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Research paper

What has happened to coastal dunes in the last half century? A multitemporal coastal landscape analysis in Central Italy

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HIGHLIGHTS

- We compared coastal dune land cover maps for the years 1954, 1986 and 2006.
- We examined multitemporal changes in landscape composition and configuration.
- Patch and edge based analyses pinpoint the most threatened coastal dune habitats.
- Agriculture, reforestation and urbanization are the major driving forces of change.

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ABSTRACT

The current degradation of the Mediterranean coastal landscape highlights the necessity of, performing long term multitemporal analysis to guide land managers seeking to improve coastal, conservation, planning and management. This work sets out to quantify landscape changes for the last, 50 years in one sector of the Italian coast, with emphasis on natural dune cover types, and to analyze, their spatial configuration in relation to the anthropogenic cover types to investigate the processes, underlying these changes. On the basis of detailed land-cover maps (dated 1954, 1986 and 2006), we, assessed landscape changes by transition matrices. The spatial pattern of natural dune cover types, (Beaches with Pioneer annual Vegetation, Herbaceous Dune Vegetation and Woody Dune Vegetation), for the three dates was described by patch-based (Patch Size and Shape Index) and edge-based metrics, (patch shared boundaries with manmade cover types) and compared using the non-parametric, Kruskal–Wallis median test. Multitemporal analyses provided a description of the coastal changes, occurred in the last half century. Particularly notable are consistent intensification of agricultural and, afforestation activities in the inner sectors of the dunes and a widespread urbanization. The natural, dune cover types, originally distributed in few large and elongated patches, have undergone a, substantial reduction of extent and an alteration in their spatial pattern, being now reduced to many, small and regular patches. A significant rise of contacts between natural dune cover types and, urbanized areas and infrastructures was observed. Such landscape analysis could be useful to develop, management strategies for coastal dune areas.

1. Introduction

Coastal dunes constitute approximately three-quarters of the world's shorelines (Bascom, 1980). Occupying transition zones between terrestrial and marine ecosystems, not only do these harsh environments host a particularly specialized flora and fauna (van der Maarel, 2003), but they also constitute one of the most dynamic landscapes on earth (Van der Meulen & Udo de Haes, 1996). Furthermore, they offer unique ecological services such as the filtration of large volumes of seawater, nutrient recycling, flood control and storm protection (McLachlan & Brown, 2006; Millennium Ecosystem Assessment, 2005).

On the other hand, in recent years, coastal dune ecosystems have undergone consistent transformations including urban expansion, agricultural and afforestation spread, industrial and harbor development (Schlacher et al., 2007). In addition, they have become a prime site for human recreation, supporting many coastal economies around the world (Schlacher et al., 2008). Coastal sandy ecosystems are currently pinpointed as one of the most threatened ecosystems, as well as being prone to a biodiversity loss (EEA, 2008). The degradation and loss of the littoral landscape is particularly

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striking on the Mediterranean coasts (Curr, Koh, Edwards, Williams, & Daves, 2000, Miccadei, Mascioli, Piacentini, & Ricci, 2011). For these reasons, in Europe, most of the plant communities growing on coastal dunes have been listed as EU Habitats in Annex I of the Habitats Directive (European Commission, 2007).

The growing concerns over the loss of biodiversity in coastal ecosystems have spurred land managers to seek better ways of managing landscapes at a variety of spatial and temporal scales. Describing changes in the distribution of land cover types over time may be crucial for preserving biological diversity and developing paradigms of sustainable ecosystem management at the landscape level (Christensen et al., 1996). In fact, when developing conservation strategies, it is essential to connect land cover spatial patterns over long time sequences in order to better understand the ecological processes underlying landscape changes (Marcucci, 2000). In this way, we can generate predictions about the future rates of change and the vulnerability of ecosystems which can help design appropriate conservation policies (Negendra, Munroe, & Southworth, 2004).

Much research has been done to describe plant diversity, community dynamics, and the effects of disturbance on biological diversity of the coastal dunes (Brown & McLachlan, 2002; Doing, 1985; Martínez, Maun, & Psuty, 2004; van der Maarel, 2003). In contrast, the analysis at landscape scale of coastal dune cover types over time has been poorly explored, especially in relation to manmade cover types, and such analysis remains an important research task (Antrop, 1993; Sluiter & de Jong, 2007). It is known that, in order to assess recent evolution of coastal dune landscapes, cover maps derived from a multitemporal sequence of remote sensed data are necessary (Ellis, Spruce, Swann, Smoot, & Hilber, 2011). This is so, despite the fact that the lack of such maps can be explained by the difficulty in mapping the complex and fine grained mosaic proper to these landscapes. This natural complexity, recognized as beneficial to species diversity (Acosta, Carranza, & Izzi, 2009), represents a limitation for landscape description using traditional land cover mapping techniques (Lucas, Shanmungam, & Barnsley, 2002). In Europe, the EU has defined a standard protocol for a multitemporal land use mapping at national and regional levels (CORINE land cover maps – EEA, 1999), but due to the used coarse scale (1:100,000 and 1:250,000), the entire coastal dune mosaic is actually summarized and mapped into few cover types (see for example Alados et al., 2004).

