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The conservation status and anthropogenic impacts assessments of Mediterranean coastal dunes

Maria Silvia Pinna [1], Donatella Cogoni, Giuseppe Fenu*, Gianluigi Bacchetta

Centro Conservazione Biodiversità (CCB), Dipartimento di Scienze della Vita e dell'Ambiente, Università degli Studi di Cagliari, Viale S. Ignazio da Laconi 11-13, I-09123 Cagliari, Italy

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ABSTRACT

Mediterranean coastal dunes have been highly modified by human impacts and understanding their conservation status is crucial to preserve these extremely vulnerable habitats.

In the present study three different diversity indices elaborated by Grunewald and Schubert (H_{dune}, a modified version of the Shannon diversity index, E_{dune}, a modified Evenness index, and N, the Naturalness index) were applied in order to assess the conservation status and anthropogenic impacts on Is Arenas dune system (CW Sardinia), one of the widest and most important in the Western Mediterranean Basin.

Within the system, two sites with different anthropic disturbance conditions were selected; 25 permanent plots were seasonally monitored and the cover of each vascular plant present was visually estimated.

The H_{dune} values were similar between sites and differences were not significant; E_{dune} showed higher value in the North than in the South site with relevant statistical differences.

Moreover a seasonal variation in the indices values was recorded, which could be linked to presence of annual plants rather than the touristic pressure. Instead, the small variability of N index suggests that the application of this index may be an important tool to assess human impact on coastal dunes, but better discriminates between sites with different disturbance degrees.

Our results highlight the usefulness of H_{dune} and E_{dune} indices to assess the conservation status of a Mediterranean coastal dune system, while these indices are less influenced by the human trampling at finer scale (sites within the beach). Spring and summer are the best seasons when the main plant diversity of Mediterranean coastal dune can be captured. The diversity indices applied, although need to be developed through further researches, could be a quickly tool allowing to assess the integrity of the coastal dunes in order to plan management actions of these complex and threatened ecosystems.

1. Introduction

Coastal dune habitats are among the most important ecosystems in Europe, as they contain a high ecological diversity in terms of environmental heterogeneity and variability of species composition (van der Maarel, 2003; Martínez and Psuty, 2004; Carranza et al., 2008; Acosta et al., 2009). This is a result of the intricate interactions between abiotic and biotic factors that cause a complex sea-to-inland environmental gradient (Carranza et al., 2008; Fenu et al., 2013a). However, these unique ecological characteristics make coastal dune systems also particularly fragile environments, which are considered among the most endangered in Europe (van der Meulen and Salman, 1996; Carboni et al., 2009; Feola et al., 2011). For example, it has been estimated that during the 20th century, the dune systems along European coasts have been reduced by about 70% (McLachlan and Brown, 2006).

Mediterranean coastal dune systems appear to suffer a larger reduction within Europe, as has been indicated for the Italian coasts (Feola et al., 2011). Human activity is the most influencing factor in the alteration of the Mediterranean coastal habitats and a large

* Corresponding author. Present address: Dipartimento di Biologia Ambientale, Sapienza Università di Roma, Piazzale A. Moro 5, I-00185 Roma, Italy.
E-mail addresses: m.silviapinna@gmail.com (M.S. Pinna), d.cogoni@unica.it (D. Cogoni), pepefenu@gmail.com (G. Fenu), bacchet@unica.it (G. Bacchetta).
[1] Present address: DIAEE Dipartimento di Ingegneria Astronautica Elettrica ed Energetica, Sapienza Università di Roma, Corso Vittorio Emanuele II 244, I-00186 Roma, Italy.

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number of coastal environments are strongly affected by touristic and related infrastructures; this situation is causing a dramatic decline in the distribution and quality of dune habitats (Davenport and Davenport, 2006).

An increasing number of papers in recent years have been focused on the effects of human disturbance on the plant diversity of Mediterranean coastal dunes (e.g. Kutiel et al., 1999; De Luca et al., 2011; Santoro et al., 2012; Attorre et al., 2013; Fenu et al., 2013b; Pintó et al., 2014). However, as seen in previous studies, Mediterranean coastal dunes are extremely complex ecosystems subjected to a great variety of environmental factors (Angiolini et al., 2013; Fenu et al., 2013a; Ciccarelli, 2014). Hence, there is a complex vegetation response with the coexistence of biotic mosaics constituted by different plant-community types in relatively small spaces (Acosta et al., 2007; Fenu et al., 2013a). Consequently, it has become relevant to develop useful indices to assess the conservation status of Mediterranean coastal dunes.

In spite of the concept of conservation status has been subject to discussion, direct measures of biodiversity or proxies can be used to assess it (e.g. Margules and Pressey, 2000; Yoccoz et al., 2001). In fact, several methods aiming to assess dune conservation status have been proposed, focusing, for example, on dune vegetation in order to estimate of best management strategies (e.g. McLachlan et al., 2013), on single species as bioindicators or parameters, such as species composition, richness, diversity and cover or landscape cover types and related structural indices (Grunewald and Schubert, 2007; Carboni et al., 2009; Attorre et al., 2013; Fenu et al., 2013b; Ciccarelli, 2014).

