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Ecosystem classification for EU habitat distribution assessment in sandy coastal environments: An application in central Italy

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Abstract Many recent developments in coastal science have gone against the demands of European Union legislation. Coastal dune systems which cover small areas of the earth can host a high level of biodiversity. However, human pressure on coastal zones around the world has increased dramatically in the last 50 years. In addition to direct habitat loss, the rapid extinction of many species that are unique to these systems can be attributed to landscape deterioration through the lack of appropriate management. In this paper, we propose to use of an ecosystem classification technique that integrates potential natural vegetation distribution as a reference framework for coastal dune EU Habitats (92/43) distribution analysis and assessment. As an example, the present study analyses the EU Habitats distribution within a hierarchical ecosystem classification of the coastal dune systems of central Italy. In total, 24 land elements belonging to 8 land units, 5 land facets, 2 land systems and 2 land regions were identified for the coastal dunes of central Italy, based on diagnostic land attributes. In central Italy, coastal dune environments including all the beach area, mobile dunes and all the fixed-dune land elements contain or could potentially hold at least one EU habitat of interest. Almost all dune slack transitions present the potentiality for the spontaneous development of EU woodlands of interest. The precise information concerning these ecosystems distribution and ecological relationships that this method produces, makes it very effective in Natura 2000 European network assessment. This hierarchical ecosystem classification method facilitates the identification of areas to be surveyed and eventually bound, under the implementation of EU Habitat directive (92/43) including areas with highly disturbed coastal dune ecosystems.

Keywords Coastal dune vegetation · Land classification · EU habitat of interest · Natura 2000 network

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Introduction

Many recent developments in estuarine and coastal science have gone against the demands of European Union legislation. The "habitats" directive 92/43/EEC

of the European Union is at present one of the world's most effective legal instruments concerning biodiversity and nature conservation (Wätzold and Schwerdtner 2004; Lee et al. 2002; Müncher et al. 2004). The directive aims at creating a coherent network under the name of Natura 2000, to protect the unique natural European heritage. The national lists of proposed sites of community interest (pSCI) for Natura 2000 already contain approximately 10,000 sites, covering about 12% of the total land cover of the European Union (cf. European Commission 2001).

Coastal dune systems, which cover relatively small areas, can however host a high level of biodiversity compared with other natural ecosystems. Furthermore, sandy seashores show an extremely specialized flora and fauna that include very few species which are also present in the flora of other terrestrial ecosystems (Kutiel et al. 2000). Dune systems are usually narrow, long and run along the coastline. Despite this narrow width, a complex sea-to-inland environmental gradient develops along this strip. According to this gradient structurally and floristically different vegetation types develop. 17 habitat types in annex I of the 92/43/EEC directive describe the important environmental heterogeneity of coastal sand dune habitats in Europe (European Commission 2003). However human pressure on coastal zones around the world has increased dramatically in the last 50 years and this phenomenon is particularly striking in the Mediterranean (Curr et al. 2000). Although Italian coastal dune system remained relatively well preserved from the morphological, hydrological and naturalistic standpoint until the nineteenth century (Garbari 1984), from the twentieth centuries a strong intensification of human activity that included cattle grazing, farming and tourism (including building up and trampling) has been registered. Coast-bound tourism, in particular, became a mass phenomenon after World War II and is now considered the principal cause of degradation of coastal dunes (Acosta et al. 2000). In addition to direct habitat loss, the rapid extinction of many species which are unique to these systems can be attributed to landscape deterioration through the lack of appropriate management (Andersen 1995; Kutiel et al. 2000; Shanmugam et al. 2003). Therefore what is needed is a landscape classification scheme that provides ecologically meaningful units for quantifying different aspects of landscape degradation. This should then be correlated to environmental and anthropic processes. In the last decade, due to this increased interest in environmental management and biodiversity conservation of degraded habitats, hierarchical ecosystem classification has become object of renewed attention, from a theoretical viewpoint and also in case-specific applications (Klijn and Udo de Haes 1994; Zonneveld 1995; Bailey 1996; Matson and Power 1996; Bredenkamp et al. 1998; Pressey et al. 2000; Acosta et al. 2005a).

Most hierarchical landscape classifications rely on concept of ecosystem as 'a volume of land and air plus organic content extended aerially over a particular part of the Earth's surface for a certain time (Rowe 1961). In this view, the whole Earth can be conceived as a unified functional ecosystem, which can be categorized into similar or dissimilar ecosystems at progressively smaller ecological scales. This enables to create a hierarchical framework, in which the pattern and function of ecosystems at each level depend on both the potentiality of lower levels and the constraints imposed by higher levels (O'Neill et al. 1989). The recognition of such a hierarchy of nested ecosystems provides a rational base for many-scaled problems in the fields of nature conservation and sustainable development (Rowe 1996).

