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Report

Biodiversity patterns of dry grasslands in the Central Apennines (Italy) along a precipitation gradient: experiences from the 10th EDGG Field Workshop

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Abstract: The 10th EDGG Field Workshop took place in a sector of the Central Apennine Mountains, Italy, in June 2017. Altogether, 22 researchers from nine European and Asian countries attended this Field Workshop. We sampled plant and insect biodiversity in submontane and lower-montane grasslands along a precipitation gradient, from the L'Aquila valley and the Fucino basin to the "Abruzzo, Lazio & Molise" National Park. The standardized EDGG sampling protocol, involving nested-plot series and additional 10-m² relevés, was used. In the course of seven days of intensive fieldwork, we sampled 20 biodiversity plots along with 57 additional normal plots (yielding a total dataset of 97 10-m² plots). Methodological additions tested in this workshop included the assessment of observer-related error (around 12% of the 10-m² plots was resurveyed by a different team). In all plots, vascular plants, bryophytes and lichens were sampled. At each nested-plot series, also insects (*Auchenorrhyncha*) were sampled by local specialists, who developed an ad-hoc sampling procedure.

Keywords: Apennines; *Auchenorrhyncha*; biodiversity; bryophyte; dry grassland; dry valleys; EDGG; Italy; lichen; nested plots; precipitation gradient; vascular plant.

Introduction

Since 2009, the EDGG has carried out research expeditions dedicated to the collection of high-quality data on biodiversity and compositional patterns of grasslands in understudied regions of the Palaearctic. The first event, attended by a small group of six scientists, took place in the Transylvanian Lowland (Romania; Dengler et al. 2009) and was followed by eight more: Central Podolia in Ukraine (Dengler et al. 2010), NW Bulgaria (Apostolova et al. 2011), Sicily (Guarino et al. 2012), NW Greece (Dengler & Demina 2012), Khakassia in Russia (Janišová et al. 2013), Navarre in Spain (Biurrun et al. 2014), Southern Poland (Kącki et al. 2014) and Serbia (Aćić et al. 2017). As a scientific group, EDGG warmly supports the exchange of knowledge among participants and, at the same time, is strongly focused on the analysis of collected data, which are used for joint publications in international peer-reviewed journals (see Dengler et al. 2012a; Pedashenko et al. 2013; Turtureanu et al. 2014; Kuzemko et al. 2014, 2016; Polyakova et al. 2016; and others currently in preparation).

Here we present our report of the 10th Field Workshop, which took place in Italy from 3rd to 11th June, 2017. It was organized by Goffredo Filibeck, Laura Cancellieri (both from University of Tuscia, Viterbo, Italy) and Marta Gaia Sperandii (University of Roma Tre, Rome). Leonardo Rosati (University of Basilicata, Potenza, Italy) generously helped with both organization and fieldwork as an expert of Apennine vegetation. Samuele Maestri (M.Sc. student at University of Tuscia) helped as an assistant to the organizers. During fieldwork in L'Aquila basin, the workshop was joined also by Anna Rita Frattaroli (University of L'Aquila) and Fabio Conti (University of Camerino) who, during the planning phase, had provided useful advice concerning some specific locations, as local experts of floristics and vegetation.

Participants in the workshop were, as usual for these EDGG events, a mixture of experienced scientists and young postdocs or Ph.D. students. Altogether 22 researchers from nine European and Asian countries attended this Field Workshop.

To complement the botanical sampling with insect biodiversity data, Adalgisa Guglielmino (University of Tuscia) and Christoph Bückle (Tübingen, Germany) joined the research expedition in order to sample *Auchenorrhyncha* (a suborder of Hemiptera, including, inter alia, leafhoppers and planthoppers).

