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Mediterranean coastal pine forest stands: Understorey distinctiveness or not?

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ABSTRACT

A common perception of plantation forests is that they constitute an "ecological desert" and that is why they are often disdained by scholars. Distribution patterns of understorey assemblages of coastal pine stands on sand dunes are still little known, despite such forests being widespread along the Mediterranean coastline, particularly in Italy. The purpose of this study of 167 plots along Italian coastlines was to analyse whether similar communities and specific species pools occur in different pine forest types dominated by *Pinus pinea*, *P. halepensis* or *P. pinaster*. Multivariate analysis was used, including the effects of sea-inland gradient and of pine canopy cover. The results indicated that pine forests show the lack of a clear floristic differentiation among different pine forest types at community level. Nevertheless, psammophilous species of coastal dunes occurring mostly in *P. halepensis* stands, and forest species mainly being linked to *P. pinea* stands, indicated a distinctiveness at species level probably related to different pine ecology as well as to the coastal zonation along the sea-inland gradient, already well-known for non-forested dunes. Thus, the natural zonation of coastal vegetation is maintained, although higher pine canopy cover affected the understory species assemblages, both herbaceous and woody, in a negative way. In light of this, species-specific management strategies are not recommended for Mediterranean coastal pine forests, and a long-sighted management should take into account actions considering floristic differentiation linked to coastal vegetation zonation. These findings should not be disregarded since they have implications for management planning and conservation and because understoreys of Mediterranean pine plantations, with a species reservoir of unknown value, have often hitherto been overlooked.

1. Introduction

Forest stands with dominance of stone pine, Aleppo pine and maritime pine (*P. pinea*, *Pinus halepensis*, *P. pinaster*) occur along almost all the low sandy coast of the Italian peninsula (Biondi et al., 2009), extending from the first back dune to the last settled innermost dune environment. Italian coastal pine forest vegetation, autochthonous or derived from ancient plantations, consists mainly of *P. pinea* or *P. halepensis* (Biondi and Blasi, 2015). Historically, the primary role of coastal pine forest stands was as a shelterbelt to protect cropland from salty sea spray and for production of pine nuts, timber and resin. These forests were mainly planted in the second half of the twentieth century or later and were maintained by humans for coastal defence against waterproofing and soil erosion (Calama et al., 2003). They are well known for their rehabilitation capacity in Mediterranean dunal environments (see Bellarosa et al., 1996), as well as for recreational uses (Cutini et al., 2013) and carbon storage and sequestration services (Drius et al., 2016). Planted forests that were established a long time ago are more likely to be a habitat for biodiversity, although a common perception is that they are "ecological deserts" (Brockerhoff et al., 2008). At European level they are included in "Coastal brown dunes covered with natural or almost natural thermophilous pines" (EUNIS Habitat Type Code B1.74), as "Mediterranean coniferous coastal dune woodland" in the European Red List of Habitats (Type Code B1.7d; Janssen et al., 2016) and in the 92/43 EEC Directive Habitat as priority habitat 2270 ("Wooded dunes with *P. pinea* and/or *P. pinaster*"), also including *P. halepensis* forests (Biondi et al., 2009). However, in recent decades, environmental concern about sandy coasts and associated pine forest have increased, mainly due to direct and indirect effects of human activities, such as coastal erosion (Raddi et al., 2009), salinisation of groundwater (Antonellini and Mollema, 2010; Zanchi and Cecchi, 2010), trampling (Santoro et al., 2012) and urban sprawl

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(Reina-Rodríguez and Soriano, 2008; Malavasi et al., 2013). These threats have been particularly intense in the last 50 years in countries bordering the Mediterranean Sea (Curr et al., 2000).

The flora of coastal pine forests has rarely been studied because artificial forests are not highly esteemed from a conservation viewpoint (Brockerhoff et al., 2008). Although pines are the most common plantation species worldwide (about 20% of total plantation area) (FAO, 2001), they have attracted relatively little in plant community research compared with other forest types. However, pine-climate interactions (Mazza et al., 2011, 2014; Cutini et al., 2015), fire practices and their effects (Fernandes and Botelho, 2004; Rigolot, 2004; Fernandes et al., 2008) and dendrochronology are widely debated in the scientific literature (Calama et al., 2003; Calama and Montero, 2005). Although they are threatened like other dunal plant communities, the understoreys of these forests and the processes that drive them are still largely unknown and the importance of plantation forests for biodiversity conservation goals is a controversial issue.

Our primary objective in this study was to understand whether pine forests with different dominant pine species can harbour a peculiar understorey species pool. We assumed that overstorey composition and structure influence understorey plant communities through modification of resources including light and soil (Messier et al., 1998; Légaré et al., 2001), with some species having special affinities for a particular overstorey type (Bartels and Chen, 2010). We analysed also the effects of sea-inland gradient and pine canopy cover on the underlying layers. Major questions were: (i) Does vegetation associated with a pine forest type form distinct communities? (ii) Are some plant species more likely to occur in one pine forest type than others? (iii) How do distance to coastline and pine canopy cover affect pine understorey species assemblages?