Within this context Blasi et al. (2000) proposed a classification system for describing and mapping Italian landscapes at different scales. Blasi's approach successfully integrates environmental frame information with different levels of ecosystem description and, in particular, incorporates the concept of potential natural vegetation (PNV; Tüxen 1956). According to Westhoff and van der Maarel (1973), the PNV express the spontaneous natural development of the environment and can be defined as "the vegetation that would finally develop in a given habitat if all human influences on the site and its immediate surroundings would stop at once". Ricotta et al. (2000, 2002) suggested using PNV distribution as a reference framework for landscape structure and function assessment. Following this, Acosta et al. (2003) applied the PNV concept for the assessment of the state of conservation of coastal dune ecosystems in central Italy.

In this paper, we propose to use an ecosystem classification approach that integrates PNV for coastal dune EU Habitats (92/43) distribution analysis and assessment. As an application the present study analyses the EU Habitats distribution within a hierarchical ecosystem classification of the coastal dune systems of central Italy.

Study area

The present study regards a coastal area extending for over 400 km in central Italy, 250 km along the Tyrrhenian Sea (Lazio Region) and 150 km along the Adriatic Sea (Molise and Abruzzo Regions). These coasts are mainly composed of sandy beaches, although some small rocky promontories and river outlets can be found. Recent dunes (Holocene) generally occupy a narrow strip along the seashore. They are not very high and are relatively simple in structure. In natural conditions, vegetation zonation follows the sea-to-inland ecological gradient, ranging from annual communities on the strandline zone of the beach to Mediterranean macchia on the inland stabilized dunes (Acosta et al. 2003, 2005b; Stanisci et al. 2004). Land cover mapping of coastal dune ecosystems is a difficult task because of the fragmentation of communities. Acosta et al. (2005b) found a good correspondence between land cover classes and vegetation types in Molise. For a detailed description of plant communities inside the study area see Acosta et al. (2001, 2003, 2005b), Pirone et al. (2001) and Stanisci et al. (2004). On the Tyrrhenian coast, the study area is characterized by Mediterranean climate while on the Adriatic coast both Mediterranean and Temperate climatic regimes are present (Biondi and Baldoni 1994). Although both coasts differ in climate, they present similar land uses. Several potential hazards threaten coastal ecosystems. Extensive human activities in littoral areas are widespread and the factors causing disturbance are of a various nature. In fact, from the twentieth century onwards a strong intensification of human activities has been registered. This includes cattle grazing, farming, tourism, road construction and expansion, reforestation and agriculture. While agriculture, forestation and building activities have eliminated many tracts of internal vegetation zonation (Pirone 1997), beach and embryo-dune coenoses are endangered because of coastal erosion, a widespread process affecting extensive areas of Central Italy (Iannantuono et al. 2004; Gruppo Nazionale per la Ricerca sull'Ambiente Costiero 2006). Despite this process of degradation, the Lazio Region reduced its natural and seminatural coastal dune extension to 24% of its potential distribution. However, only 12% of Abruzzo and 46% of Molise coastal systems present well preserved conditions (Pietrobelli and Bardi 1997; Stanisci et al. 2004).

Still, in the study area, it is possible to observe some of the last remaining strips of psammofilous coastal vegetation and coastal macchia of the Central Adriatic and Tyrrhenian coast. Many of these well preserved coastal tracts are included in the Natura 2000 European network as pSCI (CE 43/92). Currently, 15 pSCI (proposed sites of community interest) which include coastal dune EU directive 92/43 Habitat types have been proposed for the study area, 9 in Lazio, 3 in Abruzzo and 3 in Molise.

