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 socioeconomic 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"?
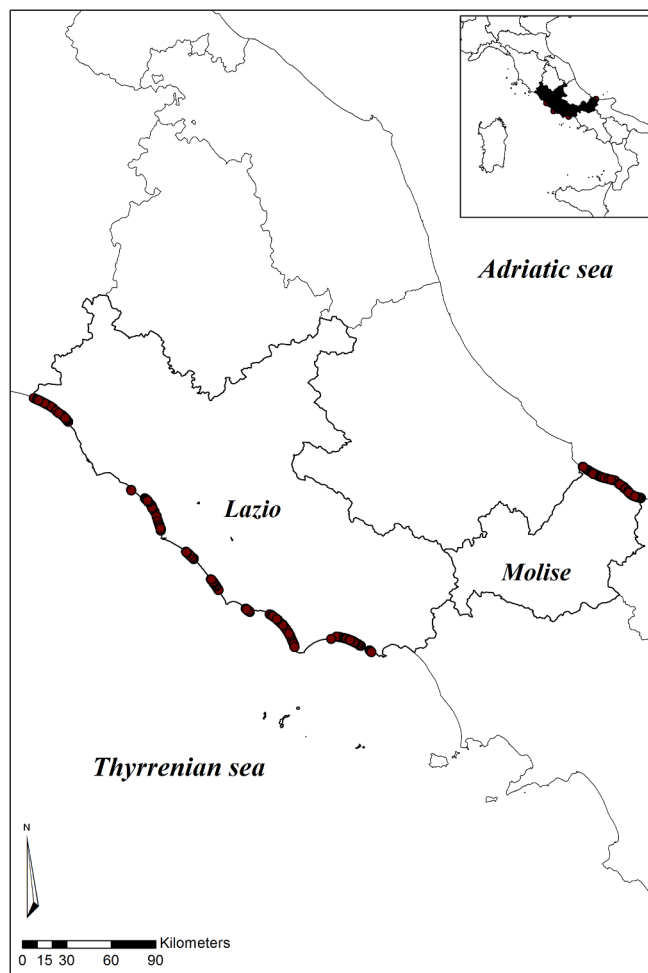- ii) Can we identify trends for diagnostic species of the involved habitats?

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

Table 1
Level 3-EUNIS type, description of the community and diagnostic species selected for this study.

Level 3-EUNIS type	Description and correspondence with EU habitats (ex Annex I 92/43/EEC)	Diagnostic species	Number of observations
B1.1 Sand beach drift lines	Pioneer annual formations characterizing the strandline zone of the beach (EU hab 1210 – Annual vegetation of drift lines)	*Cakile maritima* Scop. subsp. *maritima*, *Chamaesyce peplis* (L.) Prokh., *Polygonum maritimum* L. *Salsola kali* L.	37
B1.3 Shifting coastal dunes	Mobile coastal sand ridges which include embryonic dunes characterized by *Elymus farctus* (EU hab 2110 – Embryonic shifting dunes) and semi-permanent dune systems dominated by *Ammophila arenaria* subsp. *Australis* (EU hab 2120 – Shifting dunes along the shoreline with *Ammophila arenaria*)	*Ammophila arenaria* (L.) Link subsp. *australis* (Mabille) Laínz *Anthemis maritima* L. *Calystegia soldanella* (L.) Roem. & Schult., *Cyperus capitatus* Vand. *Echinophora spinosa* L., *Elymus farctus* (Viv.) Runemark ex Melderis subsp. *farctus*, *Eryngium maritimum* L., *Euphorbia paralias* L., *Lotus cytisoides* L. *Medicago marina* L. *Otanthus maritimus* (L.) Hoffmanns. & Link subsp. *Maritimus* *Pancratium maritimum* L. *Sporobolus virginicus* Kunth,	95
B1.4 Coastal stable dune grassland	Stable dune grasslands including chamaephytic communities of the inland dunes dominated by *Crucianella maritima* (EU hab 2210 – *Crucianellion maritimae* fixed beach dunes) and annual, species-rich communities colonizing dry interdunal depressions (EU hab 2230 – *Malcolmietalia* dune grasslands)	*Bromus diandrus* Roth subsp. *Maximus* (Desf.) Soó *Crucianella maritima* L. *Cutandia maritima* (L.) Barbey *Lagurus ovatus* L. *Medicago littoralis* Loisel. *Ononis variegata* L. *Phleum arenarium* L. subsp. *caesium* H. Scholz *Pseudorlaya pumila* (L.) *Grande* *Pycnocomon rutifolium* (Vahl) Hoffmanns & Link *Silene canescens* Ten. *Sixalix atropurpurea* (L.) Greuter & Burdet *Vulpia fasciculata* (Forssk.) Fritsch	44

EUNIS types). However, it should be noted that, as 12 plots could not be associated to any EUNIS category because they were highly degraded or highly invaded by alien species, they were labeled as "not classifiable" (NC).