In this way, the present study aims to investigate whether species-specific management is required for forests dominated by different pine species and their understoreys, as a guide for vegetation management in Mediterranean coastal areas.

2. Materials and methods

2.1. Pine forest-types

For data collection we considered the EU Directive definition of Habitat 2270 "Wooded dunes with *P. pinea* and/or *P. pinaster*" that also includes *P. halepensis* forests (Biondi et al., 2009). We then used data of three different pine forest-types dominated by: (i) Stone pine (*Pinus pinea*); (ii) Aleppo pine (*Pinus halepensis*); (iii) Maritime pine (*Pinus pinaster*).

Pinus pinea is scattered throughout the Mediterranean basin, mainly in coastal areas. In Italy this "umbrella-shaped" tree is the icon of Italian coastal forests (Mazza et al., 2014) and it is reported as native to Liguria, Tuscany, Molise and the major islands, i.e. Sicily and Sardinia (Conti et al., 2005), although there is little evidence of its nativeness (Abad Viñas et al., 2016). *Pinus halepensis* is largely present in the Western sector of the Mediterranean basin and it is the most widely distributed Mediterranean pine. In Italy the species is recognized as native to all regions except the Alps (Conti et al., 2005), although it has been widely planted (Mauri et al., 2016). *P. pinaster* has a western Mediterranean distribution; this medium-size pine mainly occurs in north and central Italy. Its presumed native distribution includes Liguria, Tuscany, Lazio and the major islands (Conti et al., 2005).

2.2. Study area

The study area included pine forests established on dunes along the coasts of the Italian peninsular. The forests occur in six admistrative regions on the coasts of the Tyrrhenian (Toscana, Lazio and Campania) and Adriatic seas (Emilia-Romagna, Molise and Puglia), including much of the distribution of pine stands in the Italian peninsular. The sites ranged about from 0 to 5 m a.s.l. and phyto-climate depends mostly on latitude, ranging from Temperate to Mediterranean, passing through transition zones (Blasi and Michetti, 2007). The study area comprises mainly calcareous sediments, although aeolian deposits also occur from place to place (Geoportale Nazionale, 2015).

2.3. Data collection

For the purpose of the present study, field sampling in *Pinus pinea* stands was performed in 2014–2015, whereas an existing database of coastal dune vegetation (Acosta et al., 2009; Malavasi et al., 2016) was mainly used for *P. halepensis* and *P. pinaste*r stands. Firstly, only plots with at least one of the pine species (*Pinus pinea*, *P. halepensis* or *P. pinaster*) were used, because our interest was the role of pines. Secondly, only plots on sandy soil were included in the dataset. Thus, a dataset based on 167 plots (2×2 m; 94 ascribed to *Pinus pinea*, 65 to *Pinus halepensis*, and 8 to *Pinus pinaster*) was defined. Each plot was assigned to a pine forest type in relation to the pine species dominant in each plot. Plant values were cover percentages of each species between 0 and 100. Distance between georeferenced plot and coastline, used as a proxy of sea-inland gradient, was determined by GIS. The study did not involve any experimental manipulations or disturbance of naturally developed relationships. Observed patterns should therefore reflect long-term plant-ecological interactions. The focal species of dunal vegetation were identified and selected using the list of diagnostic and characteristic species in the "Italian Interpretation Manual of the 92/43/EEC Directive Habitats" (Biondi et al., 2009; Biondi and Blasi, 2015). Autochthonous species names are according to Conti et al. (2005), alien species names are according to The Plant List (2013).

2.4. Data analysis

Evaluation of species composition distinctiveness in each forest type was performed using the following techniques:

(1) Multi-response Permutation Procedure (MRPP), a non-parametric multivariate procedure for testing the hypothesis of no difference in species composition between two or more groups of plots chosen *a priori* (McCune and Grace, 2002). A weighted mean within-group distance in species space is calculated using Sorensen distance. MRPP consists of two statistical tests: the *A* Statistic estimates within-group homogeneity and the *T* Statistic measures between-group separability. Higher *A* statistic values (maximum value 1) indicate a high degree of homogeneity within groups while a large negative *T* value (≤ -10.0) indicates high separability between groups. The null hypothesis was assessed by a Monte Carlo permutation procedure with 999 permutations;
(2) Non-Metric Multidimensional Scaling (NMDS) based on Euclidean distance, used to investigate community patterns without data transformations;
(3) Indicator species analysis (IndVal), performed to find species significantly associated with each forest type via 4999 randomization tests (Dufrené and Legendre, 1997).

To investigate whether sea-inland gradient and pine canopy cover significantly influenced understorey species distribution in coastal pine forests, two hybrid constrained CCAs were performed, with the Log (X+1)-transformed variable 'Distance'. The signifi-