Mapping vegetation dynamics on embryonic sand dunes: a fine-grained atlas for periodic plant monitoring in a Mediterranean protected area.

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Abstract

A field study for monitoring the vegetation dynamics on coastal sand dunes started in 2017 in the Torre Flavia Special Protection Area (Central Italy). The distribution, richness and diversity of plants (mainly halo-psammophile species) were considered. In the study area a set of conservation measures have been carried out to mitigate anthropogenic disturbances (e.g., trampling). Using a fine-grained squared grid (77 units, 10x10 m each), we recorded seven plant species (6 native and one allochtonous: *Carpobrotus* sp. *acinaciformis* vel. *edulis*) with *Thinopyrum junceum*, *Salsola kali* and *Xanthium orientale* subsp. *italicum* as dominant species. Local species richness is higher in the central part and in the south-west sector of the study area, where the dunes are higher and older. This first survey will allow to verify in the next years the success of the adopted conservation strategy.

Key words: richness, diversity, evenness, monitoring, dunal conservation.

Riassunto

Tracciare le dinamiche della vegetazione su dune sabbiose embrionali: un atlante ad alta risoluzione per il monitoraggio periodico della flora in un'area mediterranea protetta

Nel 2017 è stato avviato un monitoraggio focalizzato a studiare la dinamica della vegetazione (principalmente specie alo-psammofile), in termini di presenza, distribuzione, ricchezza e diversità di specie in un settore dunale fatto oggetto di interventi di conservazione atti a limitare il calpestio (Zona di Protezione Speciale e Monumento naturale "Palude di Torre Flavia; Italia centrale). Utilizzando una griglia quadrata a grana fine (70 unità di rilevamento, ampie ciascuna 10x10 m), sono state rilevate sette specie vegetali (una alloctona: *Carpobrotus acinaciformis* vel. *edulis*), tra cui sono risultate dominanti: *Thinopyrum junceum*, *Salsola kali* e *Xanthium orientale* subsp. *italicum*. La ricchezza di specie è risultata più elevata nel settore centrale e sud-occidentale, dove le dune sono più alte e mature. Questa prima indagine consentirà di verificare, in futuro, il successo delle misure di conservazione finalizzate a tutelare le dune.

Parole chiave: ricchezza, diversità, equiripartizione, monitoraggio, conservazione delle dune.

Introduction

Coastal dunes are transitional ecosystems hosting a highly specialized fauna and flora (McLachlan & Brown, 2006; Schlacher *et al.*, 2008). These peculiar ecosystems are particularly vulnerable to anthropogenic disturbances, such, for example, human trampling (Bowles & Maun, 1982; Lemauviel & Rozé, 2003; Schlacher *et al.*, 2007; De Feo *et al.*, 2009; Santoro *et al.*, 2012). In this regard, it is necessary to develop strategies to mitigate these threats (e.g. implementing fences or developing public communication). However, to verify the effectiveness of these interventions it is necessary to carry out specific monitoring so as to compare the occurrence, distribution and diversity of plant species before and after these interventions.

Along the northern coastline of Rome (central Tyrrhenian Italy), following the construction of a breakwater pier (in 2011), a series of embryonic dunes gradually developed. These neo-ecosystems are subject to intense trampling due to the high human pressure of citizens who frequent the beach in the late spring-summer period. To mitigate this disturbance, the Public Agency managing the protected area (Città metropoli-

tana di Roma Capitale) carried out some operational measures delimiting the embryonic dunes and placing information signs. Following these interventions, we are witnessing a progressive recovery of vegetation, as well as the nesting of two rare species of caradrid birds (*Charadrius alexandrinus* and *C. dubius*) that breeding on the site (Battisti *et al.*, 2020a). In order to study the vegetation dynamic on these dune systems over time, in 2017 a field study was started to monitor the occurrence, distribution and diversity of fine-grained dunal plants (mainly halo -psammophile species), using a fine-grained squared grid. This work reports the data of this first arrangement survey which will allow to verify the success of the conservation measures in the next years.

