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Habitat wise Assessment of Alpine vegetation and prioritization of communities for conservation in a part of Nanda Devi Biosphere Reserve of West Himalaya, India-I

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Abstract
The alpine meadows of the Indian Himalayan Region are the home of a large number of representative, natural, unique and otherwise important plants. In spite of such a high value, these meadows have not been given much attention due to their remote locations and inaccessibility. Studies integrating habitat diversity, community diversity, species richness, species diversity, concentration of dominance, soil characteristics, floristic comparison, distribution of native, endemic, economically important and rare endangered species within the communities and prioritization of communities for conservation have not been carried out so far in the alpine meadows of India and elsewhere. The present study is the first step on these lines and records 27 communities supporting 286 species, distributed in 32 sites, 9 habitats, and between 3000-4270m, amsl. Danthonia cachemyriana community represented the maximum sites (5). Species richness ranged from 8-134, species diversity from 1.20-3.04, concentration of dominance from 0.09-0.63, pH from 4.70-7.80, moisture content from 15.00-58.00%, the total available nitrogen from 0.25-4.12%, the total organic carbon from 1.24-21.56%, the total organic matter from 2.13-37.17%, and the C/N ratio from 2.61-8.86, within the communities. Based on the density 14 clusters have been identified, maximum sites were represented in clusters VII (12), VIII (4) and I (3). A negative correlation had been found between altitude and species richness ($r=-0.486$, $p<0.01$ $n=32$) and altitude and species diversity ($r=-0.398$, $p<0.05$ $n=32$) whereas a positive correlation had been found between native and endemic species ($r=0.941$, $p<0.01$ $n=27$) and species richness and native species ($r=0.987$, $p<0.01$ $n=27$) within the communities. Based on the species richness, native, endemic, economically important and rare endangered species, prioritization of the communities for conservation has been done. Development of adequate strategy and action plan for the conservation of habitats, communities, and ecosystems supporting high value species has been suggested.

Key words: *Himalaya, Alpine Meadows, Species Diversity, Nativity, Endemism, Conservation, Prioritization*

Introduction

The term *"Himalaya"* has been derived from a Sanskrit word meaning *"the abode of snow"*. A complex geologic structure, snow-capped peaks, large valley glaciers, deep river gorges and rich vegetation make it unique in the globe. The Indian Himalayan Region (IHR) comprises of Trans (Jammu & Kashmir), North West (Himachal Pradesh), West (Garhwal, Kumaun), Central (Sikkim and Darjeeling district of West Bengal) and East (Arunachal Pradesh) Himalaya (Rodger & Panwar, 1988). Owing to a great variety of physiographic and phytoclimatic conditions, the IHR fosters tropical, subtropical, temperate, sub alpine and alpine vegetation. The word "*alpine*" is generally used to denote a high mountainous region above the natural treeline abounding in low herbs, scattered shrubs, mosses and lichens (Billings, 1973; Rau, 1975). The alpine zone occupies nearly 33% of geographical area in the Himalaya, of which the vegetated and snow-bound areas constitute about 25.88% and 7.22%, respectively (Anonymous, 1989). Alpine meadows are locally known as "*Bugyal*" in Garhwal and Kumaun, *Marg* in Kashmir and *Thach* or *Dhar* in Himachal Pradesh. These areas are well known for their scenic beauty, floral diversity and repositories of a number of valuable medicinal herbs (Kala *et al.,* 1998). About 2500 plant species have been reported from the alpine zones of the Greater Himalaya of which *ca.* 200 are highly endangered, over 100 species are threatened, and 300 species are used for medicinal purposes (Rau, 1975). Due to camping, over grazing and exploitation of medicinal and wild edible plants for household use and trade, the habitats of many potential species are degrading fast and over 8 species have been listed in the Red Data Book of Indian Plants (Nayar & Sastri, 1987, 88, 90; Samant et al., 1996a). In the alpine region of the Indian Himalaya, a few sporadic studies have been carried out by some workers on community patterns, phenology, biomass and productivity, impact of grazing and prioritization (Kaul & Sarin 1971; Rawat & Pangtey, 1987; Pangtey *et al*., 1990; Sundriyal *et al.,* 1987, 1988; Rawat & Rodgers, 1988; Joshi *et al.,* 1988; Joshi & Srivastava 1988, 1991; Ram, 1992; Ram *et al.,* 1988, 1989; Sundriyal, 1989, 1992; Singh, 1991; Singh *et al.,* 1995, Negi *et al.,* 1992, 1993; Rawat & Uniyal, 1993; Nautiyal *et* *al.,* 1997; Rikhari *et al.,* 1992; Johnsing *et al.*, 1998; Kala *et al.,* 1998; Kala & Rawat, 1999; Nautiyal *et al.,* 2001; Raizada *et al.,* 1998; Uniyal *et al.,* 2002; Samant *et al.*, 2002, etc.). However, the vegetation of most of the alpine meadows has not been assessed for sites and habitat characteristics, community diversity (composition and structure), distribution pattern, species diversity, soil composition, distribution pattern of native, endemic, economically important and rare endangered species, and prioritization of communities for conservation. Present attempt has been made on these directions for the first time and integrates these components together to reach some strong conclusions.

Materials and Method

The Study Area

Nanda Devi Biosphere Reserve (NDBR) (30°05'-31°02'N to 79°12'-80°19'E) covering a total of 6,407.03 km^2 (Core zone 712.12 km^2; Buffer zone 5,148.57 km^2 and Transition zone 546.34 km^2), is situated in the northern part of west Himalaya (Fig. 1) and is among the World Heritage Sites. The reserve includes parts of Bageshwar and Pithoragarh districts in Kumaun region, and Chamoli district in Garhwal region. The buffer and transition zones are inhabited by over 100 villages. Most of the inhabitants belong to two main ethnic groups namely Indo-Mongoloid (Bhotia) and Indo-Aryans. They have been using plants as medicine, edible/food, fodder, fuel, timber, agricultural tools and various other purposes (Samant, 1996b; Joshi *et al.,* 1999, 2001). Geologically, the area falls within the Greater Himalaya or Himadri System and Zanskar range. Climatically, the area is dry with low annual precipitation. The core zone of the reserve remains snow covered almost throughout the year except mid May to October. Present study has been conducted in the alpine meadows of Pindari Catchment of the NDBR. It is located in the northern part of Bageshwar district. The area is inhabited by two buffer zone villages i.e., Khati and Leh Bagar. The major river is Pindar that originates from the Pindari Glacier. The main tributaries of the river Pindar are Sunderdhunga, Pindar and Kaphni Pindar.

