Pak. J. Bot., 48(2): 551-560, 2016.

DISTRIBUTION, SPECIES DIVERSITY AND COMPOSITION OF PLANT COMMUNITIES IN RELATION TO VARIOUS AFFECTING FACTORS IN AN ALPINE GRASSLAND AT BANDIPORA, KASHMIR

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Abstract

This study provides a broad understanding of vascular plant richness and community structure of mountain grassland (Matri) at Bandipora, Kashmir and links it various environmental variables. Employing a stratified sampling design, six sites were selected wherein vegetation was sampled by placing quadrats (n=210). Elucidating an important effect of topography and anthropic pressure, numerical classification –TWINSPAN segregated the quadrats into seven community types. Contrary to species rich communities which showed an explicit composition and localized distribution, the other communities depicted a vague composition and stretched unevenly between the lower and middle altitudes. Using canonical correspondence analysis (CCA), elevation and disturbance were found as most influencing factors whereas steepness of slope, organic carbon, soil reaction (pH) and soil salinity (electrical conductivity) were other important factors. Indices of diversity measured at two measurement scales varied differently between communities and at a macro scale (site level) highest values were recorded in least disturbed communities. However, on a micro scale (quadrat level) the indices behaved differently. For effective conservation of these species rich grasslands, acknowledging the local level variability in vegetation structure is all but crucial.

Key words: Distribution, Species diversity, Community structure, Canonical correspondence.

Introduction

Mountain vegetation has long remained a significant focus in ecological investigations primarily because its gradational patterns not only provide information about summarizing past environmental conditions but it also is crucial in envisaging a probable future outlook for mountain ecosystems (Wang *et al.,* 2002). The recognition and definition of plant communities in mountains represents an important link in understanding an interaction between vegetation and biotic and abiotic environmental variables (Mucina, 1997). The analysis of this species-environment relationship has always been a central issue in community ecology and thus with an aim to interpret the data related to this relationship and generate and test hypothesis about communities, much effort has gone to develop the multivariate techniques (Gauch, 1982). Of these techniques, the classification and ordination are treated as important approaches. These approaches have both emphasized the dominance of few key species and showed up many other indicator species that exhibit a strong fidelity to certain habitat types.

Kashmir Himalayan grasslands locally called as Bahks/Margs are an important mark and a unique heritage in Jammu and Kashmir and on account of their species rich and taxonomically diverse flora; ecological services and scenic beauty represent an important ecosystem (Rao & Casimir, 1985). These ecosystems also serve as summer pastures for nomadic communities and act as their material and cultural basis which endow these ecosystems with a high conservation value not only in them but also as part of fading cultural landscape (Dad & Khan, 2011). With most of earlier investigations being qualitative floral accounts and no emphasis placed on explicating various influencing factors, the structural and functional attributes of these grasslands have largely remained understudied. With this perspective, we studied mountain grassland in Kashmir valley with a purpose to classify its vegetation into different communities and link their distribution to various topographic and edaphic factors.

Materials and Methods

Study area: The study was conducted at Matri (34°30´N & 74°46´E) - a high altitude grassland at Bandipora, Kashmir. Enroute to higher alpine grasslands of adjacent Gurez Valley, the area stretches between 3100-3550 m (a.s.l) and during summer months acts as a main grazing base for the livestock of various nomadic communities of both nearby and far off places. In its immediate periphery, the forest mostly grows *Pinus wallichiana* and *P. roxburghiana* on drier slopes while *Cedrus deodar*a occurs sparsely. Atop the grassland few pine trees are also present, possibly the remnant of an old forest patch. Climate is temperate with four usual seasons albeit no climatic records are available for the area. Brown Bear (*Ursus arctos)*, Himalayan Black Bear (*Selenarctos thibetanus*) and common leopard (*Panthera pardus*) are its notable wildlife.

Data collection: Corresponding with peak growing season, vegetation sampling was carried at six sites. Since the sole objective was to describe the community composition of main grassland, herbaceous flora of surrounding forest was merely recorded but excluded in analysis. In total 210 quadrats were sampled whose size (0.50×0.50 m for herbs and 5×5m for shrubby patches) and number (n=35) was determined with species area curve (Misra, 1968). Within each quadrat, plant species were collected and their number and cover (%) recorded and used for analysis. Notes on habitat characteristics included geo-referenced position, aspect, slope and anthropic disturbance (quantified by primarily on percentage of unpalatable species at a site; presence and number of tracks and trails (human and animal) at a site; percent of exposed soil or bare earth due to trampling and distance of site from camping location of herdsmen.From each stand a composite soil sample from top 50cm was collected and subjected to chemical analysis. Moisture content was determined gravimetrically while soil reaction (pH), salt level (electrical conductivity) and organic carbon were determined following standard procedure (Gupta, 1999).

Data analysis: Data was pooled and resulting species by sample matrix was subjected to numerical classification using TWINSPAN (Hill, 1979). The vegetation units (here after referred to as communities) were named based on the occurrence and abundance of indicator species which occurred predominantly on one axis of ordination. To overcome the variance of abundance data, it was first transformed to percentages and then cut levels were selected (n=5) to chose pseudo species. The divisions were restricted to five because cluster obtained thereafter was too difficult for reliable ecological interpretation. Detrended Correspondence Analysis (DCA) as included in CANOCO package 4.5 (ter Braak & Smilauer, 2002) was applied to confirm the existence of different units and assess the floristic association between them. Direct gradient analysis using canonical correspondence analysis (CCA) was used to study the relationship between species composition and measured environmental variables. Owing to the presence of many rare species with very low abundance, the option 'down weighting of rare species' was used. Significance of the axes was tested with a Monte Carlo permutation procedure, as included in the CANOCO package. The variables used in CCA were coded as MOIS= soil moisture; pH= soil acidity; COND= soil conductivity; NITR= total soil nitrogen; OCAR= soil organic carbon; SLOP = degree of slope; ALTI= altitude (m) and DIST= anthropogenic disturbance. Diversity indices for communities were calculated using a) observed species richness (S- determined as total number of species recorded b) Shannon-Wiener diversity ($H' = -\sum p_i \ln p_i$, where p_i is the proportion of individuals of *i*th species and c) species evenness (E- calculated by using Hurlbert's Probability of Interspecific Encounter, PIE). All calculations were run at default levels by using EcoSim 7.0 (Goteli & Entsminger, 2003). The data were also examined using SHE (SHE: S = richness, H = *H´* diversity, E = evenness) analysis (Hayek & Buzas, 1998). Results were examined graphically to evaluate relationships among diversity measures from a single quadrat (micro-scale) to cumulative measure of community (macro-scale) across all vegetation units.

