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EU habitats monitoring along the coastal dunes of the LTER sites of Abruzzo and Molise (Italy)

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Abstract

The Italian LTER network is an integrated and shared system for ecosystem monitoring (Long Term Ecological Research-Italy). The research sites of Abruzzo and Molise are part of the LTER site 20 " Coastal sand dunes in central Italy" (www.lteritalia.it) and include 5 S.C.I. along the central Italy Adriatic coastline. The paper aims to carry out a short review of the main results recently achieved through the dune vegetation monitoring in these LTER sites and proposes a synthesis on the species composition (focal and alien species occurrence) and the spatial distribution of dune EU habitats. We recorded 17 EU dune habitats, 4 of them are priority habitats (2250*, 2270*, 3170*, 1510*). Results suggest that many EU habitats are still locally widespread, with the exception of wet slacks and evergreen woods, occurring only in residual small patches. Moreover all EU habitats host several invasive alien species and only in salt marshes they are almost absent, because of the occurrence of extreme salinity. This natural heritage is therefore vulnerable and further efforts should be made to reduce the impacts of human pressure, through increased awareness of environmental issues and the education on ecosystem services provided by the natural landscape of coastal dunes.

Key words: coastal dune, EU habitats, species composition, alien species, spatial distribution.

Introduction

The Italian LTER network is an integrated and shared system for ecosystem monitoring (Long Term Ecological Research-Italy), which joined the LTER-Europe Network in 2007, including more than 300 research sites. These sites provide ecological data and information on long-term trends of terrestrial, freshwater and marine ecosystem quality at the European scale, working for the harmonization of survey protocols of bio-ecological data, allowing an effective data comparison across Europe, improving cooperation and synergy between/amongst different actors, interest groups, networks, etc., and providing education, exchange of know-how, communication and institutional integration (Bertoni, 2012; Stoll *et al*. 2014).

The research sites of Abruzzo and Molise are part of the LTER site 20 " Coastal sand dunes in central Italy" (www.lteritalia.it) which include 6 S.C.I. along the central Italy coastline and comprise highly fragile ecosystems as several threats affect them, mainly due to direct or indirect human pressure.

As around the other Mediterranean coasts, also along Italian Adriatic coastline, human activities in coastal areas have intensified over the course of the twentieth century (Feola *et al*. 2011; Romano & Zullo, 2014). Outbound tourism, the expansion of urban areas, and the spread of agriculture and afforestation activities have strongly modified coastal landscapes (Malavasi *et al*., 2013). Moreover, climatic change affects coastal areas and may be also an important driver of the vegetation composition and plant community structure (UNEP-MAP-RAC/SPA, 2010; Prisco *et al*. 2013). Indeed, in central Italy, throughout the last fifty years, the mean temperature increased by 0,8°C and precipitations lowered by 20% (Brunetti *et al*., 2006).

Along Italian Adriatic coast, several studies underlined that human pressure modifies the structure and the composition of dune plant communities in several sites causing: 1) Change in species composition (increase of ruderal and alien species), 2) Increase of community fragmentation, 3) Loss of vegetation zonation, 4) Local/regional extinction of dune habitats (Acosta *et al*. 2007, 2008, 2009; Biondi, 1999; Buffa *et al*.,2007; Carboni *et al*. 2009; Carranza *et al*., 2008; Cicarelli, 2014; Drius *et al*., 2013; Frattaroli *et al*., 2007; Géhu & Biondi, 1994; Géhu *et al*. 1984; Genovesi *et al*., 2014; La Posta *et al*. 2008; Pirone *et al*., 2001; Stanisci *et al*., 2007; Stanisci & Conti 1990; Taffetani, 2011).

This paper aims to carry out a short review of the main results recently achieved through the monitoring of dune EU habitats at the LTER sites along Italian Adriatic coastal ecosystems. Moreover, the paper proposes a synthesis of the species composition (focal and

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alien species occurrence) and the spatial distribution of dune EU habitats occurring in the study area and subjected to long term ecological monitoring.

Materials and methods

Study area

Vegetation monitoring is performed in five Sites of European Community Interest (S.C.I.) in Abruzzo and Molise regions along Adriatic coastline (Tab. 1). The four southern S.C.I. are composed by Holocene dunes in contact with alluvial terraces or pelitic-clay hills, while the northern S.C.I. is characterised by very young sand dunes, accumulated over the last century at the foot of conglomeratic cliffs (Giorgi *et al*., 1984; Iannantuono *et al*., 2004).

