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Temporal changes in Adriatic coastal dunes: results from a short term vegetation monitoring

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Abstract
Sandy beaches surrounding the Molise coast, facing to the Adriatic sea, are relatively well preserved if compared with other Italian littorals. In this study we present the results from a short term monitoring analyses of coastal habitats (six/eight-years) using permanent transects as part of the LTER network (Long Term Ecological Research-Italy). Vegetation monitoring was carried out along 4 belt transects along the beach-inland ecological gradient, following the coastal zonation and ranging from pioneer annual communities on the beach to Mediterranean scrubs on fixed dunes. Plant communities were sampled in contiguous 1 m x 1 m plots using a 1-10 ordinal transform scale to estimates the species' cover-abundance. All transects were conducted in sites subjected to a similar touristic pressure. Through cluster analysis we identified 5 Habitats of community interest: Annual vegetation of drift lines (Habitat 1210), Embryonic shifting dunes (Habitat 2110), Shifting dunes along the shoreline with *Ammophila arenaria* (Habitat 2120), *Malcolmietalia* dune grasslands (Habitat 2230) and Coastal dunes with *Juniperus* spp. (Habitat 2250). Main temporal changes were probably related to different erosion/accretion processes acting in each transect: two transects were relatively stable (without evident coastal erosion nor accretion processes), one suffered a strong retreat while the last transect showed a slight accretion process. Moreover, our study evidences that, as coastal plant communities are highly dynamic systems, even relatively short time periods could offer useful insights of annual vegetation trends.

Key words: Dune habitats, LTER Network, temporal changes, vegetation zonation.

Introduction

Coastal sandy dunes are dynamic systems shaped by a strong sea-inland environmental gradient that harbor unique biological assemblages of flora and fauna. One of the main characteristics of coastal dunes is the spatial variability of the plant communities, which determines the typical coastal vegetation zonation, ranging from the upper beach and fore dunes close to the sea, to the more stable, inland dunes (Vagge & Biondi 1999; Acosta *et al*., 2000, 2003; Biondi, 2007; Buffa *et al*., 2007; Ciccarelli, 2015; Feola *et al*., 2011; Prisco *et al*., 2012; Ruocco *et al*., 2014).

At present, dune environments are considered to be threatened worldwide by a wide number of human activities that can directly or indirectly affect sandy shore habitats (McLachlan & Brown, 2006). The suburban sprawl, the conversion of natural habitats in favor of agriculture and the development of recreational areas linked to bathing tourism have rapidly increased in recent years, especially along the coasts (Defeo *et al*., 2009). Combined with a steady increase in population during the past half-century, these socio-economic changes have led to overbuilding, excessive resources exploitation, pollution and environmental degradation (Falcucci *et al*., 2007; Lambin *et al*., 2001). Moreover, most of the world's coastlines are in a state of erosion or retreat as a consequence of natural processes (Feagin *et al*., 2015; Provoost *et al*., 2011). So as, coastal dune monitoring has become a critical issue, representing a priority for many European countries (EEC, 1992).

The Molise coast and other surrounding beaches facing to the Adriatic sea are relatively well preserved if compared with other Italian littorals. However, Malavasi *et al*. (2013) using land cover maps derived from a multi-temporal sequence of remotely sensed data showed that this coastal dune landscape has been drastically modified by human activities over the last 50 years. In the same area Del Vecchio *et al*. (2015a), through a re-visitation study and using phytosociological relevés, investigated how coastal dune habitats have changed during two different periods. In this study, instead, we present the results from a six/eight-years monitoring analyses of coastal habitats using permanent transects. These transects are part of the LTER network (Long Term Ecological Research-Italy, www.lteritalia.it). The LTER Network manages the biodiversity data processing and organizes experts in the long monitoring systems at local, national, European and global scale. The main purposes of this long-term monitoring framework are to study ecosystems' evolution and dynamics, the relationship between biodiversity and ecological functionality and the effects of pollution and climate change.