2.2. Revisitation study

Historical plots were revisited and resampled in 2017 (hereafter T_1), following the same methods used by the original surveyors. This allowed us to evaluate changes occurred over 10–15 years. During the resurvey, special care was taken to perform the resampling during the same months in which the original sampling was done (April-May). Plot positions were relocated using a GPS unit on which historical geographic coordinates were stored (quasi-permanent plots *sensu* Kapfer et al., 2017).

2.3. Data analysis

2.3.1. Beta-diversity analysis

To assess variation in species composition over time, presence-absence matrices were used. Specifically, pairwise dissimilarity values between matched sites (old vs new) were computed using Sørensen index of dissimilarity (β_{sor}):

$$\beta_{sor} = (b + c)/(2a + b + c)$$

where a is the number of species present at both T_0 and T_1, b is the number of species exclusive to T_0 and c is the number of species exclusive to T_1. Values of the index range from 0 to 1, with 0 indicating a null dissimilarity (the communities have the same species composition)

and 1 indicating total dissimilarity (the communities do not share any species). This was done using R package betapart (function *beta.temp*, Baselga and Orme, 2012), which at the same time allows partitioning beta-diversity into the two components of turnover and nestedness (Baselga, 2012). To determine whether temporal change occurred similarly across the investigated portion of coastal zonation, differences in Sørensen values among different communities (identified through EUNIS categories) were tested using Kruskal-Wallis rank-based non-parametric test. Additionally, in order to find out which was the prevailing process behind the change, turnover and nestedness values were compared for each plot and also among different communities.

2.3.2. Variation in occurrence frequency and cover of diagnostic species

Diagnostic species (see Table 1) were identified using the Italian Interpretation Manual of the 92/43/EEC Habitats Directive (Biondi et al. 2009). Specifically, we selected a total of 29 diagnostic species, choosing those that, for each plant community, were most abundant in our study area. For each species and time point separately, occurrence frequencies (i.e. the number of plots in which a species occurs) and cover were calculated as follows.

First, standardized occurrence frequencies and cover values were calculated, for each species and time point separately, following Kapfer and Grytnes (2017). In particular, occurrence frequencies were standardized, for each diagnostic species, dividing the number of species occurrences recorded during a specific survey by the total number of plots sampled during that survey. Similarly, cover values for each time period were standardized dividing the total cover of a species recorded during a survey by the number of species occurrences in that survey. Standardized changes were then calculated for both occurrence and

cover values by subtracting old values from new values, with positive changes indicating an increase in the occurrence frequency/cover of the species and negative values indicating a decrease in the occurrence frequency/cover of the species. In order to assess whether changes in occurrence frequencies between the two time points were significant, we used McNemar's non-parametric test for dependent data (Agresti, 2003). By comparing changes in the proportion of occurrences of a certain species at T_0 and T_1, this test assesses whether the probability of the species not being present in the first survey and appearing in the second survey is equal to the probability of the species being present in the first survey and disappearing in the second survey.

To test for statistically significant cover changes between old and new relevés, exact Wilcoxon-Pratt signed rank tests for paired samples were performed for each diagnostic species in its reference habitat. This was done using R package "coin" (function: wilcoxsign_test; Hothorn et al., 2008), which allows obtaining exact *p*-values of the test statistic by specifying an argument of the function (distribution = "exact") and at the same time, by default, implements Pratt's method of handling zeros (Pratt, 1959). It should be noted that, in order to satisfy assumptions about independence of observations when performing statistical tests, each of the above-cited analyses was carried out on three different subsets ($N_{subset1}$ = 121; $N_{subset2}$ = 121; $N_{subset3}$ = 118) randomly extracted from the original 188 points dataset. These subsets were created performing three random selections of points so that the minimum distance between historical observations would be at least 100 m. (ArcGis 10.1, ESRI). All statistical analyses were performed using R (R Core Team, 2017).