As concerns climate, mean yearly temperature is 15,6 °C and total rainfall amounts to 642,7 mm [Vasto (CH) -period 1974-1998; Termoli (CB) – period 1960-1990]. Thermo-types are between meso-Mediterranean and thermo-Mediterranean and ombro-types between the dry and the humid-subhumid. (Frattaroli *et al*., 2007).

Data

The identification of dune EU habitats was achieved by sampling plant communities through the phytosociological approach and a stratified random sampling on the basis of land cover map (Carranza *et al*., 2008). Recently (2005-2013) 96 phytosociological relévés and 120 plots (4x4 m) were carried out and georeferenced along the Molise and Southern Abruzzo coastline (Acosta *et al*. 2009; Del Vecchio *et al*., 2013; Frattaroli *et al*., 2007; Prisco *et al*. 2012).

The conservation status of sand dune EU habitats is investigated at plant community level and at landscape level. The first one has been evaluated through the analysis of species composition, focusing on two main ecological groups: focal species (FS) and alien species (AS). The focal species were identified and selected according to the list of diagnostic and characteristic species reported in the "Italian Interpretation Manual of the 92/43/EEC Directive habitats" (Biondi *et al*., 2007, 2009), while alien species refer to the Italian checklist (Celesti-Grapow *et al*., 2010).

Moreover, we used belt transects for the analysis of vegetation zonation along the beach-inland direction, which can be considered a further indicator of the conservation status of the whole sand dune ecosystem, as it was assessed in previous papers (Acosta *et al*., 2000; Iannantuono *et al*., 2004). We yearly perform the vegetation sampling of 4 vegetation transects. This data set is currently being processed.

At landscape level, EU habitats distribution was investigated through vegetation mapping in GIS environment at the scale 1:5.000 and the spatial composition analysis was applied (total cover area, total number of patches) (Acosta *et al*., 2009; Carranza *et al*., 2008; de Chiro *et al*. in press). Furthermore, a multitemporal analysis of Molise coastal landscape in the last fifty years was performed (Malavasi *et al*., 2013).

Results and discussion

We recorded 17 EU dune habitats in the studied area; 4 of them are priority habitats (2250*, 2270*, 3170*, 1510*) (Tab. 2).

The set of diagnostic plant species is well represented in each recorded habitat, with the exception of 1430 and 9340, which occupy small residual areas and are floristically poor.

All habitats host several invasive alien species and only in salt marshes they are almost absent, because of the occurrence of extreme salinity.

The most widespread alien species along the embryo- and foredunes are: *Ambrosia coronopifolia, Oenothera biennis, Erigeron canadensis, Cenchrus incertus, Xanthium italicum*. They are favored by human disturbance such as trampling and artificial flattening of dunes. On the fixed dunes *Acacia saligna, O. biennis, E. canadensis, Eleagnos angustifolia, Pittosporum tobira* are common. On the other hand, in back dune marsh habitats *Amorpha fruticosa, E. canadensis, E. sumatrensis, Aster squamatus, Setaria viridis* could be found.

Analyses were carried out for the evaluation of the effects of invasive alien species on the species composition and conservation status of the most invaded EU habitats in the study area, such as *Pinus* sp.pl. woods (2270*), coastal Mediterranean maquis (2250*, 2260), wet slacks (1410, 3170*) and annual grasslands (2230) (de Chiro *et al*., in press; Del Vecchio *et al*., 2013; Di Franco *et al*., 2012; Stanisci *et al*., 2010).

We investigated the effect of *Acacia saligna* on spe-

Tab. 1 - Sites of European Community Interest (S.C.I.) in Abruzzo and Molise regions along Adriatic coastline.

Abruzzo region:
S.C.I. IT7140108 "Punta Aderci-Punta della Penna"(Chieti province); lat. 42° 10' 0" N; long.14° 42' 40" E; area: 317 ha. The site is included in the Riserva Regionale Punta Aderci.
S.C.I. IT7140109 "Marina di Vasto" (Chieti province); lat. 42° 05' 10" N; long.14° 44' 25" E; area: 57 ha.
Molise region:
S.C.I. IT7228221 "Foce Trigno-Marina di Petacciato" (Campobasso province); lat. 42° 2' 32" N; long. 14° 50' 1"E; area: 747 ha.
S.C.I. IT7222216 "Foce Biferno-Litorale di Campomarino" (Campobasso province); lat.41° 57' 58" N; long.15° 2' 28" E; area: 817 ha.
S.C. I. IT7222217 "Foce Saccione-Bonifica Ramitelli" (Campobasso province); lat. 41° 55" 42' N; long.15° 5' 56" E; area: 870 ha.

