EXPLORING LIFE FORMS
FOR LINKING ORTHOPTERAN ASSEMBLAGE
AND GRASSLAND PLANT COMMUNITY

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Abstract

Orthopterans are well known to represent the majority of insect biomass in many grassland ecosystems. However, the verification of a relationship between the traditional descriptors of orthopteran assemblage structure and plant community patterns is not straightforward. We explore the usefulness of the concept of life forms to provide insights on such ecosystem level relationship.

For this purpose, thirty sample sites in semi-natural calcareous grasslands were classified according to the relative proportion of dominant herbaceous plant life forms. Orthopteran species were grouped in four categories, based on the Bei-Bienko's life form categorization. The association among plant communities, orthopteran assemblages and environmental factors was tested by means of canonical correspondence analysis. *Orthoptera* groups were found to be associated with distinct plant communities, also indicating the effect of vegetation change on orthopteran assemblages. In particular, geobionta species were associated with all the most disturbed plant communities, while chortobionta and thamnobionta seemed to be dependent on better preserved grassland types. Therefore, the use of life forms could help informing on the relationships of orthopteran assemblages with grassland conservation state. Information on such community relationships at the local scale could also assist managers in the interpretation of habitat change maps in terms of biodiversity changes.

Keywords: functional group, grasshopper, habitat conservation, katydid, semi-natural grassland

Izvleček

Kobilice predstavljajo večino biomase žuželk v številnih travniških ekosistemih. Vendar povezava med tradicionalnimi opisi združb kobilic in rastlinskimi združbami ni enostavna. Raziskali smo uporabnost koncepta življenjskih oblik za proučevanje teh ekosistemskih odnosov. Za ta namen smo klasificirali trideset vzorčenih pol-naravnih karbonatnih travišč na podlagi deleža dominantnih življenjskih oblik zelišč. Vrste kobilic smo združili v štiri kategorije na podlagi kategorizacije življenjskih oblik po Bei-Bienko. Povezavo rastlinskih združb, vrstne sestave kobilic in okoljskih dejavnikov smo testirali z kanonično korespondenčno analizo. Skupine *Orthoptera* so se pojavljale v rastlinskih združbah in nakazovale tudi vpliv vegetacijskih sprememb na vrstno sestavo kobilic. Vrste giobiontov so se pojavljale v najbolj motenih rastlinskih združbah, medtem ko so hortobionti in tamnobionti bolj navezani na bolj ohranjene travišče tipe. Zaključimo lahko, da nam življenjske oblike lahko pomagajo povezati vrstno sestavo kobilic s naravovarstvenim statusom travišča. Informacija o teh odnosih v združbi na lokalni ravni lahko pomaga upravljavcem pri tolmačenju kart, ki prikazujejo spremembe v habitatnih tipih kot spremembe v biodiverziteti.

Ključne besede: funkcionalne skupine, kobilice, varstvo habitatov, prave cvrčalke, pol-naravna travišča.

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1. INTRODUCTION

As with most grasslands of Western Palaearctic region, Mediterranean basiphilous grasslands have developed through a mix of anthropogenic and natural processes, over long periods of grazing by domestic stock, cutting and deliberate light burning regimes (Suarez 1994, Turbé et al. 2010). Today, many of these ecosystems of high conservation value are threatened by a change of the land use that formerly created and maintained them, i.e. intensification, abandonment, afforestation, or transformation to arable fields (WallisDeVries et al. 2002, Öckinger et al. 2006, Molnár et al. 2008, Veen et al. 2009, Valkó et al. 2012, Vitasović Kosić et al. 2012). As a consequence, calcareous grasslands are earmarked for conservation and listed in Annex I of the European Habitats Directive (Council directive 92/43/EEC), and monitoring ecosystem change is required to assess the impact of conservation policies and the effectiveness of response measures within an adaptive management perspective (Ostermann 1998, Giarrizzo et al. 2015).

With reference to these issues, the use of indicators represents an efficient method to monitor changes that would be too costly or difficult to measure directly (Landres et al. 1988, Meffe & Carroll 1997). Indicators are particularly useful in complex ecosystems (Soulé 1985), as they may provide early warning of impacts and help monitor change over large temporal and spatial scales (Rapport 1992, Harris 1995).