3. Results

3.1. Temporal changes in coastal dune communities

During the resurvey we could ascertain that 44 out of the 188 historical plots actually disappeared. Upper beach and foredune plant communities were most affected by this phenomenon, with EUNIS categories B1.1 and B1.3 respectively losing 21–25% and 58–60% of the historical plots (Appendix A).

Sørensen index of dissimilarity unveiled substantial changes, as shown in Fig. 2. Two peaks can be particularly identified, the first including values around 0.9–1 and the second covering values around 0.4–0.6. With regard to the first peak, it should be noted that values of 1 (which identify a total dissimilarity between matched sites) together with relevés that completely changed in their species composition also incorporate disappeared plots.

Although the distribution of Sørensen index values seems to follow coastal zonation (Fig. 3), with high values characterizing upper beach
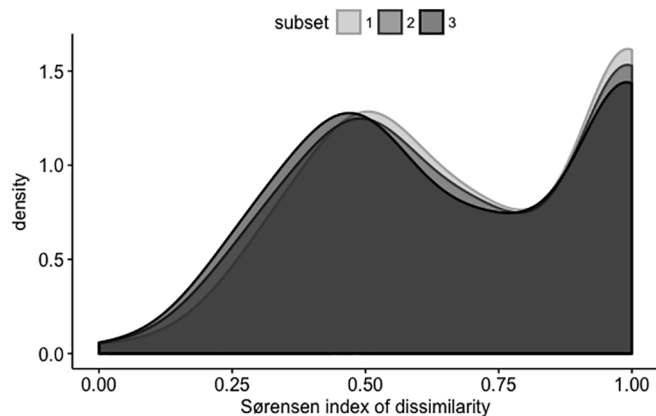

Fig. 2. Density plot reporting the values of Sørensen index of dissimilarity for the three randomly selected subsets ($N_{subset1}$ = 121; $N_{subset2}$ = 121; $N_{subset3}$ = 118) of 188 survey plots.

communities and lower values associated to more inland communities, no statistical differences were found when testing values of the index against EUNIS categories in all three subsets (Kruskal-Wallis *p* > 0.05).

Partitioning beta diversity into its two related components revealed similar results in all subsets (Table 2). In particular, turnover turned out to be the prevailing process in most cases (83–85% of the plots), while nestedness drove the change in only 12–16% of the plots. This holds for all EUNIS categories, where turnover prevailed in 78–100% of the plots (see Appendix B).

3.2. Changes in occurrence frequency and cover of diagnostic species over time

During the considered time-span, 25 out of the 29 investigated diagnostic species decreased in their occurrence frequency while the rest showed a positive trend (Appendix C). However, McNemar's tests indicated significant changes for just 8 species belonging to EUNIS categories B1.1 and B1.3, which all decreased in their occurrence. The species that underwent the most substantial decline are *Cakile maritima* and *Salsola kali*, followed by *Chamaesyce peplis*, *Echinophora spinosa*, *Elymus farctus* and *Ammophila arenaria* (Fig. 4).

As for cover changes, 12 out of 29 species experienced a decrease, while the rest experienced an increase during the considered time-span (Appendix D). However, such changes resulted to be significant for just 6 species (Fig. 5) belonging to EUNIS categories B1.1 and B1.3. The most important decrease was observed for *Ammophila arenaria*, *Salsola kali* and *Chamaesyce peplis,* while the most important increase (although relatively low) was found for *Echinophora spinosa*.

4. Discussion

During the last 10–15 years, coastal dune communities of Central Italy underwent substantial changes that can be summarized in the disappearance of almost 25% of the historical plots and in major transformations affecting most investigated communities, not only in their species composition but also in the occurrence frequency and cover of their diagnostic species. Concerning disappeared plots, some turned out to be submerged due to local erosion processes leading to a retreat of the coastline, while others, mainly in areas associated with seasonal tourism, were found to be completely unvegetated.

For all communities investigated, turnover was found to be mostly responsible for compositional changes between old and new plots, thus supporting the dynamic nature of coastal dune ecosystems (Martínez et al, 2008; Agardy et al., 2005; Buffa et al., 2012; Calvão et al., 2013). The fact that species replacement prevailed over nestedness might point to ongoing transformation processes, as also suggested by recent diachronic studies based on permanent plots (Prisco et al., 2015; Prisco et al., 2016). This seems to be supported by the analysis of diagnostic species, which revealed how all the species experiencing a statistically significant change during the considered time-span decreased in their occurrence frequency and/or in their cover, except for a slight increase in the cover of two of them.