Results

Floristic composition and soil properties: At an average of 6.93±1.26 species per quadrat, 88 vascular plant species including a fern *Osmunda claytoniana* L. belonging to 35 families and 70 genera were recorded from the study area. Asteraceae was the most speciose family represented by 15 species followed by Lamiaceae (8 spp), Polygonaceae (5 spp) and Boraginaceae (4 spp) while Brassicaceae, Caprifoliaceae, Paplionaceae, Plantaginaceae, Rosaceae, Ranunculaceae and Scrophulariaceae are all represented by three species each. With a ratio of 3.71:1, 7.5:1 and 9.75:1 between dicotyledon and monocotyledon families, genera and species respectively, the vegetation was predominately dicotyledonous.

As shown by the site based rarefaction curve results (Fig. 1), almost an asymptote was achieved across all sites which supplement the objective of comparing different plant communities by holding the adequacy of sampling effort. Across all sites, soil was acidic (4.62 to 5.2) while moisture level and electrical conductivity also differed greatly and ranged between 11.35 to 54.84% and $0.14 \mu Scm^{-1}$ and $0.96 \mu Scm^{-1}$ respectively. The differences in soil properties were found statistically significant across comparisons with altitude and slope ($p<0.05$).

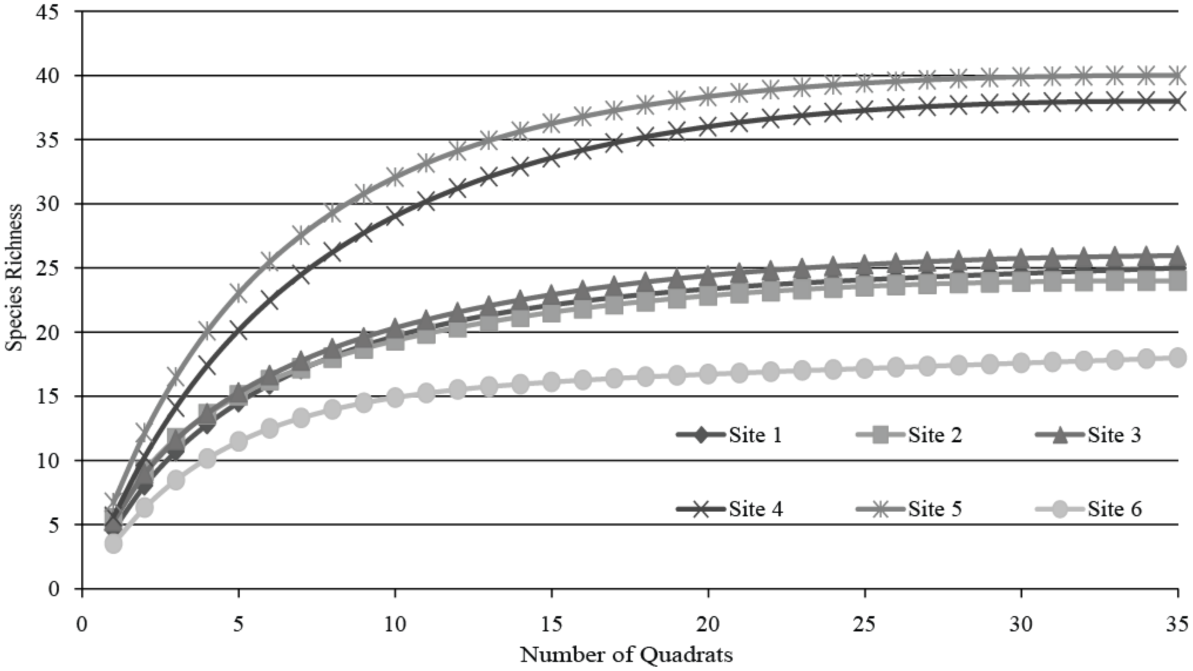

Fig. 1. Rarefaction curves for the six sites at Matri, Bandipora.

