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 & Zallo, 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...
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 relevés 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 of 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 embroyo- 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-

<table>
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<tr>
<th>Tab. 1 - Sites of European Community Interest (S.C.I.) in Abruzzo and Molise regions along Adriatic coastline.</th>
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<tbody>
<tr>
<td><strong>Abruzzo region:</strong></td>
</tr>
<tr>
<td>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.</td>
</tr>
<tr>
<td>S.C.I. IT7140109 “Marina di Vasto” (Chieti province); lat. 42° 05’ 10” N; long.14° 44’ 25” E; area: 57 ha.</td>
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<tr>
<td><strong>Molise region:</strong></td>
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<tr>
<td>S.C.I. IT7228221 “Foce Trigno-Marina di Petacciato” (Campobasso province); lat. 42° 2’ 32” N; long. 14° 50’ 1” E; area: 747 ha.</td>
</tr>
<tr>
<td>S.C.I. IT7222216 “Foce Biferno-Litorale di Campomarino” (Campobasso province); lat. 41° 57’ 58” N; long.15° 2’ 28” E; area: 817 ha.</td>
</tr>
<tr>
<td>S.C.I. IT7222217 “Foce Saccione-Bonifica Ramitelli” (Campobasso province); lat. 41° 55’ 42” N; long.15° 5’ 56” E; area: 870 ha.</td>
</tr>
</tbody>
</table>
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).

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Focal species</th>
<th>Alien species</th>
<th>Syntaxonomical attribution</th>
</tr>
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<tbody>
<tr>
<td>Annual vegetation of drift lines</td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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<tr>
<td>Embryonic shifting dunes</td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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<tr>
<td>Shifting dunes along the shoreline with <em>Ammophila arenaria</em> (white dunes)</td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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<td>Coastal dunes grassland communities with <em>Ephedra terracina</em></td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
</tr>
<tr>
<td>Coastal dunes grasslands with <em>Ammophila arenaria</em> (white dunes)</td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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<tr>
<td>Coastal dunes with <em>Juniperus procera</em></td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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<tr>
<td>Cisto-Lavanduletala dune sclerophyllous scrub</td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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<td>Wooded dunes with <em>Pinus pinea</em> and/or <em>Pinus pinaster</em></td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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<tr>
<td>Mediterranean tall humid grasslands of the Molinio-Halietum</td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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<tr>
<td>Mediterranean temporary ponds</td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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<tr>
<td>Mediterranean salt meadows (Juncetalia maritima)</td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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<tr>
<td>Mediterranean and thermo-Atlantic halophytic scrub</td>
<td><em>Ephedra distachya</em></td>
<td><em>Ammophila arenaria</em></td>
<td><em>Brachypodietalia triaenoides</em></td>
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*Acacia saligna* is the main invader of Mediterranean scrub (habitats 2250* and 2260) and coastal *Pinus pinea* 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 pinea* wood (habitat 2270*) we found an increase in ruderal grass species (*Bromus madritensis*, *Geranium purpureum*, *Oryzopsis*...).
sis milacea, 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 noting 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-

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<tr>
<th>SCI</th>
<th>TOTAL NP</th>
<th>TOTAL AREA (ha)</th>
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<tr>
<td>HABITAT</td>
<td></td>
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<tr>
<td>1210-2110</td>
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<tr>
<td>1410-420</td>
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<td>2120-2230</td>
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<tr>
<td>2230</td>
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<tr>
<td>2270*</td>
<td></td>
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<tr>
<td>3170*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1310-1410-1420-1430-1510*</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>2220-2230-2240-2260</td>
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<td></td>
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<td>2250*</td>
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<td>9340</td>
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</tbody>
</table>

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.
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 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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