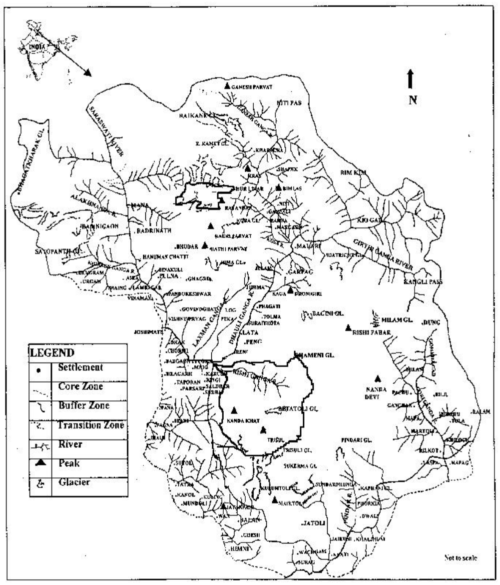

Fig 1. Location of Nanda Devi Biosphere Reserve. **(***Prepared by Lead Office, GBPIHED, Kosi-Katarmal, Almora)*

Identification and selection of sites and habitats

Attempts have been made to select sites on each and every accessible aspect along transacts between 3000-4270m, amsl. In each site, habitat type, altitude, aspect, slope, boulder percentage and dominant species were noted. Habitats were identified on the basis of physical characters (Samant *et al*., 1998a). The sites having >50% boulders of the ground cover have been identified as bouldery habitat.

Survey, sampling, identification and analysis of data

The field surveys and samplings were carried out during 1998-2000 within selected sites along transacts. For the sampling of vegetation 20x20m plot was marked in each site and 20 quadrats (1x1m) in each plot were laid by stratified method. Sampling was done in the peak season *i.e*., August and September. For data collection and analysis standard ecological methods (Grieg-Smith, 1957; Kersaw, 1973; Muller-Dombois & Ellenberge, 1974; Dhar *et al*., 1997) were followed. Shrubs present in each site were noted to update the species composition. From each site, samples of each species were collected and identified in the Institute with the help of florulas and research papers (Naithani, 1984 & 1985; Polunin & Stainton, 1984; Samant 1993, 1999; Pangtey *et al*., 1993; Hajra & Jain, 1981; and Hajra & Balodi, 1995). Abundance data of different sites were pooled to get community average in terms of density.

Community delineation, identification of nativity, endemism, human dependence and rarity

Communities have been delineated based on the 50% contribution of the total relative density of the species. Species of each community have been analyzed for nativity following (Anonymous, 1883-1970; Samant & Dhar, 1997; Samant, 1999 and Samant e*t al*., 2000), endemism following (Dhar & Samant, 1993; Samant et al., 1998a&b, 2000; Samant & Dhar, 1997; and Samant, 1999), human dependence following (Samant *et al*. 1996a, Joshi *et al*., 1999, 2001), rarity following (Samant *et al*., 1996b, 1998b).

Species diversity (H') *and concentration of dominance* (CD)

Species diversity was determined by Shanon Wiener's information statistic (H') (Shanon Weiner, 1963) and concentration of dominance by Simpson's Index (Simpson, 1949).

Soil sampling and analysis

Five soil samples were collected randomly from each site, preferably one from center and four from four corners. Soil was cored up to 20 cm depth. These samples were mixed together and a composite sample weighing 200 g of the homogenized soil was collected in air- tight polythene bags and brought to the laboratory for physical and chemical analysis. Moisture (%) and pH of the soil were measured. Moisture (%) was calculated as

$$Moisture\ (\%) = \frac{Wet\ weight\ - Dry\ weight}{Wet\ weight} \times 100$$

Soil was air dried and sieved with 2 mm mesh and, used for analysis of total nitrogen, organic carbon and organic matter following (Allen, 1974). The soil data of different sites were pooled to get community average in terms of soil parameters.

Floristic comparison studies

Polar ordination of sites has been done based on density values of herbs following (Ludwig & Reynolds, 1988) and Basic Ordination Programme Po.BAS has been used for the floristic comparison studies.

Prioritization of communities for conservation

Prioritization of the communities for conservation has been done based on the cumulative values of species richness, native, endemic, economically important and rare-endangered species.

Results

Site and habitat characteristics

The site and habitat characteristics of the study area have been presented in Table 1. Maximum sites (8) have been represented by shady moist habitat, followed by bouldery (6 sites), riverine and dry (4 sites, each), rocky (3 sites), camping, shrubberies and forest edges (2 sites, each), and marsh-wet land (1 site), respectively. 13 sites fall in North West aspect, 8 sites in West, 6 sites in South West, 4 sites in North and 1 site in South East aspect. The slope varied from 5°-65° and boulder percent from 5-52% (Table 1).

Table 1. Physical characteristics of sites and habitats in pindari alpine meadows

Site	Habitat type	Altitude (m)	Aspect	Slope (^{0})	Boulders %	Dominant species
1	2	3	4	5	6	7
1	Riverine	3300	NW	30	15	*Danthonia cachemyriana*, *Agrostis pilosula*, *Carex stracheyi*, *Parochetus communis*
2	Dry	3300	NW	10	20	*Kobresia duthiei*, *Poa alpina*, *Carex nubigena*, *Danthonia cachemyriana*
3	Dry	3360	NW	50	5	*Danthonia cachemyriana*, *Cortia depressa*, *Saxifraga pulvinaria*, *Carex stracheyi*
4	Shrubberries	3600	SE	60	35	*Cortia depressa*, *Kobresia duthiei*, *Danthonia cachemyriana*, *Saxifraga pulvinaria*
5	Shady moist	3560	SW	5	5	*Cortia depressa*, *Poa alpina*, *Circaea alpina*, *Polygonum polystachyum*
6	Marsh-wet land	3560	SW	5	5	*Circaea alpina*, *Kobresia duthiei*, *Cortia depressa*, *Poa alpine*
7	Shady moist	3560	SW	5	5	*Cortia depressa*, *Kobresia duthiei*, *Carex nubigena*, *Poa alpine*
8	Bouldery	3570	NW	25	50	*Kobresia duthiei*, *Cortia depressa*, *Poa alpina*, *Leontopodium himalayanum*
9	Bouldery	3550	NW	10	50	*Carex nubigena*, *Carex stracheyi*, *Carex obscura*, *Danthonia cachemyriana*
10	Shady moist	3560	NW	50	5	*Kobresia duthiei*, *Carex obscura*, *Danthonia cachemyriana*, *Saxifraga brachypoda*
11	Rocky	4270	NW	65	0	*Trachydium roylei*, *Carex nubigena*, *Saxifraga pulvinaria*, *Anaphalis contorta*
12	Bouldery	3590	NW	15	52	*Saxifraga pulvinaria*, *Kobresia duthiei*, *Cortia depressa*, *Carex nubigena*
13	Shady moist	4270	NW	60	5	*Poa alpina*, *Carex stracheyi*, *Polygonum affine*, *Leontopodium himalayanum*