The most considerable variation seems to have affected pioneer communities of the upper beach and foredunes (corresponding to Eunis cat. B1.1 and B1.3), which also harboured the vast majority of disappeared plots. Here, values of Sørensen index of dissimilarity turned out to be, on average, higher than in coastal dune grasslands. Indeed, although formal testing rejected statistical differences among the investigated communities, results from the analysis of temporal changes in occurrence and cover of diagnostic species support the hypothesis of the seaward portion of coastal zonation having experienced the greatest change, as also found by Prisco et al. (2015, 2016). In particular, 3 out of the 5 species tested for the upper beach sector (*Salsola kali*, *Cakile maritima* and *Chamaesyce peplis*) strongly decreased in their occurrence frequency during the time considered. However, *Salsola kali* and *Chamaesyce peplis* also decreased in their cover, while *Cakile maritima*
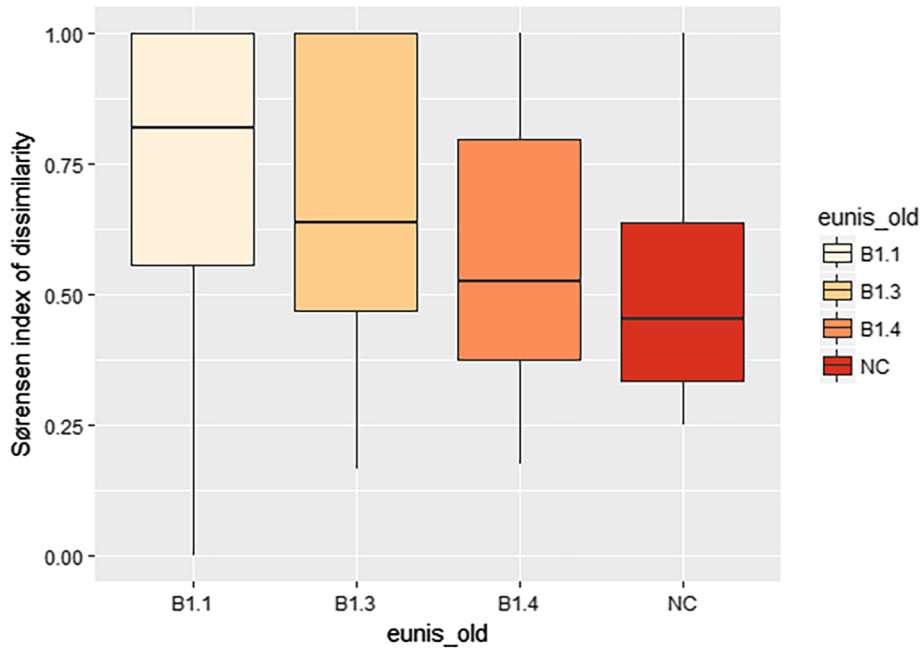
Fig. 3. Boxplot showing values of Sørensen index of dissimilarity among the considered EUNIS categories. *NB*. All three subsets are shown together.

Table 2

Partition of Sørensen index of dissimilarity. *prevalence*: % of plots in which the specified component was found to be prevailing (averaged over subsets); *sd*: standard deviation. *NB*: disappeared plots and plots that didn't change at all (Sørensen index value = 0) were excluded from this calculation.

component	prevalence	sd
nestedness	15.03	1.94
turn/nest	0.40	0.69
turnover	84.57	1.30
tot	100	–

Fig. 5. Mean temporal changes in cover calculated, over the three subsets, for diagnostic species that underwent significant changes ($p < 0.05$ in at least 2 out of the 3 subsets).
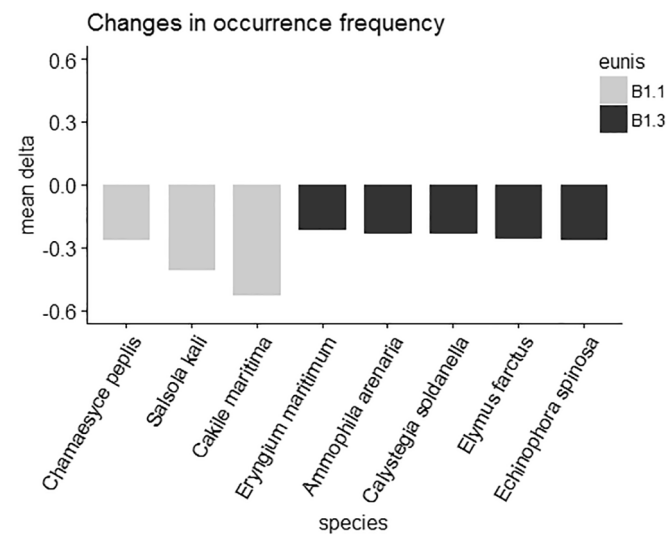