Even though some recent efforts toward a description of coastal landscape transformations at a coarse scale have been made (Ellis et al., 2011; Serra, Pons, & Sauri, 2008) and few fine scaled analyses of coastal dune mosaic structure for a single date were performed (Carboni, Carranza, & Acosta, 2009; Carranza, Carboni, Feola, & Acosta, 2010), the multitemporal pattern analysis of dune mosaic would benefit from further research. Previous studies established that coastal dune patches, largely determined by environmental constraints, are relatively small and elongated along the coast (Carboni et al., 2009; Forman, 1995). Therefore, an interesting topic to explore would be whether natural dune cover classes maintain these structural characteristics through time or if, instead, their specific spatial patterns change across the different dates. Moreover, previous research also demonstrates that the sustainability of the different dune mosaic elements is greatly influenced by specific contiguity among natural and anthropogenic land cover types (Acosta, Blasi, & Stanisci, 2000). For instance, in recent decades, the urbanization phenomenon, the intensification of agricultural practices and the spread of conifer plantations have had a strong impact on Mediterranean coastal landscapes (Curr et al., 2000; Miccadei et al., 2011; Schlacher et al., 2007). Such transformations and their direct effects on the landscape spatial configuration could expose the natural dune habitats to many potential hazards (Carranza, Acosta, Stanisci, Pirone, & Ciaschetti, 2008; O'Shea & Kirkpatrick, 2000). Accordingly, the way in which man-made cover types are distributed with respect to natural dune patches and how this arrangement can change over time are further topics to investigate.

On this basis, the present work sets out to quantify temporal landscape changes for the last 50 years (from the postwar economy up to current time) in a sector of the Italian coast (Molise region – Adriatic coast), and to analyze the spatial configuration of natural dune cover types within the coastal landscape. We focus on changes in the spatial pattern of coastal dune cover types (including several coastal dune EU Habitats – Acosta, Carranza, & Izzi, 2005; Prisco, Acosta, & Ercole, 2012) in relation to the anthropogenic ones (artificial, agricultural and afforestation patches).

2. Materials and methods

2.1. Study area

The Molise coast (Central Italy) stretches for 30 km along the Adriatic Sea (Fig. 1) and is mainly composed of sandy beaches. Recent dunes (Holocene) occupy a narrow strip along the seashore. They are not very high (less than 10 m heights) and are relatively simple in structure (usually only one dune ridge) (Acosta et al., 2009). Along the dune profile, abiotic conditions vary greatly, moving along the sea-inland gradient, shaping an habitat zonation. Under natural conditions, the vegetation zonation follows this ecological gradient, ranging from pioneer annual communities on the beach to Mediterranean maquis on the landward fixed dunes. In our study area, Mediterranean maquis can be considered the most mature vegetation type on fixed dunes also in absence of cutting or grazing. Most Italian costal dunes remain well preserved (with the exception of some areas, such as near harbors) until the development of mass summer tourism and intensive agriculture alter them (Acosta et al., 2000; Carboni, Santoro, & Acosta, 2011; Provoost, Jones, & Edmonson, 2011; Prisco et al., 2012). At present, several potential hazards, such as an intense and fast urbanization, threaten these coastal ecosystems. An additional human modification of natural dune habitats has been the afforestation with *Pinus* species (Iannantuono, Rosskopf, Stanisci, Acosta, & Aucelli, 2004; Taffetani, 2011). For these reasons, the natural vegetation has been severely damaged and reduced along the whole Adriatic coast. Nonetheless, the coastal dunes of Molise still host many EU Directive 92/43 Habitat types (Carranza et al., 2008). For this reason, in 1995, three SAC (Special Areas of Conservation), including 20 km of coastal dunes, were proposed for this area (SAC code: IT7228221, IT7222216, IT7222217). These three SAC cover about 55% of the study area.

2.2. Land cover map

In order to assess changes in the landscape, we used cover maps derived from a multitemporal sequence of remote sensed data. We produced three large scale (1:5000) land-cover maps of the Molise coast from the years 1954, 1986 and 2006 (Fig. 2). Given that in Central Italy the dune ridges are generally very narrow (Carranza et al., 2008), we mapped a 500 m wide strip starting from the coastline toward inland. The maps were derived from aerial photographs taken in summer with about 1 m resolution. Land cover was manually interpreted on screen in a GIS environment (ArcGis 9.2). The legend matches CORINE land cover expanded to a fourth level of detail for natural and semi-natural areas (Acosta et al., 2005). Ten land cover types were identified and mapped (Table 1). Particular attention was given to natural dune cover types which, according to Acosta et al. (2005), were mapped in three