PLANT SOCIOLOGY

formerly FITOSOCIOLOGIA

Volume 54 (2) - December 2017

RIVISTA SEMESTRALE - POSTE ITALIANE S.P.A. - SPED. ABB. POST. - D.L. 353/2003 - (CONV. IN L. 27/02/2004 N. 46) ART. 1, COMMA 2, DCB ANCONA TASSA RISCOSSA-TAXE PERÇUE-CMPP AN
EDITO DALLA SOCIETA' ITALIANA DI SCIENZA DELLA VEGETAZIONE ONLUS - PAVIA - DIRETTORE RESPONSABILE PROF. E. BIONDI - VOLUME 2 - II° SEMESTRE 2017

Journal of the Italian Society for Vegetation Science

Plant Sociology, Vol. 54, No. 2, December 2017, pp. 43-50
DOI 10.7338/pls2017542/05

PLANT SOCIOLOGY
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Coastal dune vegetation in central Campania: an insight on the Natural Reserve "Foce Sele-Tanagro"

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Abstract
In Italy there is a long tradition of vegetation survey with hundreds of vegetation relevés widespread throughout the Italian coastline. However, there are still some poorly investigated areas, such as the sandy shores of the Campania Region. Considering this lack of knowledge, the main aim of this study is to describe the coastal habitats within the Natural Reserve "Foce Sele-Tanagro" (central Campania). Through random sampling and multivariate analysis we recognised five dune habitats from the upper beach to a pine forest. We then analysed plant cover and richness of specific ecological guilds (typical, ruderal and alien species) along the coastal dune vegetation zonation. The two habitats closer to the seashore (upper beach and embryo dunes) and the Mediterranean maquis show the highest cover and richness of typical plant species, while the dune grasslands harbour the high total number of species. The pine forest, although artificially planted, retains its psammophilous character thanks to the occurrence of many dune species. We should also note that two important coastal dune habitats were not found in the study area: shifting dune communities with *Ammophila arenaria* and the semi-stabilized dunes with *Crucianella maritima*. Overall, in this contribution we highlight the presence of residual natural coastal dune habitats of high conservation value together with a widespread agricultural and artificial landscape matrix.

Key words: Campania region, Habitats Directive, psammophilous species, random sampling, Sele river.

Introduction

The existence of coastal ecosystems are based on a fragile equilibrium between the natural dynamism of the physical environment and the massive anthropic presence along coastal areas, especially in the Mediterranean basin (Ciccarelli, 2014; Agir *et al.*, 2017). Due to growing urbanization and to the tourist exploitation of the last century (Defeo *et al.*, 2009; Newton *et al.*, 2012; Malavasi *et al.*, 2013, 2016) coastal habitats, particularly sand dune systems, are experiencing an unsatisfactory conservation state and are among the most threatened in the near future (Genovesi *et al.*, 2014; Janssen *et al.*, 2016). Indeed, most of the typical Mediterranean coastal dune habitats have been heavily fragmented and reduced, both in terms of spatial extension and environmental quality (Acosta & Ercole, 2015).

In Italy there is a long tradition of vegetation survey and recent studies have gathered published vegetation relevés of coastal dune ecosystems covering most of the Italian coastline (Caniglia, 1978; Bartolo *et al.*, 1982; Gerdol *et al.*, 1984; Bartolo *et al.*, 1989; Biondi *et al.*, 1989; Corbetta *et al.*, 1989; Taffetani & Biondi, 1989; Lucchese & Pignatti, 1990; Stanisci & Conti, 1990; Poldini *et al.*, 1999; Vagge & Biondi, 1999; Brullo *et al.*, 2001; Stanisci *et al.*, 2004; Acosta *et al.*, 2005; Biondi & Bagella, 2005; Biondi *et al.*, 2006; Biondi, 2007; Buffa *et al.*, 2007; Caniglia, 2007; Maiorca *et al.*, 2007; Merloni & Piccoli, 2007; Gamper *et al.*, 2008; Bertacchi *et al.*, 2009; Marcenò & Romano, 2010; Minissale *et al.*, 2010; Sburlino *et al.*, 2013; Pirone *et al.*, 2014; Ciccarelli, 2015; Pinna *et al.*, 2015). However, there are still some poorly investigated areas, such as the sandy shores of the Campania Region. Among them, Esposito & Filesi (2007) have analysed the dune systems of the Natural Reserve of Castel Volturno (northern Campania) and Corbetta *et al.* (2004) described the typical dune vegetation of the Cilento National Park (southern Campania). Finally, Rosati *et al.* (2012) reviewed and updated the Flora of Cilento and Campania region.