Fig. 4. Mean temporal changes in occurrence frequency calculated, over the three subsets, for diagnostic species that underwent significant changes ($p < 0.05$ in at least 2 out of the 3 subsets).

slightly increased in its cover from T_0 to T_1. This divergence might be due to the fact that, as the species' reference habitat is the most subject to natural (occasional inundation, erosion) and anthropogenic (mechanical cleaning) disturbance, and at the same time dispersal for this
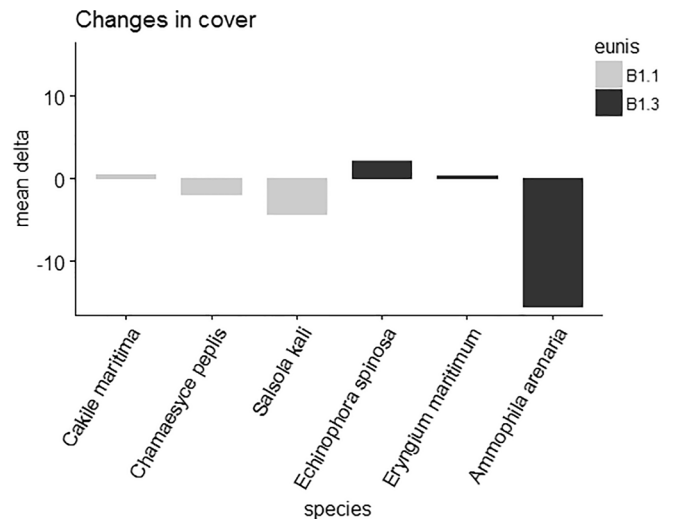
species mainly depends on tides and winds (Davy et al., 2006), populations of *C. maritima* may randomly germinate and develop more backward, in neighboring communities. However, considerations on temporal changes affecting drift line communities should be made with utmost care. Indeed, as these communities are mostly formed by annual species, whose occurrence and prevalence can be considerably dependent on climatic variations over the years, and at the same time are prone to high disturbance, they tend to be inherently ephemeral and shifting (Doing, 1985; Acosta et al., 2009; Landi et al., 2012). Together with drift line communities, foredunes turned out to experience important changes during the considered time-span. Here, the vast majority of the investigated diagnostic species showed a decreasing trend in their occurrence frequency. In particular, the disappearance of diagnostic species such as *Eryngium maritimum*, *Calystegia soldanella* and *Echinophora spinosa* might indicate ongoing degradation processes occurring in this sector. At the same time, the substantial loss in the occurrence of *Ammophila arenaria* and *Elymus farctus* raises considerable

environmental concerns, as the two rhizomatous species play a key role in dune formation and stabilization. Similar results are reported by Del Vecchio et al. (2015), who found significant changes affecting foredune habitats in the context of a 20-years revisitation study based on phytosociological relevés. However, together with an increase in the cover of *Elymus farctus* over the years, Del Vecchio et al. (2015) identified an increase in the cover of *Ammophila arenaria*, whereas we found a parallel decrease in both occurrence and cover of this species over the years.

Our results confirm the vulnerability of three important sectors of the coastal zonation: upper beach, embryo dunes and shifting dunes. By representing the first elements of coastal zonation, these communities are certainly most exposed to both natural and anthropogenic sources of disturbance such as coastal erosion and seaside mass tourism (Acosta et al., 2006; Buffa et al., 2012), which are regarded among the most important threats affecting coastal dune ecosystems. In particular, many studies already evidenced the negative impacts exerted by trampling, mechanical cleaning of the beach and other tourism-related activities on sand dune habitats (Santoro et al., 2012a; Farris et al., 2013). At the same time, it has been shown how erosion, either caused by natural phenomena or by the development of artificial infrastructures such as harbors, strongly modifies coastal zonation, often truncating its first elements (Buffa et al., 2012; Ciccarelli, 2014; Prisco et al., 2015).