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Materials and Methods

The present study concentrates on recent dunes and includes 4 Sites of Community Importance (SCIs): (A) Punta Aderci-Punta della Penna (IT7140108), (B) Foce Trigno-Marina di Petacciato (IT7228221), (C) Foce Biferno-Litorale di Campomarino (IT7222216) and (D) Foce Saccione-Bonifica Ramitelli (IT7222217). The first one is located in the Abruzzo region, very close to the Molise border, while the other 3 are located in the Molise region (Fig. 1). These dune areas are still relatively well preserved with similar anthropic pressure mainly due to tourism and are yearly monitored in the frame of the Long Term Ecological Research-Italy network (LTER Italia) (Bertoni, 2012; Stanisci *et al*., 2014). Moreover, this area is characterized by a high biodiversity, both in terms of plants and animals, confirmed by the fact that in a coastal stretch of approximately 40 kilometers four SCIs are identified (Frattaroli *et al*., 2007; Pirone *et al*., 2014; Stanisci *et al*., 2007, 2014).

Vegetation monitoring was carried out along 4 belt transects along the beach-inland ecological gradient, following the coastal zonation ranging from pioneer annual communities on the beach to Mediterranean scrubs on fixed dunes. However, as we were mainly interested in herbaceous coastal habitats, we only considered few plots of woody vegetation. Three out of the four transects were laid in sites were the coastal zonation was relatively complete and stable (without evident coastal erosion processes) and similar plant species composition, however, in one of these sites (T3) a strong coastal retreat started just before the beginning of this study due to the negative impact of a new touristic harbor in the surroundings. The first transect (T1), instead, was laid out in a site where the sandy coast was in accretion, consequently to the construction of a nearby port facilities (Miccadei *et al*., 2011). Vegetation sampling was carried out in April-May of each year, from 2010 to 2015, however, for transect T2 we conducted also a previous sampling in spring 2008. Plant communities were sampled in contiguous 1 m x 1 m plots (Acosta *et al*., 2000) using a 1-10 ordinal transform scale to estimates the species' cover-abundance. The first plot of each transect was marked with permanent poles and, in addition, the beginning/end of each transect were georeferenced using a GPS unit. In transect T2 woody vegetation of fixed dune was not considered as it had been substituted by exotic trees (Del Vecchio *et al*., 2013) and no woody vegetation occurred in transect T1.

We analyzed separate matrices for each transect and classified each plot (including all dates) according to plant community species composition by average-linkage clustering using relative Sørensens distance as dissimilarity index (PC-ORD package; McCune & Mefford, 2006). Clusters derived from this classification were assigned to an EU Habitat code following the interpretation manuals of the 92/43/EEC Habitats Directive (Biondi *et al*., 2009). In order to analyze the spatial distribution of the different habitats along each transect, we overlapped the results of the cluster analyses to the sequence of plots along each transect. With the aim of evaluate the recent temporal changes, we repeated the classification/overlapping processes for each year and for each transect. For species nomenclature we follow the checklist of the Italian Flora (Conti *et al*., 2005).