This paper aim to provide a contribution to knowledge on dune vegetation in the Campania Region, analysing coastal dune systems at the mouth of Sele river (province of Salerno), detecting and describing the coastal habitats within the Natural Reserve "Foce Sele-Tanagro". This area is not only poorly studied, but it is also heavily threatened by both human pressures (agriculture, tourism, urbanization) and coastal erosion.

Materials and methods

Study area

During the last century, the spread of urbanised areas, the building of dams and the widening of the road network in the Sele plain have significantly influenced the natural coastal evolution, reducing the delivery of fluvial sediments and causing the progressive retreat of the shoreline (Cocco & Iuliano, 1999; D'Acunzi *et al.*,

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2008; Alberico *et al.*, 2012a, 2012b), especially around the Sele mouth. Here, the sandy coast is from 40 to 400 meters wide, interrupted by littoral access roads and human structures. The dune system is characterised by irregular Mediterranean scrub vegetation and a pine forest (*Pinus halepensis)* planted at the beginning of the 20th century, following hydraulic remediation operations (Pugliesi Carratelli *et al.*, 2008). Since early '50s the anthropic alteration of Paestum's littoral was coupled with the claim for legislative measures to better manage and protect this valuable territory (Negri & Moggi, 1952). Nowadays, the study area (Fig. 1) is included in the Natural Reserve "Foce Sele-Tanagro" (EUAP0971), established in 1993, and in the Site of Community Importance "Fasce litoranee a destra e sinistra del Fiume Sele" (SIC-IT8050010). The natural reserve and the SIC were born in order to halt the landscape deterioration. Indeed, in spite of the presence of roads, canals, industries, beach resorts and camping, this site has a multitude of naturalistic, environmental, cultural, economic and social values of particular relevance, that are still poorly known.

Vegetation sampling

In a GIS environment (ESRI, 2006) we randomly placed 43 square plots of 4 m^2 throughout coastal dunes vegetation, from the first plant formations near the sea to the pine forest on stabilised dunes. Firstly, a polygon representing the study area was layered on the orthophotos (available on the website of National Geoportal, www.pcn.minambiente.it) and, then, the georeferenced points were recognised in the field through the use of a GPS unit. The list of vascular plant species identified within each plot was recorded, together with the cover percentage of each species using a 10%-interval rank scale (1=1-10%; 2=10-20%; …; 10=90-100%). Vegetation survey was conducted in April 2011. The plant species nomenclature follows Conti *et al.* (2005).

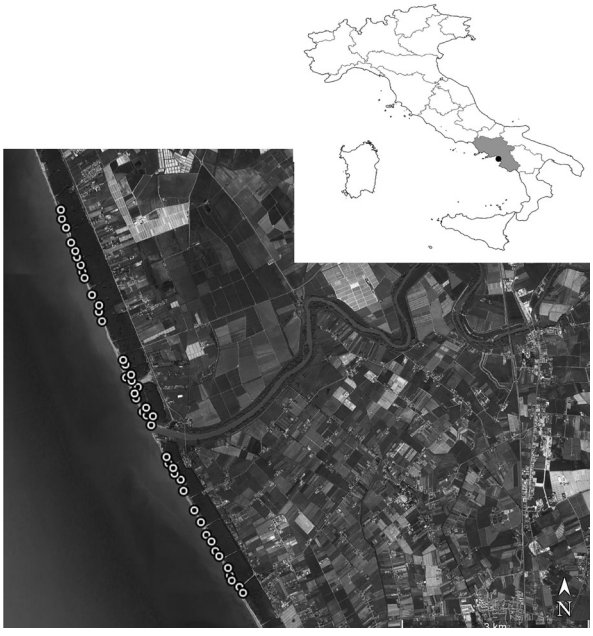

Fig. 1 - Study area located around the mouth of Sele River. Random plots are identified by white circles.

Data analysis

To identify main dune habitats, we first performed a cluster analysis of the plots (matrix of 43 plots x 51 species; PC-ORD software; McCune & Mefford, 2006) by average linkage clustering using relative Sørensen's distance as dissimilarity index. Then, within the floristic composition of each clusters recognised, we identified the typical species listed in the Interpretation Manual of Habitats Directive (Biondi *et al.*, 2009; European Commission, 2013). In this way we were able to assigned a habitat type (*sensu* 92/43/EEC Habitats Directive; Gigante *et al.*, 2016) to each cluster according to the plant community.