14	Shrubberries	4270	N	60	5	*Danthonia cachemyriana*, *Carex stracheyi*, *Cortia depressa*, *Polygonum affine*
15	Shady moist	3570	W	15	5	*Poa alpina*, *Cortia depressa*, *Kobresia duthiei*, *Trachydium roylei*
16	Riverine	3570	W	10	10	*Saxifraga pulvinaria*, *Carex stracheyi*, *Cortia depressa*, *Kobresia duthiei*
17	Bouldery	3550	W	15	50	*Cortia depressa*, *Kobresia duthiei*, *Saxifraga pulvinaria*, *Poa pratensis*
18	Riverine	3540	W	50	5	*Poa alpina*, *Carex nivalis*, *Poa pratensis*, *Bupleurum candollei*
19	Camping site	3540	SW	5	5	*Rumex nepalensis*, *Cardamine impatiens*, *Capsella bursa-pastoris*, *Potentilla peduncularis*
20	Bouldery	3140	W	15	50	*Danthonia cachemyriana*, *Poa pratensis*, *Carex obscura*, *Poa alpine*
21	Shady moist	3380	NW	45	10	*Senecio chrysanthemoides*, *Dryopteris panda*, *Ranunculus brotherussi*, *Ranunculus diffusus*
22	Rocky	3600	SW	60	0	*Danthonia cachemyriana*, *Carex setosa*, *Nardostachys grandiflora*, *Androsace rotundifolia*
23	Shady moist	3600	N	45	5	*Carex stracheyi*, *Poa pratensis*, *Carex haematostoma*, *Aconitum balfouri*
24	Rocky	3600	N	30	0	*Picrorhiza kurrooa*, *Carex stracheyi*, *Dactylis glomerata*, , *Bromus himalaicus*
25	Bouldery	3340	W	45	50	*Danthonia cachemyriana*, *Kobresia duthiei*, *Trachydium roylei*, *Parochetus communis*
26	Riverine	3400	NW	10	5	*Carex nubigena*, *Kobresia duthiei*, *Cortia depressa*, *Poa alpina*
27	Dry	3200	W	50	5	*Danthonia cachemyriana*, *Dactylis glomerata*, *Carex nubigena*, *Bromus himalaicus*
28	Camping site	3200	W	10	5	*Rumex nepalensis*, *Polygonum polystachyum*, *Poa alpina*, *Galium elegans*
29	Dry	3270	N	50	5	*Danthonia cachemyriana*, *Trachydium roylei*, *Bupleurum candollei*, *Carex stracheyi*
30	Forest edge	3000	NW	15	5	*Cortia depressa*, *Danthonia cachemyriana*, *Carex obscura*, *Bupleurum lanceolata*
31	Shady moist	3200	SW	45	5	*Cortia depressa*, *Poa alpina*, *Carex obscura*, *Carex stracheyi*
32	Forest edge	3100	NW	15	5	*Agrostis pilosula*, *Poa alpina*, *Carex nubigena*, *Poa pratensis*

Community diversity, distribution pattern and species composition

A total of 27 communities have been delineated in the alpine area falling between 3000-4270m, amsl. The community types, altitudinal distribution, representation in site/s, habitat/s and major associates have been presented in Table 2. Among the communities, *Danthonia cachemyriana* community represented maximum sites (5 sites), followed by *Cortia depressa-Poa alpina* mixed community (2 sites) whereas the remaining communities were represented in one site only (Table 2).

Table 2. Community types, their distribution and major associates

Community type	SR	Habitat type/s	Altitudinal range (m)	Major associates
1	**2**	**3**	**4**	**5**
Agrostis pilosula-Poa alpina-Carex nubigena- Poa pratensis mixed	1	4	3100	*Cerastium cerastioides*, *Parochetus communis*, *Anaphalis contorta*, *Danthonia cachemyriana*
Carex nubigena-Carex stracheyi mixed	1	1	3550	*Carex obscura*, *Danthonia cachemyriana*, *Poa alpina*, *Polygonum affine*
Carex nubigena-Kobresia	1	6	3400	*Cortia depressa*, *Poa alpina*, *Dactylis*

duthiei mixed				*glomerata*, *Polygonum affine*
Carex stracheyi-Poa pratensis- Carex haematostoma-Aconitum balfourii mixed	1	8	3600	*Picrorhiza kurrooa*, *Danthonia cachemyriana*, *Valeriana pyrolaefolia*, *Viola biflora*
Circaea alpina-Kobresia duthiei-Cortia depressa-Poa alpina mixed	1	5	3560	*Campanula colorata*, *Agrostis pilosula*, *Epilobium roseum*, *Dactylis glomerata*
Cortia depressa	1	1	3550	*Kobresia duthiei*, *Saxifraga pulvinaria*, *Poa pratensis*, *Carex obscura*
Cortia depressa-Danthonia cachemyriana mixed	1	4	3000	*Carex obscura*, *Bupleurum lanceolatum*, *Anaphalis contorta*, *Chrysosplenium carnosum*
Cortia depressa-Kobresia duthiei mixed	1	8	3560	*Carex nubigena*, *Poa alpina*, *Trachydium roylei*, *Saxifraga jacquemontiana*
Cortia depressa-Kobresia duthiei-Danthonia cachemyriana mixed	1	9	3600	*Saxifraga pulvinaria*, *Carex nubigena*, *Trachydium roylei*, *Bupleurum candollei*
Cortia depressa-Poa alpina mixed	2	8	3200-3560	*Carex obscura*, *Carex stracheyi*, *Polygonum polystachyum*, *Parochetus communis*
Danthonia cachemyriana	5	1, 3, 7, 9	3200-4270	*Carex setosa*, *Kobresia duthiei*, *Carex stracheyi*, *Trachydium roylei*
Danthonia cachemyriana-Agrostis pilosula mixed	1	6	3300	*Carex stracheyi*, *Parochetus communis*, *Agrostis munroana*, *Anaphalis contorta*
Danthonia cachemyriana-Cortia depressa mixed	1	3	3360	*Saxifraga pulvinaria*, *Carex stracheyi*, *Agrostis munroana*, *Parochetus communis*
Danthonia cachemyriana-Poa pratensis-Carex obscura-Poa alpina mixed	1	1	3140	*Galium asperifolium*, *Carex nubigena*, *Clinopodium umbrosum*, *Viola biflora*
Kobresia duthiei	1	1	3570	*Cortia depressa*, *Poa alpina*, *Leontopodium himalayanum*, *Dactylis glomerata*
Kobresia duthiei-Carex obscura-Danthonia cachemyriana mixed	1	8	3560	*Saxifraga brachypoda*, *Potentilla atrosanguinea*, *Polygonum affine*, *Carex nubigena*
Kobresia duthiei-Poa alpina-Carex nubigena mixed	1	3	3300	*Danthonia cachemyriana*, *Cortia depressa*, *Parochetus communis*, *Bupleurum candollei*
Picrorhiza kurrooa-Carex stracheyi-Dactylis glomerata-Bromus himalaicus mixed	1	7	3600	*Fragaria nubicola*, *Epilobium latifolium*, *Stellaria decumbens*, *Androsace sarmentosa*
Poa alpina	1	8	4270	*Carex stracheyi*, *Polygonum affine*, *Leontopodium himalayanum*, *Carex haematostoma*
Poa alpina-Carex nivalis-Poa pratensis-Bupleurum candollei mixed	1	6	3540	*Cortia depressa*, *Trachydium roylei*, *Parochetus communis*, *Circaea alpina*
Poa alpina-Cortia depressa mixed	1	8	3570	*Kobresia duthiei*, *Trachydium roylei*, *Circaea alpina*, *Polygonum polystachyum*
Rumex nepalensis-Cardamine impatiens mixed	1	2	3540	*Capsella bursa-pastoris*, *Potentilla peduncularis*, *Circaea alpina*, *Arisaema flavum*
Rumex nepalensis-Polygonum polystachyum-Poa alpina-Galium elegans mixed	1	2	3200	*Circaea alpina*, *Hackelia uncinata*, *Urtica hyperborea*, *Cardamine impatiens*
Saxifraga pulvinaria-Carex stracheyi mixed	1	6	3570	*Cortia depressa*, *Kobresia duthiei*, *Carex nubigena*, *Polygonum affine*
Saxifraga pulvinaria-Kobresia duthiei mixed	1	1	3590	*Cortia depressa*, *Carex nubigena*, *Bupleurum longicaule*, *Polygonum affine*
Senecio chrysanthemoides-Dryopteris panda-Ranunculus brotherussi-Ranunculus diffusus mixed	1	8	3380	*Carex nivalis*, *Hackelia uncinata*, *Polygonum polystachyum*, *Valeriana hardwickii*
Trachydium roylei	1	7	4270	*Carex nubigena*, *Saxifraga pulvinaria*, *Anaphalis contorta*, *Polygonum affine*