Arthropods have been widely used as indicators for the monitoring of semi-natural ecosystems, primarily because they provide several significant ecosystem services, e.g. pollination, pest control, wildlife nutrition and dung decomposition (Losey & Vaughan 2006, Steffan-Dewenter & Westphal 2008), and their response to environmental change seem to be more rapid than those of vertebrate communities (Thomas et al. 2004).

Orthopterans, playing an essential role in grassland ecosystems and representing a pivotal element in trophic food webs, could be efficiently used for environmental monitoring (Henle et al. 1999, Maas et al. 2002). They can represent the bulk of the overall invertebrate biomass in the grass layer (Gangwere et al. 1997, Jamison et al. 2002, Whiles & Charlton 2006), readily responding to changes in habitat quantity (Baldi & Kisbenedek 1999) and traditional grazing activities (Batáry et al. 2007, Sorino et al. 2009, Weiss et al. 2013). Furthermore, they represent the main food resource for many other taxa, including endangered species of birds, reptiles and mammals (e.g. Kok & Louw 2000), and have been used as model organisms in multi-trophic models based on functional composition (Moretti et al. 2013).

Although orthopterans have been widely shown to be dependent on vegetation structure (Ryszkowski et al. 1993, Baldi & Kisbenedek 1997, Hochkirch et al. 2008, Weyer et al. 2012, Rácz et al. 2013) and plant species assemblages (Otte 1976, Evans 1988, Quinn et al. 1991, Filding & Brusven 1993), the verification of a relationship between orthopteran species assemblages and plant community patterns is not straightforward.

In this regard, the commonly used measures for the description of community structure, overall species richness and diversity, are increasingly being questioned in connection with their role as biodiversity surrogates, while functional groups are gaining momentum in supplying synoptic information on community structure and on species-environment relationship (McGill et al. 2006, Suding & Goldstein 2008). A number of ecosystem functions and processes, both in natural and managed ecosystems, may depend more on the functional role of species than on species composition (Hooper & Vitousek 1997, Díaz et al. 2007, Helsen et al. 2012, Paušič & Čarni 2012) and, in many cases, their functions ultimately rely on the interactions between primary producers and other trophic levels (Loreau et al. 2001, Kremen et al. 2007). Moreover, as environmental conditions could affect the distribution of both animals and plants in the same way, methods similar to those used for plants can be developed for interpreting the functional characteristics and changes of animal assemblages (Hodgson 1991).

For instance, the concept of life forms, as traditionally conceived for plants (Raunkiaer 1934), has been recently used to monitor habitat changes (Bunce et al. 2008) and global vegetation dynamics (McMahon et al. 2011). Life forms have also been meaningfully associated with metrics derived from remote sensing techniques (Kosmidou et al. 2014). Similarly, this concept has been suitably used for the categorization of orthopteran communities (Bei-Bienko 1950), thus providing potential cues for interpreting their relationship with plant community patterns.

Therefore, we explore the usefulness of orthopteran life forms to provide insights on the conservation status of protected plant communities, with

particular regard to perennial grassland type of the endemic alliance *Hippocrepido glaucae-Stipion austroitalicae* Forte & Terzi 2005 (class *Festuco-Brometea* Br.-Bl. & Tx. ex Br.-Bl. 1949, order *Scorzonero-Chrysopogonetalia* Horvatić et Horvat 1956).

This research complements the modelling strategy of the Biodiversity Multisource Monitoring System: from Space to Species (BIO SOS) project (FP7-SPA-2010-1-263435), a three-year research project aimed at developing a pre-operational system for cost- and time-effective monitoring of changes in the land cover and habitats, in order to investigate the impact of habitat fragmentation and transformation on plant and animal communities.

2. STUDY AREA

The study area is located in Southern Italy within the Natura 2000 Murgia Alta site (SCI/SPA IT9120007, according to Habitat Directive 92/43 and Bird Directive 147/2009), spanning over 125,880 ha and partly designated as a national park (D.P.R. 10/03/2004) (Figure 1).

The Alta Murgia plateau is characterized by a deep and compact platform of Cretaceous limestone and a typically sub-Mediterranean climate. The upper part of Alta Murgia is mainly covered by large areas of semi-natural grasslands (Forte et al. 2005), developed through a mix of anthropogenic and natural processes and mainly maintained by sheep grazing. Grasslands cover ~29,800 ha (24% of the total area of the Natura 2000 site) and represent what remains from the ~80,000 ha existing at the beginning of the 20th century (Boccaccio et al. 2012). Substantial losses of this ecosystem type have occurred between 1990 and 2000, mainly due to EU incentives promoting durum wheat production, contemporaneous to the enforcement of the 92/43/EEC directive.

