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Dune habitats of the Migliarino – San Rossore – Massaciuccoli Regional Park (Tuscany – Italy)

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ABSTRACT

Here we present a map of dune habitats (*in accordance with Directive 92/43/EEC, MD 20 January 1999*) developed from a long-term survey of dune vegetation in the Migliarino San Rossore Massaciuccoli Regional Park, northern Tuscany, Italy. The 1:7500 map covers a total area of about 394 ha, was created in the geographical information system environment for print and digital versions. The aim of this work, in addition to outlining the current vegetation landscape in the printable map, is to monitor changes in dune habitats on the digital version. Phenomena such as coastal erosion and human pressure can be monitored in order to identify appropriate management tools for mitigating or eliminating disturbance factors. The shape and spatial coverage of habitats, identified by previous vegetation surveys in the field, were drawn on the basis of orthophotos using MapInfo®. The study reveals numerous highly significant habitats in terms of conservation, which are often significantly altered in terms of their distribution and surface area due to human activities and coastal erosion.

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Dune habitats; vegetation map; anthropogenic pressure; coastal erosion; protected areas; Tuscany

1. Introduction

Sandy coastal ecosystems occupy the transition zone between marine and sedimentary terrestrial environments, and are susceptible to constant changes in their morphological structure and vegetation landscape (Brown & McLachlan, 2002; Costa, Cordazzo, & Seeliger, 1996; Hesp, 1991; Maun, 2009). These ecosystems show considerable biodiversity, in terms of plant species and communities, often along a well-defined zone, provided that they have not undergone excessive change (Acosta, Ercole, Stanisci, De Patta Pillar, & Blasi, 2007; Prisco, Acosta, & Ercole, 2012). The beaches and dune habitats of these ecosystems are particularly fragile and vulnerable environments as a result of the dual threat posed by continued coastal erosion and anthropogenic pressure (Cori, 1999; Doody, 2013; Martinez, Psuty, & Lubke, 2004; Schlacher et al., 2008), and due to their specific ecosystem functions they are thus particularly worthy of attention and protection (Provoost, Ampe, Bonte, Cosyns, & Hoffmann, 2004; Van der Maarel, 2003; Van der Meulen & Udo de Haes, 1996). Detailed mapping of these plant communities is thus of great importance for monitoring and managing these environments.

Italy has a coastline of about 7500 km, of which approximately 37% is rocky coasts and 63% sandy (ISPRA, 2011). The sandy coasts are characterized by a great diversity of habitats of high natural and environmental interest (Biondi et al., 2012; Macchia, Pranzini,

& Tomei, 2005; Pignatti, 1993). However, 56.2% of the Italian peninsular has been transformed by urbanization and over 22% of coasts have been affected by permanent soil consumption (ISPRA, 2016; Legambiente, 2015). Coastal erosion is another factor that affects around 45% of sandy coasts (Ferretti, Barsanti, Delbono, & Furia, 2003; Valpreda & Simeoni, 2003).

In most cases, human pressure and coastal erosion act synergistically, making these habitats highly vulnerable and threatened, as has been recognized by the international community (Carranza, Acosta, Stanisci, Pirone, & Ciaschetti, 2008; Doody, 2013).

The coastal sector of the Regional Park of Migliarino San Rossore Massaciuccoli (Tuscany, Italy) is of particular interest. With a total length of about 30 km, this protected area has stretches of coastline in progradation, some in erosion, and others in balance, and the entire coastline is affected very differently by human pressure.

Previous studies on vegetation traits in this area have described the main psammophilous plant communities and highlighted their distribution and conservation status (Arrigoni, 1990; Bertacchi & Lombardi, 2014; Bertacchi, Lombardi, & Bocci, 2009; Bertacchi, Zuffi, & Lombardi, 2016; Sani & Tomei, 2006; Sani, Monacci, Trimarchi, & Tomei, 2010; Tomei, Bertacchi, Sani, & Consiglio, 2004). However, except for two vegetation maps of two areas of the park, but not specifically of dune areas (Sani et al., 2010; Tomei et al., 2004), or partial technical mapping of some areas of the park (<http://www.parcosanrossore.org/>), detailed

mapping of the dune vegetation landscape of this area has never been carried out. The creation of a diachronic aerial orthophotography database (GEOSCOPIO, Tuscan regional government) and the subsequent use of the large-scale orthophotos in a geographical information system (GIS), has led to the production of a detailed thematic map.

2. Area of study

The Migliarino San Rossore Massaciuccoli park (Tuscany, Pisa) lies between 43° 51' 36" – 43° 35' 25" N and 10° 14' 26" – 10° 21' 11" E (Figure 1). It was established in 1979 in order to safeguard around 23,150 ha of dunes, mesophilous and xerophilous forests, wetlands and agro-forestry landscape, along approximately 30 km of coast. In 2004, the park was designated by UNESCO a Biosphere Reserve (<http://www.parcosanrossore.org>).

Although only constituting a fraction of the surface area of the park (about 394 ha, 1.7% of the total area), the recent dune bands represent an area of extraordinary richness in terms of unique habitats and endemic plants. At the same time, however, there is strong anthropogenic pressure, linked to seaside tourism and the presence of urban settlements, and on some stretches significant erosion (GNRAC, 2006).

