounding ocean and the topography of the island, which together produce high levels of relative atmospheric humidity and low temperature variation throughout the year. The study was made in the evergreen laurel forest (Laurisilva). Its original area in the archipelago has been drastically reduced since human settlement, and nowadays covers about 5% of the archipelago, in the most unaccessible and mountainous regions. For the current investigation was done in pedestrian trails in Terceira and S. Miguel that passed through a patch of native forest. The forest from both islands does not present structural differences, both being characterized by reduced tree structure (up to 5m, rarely going to 10), shallow soil and roughed terrain. The degree of conservation is, however, much worse at S. Miguel, presenting a dominance by Clethra arborea, while in terceira the forest structure is much closer to a pristine state. From each trail, only the segments that were in native forest were included, excluding other habitats from the study. Once the vegetation structure represented the forest, that as considered the beginning of the study area. Distance within this segment is counted using the most common direction of traffic by tourists.

## Site Selection

Since in propagation in space from a point, the area increases logarithmically, we have used this scale to select the sites. The trail segment was identified in satellite photography, and then fine tuned in the field. From there, three sites were selected upon a logarithmic gradient of distance by the beginning of the trail, at 0m, 50m and 250m. Another site was added in the section of the trail with the most pristine surrounding forest (Max), and two controls were placed inside the forest, at 50m and 250m from the nearest trail point. Two sites sampled in 2013, with the same methodology, were at about 250m from trails from this study, and such data was used for this study.

##Sampling procedures

Spiders were sampled using plots of 50x50m. Sampling followed the COBRA Monitoring protocol presented in Borges et al (2018). For each forest fragment, and in order to obtain confidence about the representativity of the sampling , one COBRA Inventory protocol is necessary. The latter comprises four hours of aerial search (AAS), four hours of tree beating (BEAT), four vegetation Sweeping (SEW) and 48 pitfall traps, posteriorly arranged in groups of 4 to make a sample unit. For consistency, the Inventory protocol was always done in the most pristine area known in the fragment. The remaining sites were sampled with the COBRA Monitoring protocol (4 hours AAS and 2 Hours BEAT) Sorting was made between December 2017 and October 2018 with the aid of an expert taxonomist. The resulting database was then completed with the functional data known to each spider species in the Azores.

## Data Analyses

We analysed the data in four subsets: all species, Natives (Includes endemics, natives and Indigenous), Non-Indigenous (includes introduced and invesives) and Endemics. All analyses were repeated for each subset. We considered the distance from each sampling point to the trail as a factor, since we expect that the controls will have less non-indigenous species, for not having the edge effects caused by trail infrastructure and the impacts from human use. Distance to edge was elected as a covariate, since the source-sink effect magnitude is dependant on the souce distance. The distance to the beginning of the trail was selected to represent the treatments, since it converts them to a continuous variable and defines precisely the distance of the Max sampling area. It also allows for the verification of the dispersal dinamycs of linear structures (references) such as trails trails included (references), is occuring in this study system. The response variables necessary to study our hypothesis are the taxonomical and functional alpha diversity of natives ans non-indigenous, the proportion of non-indigenous, the proportion of endemics, the proportion of and the three components of beta-diversity (Total, Richness and Relapcement) for taxonomic and functional traits of all species. Aditionally, we will calculate other response variables in order to provide the widest possible support for future studies on which they may be relevant (table 1 in attachment.) They variables were regressed against the three fixed variables in a GLMM, including trail identitiy as a random factor, in order to exclude the location effect from the treatments. The GLMM were implemented in R using glmmTMB package. We used the Performance package to assess for colinearity between fixed variables, All possible models were then compared using the corrected Akaike information criterion, and model weights of each variable were assessed to determine their overall influence of on each response variable. All fixed variables were standardized with the scale() function.

# Results

(table with: sampled areas used as control, S, n, Chao1, chao2, jacknife 1, jacknife 2, and completeness)

A total for 16602 spiders representing 13 families were collected in 194 samples, of these 3428 were adults. We used the estimators Chao1, Chao2, Jacknife and Jacknife 2 to assess the expected richness for each sampling site, and calculated completeness based on it. The completeness obtained made possible to confirm that the monitoring protocols were viable for interpretation in terms of community studies.