Several dry grassland types occur in Alta Murgia and at least two habitat types listed in Habitat Directive 92/43/EEC, i.e. 62A0 Eastern sub-Mediterranean dry grasslands of the *Scor-*
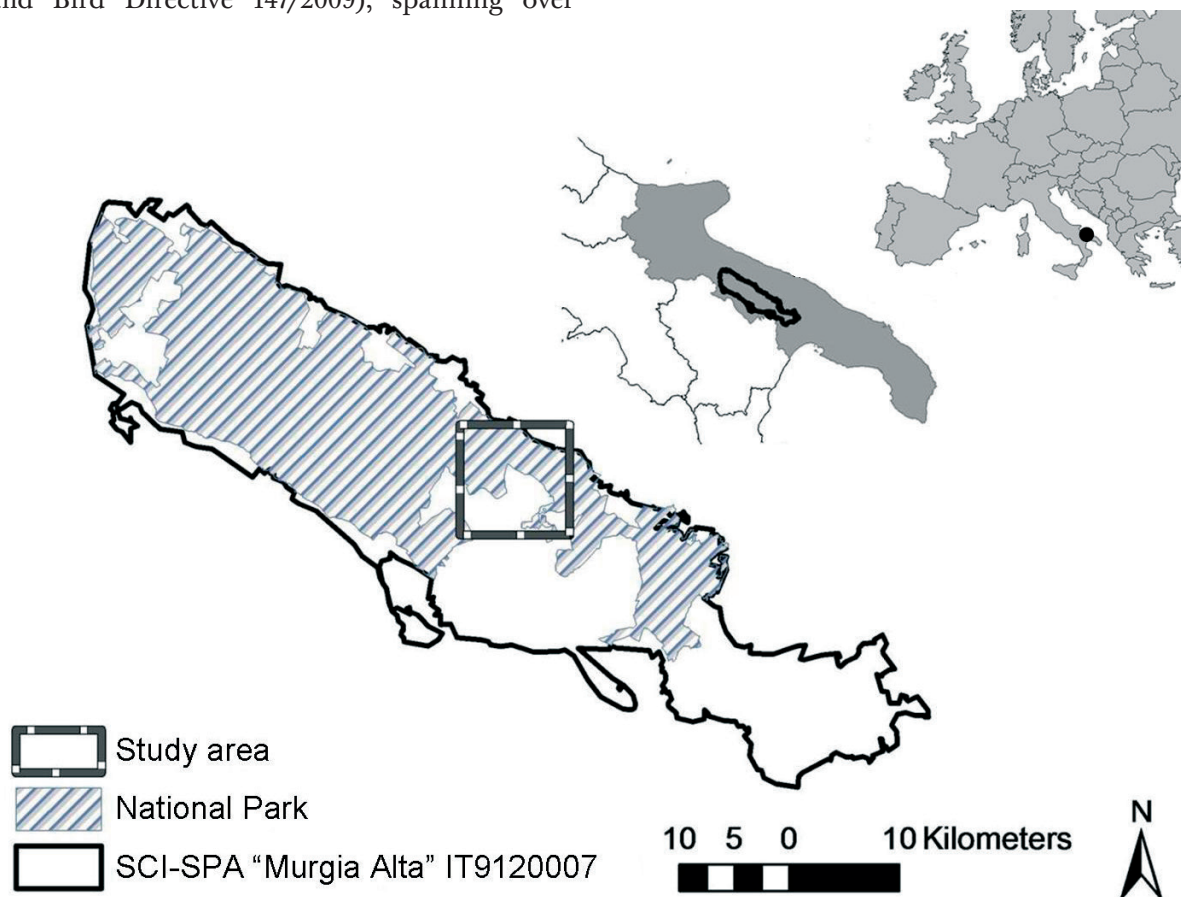

Figure 1: Map of the study region in the Natura 2000 site Murgia Alta IT9120007.
Slika 1: Zemljevid raziskovanega območja Murgia Alta IT9120007 v območju Natura 2000.

