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A spatial scale assessment of habitat effects on arthropod communities of an oceanic island

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ABSTRACT

Most habitats in the Azores have undergone substantial land-use changes and anthropogenic disturbance during the last six centuries. In this study we assessed how the richness, abundance and composition of arthropod communities change with: (1) habitat type and (2) the surrounding land-use at different spatial scales. The research was conducted in Terceira Island, Azores. In eighty-one sites of four different habitat types (natural and exotic forests, semi-natural and intensively managed pastures), epigaeic arthropods were captured with pitfall traps and classified as endemic, native or introduced. The land-use surrounding each site was characterized within a radius ranging from 100 to 5000 m. Non-parametric tests were used to identify differences in species richness, abundance and composition between habitat types at different spatial scales. Endemic and native species were more abundant in natural forests, while introduced species were more abundant in intensively managed pastures. Natural forests and intensively managed pastures influenced arthropod species richness and composition at all spatial scales. Exotic forests and semi-natural pastures, however, influenced the composition of arthropod communities at larger scales, promoting the connectivity of endemic and native species populations. Local species richness, abundance and composition of arthropod communities are mostly determined by the presence of nearby natural forests and/or intensively managed pastures. However, semi-natural pastures and exotic forests seem to play an important role as corridors between natural forests for both endemic and native species. Furthermore, exotic forests may serve as a refuge for some native species.

1. Introduction

Habitat loss and disturbance of natural landscapes due to human action have been implicated as the main causes of the current global biodiversity decline (Didham et al., 1998, 2007; Parker and Nally, 2002; Hoekstra et al., 2005). Such modification of natural habitats generally increases the landscape heterogeneity, resulting in a mosaic of patches in which both natural, semi-natural and exotic habitat types are more or less interconnected (Malanson and Cramer, 1999; Ricketts, 2001; Fischer and Lindenmayer, 2007). Adjacent patches of different habitats create edge effects and an opportunity for extinction-proneness of disturbance sensitive species (Didham et al., 1998). This mosaic of habitat types may change the spatial dynamics of species at the regional scale and consequently their regional and local scale distribution and abundance (Ricklefs, 2008). In oceanic islands, which have often been free from human influence until recently, this may mean the spread of exotic species putting endemic and native species at risk (Borges et al., 2006). The study of species richness, abundance and composition changes across habitat types, as well as of habitat connectivity, is crucial for understanding current local diversity and promoting adequate conservation management strategies (Williamson, 1996; Olden, 2006). Therefore, it is critical to understand which habitat types are required to support populations of endemic and threatened taxa of high value for conservation of local biodiversity.

The Azorean archipelago, which was mostly covered by *Laurisilva* forest prior to human settlement, has undergone drastic land-use changes since the first inhabitants arrived almost 600 years ago. The islands are currently characterized by a dominance of non-native habitat types: intensively managed pastures for cattle; arable land with several types of crops (e.g., corn, potatoes, tea, orchards, etc.); large uniform forests of exotic species; abandoned crop fields and pastures covered with exotic invasive plants

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(e.g. *Pittosporum undulatum*); semi-natural high-altitude pastures. Protecting pristine forests is considered to be one of the most common and effective conservation strategies worldwide, but it is a particularly challenging task in this archipelago since the original Azorean forests are now restricted to a few high-altitude fragments (see Borges et al., 2005, 2006). The fragments, varying in size from 4 to 1000 ha, are often disturbed by the invasion of introduced species (Silva and Smith, 2004; Borges et al., 2006). This disturbance is also reflected in the varying values of biotic integrity that arthropod communities across natural forest fragments present (Cardoso et al., 2007).

Local diversity is determined not only by local conditions, but also by the regional species pool, which in turn depends on regional environmental conditions and historical factors (Ricklefs, 1987, 2008; Borges and Brown, 2004; He et al., 2005). This regional species pool affects the probability of immigration of individuals from neighbouring localities, which depends on the degree of isolation of each locality as well as on the dispersal ability of focal species (Wiens, 1989; Batáry et al., 2007). Hence, local diversity depends on the land-use surrounding each site, and more distant patches with similar habitat qualities are less likely to act as sources of dispersal (Stephens and Krebs, 1986; Hanski, 1999). These arguments and others highlight the widely recognized view that spatial scale is of vital importance for understanding ecological patterns and processes (Whittaker et al., 2001; Rahbek, 2005; Turner and Tjørve, 2005).

The spatial scale dependence of species richness or abundance can be analysed using a multiple scale approach (Pearman, 2002). In arthropods (see Chust et al., 2004; Holland et al., 2004; Clough et al., 2005; Gaucherel et al., 2007; González-Mejias et al., 2007; Hendrickx et al., 2007; Driscoll, 2008), such analysis can help to identify the spatial scales at which a predictor variable influences species richness and abundance of local communities.