In order to characterize the climate, temperature and precipitation data were used from a weather station located at the eastern edge of the park (San Piero a Grado, Pisa). Annual average rainfall for the ten-year period from 1997 to 2007 was 773 mm, with the highest rainfall recorded in the autumn, and an annual average temperature of 14.4°C, with maximum values close to 30°C. The area exhibits a period of summer drought and water shortages from June to September. According to the bioclimatic classification of Rivas-Martinez and Rivas-Saenz (2015), the area has a Mediterranean macrobioclimate, with an upper meso-Mediterranean thermotype and a lower sub-humid ombrotpe.

The coastline of the park can be divided into three different sectors in relation to coastal dynamics and anthropization (Figure 1):

- (1) The *northern sector* (N), about 8 km long is subject to protective restrictions but freely accessible to the public and with a low level of urbanization. The coastline is prograding (approximately 140 m since 1954).
- (2) The *central sector* (C), about 11 km long is subject to protective restrictions and closed to the public. The coastline is undergoing rapid erosion (approximately 180 m since 1954).
- (3) The *southern sector* (S), about 11 km long, is open to the public with partial protective restrictions. The coastline is essentially in equilibrium and

mostly highly urbanized in the areas behind the beaches (Bini, Casarosa, & Ribolini, 2008; <http://www.regione.toscana.it/-/geoscopio-wms>; <http://www.parcosanrossore.org>).

3. Methodology

The study concerned the area between the shoreline and the inner boundary of the maritime fixed dune in contact with other land cover types (i.e. inner woodlands, wetlands, agricultural and urban areas). The landward extent of the dune varies between 20 and 300 m depending on the sectors studied.

The study consisted of three stages:

- (a) *Photo-interpretation of the vegetation landscape and vegetation surveys* – The vegetation coverage and edges were initially assessed through an analysis of aerial 1:2000 orthophotos provided by the WMS Geoscope Service of the regional administration (2013) (<http://www502.regione.toscana.it/geoscopio/ortofoto.html>). Over time, over 250 phytosociological surveys have been carried out on identified dune vegetation. The study of the plant communities was performed according to the Zurich-Montpellier School, adopting the abundance–dominance indices proposed by Braun-Blanquet (1964). The analysis and description of the coenoses takes account of the latest methodological acquisitions (Biondi, 2011; Biondi et al., 2014; Géhu & Rivas-Martínez, 1981) in accordance with the International Code of Phytosociological Nomenclature (Weber, Moravec, & Theurillat, 2000).
- (b) *Detection of habitats* – On the basis of previous field surveys (Bertacchi & Lombardi, 2014; Bertacchi et al., 2009, 2016; Sani et al., 2010; Tomei et al., 2004) and 2016 field updating, the vegetation was typified by the categories described by the Habitats Directive (*Directive 92/43/EEC, MD 20 January 1999*) (Biondi et al., 2012; Carranza et al., 2008; European Commission DG Environment, 2013). For the purposes of mapping and subsequent processing of the data gathered, the following habitats were considered ‘key’ features of psammophilous vegetation: 1210 Annual vegetation of drift lines; 2110 Embryonic dunes; 2120 White dunes; 2210, 2230, 2240 *Crucianellion* fixed dunes and *Malcomietalia* and *Brachypodetalia* dune grasslands; 2250 Coastal dunes with *Juniperus* spp. Habitats 9340 *Quercus ilex* and *Quercus rotundifolia* forests and 2270 Wooded dunes with *Pinus pinea* and/or *Pinus pinaster* were mapped as a single type. The three habitats 2210, 2230 and 2240 were also mapped as a single type, since