As long-term perspectives are increasingly needed to study compositional changes in many ecosystems, resurveying studies represent a valuable and cost-effective solution. Although it is very difficult to avoid some of the bias they are naturally prone to (e.g. relocation bias, observer bias), efforts can be made to minimize them and much depends on the analyzed ecosystem. In this context, revisitation approaches based on georeferenced and standardized random plots, reducing relocation inaccuracy and avoiding biases deriving from both scale-dependence of inter-specific correlations and violation of statistical assumptions about randomness (Chytrý and Otýpková, 2003; Jandt et al., 2011; Michalcová et al., 2011), provide reliable estimates of change while at the same time allowing wide spatial coverage. Being highly dynamic ecosystems, coastal dunes can be considered a useful testing system for resurveying approaches based on standardized, georeferenced random plots, even when considering short- to medium time-spans. However, with this work we intend to highlight that also other ecosystems could actually benefit from the use of such approaches, especially when based on standardized, georeferenced random plots instead of phytosociological plots.

5. Conclusion

Despite being challenging, revisitation studies are highly recommendable tools for analyzing temporal dynamics in plant communities (Hédl et al., 2017; Kapfer et al., 2017). This study, based on georeferenced random plots, revealed substantial changes affecting coastal dunes of Central Italy in the last 10–15 years. In particular, by conducting analyses at both the community- and species-level, we provide evidences of upper beach and foredunes communities having experienced major transformations during the considered time-span. At the same time, partitioning beta diversity allowed to identify species turnover as the main driver of change. Whereas further research will be needed to confirm such trends and investigate possible causes, we stress the value of resurveying approaches in incrementing knowledge of vegetation dynamics and, to this regard, we highlight their usefulness in providing a good basis for the implementation of effective conservation strategies, especially in endangered habitats.

Acknowledgements

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2018.09.039.

References

Acosta, A., Ercole, S., Stanisci, A., Blasi, C., 2006. Sandy coastal ecosystems and effects of disturbance in Central Italy. J. Coastal Res. 39, 985–989.

Acosta, A.T.R., Carranza, M.L., Izzi, C.F., 2009. Are there habitats that contribute best to plant species diversity in coastal dunes? Biodivers. Conserv. 18, 1087–1098. https://doi.org/10.1007/s10531-008-9454-9.

Agardy, T., Alder, J., 2005. Coastal systems. Conditions and Terms In: Hassan, R. (Ed.), Millennium Ecosystem Assessment: Strengthening Capacity to Manage Ecosystems Sustainably for Human Well Being. Island Press, Washington, D.C., pp. 513–549.

Agresti, A., 2003. Categorical Data Analysis. John Wiley & Sons.

Angiolini, C., Bonari, G., Landi, M., 2017. Focal plant species and soil factors in Mediterranean coastal dunes: an undisclosed liaison? Estuar. Coast. Shelf Sci. https://doi.org/10.1016/j.ecss.2017.06.001.

Bakker, J.P., Olff, H., Willems, J.H., Zobel, M., 1996. Why do we need permanent plots in the study of vegetation dynamics? J. Veg. Sci. 7, 147–156.

Baselga, A., 2010. Partitioning the turnover and nestedness components of beta diversity. Glob. Ecol. Biogeogr. 19 (1), 134–143.

Baselga, A., 2012. The relationship between species replacement, dissimilarity derived from nestedness, and nestedness. Glob. Ecol. Biogeogr. 21 (12), 1223–1232.

Baselga, A., Orme, C.D.L., 2012. betapart: an R package for the study of beta diversity. Meth. Ecol. Evol. 3 (5), 808–812.

Biondi, E., Blasi, C., Burrascano, S., Casavecchia, S., Copiz, R., Del Vico, E., et al., 2009. Italian interpretation manual of the 92/43/EEC directive habitats. http://vnr.unipg.it/habitat/index.jsp.

Buffa, G., Fantinato, E., Pizzo, L., 2012. Effects of disturbance on sandy coastal ecosystems of N-Adriatic coasts (Italy). Biodiversity Enrichment in a Diverse World. InTech.