Tab. 2 - Summary of the 17 coastal EU habitats (* = priority habitat) recorded in the LTER sites of Abruzzo and Molise coastline. For each habitat was reported information regarding focal species, alien species and syntaxonomical attribution. Species names have been updated according to the recent checklist of the Italian Flora (Conti et al. 2005) and syntaxa names refer to Italian EU habitats (Biondi *et al*. 2009).

Habitat	Focal species	Alien species	Syntaxonomical attribution
1210 Annual vegetation of drift lines	*Cakile maritima, Salsola kali, Chamaesyce peplis*	*Xanthium orientale* subsp. *italicum*	*Salsolo kali-Cakiletum maritimae* Costa e Manzanet 1981 nom. mut. propos. in Rivas-Martínez et al. 2002
2110 Embryonic shifting dunes	*Elymus farctus, Eryngium maritimum, Echinophora spinosa, Otanthus maritimus, Sporobolus virginicus, Cyperus capitatus*	*Xanthium orientale* subsp. *italicum, Ambrosia coronopifolia,Oenothera biennis, Erigeron canadensis*	*Echinophoro spinosae-Elymetum farct* Géhu 1987, *Sporoboletum arenarii* (Arénes 1924) Géhu & Biondi 1994
2120 Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)	*Ammophila arenaria, Eryngium maritimum, Echinophora spinosa, Euphorbia paralias, Anthemis maritima, Medicago marina, Lotus creticus*	*Xanthium orientale* subsp. *italicum, Ambrosia coronopifolia,Oenothera biennis, Erigeron canadensis*	*Echinophoro spinosae-Ammophiletum australis* (Br.-Bl. 1933) Géhu, Rivas-Martinez & R. Tx. 1972 in Géhu et al. 1984
2220 Coastal dunes grassland communities with *Euphorbia terracina*	*Euphorbia terracina, Verbascum garganicum, Artemisia campestris* subsp. *variabilis*	*Oenothera biennis, Cenchrus incertus, Ambrosia coronopifolia, Erigeron canadensis, Xanthium orientale* subsp. *italicum*	*Verbasco garganici-Euphorbietum terracinae* Biondi, Casavecchia & Biscotti 2007
2230 *Malcolmietalia* dune grasslands	*Malcolmia ramosissima, Vulpia fasciculata, Silene colorata subsp. canescens, Medicago litoralis , Ononis variegata, Pseudorlaya pumila, Cutandia maritima, Phleum arenarium, , Polycarpon diphyllum, Lophocloa pubescens.*	*Oenothera biennis, Cenchrus incertus, Ambrosia coronopifolia, Erigeron canadensis, Xanthium orientale* subsp. *italicum*	*Sileno coloratae-Vulpietum membranaceae* (Pign. 1953) Géhu & Scoppola 1984, *Sileno coloratae-Ononidetum variegatae* Géhu & Géhu-Franck 1986, *Ambrosio coronopifoliae-Lophocloetum pubescentis* Biondi, Brugiapaglia, Allegrezza & Ballelli 1992
2240 *Brachypodietalia* dune grasslands with annuals	*Trachynia distachya, Lagurus ovatus, Anchusa hybrid, Bromus gussonei.*	*Acacia saligna, Oenothera biennis Cenchrus incertus,* *Erigeron canadensis, E.sumatrensis, Xanthium orientale* subsp. *italicum*	*Trachynion distachyae* Rivas-Martinez 1978
2250* Coastal dunes with *Juniperus* spp.	*Juniperus macrocarpa, Asparagus acutifolius, Pistacia lentiscus, Phillyrea angustifolia, Prasium majus, , Lonicera implexa, Clematis flammula.*	*Acacia saligna, Erigeron canadensis, Oenothera biennis*	*Asparago acutifolii-Juniperetum macrocarpae* (R. et R. Molinier 1955) De Bolos 1962 razza tipo Géhu, Costa & Biondi 1990
2260 *Cisto-Lavanduletalia* dune sclerophyllous scrubs	*Cistus creticus, Cistus salviifolius, Erica multiflora, Rosmarinus officinalis,, Pistacia lentiscus, Halimium halimifolium, Helichrysum italicum, Rosmarinus officinalis*	*Acacia saligna, Erigeron canadensis, Oenothera biennis*	*Erico multiflorae-Halimietum* *halimifolii* Taffetani & Biondi 1989, *Cisto eriocephali-Rosmarinetum officinalis* Biondi 1999, *Helianthemo jonii-Fumanetum thymifoliae* Taffetani & Biondi 1989
2270* Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*	*Pinus pinea, P. pinaster, P. halepensis, Juniperus. macrocarpa, Asparagus acutifolius, Pistacia lentiscus, Phillyrea angustifolia, Rhamnus alaternus, Daphne gnidium, Osyris alba, Rubia peregrina, Smilax aspera, Clematis flammula*	*Acacia saligna, Eucalyptus camaldulensis, Eucaliptus globulus,Pittosporum tobira*	*Pinetalia halepensis* Biondi et al.2014
6420 Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion*	*Erianthus ravennae,Schoenus nigricans, Juncus maritimus, J. acutus*	*Erigeron canadensis, E. sumatrensis, Oenothera biennis, Amorpha fruticosa, Eleagnus angustifolia*	*Eriantho ravennae-Schoenetum nigricantis* (Pignatti 1953) Géhu 1984, *Holoschoenetum romani* Br.-Bl. (1931) 1952
3170* Mediterranean temporary ponds	*Juncus bufonius, Lythrum tribracteatum, Isolepis cernua, Serapias vomeracea*	*Erigeron canadensis, Aster squamatus*	*Lythrion tribracteati* Rivas Goday & Rivas-Martínez ex Rivas Goday 1970
1310 *Salicornia* and other annuals colonizing mud and sand	*Salicornia patula, Suaeda vera, Puccinellia convoluta*	*Aster squamatus*	*Salicornion patulae* Géhu & Géhu-Franck 1984
1410 Mediterranean salt meadows (*Juncetalia maritimi*)	*Juncus maritimus, J. acutus, Carex extensa, Plantago crassifolia, Artemisia caerulescens, Elymus athericus, Limbarda crithmoides*	*Erigeron bonariensis,* *Erigeron canadensis,* *Aster squamatus, Setaria viridis*	*Schoeno nigricantis-Plantaginetum crassifoliae* Br.-Bl. (1931) 1952, *Plantagini crassifoliae-Caricetum extensae* Géhu et Biondi 1988
1420 Mediterranean and thermo-Atlantic halophilous scrubs *(Sarcocornetiea fruticosi)*	*Arthrocnemum fruticosum, Halimione portulacoides, Inula crithmoides, Suaeda vera, Aeluropus litoralis*		*Salicornion fruticosae* Br.-Bl. 1933