Study area

The study area (Torre Flavia wetland—Natural Monument) is located on the Tyrrhenian coast (Ladispoli; province of Rome; Central Italy; 41.57' N; 12.02' E) and designated as a "Special Protection Area" (code IT6030020; 147/2009/CE 'Birds' Directive; European Commission, 1979; Fig. 1). The present wetland (about 43 ha) is a relict of a larger area that was recently drained and transformed (Battisti, 2006). Along the coastline, the area is characterized by a number of typical coastal habitats identified by the European Commission (2007) and by the Italian Ministry for the Environment (Biondi *et al.*, 2009). They were classified in accordance with the "Habitats Directive" (European Commission, 1992, 2007). The dune vegetation of the area can be considered relatively homogeneous: it corresponds mainly to the Habitat 2110 (Embryonic shifting dunes), characterized by the dominance of *Thinopyrum junceum* and *Anthemis maritima* (Ceschin & Cancellieri, 2006).

The protected area is managed by a Public Agency (Città Metropolitana di Roma Capitale) which periodically carries out conservation actions on priority targets for mitigating anthropogenic threats (e.g. trampling on dunal plants; Battisti *et al.*, 2008; 2020a; 2020b). In particular, since 2017 some interventions have been started to protect the dunes from people trampling, delimiting these areas with poles and ropes and signalling them with signs designed to increase public awareness of the value of these neo-ecosystems.

Methods

We defined a fine-grained grid composed of 77 10x10m cells over-imposed on the dunal system covering a total area of 7700 square meters. An operator (Susanna Ioni) carried out a field sampling in each 10x10 cell recording the occurrence and cover of each plant species.

We used cover-abundance as a measure of plant cover, according to Braun-Blanquet phytosociological approach in

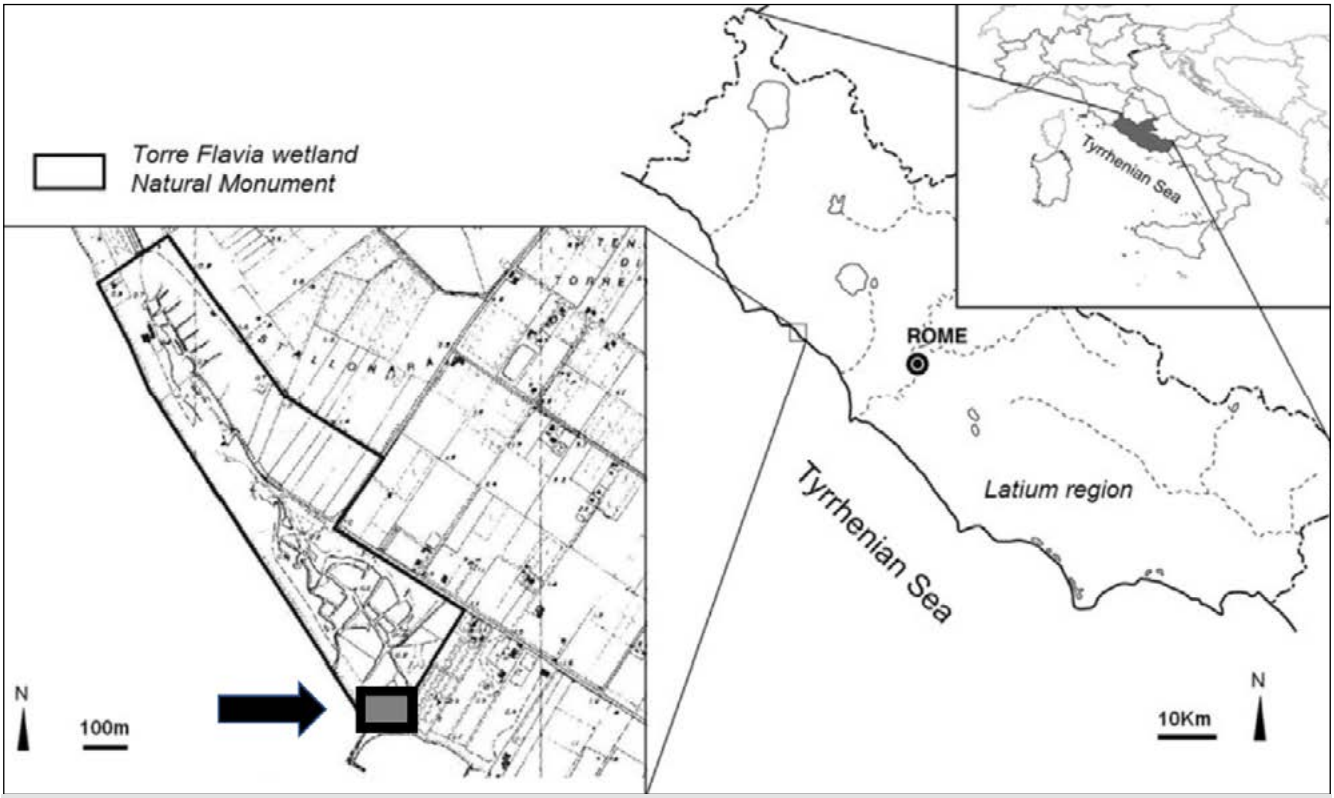

Figure 1. Map of the study area (black box indicated by a row) in the Torre Flavia Special Protection Area (central Italy).