Materials and methods

The beach dune ecosystems of central Italy were classified following the Blasi et al. (2000) approach, which we adapted to describe coastal vegetation (Acosta et al. 2003). This method used an intuitive, divisive approach based on available data merely using a map overlay methodology. For a detailed description of the adopted hierarchical ecosystem classification method and its general theoretical framework see Blasi et al. 2000. The Blasi's hierarchical framework from a higher to lower level of abstraction, comprises: land regions (LR), land systems (LS), land facets (LF), land units (LU) and land elements (LE). Land regions are defined at broad ecological scales >250.000. They are determined by macroclimatic features. This is because macroclimate is the main factor which influences landform processes as well as vegetation and soil distribution at smaller scales (Rivas Martínez 1996; Gavilàn and Fernandez-Gonzalez 1997). Furthermore, macroclimate is the relevant land attribute for classifying coastal dune system at broad scales (Westhoff and Shouten 1979). Within land regions, land systems are delimited according to significant lithological differences. Land facets are separated at intermediate scales, and delimited according to the lithomorphology features and local bioclimatic types (rainfall and temperature regimes). According to the Blasi et al. (2000) proposal, land units (LU) are defined at a detailed scale. A land unit is determined by a major vegetation series that evolve in one consequent PNV type. Nevertheless in psamophilous coastal vegetation at this scale it is not possible to identify a single association, although major coastal phyto-toposequenza (geosigmeta) could be recognized. For this reason, in this study the LU description is based on coastal

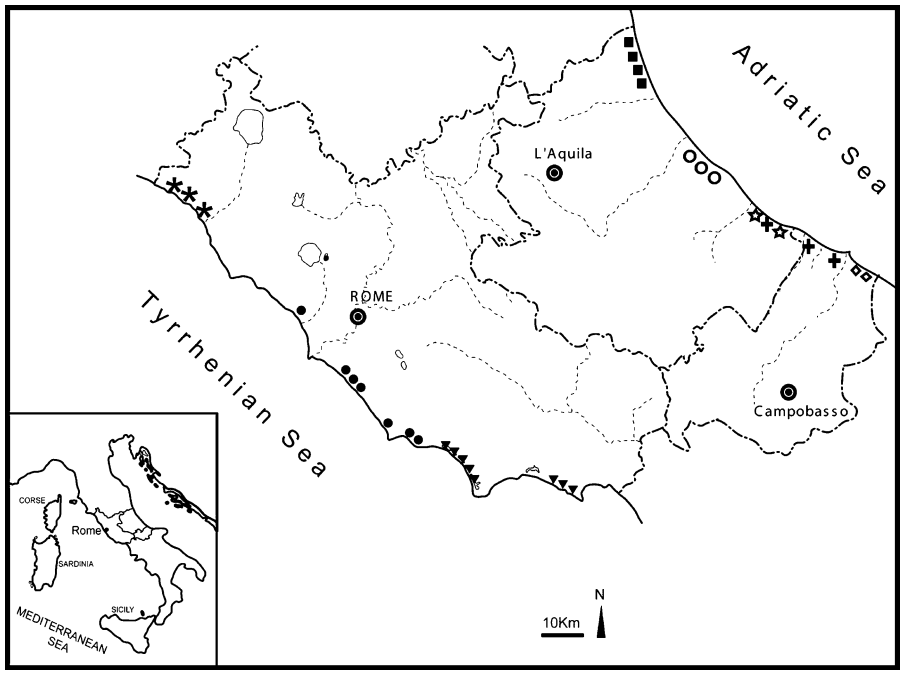

Fig. 1 Location of major coastal dunes in Lazio, Abruzzo and Molise Regions. For a detailed description of the different land units (LU) see Table 2. *Asterisks* LU-1.1.1.1.; *dark shaded circles* LU-1.1.2.1.; *empty circles* LU-1.1.2.2.; *dark shaded triangles* LU-1.1.3.1.; *cross* LU-1.1.4.1.; *empty star* LU-1.1.4.2.; *rhomboid* LU-1.1.4.3; *dark shaded squares* 2.1.1.1

dune geosigmeta determined by the assemblage of different plant communities along a complex gradient. At even smaller scales it is possible to identify plant communities (associations) along the dune morphology, defining land elements (LE). It is observed that in most cases the coastal substrate deviates from more inland ones (Olson and van der Maarel 1989).

In the study area, recent dunes can be found in contact with ancient dunes and coastal plains with heterogeneous lithology (belonging to different LS) in dune slacks. Since environmental conditions of the transition area could influence the inner part of the coastal zonation, at LE level the classification scheme considers not only plant communities along the dune morphology but also information regarding the contact area (inland LS).