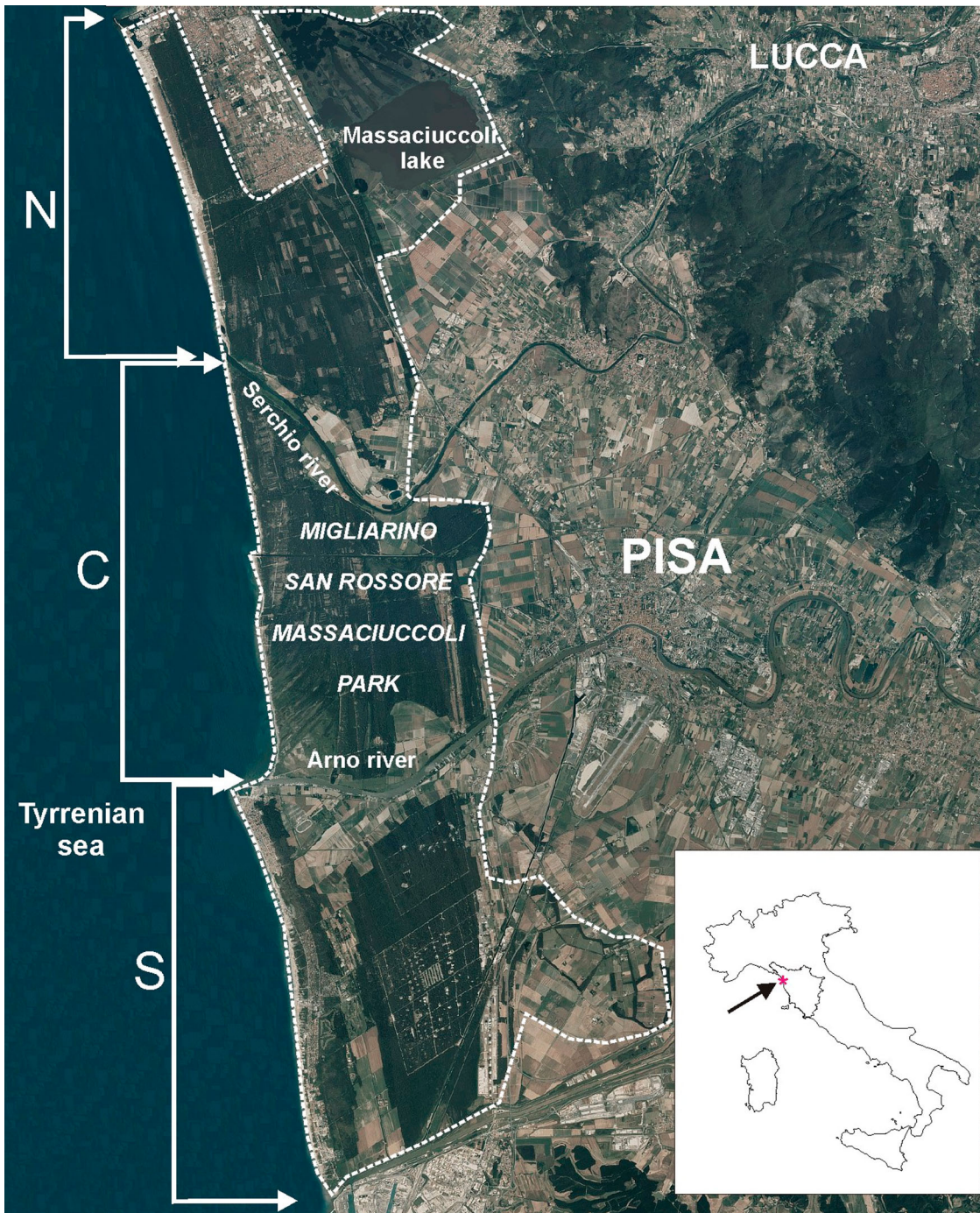


Figure 1. The study area and the three sectors of the investigated coast.

they are part of a single mosaic they cannot be clearly separated from each other. Habitat 6420 Mediterranean tall humid herb grasslands and H7210 Calcareous fens, although not exactly distributed in the context of dune habitats, occur in humid dune slacks within the dune field, and were also mapped. In addition to natural habitat types, we also mapped 'no habitat' types: anthropic aphytic area, that is, areas devoid of vegetation due to the permanent bathing establishments, parking areas, access roads, trampled paths and areas of sandy shores occupied on a seasonal basis and associated with bathing by tourists and locals.

(c) *Mapping of habitat data* – On the basis of high resolution and geo-referenced 1:2000 orthophotos (year 2013, and after field updating), overlaid onto the official 1:10,000 Regional Technical Map, assigning each digitized area to a specific phytosociological community and, consequently, to a specific habitat, the map of the coastal habitats was created using MapInfo 10.5[®] (Figure 2). The final map layout was produced using CorelDraw X3 13.0[®]. Although the final map layout is 1:7500, the level of detail refers to the GIS processing at a scale of 1:2000. Due to the cartographic representation on a single sheet, in the final layout of the map, the central sector C was divided into two sub-sectors C1 and C2. The



Figure 2. Example of overlap of mapping (thematic layers) on the topographic map and orthophoto layers.

	all sectors	N	C	S
Total area	394	204	96.4	93.6
Aphytoic anthropic area	136.6	69	3.8	63.8
Dune habitats	257.4	139.6	88	29.8

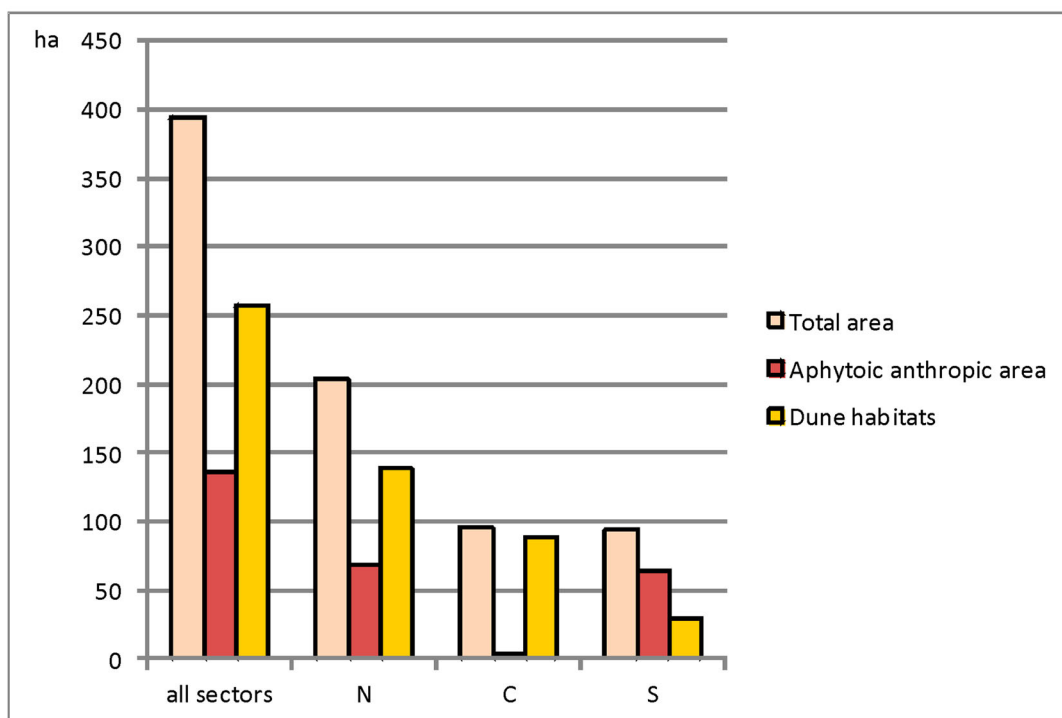


Figure 3. Surface area (ha) relating to land cover of the investigated area.

two shorelines of 1954 and 2013 were extrapolated from the aerial photos of the respective years. The entire stretch of the coastal resort of Marina di Pisa, consisting of an urban development up to the seashore, was excluded from the analysis.