Study area
National Park
SCI-SPA "Murgia Alta" IT9120007

10 5 0   10 Kilometers

N

zoneratalia villosae and 6220* Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*, are associated with semi-natural dry grasslands. The majority of protected invertebrates of Alta Murgia, including the orthopterans *Saga pedo* (Pallas), *Decticus loudoni* Ramme, *Pterolepis japygia* La Greca and *Prionotropis appula* (Costa), mainly depend on grasslands and are of particular interest due to their biogeographical peculiarities (La Greca 1959, Labadessa 2014). Moreover, *Orthoptera* are known to have a key role in Alta Murgia grassland ecosystems, especially considering their primary value as food resource for the globally threatened lesser kestrel (*Falco naumanni* Fleischer), whose local population represents the most important in Italy and amongst the largest in Europe. The occurrence of endemic plant communities, as well as several threatened plant and animal species, highlight the necessity of implementing conservation actions in this area.

3. SAMPLING METHODS AND ANALYSES

A stratified random sampling within a regular standard grid (Directive 2007/2/EC, INSPIRE 2010) was applied according to the protocols of the BIO SOS project (Mairota et al. 2013). A set of thirty linear 80x5 m transects was selected within the same number of grassland patches, representative of different degrees of habitat fragmentation and landscape matrix types (Mairota et al. 2013).

Cover values (%) of herbaceous plant species, overall grass layer, rocks and bare soil were visually estimated along transects. Grass height (cm) was recorded as mean height of the grass layer, and slope angle (0°–90°) was measured with a hand-held clinometer.

Plant species were categorised according to life form classification *sensu* Raunkiaer (1943). This information was also used to compute the forb/grass ratio, as a proportion of the cover of leafy species (forbs) to graminoid species (grasses).

The 30 sites were classified by means of hierarchical clustering in order to identify the main plant community types. The clustering was based on the relative proportion of dominant plant life form cover values (overall representing more than 80% of soil cover) using unweighted pair-group method with arithmetic mean (UPGMA) (Sokal & Michener 1958).

Adult grasshoppers and katydids (*Orthoptera*: *Acridoidea* and *Tettigonioidea*) were caught along the thirty linear transects using a butterfly-net (Pollard 1979), then identified and released. Due to the necessity of implementing a quick and easily replicable sampling methodology, quantitative data of *Calliptamus barbarus barbarus* (O.G. Costa) and *Calliptamus italicus* (Linnaeus) were merged under the heading *Calliptamus* spp., as the correct identification of these two similar species would have needed careful examination (Labadessa 2014). The number of individuals per plot was thus estimated, consisting of the maximum number of observations found during sampling replicates. Overall number of individuals (abundance, N), number of species (species richness, S), and species diversity (Shannon's index, H') were then computed for each plot. Surveys were repeated every two weeks (12 sampling sessions) from March to September 2012, with adult orthopterans mainly observed during summer (June – September) (Labadessa 2014). All orthopteran species were then grouped in four categories based on Bei-Bienko's (1950) life forms, i.e. thamnobionta, chortobionta, geo-chortobionta, geobionta. Such life form categories are based on the behavioural specialization for a grassland structural layer, respectively, on grassland canopy, grass stems, grass/soil interface and soil/rock surface. Species richness, abundance and Shannon's diversity were computed for each group.

Canonical correspondence analyses (CCA) was used to provide a simultaneous ordination of variables referred to life form assemblages and the sample sites, in function of environmental parameters. The selected orthopteran life form groups were used as left variable set (response variables), the thirty sites as objects, the environmental variables (slope, grass height and cover, rocks and bare soil cover, forb/grass ratio) as right variable set. A symmetric weighting option ($\alpha = 0.5$) was applied to CCA. Analyses were performed in SYN-TAX 2000 (Podani 2001).

In order to underline the site characteristics, the 30 sites plotted in the ordination graphs were then labelled according to the plant community types resulting from plant life form clustering.

5. RESULTS

A remarkable variation in plant community assemblage and species richness, overall consisting

of 329 vascular plant species, was recorded from the sample sites. However, the distribution of plant species richness (S_{mean} = 102.83 ± 18.45) and diversity (H'_{mean} = 2.43 ± 0.46) were neither sufficient to provide a clear identification of plant communities nor to define the conservation status of sampled grasslands.