In general, a total of 292 species (14 shrubs, 278 herbs including 20 pteridophytes) had been recorded. However, 286 species (12 shrubs, 274 herbs including 20 pteridophytes) had been recorded in the sampling sites. Analysis of distribution pattern of species indicated that 82.12% species had regular distribution; 9.85% species had random distribution; and 8.03% species had contagious distribution among the sites and 80.29% species had regular distribution; 11.68% species had random distribution; and 8.03% species had contagious distribution among the communities.

Community diversity: composition and structure

Species richness among the communities ranged from 8-134. It was highest in *Danthonia cachemyriana* community (134), followed by *Danthonia cachemyriana-Cortia depressa* mixed (61), *Carex stracheyi-Poa pratensis-Carex haematostoma-Aconitum balfourii* mixed (60), *Agrostis pilosula-Poa alpina-Carex nubigena-Poa pratensis* mixed and *Cortia depressa-Poa alpina* mixed (59, each), and *Danthonia cachemyriana-Agrostis pilosula* mixed (58), communities (Table 3). The density ranged from 40.55-3296.25 Ind m^{-2}. *Saxifraga pulvinaria-Carex stracheyi* community had maximum density (3296.25 Ind m^{-2}), followed by *Saxifraga pulvinaria-Kobresia duthiei* mixed (2672.15 Ind m^{-2}), *Cortia depressa* (2556.25 Ind m^{-2}), *Cortia depressa-Kobresia duthiei-Danthonia cachemyriana* mixed (2203.10 Ind m^{-2}), *Kobresia duthiei-Poa alpina-Carex nubigena* mixed (2055.50 Ind m^{-2}), and *Cortia depressa-Kobresia duthiei* mixed (2048.95 Ind m^{-2}), communities (Table 3).

Species diversity (H') *and concentration of dominance* (CD)

H' ranged from 1.20-3.04. It was highest in *Agrostis pilosula-Poa alpina-Carex nubigena-Poa pratensis* mixed community (3.04), followed by *Carex stracheyi-Poa pratensis-Carex haematostoma-Aconitum balfourii* mixed (2.95), *Danthonia cachemyriana-Poa pratensis-Carex obscura-Poa alpina* mixed (2.80) and *Picrorhiza kurrooa-Carex stracheyi-Dactylis glomerata-Bromus himalaicus* mixed (2.77), *Poa alpina-Carex nivalis-Poa pratensis-Bupleurum candollei* mixed (2.68), and *Senecio chrysanthemoides-Dryopteris panda-Ranunculus brotherussi-Ranunculus diffusus* mixed (2.67), communities (Table 3). Cd ranged from 0.09-0.63. It was highest in *Danthonia cachemyriana* community (0.63), followed by *Trachydium roylei* (0.42), *Poa alpina-Cortia depressa* mixed (0.37), *Kobresia duthiei* (0.35) and *Saxifraga pulvinaria-Kobresia duthiei* mixed (0.34), communities (Table 3).

Table 3. Community wise distribution of species richness, total density, diversity and concentration of dominance of species

S.N.	Community type	Species richness	Total density (Indm^{-2})	Diversity (H')	Concentration of dominance (Cd)
1	2	3	4	5	6
1	*Agrostis pilosula-Poa alpina-Carex nubigena-Poa pratensis* mixed	59	347.00	3.04	0.09
2	*Carex nubigena-Carex stracheyi* mixed	52	564.55	2.44	0.16
3	*Carex nubigena-Kobresia duthiei* mixed	44	1204.45	2.05	0.21
4	*Carex stracheyi-Poa pratensis-Carex haematostoma-Aconitum balfourii* mixed	60	284.45	2.95	0.14
5	*Circaea alpina-Kobresia duthiei-Cortia depressa-Poa alpina* mixed	17	875.30	1.75	0.20
6	*Cortia depressa*	43	2556.25	1.65	0.31
7	*Cortia depressa-Danthonia cachemyriana* mixed	45	359.60	2.53	0.16
8	*Cortia depressa-Kobresia duthiei* mixed	26	2048.95	1.64	0.26
9	*Cortia depressa-Kobresia duthiei-Danthonia cachemyriana* mixed	38	2203.10	2.04	0.19
10	*Cortia depressa-Poa alpina* mixed	59	513.58	2.02	0.27
11	*Danthonia cachemyriana*	134	1249.50	1.27	0.63
12	*Danthonia cachemyriana-Agrostis pilosula* mixed	58	643.85	2.66	0.17
13	*Danthonia cachemyriana-Cortia depressa* mixed	61	1146.10	2.44	0.17
14	*Danthonia cachemyriana-Poa pratensis-Carex obscura-Poa alpina* mixed	57	462.70	2.80	0.12
15	*Kobresia duthiei*	37	1137.50	1.54	0.35
16	*Kobresia duthiei-Carex obscura-Danthonia cachemyriana* mixed	42	563.25	2.06	0.23
17	*Kobresia duthiei-Poa alpina-Carex nubigena* mixed	44	2055.50	2.02	0.21
18	*Picrorhiza kurrooa-Carex stracheyi-Dactylis glomerata-Bromus himalaicus* mixed	25	61.35	2.77	0.09
19	*Poa alpina*	39	464.75	2.02	0.31
20	*Poa alpina-Carex nivalis-Poa pratensis-Bupleurum candollei* mixed	50	565.00	2.68	0.17
21	*Poa alpina-Cortia depressa* mixed	17	1885.85	1.20	0.37
22	*Rumex nepalensis-Cardamine impatiens* mixed	8	40.55	1.56	0.27
23	*Rumex nepalensis-Polygonum polystachyum-Poa alpina-Galium elegans* mixed	25	102.65	2.61	0.10