cies composition of coastal dunes, as this species is the main invader of Mediterranean scrub (habitats 2250* and 2260) and coastal *Pinus* dune wood (habitat 2270*) along the Molise coast (Del Vecchio *et al*., 2013). We compared species richness in invaded and non-invaded plots with rarefaction curves and analyzed the frequency of focal and ruderal species, identified according to Pignatti (2005). Although we did not find significant effects of *Acacia saligna* on total species richness, we observed significant results when species belonging to particular guilds were considered. In the invaded plots of the *Pinus* dune wood (habitat 2270*) we found an increase in ruderal grass species (*Bromus madritensis, Geranium purpureum, Oryzop-*

sis miliacea, Parietaria officinalis), with a significant decrease in focal species. Since *Acacia saligna* has been introduced relatively recently (approximately 1950), it is possible that our findings represent only an early stage of the invasion process, whereas other effects could be observed at a later stage.

As concerns the EU habitats of wet slack, we detected a relationship between the abundance of invasive alien species and species richness (Di Franco *et al*., 2012). The 1410 and 3170* are the most invaded habitats in back dune slacks and, here, the most widespread species are *Erigeron canadensis* and *Aster squamatus*. The frequency of these aliens is higher in plots characterized by high species richness, as it was previously assessed in other habitat types (Acosta *et al*., 2008, 2009; Gaertner *et al*. 2009).