In particular land regions, systems, facets and units of central Italy coastal dunes were obtained by integrating the information derived from ancillary thematic maps, such as phytoclimatic maps (Blasi 1994, 2003; Paura 1996; scale 1:250000), a litostratigraphic map (Bigi et al. 1988) and geologic maps (1:25:000) produced by the Italian Geologic service. Since information was quite easy to handle, the maps were digitalized as GIS data vector layers in ArcView 3.2 (ESRI 2000). Information concerning the land elements distribution (potential coastal vegetation–zonation) was derived from detailed dune morphology field observations and original phytosociological relevés and from previous phytosociological studies, in which the proposals of coastal sand dune PNV had already been described (Pirone 1983, 1997; Géhu et al. 1984; Taffetani and Biondi 1989; Stanisci and Conti 1990; Biondi 1999; Acosta et al. 2001; Pirone et al. 2001; Blasi et al. 2002; Iannantuono et al. 2004; Stanisci et al. 2004).

To analyze the EU directive habitat distribution within the hierarchical ecosystem classification we integrate European and national documents (European Commission 2003; APAT 2005; Petrella et al. 2005) that describe them with the most recent Italian sinphytosociological revision of coastal dune vegetation (Biondi 1999).

Results and discussion

The Central Italy coastal dune ecological heterogeneity is expressed in a high number of environmental units. Overall 24 land elements belonging to 8 land units, 5 land facets, 2 land systems and 2 land regions were recognized, based on diagnostic land attributes (Fig. 1). Each land unit is a complex of different plant

Table 1 Land regions (L.R.), systems (L.S.), facets (L.F.), units (L.U.) and elements (L.E.) found in central Italian coastal dune environments

L. R.	L. S.	L. F.	L. U.	L. E.
1. Mediterranean	1.1.Coastal sand dunes	1.1.1. Recent coastal dunes under meso-Mediterranean dry-subhumid climate	1.1.1.1. Coastal dune vegetation zonation in contact with alluvial deposits	1.1.1.1.1. Beaches and mobile dunes 1.1.1.1.2. Fixed dunes 1.1.1.1.3. Dune slacks transition to alluvial deposits
		1.1.2. Recent coastal dunes under meso-Mediterranean subhumid climate	1.1.2.1. Coastal dune vegetation zonation in contact with ancient dune deposits	1.1.2.1.1. Beaches and mobile dunes 1.1.2.1.2. Fixed dunes 1.1.2.1.3. Dune slacks transition
			1.1.2.2. Coastal dune vegetation zonation in contact with fine bright Pleistocenic sands	1.1.2.2.1. Beaches and mobile dunes 1.1.2.2.1. Fixed dunes 1.1.2.2.2. Dune slacks transition
		1.1.3. Recent coastal dunes under termo-Mediterranean subhumid climate	1.1.3.1. Coastal dune vegetation zonation in contact with lacustrine deposits and coastal lakes	1.1.3.1. 1.Beaches and mobile dunes 1.1.3.1.2. Fixed dunes 1.1.3.1.3. Dune slacks transition
		1.1.4. Recent coastal dunes under meso-Mediterranean dry climate	1.1.4.1.Coastal dune vegetation zonation in contact with fine sand and clay alluvial deposits	1.1.4.1.1. Beaches and mobile dunes 1.1.4.1.2. Fixed dunes 1.1.4.1.3. Dune slacks transition
			1.1.4.2.Coastal dune vegetation zonation in contact with conglomeratic gravel deposits	1.1.4.2.1. Beaches and mobile dunes 1.1.4.2.2. Fixed dunes 1.1.4.2.3. Dune slacks transition
			1.1.4.3. Coastal dune vegetation zonation in contact with ancient dunes	1.1.4.3.1. Beaches and mobile dunes 1.1.4.3.2. Fixed dunes 1.1.4.3.3. Dune slacks transition
2. Temperate	2.1.Coastal sand dunes	2.1.1. Recent coastal dunes under meso-temperate subhumid climate	2.1.1.1. Coastal dune vegetation zonation in contact with Pleistocenic bright sands	2.1.1.1.1. Beaches and mobile dunes 2.1.1.1.2. Fixed dunes 2.1.1.1.3. Dune slacks transition

Table 2 Potential natural vegetation types that characterize coastal dune seashore-inland ecosystem zonation in central Italy