Hierarchical clustering was effective in providing a community classification of sampled sites in four main clusters. This was based on the relative cover values of five dominant life form categories, i.e. caespitose hemicryptophytes (perennial grasses), caespitose therophytes (annual grasses), rhizomatous geophytes and leafy biennials/therophytes (short-lived dicots), that represented over 85% of herbaceous cover within the sampled grasslands. The proportion of selected life form categories within each community cluster is shown in Figure 2.

Cluster a (9 plots) includes those communities showing the highest proportion of hemicryptophytic grasses (i.e. due to *Stipa austroitalica* Martinovsky and *Festuca circummediterranea* Patzke) and chamaephytes (*Euphorbia spinosa* L., *Satureja montana* L.). These represent the better-preserved rocky grassland type, belonging to the alliance *Hippocrepido glaucae-Stipion austroitalicae* Forte & Terzi 2005 and referred to the association *Acino suaveolentis-Stipetum austroitalicae* Forte & Terzi
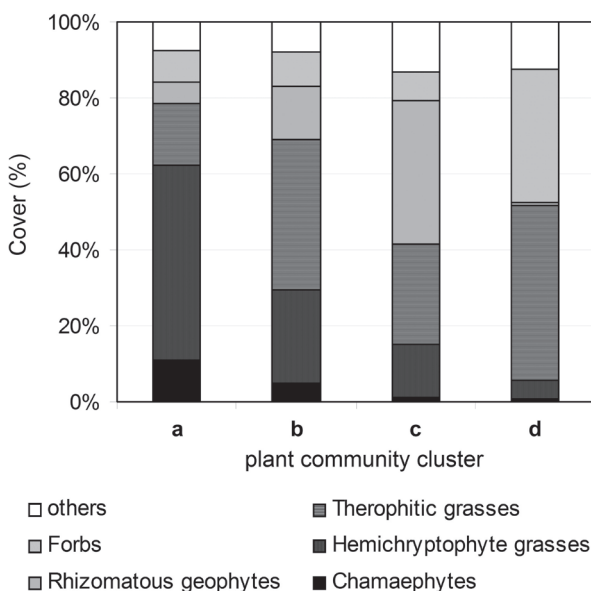
2005 for the area of Alta Murgia (Forte et al. 2005). Cluster b (11 plots) includes a number of therophitic or mixed therophitic-hemicryophytic grass communities, generally dominated by *Dasypyrum villosum* (L.) P. Candargy, non Borbás with a minor contribution of *S. austroitalica*, which could be determined by both natural meso-climatic or human induced factors. Communities in cluster c (6 plots) are largely dominated by the rhizomatous geophyte *Asphodelus ramosus* L., with high percentage of annual grasses (mainly *Dasypyrum villosum* or *Trachynia distachya* (L.) Link.), thus indicating increased grazing activity or high burning frequency. Cluster d (4 plots) shows a higher proportion of biennial and annual forbs, and includes different sub-nitrophilic and nitrophilic communities determined by severe human disturbance (e.g. frequent mowing, plowing or burning).

Therefore, the four plant community clusters seemingly represent different stages along a gradient of alteration of the focal grassland type.

Overall 31 species of Orthoptera were recorded in the sample sites, with *Calliptamus* species (365 individuals), *Tylopsis liliifolia* (Fabricius) (168 ind.) and *Euchorthippus declivus* (Brisout de
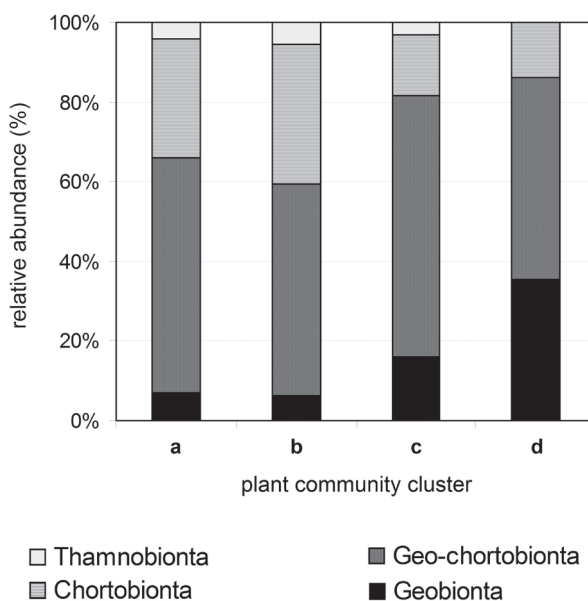

Figure 2: Distribution of plant life form cover values (%) among plant community clusters a-d.
Slika 2: Porazdelitev pokrovnosti (%) življenjskih oblik med klastri (a-d) rastlinskih združb.