4. Results

Analysis of the data relating to the surfaces of the different types of land cover mapped shows how the anthropic aphytoic area is, with a coverage of ca 136 ha, equal to 34.6% of the total investigated area. However, the land cover is distributed differently depending on the stretch of coast examined. In the north (N), of a total of 204 ha of total dune area, 69 ha are anthropic (31.8%); in the central sector, of a total of around 96.4 ha, only 3.8 are anthropic (3.9%); in the southern sector, 63.8 ha (68.1%) out of a total of 93.6 are anthropic. Surfaces occupied by the dune habitats decrease considerably moving from north to south: 139.6, 88 and 29.8 ha for the N, C and S sectors, respectively (Figure 3). Despite being difficult to measure as a result of daily and seasonal fluctuations, the natural aphytoic zone (the portion of the Earth's surface located between the shoreline and the annual vegetation of drift lines), occupies an overall area of around 30 ha.

In the strip pertaining to the sandy shore and dune environment, the field surveys revealed a large vegetational grouping, characterized by a total of 21 associations and sub-associations in addition to other phytocenotic elements ascribable to other syntaxonomic

groups. The associations identified in the study area represent a phytocenotic grouping which is representative of the sedimentary coasts of the Tyrrhenian (Acosta & Ercole, 2015; Arrigoni, 1990; Bertacchi & Lombardi, 2014; Bertacchi et al., 2009; Sani & Tomei, 2006; Vagge & Biondi, 1999). In line with European Directive 92/43, 11 different habitats were identified, three of which are of EU Interest (*), plus one ecotonal type (Table 1). On the basis of these data, the Map of Dune Habitats of the M.S.M Regional Park (Main Map) was created.

H1210 Annual vegetation of drift lines: The characteristic association of this habitat is *Salsolo kali-Cakiletum maritimae* (Costa & Manzanet 1981 corr. Rivas-Martínez et al. 2002) which is present in all of the three stretches of the coast mapped, though with the lowest value of the strictly psammophilous habitats. This habitat usually covers very limited areas in the dune zonation (Biondi et al., 2014), and here coverage values vary considerably within the three sectors, decreasing from north to south, with low values in sector C (1.5 ha) and very low values in sector S (0.7 ha) (Figure 4).

H2110 Embryonic shifting dunes: Characterized by the associations *Echinophoro spinosae-Elymetum farcti* Gehu 1988 and *Elymo farcti-Spartinetum junceae* (Vagge & Biondi 1999), in addition to some variants. This habitat shows high total coverage values, although with a discontinuous distribution, since it is only present without interruption in sector N (17.8 ha). In sector C (with respect to total percentage coverage of psammophilous vegetation), it is almost absent (1.2 ha, ca 1.3% of all dune habitats in this sector) (Figure 4).

Table 1. Phytosociological communities (alliance, associations, sub-associations, facies, variants, groupings) identified in the investigated area and related habitats.

Phytosociological communities	Habitats (Directive 92/43/EEC)
1 <i>Salsolo kali-Cakiletum maritimae</i> Costa e Manzanet 1981 corr. Rivas-Martínez et al. 2002	1210: Annual vegetation of drift lines
1b subass. <i>xanthetosum italicum</i> Gehù et al. 1984	
2 <i>Echinophoro spinosae-Elymetum farcti</i> Gehu 1988	2110: Embryonic shifting dunes
2b – var. a <i>Solidago litoralis</i>	
2c – var. a <i>Sporobolus virginicus</i>	
2d subass. <i>otanthetosum maritimi</i> Géhu & Biondi 1994	
3 <i>Elymo farcti-Spartinetum junceae</i> Vagge & Biondi, 1999	
4 <i>Echinophoro spinosae-Ammophiletum arundinaceae</i> Géhu, Rivas-Martínez, R.Tx. 1992	2120: Shifting dunes along the shoreline with <i>Ammophila arenaria</i> (white dunes)
4a – subass. <i>solidaginetosum litoralis</i> Vagge & Biondi 1999	
4b – facies ad <i>Ammophila arenaria</i>	
4c – facies a <i>Euphorbia paralias</i>	
5 <i>Pycnomono rutifolii-Seseletum tortuosi</i> Arrigoni 1990 6 <i>Sileno coloratae-Vulpietum membranaceae</i> (Pignatti 1953) Géhu & Scoppola 1994 7 <i>Helichryso stoechadis-Cistetum eriocephali</i> Biondi 1999	2210: <i>Crucianellion maritimae</i> fixed beach dunes 2230: <i>Malcolmietalia</i> dune grasslands 2240: <i>Brachypodietalia</i> dune grasslands with annuals
8 <i>Asparago acutifolii-Juniperetum macrocarpae</i> (R. et R. Molinier 1955) De Bolos 1962	2250*: Coastal dunes with <i>Juniperus</i> spp.
9 <i>Spartio juncei-Juniperetum macrocarpae</i> Vagge & Biondi 1999	
10 <i>Quercion ilicis</i> Br. Bl. Ex Molinier 1934	2270*: Wooded dunes with <i>Pinus pinea</i> and/or <i>Pinus pinaster</i> 9340: <i>Quercus ilex</i> and <i>Quercus rotundifolia</i> forests 6420: Mediterranean tall humid herb grasslands of the <i>Molinio-Holoschoenion</i>
11 <i>Schoeno nigricantis-Erianthetum ravennae</i> Pignatti 1953	
11b – subass. <i>periplocetosum graecae</i> Vagge & Biondi 1999	
11c – subass. <i>spartinetosum versicoloris</i> Bertacchi & Lombardi 2014	
12 <i>Phragmitetum australis</i> Gams 1927	7210* Calcareous fens with <i>Cladium mariscus</i> and species of the <i>Caricion davallianae</i> (in humid dune slacks)
13 <i>Cladietum marisci</i> (Allorge 1922) Zobrist 1935	
14 Groupments at <i>Alnus glutinosa</i> , <i>Amorpha fruticosa</i> , <i>Populus</i> sp.pl., <i>Periploca graeca</i>	Ecotonal wet scrublands in humid dune slacks

