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Monitoring biodiversity patterns in three Mediterranean mountain pastures in the Pollino National Park (S-Italy)

D. Gargano[1], S. Aiello[1], T. Abeli[2], A. Schettino[3], L. Bernardo[1]

[1]*Department of Biology, Ecology and Earth Sciences, University of Calabria, via P. Bucci, I-87036, Rende (CS). Current address: Natural History Museum and Botanical Garden, University of Calabria, Loc. Polifunzionale, I-87036, Rende (CS), Italy.*
[2]*Department of Earth and Environmental Sciences, University of Pavia, via S. Epifanio 14, I-27100, Pavia, Italy.*
[3]*Pollino National Park, Complesso Monumentale Santa Maria della Consolazione, I-85048, Rotonda (PZ), Italy.*

Abstract

We are monitoring three mountain herbaceous communities (a snow-bed community, a mesophile meadow and a xeric pasture) in the Pollino National Park (S-Apennines, Italy), in order to investigate relationships among climate, soil properties, vegetation structure (composition and spatial heterogeneity) and dynamics (seasonal patterns of species richness). To date, field data revealed striking differences of climate, soil and vegetation traits among the communities. The mesophile and the xeric community show a higher species richness than the snow-bed one, while the mesophile and the snow-bed community have a higher floristic relatedness. Species-area relationships evidence a substantial spatial heterogeneity in all sites. In two cases local plant diversity patterns appear significantly related to soil traits. Differences in seasonal biodiversity patterns are also evident, suggesting that contrasting mountain communities may be differently affected by climate warming components (*i.e.* summer drought vs. spring warming).

Key words: biodiversity, climate change, seasonal dynamics, soil analyses, species-area relationships, vegetation.

Introduction

Mountain areas had a central role in improving plant diversity in the Mediterranean global biodiversity hotspot (Thompson, 2005; Cañadas *et al.*, 2014). Currently, increasing global temperatures are promoting significant floristic rearrangement in European mountain floras (Gottfried *et al.*, 2012). The consequences of such changes on regional biodiversity vary across mountain ranges. The available data suggest that lower-latitude European mountains are subjected to pronounced biodiversity loss and turnover (Pauli *et al.*, 2012). Because the ecosystem functioning and services depend on biodiversity (Vogel *et al.*, 2012; Isbell *et al.*, 2015), understanding plant diversity patterns in these areas is crucial to preserve an unrepeatable biodiversity heritage under ongoing environmental changes.

An array of historical and contemporary drivers contributed to current plant diversity patterns in Mediterranean mountains. Over time, the Mediterranean rangelands acted as key refuge areas, corridors facilitating floristic exchanges, and sites for active plant speciation (Quézel, 1985). The plant migrations promoted by geological or climatic events strongly influenced the current Mediterranean mountain flora (Thompson, 2005). On the Apennine range, in the Italian Peninsula, this is proved by the numerous species shared with the eastern European regions and the alpine and northern European areas. Floristic components that represent the legacy of plant migrations occurred respectively at the end of the Tertiary Age and during the ice ages of the Pleistocene (Pignatti, 1978). The long-history of human impact also promoted floristic diversification on Mediterranean mountains, due to the fragmentation of forest ecosystems and their replacement by species-rich open communities (Thompson, 2005).

The contemporary drivers of plant diversity on the Mediterranean mountains include regional and local variations of topography (*i.e.* elevation; ground surface), soil (*i.e.* bedrock, texture, drainage, and further physical and chemical features), and climate (*i.e.* temperature, rainfall, snow, and their seasonal patterns) (Thompson, 2005). Accordingly, variations of geomorphology and soil features were often related to mountain vegetation patterns at regional (Sebastià, 2004; Garcia-Palacios, 2012) and local (Miller & Alpert, 1984; Tillman & Olff, 1991; Gough *et al.* 2000; Gargano *et al.*, 2010) scales. Such relationships between abiotic ecosystem components and vegetation depend on the influence that the spatial heterogeneity of resource patterns exert on composition, productivity and functioning of plant assemblages (Bliss *et al.*, 2002; Maestre *et al.*, 2005). In addition, in Mediterranean climatic areas, vegetation shows also a substantial temporal heterogeneity. Because climate variations challenge the maintenance of species homeostasis (Bozinovic *et al.*, 2011), inter-seasonal climate differences are recognized as a major driver of plant selec-

Corresponding author: Domenico Gargano. *Natural History Museum of Calabria and Botanical Garden, University of Calabria, Loc. Polifunzionale, I-87036, Rende (CS), Italy; e-mail: domenico.gargano@unical.it*

tion in the Mediterranean region, where they induces contrasting limitations to plant growth around the year (*i.e.* winter cold stress vs. summer aridity and heat stress) (Mitrakos, 1980, 1982; Prentice *et al*., 1992). As a consequence, Mediterranean plant communities reveal consistent biodiversity variations across seasons (Vylamazalová *et al*., 2012).