For each habitat type we analysed plant cover and richness of specific ecological guilds: typical, ruderal and alien species, as described and listed in previous studies (Santoro *et al.*, 2012; Del Vecchio *et al.*, 2015a, 2016; Prisco *et al.*, 2016). For "typical" species we followed Biondi *et al.* (2009) and are defined here as characteristic plant species crucial to set up specific vegetation associations within a dune sector, affecting habitat structure and functions (*i.e.* key species). "Ruderal" species do not specifically belong to a coastal dune habitat (they do not growth exclusively on sand dunes), being opportunistic and well adapted to various and often disturbed environments (Biondi *et al.*, 2012). Moreover, the presence of alien species (listed in Celesti-Grapow *et al.*, 2009) could be used as indicator of environmental changes and native communities alterations (Carboni *et al.*, 2011; Jucker *et al.*, 2013; Del Vecchio *et al.*, 2015b). For each habitat type we calculated the number and the cover frequency (calculated by summing the percentage cover of each species in one specific guild divided by the total cover of all species) of typical, ruderal and alien species.

Results

Through cluster analysis we identified 5 habitats of the typical Mediterranean dune zonation: the upper beach (Habitat 1210 Annual vegetation of drift line), the embryo dune (Habitat 2110 Embryonic shifting dunes), the dune grasslands (Habitat 2230 *Malcolmietalia* dune grasslands), the Mediterranean maquis (Habitat 2260 *Cisto-Lavanduletalia* dune sclerophyllous scrubs) and the pine forest (Habitat 2270 Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*) (Fig. 2).

Woody habitats are clearly separated from herbaceous ones, moreover, maquis and pine forest maintain their

floristic identity. On the contrary, in herbaceous habitats there is not always a clear distinction among them.

Below we propose a brief description of each habitat identified, focusing on the cover and richness of the ecological guilds (typical, ruderal and alien species) (Fig. 3).

Habitat 1210 Annual vegetation of drift line

More than 50% of the total cover is by typical species, in particular, the most abundant species are *Salsola kali* and *Cakile maritima*. There are also some species belonging to nearby habitats, such as embryo dunes (*Elymus farctus* and *Sporobolus virginicus*). We found only one ruderal species (*Raphanus raphanistrum*) and *Xanthium orientale*, an alien species according to Celesti-Grapow *et al.* (2009) (Tab. 1).

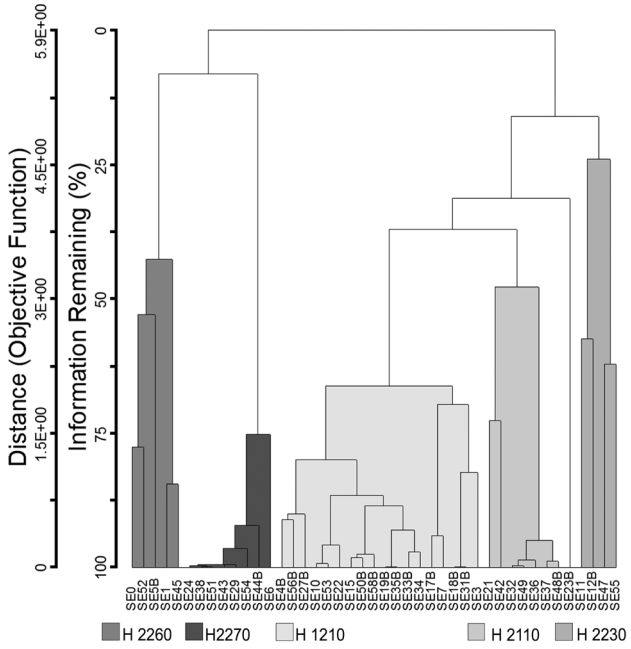

Fig. 2 - Results of cluster analysis: the 43 random plots can be gathered in 5 dune habitats (2260 = Mediterranean maquis; 2270 = pine forest; 1210 = upper beach; 2110 = embryo dune; 2230 = dune grasslands).

Habitat 2110 Embryonic shifting dunes

This habitat is characterised by the dominance of typical species of embryo dunes, such as *Elymus farctus* and *Sporobolus virginicus*, while there are very few ruderal species (Tab. 1). Other species found are from mobile dune (*Pancratium maritimum*) and upper beach habitat (*Cakile maritima*).