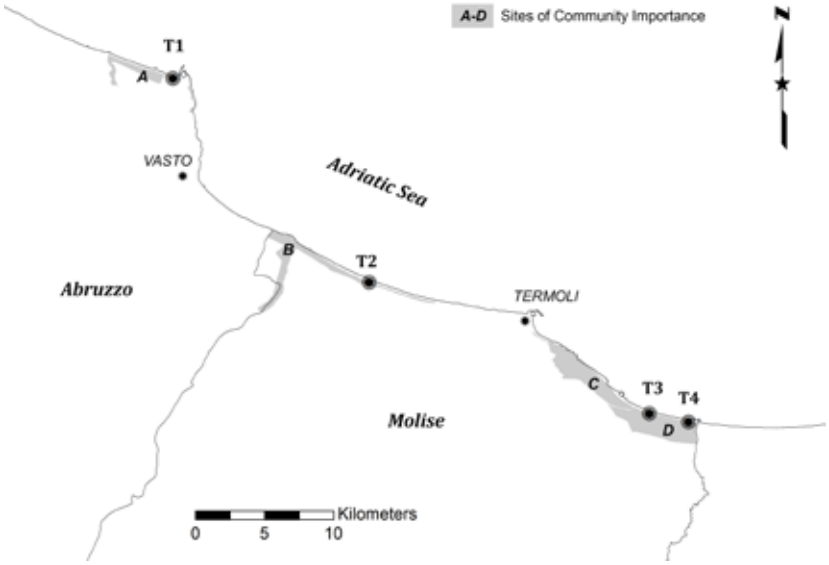

Fig. 1 - Geographical position of the 4 vegetation transects along the coast of the Abruzzo and Molise regions (T1-T4). Sites of Community Importance (A-D) are shown in grey.

Tab. 1 - List of EU Habitats identify by the cluster analysis with the corresponding phytosociological association for each transect. Syntaxonomy follows Biondi & Galdenzi (2014).

EU Habitat	Transect	Phytosociological association	Total n° of plot
1210 Annual vegetation of drift lines	T2, T3	*Salsolo kali-Cakiletum maritimae* Costa e Manzanet 1981	19
2110 Embryonic shifting dunes	T1 T2, T4	*Echinophoro spinosae-Elymetum farcti* Géhu 1987 *Elymetum farcti* Br.-Bl. 1933	384
2120 Shifting dunes along the shoreline with *Ammophila arenaria*	T1, T2, T4	*Ammophiletum arenariae* Br.-Bl. (1921) 1933	412
2230 *Malcolmietalia* dune grasslands	T1 T2, T3 T4	*Ambrosio coronopifoliae-Lophochloetum pubescentis* Biondi, Brugiapaglia, Allegrezza, Ballelli 1989 *Sileno coloratae-Vulpietum membranaceae* (Pignatti 1953) Géhu & Scoppola 1984 *Sileno coloratae-Ononidetum variegatae* Géhu et al. 1986	719
2250 Coastal dunes with *Juniperus* spp.	T3, T4	*Asparago acutifolii-Juniperetum macrocarpae* Géhu & Biondi 1994	58

Results

Through cluster analysis we identified 5 Habitats of community interest: Annual vegetation of drift lines (Habitat 1210), Embryonic shifting dunes (Habitat 2110), Shifting dunes along the shoreline with *Ammophila arenaria* (Habitat 2120), *Malcolmietalia* dune grasslands (Habitat 2230) and Coastal dunes with *Juniperus* spp. (Habitat 2250) (Tab. 1).

The habitat closer to the seashore (H 1210), which represents the first pioneer formations of herbaceous annual plants, was found only in a very few plots and not in all transects (Fig. 2). The most important species were *Cakile maritima* and *Salsola kali*, although in transect T3 *Calystegia soldanella* and *Elymus farctus* were also found.

Habitats 2110 and 2120, typical of the first semi-stable part of the dune zonation, were well represented in all transects. The dominant species in embryo dunes (H 2110) are about the same in all transects (*Elymus farctus*, *Echinophora spinosa*, *Calystegia soldanella* and *Medicago marina*), all these being diagnostic species of the habitat (Biondi *et al*., 2009).

On mobile dunes (H 2120), the most abundant species was the tussock grass *Ammophila arenaria*, which is not only diagnostic species of this habitat, but also a very important species which promotes the dune stabilization and its increasing in height. Few other species can be also found such as *Calystegia soldanella*, *Lotus cytisoides* and *Silene colorata*.