		Beaches and mobile dunes								Fixed dunes								Dune slacks transition							
	Land facets	1.1.1	1.1.2		1.1.3	1.1.4			2.1.1	1.1.1	1.1.2		1.1.3	1.1.4			2.1.1	1.1.1	1.1.2		1.1.3	1.1.4			2.1.1
	Land Elements	1.1.1.1.1	1.1.2.1.1	1.1.2.2.1	1.1.3.1.1	1.1.4.1.1	1.1.4.2.1	1.1.4.3.1	2.1.1.1.1	1.1.1.1.2	1.1.2.1.2	1.1.2.2.2	1.1.3.1.2	1.1.4.1.2	1.1.4.2.2	1.1.4.3.2	2.1.1.1.2	1.1.1.1.3	1.1.2.1-3	1.1.2.2.3	1.1.3.1.3	1.1.4.1.3	1.1.4.2.3	1.1.4.3.3	2.1.1.1.3
	PNV classes																								
Annual and perennial grass vegetation	*Salsolo-Cakiletum maritimae*	•	•	•	•	•	•	•	•																
	Echinophoro spinosae-Elytrigietum juncei/Sporoboletum arenarii	•	•	•	•	•	•	•	•																
	Echinophoro-Ammophiletum australis	•	•	•	•	•	•	•	•																
Annual grass, chamephytic nanophanerophytic and phanerophytic vegetation	*Loto-Crucianelletum maritimae*									•	•		•												
	Sileno coloratae-Vulpietum membranaceae									•	•	•	•	•	•	•	•								
	Eriantho-Schoenetum nigricantis and other communities of the *Juncetalia maritimae*										•	•	•	•	•	•	•								
	Sileno coloratae-Ononidetum variegatae									•	•		•	•	•	•	•								
	Asparago-Juniperetum macrocarpae									•	•		•	•		•									
	Phyllireo angustifoliae-Juniperetum turbinatae										•		•												
	Pistacio-Rhamnetum									•	•		•	•	•	•									
Phanerophytic vegetation	*Cyclamino hederifolii-Quercetum ilicis* temophilous variant																	•	•	•		•		•	
	Cyclamino hederifolii-Quercetum ilicis mesophilous variant																				•		•		•
	Roso-Quercetum pubescentis																					•			
Contact Land System																		**Alluvial deposits**	**Ancient dune**	**Bright plesitocenic sand**	**Lacustrine deposits with coastal lakes**	**Clay and sand alluvial deposits**	**Conglomeratic gravel deposits**	**Ancient dune**	**Brighe pleistocenic sand**

Dots indicate the presence of the different plant communities inside each land element

Table 3 Correspondences between EU directive habitats and land elements in terms of PNV classes present in the study area

EU habitat type	Land elements
Sea dunes	
2210 *Crucianellion maritimae* fixed beach dunes	*Loto-Crucianelletum maritimae*
2220 Dunes with *Euohorbia terracina*	*Sileno coloratae-Vulpietum membranaceae*
2230 *Malcomietalia* dune grasslands (*Malcolmia ramosissima*)	*Sileno coloratae-Ononidetum variegatae*
*2250 Coastal dune with *Juniperus* sp. (*J. macrocarpa* e *turbinata*)	*Asparago-Juniperetum macrocarpae* and *Phyllireo angustifoliae-Juniperetum turbinatae*
2260 *Cisto-Lavanduletea* dune sclerophyllous scrubs	*Pistacio-Rhamnetum*
*2270 Wooded dunes with *Pinus pinea* and/or *Pinus pinaster* (*P. pinaster*, *pinea*, *halepensis*)	
2110 Embryonic shifting dunes	*Echinophoro spinosae-Elytrigietum juncei*/*Sporoboletum arenarii*
2120 Shifting dunes along the shoreline with *Ammophila arenaria*	*Echinophoro-Ammophiletum australis*
Coastal and halophytic habitats	
1210 Annual vegetation on drift lines (*Cakilitea maritimae*)	*Salsolo-Cakiletum maritimae*
1410 Mediterranean salt meadows (*Juncetalia maritimae*)	*Eriantho-Schoenetum nigricantis* and other communities of the *Juncetalia maritimae*
Mediterranean sclerophyllous forests:	
9340 *Quercus ilex* and *Q. rotundifolia* forests	*Cyclamino hederifolii-Quercetum ilicis*

communities within seashore-inland zonation. These plant community sequences are characterized by a structural gradient (different life forms related to different plant communities), ranging from the most pioneer annual communities on the beach, to different woods in the sheltered zone. In order to show the land classification structure and the environmental variability of the study area, the land units are briefly described in Table 1 and the land elements in terms of PNV classes are summarized in Table 2.

Coastal dune vegetation is usually recognized as azonal, a fact evidenced by precedent Mediterranean synchorology maps. In fact it has been shown that many coastal associations have a wide geographical distribution (Géhu et al. 1989). Our study confirmed this as the five land facets (characterized by different bioclimatic regimes) have similar beach dune plant communities (Table 2). Conversely, climatic macchia, evergreen woods and deciduous forests that develop in the foredune are characterized by floristic and coenological features related to local climatic morphologic and lithologic features.