24	*Saxifraga pulvinaria-Carex stracheyi* mixed	35	3296.25	1.66	0.25
25	*Saxifraga pulvinaria-Kobresia duthiei* mixed	32	2672.15	1.44	0.34
26	*Senecio chrysanthemoides-Dryopteris panda-Ranunculus brotherussi-Ranunculus diffusus* mixed	24	85.65	2.67	0.09
27	*Trachydium roylei*	23	1053.50	1.33	0.42

Soil composition

pH, moisture content (%), total nitrogen (%), total organic carbon (%), total organic matter (%) and C/N ratio have been presented (Table 4). pH ranged from 4.70-7.80, it was highest for *Danthonia cachemyriana-Agrostis pilosula* mixed community (7.80); Moisture content ranged from 15.00-58.00%, it was highest for *Rumex nepalensis-Cardamine impatiens* mixed community (58.00%); the total available nitrogen ranged from 0.25-4.12%, it was highest for *Rumex nepalensis-Cardamine impatiens* mixed community (4.12%); the total organic carbon ranged from 1.24-21.56%, it was highest for *Rumex nepalensis-Cardamine impatiens* mixed community (21.56%); the total organic matter ranged from 2.13-37.17%. It was highest for *Rumex nepalensis-Cardamine impatiens* mixed community (37.17%); and the C/N ratio ranged from 2.61-8.86, it was highest for *Picrorhiza kurrooa-Dactylis glomerata-Carex stracheyi-Bromus himalaicus* mixed community (8.86) (Table 4).

Table 4. Community wise mean pH, moisture content (MC), total nitrogen (TN), total organic carbon (OC), total organic matter (OM) and C/N ratio within identified communities

S.N.	Community type	Mean soil variables					
		MC (%)	PH	OM (%)	OC (%)	TN (%)	C/N ratio
1	2	3	4	5	6	7	8
1	*Agrostis pilosula-Poa alpina-Carex nubigena-Poa pratensis* mixed	28.00	4.70	7.47	4.33	0.66	6.56
2	*Carex nubigena-Carex stracheyi* mixed	32.00	5.20	5.96	3.46	0.67	5.16
3	*Carex nubigena-Kobresia duthiei* mixed	37.00	5.90	3.95	2.29	0.44	5.20
4	*Carex stracheyi-Poa pratensis-Carex haematostoma-Aconitum balfourii* mixed	48.00	4.90	14.36	8.33	1.50	5.55
5	*Circaea alpina-Kobresia duthiei- Cortia depressa-Poa alpina* mixed	23.00	5.40	4.67	2.71	0.61	4.44
6	*Cortia depressa*	30.00	5.90	7.32	4.25	0.94	4.52
7	*Cortia depressa-Danthonia cachemyriana* mixed	43.00	5.10	13.23	7.67	1.58	4.85
8	*Cortia depressa-Kobresia duthiei* mixed	15.00	6.10	7.90	4.59	0.74	6.20
9	*Cortia depressa-Kobresia duthiei- Danthonia cachemyriana* mixed	23.00	7.60	5.33	3.09	0.70	4.41
10	*Cortia depressa-Poa alpina* mixed	40.50	5.40	8.04	4.66	1.36	3.50
11	*Danthonia cachemyriana*	34.80	5.54	14.29	8.29	1.15	7.05
12	*Danthonia cachemyriana-Agrostis pilosula* mixed	35.00	7.80	2.13	1.24	0.25	4.96
13	*Danthonia cachemyriana-Cortia depressa* mixed	26.00	5.30	6.61	3.83	0.68	5.63
14	*Danthonia cachemyriana-Poa pratensis-Carex obscura-Poa alpina* mixed	37.00	5.10	11.93	6.92	1.31	5.28
15	*Kobresia duthiei*	17.00	6.10	5.05	2.93	0.56	5.23
16	*Kobresia duthiei-Carex obscura-Danthonia cachemyriana* mixed	39.00	6.20	11.66	6.76	0.97	6.97
17	*Kobresia duthiei-Poa alpina-Carex nubigena* mixed	25.00	6.30	8.46	4.91	0.80	6.14
18	*Picrorhiza kurrooa-Carex stracheyi-Dactylis glomerata-Bromus himalaicus* mixed	54.00	4.90	21.07	12.22	1.38	8.86
19	*Poa alpina*	29.00	6.20	9.17	5.32	0.79	6.73
20	*Poa alpina-Carex nivalis-Poa pratensis-Bupleurum candollei* mixed	25.00	4.80	4.41	2.56	0.45	5.69
21	*Poa alpina-Cortia depressa* mixed	30.00	5.50	6.04	3.51	0.67	5.24
22	*Rumex nepalensis-Cardamine impatiens* mixed	58.00	5.60	37.17	21.56	4.12	5.23
23	*Rumex nepalensis-Polygonum polystachyum-Poa alpina-Galium elegans* mixed	28.00	5.50	9.49	5.50	2.11	2.61
24	*Saxifraga pulvinaria-Carex stracheyi* mixed	34.00	7.00	4.10	2.38	0.50	4.76
25	*Saxifraga pulvinaria-Kobresia duthiei* mixed	31.00	5.30	8.60	4.99	0.67	7.45

26	*Senecio chrysanthemoides-Dryopteris panda-Ranunculus brotherussi-Ranunculus diffuses* mixed	41.00	5.00	11.80	6.85	1.00	6.85
27	*Trachydium roylei*	31.00	5.80	7.90	4.59	0.69	6.65

Floristic comparison

Based on the density 14 clusters have been identified. Maximum sites were represented in cluster VII, followed by cluster VIII, I, IV and V. The remaining clusters were represented by one site only (Table 5 & Fig. 2).