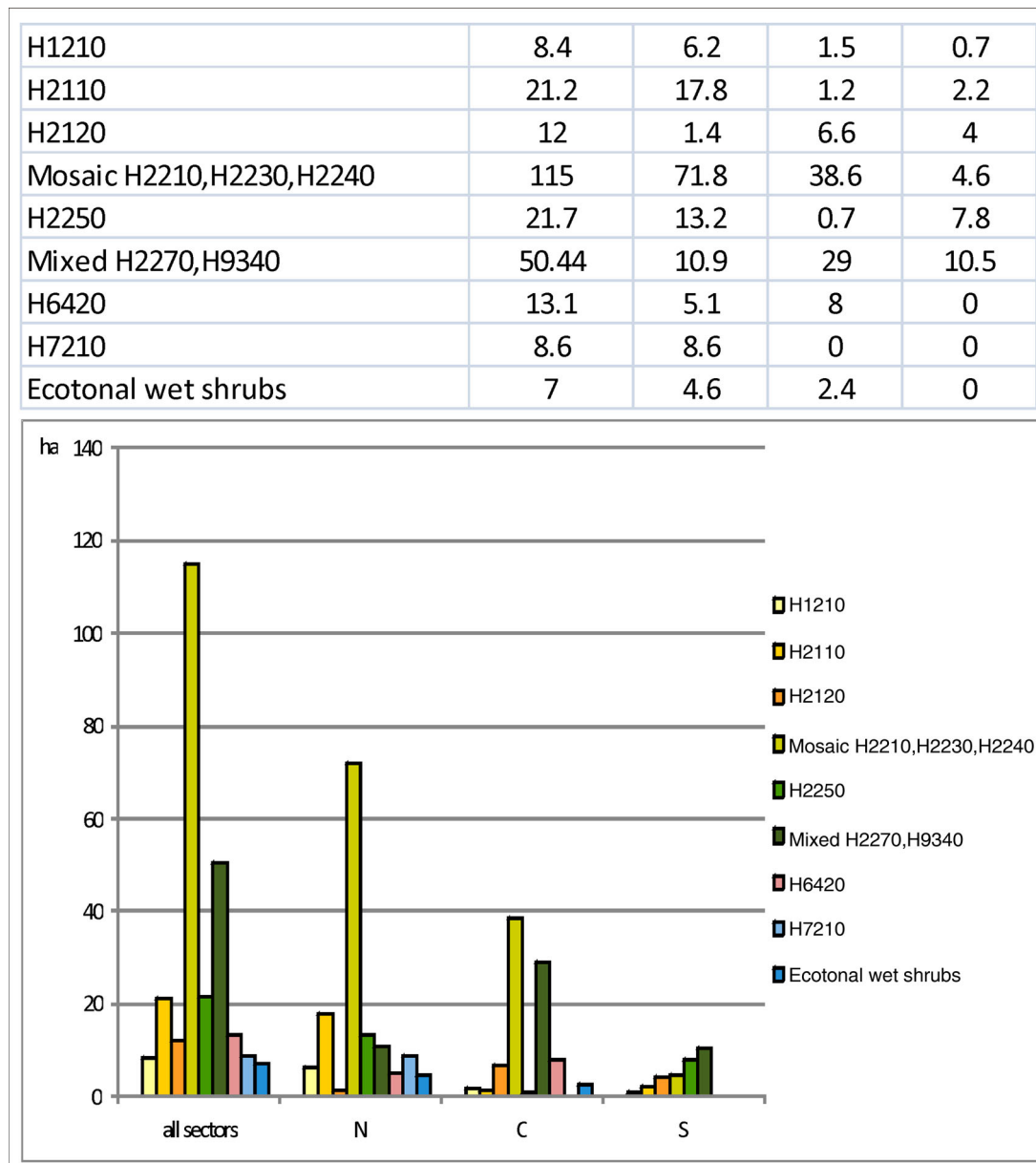


Figure 4. Surface area (ha) of the habitats of the investigated area.