Our study addresses how spatial scale affects the relationship between the habitat and diversity of local arthropod communities on an oceanic island (Terceira Island, archipelago of the Azores) that has been subject to a relatively recent but intense process of anthropogenic disturbance. Using a sampling of local arthropod communities across the four main habitat types present on Terceira Island, which differ in both their arboreal cover (forest *vs.* pastures) and origin (natural *vs.* exotic), the aims of this study were to understand how richness, abundance and composition of endemic, native and introduced arthropod communities change with: (1) habitat type and (2) the surrounding land-use at different spatial scales. We tested if, as expected, habitat type and land-use structure do not greatly affect the diversity of introduced species, due to their supposedly higher dispersal ability and their aptitude to be adapted to a wider range of environmental conditions. On the contrary, and according to the evolutionary species pool hypothesis (Pither and Aarssen, 2005), endemic and native species should colonize and survive on more environmentally specialized conditions, being therefore also more deeply influenced by the landscape structure of historically favourable and common habitats. Thus, we expected that endemic and native species respond more negatively to matrix heterogeneity than exotic species.

2. Materials and methods

2.1. Study area

The Azorean archipelago is located in the North Atlantic Ocean, roughly between the coordinates 37–40°N latitude and 25–31°W longitude. It is composed of nine main islands and some small islets aligned on a WNW–ESE course and is fully oceanic, that is, made up of volcanic islands of recent origin (the oldest island, S.Maria, being 8.12 Myr B P). Terceira Island (Fig. 1), with an area of c. 402 km^2 and maximum elevation of 1021 m, is comprised of four main volcanic mountain ranges (Serra de Santa Bárbara, Serra do Morião, Pico Alto and Serra do Cume). The climate is temperate oceanic, i.e., strongly influenced by the proximity of the ocean and by the island topography, which produces high levels of relative atmospheric humidity, especially in the native, high altitude, semi-tropical, evergreen laurel forest (*Laurisilva*). The temperate oceanic climate is also characterized by little temperature fluctuation throughout the year. The natural *Laurisilva* forest is characterized by reduced tree stature (usually up to 5 m, rarely reaching 10 m), shallow soil and rugged terrain.

For the current investigation, we used a gradient of human induced land-use changes in Terceira (Fig. 1). The map was generated using aerial photography and fieldwork. A detailed spatial distribution of exotic forest was obtained from the Azorean Forest Services. From these sources, we discriminated the following four habitat types, which comprise around 87% of the total island area: natural forests, exotic forests (*Eucalyptus* spp. and *Cryptomeria japonica*), semi-natural pastures and intensively managed pastures.

2.2. Site selection

Eighty-one sites were sampled (Fig. 1): 45 in natural forests, 9 in exotic forests, 11 in semi-natural pastures and 16 in intensively managed pastures. Fifty-six percent of the sampling sites were in natural forests, which occupy around 9% of the total island area, while only 20% of the sampling sites were in intensively managed pastures, which are the most widely distributed habitat type, representing almost 48% of the total island area. The number of sampling sites for the other two habitat types was relatively proportional to the amount of the island that each habitat covers: 11% and 14% of sampling sites were exotic forests and semi-natural pastures respectively, each of which occupies around 15% of the island's area. The sampling was intentionally biased towards the habitats in which we knew that higher number of endemic species and higher beta diversity occurred (natural forests). We tried to spread the sampling sites all over the island independently of the surrounding land-use matrix, although intensively managed pastures tend to be located in peripheral low-altitude areas, while natural forests tend to be present only in central high-altitude areas (see Fig. 1).

2.3. Sampling procedures

At each site, epigaeic soil fauna were captured along 150 m long transects. Thirty pitfall traps, plastic cups with a top diameter of 42 mm and 78 mm deep, were dug into the soil so that the rim of the cup was level with the surface. Half of the traps were filled with approximately 60 ml of diluted ethylene glycol (anti-freeze liquid) and the other half with the same volume of a general attractive solution (Turquin), which was made of dark beer and some preservatives (10 g chloral hydrate + 5 ml formalin + 5 ml acetic acid for 1 L of beer; see Turquin, 1973). Traps were spaced 5 m from one another, alternating Turquin and ethylene glycol traps, and were left in the field for two weeks in the summers of different years (see Borges et al., 2005 for a complete description). The majority of arthropods were identified at the species level or, when this was not possible, morphospecies. All species were classified as endemic, native or introduced. Endemic species are those that occur only in the Azores as the result of either speciation events (neoendemics) or extinction of the populations in other places (palaeoendemics). Native non-endemic species arrived by long-distance dispersal to the Azores, cannot be associated with human activities (intentional or accidental human introduction) and are