Habitat 2230* Malcolmietalia *dune grasslands

The dune grassland is the habitat with the highest species richness (Tab. 1). Here we found different typical species (such as *Lotus creticus*, *Lagurus ovatus*, *Centaurea sphaerocephala*, *Catapodium balearicum*) and various ruderals and species from other habitats. However, the total species cover is quite well-distributed in the three ecological guilds. Ruderals that contribute most to the total cover are only three (*Bromus diandrus*, *Lobularia maritima* and *Hordeum murinum*), while species of other habitats come from embryo, mobile and fixed dune habitat (*i.e. Pancratium maritimum*, *Lotus cytisoides*, *Smilax aspera*). Moreover, we found *Glaucium flavum* in this habitat, a species usually found in sandy, gravelly or pebbly beaches.

Habitat 2260* Cisto-Lavanduletalia *dune sclerophyllous scrubs

This habitat is well defined by typical woody species of the Mediterranean maquis (*Smilax aspera*, *Phillyrea angustifolia*, *Rhamnus alaternus*, *Lonicera implexa* and *Pistacia lentiscus*), that reach the 80% of total plant cover. Ruderal species are rare, while we found the alien species *Acacia saligna* (Tab. 1).

***Habitat 2270 Wooded dunes with* Pinus pinea *and/or* Pinus pinaster**

In the pine forest, although the cover of typical species is 80% (mainly due to *Pinus halepensis* and *Smilax aspera*), the number of ruderals (*i.e. Reichardia picroides*, *Bromus diandrus* and *Lobularia maritima*) and species from other habitats is particularly high. It's worth to highlight that we found species of all herbaceous and wooded habitats of the coastal zonation (Tab. 1).

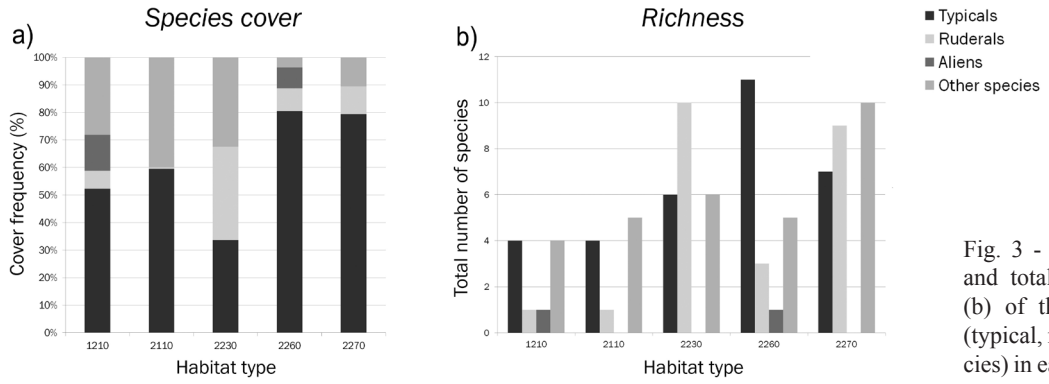

Fig. 3 - Cover frequency (a) and total number of species (b) of the ecological guilds (typical, ruderal and alien species) in each habitat identified.

Tab. 1 - Total list of species recorded in the random plot grouped according to the ecological guild ("typical", "alien", "ruderal and other species"). For each habitat type the mean cover per plot (percentage) and the frequency (number of occurrences on the total number of plots) are reported.

