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Back into the past: Resurveying random plots to track community changes in Italian coastal dunes

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ABSTRACT

Resurveying studies are commonly appreciated as a means to monitoring temporal changes in plant diversity. However, most of them still rely on phytosociological plots, which, although representing an invaluable source of data, can lead to biased estimates of vegetation changes. At the community-level, temporal changes can be quantified by means of beta-diversity measures. However, compositional variation can be the result of two different, often contrasting, processes: turnover and nestedness. In this context we test the effectiveness of resurveying approaches based on quasi-permanent plots in revealing temporal changes in herbaceous communities of Mediterranean coastal dune systems. Indeed, due to their being highly dynamic, coastal dunes can be considered ideal habitats for implementing such tools. In particular, we quantified temporal changes in species composition occurred over 10–15 years by calculating Sørensen index of dissimilarity and, in order to determine whether the change was really driven by species turnover, we partitioned Sørensen index into its two components of turnover and nestedness. At the same time, since diagnostic species are considered to be particularly sensitive to habitat modifications and helpful in assessing changes in the ecological structure of a community, we analyzed temporal changes in the occurrence and cover of diagnostic species of the investigated habitats. Results show that coastal dune communities of our study area underwent consistent changes during the analyzed time-span. Almost 25% of the historical plots disappeared. Major transformations, mainly driven by species turnover, involved upper beach communities, embryonic and mobile dunes, as revealed by the parallel analysis of beta diversity and diagnostic species. This work shows how resurveying approaches can efficiently reveal useful insights on vegetation dynamics, therefore providing a solid basis for the implementation of effective conservation strategies, especially in endangered habitats.

1. Introduction

In the last decades, global changes and anthropogenic pressures seriously affected the structure and functioning of ecosystems across the globe, eventually becoming major drivers of alteration in their composition and diversity (Walther et al., 2005; Verheyen et al., 2016; Hédl et al., 2017). Quantifying such alteration, along with identifying main trends, is a crucial task in the protection and management of natural systems (Kapfer et al., 2017) and is therefore considered a priority issue in conservation ecology.

Resurveying studies, consisting in the re-sampling of vegetation plots historically surveyed by other authors, are being increasingly used as a means to detect temporal changes in the vegetation of many ecosystems. In order to maximize reliability and robustness of subsequent analyses, resurveying studies should be able to accurately retrieve original plot location and, to this regard, permanent plots currently represent the most precise tools. However, permanent plots can be highly resource-intensive and their coverage is in most cases spatially limited (Hédl et al., 2017). On the other hand, quasi-permanent plots, i.e. plots that can be relocated using a plot-specific geographic position (*sensu* Kapfer et al., 2017), despite retaining a certain degree of relocation error, stand for a valid, cost-effective alternative. Although such tools are starting to gain popularity, they still mostly rely on phytosociological data, mainly because of the long tradition of phytosociological relevés providing an invaluable source of data in a variety of habitats (Bakker et al., 1996; Ross et al., 2010). However, as phytosociological relevés are traditionally based on preferential sampling, their use in revisitation studies and associated analyses violates the statistical

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assumptions of randomness and independence of observations (Lájer, 2007; Michalcová et al., 2011) which, together with the frequent lack of geographical coordinates, can result in biased estimates of vegetation change (Jandt et al., 2011; Chytrý et al., 2014).

Whittaker (1960, 1972) introduced the concept of beta diversity (the amount of variation in species composition among a set of sampling units) for linking local-scale diversity (or alpha diversity) to regional-scale diversity (gamma diversity). Since then, beta diversity has become a primary tool for examining changes in the composition of species assemblages, not only along spatial or environmental gradients, but also along temporal gradients. In this context, Baselga (2010) and Baselga (2012) suggested how the concept of beta diversity actually involves two distinct processes, one (temporal turnover) being the real temporal variation of species assemblages from one time to another, and the other (nestedness resultant-dissimilarity) being an effect of the poorest site being a strict subset of the richest site. As these two components may show contrasting patterns, their separation is crucial in order to assess actual temporal trends in biodiversity (see Baselga 2012 and references therein).

While beta diversity measures focus on quantifying changes between communities, they give no insights about temporal trends experienced by single species. In this sense, diagnostic species (i.e. species that, guaranteeing both existence and functionality of their habitats, can be considered representative of different vegetation types and are particularly sensitive to a range of threats and habitat modifications) are being increasingly used by researchers as crucial units for monitoring biodiversity (Santoro et al., 2012b; Del Vecchio et al., 2016; Angiolini et al., 2017). Providing information about underlying abiotic components, diagnostic species can help evaluate changes in the ecological structure of a community (Lambeck, 1997; Kimball et al., 2010; Del Vecchio et al., 2016), and are therefore of great use in the assessment of temporal changes.