It is worth to highlight that in transect T1 (carried out in a site where the coast is in accretion) the former two habitats (H 2110 and H 2120) were clearly defined in all years. We could interpret this result as a well preserved vegetation zonation. On the contrary, in transect T3 (carried out in a site currently suffering a strong erosion processes) these habitats were mixed up and there was not a clear differentiation between embryo and mobile dune. Moreover, diagnostic species of habitats 2110 and 2120 such as *Ammophila arenaria*, *Elymus farctus* and *Sporobolous virginicus* were found together with typical plants of dune grasslands (H 2230) such as *Silene colorata* and *Lotus cytisoides*. Temporal trends showed that this mixed habitat develops at expense of dune grasslands when they are exposed directly to the beach due to coastal erosion (Fig. 2).

In the three transects without evident erosion processes, the most widespread habitat was the dune grasslands (H 2230). Here, the most important temporal trend was the constant increase of this habitat at the expense of more pioneer habitats (H 2110 and H 2120). We should note that in transect T1 we registered high cover values of the exotic species *Ambrosia coronopifolia*, together with the natives *Rostraria litorea*, *Medicago littoralis* and *Vulpia fasciculata*. In the other transects this habitat is characterized by the typical diagnostic annual species, in particular *Silene colorata*, *Vulpia fasciculata*, *Ononis variegata* and *Lotus cytisoides*.

Woody vegetation of fixed dune with junipers (H 2250) was recorded only in transects T3 and T4. This habitat remained relatively stable during our monitoring study. The most abundant species were *Juniperus oxycedrus* subsp. *macrocarpa* and *Asparagus acutifolius*, however, looking at the other high-cover spe-