Calvão, T., Pessoa, M.F., Lidon, F.C., 2013. Impact of human activities on coastal vegetation-a review. Emirates J. Food Agric. 25 (12), 926.

Carranza, M.L., Acosta, A.T.R., Stanisci, A., Pirone, G., Ciaschetti, G., 2008. Ecosystem classification and EU habitat distribution assessment in sandy coastal environments. Environ. Monit. Assess. 140 (1–3), 99–107.

Chytrý, M., Otýpková, Z., 2003. Plot sizes used for phytosociological sampling of European vegetation. J. Veg. Sci. 14 (4), 563–570.

Chytrý, M., Tichý, L., Hennekens, S.M., Schaminée, J.H., 2014. Assessing vegetation change using vegetation-plot databases: a risky business. Appl. Veg. Sci. 17 (1), 32–41.

Ciccarelli, D., 2014. Mediterranean coastal sand dune vegetation: influence of natural and anthropogenic factors. Environ. Manage. 54 (2), 194–204.

Davies, C.E., Moss, D., Hill, M.O., 2004. EUNIS habitat classification revised 2004. Report to: European Environment Agency-European Topic Centre on Nature Protection and Biodiversity, pp. 127–143.

Davy, A.J., Scott, R., Cordazzo, C.V., 2006. Biological flora of the British Isles: Cakile maritima Scop. J. Ecol. 94 (3), 695–711.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., et al., 2009. Threats to sandy beach ecosystems: a review. Estuar. Coast. Shelf Sci. 81, 1–12.

Del Vecchio, S., Prisco, I., Acosta, A.T., Stanisci, A., 2015. Changes in plant species composition of coastal dune habitats over a 20-year period. AoB Plants 7. https://doi.org/10.1093/aobpla/plv018.

Del Vecchio, S., Slaviero, A., Fantinato, E., Buffa, G., 2016. The use of plant community attributes to detect habitat quality in coastal environments. AoB Plants 8. https://doi.org/10.1093/aobpla/plw040.

Doing, H., 1985. Coastal fore-dune zonation and succession in various parts of the world. In: Ecology of Coastal Vegetation. Springer, Dordrecht, pp. 65–75.

ESRI, 2011. ArcGIS Desktop: Release 10. Environmental Systems Research Institute, Redlands, CA.

Farris, E., Pisanu, S., Ceccherelli, G., Filigheddu, R., 2013. Human trampling effects on Mediterranean coastal dune plants. Plant Biosyst. – Int. J. Deal. Aspects Plant Biol. 147 (4), 1043–1051.

Fenu, G., Carboni, M., Acosta, A.T., Bacchetta, G., 2013. Environmental factors influencing coastal vegetation pattern: new insights from the Mediterranean Basin. Folia Geobotanica 48 (4), 493–508.

Hédl, R., Bernhardt-Römermann, M., Grytnes, J.A., Jurasinski, G., Ewald, J., 2017. Resurvey of historical vegetation plots: a tool for understanding long-term dynamics of plant communities. Appl. Veg. Sci. 20 (2), 161–163.

Hothorn, T., Hornik, K., Van De Wiel, M.A., Zeileis, A., 2008. Implementing a class of permutation pests: the coin package. J. Stat. Softw. 28 (8), 1–23. http://www.jstatsoft.org/v28/i08/.

Jandt, U., von Wehrden, H., Bruelheide, H., 2011. Exploring large vegetation databases to detect temporal trends in species occurrences. J. Veg. Sci. 22 (6), 957–972.

Janssen, J.A.M., Rodwell, J.S., Criado, M.G., et al., 2016. In: European Red List of Habitats. Part 2. Terrestrial and Freshwater Habitats. European Union. https://doi.org/10.2779/091372.

Kapfer, J., Grytnes, J.A., 2017. Large climate change, large effect? Vegetation changes over the past century in the European High Arctic. Appl. Veg. Sci. 20 (2), 204–214.

Kapfer, J., Hédl, R., Jurasinski, G., Kopecký, M., Schei, F.H., Grytnes, J.A., 2017.

Resurveying historical vegetation data–opportunities and challenges. Appl. Veg. Sci. 20 (2), 164–171.

Kimball, S., Angert, A.L., Huxman, T.E., Venable, D.L., 2010. Contemporary climate change in the Sonoran Desert favors cold-adapted species. Glob. Change Biol. 16 (5), 1555–1565.