Figure 3: Distribution of relative abundance (%) of orthopteran life forms (thamnobionta = grass canopy; chortobionta = grass stems; geo-chortobionta = grass/soil interface; geobionta = soil/rocks) among plant community clusters a-d.
Slika 3: Porazdelitev relativne abundance (%) življenjskih oblik kobilic (tamnobionti = plast trav; hortobionti=stebla trav; geo-hortobionti = stik trave in tal; geobionti = tla/kamnina) med klastri (a-d) rastlinskih združb.

Barneville) (147 ind.) among the most abundant and frequent. Values of species richness (S_{mean} = 10.33 ± 3.14) and Shannon's diversity (H'_{mean} = 1.90 ± 0.31) were rather constant among sites, showing significant mutual correlation (r (28) = 0.83, p < 0.001). With the exception of the two most degraded grassland plots (sites 10, 14) included in plant community cluster d and showing a minimum of orthopteran species richness (S = 4), overall richness and diversity indices were not sufficient to distinguish orthopteran assemblages and to provide a relationship with a particular plant community type.

Preliminary cues on the relationships with vegetation structure can be gained by observing the distribution of orthopteran life form categories along plant community clusters (Figure 3).

In particular, a higher percentage of thamnobionta and chortobionta, that are supposed to be associated with better structured and taller vegetations, was found in clusters a and b, while the proportion of geobionta clearly increases in most degraded plant communities c and d.

In order to investigate the association with site environmental conditions, the four orthopteran life forms were tested as response variables by means of canonical correspondence analyses (CCA).

The canonical correspondence analyses (CCA), with sampling sites as objects and environmental parameters (rock cover, slope, grass cover and height, bare soil cover) as covariates, allows the quantification of such a relationship (Table 1).

A strong association of orthopteran life forms with the first two ordination axes is shown (explaining over 95% of variance), along with a distinct ordination of sites as a function of environmental variables. In order to match this ordination with the plant community classification, sites in the graph were labelled according to their respective plant community cluster (a, b, c, d) (Figure 4).
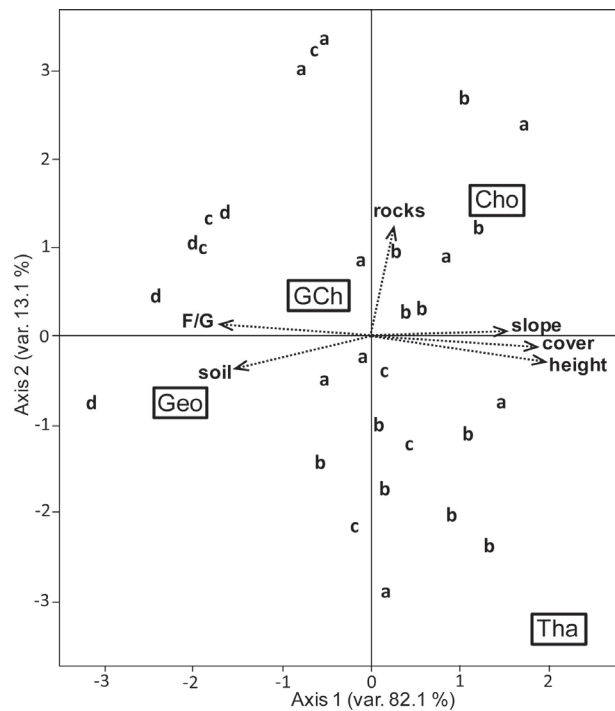

Figure 4: Triplot of the first two CCA axes (symmetric weighting α = 0.5) of orthopteran life forms (boxes: Tha = thamnobionta; Cho = chortobionta; GCh = geo-chortobionta; Geo = geobionta) and the thirty sites, ordinated by environmental variables (arrows). Sites are labelled by plant community cluster (a-d).
Slika 4: Graf prvih dveh CCA osi (simetrično uteževanje α = 0.5) življenjskih oblik kobilic (škatle: Tha = tamnobionti; Cho = hortobionti; GCh = geo-hortobionti; Geo = geobionti) in trideset vzorčnih mest razporejenih glede na okoljske dejavnike (puščice). Vzorčna mesta so označena s klastri rastlinskih združb (a-d).