In central Italy, changes in the coastal dune environment along a compressed sea-inland gradient has led to the possible development of 11 EU habitats of interest (EU 43/92). Table 3, shows the correspondences between the EU directive habitat and the land elements present in the study area. Note that all the beach and mobile dunes and all the fixed-dune land elements contain or could potentially hold at least one EU habitat of interest. In addition, almost all dune slack transitions could potentiality develop EU woodlands of interest.

Conclusions

The ecosystem classification approach applied in the present work, fulfils the requirements of policy making and environmental assessment, providing descriptive units with different potential applications, according to the scale of problems under investigation and the desired accuracy of the results. Land systems and facets can be effectively used from national down to regional level. Land units and elements are more suitable for the evaluation of environmental quality and impacts, and for land management at local scales. This approach could be essential for conservation policy efficacy assessment, because it constitutes a clear and easy applicable monitoring instrument that allows the planners to evaluate if an action works or not, or how a given action is effective in achieving a given objective. Furthermore, the precise information concerning the ecosystem distribution and ecological relationships that can be obtained from this method make it very effective in Natura 2000 European network assessment. Indeed, this hierarchical ecosys-

tem classification method facilitates the identification of areas to be surveyed and eventually bound, under the implementation of the EU Habitat directive (92/43). This includes highly disturbed coastal dune ecosystems.

The inclusion of PNV in the land classification scheme is specially important in land planning and management in Europe where plant sociology is largely employed. The proposed approach seems to be quite effective in dealing with coastal dune monitoring and conservation status evaluation. In this way, land elements could be used as a reference model to analyze the influence of anthropogenic changes such us landscape transformation or the introduction and naturalization of exotic species. In other words, based on PNV distribution, it is possible to establish sites of scientific interest where no floristic or faunistic priority presently occurs, but where potential for spontaneous restoration of such characteristics exists.

With this in mind, we hope that several case studies will be carried out in the near future to adequately test and refine this approach. Moreover, further efforts must be made in order to provide ecological information for increasingly larger coastal areas which contain many endangered habitats and where a uniform conservation and monitoring methodology has yet to be established.

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References

Acosta, A., Blasi, C., Esposito, S., & Stanisci, A. (2001). Analisi della vegetazione delle dune costiere del Lazio Centro-meridionale. *Informatore Botanico Italiano, 32*(1), 5–10.

Acosta, A., Blasi, C., & Stanisci, A. (2000). Spatial connectivity and boundary patterns in coastal dune vegetation in the Circeo National Park, Central Italy. *Journal of Vegetation Science, 11*, 149–154.

Acosta, A., Carranza, M. L., & Giancola, M. (2005a). Landscape change and ecosystem classification in a municipal district of a small city (Isernia, Central Italy). *Environmental Monitoring and Assessment, 108*(1–3), 323–335.

Acosta, A., Carranza, M. L., & Izzi, C. F. (2005b). Combining land cover mapping with coastal dune vegetation analyses. *Applied Vegetation Science, 8*, 133–138.

Acosta, A., Stanisci, A., Ercole, S., & Blasi, C. (2003). Sandy coastal landscape of the Lazio region (central Italy). *Phytocoenologia, 33*(4), 715–726.

Andersen, U. V. (1995). Resistance of Danish coastal vegetation types to human trampling. *Biological Conservation, 71*, 223–230.

APAT (2005). La realizzazione in Italia del progetto europeo Corine Land Cover 2000. Agenzia per la protezione dell'ambiente e per i servizi tecnici Rapporti 36/2005.

Bailey, R. G. (1996). *Ecosystem geography*. New York: Springer.

Bigi, G., Cosentino, D., & Parlotto, M. (1988). *Modello litostratigrafico-strutturale della Regione Lazio. Scala 1:250000*. Regione Lazio-Università degli Studi di Roma "La Sapienza", Rome.

Biondi, E. (1999). Diversità fitocenotica degli ambienti costieri italiani. *Bollettino del Museo Civico di Scienze Naturali di Venezia, 49*, 39–105.

Biondi, E., & Baldoni, M. (1994). The climate and vegetation of peninsular Italy. *Colloques Phitosociologiques, 23*, 675–721.

Blasi, C. (1994). Fitoclimatologia del Lazio. *Fitosociologia, 27*, 151–175.

Blasi, C. (2003). Bioclimate of Italy. In C. Blasi (Ed.), *Ecological information in Italy* (pp. 11–12). Rome, Italy: Ministero dell'Ambiente e della Tutela del territorio-Società Botanica Italiana.