In this framework, taking advantage of a large coastal vegetation database comprising standardized random plots originally sampled since 2002 (Sperandii et al., 2017), we tested the effectiveness of resurveying approaches based on quasi-permanent random plots for assessing temporal changes in Mediterranean coastal dunes. Indeed, despite their being highly suitable systems for implementing such approaches, up to our knowledge revisitation studies focusing on Mediterranean sandy habitats and making use of quasi-permanent random plots haven't been implemented yet.

Being transitional ecosystems located at the boundary between land and sea, coastal dunes are unique habitats characterized by constraining environmental conditions that limit survival and successful reproduction to a relatively small set of highly specialized plant species (Maun, 2009; Fenu et al., 2013; Marcenò et al., 2018). Such environmental constraints, together with their ecotonal nature, make coastal dunes highly dynamic ecosystems where even short time-spans can be enough to track vegetation changes (Sperandii et al., 2018). At the same time, in spite of a prominent conservation value (Van der Maarel 2003; Martínez et al. 2008; Acosta et al., 2009) and a wide range of socio-economic services provided (Defeo et al., 2009), coastal dunes appear among the most threatened ecosystems on earth (Schlacher et al., 2007; Janssen et al., 2016).

In consideration of the above, we endeavor to answer the following research questions:

- i) To what extent have coastal dune habitats of Central Italy changed over the last 10–15 years?
- ii) Can we relate this change to a real "species turnover" or rather to a "nestedness effect"?
- ii) Can we identify trends for diagnostic species of the involved habitats?

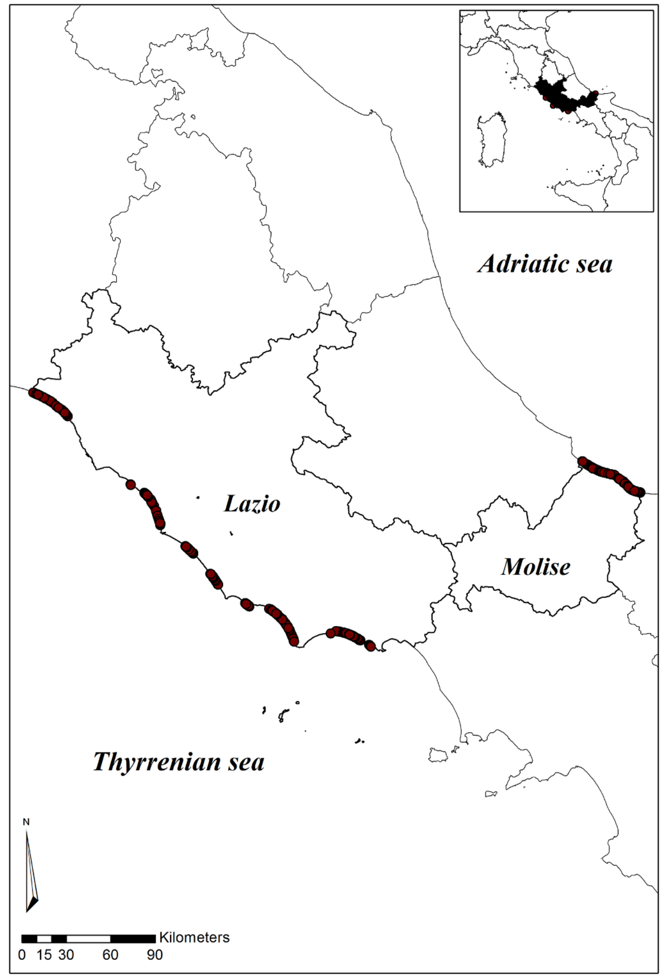

Fig. 1. Main dune systems of Lazio and Molise (Central Italy).

2. Materials & methods

This resurveying study was performed on coastal dune systems located in Central Italy along the Thyrrenian and Adriatic coasts (Fig. 1). Throughout the study area, climate is Mediterranean (Carranza et al., 2008) and holocenic dune systems occupy a narrow stripe along the seashore.

2.1. Historical data

A total of 188 historical relevés were extracted from an existing database of Italian coastal dunes ("RanVegDunes"; Sperandii et al., 2017). This database consists of original georeferenced relevés collected since 2002, for which sandy vegetation was recorded in standardized 4-m^2 random quadrats (i.e. plots). For each plot, a species list was available with abundance values estimated using a percentage cover scale. Additional information, for each plot, includes a level 3-EUNIS code assigned according to the EUNIS habitat classification system (Davies et al., 2004; Table 1). The selected 188 plots were originally sampled between 2002 and 2007 (hereafter T_0) throughout the first portion of the coastal zonation, therefore including annual pioneer communities of the upper beach, embryonic dunes, mobile dunes and coastal stable dune grasslands. Specifically, 63 plots were sampled in 2002, 56 were sampled in 2005 and 59 in 2007. As in this paper we will consider plant communities in terms of level-3 EUNIS habitats, it is necessary to clarify that the above-mentioned investigated communities correspond to EUNIS categories B1.1, B1.3 and B1.4 (see Table 1 for description of the communities and distribution of the plots among