The primary axis, alone representing over 80% of explained variance, seems to describe a gradient of decreasing grazing pressure, as indicated by grass cover and height, the forb/grass ratio (F/G) and the bare soil cover. Among orthopterans, geobionta (Geo) were strongly associated with higher values of bare soil and forb cover,

Table 1: Summary of the CCA ordination of orthopteran life forms. Symmetrical weighting (α = 0.5).
Tabela 1: Povzetek CCA ordinacije življenjskih oblik kobilic. Simetrično uteževanje α = 0.5.

	AXIS 1	AXIS 2	AXIS 3	AXIS 4	AXIS 5
Eigenvalues (variance explained for left set by canonical axes from right set)	0.027	0.004	0.002	0.000	0.000
Cumulative percentage variance of inter-set relation	82.112	95.212	100.000	100.000	100.000
Between-set correlations	0.662	0.337	0.423	-0.079	0.069

which also indicated the most disturbed plant communities (cluster d). With the exception of geo-chortobionta (GCh), mainly including generalist species, the other orthopteran categories showed positive association with the first axis. Moreover, the relationship of chortobionta (Cho) with the secondary axis, which seems to be determined by soil rockiness, and thus with better preserved rocky grasslands of cluster a, further supports the explanatory value of this analysis.

5. DISCUSSION AND CONCLUSIONS

Analyses based on overall indices of species richness and diversity, for both plant and orthopteran assemblages, were not appropriate to describe the patch quality in grasslands of conservation concern. Conversely, vegetation clusters derived from hierarchical classification of plant life form assemblages seem to fit a gradient of disturbance, with regard to the considered grassland type. The use of plant life forms provides valuable insights into the major drivers of communities and species assemblages (e.g. environmental and anthropogenic conditions). This is in accordance with the tenet that a number of ecosystem functions and processes may depend more on the functional role of species than on species composition (Helsen et al. 2012).

Orthopteran life forms (Bei-Bienko 1950) showed associations with plant life form assemblages, in agreement with Morecroft et al. (2009) findings regarding the relationships between animal functional groups and plant community variables. This result demonstrates the influence of herbaceous vegetation changes, especially those driven by a change in human pressure, in shaping orthopteran assemblages. In particular, geobionta species were associated with all the most disturbed plant communities, occurring in overgrazed and nitrophilic conditions. This suggests that changes in the relative abundance of geobionta may be used to locally interpret the effects of environmental and land use changes, in line with research demonstrating that organismal functional traits are one of the key controls on ecosystem properties (Casanoves et al. 2011, Pla et al. 2012). In contrast, thamnobionta and chortobionta seemed to be dependent on relatively better preserved grassland types. Chortobionta, in particular were mainly associated with most of the plant communities dominated by peren-nial grasses and chamaephytes, corresponding to rocky grasslands of high conservation value.

From an analytical perspective, the use of life forms allowed for the considerable reduction of the number of variables, often required in multivariate analysis and as, in several cases, ecosystem responses are maximized with very few variables (e.g., Haggar & Ewel 1997, Hiremath & Ewel 2001).

Therefore, the use of life forms could help informing on the relationships between orthopteran assemblages and grassland conservation state, also assisting managers in the interpretation of habitat change maps in terms of biodiversity changes.

These findings are challenging for future ecological studies, demonstrating the potential value of life form classification to inform on the role of orthopterans within communities and ecosystems, and providing inferences about grassland structure. The proposed approach may also provide a cost-efficient method to monitor the conservation state of protected semi-natural grasslands ecosystems, which is required given their complexity (Soulé 1985, Landres et al. 1988, Meffe & Carroll 1997). Monitoring change over large temporal and spatial scales is indeed a prerequisite for conserving biodiversity, fulfilling the need for effective response measures within an adaptive management perspective (Rapport 1992, Harris 1995, Loreau et al. 2001).

6. ACKNOWLEDGEMENTS

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