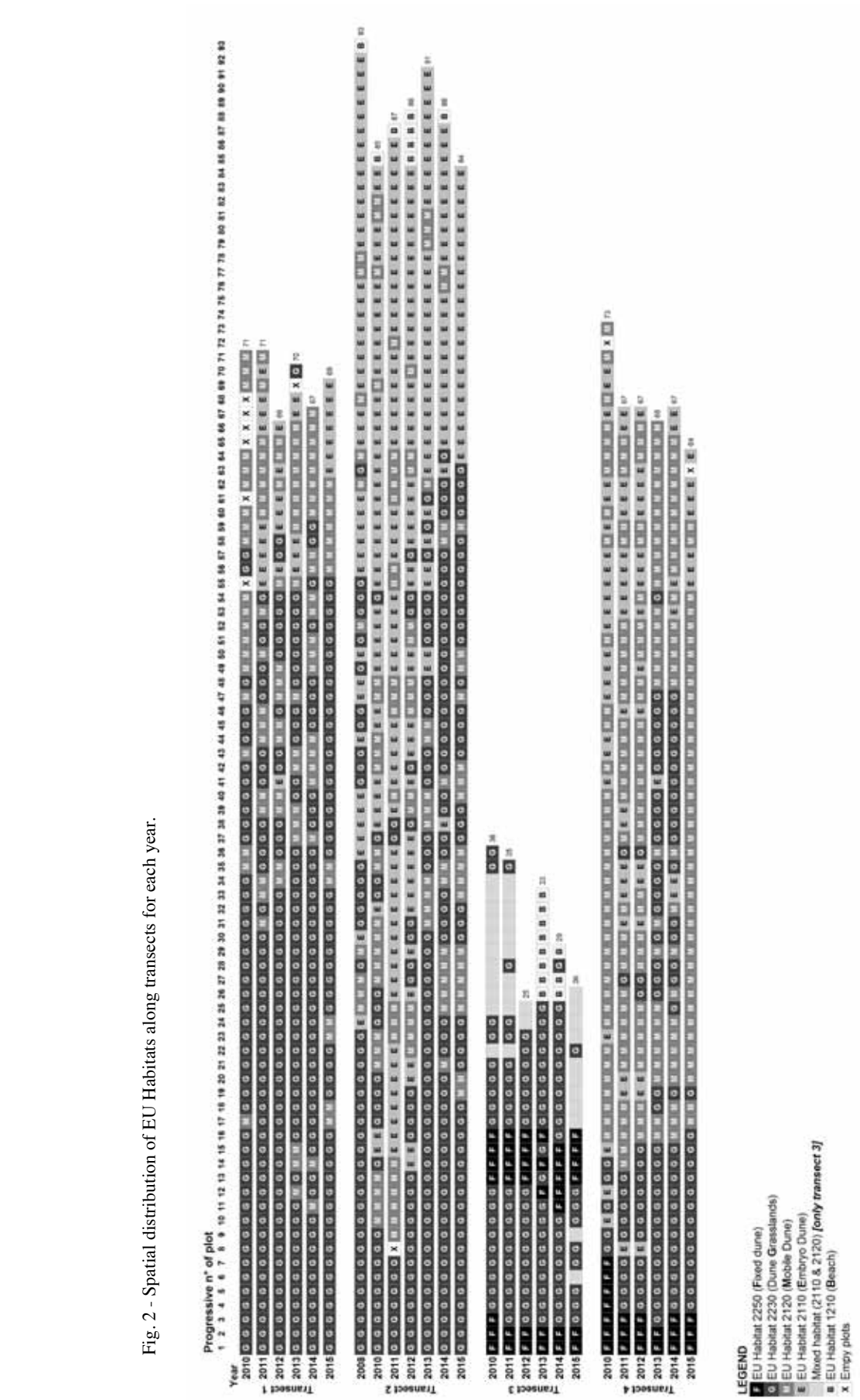

Fig. 2 - Spatial distribution of EU Habitats along transects for each year.

cies, some differences can be highlighted. In transect T3 we found some dune grasslands species, such as *Lotus cytisoides* and *Silene colorata*. On the contrary, in the more stable transect T4, plant community was enriched by *Phillyrea angustifolia* and *Rosmarinus officinalis*, characteristic species of the Mediterranean scrub.

Discussion and conclusion

Main temporal changes observed in this monitoring study were probably due to different erosion/accretion processes acting in each transect. Transects T2 and T4 were relatively stable (without evident coastal erosion nor accretion processes), transect T3 suffered a strong retreat while transect T1 showed a slight accretion process.

In terms of floristic composition and structure, coastal dune habitats were well-characterized especially in accretion or stable sites. We interpreted these results as related to the increasing level of stability of the whole dune system over the years. In particular, in transect T1 we observed a clear vegetation zonation with well-defined coastal habitats, even if the number of species is lower than in the other research sites. As we said before, in this site the dune system is very young, thus probably many psammophilous species have not colonize it yet. On the contrary, some invasive alien species such as *Ambrosia coronopifolia* are already widespread, probably taking advantage of ecological empty niches.

A different situation was described for transect T3. It has been carried out in a site with a recent strong erosion process which was related to the total removal of the first dune habitats. As a consequence, we observed a compressed dune vegetation zonation with the partial overlap between the most pioneer herbaceous dune habitats, a decrease in dune grasslands and an altered species composition in the fixed dune with junipers (H 2250).

It is worth to highlight that this monitoring study has been conducted in an area subjected to a similar touristic pressure. Therefore, we could affirm that temporal changes in habitat distribution and in plant species composition seem to be related to coastal erosion/accretion processes, as it has been described in previous general surveys (Iannantuono *et al*., 2004).

The Italian Adriatic coast is endangered by several human pressures (summer tourism, trampling, expansion of urban areas, etc.), causing invasion of alien and ruderal species, habitat fragmentation and loss of dune zonation structure (Del Vecchio *et al*., 2015b; Drius *et al*., 2013; Sciandrello *et al*., 2015). Nevertheless, this study also provides encouraging results suggesting that where the coast is included into the Natura 2000 Network and is sufficiently stable, coastal dune habitats could locally widespread. Moreover, our results evidence that, as coastal plant communities are highly dynamic systems, even relatively short term studies could offer useful insights in annual trends.

Finally, we should emphasize the importance of the long term monitoring programs in assessing the dynamics and the temporal changes of fragile ecosystems, as coastal habitats. Species composition changes or alterations, as well as habitats fragmentation or disappearance could play an important role as bio-indicators of ecosystem integrity and functioning.

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