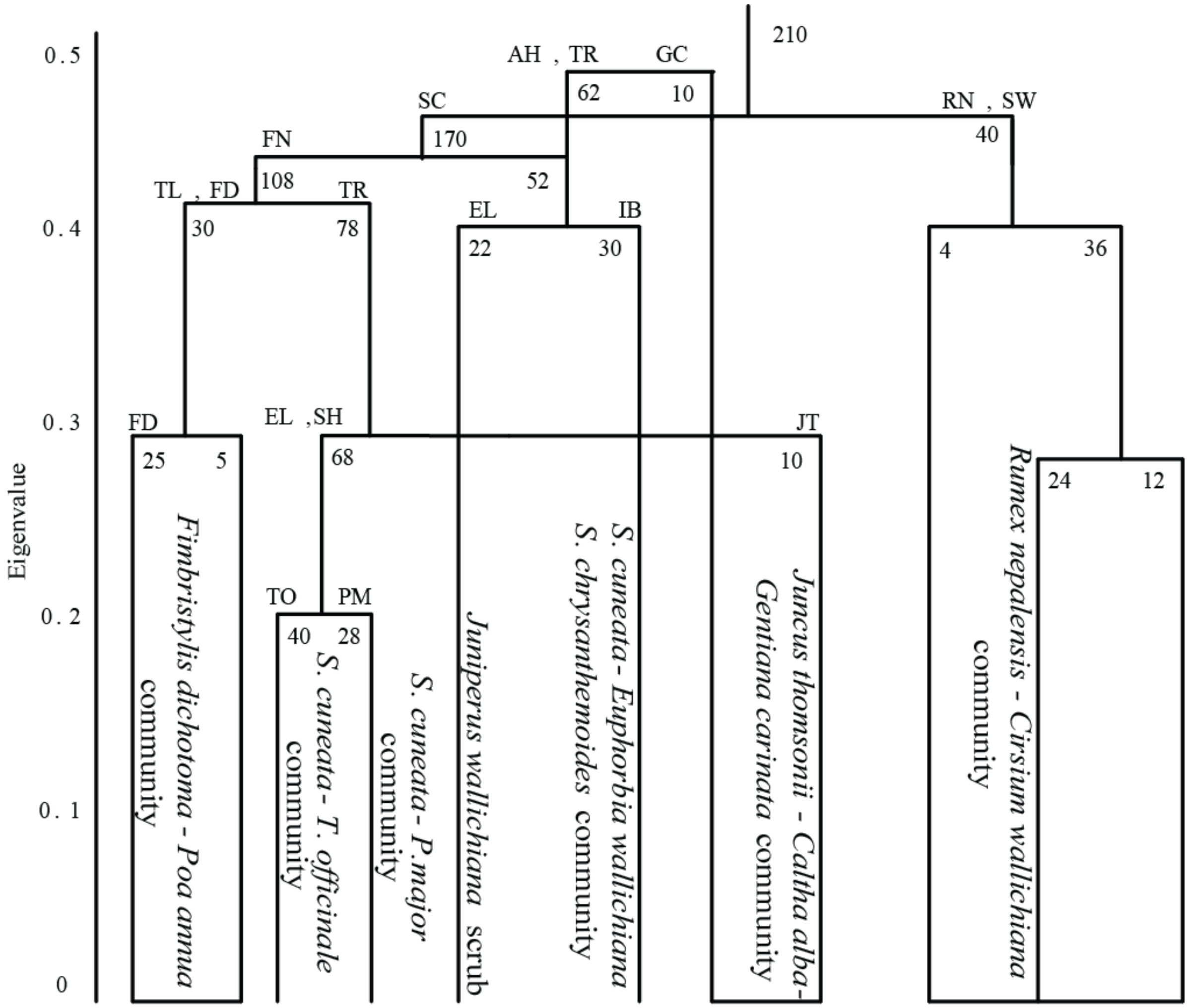

Fig. 2. TWINSPAN classification of sampling quadrats at Matri, Bandipora. Indicator species for each division, wherever they occur, are indicated by following abbreviations. AH=*Arabidopsis himaliaca,* EL=*Epilobium laxum*, FD=*Fimbristylis dichotoma*, FR=*Frageria nubicola*, GC=*Gentiana carinata*, IB=*Impatiens brachycentra*, JT=*Juncus thomsonii*, PM=*Plantago major*, RN=*Rumex nepalensis*, SC= *Sibbaldia cuneata*, SH=*Salvia hians*, SW=*Sambucus wightiana*, TL=*Thymus linearis*, TO=*Taraxicum officinale* & TR= ***Trifolium repens.*** Numbers of quadrats in a community are also indicated.

Vegetation classification: At first TWINSPAN division (λ = 0.465) quadrats characteristic of heavily disturbed surfaces and slopes were separated; suggesting that the initial division was essentially a classification of noxious vascular plants. Altitude was more crucial for second split (λ = 0.445) with plots separating into two main types; one characteristic of middle altitudes and other confined mostly to higher altitudes. Th next three divisions were based mostly on substrate character (dry vs. moist, stable vs. unstable), vegetation type (shrub vs. herbaceous) and slope steepness (gentle vs. steep). However, further onwards ($\lambda < 0.2$) vegetation was homogenous in as much as having wide representation of only a handful species and so classification was stopped. Based on these five splitting steps, 210 quadrats were divided into eleven TWINSPAN groups (Fig. 2) that represented seven communities. These communities differed in terms of distribution, structure and richness. A brief description about these communities is given under:

A. *Rumex – Cirsium* community: Separating on first split, this community persists almost exclusively at lower altitudes around camping sites and other heavily disturbed surfaces and slopes. *Rumex nepalensis* Spreng is the most dominant species while *Conyza canadensis* (L) Cronquist, *Polygonum aviculare* L. and *Malva neglecta* Wall are other important associates. A dense intermix of *Cirsium wallichii* DC and *C. falconeri* (Hook f.) Petrak is an important variant of this community. Due to its spiny morphology and presence of few poisonous species like *Urtica dioca* L, the community ranks low to livestock.

B. *Fimbristylis – Poa* community: With a fair coverage area (n=30), this community grows mostly on abandoned camping sites, animal resting places and flock paths at altitudes well below 3200 m. Being a known weedy species *Fimbristylis dichotoma* Vahl forms long colonies with *Poa annua* L. while *Cerastium cerastoides* (L.) Britton and *Cyanoglossum glochidiatum* Wall.ex Benth are other important species.

C. *Juncus- Caltha- Gentiana* community: Growing mostly on moistened soil surfaces, stream routes and areas with high seasonal surface moisture, this community with a relatively lesser coverage (n= 20) spans broad (3200-3400 m). Profuse abundance of *Juncus thomsonii* Buchen and *Gentiana carinata* Griseb with *Veronica beccabunga* L., *Caltha alba* Camb and *Swertia petiolata* D.Don being other frequent associates is an important feature of this community.

D. *Sibbaldia- Taraxacum* community: Established mostly on rolling landmasses and smooth surfaces, this community appears as a dense mat due to *Sibbaldia cuneata* Kunze which grows too close to ground. From grazing standpoint, this community is particularly important because a) it is grazed for longer periods b) has a high coverage (n=40) and c) grows many palatable species like *Taraxacum officinale* Webber and *Trifolium repens* L. On flatter surfaces with stable substrate, *Eremurus himalaicus* Baker and *Senecio jacquemontianus* Decne form a distinct sub unit which also acts as good forage.

E. *Sibbaldia- Plantago* community: On a broader scale with an almost similar floristic composition, this community is strongly related to preceding unit and forms an indistinguishable association with it. However in having an abundance of *Plantago major* L. and *P. ovata* Forssk it appears different while the perennial monocotyledon *Iris hookeriana* Foster gives it a more vivid appearance. Together with *Sibbaldia- Taraxacum* community, it is prevalent at middle altitudes and owing to its coverage forms an important component of grassland vegetation.