Table 5. Clusters and their representative sites

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
22, 27, 25	14	3	1, 29	20, 30	4	5, 6, 9, 10, 11, 12, 13, 16, 17, 18, 31, 32	7, 8, 15, 26	2	21	23	24	28	19

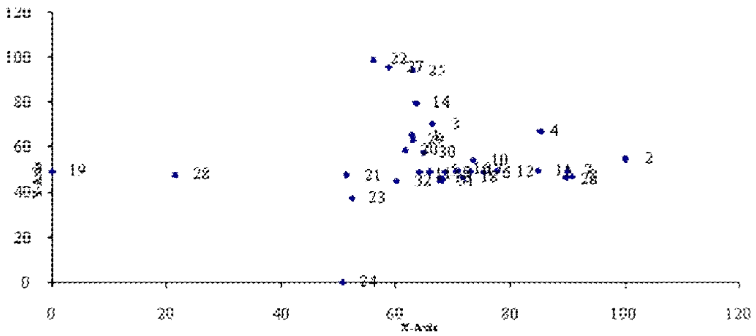

Fig. 2. Polar Ordination of 32 sites based on density of herbs

Distribution pattern of the native and endemic species within communities

The distribution of native and endemic species including near endemic ones within the identified communities have been presented in (Table 6). The maximum natives were recorded in *Danthonia cachemyriana* community (89 spp.), followed by *Danthonia cachemyriana -Cortia depresa* mixed (43 spp.), *Carex stracheyi-Poa pratensis- Carex haematostoma-Aconitum balfourii* mixed (42 spp.) and *Agrostis pilosula-Poa alpina-Carex nubigena-Poa pratensis mixed* (38 spp.), communities. The least natives were recorded in *Rumex nepalensis-Cardamine impatiens* mixed community (2 spp. only). The maximum endemic species including near endemic ones (44 spp.) were found in *Danthonia cachemyriana* community, followed by *Carex stracheyi-Poa pratensis- Carex haematostoma-Aconitum balfourii* mixed (26 spp.), community. In *Rumex nepalensis-Cardamine impatienses mixed community the endemic and near endemic species were* absent.

Distribution pattern of the economically important species within communities

The distribution pattern of economically important species indicated that the highest useful species were distributed in *Danthonia cachemyriana* (81 spp.) community, followed by *Agrostis pilosula-Poa alpina-Carex nubigena-Poa pratensis* mixed (44 spp.), *Cortia depressa-Poa alpina* mixed, and *Danthonia cachemyriana-Cortia depressa* mixed (43 spp., each), *Danthonia cachemyriana-Agrostis pilosula* mixed, *Danthonia cachemyriana-Poa pratensis-Carex obscura-Poa alpina* mixed, *Kobresia duthiei-Poa alpina-Carex nubigena* mixed (38 spp., each), *Poa alpina-Carex nivalis-Poa pratensis-Bupleurum candollei* mixed (36 spp.) and *Carex stracheyi-Poa pratensis-Carex haematostoma-Aconitum balfourii* mixed (32 spp.), communities. The least useful species were distributed in *Rumex nepalensis-Cardamine impatiens* mixed (6 spp.) community (Table 6).

Distribution pattern of the rare endangered species within communities

The distribution pattern of rare endangered species within the communities indicated that maximum rare-endangered species were distributed in *Danthonia cachemyriana* community (24 spp.), followed by *Carex stracheyi-Poa pratensis- Carex haematostoma-Aconitum balfourii* mixed (14 spp.) and *Carex nubigena-Carex stracheyi* mixed (11 spp.), communities. The least rare species were distributed in *Circaea alpina-Kobresia duthiei-Cortia depressa-Poa alpina* mixed and *Rumex nepalensis-Polygonum polystachyum-Poa alpina-Galium elegans* mixed community (1 spp., each only). In *Cortia depressa-Kobresia duthiei* mixed and *Rumex nepalensis-Cardamine impatiens* mixed, communities rare-endangered species were absent (Table 6).

Table 6. Community wise distribution of native, endemic, economically important and rare- endangered species

Community type	Native species	Endemic and Near endemic species	Economically important species	Rare-Endangered species
Agrostis pilosula-Poa alpina-Carex nubigena-Poa pratensis mixed	38	14	44	7
Carex nubigena-Carex stracheyi mixed	35	19	25	11
Carex nubigena-Kobresia duthiei mixed	25	18	25	6
Carex stracheyi-Poa pratensis-Carex haematostoma-Aconitum balfourii mixed	42	26	32	14
Circaea alpina-Kobresia duthiei-Cortia depressa-Poa alpina mixed	6	5	11	1
Cortia depressa	29	17	29	4
Cortia depressa-Danthonia cachemyriana mixed	29	18	28	6
Cortia depressa-Kobresia duthiei mixed	19	12	21	0
Cortia depressa-Kobresia duthiei-Danthonia cachemyriana mixed	29	22	23	4
Cortia depressa-Poa alpina mixed	37	17	43	5
Danthonia cachemyriana	89	44	81	24
Danthonia cachemyriana-Agrostis pilosula mixed	37	21	38	6
Danthonia cachemyriana-Cortia depressa mixed	43	23	43	7
Danthonia cachemyriana-Poa pratensis-Carex obscura-Poa alpina mixed	35	14	38	4
Kobresia duthiei	28	15	15	5
Kobresia duthiei-Carex obscura-Danthonia cachemyriana mixed	32	19	23	4
Kobresia duthiei-Poa alpina-Carex nubigena mixed	33	17	38	3
Picrorhiza kurrooa-Dactylis glomerata-Carex stracheyi-Bromus himalaicus mixed	18	8	12	4
Poa alpina	29	20	20	7
Poa alpina-Carex nivalis-Poa pratensis-Bupleurum candollei mixed	33	19	36	6
Poa alpina-Cortia depressa mixed	11	6	14	2
Rumex nepalensis-Cardamine impatiens mixed	2	0	6	0
Rumex nepalensis-Polygonum polystachyum-Poa alpina-Galium elegans mixed	14	4	17	1
Saxifraga pulvinaria-Carex stracheyi mixed	24	14	22	2
Saxifraga pulvinaria-Kobresia duthiei mixed	23	13	16	2
Senecio chrysanthemoides-Dryopteris panda-Ranunculus brotherussi-Ranunculus diffuses mixed	14	4	16	3
Trachydium roylei	14	8	9	7

Prioritization of communities for conservation

Based on the species richness, native, endemic, economically important and rare endangered species, *Danthonia cachemyriana* (Species richness: 134; Natives: 89; Endemic: 44; Rare-endangered: 24; Economically important: 81); *Agrostis pilosula-Poa alpina-Carex nubigena-poa pratensis* mixed (Species richness: 59; Natives: 38; Endemic: 14; Rare-endangered: 7; Economically important: 44); *Danthonia cachemyriana-Agrostis pilosula* mixed (Species richness: 58; Natives: 37; Endemic: 21; Rare-endangered: 6; Economically important: 38); *Cortia depressa-Poa alpina* mixed (Species richness: 59; Natives: 37; Endemic: 17; Rare-endangered: 5; Economically important: 43); *Carex nubigena-Carex stracheyi* mixed (Species richness: 52; Natives: 35; Endemic: 19; Rare-endangered: 11; Economically important: 25); and *Kobresia duthiei-Poa alpina-Carex nubigena* mixed (Species richness: 44; Natives: 33; Endemic: 17; Rare-endangered: 3; Economically important: 38), communities have been identified as high value communities and prioritized for conservation.