vegetation science (Braun-Blanquet, 1964). It is based on cover percentages, but uses abundance estimates for species with a low plant cover. Cover was estimated using the original 5-point cover scale (Braun-Blanquet or the Domin scale; Braun-Blanquet, 1932), assigning '+' when species was occasional (cover<1%), 1: >1-5%; 2: >5-25%; 3: >25-50%; 4: >50-75%; 5: >75-100%. We reported data on plant occurrence and cover on species-specific maps (Autodesk version for students), obtained using a professional flying drone (DJI Phantom 4). We developed a map of autochthonous species richness (i.e. excluding the non-native and introduced *Carpobrotus* sp.) for all the fine-grained grid.

For each species, we obtained both the total number of occurrences (and relative frequency; fr occ) and the total cover in the dunal system (summing the values of cover and assigning 0,5 to '+' values; and the relative frequency, fr cov). We considered as dominant species the species with a frequency > 0.15.

Finally, we obtained: (i) the total number of species (S), (ii) the Shannon-Wiener diversity index as $H'=-\Sigma fr \times \ln(fr)$, (iii) the evenness index (as e = H/Hmax where Hmax = ln(S) (Magurran, 2013 for a review), both for all the species assemblage and for the assemblage of the only native species. The diversity and evenness indices have been calculated both on occurrence and species cover.

To test for differences between frequencies, we performed a paired χ^2 test (with Yates correction). Alpha level was set at 0.05 level.

Results and Discussion

Totally, we obtained 239 occurrences belonging to 7 plant species (6 native and one allochthonous; Table 1). *Thinopyrum junceum*, *Salsola kali* and *Xanthium orientale* subsp. *italicum* were the dominant species (fr>0.15, both in occurrence and cover).

We observed a significant threshold between the frequencies of occurrence of dominant *Xanthium orientale* and the first not dominant species (*Anthemis maritima*: $\chi^2 = 6.189$, $p = 0.012$). Differences between the first three dominant species (*Thinopyrum junceum* vs. *Salsola kali*: $\chi^2 = 0.264$, $p = 0.607$; *Salsola kali* vs. *Xanthium orientale* subsp. *italicum*: $\chi^2 = 3.503$, $p = 0.061$) and between other not dominant species (*Anthemis maritima* vs. *Cakile maritima*: $\chi^2 = 0.96$, $p = 0.327$; *Cakile maritima* vs. both *Carpobrotus* sp. and *Euphorbia peplis*: $\chi^2 = 0.587$, $p = 0.443$) were not significant.

Carpobrotus sp. (*acinaciformis* vel. *edulis*) was the only allochthonous introduced species. Shannon-Wiener diversity index was H' = 1.73 for occurrences, and H' = 1.70 for cover; evenness index was e = 0.889 (occurrence) and e = 0.874 (cover). Considering only the native plant community we obtained the following values: H' = 1.62 (occurrence) and 1.57 (cover); e = 0.904 (occurrence) and 0.876 (cover).

Maps with local species distribution have been reported in Fig. 1. Local species richness shows its higher value in the central part and in the south-west sector, where the dunes are higher.

Species	**n occ**	**fr occ**	**cover**	**fr cov**
Thinopyrum junceum	68	0.285	59.5	0.296
Salsola kali	62	0.259	52	0.259
Xanthium orientale	44	0.184	39.5	0.197
Anthemis maritima	24	0.1	20.5	0.102
Cakile maritima	17	0.071	11.5	0.057
Carpobrotus sp.	12	0.05	11.5	0.057
Euphorbia peplis	12	0.05	6.5	0.032
Total	239	1	201	1

Tab. 1. Occurrences (n occ) and cover (and relative frequencies; fr occ and fr cov) of plant species on the dunal system studied.

In the south-east sector number of species is lower (Fig. 2).