Recent works showed that spatial ecosystem complexity can buffer the impact of anomalous environmental conditions as those promoted by the climate change (Fridley *et al*., 2011; Godfree *et al*., 2011). On the contrary, the possible relationships between ecosystem seasonal patterns and responsiveness to climate change remain rather unexplored. Yet, the seasonal timing of biodiversity expression may have important implications under the ongoing climate warming. Several components of climate warming, (*e.g.* increasing temperature, decreasing rainfall), may alter seasonal biological dynamics (*i.e.* plant growth and reproduction) which are crucial for the maintenance of community composition and structure (Parmesan & Yohe, 2003; Cleland *et al*., 2007). The raising winter temperature induces an overall anticipation of spring phenological events (Fu *et al*., 2014), with major effects on early flowering taxa (Fitter & Fitter, 2002). In the late growing season, climate warming increases the likelihood of events of unusually high temperature and drought (Orsenigo *et al*., 2014), which may affect extent and timing of plant flowering, fruiting and recruitment (*e.g.* Abeli *et al*., 2012; Mondoni *et al*., 2012). Overall, in Mediterranean mountain ecosystems, increasing temperature may exacerbate the typical regime of summer stress, causing a higher risk of biodiversity loss (Pauli *et al*., 2012). Then, the temporal timing of biodiversity expression in oro-mediterranean communities might make them differently exposed to early- or late- acting components of climate change.

We are investigating patterns of species richness and dynamics in high-mountain herbaceous communities of the Pollino Massif (Southern Apennine), in the heart of Mediterranean Basin. In this paper we characterize three different plant communities based on a) climate and soil properties, b) floristic composition and, finally c) spatial and seasonal biodiversity variations. The obtained results are used to address the following questions: 1) how do abiotic and biotic ecological components differ among the study communities? 2) how do spatial and temporal diversity patterns vary among ecologically different herbaceous communities? 3) do such different seasonal biodiversity patterns reflect a different sensitiveness to climate warming components?

Materials and methods

Study area and definition of sampling units
We carried out field work over two seasons (2012

and 2013) in three sites located in the Pollino National Park, a large protected area in the Southern Italy (Fig. 1). The landscape complexity of this territory allows the maintenance of an extraordinary plant diversity which is facing significant environmental variations due to land use (Gargano *et al*., 2012) and climate changes (Federico *et al*., 2009, 2010).

The first study site (Grande Porta del Pollino, hereafter GPP: N 39.92508°, E 16. 20968°; elevation: 1,900 m a.s.l) occurred in a large doline where prevalent vegetation was dominated by *Alopecurus alpinus* Vill., *Poa alpina* L., along with *Bellis pusilla* (N. Terracc.) Pignatti, *Crepis aurea* (L.) Cass. subsp. *glabrescens* (Caruel) Arcang. Such species are typical of the snow-bed fragments of the Southern Apennine, which are communities constituted by small herbs adapted to low temperature and longstanding snow cover (Tomaselli *et al*., 2003; Gargano *et al*., 2010). The second site (Piano di Ruggio, hereafter PR: N 39.91197°, E 16.13053°; elevation: 1570 m a.s.l) was mainly covered by mesophile grasslands characterized by numerous grasses (e.g. *Festuca microphylla* (St.-Yves ex Coste) Patzke, *Dactylis glomerata* L. subsp. *hispanica* (Roth.) Nyman, *Alopecurus pratensis* L., *Cynosurus cristatus* L.), together with rare endemic taxa (*i.e.* *Plantago media* L. subsp. *brutia* (Ten.) Arcang.), and species close to their range border (*i.e. Gentiana lutea* L.). On the calcareous Apennine such communities are