The Shannon diversity index, H index (Shannon and Weaver, 1949), is frequently used in ecological studies regarding vegetation analysis (i.e. Carboni et al., 2009). Unfortunately, the Shannon index fails to highlight major changes, such as fragmentation, which occur in the coastal dunes as a result of disturbance (Grunewald and Schubert, 2007). In addition, an index suitable to assess the conservation status of coastal dunes must consider qualitative or quantitative species measures with respect to the extent of the habitat (Grunewald and Schubert, 2007). For this reason, Grunewald and Schubert (2007) have developed a new index (H_{dune}), based on the H index, which allows us to clearly distinguish between the different sites and their different levels of anthropogenic impacts on coastal dunes. H_{dune} is also more useful than the H index in extreme habitats such as coastal dunes (De Luca et al., 2011; Attorre et al., 2013), where natural stressful conditions determine the presence of a few species with high dominance (Martínez and Psuty, 2004). In fact, the H_{dune} index, uses the abundance of species (as cover percentage) in relation to a constant sampling area, and unlike the H index is able to detect changes in both plant species richness and total cover (Attorre et al., 2013; Ciccarelli, 2014).

As far as we know, few studies have been developed on Mediterranean coastal dune systems (Attorre et al., 2013; Ciccarelli, 2014) to explore the usefulness of the approach elaborated by Grunewald and Schubert (2007) for the oceanic coastal dune of Baltic Sea (German and Polish coasts).

The Mediterranean Basin shows a unique character that results from both geographic conditions and historical and social developments; the Mediterranean Sea is a semi-enclosed basin surrounded by a complex orography, which strongly affects and often controls the local climate; it is characterised by high water temperature and salinity, and more limited tides, waves and meteorological phenomena (compared to the oceanic storms and hurricanes; Fenu et al., 2013a). Considering the relevant differences in the intensity of natural stress and disturbance between Oceanic and Mediterranean coastal systems, we hypothesise different responses of the indices in these two different situations.

In order to test this hypothesis, we selected the Is Arenas coastal system as a study area, which is a large well-developed dune system located in the Northeastern sector of the Sinis Peninsula (CW Sardinia; Fig. 1). The geomorphological and sedimentological complexities, as well as the qualitative and quantitative floristic richness denote the high naturalistic interest and make it one of the most representative and well-conserved Mediterranean coastal dune systems (Fenu et al., 2012, 2013a). Within this area, the Northern and the Southern zones strongly differ at the morpho-sedimentological and at the human pressure levels; in addition, the whole system shows considerable seasonal variations at the morphological and structural levels (Fenu et al., 2012).

The aim of this study was to analyse the conservation status of Is Arenas dune system by applying the protocol of Grunewald and Schubert (2007). The particular objectives were: 1) to assess the conservation status of dune systems; 2) to detect differences in conservation status within the study area, comparing two sites of the dune system with different anthropic pressure levels; and 3) to understand whether the seasonal variations of the beach affect, at the morphological level, the indices proposed by Grunewald and Schubert (2007).

2. Materials and methods

2.1. Study area

The dune system of Is Arenas (Fig. 1) represents one of the most important coastal dune systems of the Western Mediterranean Basin (Fenu et al., 2012). Geologically, the area mainly consists of Quaternary deposits that form a sedimentary complex, where Holocene sandstones and Aeolian sands form the upper limit of the succession (Carboni et al., 1998). The Is Arenas beach, having a NW-SE aspect representing the main exposure to the mistral, west winds and the dominant wave rays (Simeone and De Falco, 2012; Fenu et al., 2013a), presents a transverse profile, characterised by a submerged beach, an intertidal zone, a backshore and a well-developed dune system. The morphological structuring of the beach shows important seasonal variations: in the summer numerous morphologies were recorded, which allowed the beach to be classified as a typically reflective type according to the classification of Pranzini (2004). During the remaining seasons, with the progressive homogenisation of the morphologies, a winter dissipative type profile was observed, indicating the intense erosive action of the waves in winter (Fenu et al., 2012).

A substantial lack of homogeneity is present between the Northern and Southern part of the dunal systems. The Northern zone is generally wider, with lower conductivity, organic matter, and carbonate content, and a higher pH than the Southern zone. Conversely, the Southern area is narrower with finer grain sizes; however these differences do not correspond to significant variations in the number of taxa and vegetation cover (Simeone and De Falco, 2012; Fenu et al., 2012).

From the climatic point of view, the study area shows a typical Mediterranean annual trend of temperatures (mean temperature = 16.9 °C) and precipitations (mean rainfall = 536.7 mm; Fenu et al., 2012).

The vegetation zonation follows a typical sea-inland ecological gradient, spanning annual dominated communities on the strandline zone of the beach to shrubby or forest communities on the stabilised dunes (Fenu et al., 2012, 2013a).

The Is Arenas coastal dunes system is widely modified by human recreational activities: in the Northern part of the beach there are several touristic installations (four camping; Fig. 1), while in the Southern part the level of human disturbance is quite low and no touristic installations are present (Fig. 1). This causes an important