F. *Sibbaldia- Euphorbia- Senecio* community: This community is found predominantly on human tracks and trails and surfaces that receive grazers for relatively longer period. Long mats of *S. cuneata* interspersed with perennial clumps of *Euphorbia wallichii* Hook and scattered *Senecio chrysanthemoides* DC is its general outline. The overall habitat is generally free from rock, boulder, stony slopes and substrate but whatever is available, is occupied mostly by shrubby *Rosa webbiana* Wallich ex Royle and *Artemisia roxburghiana* Wall that grow quite common towards rocky unstable slopes and coarse boulders. *Geranium pratense* L, *Lathyrus himalensis* Camb, *Salvia hians* Royle ex Benth and *Ranunculus hirtellus* Royle are important herbaceous associates.

G. *Juniperus* scrub community: Growing in an erratic fashion across the whole elevational length, this community grows gregariously on sunny slopes and other drier surfaces where soil is hard and compact. Being evergreen and prostrate in habitat, *Juniperus walichiana* forms large dense patches with *Trillium govanianum* Wall ex Royle, *Epilobium laxum* Royle, *Polygonum alpinum* All, *Heracleum candicans* Wall ex DC and *Rheum webbianum* Royle being other conspicuous species found in and around these patches. A brief conspectus of these community types is provided in Table 1.

Table 1. Summary of seven plant communities at Matri, Bandipora.

Name of community	***Rumex nepalensis Cirsium wallichii* community**	***Fimbristyllis dichotoma Poa annua* community**	***Juncus thomsonii Gentiana carinata* community**	***Sibbaldia cunneata Taraxacum officinale* community**	***Sibbaldia cunneata Plantago major* community**	***S. cuneata- Euphorbia wallichii- S. chrysanthemoides* community**	***Juniperus wallichiana scrub***
Type	1	2	3	4	5	6	7
Dominant & Characteristic species	*Rumex nepalensis* *Cirsium wallichii* *Sambucus wightiana*	*Fimbristyllis dichotoma* *Poa annua* *Cyanoglossum glochidiatum* *Cerastium trigynum*	*Juncus thomsonii* *Gentiana carinata* *Swertia petiolata*	*Sibbaldia cuneata* *Trifolium repens*	*Sibbaldia cuneata* *Plantago major*	*Euphorbia wallichii* *Senecio chrysanthemoides*	*Juniperus wallichiana* *Bergenia ciliata*
Important species	--------	--------	*Caltha alba*	-------	*Iris hookeriana*	*Lathyrus himalensis* *Artemisia roxburghiana*	*Trillium govanianum* *Podophyllum hexandrum* *Rheum webbianum*
Habitat	Flatland and surfaces adjacent to camping sites	Abandoned camping sites, animal resting places.	Mesic habitats close to moisture laden surfaces	Undulating and rolling landmasses and surfaces	Rolling land surfaces	Surfaces free from rock substrate	Relatively steep slope across a wide altitudinal gradient
Variant, if any	*C. falconeri-C. wallichii*	--------	---------	*Eremurus himalaicus- Senecio jacquemontianus*	--------	--------	--------
No. of plots	40	30	20	40	28	30	22
Comments, if any	Major nitrophilic community	Expected to increase coverage	Wide altitudinal distribution	Important for livestock	Good feed value	Lone rush community	Important from biodiversity perspective

Table 2. Species diversity (*H'*) and richness (S) and Evenness (PIE) of seven communities at Matri, Bandipora.

Type†	Macro level			Micro level		
	H'	PIE	S	Avg. *H'*	Avg. PIE	Avg. S
1	1.53	0.67	37	0.92	0.47	5.27
2	2.02	0.77	36	1.37	0.65	7.64
3	2.23	0.81	37	1.17	0.57	5.88
4	1.87	0.74	37	1.19	0.58	7.01
5	2.25	0.85	52	1.13	0.56	5.80
6	2.20	0.80	36	1.57	0.68	9.45
7	2.33	0.79	42	1.37	0.66	6.42

† See text for the types

Patterns of species richness and diversity: Diversity indices were calculated from a single quadrat (micro-scale) to whole community (macro-scale) and abbreviated as-S_{avg} (average richness), H'_{avg} (average diversity) and E_{avg} (average evenness). This not only helped to understand differences at a micro level but as number of quadrats forming a community differed, it was also addressed. Across communities, *Juniperus* dominated scrub and *Sibbaldia- Euphorbia- Senecio* community were highly diverse (H'=2.33 & 2.25 respectively) while noxious *Rumex–Cirsium* community was least diverse (Table 2). Considering species richness, while *Sibbaldia- Euphorbia- Senecio* community *and Juniperus* scrub recorded the highest richness (S=52 & 42 respectively), *Rumex–Cirsium* community was equally important (S=37). On a micro-scale, differences were more evident and species poor *Juncus-Gentiana* and *Fimbristylis–Poa* community (Table 2) recorded the highest average richness (S_{avg}=9.45±3.92 & 7.64±1.81 respectively) while *Rumex- Cirsium* community was least rich (S_{avg}=5.27±1.73). The other indices (E_{avg} and H'_{avg}) also behaved similarly. The results of variance (ANOVA) showed that across communities, observed differences were statistically significant between richness- S_{avg} (F= 3.88, F_{crit} = 1.23 and $p<0.01$), evenness - E_{avg} (F= 9.64, F_{crit} =1.23 and $p<0.01$) and diversity- H'_{avg} (F= 8.99, F_{crit}= 1.22 and $p<0.01$).

The SHE analysis curves showing differences in diversity indices between different communities is shown in Fig. 3. Unlike *Juncus-Gentiana* community wherein ln (S) curve did not level off because of continued species accumulation, other communities recorded an initial rapid species accumulation while few additional species were added during later stage which leveled the ln (S) curve (Fig. 3). SHE analysis curves also showed that across communities, the cumulative ln (E)/ln(S) curve followed a random pattern, suggesting that each community was not best fit by a log normal species abundance distribution. This was evident particularly for the weedy *F. dichotoma* dominated community.