Fig. 1 - Location of the Pollino National Park (on the left in gray) with respect to the Italian peninsula, and position of the study sites within the protected area. GPP, Grande Porta del Pollino. PR, Piano di Ruggio. MS, Monte Serra.

confined to flat surfaces which allow the formation of rich loamy soils. The third study site (Mt. Serra, hereafter MS: N 39.84804°, E 16.09311°; elevation: 1,400 m a.s.l.) was a rocky pasture dominated by *Festuca circummediterranea* Patzke, *Poa bulbosa* L., *Bromus erectus* Huds., *Koeleria lobata* (M. Bieb.) Roem. & Schult., *Armeria canescens* (Host) Ebel. This vegetation type is very frequent on Apennines, especially on rocky surfaces showing little developed soils and high drainage. Due to the rocky nature of the topsoil, such pastures are structurally characterized by a discontinuous vegetation cover. All species names cited above agree with Conti *et al*. (2005).

To carry out field observations in absence of grazing, in each study stand we delimitated a 10 x 10 m area by a fence. Within the fenced area we permanently defined 8 sampling units of 3 m^2 for investigating abiotic (*i.e.* climate and soil) and biotic (*i.e.* species occurrence and cover) traits.

Climate and soil sampling

We monitored soil temperature by using data-loggers (Hobo® Pendant UA-001-64) with a logging interval of 1 h. Data-loggers were positioned at a depth of 4 cm in the soil of each sampling unit. Since snow cover has an insulating effect which stabilizes soil temperature around 0.5 °C, we used temperature data to evaluate occurrence and length of periods with persistent snow cover. To this scope we considered the no. of consecutive days (at least 10 consecutive days) with 0 < average temperature < 1 °C.

To determine soil traits, we took small soil samples (1-2 Kg) representing all soil horizons in each sampling unit by using an Edelman-type manual auger with penetration capacity of 100-120 cm. We stored samples collected in the field in polyethylene bags for subsequent laboratory analyses. Here, we measured a set of variables accounting for textural and chemical soil traits. Soil texture (% of sand, silt, and clay) was analyzed by the Boyocous method. Organic matter [OM (g/Kg)] was derived from the content in organic carbon determined by the Walkley-Black method. Soil pH was determined by potentiometric measurement in soil-water suspension. Cation exchanged capacity [CEC (meq/g)] was calculated on the basis of the compulsive exchange between a barium-soil and magnesium sulfate solution; the amount of exchanged magnesium was measured by EDTA titration. The atomic spectrometric methods were used to determine base saturation: Magnesium [Mg (meq/g)] and Calcium [Ca (meq/g)] by atomic absorption; Potassium [K (meq/g)] and Sodium [Na (meq/g)] by atomic emission. All soil analyses were carried out according to the official guidelines MUACS (D.M. 11/05/1992 e D.M. 13/09/1999). Such analyses supported soil classification based on the WRB (FAO 2006) model. Soil

traits were evaluated for each soil horizon (A1, A2, Bw), and then averaged to have a unique value per sampling unit.

Vegetation sampling

To minimize interference with plant growth, we studied patterns of species occurrence and cover in each sampling unit by using the phytosociological approach. Hence, over two years, we recorded plant cover data according to the scale: r = rare species; += cover < 1%; 1= 1<cover<20%; 2= 20<cover<40%; 3= 40<cover<60; 4= 60<cover<80%; 5= 80<cover<100%.

To investigate temporal variation of community composition and structure, we repeated field surveys at 10 days-intervals in each stand. Overall, we performed 408 surveys (GPP=104, PR=152, MS=152), which allowed to follow vegetation dynamics over the whole vegetative and blooming period.

Data analyses

Before performing statistical analyses, we transformed plant cover data following van der Maarel (1979). Therefore: r=1, +=2, 1=3, 2=5, 3=7, 4=8, 5=9. For each relevés, we calculated the Shannon diversity index by using the transformed cover values as a proxy of relative species importance (Mendes *et al*., 2008; Hejda *et al*., 2009). To explore the floristic relationships among the study sites we performed a cluster analysis on the relevès matrix (118 species x 408 relevès), by using the incremental sum of squares as classification method and the chord distance as similarity measure.

We evaluated spatial and temporal variations of floristic structure based on two biodiversity estimators: species richness (*SR*) and the Shannon diversity index (*H*). We studied spatial accumulation patterns of plant diversity by means of species-area relationships, using a linear regression model to check the strength of the relationships between surface sampled and *SR*. Local soil effects on plant diversity and abundance were evaluated by using the Pearson correlation to test relationships between soil traits, and between soil parameters and *H*.