Moreover, dune annual grasslands (2230) in the study area often are heavily invaded by *Oenothera biennis, Erigeron canadensis* and *Xanthium italicum* (Acosta *et al*., 2008; de Chiro *et al*., in press; Frattaroli *et al*., 2007). As recorded in Carboni *et al*. (2011), transition dune is probably the most invaded sector of sand dune vegetation zonation, and such high level of invasion can be partially explained because of greater propagule pressure along this section of the dune profile. In order to explain the successful colonization of these species, we investigated the plant traits of a set of native and invasive alien species along Molise coast (Stanisci *et al*., 2010). The results highlight that large leaf area, the reproductive period in late summer, a biennial/annual life cycle and thick, long roots are most common plant traits of the investigated invasive species.

Regarding vegetation transects in the LTER-Italy sites (conducted since 2001) we have carried out some preliminary analyses. We have observed changes in habitat distribution and plant species composition and these changes seemed to be mainly related to coastal erosion/accretion processes.

At landscape level (Tab. 3), it is worth nothing that the foredune habitats with open and herbaceous vegetation (drift line: 1210), embryonic shifting dunes: 2110 and shifting dunes: 2120) are well represented amounting to about 90 hectares in total. Transition dune and fixed dune habitats have a more restricted distribution with *Juniperus* sp. formations (2250*) present only in one S.C.I (Ramitelli) and the mosaic of dune grasslands (2220, 2230, 2240) and *Cistus* sp. formations (2260) circumscribed to the Molise coast. *Quercus ilex* forests (9340) are very rare, with two small residual patches in Ramitelli area. On the other hand, most of the analyzed area is characterized by *Pinus* spp backdune forests (2270*) which covers almost 100 ha distributed on 17 patches. Finally, habitats of wet slacks are present in fine grained mosaics (1310-1410-1420-1430-1510*-6420), distributed in small patches near the Biferno river mouth.

Conclusion

Coastal dune natural vegetation has been severely damaged and reduced along the whole Adriatic coast in the last 50 years. Nonetheless, our studies in Abruzzo and Molise regions suggest that many EU Directive 92/43 habitat types are still locally widespread, with the exception of wet slacks and evergreen wood habi-

Tab. 3 - Landscape features of the 17 coastal EU habitats (* = priority habitat) monitored in LTER sites of Abruzzo and Molise regions For each habitat was reported information regarding cover area and total number of patches in each SCI and globally in the study area.

	SCI										TOTAL NP	TOTAL AREA (ha)
	PUNTA ADERCI		MARINA DI VASTO		TRIGNO		BIFERNO		RAMITELLI			
HABITAT	AREA (ha)	NP	AREA (ha)	NP	AREA (ha)	NP	AREA (ha)	NP	AREA (ha)	NP		
1210-2110	3.9	22	2.5	25	13.8	31	7.5	16	8.8	5	99	36.5
1410-420	0.1	1	6.1	11	.	.	.	.	.	.	12	6.1
2120-2230	2	1	3.1	19	10	19	1.2	4	9.4	4	47	25.7
2230	1.2	2	6.2	14	.	.	.	.	.	.	16	7.4
2270*	.	.	2	2	47.4	6	41.6	6	3.5	1	15	94.5
3170*	.	.	0.01	1	.	.	.	.	.	.	1	0.01
1310-1410-1420-1430-1510*-3170*-6420	.	.	.	.	.	.	12.6	9	0.4	1	10	13
2220-2230-2240-2260	.	.	.	.	15	19	2.7	6	29.8	23	48	47.5
2250*	.	.	.	.	.	.	.	.	18.5	17	17	18.5
9340	.	.	.	.	.	.	.	.	0.4	2	2	0.4

tats occurring only in residual small patches. Moreover all habitats host several invasive alien species and only in salt marshes they are almost absent, because of the occurrence of extreme salinity. This natural heritage is therefore vulnerable and further efforts should be made to reduce the impacts of human pressure, through increased awareness of environmental issues and the education on ecosystem services provided by the natural landscape of coastal dunes.

For facing and mitigating the effects of human pressures on priority habitats, a project Life plus is ongoing with the participation of local decision makers (Campomarino and Petacciato municipalities). The project LIFE NAT/IT/000262 Maestrale provides concrete action for for the removal of some local *Acacia saligna* stands, contrasting trampling effects and enlarging wet habitats (http://lifemaestrale.eu/).

The information derived from these studies could be also useful to evaluate the response of coastal dune habitats to different global change scenarios and to estimate future possible range shifts for long-term conservation efforts. However, studies which combine both plant and animal biodiversity and the associated ecological services are still needed and could help to identify the most effective strategies for sustainable management, in order to prevent the high economic costs derived from the loss of the coastal dunes.

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