H2120 Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes): Characterized by the associations *Echinophoro spinosae-Ammophiletum arundinaceae* (Géhu, Rivas-Martinez, R.Tx. 1992), with its sub-associations and facies, this habitat covers a very small area and shows a high degree of fragmentation in sector N (1.4 ha) (Figure 4; Main Map). In sector C the habitat is extensive and without interruption, at least up to where erosion is not relevant (6.6 ha) (Figure 4; Main Map). In sector S it shows higher coverage values in terms of the total percentage coverage of psammophilous vegetation in this sector (4 ha, ca 13% of dune habitats in this sector) (Figure 4).

H2210 *Crucianellion maritimae* fixed beach dunes; H2230 *Malcolmietalia* dune grasslands; H2240 *Brachypodietalia* dune grasslands with annuals: These three habitats are barely separable from a cartographic perspective, given their natural admixture on the surfaces

of the consolidated dunes, which is why they are included under the single cartographic theme. Characterized by three associations: *Pycnomono rutifolii-Sesletum tortuosi* (Arrigoni 1990), *Sileno coloratae-Vulpietum membranaceae* (Pignatti 1953; Géhu & Scoppola 1994) and *Helichryso stoechadis-Cistetum eriocephali* (Biondi 1999), this mosaic has the highest total coverage values (115 ha), and is particularly extensive in sector N (71.8 ha) (Figure 4).

H2250* Coastal dunes with *Juniperus* spp.: This habitat is characterized by two associations, *Asparago acutifolii-Juniperetum macrocarpae* (R. et R. Molinier 1955; De Bolos 1962) and, to a lesser extent, *Spartio juncei-Juniperetum macrocarpae* (Vagge & Biondi 1999). This habitat has the highest coverage values in the retrodunal expanses of sector N (13.2 ha), and is also well represented, despite the anthropization, in sector S, albeit with a much lower occurrence than in the

coverage of N (7.8 ha). It is almost non-existent and only accounts for some micro populations in the central sector C (0.7 ha) (Figure 4).

H2270* Wooded dunes with *Pinus pinea* and/or *Pinus pinaster* and H9340: *Quercus ilex* and *Quercus rotundifolia* forests. Considering these two habitats in one mapping unit, they are represented by the mosaic of forest communities included in the *Quercion ilicis* Br. Bl. Ex (Molinier 1934) alliance. These mainly represent the inner framework behind the dunes of psammophilous coastal communities. Cartographically they were recognized up to the inner edge of the fixed dune.

H6420 Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion*: The characteristic association is *Schoeno nigricantis-Erianthetum ravennae* (Pignatti 1953) and its subassociations. Although it is not exactly a dune habitat (due to its strictly hygrophilous nature), this habitat is often present in the sandy depressions between the mosaic of habitats H2210, 2230, 2240 and habitat 2250, 2270 and 9340. In our study area, this habitat is only present in the N and C sectors with 5.1 and 8 ha, respectively (Figure 4).

H7210* Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* (in humid dune slacks): *Phragmitetum australis* (Gams 1927) and *Cladietum marisci* (Allorge 1922; Zobrist 1935) characterize this habitat. These are two markedly hydro-hygrophilous associations which are present exclusively in N, mixed with H2210 habitats, 2230 2240, H2250, H6420 in depressions behind the dunes (Figure 4; Main Map).

Ecotonal wet shrubs in humid dune slacks: Small nucleus of mixed hygrophilous microwoods of *Alnus glutinosa*, *Amorpha fruticosa*, *Populus* sp.pl., *Periploca graeca* grow with very small surfaces in sectors N and C, around habitat H7210.

5. Discussion and conclusions

A breakdown of the data for the three sectors, characterized by different geomorphological and anthropic dynamics, shows that habitat distribution and surface area are significantly different (Figures 3 and 4; Main Map). This fact, on the basis of the investigations carried out to date (Bertacchi & Lombardi, 2014; Bertacchi et al., 2009, 2016), can be attributed both to the above-mentioned prograding and/or eroding coastline and to anthropogenic pressure.

The northern sector is characterized by three (two very broad, one extremely narrow) stretches of beach where there are no psammophilous habitats (Figure 3; Main Map). These correspond to two areas subject to complete, permanent anthropic occupation and a pedestrian path. While habitats 2110, 2210/2230/2240 and 2250 occur along the entire stretch of coastline, and are interrupted only where permanently

occupied anthropic areas exist, habitats 1210 and 2120 arise less frequently (Main Map, N sector). Habitat 1210 can be easily accounted for by the seasonal occupation by bathers and by the clean-up operations associated with them, which result in the total eradication of the habitat, as already described for sector S (Bertacchi & Lombardi, 2014; Bertacchi et al., 2009).

Habitat 2120 occurs less frequently and in a more fragmented manner than the neighbouring habitats. The fragmentation is probably connected with a high degree of trampling, and with the very large number of accessways to the beach and to the anthropic wear of the dune (*research in progress*). This anthropic wear is often parallel to the coastline, that is, on the summit of the dune relief that coincides with the habitat (Figure 2; Main Map).

