Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
Article DOI: 10.21474/IJAR01/5452
DOI URL: http://dx.doi.org/10.21474/IJAR01/5452

RESEARCH ARTICLE

ASSESSMENT OF VEGETATION AND PRIORITIZATION OF COMMUNITIES FOR CONSERVATION IN LATAKHARAK ALPINE MEADOWS OF NANDA DEVI BIOSPHERE RESERVE, WEST HIMALAYA, INDIA.

S. C. Arya[1] and S. S. Samant[2].

1. G.B. Pant National Institute of Himalayan Environment and Sustainable Development North-East Unit, Vivek Vihar, Itanagar- 791 113, Arunachal Pradesh.
2. G.B. Pant National Institute of Himalayan Environment and Sustainable Development Himachal Unit, Mohal-Kullu-175 126, Himachal Pradesh, India.

Manuscript Info

Manuscript History

Received: 17 July 2017
Final Accepted: 19 August 2017
Published: September 2017

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

Abstract

Himalaya is considered as the repository of the biological diversity. The richness of the biological diversity is due to its unique climatic conditions, topography and diverse habitats. The alpine meadows of Himalayan Region are very unique in terms of plant diversity and contains the habitats of many important and high value plant species. They are very rich in native and endemic plant species and very famous its scenic beauty. The present study was carried out to assess the rich plant diversity of alpine meadows in a part of Nanda Devi Biosphere Reserve. The study includes assessment of species richness, species diversity, community diversity, distribution of native, endemic, economically important and rare endangered species within the communities and prioritization of communities for conservation. During the study 10 alpine plant communities supporting 213 species, distributed in 32 sites, 8 habitats, and between 3675-4075m, amsl. 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.

Introduction:-

The alpine meadows, locally known as "*Bugyal*" in Garhwal and Kumaun, *Marg* in Kashmir and *Thach* or *Dhar* in Himachal Pradesh are very unique in terms of topography, climate, plant species. The alpine meadows located above the timber line above the average 3000m amsl altitude and consists small 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). These areas are famous for their picturesque beauty, rich 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

Corresponding Author:- S. C. Arya.
Address:- G.B. Pant National Institute of Himalayan Environment and Sustainable Development North-East Unit, Vivek Vihar, Itanagar- 791 113, Arunachal Pradesh.

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.

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). Present study has been conducted in the Latakharak alpine meadows, located in the Chamoli district, a part of NDBR.

Methods:-

Identification and Selection of Sites and Habitats:-

Sites have been selected in 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'):-

Species diversity was determined by Shanon Wiener's information statistic (H') (Shanon Weiner, 1963).

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:-
Maximum sites (11) have been represented by dry habitat, followed by bouldery and shrubberies (4 sites, each), shady moist, rocky and riverine (3 sites, each), forest edge (2 sites) and camping site (1 site), respectively. Nine sites fall in S aspect, 8 in W aspect, 7 in NW aspect, 4 in N aspect, 2 in SW aspect and, 1 in E and SE aspects, each. The slope varied from 5°-65° and boulder percent from 5-60% (Table 1).

Community Diversity, Distribution Pattern and Species Composition:-
A total of 10 communities have been delineated in the alpine area falling between 3675-4075m, amsl. The community types, altitudinal distribution, representation in site/s, habitat/s and major associates have been presented in Table 2. *Carex stracheyi* represented in maximum sites (16), followed by *Danthonia cachemyriana-Carex stracheyi* mixed (6 sites), *Danthonia cachemyriana* (3 sites). Rest of the communities represented in one site only (Table 2).

In general, a total of 227 species (12 shrubs, 215 herbs including 19 pteridophytes) had been recorded. However, 213 species (11 shrubs, 202 herbs including 19 pteridophytes) had been recorded in the sampling sites. Analysis of distribution pattern of species indicated that 81.19% species had regular distribution pattern; 9.90% species had random distribution pattern; and 8.91% species had contagious distribution pattern among the sites; and 85.15% species had regular distribution pattern; 8.91% species had random distribution pattern; and 5.94% species had contagious distribution pattern among the communities.