Aims and study area

The main topic of the 10th Field Workshop was sampling plant richness and composition patterns across a precipitation gradient in the Central Apennine Mountains (Abruzzo and Lazio regions, Italy). Because of the rain-shadow effect, some inner valleys in this area (Fucino basin, Capestrano valley, L'Aquila valley) feature low annual precipitation values (less than 600 mm). In these Apennine "continental valleys", there is a number of taxa featuring a disjunction with E-European steppes: e.g. *Alyssum desertorum, Androsace maxima, Astragalus exscapus, Crocus variegatus, Goniolimon italicum, Salvia aethiopis, Sideritis italica, Stipa capillata* (Conti & Bartolucci 2015; Morretti et al. 2015; Cancellieri et al. 2017a). The flora of these basins is thus somewhat similar to that of the well-known Alpine "dry valleys" (Schwabe & Kratochwil 2004; Wiesner et al. 2015). However, while in the Alps the precipitation regime features a summer maximum, in the Apennines there is a sub-Mediterranean climate with a summer drought or at least with a summer rainfall minimum (Gerdol et al. 2008; Blasi et al. 2014; Filibeck et al. 2015), leading to an interesting mixture of steppic and Mediterranean elements in the grassland flora. Just a few kilometers away from such dry inner valleys, the W-facing outer slopes of the Apennines feature a "sub-Mediterranean oceanic" climate, characterized by very high annual precipitation, up to 1500 mm. The whole gradient is often compressed into a transect of less than c. 15 km. The expedition was organized in order to sample plant and insect diversity in grasslands within a pre-defined elevational belt (Apennine sub-montane and lower-montane bioclimatic belts, i.e. between 700 and 1300 m a.s.l.: Gerdol et al. 2008) and bedrock (limestones and calcareous conglomerates), but moving along the precipitation gradient, relying on high-resolution interpolated climatic data provided by M. Brunetti (Institute of Atmospheric Sciences and Climate, Bologna, Italy).

Much of our vegetation sampling was performed within the "Abruzzo, Lazio & Molise" National Park and within its buffer area, except for a couple of days spent in other districts, such as the foothills of the Monte Velino massif and L'Aquila basin (**Fig. 1**). The National Park was established in 1923, originally with the aim of protecting areas of relatively intact forests and two endemic taxa of large mammals, the Marsican brown bear (*Ursus arctos marsicanus*) and the Apennine chamois (*Rupicapra pyrenaica ornata*). The area also hosts a large population of wolf (*Canis lupus*), and red deer (*Cervus elaphus*) was reintroduced in the 1970s. However, the park nowadays aims at protecting the full diversity of habitats and the traditional agro-pastoral activities that maintain them (Primi et al. 2016). The park and its immediate surroundings encompass a rich flora featuring 2114 vascular plant species and subspecies, including 137 taxa endemic to Italy (Conti & Bartolucci 2015).

The prevailing geological substrata in the study area are Mesozoic limestones and dolomites; conglomerate, calcareous arenite, clay and marl substrata also occur. The geomorphology is characterized by widespread karstic landforms (**Fig. 2**). At low elevations (500-800 m a.s.l.), the climate is sub-Mediterranean, with one or two dry months in the summer, annual precipitation between 700-1200 mm, mean annual temperature >10°C and only minimal occurrence of frost. The landscape within this belt is dominated by *Quercus pubescens* and *Q. cerris* woods, along with large extensions of secondary grasslands. Across the submontane (800–1200 m a.s.l.) and montane belts (1200-1800 m a.s.l.), summer drought stress decreases with altitude (although the precipitation regime still features a distinct minimum in summer and maximum in autumn), and the incidence of winter/spring frost is greater: annual precipitation is between 1100-1600 mm, and mean annual temperature is between 6 and 9 °C (Filibeck et al. 2015). Most of the landscape within the montane belt is dominated by *Fagus sylvatica* forests and by sec-