Our data suggest as the area can be divided into three sectors with different species in each: the NW sector, the E sector and the SW sector. The NW sector is characterized by slightly higher dunes at a bigger distance from the sea; the E sector is characterized by low dunes and by an intermediate distance from the sea and the SW sector is close to the sea with low dunes. The floristic composition, the morphology and the position suggest that the SW and E sectors can be referred to embryonic dunes whereas the NW sector is an initial stage of white dunes.

The mapped species can be easily clustered into the two types of dunes (Géhu *et al.*, 1984). *Anthemis maritima* L. is a species of *Ammophilion*, Br.-Bl. 1933. i.e of typical sand dunes: it occurs mainly in the NW sector. *Thinopyrum junceum* (L.) Á. Löve, is a species of embryonic shifting dunes [*Agropyrion juncei* (Tüxen 1963); Géhu, Rivas-Martinez & Tüxen ex Géhu *et al.*, 1984]: it is present in all three sectors (more abundant in the NW and E), signalling the process of formation of the dunes. *Euphorbia peplis* L. and *Salsola kali* L. are typical species of the foredune, where they colonize, in natural conditions, the drift left by the sea. They occur however also in disturbed dunes, in the E and SW sectors, indicating the pioneer character of these sector. *Xanthium orientale* subsp. *italcum* is an invasive species that is nonetheless well established in foredunes all around the Mediterranean: it has a similar ecology to *E. peplis* and *Salsola kali* and is also present in the E and SW sectors.

Briefly, SW and E sectors are a pioneer form of embryonic dunes (Habitat 2110) with many characteristic species of foredunes, whereas the NW sectors is an initial stage of typical sand dunes (*Ammophilion* - Habitat 2120) according to Braun-Blanquet (1932, 1964). The NW sector dunes lacks the typical presence of *Ammophila arenaria*. Probably, this fact is due to a local slow sand colonization by this species after local extinctions.

We observed a balancement between frequencies both in occurrences and in cover. The only non-native taxa (*Carpobrotus* sp.), an invasive South-African species, occurs due to the pre-

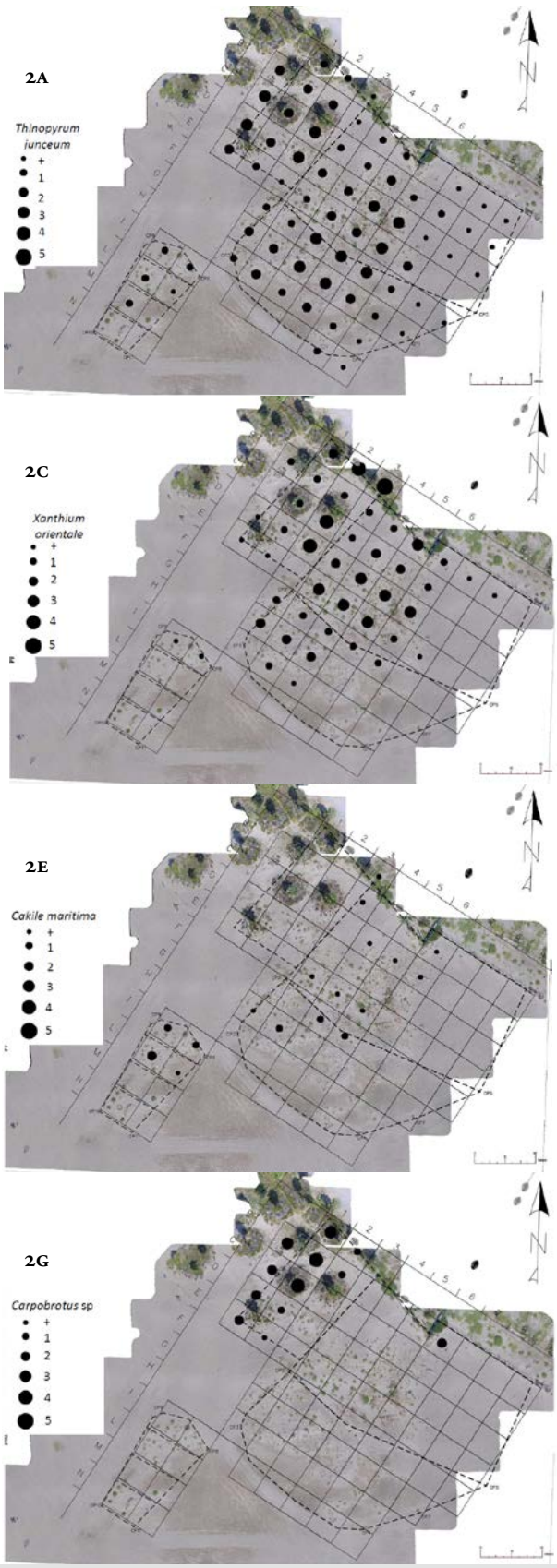

Fig. 2 a, b, c, d, e, f, g. Local distribution maps of the plant species (bar represents 40 m in length, divided into 10 m sub-bars).