Community Diversity: Composition and Structure:-
Species richness among the communities ranged from 6-141. It was highest in *Carex stracheyi* (141), followed by *Danthonia cachemyriana-Carex stracheyi* mixed (124), *Danthonia cachemyriana* (87) and *Carex obscura* (42), communities (Table 3). The density ranged from 26.95-1767.20 Ind m-2. *Carex stracheyi-Danthonia cachemyriana* mixed community had maximum density (1767.20 Ind m-2), followed by *Danthonia cachemyriana-Carex stracheyi* mixed (1687.38 Ind m-2), *Danthonia cachemyriana-Cortia depressa-Carex stracheyi* mixed (1562.10 Ind m-2) and *Danthonia cachemyriana* (1004.60 Ind m-2), communities (Table 3).

Species Diversity (H'):-
Species diversity (H') ranged from 1.39-2.62. It was highest in *Fragaria nubicola-Galium acutum-Viola biflora-Cardamine impatiens* mixed community (2.62), followed by *Danthonia cachemyriana-Picrorhiza kurrooa* mixed (2.25), *Danthonia cachemyriana-Polygonum affine* mixed (2.11) and *Carex obscura* (1.84), communities (Table 3).

Distribution Pattern of the Native and Endemic Species within Communities:-
Out of the total 227 species, 71.73% species were natives. Among the natives, 3.70% species were endemic and 48.77% species were near endemic and, rest 47.53% species had wide global distribution. Of the natives, 93.21% species were herbs and 6.79% species were shrubs. Endemic species were represented in herbs only whereas near endemic species were represented in both the life forms. Among the near endemic species, 93.67% species were herbs and 6.33% species were shrubs.

The distribution of native and endemic species including near endemic ones within the identified communities from Latakharak alpine meadows have been presented in Fig. 2. The maximum natives (99 spp.) were recorded in *Carex stracheyi* community, followed by *Danthonia cachemyriana -Carex stracheyi* mixed (89 spp.) and *Danthonia cachemyriana* (61 spp.), communities. The least natives were recorded in *Polygonum polystachyum* community (3 spp. only). The maximum endemic species including near endemic ones (52 spp.) were found in *Carex stracheyi* community, followed by *Danthonia cachemyriana -Carex stracheyi* mixed (50 spp.) and *Danthonia cachemyriana* (27 spp.), communities. In *Polygonum polystachyum* community the endemic and near endemic species were absent.

Distribution Pattern of the Economically Important Species within Communities:-
From the Latakharak alpine meadows, 125 economically important species (10 shrubs, 115 herbs including 2 pteridophytes) belonging to 39 families and 91 genera had been recorded. These species were used for various purposes such as medicine (86 spp.), wild edible/food (38 spp.), fodder (48 spp.), fuel (3 spp.), religious (10 spp.) and various other purposes (11 spp.). Amongst the species, 15 species had multipurpose utility whereas 74 species had single utility.

The richness of economically important species among the identified communities ranged from 3-27. The highest species were distributed in *Carex stracheyi* (75 spp.), followed by *Danthonia cachemyriana-Carex stracheyi* (71 spp.), *Danthonia cachemyriana* (51 spp.) and *Carex obscura* (27 spp.) communities. The least useful species were distributed in *Polygonum polystachyum* community (3 spp.).

Distribution Pattern of the Rare Endangered Species within Communities:-
A total of 38 species (1 shrub, 37 herbs including 5 pteridophytes) belonging to 32 genera and 21 families have been identified as threatened from Latakharak alpine meadows. Maximum rare species were distributed in *Carex stracheyi* community (24 spp.), followed by *Danthonia cachemyriana- Carex stracheyi* mixed (18 spp.) and *Danthonia cachemyriana* mixed (10 spp.), communities. The least rare species were distributed in *Fragaria nubicola-Galium acutum-Viola biflora-Cardamine impatiens* mixed community (1 spp. only). In *Polygonum polystachyum* community the rare species were absent.