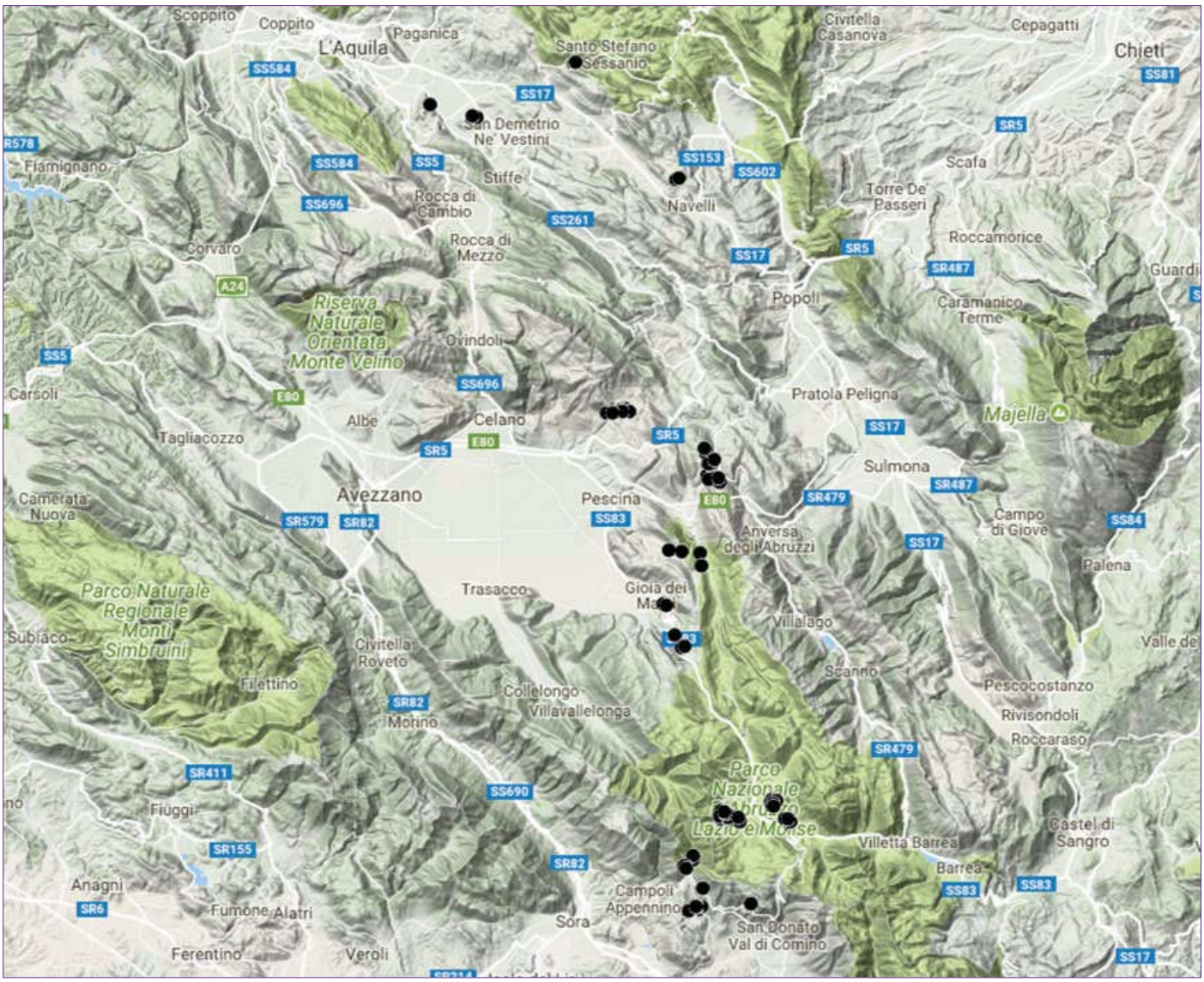

Fig. 1. ***Map of the study area indicating the position of the sampled plots (black dots).***

Fig. 2. ***Typical geomorphological features of the study area, with dry karstic valleys devoid of water courses. Olmo di Bobbi pass, near Cocullo (buffer area of "Abruzzo, Lazio & Molise" National Park). Photo: M. Janišová.***

Fig. 3. ***Landscape mosaic (1300 m a.s.l., montane belt) composed of beech forests, abandoned forested pastures ("difese") and secondary dry grasslands. Pesco di Lordo valley, near Pescasseroli ("Abruzzo, Lazio & Molise" National Park). Photo: M. Janišová.***

ondary grasslands (**Fig. 3**). Finally, the subalpine belt (>1800 m a.s.l.; not included in our sampling) is characterized by prolonged snow cover and late-spring frost. This belt is covered mainly with primary grasslands, prostrate shrub vegetation, rocks and screes (Bruno & Bazzichelli 1966).