Discussion

The present study reports 27 communities and 292 species and analyses these species for nativity, endemism, human dependence and rarity. The high diversity of the native, endemic, economically important, and rare-endangered species indicated the high conservation value of the meadows. The growth and establishment of high altitude plants are influenced by topography, climate and edaphic factors (Kala *et al*., 1998). Alpine plants are distributed over different microhabitats and altitude with distinct ecological requirements (Rawat & Uniyal, 1993). In the study area, the distribution of communities and species changes in response to habitats. The tussuck forming grasses and cushion and spreading forbs covers the maximum part of the alpine meadows. Similar distribution of the species has been also noted by earlier workers in other alpine meadows of the west Himalaya (Ram, 1988; Kala *et al*., 1998). These species grow fast by prohibiting the growth of other species (Harper, 1977; Grime, 1979). The cushion and spreading forbs such as *Saxifraga pulvinaria*, *Cortia depressa*, etc. were also dominated in the alpine habitats. In general, considering all the sites together, most species showed regular distribution pattern both, among sites and communities in all the areas. But, within sites/plots the distribution pattern was contagious. Such distribution pattern of the species in other alpine meadows has been also reported (Ram, 1988; Nautiyal *et al.*, 1997). The total density range (40.55-3296.25Ind m^{-2}) was comparatively higher than the other alpine meadows of Himalayan region. Most of these high density were dominated by grasses, sedges, cushion, and spreading forbs indicating the proliferation of these communities in the area. The low density of *Rumex nepalensis-Cardamine impatiens* mixed, *Picrorhiza kurrooa-Carex stracheyi-Dactylis glomerata-Bromus himalaicus* mixed, *Senecio chrysanthemoides-Dryopteris panda-Ranunculus brotherussi-Ranunculus diffusus* mixed, and *Rumex nepalensis-Polygonum polystachyum-Poa alpina-Galium elegans mixed*, communities may be due to high biotic pressures. Some of these communities were found in camping sites and dominated by weeds *i.e*., *Polygonum polystachyum*, *Rumex nepalensis*, *Impatiens sulcata*, etc. These are the characteristic species of the camping sites where the organic matter was found accumulated due to the excretory wastes of the animals. In camping sites, these species do not allow other species to grow. Among the habitats, camping sites, shrubberries, rocky and forest edges showed the lowest densities. This may be due to the dominance of *Rumex nepalensis*, *Polygonum polystachyum*, etc. in the camping sites, shrubs in the shrubberies and homogenous distribution of species, respectively, and also, low density of tussock forming grasses in these habitats. The species richness (8-134) was comparatively high when compared to the Panwali Kantha bugyal (5-42) (Raizada et al., 1998). The H' (1.33-3.04) was within the reported range for Valley of Flowers (Kala et al., 1998). The Cd showed slight variations i.e., 0.09-0.63. This may be attributed due the range of habitats and richness of the species.

A significant negative correlation had been found between altitude and species richness ($r=-0.486$, $p<0.01$ $n=32$) indicating that with the increasing altitude the species richness decreased. (Fig. 3). The altitude had been negatively correlated with diversity ($r=-0.398$, $p<0.05$ $n=32$) indicating that the diversity decreased with increasing altitude (Fig. 4).

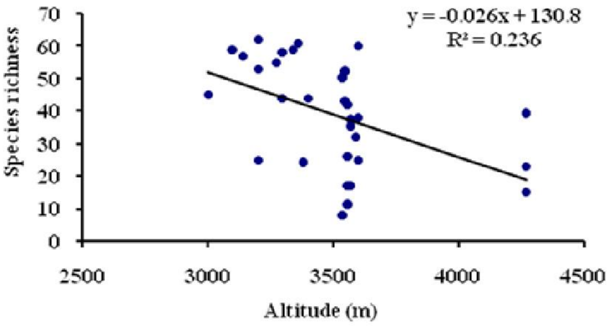

Fig. 3. Correlation between altitude and species richness

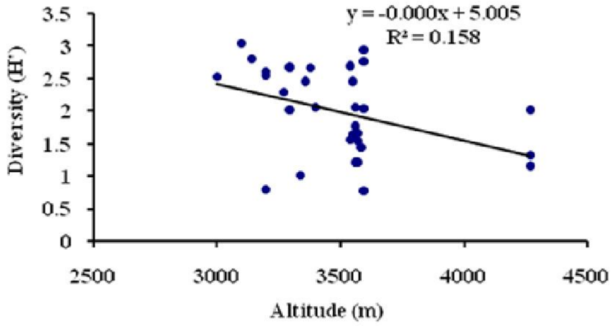

Fig. 4. Correlation between altitude and species diversity

The occurrence of maximum number of species in *Danthonia cachemyriana*, community may be attributed due to their wide range of distribution and habitat preference. Similarly, the occurrence of minimum number of species in *Rumex nepalensis-Cardamine impatiens* mixed, *Circaea alpina-Kobresia duthiei-Cortia depressa-Poa alpina* mixed, and *Poa alpina-Cortia depressa* mixed communities may be due to their narrow range of distribution and restricted habitats. These communities were represented in camping sites and marsh-wet habitats. These habitats have been developed due to the camping by sheep grazers and also by trampling of sheeps and goats (Ram & Singh, 1994).

The maximum diversity in the communities, such as *Agrostis pilosula-Poa alpina-Carex nubigena-Poa pratensis* mixed, *Carex stracheyi-Poa pratensis-Carex haematostoma-Aconitum balfourii* mixed, *Danthonia cachemyriana-Poa pratensis-Carex obscura-Poa alpina* mixed, *Picrorhiza kurrooa-Carex stracheyi-Dactylis glomerata-Bromus himalaicus* mixed, *Poa alpina-Carex nivalis-Poa pratensis-Bupleurum candollei* mixed, *Senecio chrysanthemoides-Dryopteris panda-Ranunculus brotherussi-Ranunculus diffusus* mixed, *Danthonia cachemyriana-Agrostis pilosula* mixed, *Rumex nepalensis-Polygonum polystachyum-Poa alpina-Galium elegans* mixed, *Cortia depressa-Danthonia cachemyriana* mixed may be due to heterogeneous composition of the species with almost similar trend of distribution. The minimum diversity in the communities, such as *Poa alpina-Cortia depressa* mixed, *Danthonia cachemyriana*, *Trachydium roylei*, *Saxifraga pulvinaria-Kobresia duthiei* mixed, *Kobresia duthiei*, *Rumex nepalensis-Cardamine impatiens* mixed, may be mainly due to narrow range of distribution, habitat restriction and dominance of some species.

The soil charactersitsc are more or less comparable with the reported values by other workers in alpine meadows (Rikhari *et al.*, 1992; Nautiyal *et al.*, 1997; Kala *et al.*, 1998; Ram, 1988; Raizada *et al.*, 1998). However, some values reported for other alpine meadows differ slightly. This may be due to difference in topography and habitats, and also, probably due to different sampling methods.