Ordination of plant communities: The ordination analysis carried by using DCA (Detrended Correspondance Analysis) effectively separated seven community types and thus supported the decisiveness of TWINSPAN in separating vegetation data (Fig. 4). The results showed that communities were located along a major compositional gradient although some overlapping was also apparent. With an eigenvalue of 0.680, the first DCA axis explained 25.27% of total data variance and separated communities according to a combination of surface substrate, slope steepness and shrub cover. Consistent with TWINSPAN results the second axis with an eigenvalue of 0.430 and explaining 16.27% data variance, separated communities on anthropic disturbance and altitude. As shown in Fig. 4, the noxious *Rumex-Cirsium* community persisting on disturbed surfaces forms tight clusters as against *Juncus-Gentiana* community which stretching across a broad altitudinal gradient spreads unevenly in ordination diagram. Furthermore, a high intermixing of *Sibbaldia- Taraxacum* community with *Sibbaldia- Plantago* at relatively lower disturbed sites is also evident.

Influence of environmental factors on vegetation: Canonical Correspondence Analysis – CCA showed that the first two ordination axes explained 59.9% of species variability with a cumulative percentage variation of 61.9% in species-environment correlation (Table 3). These observations are well supported fully by a recorded high species environment correlation of 0.978 and 0.957 along the first two axes respectively. The first CCA axis is positively related to altitude and slope steepness but shows a negative correlation with anthropic disturbance and soil organic carbon. Along the second axis, soil acidity and soil moisture are particularly significant (Fig. 5). The ordination diagram points to the separation of distinct community types with several forbs like *R. nepalensis, Sambucus wightiana* Wall and *U. dioca* occupying the upper left of ordination space. The presence of these species is indicative of nutrient rich and highly grazed and disturbed sites. Such an occurrence contrasts well with species characteristic of low disturbed sites such as *Podophyllum hexandrum* Royle, *Clinopodium vulgare* L and *Solidago virga-aurea* L that are located in the lower right of ordination plot.

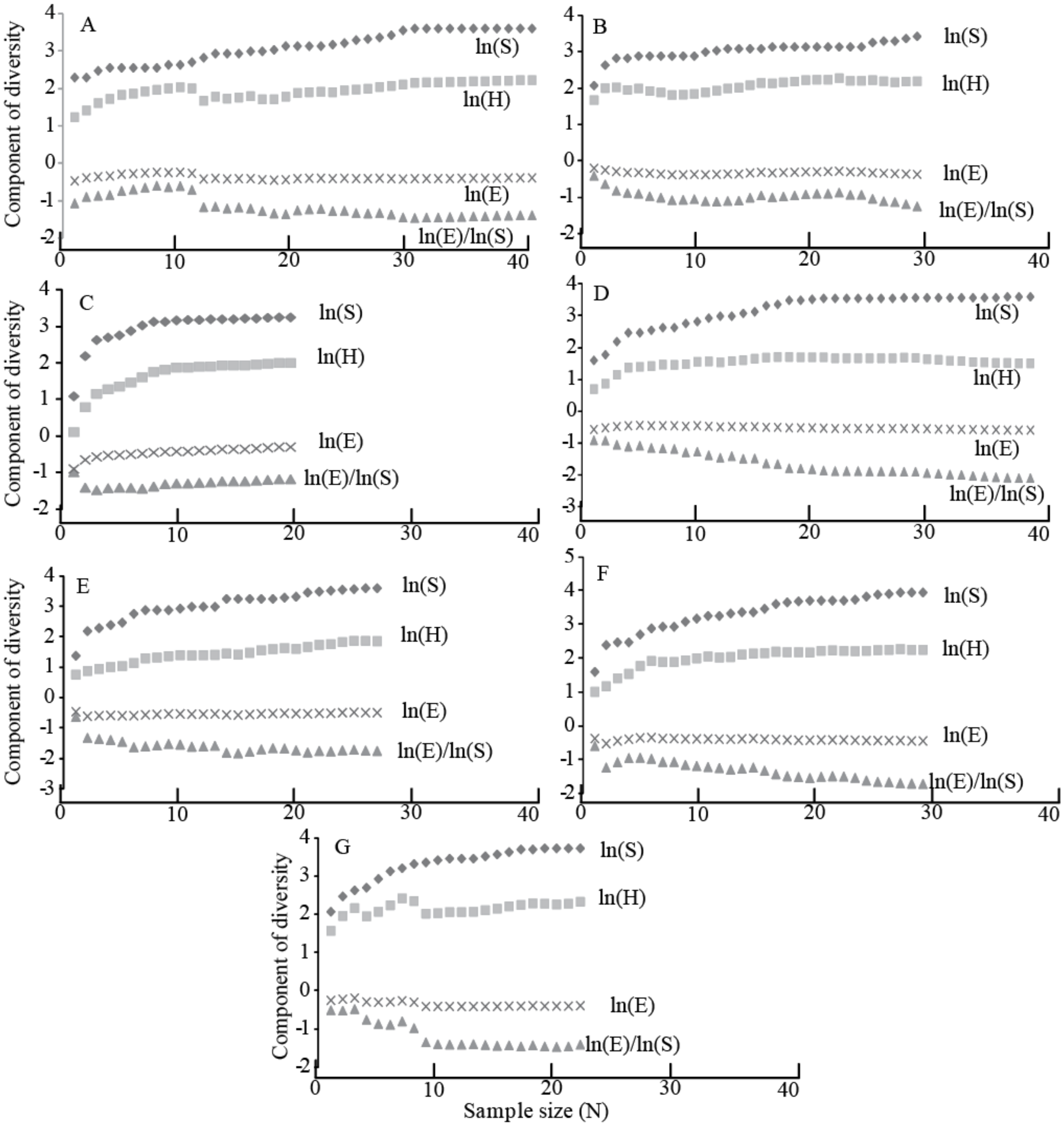

Fig. 3. SHE analysis curves of seven community types at Matri, Bandipora. The communities are abbreviated as A= *Rumex–Cirsium*, B= *Fimbristylis–Poa*, C= *Juncus- Caltha- Gentiana*, D= *Sibbaldia-Taraxacum*, E= *Sibbaldia- Plantago*, F= *Sibbaldia- Euphorbia-Senecio* and G= *Juniperus* scrub.