Finally, to evaluate relationships between climate and community seasonal dynamics we derived the following three variables from hourly temperature data: the average of maximum daily temperatures of the decade preceding each survey (MT_{10}), the average of minimum daily temperatures of the decade preceding each survey (mT_{10}), and the average of mean daily temperatures of the decade preceding each survey (T_{10}). For each studied community we analyzed the strength of the effects of such temperature parameters on the seasonal variations of *H* by a multiple linear regression model. To avoid problems with the collinearity among predictors resulted from a first regression run, we followed a factor analysis approach to create a new set of

independent and uncorrelated variables fitting the response variable as well as the original predictors. This was done by performing principal component analysis (PCA) on standardized values of MT_{10}, mT_{10} and T_{10}. The standardization of each variable was done by subtracting mean from each value and then dividing it for standard deviation. In the last step, we ran a regression model in which the values of H were regressed against the factor scores produced by the factor analysis. In this analysis we applied a stepwise regression method to evaluate the relative contribution of the three original predictors in influencing the response variable.

Results

Climate and soil features

The average temperature measured over the period January 2012 - December 2013 clearly varied across the study sites (Tab. 1). We recorded a marked thermophily of MS site compared to PR and GPP. The differences in average temperature were also accompanied by diverse patterns of temperature dynamics across seasons. PR and, especially, GPP showed a long phase with stable temperature corresponding to a durable snow cover. This was followed by an abrupt temperature increase at the spring. In contrast, at MS the soil temperature varied greatly during the whole year, long periods with persistent snow cover were almost absent, and the temperature increased gradually from spring to the summer.

Field observations and subsequent laboratory analyses revealed also substantial pedological differences among the study sites (Tab. 1). MS showed a rendic soil where the thin litter layer had overlain directly the calcareous bedrock (this caused the extremely high value of organic matter reported in Tab. 1). We classified this soil as a Hyperumi-Rendzic-Leptosol, where the coarse texture was accompanied by high pH and calcium content. Instead, at PR and GPP the soil showed well structured horizons. The PR soil qualified as Haplic Phaeozem, and revealed a loamy texture with sub-neutral pH values, the amount of calcium resulted to be almost halved than MS. Finally, the GPP soil resulted to be a Haplic Cambisol (Humic Dystict), it was also characterized by a loamy texture, but organic matter, pH and calcium content were much lower than PR (Tab. 1). Textural traits appeared to be strongly related to all other soil features (Tab. 2), suggesting that soil structure is a relevant driver of other nutritional properties. As revealed by textural soil properties, the study sites defined a gradient whose extremes were GPP and MS (Fig. 2). At GPP the soil structure appeared to be unbalanced due to the large fraction of silt and clay and the poorness of sand (Fig. 2). Contrariwise, the MS soil was very poor in clay content (Fig. 2). Instead, due to the balanced soil texture, PR constituted

Tab. 1 - Average values ± standard deviation of climate, soil, floristic traits and vegetation characterization of the three study sites.

Parameter	GPP	PR	MS
Altitude (a.s.l.)	1,900	1,570	1,400
Average temperature (°C)*	6.7 ± 7.1	8.2 ± 7.0	11.8 ± 8.9
Minimum temperature (°C)*	4.5 ± 4.6	5.8 ± 5.0	8.0 ± 6.5
Persistent snow cover (days)*,**	310	216	38
Sand (%)	7.2 ± 2.4	27.4 ± 3.7	37.5 ± 18,2
Silt (%)	70.3 ± 2.3	59.7 ± 3.5	59.0 ± 19.0
Clay (%)	22.5 ± 1.8	13.0 ± 1.5	3.5 ± 2.3
pH	4.8 ± 0.1	6.9 ± 0.4	7.2 ± 0.1
Organicmatter (g/Kg)	93.2 ± 8.6	122.1 ± 13.1	262.1 ± 6.3
C/N	10.7 ± 0.5	11.6 ± 0.4	10.6 ± 2.8
Ca (meq/g)	1.8 ± 1.0	23 ± 5.8	43.8 ± 0.7
Speciesrichness	9.9 ± 2.1	29.7 ± 4.3	29.3 ± 4.1
Shannon index (H)	2.153 ± 0.2	3.289 ± 0.2	3.269 ± 0.1
Community physiognomy	Snow-bed	Mesophile meadow	Xeric pasture
Vegetation type	*Bellidi pusillae-Alopecuretum gerardii*	*Meo-Asphodeletum*	*Bromion erecti*

*Reference period 01 January 2012 - 31 December 2013.**Sum over 2 years.