Prioritization of Communities for Conservation:-
Based on the species richness, native, endemic, economically important and rare endangered species, *Carex stracheyi* (Total species 141; Natives 99; Endemic 52; Rare-endangered 24; Useful species 75); and *Danthonia cachemyriana-Carex stracheyi* (Total species 124; Natives 89; Endemic 50; Rare-endangered 18; Useful species 71), communities have been identified as high value communities and prioritized for conservation.

Table 1:- Physical Characteristics of Sites and Habitats.

Site	Habitat type	Altitude (m)	Aspect	Slope (^{0})	Boulders %	Dominant species
1.	Camping site	3715	W	5	5	*Polygonum polystachyum, Rumex nepalensis, Fragaria nubicola, Hackelia uncinata*
2.	Dry	3715	S	15	5	*Danthonia cachemyriana, Carex stracheyi, Trachydium roylei, Carex nubigena*
3.	Dry	3700	S	15	5	*Danthonia cachemyriana, Carex stracheyi, Dactylis glomerata, Lactuca macrorhiza*
4.	Dry	3685	E	20	5	*Danthonia cachemyriana, Carex nubigena, Carex stracheyi, Eragrostis nigra*
5.	Forest edge	3690	N	25	5	*Danthonia cachemyriana, Anaphalis busua, Polygonum affine, Carex obscura*
6.	Dry	3685	S	30	5	*Carex stracheyi, Danthonia cachemyriana, Cortia depressa, Carex obscura*
7.	Shady moist	3680	S	50	5	*Danthonia cachemyriana, Cortia depressa, Carex stracheyi, Dactylis glomerata*
8.	Bouldery	3675	S	40	50	*Danthonia cachemyriana, Carex stracheyi, Carex obscura, Cyananthus lobatus*
9.	Dry	3720	W	5	5	*Danthonia cachemyriana, Carex stracheyi, Cortia depressa, Carex obscura*
10.	Dry	3740	W	25	5	*Carex stracheyi, Danthonia cachemyriana, Carex setosa, Poa alpina*
11.	Dry	3750	S	45	5	*Carex stracheyi, Cyananthus lobatus, Carex obscura, Cortia depressa*
12.	Bouldery	3750	W	45	50	*Danthonia cachemyriana, Carex stracheyi, Carex obscura, Dactylis glomerata*
13.	Rocky	3815	SW	65	0	*Carex stracheyi, Danthonia cachemyriana, Nardostachys grandiflora, Lepisorus tenuipes*

14.	Shady moist	3850	SE	50	5	*Danthonia cachemyriana, Carex stracheyi, Cyananthus lobatus, Carex nivalis*
15.	Bouldery	3850	S	25	52	*Danthonia cachemyriana, Carex stracheyi, Carex setosa, Cyananthus lobatus*
16.	Riverine	3875	S	45	25	*Carex obscura, Dactylis glomerata, Poa pratensis, Circaea alpina*
17.	Shrubberries	3900	N	25	5	*Carex stracheyi, Viola biflora, Poa pratensis, Cystopteris fragilis*
18.	Dry	3925	NW	40	5	*Carex stracheyi, Danthonia cachemyriana, Cortia depressa, Kobresia duthiei*
19.	Riverine	3925	NW	35	15	*Carex stracheyi, Danthonia cachemyriana, Senecio kunthianus, Polygonum affine*
20.	Shrubberries	3925	N	35	5	*Danthonia cachemyriana, Picrorhiza kurrooa, Polygonum affine, Gentiana kurroo*
21.	Rocky	3925	NW	65	0	*Carex stracheyi, Carex nubigena, Saxifraga pulvinaria, Danthonia cachemyriana*
22.	Shrubberries	4000	NW	50	5	*Carex stracheyi, Polygonum affine, Anaphalis contorta, Viola biflora*
23.	Dry	4000	W	50	5	*Carex stracheyi, Danthonia cachemyriana, Trachydium roylei, Polygonum affine*
24.	Dry	4015	NW	50	5	*Carex stracheyi, Carex obscura, Polygonum affine, Carex nubigena*
25.	Shady moist	4060	SW	40	5	*Carex stracheyi, Danthonia cachemyriana, Polygonum affine, Nardostachys grandiflora*
26.	Bouldery	4075	W	30	60	*Carex stracheyi, Polygonum affine, Viola biflora, Anaphalis contorta*
27.	Shrubberries	4050	NW	35	35	*Danthonia cachemyriana, Polygonum affine, Anaphalis contorta, Cerastium cerastioides*
28.	Riverine	4050	W	25	10	*Carex stracheyi, Carex setosa, Thlaspi andersonii, Picrorhiza kurrooa*
29.	Rocky	4060	W	45	0	*Carex stracheyi, Danthonia cachemyriana, Nardostachys grandiflora, Polygonum affine*
30.	Dry	4010	S	60	5	*Carex stracheyi, Danthonia cachemyriana, Trachydium roylei, Saxifraga parnassifolia*
31.	Bouldery	4010	NW	35	50	*Carex stracheyi, Poa alpina, Polygonum affine, Carex obscura*
32.	Forest edge	3680	N	15	5	*Fragaria nubicola, Galium acutum, Viola biflora, Cardamine impatiens*