Discussion

With no previous community description being available for this area, this study by using quantitative techniques has attempted to describe and link it to various environmental factors. Based on floristic composition and distribution, seven vegetation units were segregated that provide an initial indication of landform diversity and environmental heterogeneity of the area. The first split of TWINSPAN (λ=0.465) points to the vegetation heterogeneity at a broader scale while at succeeding separations, a definite vegetation homogenization is also apparent. The difficulty of separating small dispersed plots in plant community classifications has been attributed to niche overlap (Wang *et al.*, 2000). This becomes more important for our area because except for *R. nepalensis* community there are not many differential species separating discrete communities. It is because of this that segregated communities do not seem to provide detailed differences in ecological conditions among different habitats of landscape. Nonetheless based on the abundance of different indicator species, communities show a definite floristic similarity with the neighboring alpine pastures of Gurez valley, Kashmir (Dad & Reshi, 2013), with several communities harboring similar species composition across the area.

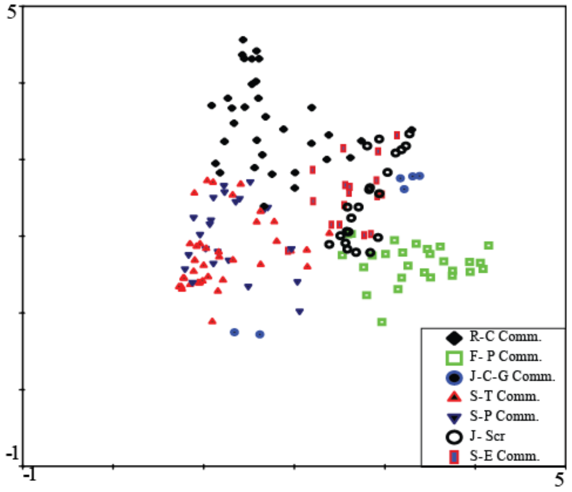

Fig. 4. DCA ordination of sampling plots showing different plant communities. The communities are abbreviated as R-C= *Rumex–Cirsium*, F-P= *Fimbristylis–Poa*, J-C-G= *Juncus-Caltha- Gentiana*, S-T= *Sibbaldia-Taraxacum*, S-P= *Sibbaldia-Plantago*, S-E= *Sibbaldia- Euphorbia- Senecio* and J-Scr= *Juniperus* scrub.

Results of DCA also supported TWINSPAN divisions and substantiated the existence of different communities. Specifically, *R. nepalensis* community separates characteristically (Fig. 4) while a species overlap in other communities is also apparent. This indicates that community differentiation is based not only on floristic differences but also on relative proportion of species in their respective vegetation units. On account of this, the indicator species of each community can be used as a snapshot to provide precious ecological information about the vegetation structure of each community. In this study area, the noxious community is present mostly around the camping sites and has a preponderance of many unpalatable species which is indicative of a high biotic pressure in the area. Years of grazing, trampling and fuel-wood cutting have affected the composition and distribution of this community. This is also evident in other Himalayan grasslands wherein workers opined that the development of such a community is facilitated by selective grazing in which the animals usually graze the palatable forbs and limit their advancement while other ruderal species remain unchecked (Nautiyal *et al.,* 2004). McIntyre & Lavorel (2001) have also reported high level of grazing to be associated with the incidence and dominance of annual grasses and leafy perennials at high alpine grasslands. Similarly the plant communities dominated by *S. cuneata* are confined more towards middle altitudes and lack a definite structure. Due to high internal variation, these communities are characterized by a regular alteration in species composition. Such continuity in plant associations of middle altitudes has also been reported for other Himalayan grasslands (Kala & Uniyal, 1999).

A high species environment correlation and high cumulative percentage of variance reflected that the measured environmental variables used in CCA explained a major part of gradient variation. An analysis of these variables points that these operate at different levels to influence the vegetation structure. As shown by CCA ordination (Fig. 5), altitude and biotic disturbance are particularly influential while steepness of slope and other edaphic factors like soil organic carbon, acidity and moisture were also important. Previous studies have also shown that along an altitudinal gradient many ecological, biological and historical factors affect species distribution (Colwell & Lees, 2000). In our study, with few exceptions, plant species with differing altitudinal locations were placed almost perfectly along this gradient. All along this gradient, topography represented by steep slope and high salt laden soil conditions appear to be responsible particularly for the distribution of *Juniperus* dominated scrub and partially for *Sibbaldia- Euphorbia- Senecio* community. Previous studies have also reported slope steepness (Zhang, 2002) and soil conductivity (Kazuhiro, 2003) as important in influencing species distribution. In our study area, a possible reason for soil conductivity to influence community distribution could be due to the nutrient accumulation in their coverage areas wherein nutrient accumulation is facilitated mostly by *Pinus* trees which build up nutrients by litter accrual. These trees besides minimizing the high slope erodibility also put a check on other disturbance factors because fearing wild animal attacks, not many animals are allowed to graze such areas. This increases the species richness in and around such shrubby patches which among others include *Arisaema jacquemontii* Blume, *Achillea millefolium* L, *Bergenia ciliata* (Haw) Sternb, *Clinopodium vulgare* L, *Hackelia uncinata* (Benth), *Heracleum candicans* Wall.ex DC, *Podophyllum hexandrum* Royle and *Viola biflora* L. At lower altitudes, these *Juniperus* dominated patches are less common because local people use it as a chief source of firewood. For other communities like *Fimbristylis-Poa,* soils with high acidity made available by organic material degradation and animal dung appear to be highly important. This organic material seems to be both autogenic and allogenic since it could also be brought down from the higher reaches of grassland by various means. Although currently this community is not so dominant but given that nomads routinely change their animal resting places will facilitate its rapid advancement to newer areas. The absence of a distinct boundary between various communities (Fig. 4) and built up of few species at centre of ordination diagram (Fig. 5) could be due to our gradient choice, meaning that other variables which we did not took into account could also be playing an important role in vegetation- environment relationship at this area.

In determining vegetation structure across Indian Himalayan grasslands, disturbance in the form of overgrazing has been reported to be an important factor (Nautiyal *et al.,* 2004). Our results (Fig. 5) further substantiate it wherein the high elevated and protected herbaceous species are shown negatively correlated with disturbance. Across the ordination space, noxious community is directly and positively related to disturbance factors. This means the density, presence and distribution of its character species increases with increasing factors like overgrazing and trampling. While grazing is prevalent throughout our study area, with obvious impacts on vegetation composition and structure but yet between species the response to such factors varies greatly. Among all species, *C. wallichii P. annua, R. nepalensis,* and *S. wightiana* grew gregariously in response to disturbance and were almost omnipresent (Fig. 6). These species colonized vast areas and due to their abundance and dominance appeared as permanent feature of vegetation.