Tab. 2 - Pearson's correlations among the soil traits evaluated in the study.

	SAND	SILT	CLAY	pH	OM	C/N	Ca
SAND	1.000	-0.884**	-0.726**	0.753**	0.669**	0.326	0.756**
SILT		1.000	0.320	-0.438*	-0.307	-0.478	-0.391
CLAY			1.000	-0.881**	-0.905**	0.043	-0.957**

**, the correlation is significant at the 0.01 level. *, the correlation is significant at the 0.05 level.

the central portion of the gradient (Fig. 2). Also, MS showed greater soil texture variations among sampled plots, while at GPP and PR soil structure showed less spatial heterogeneity (Fig. 2).

Floristic relationships and biodiversity patterns

Overall, the floristic surveys allowed us to identify 118 taxa. The three communities showed evident differences in terms of species richness, and were floristically well differentiated. Indeed, 84% of the recorded species resulted limited to a single site. As a consequence, the numerical classification assigned the relevés to three well defined clusters, each accounting for one of the study sites (Fig. 3). However, the cluster analysis evidenced that the PR and GPP communities had a higher floristic relatedness compared to MS (Fig. 3).

As far as biodiversity comparisons among stands are concerned, MS and PR showed similar levels of species richness, average amount of species per sampling unit, and H (Tab. 1), while GPP showed much lower values for all the biodiversity proxies (Tab. 1).

Spatial biodiversity patterns

Based on SAR models, the amount of species recorded significantly increased with the sampled area in all the study sites (Fig. 4). At GPP the levels of H were positively related to the percent of sand in the soil ($r = 0.78$; $P = 0.02$; $N = 8$), while at MS, H increased
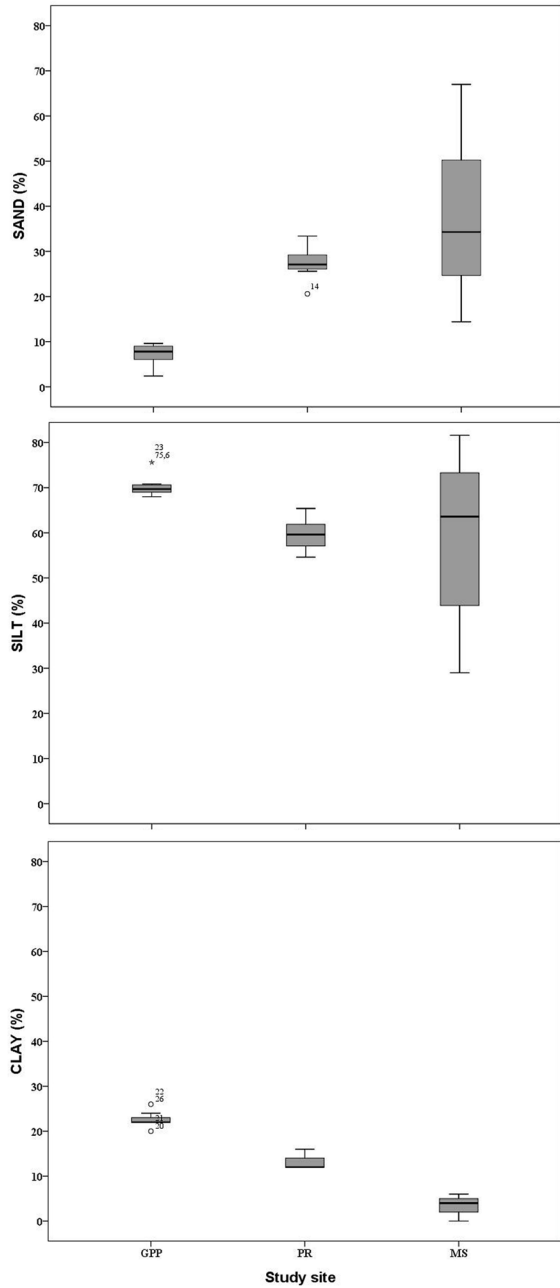
Fig. 2 - Boxplots showing soil texture features (%) of the three study sites. Vertical bars represent 95% of confidence interval.

with the fraction of clay ($r = 0.72$; P = 0.04; N = 8). In contrast, at PR we did not find relationships between biodiversity proxies and soil traits.