The harsh and tough climatic and topographic conditions of an alpine area are unfavorable for the invasion of non-native species; hence the percentage of non- natives is comparatively low in this region. The unique topography, severe climatic conditions and remoteness of the NDBR do not allow many human settlements. Hence, the degree of anthropogenic pressure is low compared to the subtropical and temperate zones of IHR. This has led to the high diversity of native and endemic species. A positive correlation had been found between native and endemic species among the communities (r=0.941, p<0.01 n=27) (Fig. 5). A correlation between species richness and native species had been found positive among the communities (r=0.987, p<0.01 n=27) (Fig. 6).

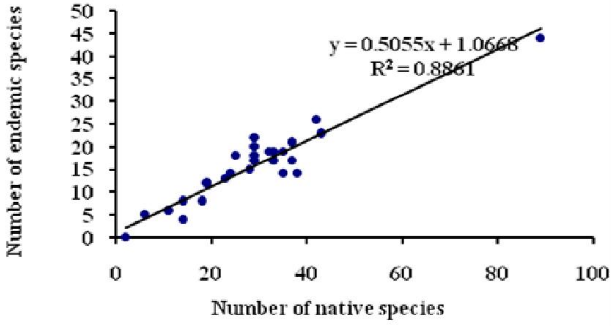

Fig. 5. Correlation between native and endemic species

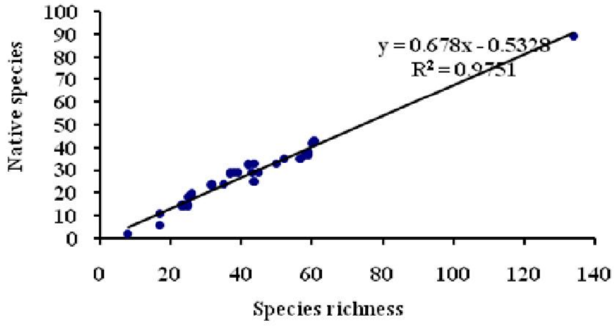

Fig. 6. Correlation between species richness and native species

The habitat degradation and overexploitation of the economically important native species such as *Aconitum balfourii*, *A. heterophyllum*, *Angelica glauca*, *Megacarpaea polyandra*, *Dactylorhiza hatagirea*, *Polygonatum verticillatum*, *Arnebia benthamii*, *Picrorhiza kurrooa*, *Nardostachys grandiflora*, *Pleurospermum angelicoides*, *Podophyllum hexandrum*, *Jurinella macrocephala*, *Saussurea obvallata*, *Rheum australe*, *R. spiciforme*, etc., had caused population depletion to a great extent in the wild. Continuous overexploitation of such species may lead to their early extinction from their natural habitats (Samant *et al.*, 2001). Therefore, timely human interventions for the conservation of these species are urgently required. A significant positive relationship had been found between the number of economically important species and number of rare-endangered species (r=0.730, p<0.01 n=27) (Fig. 7) among the communities indicating that the use of the species was directly proportional to the rarity of the species.

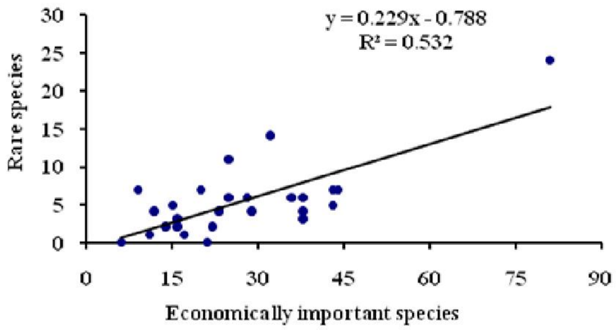

Fig. 7. Correlation between economically important species and rare-endangered species

The communities such as *Danthonia cachemyriana* (Species richness: 134; Natives: 89; Endemic: 44; Rare-endangered: 24; Economically important: 81); *Agrostis pilosula-Poa alpina-Carex nubigena-Poa pratensis* mixed (Species richness: 59; Natives: 38; Endemic: 14; Rare-endangered: 7; Economically important: 44); *Danthonia cachemyriana-Agrostis pilosula* mixed (Species richness: 58; Natives: 37; Endemic: 21; Rare-endangered: 6; Economically important: 38); *Cortia depressa-Poa alpina* mixed (Species richness: 59; Natives: 37; Endemic: 17; Rare-endangered: 5; Economically important: 43); *Carex nubigena-Carex stracheyi* mixed (Species richness: 52; Natives: 35; Endemic: 19; Rare-endangered: 11; Economically important: 25); and *Kobresia duthiei-Poa alpina-Carex nubigena* mixed (Species richness: 44; Natives: 33; Endemic: 17; Rare-endangered: 3; Economically important: 38) indicated high conservation value, hence merit priority attention for conservation. The richness of economically important species in these communities indicates high anthropogenic pressure. If indiscriminate exploitation of the useful species from these communities continues, there is a possibility of extinction of these species from their natural habitats leading to habitat alterations and ecosystem imbalance. Therefore, there is an urgent need to pay adequate attention for the conservation of these communities supporting ecologically and economically important species.

Conclusions

The present study provides comprehensive information on sites and habitat characteristics, community diversity (composition and structure), distribution patterns, species diversity, concentration of dominance, soil composition of each identified community, floristic comparison, distribution of native, endemic, economically important and rare-endangered species, and prioritization of communities for conservation. Such an integrated study has not been carried out so far in India and elsewhere except by (Joshi & Samant, 2004). Occurrence of 27 alpine communities, mostly representative ones and 292 species in the study area suggested its importance from the point view of conservation. The present study indicated that species richness and species diversity (H') decreased with the increasing altitude. Decreasing trend of the species with the increasing altitude has been also reported in the IHR (Samant & Dhar, 1997, Samant et al., 1998a, 1998b). Habitat wise assessment of the alpine vegetation has been carried out for the first time in the IHR. Since, habitats not only play an important role in the growth and development of species, but also maintain diversity of the species in an area. Therefore, conservation of habitats is most important than to species. If habitats are conserved, the species present will be conserved automatically. The communities with wide range of distribution had high species richness and species diversity compared to the communities with narrow range of distribution. Camping sites were mainly dominated by *Rumex nepalensis*, *Polygonum* *polystachyum*, etc. Proliferation of these species in the area is causing habitat alterations, loss of biodiversity as well as ecosystem imbalance.

In view of the importance of biodiversity of alpine meadows in NDBR adequate strategy and action plan for the conservation of habitats, communities, and ecosystems supporting high value species need to be developed and their monitoring at a regular time intervals be promoted. Rotational grazing may be allowed for the conservation and management of alpine meadows.

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Ethics
All the authors read and approved the manuscript and no ethical issues involved.

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