Lájer, K., 2007. Statistical tests as inappropriate tools for data analysis performed on non-random samples of plant communities. Folia Geobotanica 42 (2), 115.

Lambeck, R.J., 1997. Focal species: a multi-species umbrella for nature conservation. Conserv. Biol. 11 (4), 849–856.

Landi, M., Ricceri, C., Angiolini, C., 2012. Evaluation of dune rehabilitation after 95 years by comparison of vegetation in disturbed and natural sites. J. Coastal Res. 28 (5), 1130–1141.

Marcenò, C., Guarino, R., Loidi, J., Herrera, M., Isermann, M., Knollová, I., Tichý, L., Tzonev, R.T., Acosta, A.T.R., FitzPatrick, Ú., Iakushenko, D., Janssen, J.A.M., Jiménez-Alfaro, B., Kącki, Z., Keizer-Sedláková, I., Kolomiychuk, V., Rodwell, J.S., Schaminée, J.H.J., Šilc, U., Chytrý, M., 2018. Classification of European and Mediterranean coastal dune vegetation. Appl. Veg. Sci. https://doi.org/10.1111/avsc.12379.

Martínez, M.L., Psuty, N.P., Lubke, R.A., 2008. A perspective on coastal dunes. In: Coastal Dunes. Springer, Berlin, Heidelberg, pp. 3–10.

Maun, M.A., 2009. The biology of coastal sand dunes. Oxford University Press.

Michalcová, D., Lvončík, S., Chytrý, M., Hájek, O., 2011. Bias in vegetation databases? A comparison of stratified-random and preferential sampling. J. Veg. Sci. 22 (2), 281–291.

Pratt, J.W., 1959. Remarks on zeros and ties in the Wilcoxon signed rank procedures. J. Am. Stat. Assoc. 54 (287), 655–667.

Prisco, I., Stanisci, A., Acosta, A.T.R., 2015. Temporal changes in Adriatic coastal dunes: results from a short term vegetation monitoring. Plant Sociol. 52 (2), 95–100.

Prisco, I., Stanisci, A., Acosta, A.T., 2016. Mediterranean dunes on the go: evidence from a short term study on coastal herbaceous vegetation. Estuar. Coast. Shelf Sci. 182, 40–46.

Core Team, R., 2017. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria https://www.R-project.org/.

Ross, L.C., Woodin, S.J., Hester, A., Thompson, D.B., Birks, H.J.B., 2010. How important is plot relocation accuracy when interpreting re-visitation studies of vegetation change? Plant Ecol. Divers. 3 (1), 1–8.

Santoro, R., Jucker, T., Prisco, I., Carboni, M., Battisti, C., Acosta, A.T.R., 2012a. Effects of trampling limitation on coastal dune plant communities. Environ. Manage. 49 (3), 534–542.

Santoro, R., Carboni, M., Carranza, M.L., Acosta, A.T.R., 2012b. Focal species diversity patterns can provide diagnostic information on plant invasion s. J. Nat. Conserv. 20 (2), 85–91.

Schlacher, T., Dugan, J., Schoeman, D.S., Lastra, M., Jones, A., Scapini, F., McLachlan, A., Defeo, O., 2007. Sandy beaches at the brink. Divers. Distrib. 13 (5), 556–560.

Sperandii, M.G., Prisco, I., Stanisci, A., Acosta, A.T., 2017. RanVegDunes-A random plot database of Italian coastal dunes. Phytocoenologia 231–232.

Sperandii, M.G., Prisco, I., Acosta, A.T.R., 2018. Hard times for Italian coastal dunes: insights from a diachronic analysis based on random plots. Biodivers. Conserv. 27 (3), 633–646.

Van Der Maarel, E., 2003. Some remarks on the functions of European coastal ecosystems. Phytocoenologia 33 (2–3), 187–202.

Verheyen, K., De Frenne, P., Baeten, L., Waller, D.M., Hédl, R., Perring, M.P., De Lombaerde, E., 2016. Combining biodiversity resurveys across regions to advance global change research. Bioscience 67 (1), 73–83.

Walther, G.R., Berger, S., Sykes, M.T., 2005. An ecological 'footprint' of climate change. Proc. Royal Soc. London B: Biol. Sci. 272 (1571), 1427–1432.

Whittaker, R.H., 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecol. Monogr. 30, 279–338.

Whittaker, R.H., 1972. Evolution and measurement of species diversity. Taxon 213–251.