Seasonal biodiversity patterns

As far as the effects of the temperature on season-al biodiversity variations are concerned (Fig. 4), the stepwise linear regression model (Tab. 3) showed no relationships at GPP ($R^2 = 0.013$; P = 0.639; N = 104). Instead, at both PR and MS sites we have found significant effects of temperature variations on the level of H (respectively $R^2 = 0.240$, P < 0.001, N = 152, and $R^2 =$

0.164, P < 0.001, N = 152). Based on the regression coefficients the highest effects were due to the second component score produced by the PCA carried out on the original temperature variables (Tab. 3). Since most of the variance observed on this component was due to mT_{10} (Tab. 4), the variation of minimum temperature during the days preceding our surveys resulted to have major consequences on biodiversity. Also, the regres-sion coefficients showed in Tab. 3 indicated that such temperature variations induced contrasting effects on biodiversity in the two communities (positive at PR and negative at MS).

Discussion

Ecological relationships among communities

The spatial heterogeneity of the Mediterranean land-scape contributes substantially in increasing local and overall plant diversity (Thompson, 2005). At regional scale the complexity of Mediterranean landscapes produces marked ecological differences which have a major role in structuring vegetation patterns. As evi-denced by Sebastiá (2004), most of such differences are related to abiotic variations depending on topog-raphy and soil features. Accordingly, our study sites revealed striking differences in soil traits (*i.e.* texture, pH) which affect the nutritional status of the soil and, then, composition and structure of plant communities. Especially, soil texture appeared a powerful ecologi-cal predictor due to its relationships with other soil properties. Indeed, in spite of a comparable species

Tab. 3 - Stepwise regression coefficients for the factor scores obtained by the PCA carried out on standardized MT_{10}, mT_{10} and T_{10} variables. Dependent variable = H.

Site	Model		B	SDE	β	t	Sig.
GPP	1	(Constant)	0.3315	0.0048		69.382	0.000
		REGR factor score 1	-0.0037	0.0046	-0.0868	-0.799	0.426
		REGR factor score 2	0.0013	0.0061	0.0217	0.217	0.829
		REGR factor score 3	0.0067	0.0055	0.1328	1.230	0.222
PR	1	(Constant)	0.5174	0.0015		353.642	0.000
		REGR factor score 2	0.0115	0.0017	0.4739	6.591	0.000
	2	(Constant)	0.5164	0.0015		338.839	0.000
		REGR factor score 2	0.0110	0.0017	0.4536	6.340	0.000
		REGR factor score 3	0.0060	0.0027	0.1599	2.235	0.027
MS	1	(Constant)	0.5166	0.0015		340.483	0.000
		REGR factor score 2	-0.0063	0.0012	-0.3886	-5.166	0.000
	2	(Constant)	0.5174	0.0016		332.517	0.000
		REGR factor score 2	-0.0065	0.0012	-0.4062	-5.423	0.000
		REGR factor score 3	0.0022	0.0011	-0.1548	2.067	0.040

Tab. 4 - Regression scores of the standardized variables on the three components extracted by PCA.

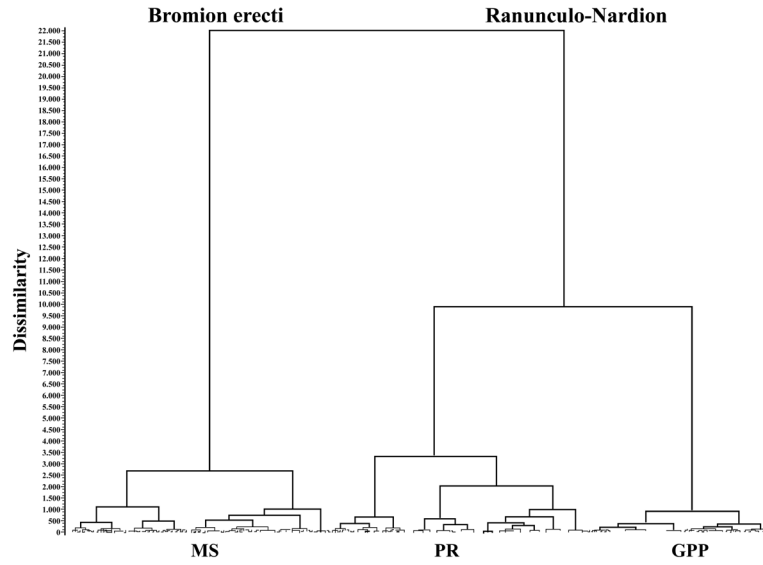| Variable	1	2	3
(z)MT_{10}	0.895	0.443	0.051
(z)mT_{10}	0.446	0.894	0.055
(z)T_{10}	0.694	0.678	0.241