Blasi, C., Carranza, M. L., Frondoni, R., & Rosati, L. (2000). Ecosystem classification and mapping: A proposal for Italian landscapes. *Applied Vegetation Science, 3*, 233–242.

Blasi, C., Filesi, L., Stanisci, A., Frondoni, R., Di Pietro, R., & Carranza, M. L. (2002). Excursion to the Circeo National Park (Lazio, Central Italy). *Fitosociologia, 39*(Suppl. 3), 91–130.

Bredenkamp, G., Chytrý, M., Fischer, H. S., Neuhäuslova, Z., & van der Maarel, E. (1998). Vegetation mapping: Theory, methods and case studies. *Applied Vegetation Science, 1*, 162–164.

Curr, R. H. F., Koh, A., Edwards, E., Williams, A. T., & Daves, P. (2000). Assessing anthropogenic impact on Mediterranean sand dunes from aerial digital photography. *Journal of Coastal Conservation, 6*, 15–22.

ESRI (2000). Arc-View 3.2. California, USA.

European Commission (2001). The Natura 2000 Barometer. Available from: http://www.eu.int/comm/ environment/ nature.

European Commission DG Environment (2003). Natura 2000. Interpretation manual of European Union Habitats EUR25. 127 pp. Available from: http://europa.eu.int/.

Garbari, F. (1984). Aspetti della vegetazione e della flora delle nostre coste marine. *Agricoltura e Ambiente, 23*, 45–48.

Gavilàn, R., & Fernandez-Gonzalez, F. (1997). Climatic discrimination of Mediterranean broad-leaved sclerophyllous and deciduous forests in central Spain. *Journal of Vegetation Science, 8*(3), 377–386.

Géhu, J. M., Biondi, E., Costa, M., & Géhu-Franck, J. (1989). Eléments de cartographie synchorologique pour une expression synthetique de la géosynvicanriance et du synéndemisme des associations végétales littorales du pourtour méditerranéen dans un souci d'évaluation de l'originalité et de la conservation du patrimoine biosyngénétique. *Colloques Phytosociologiques, 19*, 45–54.

Géhu, J. M., Costa, M., Scoppola, A., Biondi, E., Marchiori, S., Peris, J. B., et al. (1984). Essay synsystèmatique et synchorologique sur les vègetations littorales italiennes dans un but conservatoire. Documents. *Phytosociologiques, 8*, 393–474.

Gruppo Nazionale per la Ricerca sull'Ambiente Costiero (2006). *Lo stato dei litorali italiani.* Studi costieri no. 10 (p. 174). Firenze: Nuova Grafica Fiorentina.

Iannantuono, E., Rosskopf, C. M., Stanisci, A., Acosta, A., & Aucelli, P. P. C. (2004). Effetti della dinamica costiera sull'evoluzione dei sistemi dunali presenti lungo la costa molisana (Italia meridionale). *Atti Accademia Nazionale dei Lincei-Roma, 205*, 321–331.

Klijn, F., & Udo de Haes, H. A. (1994). A hierarchical approach to ecosystems and its implications for ecological land classification. *Landscape Ecology, 9*, 89–104.

Kutiel, P., Peled, Y., & Geffen, E. (2000). The effect of removing scrub cover on annual plants and small mammals in a coastal sand dune ecosystem. *Biological Conservation, 94*, 235–242.

Lee, J. T., Bailey, N., & Thompson, S. (2002). Using geographical information systems to identify and targets sites for creation and restoration of native woodlands: A case study of Chiltern Hills, UK. *Journal of Environmental Management, 64*, 25–34.

Matson, B. E., & Power, R. G. (1996). Developing an ecological land classification for the Fundy Model Forest, south-eastern New Brunswick, Canada. *Environmental Monitoring and Assessment, 39*, 149–172.

Müncher, C. A., Bunce, R. G. H., Hennekens, S. M., & Shamineè, J. H. (2004). Mapping European Habitat to support the design and implementation of a Pan-European Network; the PEENHAB project. Wageningen, Alterra. Alterra report 952. Nederland. pp. 124.

O'Neill, R. V., Johnson, A. R. & King, A. W. (1989). A hierarchical framework for the analysis of scale. *Landscape Ecology, 3*, 193–205.

Olson, J. S., & van der Maarel, E. (1989). Coastal dunes in Europe: A global view. In F. van der Meulen, P. D. Jungerius, & J. H. Visser (Eds.), *Perspectives in coastal dune management* (pp. 3–32). The Hague, The Netherlands: SPB Academic Publishing.