The central sector exhibits particular characteristics. These include the severe depletion of habitat 2250 which is only present at certain points along the entire sector, the almost total absence of H2110 and the exclusive presence of H1210 in a third of the sector that coincides with the stretch close to the mouth of the River Arno and protected by fences, where it is almost completely devoid of habitats, H1210, H2120 and the H2210 H2230, H2240 mosaic (Figure 4, Main Map, C2). This can be interpreted as a consequence of severe erosion which has affected this sector for almost a century (Bini et al., 2008) with the habitats responding in different ways to the erosion (Bertacchi et al., 2016).

The southern sector (Main Map, S) exhibits an overall significant impoverishment affecting the psammophilous habitats, which visibly coincides with the historical exploitation of the beaches and the areas behind used for bathing purposes. Overall, all of the habitats are severely compromised, with the exception of 2250. This latter habitat, by establishing itself on consolidated dune, was recorded with a frequency of slightly over 50% of the observed cases. In this sector, the distribution of other psammophilous habitats is linked to the consolidated *Juniperus* dune, where such habitats often then form mosaics of microhabitats (Bertacchi & Lombardi, 2014; Bertacchi et al., 2009) (Figure 4; Main Map, S).

The different presence of habitats due to the impact of anthropic pressure is clearly related to the different ways this is expressed and where it occurs. Where the anthropic impact is permanent (bathing facilities, buildings, car parks, etc.), all habitats have disappeared without distinction. Where the action is temporary, habitats 1210 and 2120 seem to be the most vulnerable (Bertacchi & Lombardi, 2014; Bertacchi et al., 2009). These results are in line with other studies in the literature (Ercole, Acosta, & Blasi, 2007; Lomba, Alves, & Honrado, 2008; Lucrezi, Saayman, & van der Merwe, 2014; Martins, Neto, Gutierrez, & Costa, 2014; Santoro,

Jucker, Carboni, & Acosta, 2012). The ‘natural’ alteration factor coastal erosion, is selective towards those species and plant communities that are not able to ‘follow’ the erosion process inwards. However, when the amount of erosion is significant, in terms of the retraction speed of the coast line, all the habitats have been eliminated (Bertacchi et al., 2016; Ciccarelli, 2014; Doody, 2013; Feagin, Sherman, & Grant, 2005; Schlacher et al., 2008)

Although mapping tools are frequently used in environmental studies in coastal areas (Acosta, Carranza, & Izzi, 2005; ISPRA, 2009; Tomasella et al., 2007; Vagge, Corradi, Ferrari, Balduzzi, & Mariotti, 2007), in the scientific literature in Italy little research has been published on the vegetation or habitat cartography of dune environments. Except for the cartographic work (1:5000) on dune vegetation by Pedrotti, Orsomando, and Cortini Pedrotti (1975), other thematic maps of coastal areas have almost always been carried out at smaller scales and, consequently, have few details with regard to the typology mapped (Arrigoni, Nardi, & Raffaelli, 1985; Tomei et al., 2004; Guarino, Minissale, & Sciandrello, 2008). On the other hand, psammophilous plant communities/habitats always involve limited areas and linear landscape traits. In addition, the geomorphological mapping basemaps for sandy systems are often out-dated and at small-scale. Consequently, before the advent of digital technology, the large-scale cartographic reproduction of these environments was difficult. Today, the combined use of field surveys, aerial/satellite photos, LIDAR technology and GIS, provides a snapshot at any given time of the land occupied by plant communities or habitats, which are naturally subject to diachronic spatial fluctuations, owing to the natural instability of sedimentary coastal environments, and of following their dynamics over time (Acosta et al., 2005; Balduzzi, Bozzano, Corradi, Mariotti, & Vagge, 2006; Bertacchi & Lombardi, 2014; Curr, Koh, Edwards, Williams, & Davies, 2000; Höfle & Rutzinger, 2011; Malavasi, Santoro, Cutini, Acosta, & Carranza, 2013). Thus, the data obtained and the map created provide a detailed contribution to the distribution of dune vegetation of the Park S. Rossore Migliarino Massaciuccoli and paint a fairly accurate picture of the vegetational landscape.

The digital version of this map, produced in MapInfo®, is in use at the Laboratory of Geobotany and Applied Botany, D.A.F.E, University of Pisa and will soon be available at the Migliarino San Rossore Regional Park. This work also represents a new contribution to the mapping of large-scale linear environments such as coastal areas, with a view to unifying the map surveys related to the Italian coast, and could provide a valuable tool for managing the entire coastline.

Software

The map was produced using MapInfo 10.5®. The final map layout was undertaken using CorelDraw X3 13.0®. The topographic layer is from the Tuscany Regional Geo-referenced data (GEOSCOPIO, <http://www502.regione.toscana.it/geoscopio/cartoteca.html>), using Gauss-Boaga plane coordinates – Roma 1940 [EPSG 3003]: Technical Map 1:10,000 – Sheets n° 260150, 260160, 272040, 272080, 272120, 272160, 283040. The orthophotographic layer is from WMS Geoscope Service of the Tuscany Region (Ortophotos 1:2000, year 2013; Ortophotos 1:10,000, year 1954) (<http://www502.regione.toscana.it/geoscopio/ortofoto.html>).