Guild	Species	Mean cover per plot (%) Habitat type					Frequency Habitat type				
		1210	2110	2230	2260	2270	1210	2110	2230	2260	2270
TYPICAL	Asparagus acutifolius L.		.	.	0.60	0.13	.	.	.	0.60	0.13
	Cakile maritima Scop. subsp. maritima	1.91	2.40	.	0.20	0.13	0.95	0.60	.	0.20	0.13
	Catapodium balearicum (Willk.) H. Scholz	.	.	5.00	.	.	.	.	0.33	.	.
	Centaurea sphaerocephala L.	.	.	7.67	.	.	.	.	0.67	.	.
	Chamaesyce peplis (L.) Prokh.	0.23	0.40	.	.	.	0.23	0.40	.	.	.
	Clematis flammula L.	.	.	.	0.80	.	.	.	.	0.40	.
	Elymus farctus (Viv.) Runemark ex Melderis subsp. farctus	0.45	9.00	.	3.00	.	0.14	0.20	.	0.20	.
	Eryngium maritimum L.	.	0.60	0.33	.	.	.	0.20	0.33	.	.
	Glaucium flavum Crantz	.	.	8.33	.	.	.	.	0.33	.	.
	Juniperus phoenicea L.	.	.	.	5.00	.	.	.	.	0.20	.
	Lagurus ovatus L.	.	.	8.33	.	0.38	.	.	0.33	.	0.13
	Lonicera implexa Aiton subsp. implexa	.	.	.	8.00	.	.	.	.	0.40	.
	Lotus creticus L.	.	.	11.67	.	.	.	.	0.33	.	.
	Lotus cytisoides L.	.	1.60	7.67	.	.	.	0.20	0.67	.	.
	Matthiola sinuata (L.) R. Br.	.	.	.	.	1.50	.	.	.	.	0.38
	Pancratium maritimum L.	0.14	6.00	11.67	0.20	0.38	0.14	0.80	0.33	0.20	0.13
	Phillyrea angustifolia L.	0.05	.	.	23.00	0.13	0.05	.	.	0.60	0.13
	Pinus halepensis Mill.	.	.	.	.	75.00	.	.	.	.	1.00
	Pistacia lentiscus L.	.	.	.	6.60	0.13	.	.	.	0.40	0.13
	Polygonum maritimum L.	0.18	.	.	.	.	0.18	.	.	.	.
	Prasium majus L.	.	.	.	1.60	0.38	.	.	.	0.20	0.13
	Rhamnus alaternus L. subsp. alaternus	.	.	.	15.00	.	.	.	.	0.60	.
	Rubia peregrina L.	.	.	.	4.60	1.88	.	.	.	0.40	0.13
	Salsola kali L.	2.41	2.20	.	.	1.88	0.82	0.80	.	.	0.13
	Silene colorata Poir.	.	1.60	2.67	.	0.13	.	0.20	0.33	.	0.13
	Smilax aspera L.	.	.	5.00	30.20	2.00	.	.	0.33	1,00	0.25
	Sporobolus virginicus Kunth	1.91	7.60	.	.	1.88	0.23	0.60	.	.	0.13
ALIEN	Acacia saligna (Labill.) H.L.Wendl.	.	.	.	9.00	.	.	.	.	0.20	.
	Xanthium orientale L. subsp. italicum (Moretti) Greuter	1.18	.	.	.	.	0.36	.	.	.	.
RUDERAL & OTHER SPECIES	Anagallis arvensis L.	.	.	.	.	1.00	.	.	.	.	0.13
	Arum italicum Mill. subsp. italicum	.	.	.	.	0.25	.	.	.	.	0.25
	Atriplex prostrata Boucher ex DC.	.	.	.	0.80	.	.	.	.	0.40	.
	Borago officinalis L.	.	.	0.33	.	.	.	.	0.33	.	.
	Briza maxima L.	.	.	2.67	.	.	.	.	0.33	.	.
	Bromus diandrus Roth subsp. diandrus	.	.	14.00	.	3.13	.	.	0.67	.	0.13
	Calendula arvensis L.	.	.	1.33	.	.	.	.	0.67	.	.
	Carduus pycnocephalus L. subsp. pycnocephalus	.	.	0.33	.	0.13	.	.	0.33	.	0.13
	Euphorbia terracina L.	.	.	2.00	0.20	0.38	.	.	0.67	0.20	0.13
	Geranium molle L.	.	.	.	.	0.38	.	.	.	.	0.13
	Hordeum murinum L. subsp. leporinum (Link) Arcang.	.	.	5.00	.	.	.	.	0.33	.	.
	Hypochaeris radicata L.	.	.	.	.	0.38	.	.	.	.	0.13
	Lobularia maritima (L.) Desv. subsp. maritima	.	.	8.33	.	1.38	.	.	0.33	.	0.25
	Osyris alba L.	.	.	.	0.20	.	.	.	.	0.20	.
	Piptatherum miliaceum (L.) Coss.	.	.	.	1.60	0.38	.	.	.	0.20	0.13
	Raphanus raphanistrum L.	0.59	0.20	1.67	.	.	0.59	0.20	1.00	.	.
	Reichardia picroides (L.) Roth	.	.	1.33	.	3.25	.	.	0.67	.	0.25
	Rubus ulmifolius Schott	.	.	.	8.00	.	.	.	.	0.40	.
	Rumex crispus L.	.	.	.	0.20	.	.	.	.	0.20	.
	Sonchus bulbosus (L.) N. Kilian & Greuter subsp. bulbosus	.	.	3.00	.	3.63	.	.	0.67	.	0.38
	Sonchus oleraceus L.	.	.	.	.	0.13	.	.	.	.	0.13
	Urospermum picroides (L.) Scop. ex F.W. Schmidt	.	.	2.67	.	.	.	.	0.33	.	.