Table 3. Eigenvalues and percentage of variance explained by CCA and canonical axes along with the results of intra-set correlation of environmental factors.

CCA	**Axis 1**	**Axis 2**
Eigenvalues	0.472	0.414
Species-environment correlations	0.978	0.957
Cumulative percentage variance of species data	29.9	59.9
---of species environment relation	31.9	61.9
Sum of all eigenvalues	1.879	
Sum of all canonical eigenvalues	1.035	

Canonical coefficient and Intra-set correlations for environmental factors

Variable	**Code**	**Canonical coefficient**		**Intra-set correlations**	
		Axis 1	**Axis 2**	**Axis 1**	**Axis 2**
Moisture	MOIS	-0.202	0.188	-0.312	0.144
pH	pH	**0.645**	0.035	-0.424	-0.266
Conductivity	COND	-0.238	0.230	**-0.512**	0.108
Slope	SLOP	0.123	-0.025	**0.742**	-0.045
Altitude	ALTI	**0.966**	**-0.881**	0.612	-0.383
Nitrogen	NITR	-0.265	0.024	-0.334	0.032
Organic carbon	OCAR	-0.263	**0.901**	-0.408	-0.281
Disturbance	DIST	**-0.808**	**0.746**	**-0.621**	**-0.772**

Note: Values in bold are significant at 5% probability level

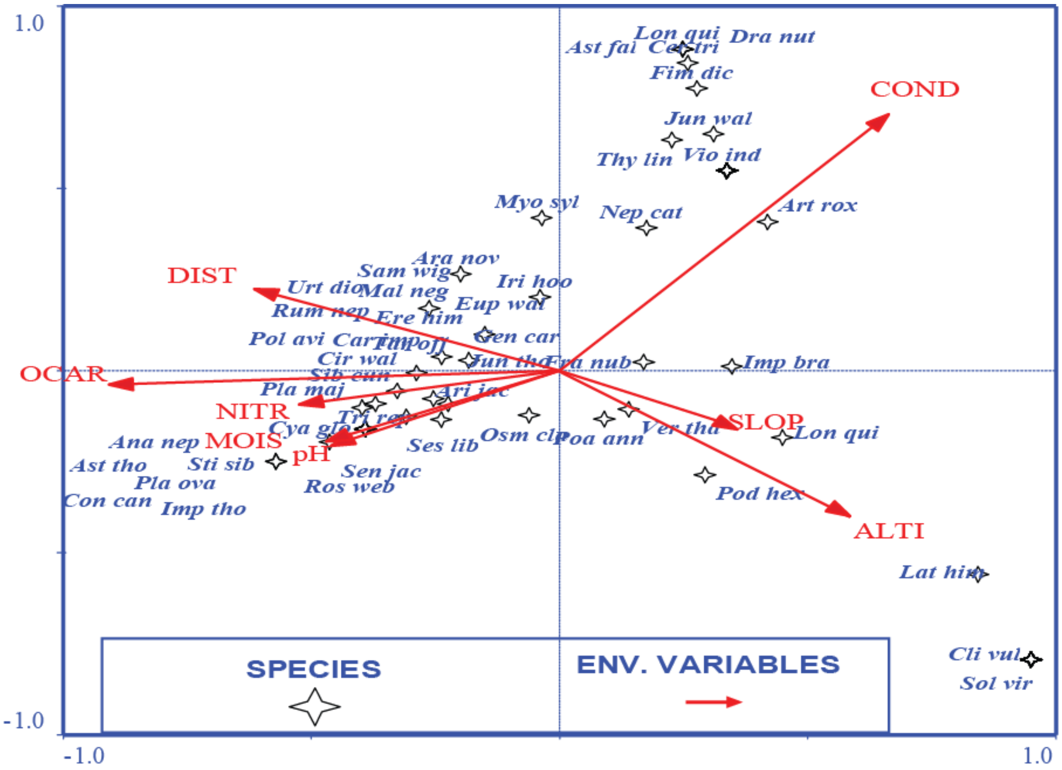

Fig. 5. Species-environment biplot of CCA, displaying relation of fitted plant species (symbols) to environmental factors (arrows).The abbreviations (in alphabetical order) for different species are *Ana nep(Anaphalis nepalensis), Ara nov (Arabis nova), Aris jac (Aris jacquemontii*), *Ast fal* (*Aster falconeri*), *Ast tho (Aster thomsonii*), *Art rox (Artimisia roxburghiana*), *Cer cer (Cerastium cerastoides), Cir wal* (*Cirsium wallichii*), *Cir fal (Cirsium falconeri), Cli vul (Clinopodium vulgare), Con can (Conyza canadensis), Cya glo* (*Cyanoglossum glochidiatum*), *Dra nut (Dracocephalum nutans), Ere him* (*Eremurus himalaicus*), *Eup wall (Euphorbia wallichii), Fim dic (Fimbristyllis dichotoma), Fra nub* (*Frageria nubicola*), *Gen car (Gentiana carinata), Imp bra* (*Impatiens brachycentra*), *Imp tho (Impatiens thomsonii), Iri hoo* (*Iris hookeriana*), *Jun tho* (*Juncus thomsonii*), *Jun wal (Juniperus wallichiana), Lat him (Lathyrus himalensis), Lon qui (Lonicera quinqualaris), Mal neg* (*Malva neglecta*), *Myo syl (Myosotis sylvatica), Nep cat* (*Nepeta cataria*), *Osm cla* (*Osmunda claytoniana*), *Pla maj (Plantago major), Pla ova* (*Plantago ovata*), *Poa ann* (*Poa annua*), *Pod hex* (*Podophyllum hexandrum*), *Pol avi* (*Polygonum aviculare*), *Ros web (Rosa webbiana), Rum nep (Rumex nepalensis), Sam wig (Sambucus wightiana), Ses lib* (*Seseli libanotis*), *Sib cun* (*Sibbaldia cuneata*), *Sen chr (Senecio chrysanthemoides), Sol vir (Solidago virga-aurea), Sti sib* (*Stipa sibirica*), *Tar off* (*Taraxicum officinale*), *Thy lin* (*Thymus linearis*), *Tri rep* (*Trifolium repens*), *Urt dio* (*Urtica dioca*), *Vio ind= Viola indica.* The two displayed ordination axes together explained 61.9% of the total variation.