In the Central Apennines, transhumance shepherding emerged during the 6th century BC or earlier (Brown et al. 2013) and was widely practiced until the 1950s. Nowadays, most of the husbandry is sedentary, and sheep stocking rates are drastically lower than those of the early twentieth century. The most common stocking system now involves grazing from mid-June to mid-October in public pasturelands, leased by each municipality to individual farmers. In the study area, the decrease of sheep husbandry has resulted in a steep increase in bovine and equine grazing. Most of the cattle and horses nowadays belong to "part-time farmers" (i.e., people who derive their main income from other activities). The animals are thus left free-ranging night and day in the wild, sometimes without being checked for many months (Primi et al. 2016). This is probably leading to major changes in both floristic composition and landscape patterns.

Mowing has never been a large-scale management system in the study area, because of the sub-Mediterranean summer drought (coupled with the limestone bedrock and karst hydrology), which yields only one harvest per year (Manzi 1990). Moreover, hay was not a crucial commodity as sheep flocks were moved to the mild-climate coastal lowlands in winter, so mowing was necessary only for the winter needs of the small population of cattle, which was not involved in transhumance. Although hay-making was connected to a complex and interesting system of co-ordinated management between private and public land (including the possibility for shepherds to hire the right of grazing their flocks in private lots after the mowing season: **Fig. 4**) (Manzi 1990), it was, and still is, restricted to the more productive and mesic habitats (such as clayey slopes, deep-soil bottoms of karst depressions, seasonally flooded plains, etc.), that are not included in the sampling scheme of this Workshop.

Fig. 4. ***Complex pattern of land-use types in the landscape of Colli Bassi near Pescasseroli ("Abruzzo, Lazio & Molise" National Park): the conglomerate hillocks are public land and are covered with dry grassland used for grazing, while the small doline depressions (appearing to be greener in this picture) are private properties and are used for wheat crops (as in this picture) or for hay-making. Shepherds hire the right of grazing the hillock grasslands from the municipality, and the right of grazing the doline bottoms (in order to exploit the regrowth after the crop or hay has been harvested) from a consortium of landowners. Photo: M. Janišová.***

In spite of a few phytosociological studies on the Central Apennine dry basins (Avena & Blasi 1979; Tammaro 1984, 1995; Frattaroli 1989; Pirone & Tammaro 1997; Pirone et al. 2001; Theurillat et al. 2007), knowledge on grassland biodiversity and composition patterns, and on their relationships with environmental variables, is still very limited. The grasslands of the submontane and montane belts of the Abruzzo National Park itself are not very well known, although some phytosociological data were presented by Bruno & Bazzichelli (1966), Biondi et al. (1992), Pedrotti et al. (1992), Lucchese et al (1995), Di Pietro et al. (2005) and Primi et al. (2016). A paper on biodiversity patterns of the karstic basins in the upper-montane belt of the Park's core area, based on randomized nested plots (restricted to the 0.01, 0.1 and 1 m^2 spatial scales) is currently under preparation by G. Filibeck et al. (see also Cancellieri et al. 2017b).