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Disclosure statement

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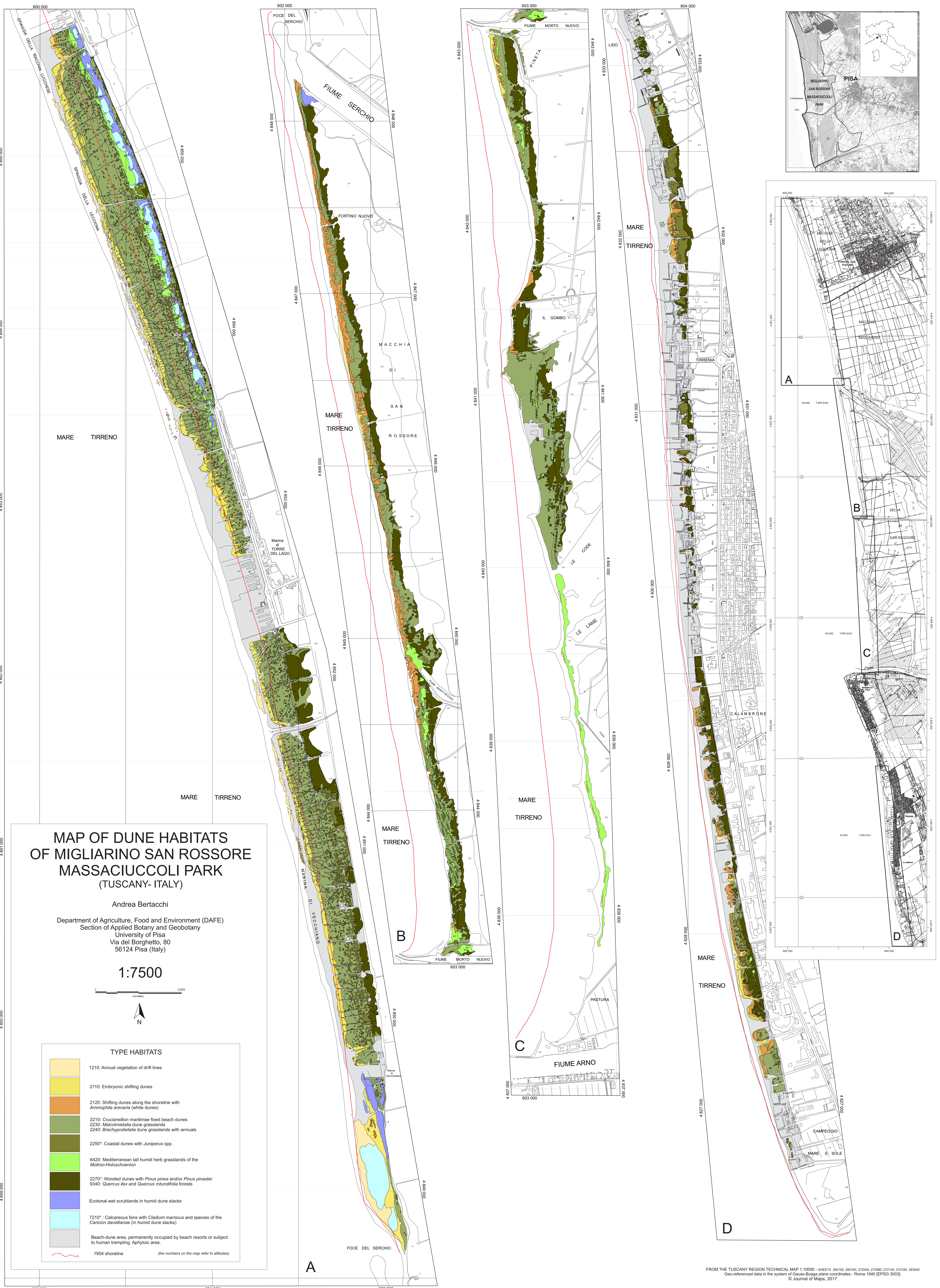
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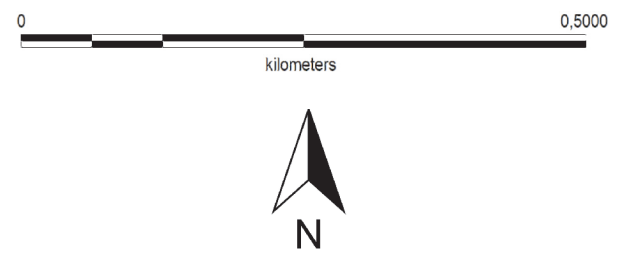


MAP OF DUNE HABITATS OF MIGLIARINO SAN ROSSORE MASSACIUCCOLI PARK (TUSCANY- ITALY)

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TYPE HABITATS	
	1210: Annual vegetation of drift lines
	2110: Embryonic shifting dunes
	2120: Shifting dunes along the shoreline with <i>Ammophila arenaria</i> (white dunes)
	2210: <i>Crucianellion maritimae</i> fixed beach dunes
	2230: <i>Malcolmietalia</i> dune grasslands
	2240: <i>Brachypodietalia</i> dune grasslands with annuals
	2250*: Coastal dunes with <i>Juniperus</i> spp.
	6420: Mediterranean tall humid herb grasslands of the <i>Molinio-Holcussetum</i>
	2270*: Wooded dunes with <i>Pinus pinea</i> and/or <i>Pinus pinaster</i>
	9340: <i>Quercus ilex</i> and <i>Quercus rotundifolia</i> forests
	Ecotonal wet scrublands in humid dune slacks
	7210*: Calcareous fens with <i>Cladium mariscus</i> and species of the <i>Caricion davallianae</i> (in humid dune slacks)
	Beach-dune area, permanently occupied by beach resorts or subject to human trampling, Aphytoic area.
	1954 shoreline (the numbers on the map refer to altitudes)