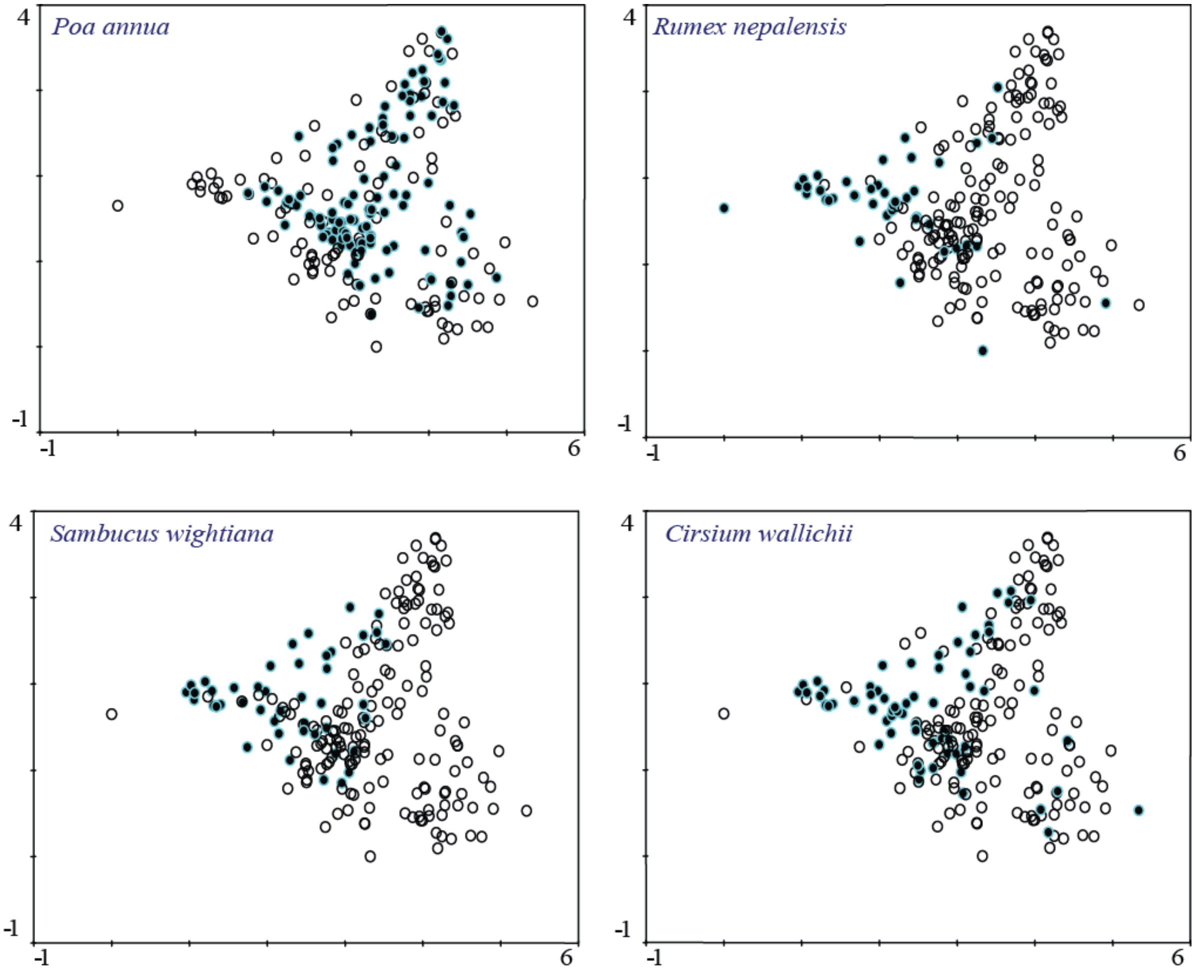

Fig. 6. Distribution of dominant invasive species at Matri, Bandipora. Filled circles show presence while unfilled show absence.

The recorded average diversity of communities (H'_{avg} = 1.53-2.33) compares well with investigations carried in other Kashmir Himalayan grasslands (Dad & Reshi, 2013). It suggests that biotic disturbance did not seem to affect the richness and diversity of communities as profoundly as it affects their structural variability. A high biotic disturbance has previously been also reported to disturb the natural balance of alpine vegetation communities and prevent them from attaining maturity (Saxena & Singh, 1982). On both macro and micro scale (Table 2), our results showed that segregated communities had moderate species evenness which suggests that individual species across communities did not display a uniform distribution and thus are locally rare. The results of SHE analysis curves (Fig. 3) add to it and further showed that greater diversity in communities was primarily a function of increasing richness (In S) but not always. In *R. nepalensis* community both richness (In S) and evenness (ln E) affected the diversity (ln *H'*) curve, although changes in evenness (In E) were only moderate. However, in *Juniperus* scrub evenness (In E) recorded a slight decreasing trend despite an increasing richness (In S) curve. This reflects that the added species are rarer and uncommon while in nitrophilic community the small changes in evenness (In E) indicate that added species are more common and frequent. It is because of them that the diversity (ln *H'*) curve is maintained on a higher side. Other notable feature of SHE analysis was its assertion that greater diversity in communities is also a function of increasing richness ln(S) as diversity increased majorly from greater richness ln(S) while evenness (In E) also played a minor role. To summarize, it is postulated that both historical and contemporary factors affect the species assemblages of high altitude grasslands of Kashmir and to get more detailed insights, a more comprehensive study across a large geographical area across the whole Kashmir Himalaya is advocated.

Acknowledgements

Financial assistance provided by the University Grants Commission, New Delhi under its Dr. D.S Kothari Post Doctoral Fellowship Programme (F-4-2/2006(BSR)/13-20 674/2012(BSR) is highly acknowledged.Taxonomical assistance provided by Prof. A. R. Naqshi is also duly acknowledged.

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(Received for publication 25 January 2014)