Sampling methodology

The sampling design basically followed the standard EDGG methodology, with a few additions tested during the 2017 Field Workshop. The implementation of the standard EDGG protocol throughout all the Research Expeditions/Field Workshops allows large-scale comparisons and synthesis of phytodiversity data (Dengler et al. 2016a). Originally developed by Dengler (2009), subsequently revised and improved, and recently described (Dengler et al. 2016b), this protocol consists of an intensive nested plot sampling, covering plot sizes of 0.0001, 0.001, 0.01, 0.1, 1, 10 and 100 m^2 (altogether forming a so-called "biodiversity plot") (**Fig. 5**) and complemented by additional 10-m^2 "normal" plots (**Fig. 6**). Plots were arranged in the landscape in order to cover a variety of physical habitats (as for land-form types, slope aspect and inclination, etc.) and vegetation types; each plot was placed in a visually homogeneous stand. For each plot and subplot, all terricolous vascular plants, bryophytes and lichens were identified and recorded whereas, for 10 m^2 subplots and "normal" plots, percentage cover values for the species were visually estimated and a set of environmental parameters (including GPS coordinates, elevation, slope, aspect, microrelief, soil depth, cover of rocks and stones, land form, land use), together with detailed structural data of the vegetation (e.g. mean vegetation height), were measured. A mixed soil sample was taken for laboratory analysis.

One of the main methodological novelties introduced in the 10th Field Workshop was the estimation of observer-related error. Most studies on this topic have found mean values of pseudo-turnover (i.e. of the difference in species composition between teams of observers, surveying the same plot) ranging from 10% to 30% (Morrison 2016). These figures are large enough to blur and potentially bias the relationships between environmental variables and vegetation patterns, but this issue is still surprisingly disregarded in the vast majority of

Fig. 5. ***Starting a biodiversity plot on a conglomerate hillock. Colli Bassi, near Pescasseroli ("Abruzzo, Lazio & Molise" National Park). Photo: M. Janišová.***

papers. In order to estimate measures of inter-observer pseudo-turnover, around 12% of the 10-m^2 plots were resurveyed by a different team. Additionally, we made sure that each 10-m^2 plot was surveyed by at least three people, and we also recorded the starting and finishing time.

Grazing plays a significant role in our study area, with complex spatial patterns of both grazing intensity (number of animals per unit area) and type (different species of domestic animals occur in different areas: sheep, goats, cattle, horses), so another major addition to the protocol was a detailed grazing load assessment. This was achieved through a survey based on faecal pellet transects, performed a few days after the expedition at each sampling location by a dedicated team (composed of graduate students of wildlife management from the University of Tuscia, supervised by A. Amici and R. Primi).

Minor innovations introduced this year included: burying a magnet in every 10-m^2 subplot or normal plot, in order to potentially enable re-visitation studies in the future with precise re-localisation of the plots; sampling soil depth at five pre

Fig. 6. ***Performing a 10-m^2 "normal" plot on a species-rich calcareous hump. Olmo di Bobbi pass, near Cocullo. Photo: G. Filibeck.***

-defined points (in order to prevent any unwitting bias when sampling very stony or rocky sites, for instance), instead of choosing the points haphazardly; using a predefined legend (tailored on the specific landscape of the study area) for noting down land-use and land-forms. Contrary to practice on the 2016 Field Workshop, we did not sample standing biomass, because of the huge variability in grazing intensity among the study sites.

Following previous experiences of invertebrate-sampling in EDGG expeditions (e.g. in the 2014 Field Workshop a specialized taxonomist sampled spiders in the biodiversity plots), this year we invited two entomologists to join the expedition in order to test cross-taxon patterns between plants and *Auchenorrhyncha*. An *ad-hoc* procedure was developed during the planning phase and refined in the field in order to avoid effects on the entomological sampling arising due to the activities of botanists in the plot (or vice versa, such as effects on the vegetation due to trampling of the vegetation by entomologists). Insects were sampled along a 5-m wide strip, surrounding each biodiversity plot on three sides, in order to leave one side available to the botanists for accessing the plot. A 1-m wide buffer was also left between the biodiversity plot edges and the entomological "sampling strip". Insect samples were collected using a vacuum aspirator (100 soil contacts on each of the three sides) and, in addition, with a sweep net (100 sweeps on each of the three sides) (**Fig. 7**).

Workshop presentations

At the beginning of the Field Workshop, G. Filibeck gave two keynote talks, one introducing the study area and another on the methodological additions.