Discussion

Five habitats have been recognised along the dunes of the Natural Reserve "Foce Sele-Tanagro". The two habitats closer to the seashore (Habitat 1210 and 2110) and the Mediterranean maquis (Habitat 2260) show the highest cover and richness of typical plant species and, at the same time, a few number of ruderals or alien species. The first stages of sand accumulation near the sea harbour plant communities living in a very coercive and stressed environment that usually limits the spread of other species not highly specialized. Only species well-adapted to the effects of tides, salt spray and soil salinity can survive here (Fenu *et al.*, 2013; García-Cervigón *et al.*, 2013). On the other hand, species in the Mediterranean maquis grow in a more stable environment where competition processes are probably more relevant (Bertness & Callaway, 1994; Conti *et al.*, 2017). However, in this habitat we found the exotic *Acacia saligna*. In Italy, the impact of this alien species have already been studied in coastal areas of the Molise Region. In fact, the presence of *A. saligna* has been related to a higher number of ruderals compared with non-invaded areas, it could reduce number and cover of the typical species in wooded communities of fixed dunes and it could also modify soil characteristics by increasing the levels of total nitrogen and of organic matter (Del Vecchio *et al.*, 2013;

Calabrese *et al.*, 2017; Prisco *et al.*, 2017). Although *A. saligna* is so far very localized in the study area, it could be the first alarm signal for a community-scale change, making necessary to limit the expansion of this exotic plant to prevent changes in the dune community structure and function in the future.

The dune grasslands (Habitat 2230) is characterised by a mosaic of assorted dune species. This habitat, being the transition from the open vegetation of the first dunes to the semi-stable communities of the most inner dunes, show the typical species of this habitat coupled with species from other habitats, including also various ruderals.

We should also highlight that two important coastal dune habitats were not found in the study area: shifting dune communities with *Ammophila arenaria* (Habitat 2120 Shifting dunes along the shoreline with *Ammophila arenaria* – white dunes) and the semi-stabilized dunes with *Crucianella maritima* (Habitat 2210 *Crucianellion maritimae* fixed beach dunes) (Fig. 4a). Thus, in the study area the central part of the typical Mediterranean dunal zonation is incomplete and it is represented by only one habitat dominated by terophytes with the presence of many species characteristic of the nearby habitats. On the contrary, in the Natural Reserve of Castel Volturno (northern Campania), Esposito & Filesi (2007) found the chamaephytic vegetation with *Crucianella maritima* (*Crucianelletum maritimae* Br.-Bl. 1933), which is now quite rare and often reduced to few and fragmented patches along the coasts of the peninsula.

It is worth also to note the presence of *Glaucium flavum*. Along southern Italy's coasts this species was observed within the therophytic vegetation of the dune grasslands as characteristic species of the association *Glaucio flavi-Matthioletum tricuspidatae* (Blasi *et al.*, 1983). Being a nitrophilous species and a good colonizer of bare ground, *Glaucium flavum* is found mainly on well-drained habitats such as shingle, gravel, sand, cliffs and waste sites. A recent study has highlighted the presence of *G. flavum* in anthropized grasslands with high levels of trace metal contamination (Cambrollé *et al.*, 2011), so this species could be considered as a proper bio-indicator of degraded areas with high human impact.

The afforested area with *Pinus halepensis* is the most widespread habitat in the study area, followed by an intense development of artificial areas and agricultural lands (Berardo, 2012). Pine forest retains its psammophilous character hosting both many dune species and some typical species of the Mediterranean maquis. Indeed, *Pinus halepensis* is well adapted to coastal dune habitats and, in some cases, the pine understorey assemblages followed the natural vegetation composition of sandy dunes, which increases their conservation value, as evidenced by Bonari *et al.* (2017).