Fig. 3 - Numerical classification of the relevés taken in the three different communities.
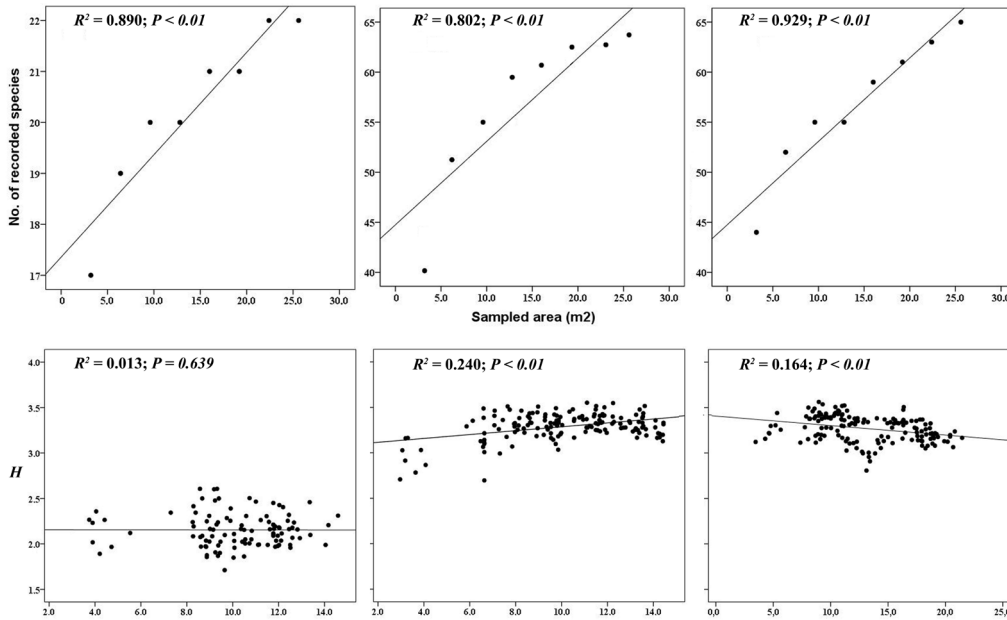

Fig. 4 - Species-area relationships (top) and seasonal biodiversity patterns (bottom) found in the three study communities. *H*, Shannon diversity index. mT_{10}, average of daily minimum temperatures recorded in the decade preceding each floristic survey.

richness (MS = 63 *taxa*, GPP+PR = 69 *taxa*), the classification of floristic data indicated a major differentiation (shared species < 12%) between the community established on soil with coarse texture (MS) and those found on loamy soils (PR and GPP). Since soil texture greatly influences the drainage rate of water provided by rainfall and snowmelt (Ellenberg, 1986), our findings fit the expectation that the shift from xeric to mesic conditions is the most relevant ecological transition in differentiating Mediterranean mountain grasslands (Sebastiá, 2004). In addition, the snow-bed community, floristically related to the PR mesic vegetation by the cluster analysis, resulted established on soil with a very low pH. Soil pH is a further important driver of soil nutrients availability (Tillmann & Olff, 1991; Pärter, 2002) and, in cold environments, its decrease is often paralleled by a loss of plant richness (*e.g.* Gough *et al.*, 2000). This was evident for the GPP community, and supports the hypothesis that the snowbed communities of the southern Apennine are an ecological variant of mesophile meadows, specialized to extreme mountain environments (Tomaselli *et al.*, 2003), where plant productivity is limited by severe climatic and soil constraints.