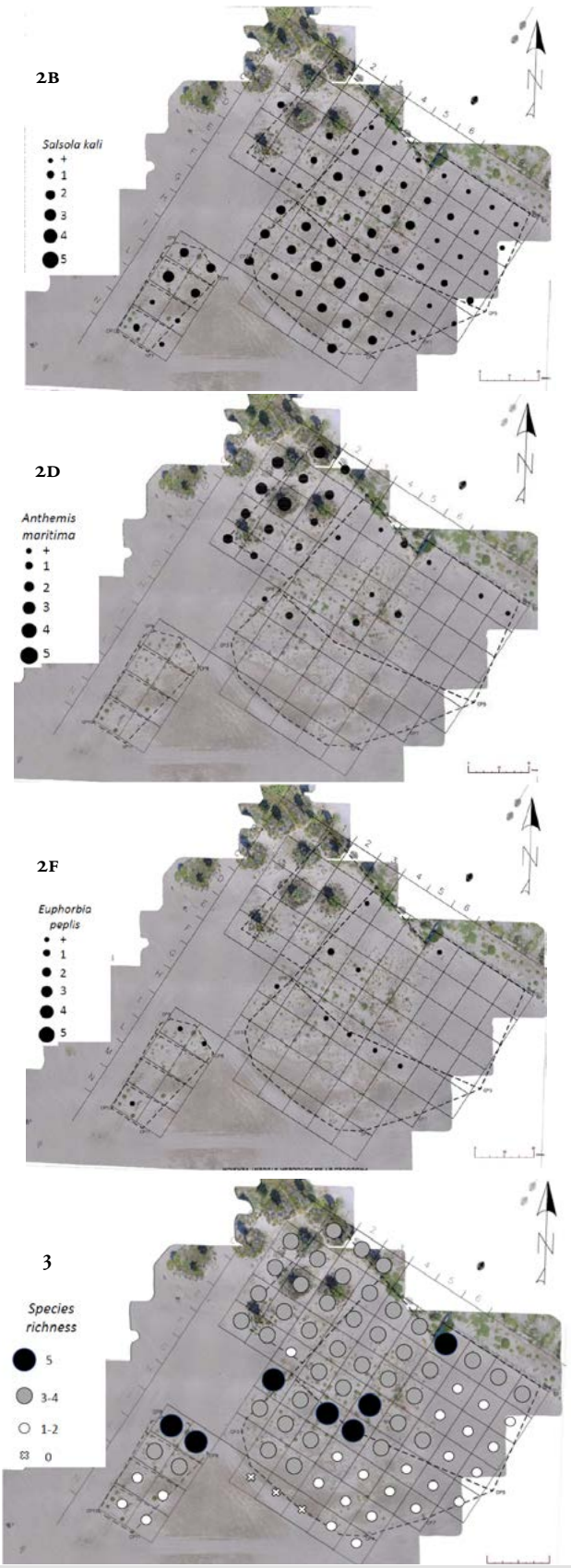

Figure 3. Map of local species richness.

sence of a bathhouse (in the North-Western sector of the grid), who voluntarily introduced the species in the last decade (see Garzia *et al.*, 2019): however, this species has already colonize a sector inside the dune (isolated plants in the north-east sector).

The pattern of species richness shows the high number of species (n = 5) where the dune is higher and more structured (central part and sector in the south-west). In the SE sector, physical factors (winter storms, strong winds) stress the system and the dune has not yet been structured: consequently number of species is lower or they are absent. In the fringes of E and SW sectors, where the colonization process is just at its beginning, the number of species is higher inward. But the highest values are reached in an intermediate ecotonal belt where the typical initial stages of sand dunes and embrionic dunes meet: in this ecotone species from different species. pool coexist, thus increasing the species richness.

These first data indicate an ongoing dynamics. Monitoring in next years will allow to describe the species succession and, in such a way, to verify both the effectiveness of the decreasing people trampling and of the decreasing expansion of non-psammophytes, according to the strategy promoted by the public Agency (see Valcheva *et al.*, 2019).

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