Paura, B. (1996). Lineamenti fitoclimatici del Molise. *Giornale Botanico Italiano, 1*(130), 521–527.

S. Petrella, F. Bulgarini, F. Cerfolli, M. Polito, & C. Teofili (Eds.) (2005). *Libro rosso degli Habitat d'Italia*. Roma: WWF Italia, UNLUS.

Pietrobelli, M., & Bardi, S. (1997). Environmental design and coastal zone improvement. *Journal of the International Association of Environmental Design, 1*, 59–64.

Pirone, G. (1983). La vegetazione del litorale pescarese (Abruzzo). *Notiziario della Società Italiana di Fitosociologia, 18*, 37–62, Roma.

Pirone, G. (1997). La vegetazione del litorale di Martinsicuro nel contesto dell'ambiente costiero dell'Abruzzo: Aspetti e problemi. In L. Adamoli, D. Febbo, & G. Pirone (Eds.), *Le dune di Martinsicuro nel sistema costiero dell'Abbruzzo. Comune di Martinsicuro*. Italia: Edigrafital Teramo.

Pirone, G., Corbetta, F., Frattaroli, A. R., & Ciaschetti, G. (2001). Aspetti della vegetazione costiera dell'Abruzzo. *Biogeographia, 22*, 169–191.

Pressey, R. L., Hager, T. C., Ryan, K. M., Schwarz, J.,Wall, S., Ferrier, S., et al. (2000). Using abiotic data for conservation assessments over extensive regions: Quantitative methods applied across New South Wales, Australia. *Biological Conservation, 96*(1), 55–82.

Ricotta, C., Carranza, M. L., Avena, G., & Blasi, C. (2000). Quantifying the deviation of landscape diversity from potential natural vegetation with Shannon's entropy. *Applied Vegetation Science, 3*, 157–162.

Ricotta, C., Carranza, M. L., Avena, G. C., & Blasi, C. (2002). Are potential natural vegetation maps a meaningful alternative to neutral landscape models? *Applied Vegetation Science, 5*(2), 271–275.

Rivas Martínez, S. (1996). Clasificación bioclimática de la tierra. *Folia Botanica Madrilense, 16*, 1–32.

Rowe, J. S. (1961). The level-of-integration concept and ecology. *Ecology, 42*, 420–427.

Rowe, J. S. (1996). Land classification and ecosystem classification. *Environmental Monitoring and Assessment, 39*, 11–20.

Shanmugam, S., Lucas, N., Phipps, P., Richards, A., & Bansley, M. (2003). Assessment of remote sensing techniques for habitat mapping in coastal dune ecosystems. *Journal of Coastal Research, 19*(1), 64–75.

Stanisci, A., Acosta, A., Ercole, S., & Blasi, C. (2004). Plant communities on coastal dunes in Lazio. Italy. *Annali di Botanica (Roma) 4*, 115–128.

Stanisci, A., & Conti, F. (1990). Aspetti vegetazionali di un settore costiero molisano-abruzzese. *Annali di Botanica (Roma), 48*(7), 85–93.

Taffetani, F., & Biondi, E. (1989). La vegetazione del litorale molisano e pugliese tra le foci dei fiumi Biferno e Fortore (Adriatico Centro-meridionale). *Colloques Phytosociologiques, 18*, 323–350.

Tüxen, R. (1956). Die heutige potentielle natürlche Vegetation als Gegenstand der Vegetationskartierung. *Angewandte Pflanzensoziologie (Stolzenau), 13*, 5–42.

Wätzold, F., & Schwerdtner, K. (2004). Why be wasteful when preserving a valuable resource? A review article on cost-effectiveness of European biodiversity conservation policy. *Conservation Biology, 123*, 327–338.

Westhoff, V., & Shouten, M. G. C. (1979). The diversity of European coastal ecosystems. In: R. L. Jefferies & A. J. Davy (Eds.), *Ecological processes ion coastal environments* (pp. 1–21). Oxford: Blackwell.

Westhoff, V., & van der Maarel, E. (1973). The Braun–Blanquet approach. In R. H. Whittaker (Ed.), *Ordination and classification of communities. Handbook of vegetation science* (vol. 5, pp. 617–726). The Hague: Junk.

Zonneveld, I. S. (1995). *Land ecology: An introduction to landscape ecology as a base for land evaluation, land management and conservation*. Amsterdam: SPB Academic Publishing.