Spatial and seasonal ecological patterns within communities

The relative contribution of the different drivers of plant assemblage may depend on the considered scale (Rahel, 1990). Abiotic (climate, geomorphology, soil) and biotic (disturbance, biotic interactions) drivers may be more relevant at landscape and local scale, respectively (Sebastiá, 2004). Nonetheless, consistent relationships between soil and vegetation patterns may occur also at small spatial scales, depending on local geomorphology (*e.g.* Miller & Alpert, 1984; Gargano *et al.*, 2010), as well as on disturbance (Gigon & Leutert, 1996). All the plant communities considered in our work revealed considerable local variations, fitting the general expectation that the species encountered increase with the sampled area (Crawley & Harrald, 2001). This may result from the influence of soil heterogeneity on local plant patterns (Garcia-Palacios *et al.*, 2012). However, the importance of soil properties in differentiating plant communities may vary among phytocoenosis types (Critchley *et al.*, 2002). In our study the effects of local soil variations on biodiversity depended on the ecological context. The mesophile PR community revealed no relationships between local patterns of soil and plant diversity. Instead, according to a minimum law, small variations in the rarest soil component (% of clay and sand at MS and GPP respectively) promoted a significant rise of local plant diversity in the two 'extreme sites'.

Climate variations may alter community composition because they induce physiological limitations on species (Bozinovic *et al.*, 2011). Mediterranean climate constrains vegetation by different patterns of seasonal stress (Mitrakos, 1980, 1982; Prentice *et al.*, 1992), which promote striking intra-annual variations of composition and structure in plant communities (Vylamazalová *et al.*, 2012). Our models indicated that extent and fashion of such variations vary substantially among ecologically different communities. As a probable consequence of the short season suitable to plant growth, we did not find significant dynamics in the coolest site. In contrast, species diversity increased with temperature in the mesic site, indicating that in this context winter and spring low temperatures may exert major constraints than summer aridity stress. Finally, in the site showing higher thermophily and soil poorness, the vegetation appeared to be more severely constrained by summer drought, as suggested by the declining diversity from spring to summer.

Conservation implications under the ongoing environmental changes

As known for the whole Mediterranean region (Bates *et al.*, 2008), precipitations are significantly decreasing in our study area (Federico *et al.*, 2009, 2010). The consequent sharpening of summer drought stress can threaten ecological systems as the Mediterranean grasslands, which are very sensitive to rainfall variations (Figueroa & Davy, 1991). Under this scenario, the differences in biodiversity patterns described above have relevant implications. The maintenance of the community homeostasis under new climate scenarios requires the ability of the species to cope with a wide range of ecological conditions (Bozinovic *et al.*, 2011). The range of species tolerance is affected by high-level interactions, and it often augment in (functionally)-diverse communities (Urbina *et al.*, 2015). This furnishes a functional justification for the higher resilience of species-rich communities (Reich *et al.*, 2001; Tillman *et al.*, 2006). Hence, the scarce dynamics of the species-poor GPP vegetation provides a further evidence that highly specialized snow-bed communities tend to adopt a resistant behavior against novel environmental conditions (Baptist *et al.*, 2009). However, because high diversity is thought to increase productivity while it reduces resistance to drought stress (Vogel *et al.*, 2012), ongoing climate variations can severely constrain also species-rich communities as MS and PR. Especially, fertile grasslands can experience more severe drought constraints (Grime *et al.*, 2000). Therefore, a more pronounced productivity loss may occur in mesic communities like PR, which exhibit their maximum diversity in the summer. According to (Vogel *et al.*, 2012), the impact of increasing aridity on high-mountain grasslands may be further exacerbated by the Mediterranean pastoral systems, which favor an intensification of summer grazing pressure in high-mountain belts (Gargano *et al.*, 2012). Instead, xerophitic plant communities as MS appear less sensitive to increasing summer aridity, because in this period most of species have concluded their growth cycle. In this case, major concerns may originate from spring climate variations. Indeed, the anticipation of plant growth promoted by warmer spring temperature may increase the risk to undergo unfavorable climate events, especially in early flowering taxa (Fitter & Fitter, 2002). This may challenge the maintenance of composition and structure in communities characterized by early seasonal biodiversity peaks.

Our work suggests that oro-mediterranean herbaceous communities are suitable to investigate relationships among abiotic ecological traits, (seasonal) biodiversity patterns, and possible effects of climate change. A complex interplay of abiotic vegetation drivers (*i.e.* climate, soil) originates biodiversity patterns which can confer to communities a different sensitiveness versus climate change components.

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