In the subsequent days, participants who had received a travel grant gave oral presentations, namely:

J. Dengler: *Phytodiversity of Palaearctic grasslands: background of EDGG Field Workshops and the GrassPlot database;*

I. Dembicz: *Drivers of plant species richness patterns at different spatial scales and taxonomic levels – a case study from two Bulgarian mountains;*

D. Vynokurov: *Coenotic differentiation of the steppe and desert vegetation of the Republic of Kalmykia.*

Data analysis

Vascular plant specimens were taken to the University of Tuscia, where L. Cancellieri is coordinating a small team working on their identification during the winter. The Floristics Research Centre in Barisciano (Gran Sasso National Park), coordinated by F. Conti, will help with the identification of critical taxa. Bryophytes and lichens were sent to M. Aleffi (University of Camerino) and G. Potenza (University of Basilicata), respectively, who are currently working on their determination. Soil samples were transported to A. Vacca (University of Cagliari) for analysis.

Preliminary results

During the course of seven days of intensive fieldwork, we sampled 20 biodiversity plots, along with 57 additional normal plots (yielding a total dataset of 97 10-m^2 plots). Further-

Fig. 7. ***Entomologists at work adjacent to a biodiversity plot. Photo: L. Rosati.***

more, 12 10-m^2 plots within the biodiversity plots were resurveyed, so that pseudo-turnover assessment could be performed on ca. 12 % of the plots.

The vascular plant species with highest average cover included (in alphabetical order, as cover values have not been fully analysed yet): *Bromopsis erecta (=Bromus erectus), Carex caryophyllea, Festuca circummediterranea, Helictochloa praetutiana (=Avenula praetutiana), Koeleria splendens* and *Phleum hirsutum* subsp*. ambiguum* among graminoids; *Anthyllis vulneraria, Hippocrepis comosa* and *Medicago lupulina* for legumes; *Globularia meridionalis, Helianthemum* spp., *Helichrysum italicum* and *Satureja montana* as for chamaephytes.

While we are still busy with plant determination, a preliminary overview of vascular plant species richness (cryptogam species richness data are not reliable at this stage), based on the unrevised field notes, shows relatively high values (**Table 1**) when compared to other regions of the Palaearctic (Dengler et al. 2016a), almost approaching the richness values found during the 2014 expedition in Navarre, Spain (Biurrun et al. 2014).

Table 1. Preliminary vascular plant species richness data for the dry grasslands in the study region.

Plot size (m^2)	*n*	Mean	Min	Max
0.0001	40	2.7	0	6
0.001	40	4.6	0	10
0.01	40	8.9	1	18
0.1	40	18.6	9	30
1	40	31.6	19	46
10	97	49.5	25	79

Conclusions and outlook

Once the plant identification is completed, the data from the 10th EDGG Field Workshop will be used to produce at least two papers: one describing plant diversity patterns across the precipitation gradient and other environmental gradients of the study area, and another one on the relationship between species composition and environmental variables. Moreover, at least two additional research topics will be analyzed, such as the relationship between plant and insect patterns along the study gradient and the analysis of pseudo-turnover.

The data from this Workshop will be included in GrassPlot, the Database of Scale-Dependent Phytodiversity Patterns in Palaearctic Grasslands (Janišová et al. 2017) (formerly: *Database Species-Area Relationships in Palaearctic Grasslands*; GIVD ID EU-00-003; Dengler et al. 2012b). The inclusion of data in international databases will also allow future large-scale comparative studies and promote scientific networking between researchers.

The EDGG is continuing the expedition program and the next 11th Field Workshop will be held in Austria (6th – 13th July 2018), organized by M. Magnes (see a detailed call in this issue on pp. 12-25).

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Author contribution

The paper was written by GF and MGS, with substantial contributions by JD and IB. All authors contributed to the text editing. The appendix text was written by EB, NS and NT; they also selected the pictures for the photo diary, that were provided by the authors listed at the end of the appendix.

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Group photo of the 10th EDGG Field Workshop. Photo: M. Janišová.