(table with sampled areas, total abundance, natives abundance, non-indigenous abundance, endemics abundance, proportion of non-indigenous, functional values (all, nat, NIND, end))

##Effects of beginning of trail, distance to trail and distance to edge (Apresentar tabela com variáveis em estudo, modelos seleccionado, coeficiente da(s) variável(eis), R2c, R2m, e pesos AIC)

We tested each response variable against the combinations against no fixed variable (only with trail identity as random variable), each single variable, fixed variable as pairs and all fixed variables. The various models werethen ranked according to the AICc criteria, and only the lowest-ranking models and the ones that differed less that 2 units were discarded. All selected models had one or no fixed variable. Whenever there were more than one model, the one that had higher conditional R^2 (who describes the variation explained by both the fixed and random variables) we selected. The abundance of non-native species was explained with a model that had the distance to the beginning of the trail as a predictor. The negative coefficient for this variable (-0.305 ) results that the sites closest to the trail present higher abundance of non-native species, and as the sampling sites went further from this point, the abundance of non-indigenous species shown a tendency to decrease. With a modest This was the most relevant variable when selecting between the models, as shown by the highe AICc variable weight. Functional diversity was explained with a model where this variable varied positively with the distance to the beginning of the trail. The further from its beginning, the higher whas the variety of functions spider community performed in the ecossystem. The AICc weight of this variable was higher than the other, meaning that it was the most relevant when building and evaluating the models. Pairwise distance beta values of the endemic community were explained by a model where it varied negatively with the distance to the trail, meaning that the community was more similar to the control areas (more pristine), if the sampling area wasn’t adjacent to the trail. The functional pairwise beta values for the functional space pf endemic species is represented by a model where this variable responds negatively to the increase of distance to the beginning of the trail, meaning that the closest to the beginning it is, the more disturbed the community becomes. The same pattern is observed for the pairwise distance beta values for the natives population. All three had a higher value for trail distance as AICc weight.

##Discussion

The Azores were until quite recently (2015) a reasonably unknown touristic destination. Having won several awards for best touristic destination from that year on, together with the opning of the airline market to low-cost companies, resulted in a visible expansion of the touristic activities in the archipelago (references). The trail infrastructures and environment are therefore exposed to a higher number of visitirs for about two years, at the time of sampling for this study. When compared to Madeira, a Macaronesian island with similar habitats who has X years of high volume tourism (references), The azores Islands are still very much protected from the long term impacts caused by constant visitation.This study was intended to establish the first monitoring time of a temporal series, serving as control standard for future monitoring so that there is information about the status os the spider communities who are in contact with the trail. Future monitoring actions may now elaborate a pairwise temporal and spatial study for alpha ens beta diversity studies, witha nearly-before disturbance reference point for comparison. Our results confirm that a significant effect of associated to the presence and use of trail in the spider community composition. The relations established by the models are not enough to establish a causation, but the fact that the models and the variable coefficients are corroborating our hypothesis indicate that The selected models point The distance to the beginning of the trail is the best predictor for the richness of Non-Indigenous species. That effect was not observed for their respective abundance, where the selected model had no fixed variable. This meets the results of several studies about the arthrpod dinamics in the native forests, where areas of native forest exposed to edges, being more exposed to the source of non-indigenous species, are more prone to receive these species. However, these struggle to maintain their presence there, and their abundances are kept lower than expected by the time tyey are reported as present. The present dinamics is more of a constant flux of new visitors rather than an established population. Moreover, the only model available for predicting the the proportion of Functions provided by non-indigenous species among all the functions of a given sampling site is only explained by the random variable, which indicates that there isn’t a ecological shift caused by the substitution of natives ny the non-indigenous when it comes to performing ecological funcions. This implicates that the results identifies the trail insfrastructure as marginal, but contributing factor to explain the entry of non-native species, effect that is already established for plants(references), but less for athropods (reference). This can be explained by the low to moderate visiting rates they experienced for the last years. since not only the presence of the infrastructure but the visitation rate are relevant to the rate of the source effect (reference), with the observed increase in visitation we can expect the amplification of these effects.  
Beta diversity results indicate that in order to understand the changes in the different sampled communities, one must take into account the distance to the beginning of the trail. The results go towards confirming expected output of trail disturbance, and All the results obtained go towards confirming the initial hypothesis, without however being significant enough to establish a causation. This can be understood given the moderate exposure there has been up so far to recreational impacts, since the Azores visitation rates we low until little before the beginning of this study.