Overall, we could evidence that, despite its relevant natural value, the coastal dune landscape of the study area is currently heavily anthropized. Major threats are mainly related to the seaside exploitation, human trampling, transit of motor vehicles and coastal erosion (Fig. 4b-c), which cause the reduction and fragmentation of dune vegetation. After moderate historical trends of progradation, since 1984 the Sele mouth has experienced coastal erosion, pinpointing the vulnerability of Sele river coastal plain system to human disturbance (Alberico *et al.*, 2012b). Moreover, during the vegetation sampling, a consistent accumulation of

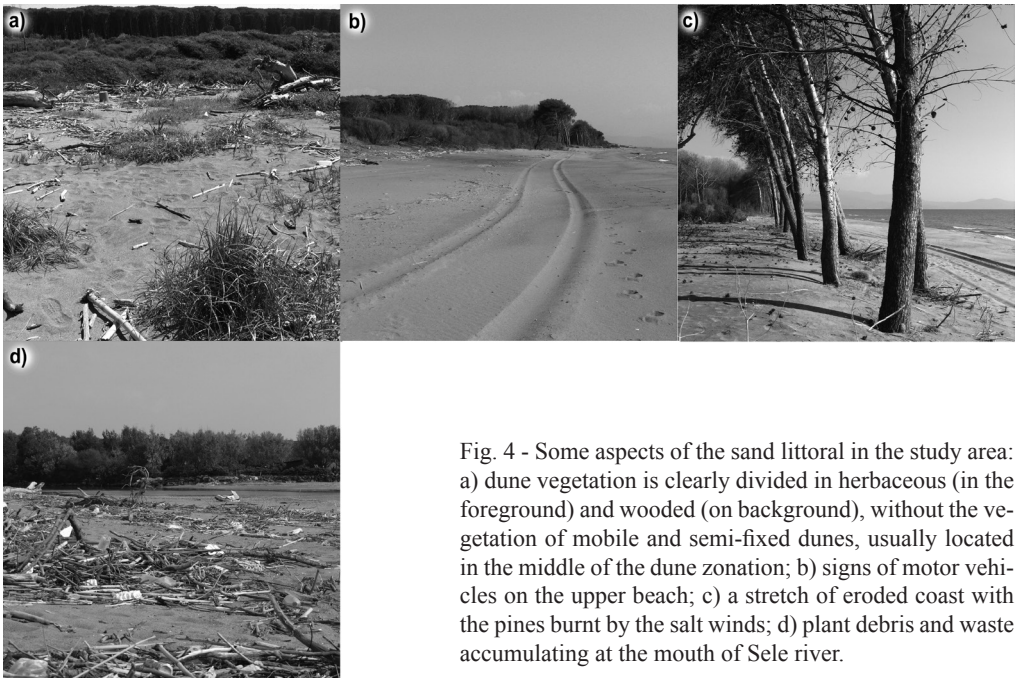

Fig. 4 - Some aspects of the sand littoral in the study area: a) dune vegetation is clearly divided in herbaceous (in the foreground) and wooded (on background), without the vegetation of mobile and semi-fixed dunes, usually located in the middle of the dune zonation; b) signs of motor vehicles on the upper beach; c) a stretch of eroded coast with the pines burnt by the salt winds; d) plant debris and waste accumulating at the mouth of Sele river.

waste was observed mainly close to the river mouth (Fig. 4d). The presence and the accumulation of litter on the beaches, resulting from the nearby presence of urban areas coupled with the rivers acting as carriers, is an increasing problem affecting coastal and marine ecosystems worldwide (Poeta *et al.*, 2016).

In conclusion, coastal dune vegetation of the Natural Reserve "Foce Sele-Tanagro" area presents a reasonable conservation state, however, the area is subjected to different threats and anthropic impacts. In this contribution we highlight the presence of residual natural coastal dune habitats of high conservation value in a widespread agricultural and artificial landscape matrix. Further efforts should be made to reduce the impacts of human pressure, also promoting environmental education on ecosystem services provided by the natural landscape of coastal dunes. Moreover, as human activities in coastal areas will probably intensify in the future, a multitemporal vegetation monitoring is strongly recommended and encouraged.

Acknowledgements

We would like to thanks Silvia Del Vecchio, Marta Carboni, Riccardo Santoro and Tommaso Jucker for their help during the fieldwork activity. We are grateful to Gabriella Buffa and Edoardo Biondi for their useful comments on the manuscript.

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