Table 2:-Community types, their distribution and major associates

Community type	**SR**	**Habitat type/s**	**Altitudinal range (m)**	**Major associates**
Carex obscura	1	6	3875	*Dactylis glomerata, Poa pratensis, Circaea alpina, Galium acutum*
Carex stracheyi	16	1, 3, 6, 7, 8, 9	3740-4075	*Danthonia cachemyriana, Polygonum affine, Carex nubigena, Viola biflora*
Carex stracheyi-Danthonia cachemyriana mixed	1	3	3685	*Cortia depressa, Carex obscura, Trachydium roylei, Cyananthus lobatus*
Danthonia cachemyriana-Cortia depressa-Carex stracheyi mixed	1	8	3680	*Dactylis glomerata, Cyananthus lobatus, Trachydium roylei, Bupleurum lanceolatum*
Danthonia cachemyriana	3	3, 4, 8	3685-3850	*Carex stracheyi, Carex nubigena, Trachydium roylei, Cyananthus lobatus*
Danthonia cachemyriana-Carex stracheyi mixed	6	1, 3	3675-3850	*Carex obscura, Trachydium roylei, Cortia depressa, Dactylis glomerata*
Danthonia cachemyriana-	1	9	3925	*Polygonum affine, Gentiana kurroo,*

Picrorhiza kurrooa mixed				*Fragaria nubicola, Saxifraga parnassifolia*
Danthonia cachemyriana-Polygonum affine mixed	1	9	4050	*Anaphalis contorta, Cerastium cerastioides, Thalictrum chelidonii, Bergenia stracheyi*
Fragaria nubicola-Galium acutum-Viola biflora-Cardamine impatiens mixed	1	4	3680	*Impatiens racemosa, Carex obscura, Lactuca dissecta, Polygonum polystachyum*
Polygonum polystachyum	1	2	3715	*Rumex nepalensis, Fragaria nubicola, Hackelia uncinata, Elsholtzia eriostachys*

Abbreviations used: SR=Site representation; 1= Bouldery; 2= Camping site; 3= Dry; 4= Forest edge; 6= Riverine; 7= Rocky; 8= Shady moist; 9= Shrubberries

Table 3:-Community wise distribution of species richness, total density and species diversity

S.N.	Community type	**Species richness**	**Total density (Indm^{-2})**	**Diversity (H')**
1.	*Carex obscura*	42	403.95	1.84
2.	*Carex stracheyi*	141	660.24	1.39
3.	*Carex stracheyi-Danthonia cachemyriana* mixed	40	1767.20	1.65
4.	*Danthonia cachemyriana-Cortia depressa-Carex stracheyi* mixed	40	1562.10	1.68
5.	*Danthonia cachemyriana*	87	1004.60	1.59
6.	*Danthonia cachemyriana-Carex stracheyi* mixed	124	1687.38	1.54
7.	*Danthonia cachemyriana-Picrorhiza kurrooa* mixed	21	78.65	2.25
8.	*Danthonia cachemyriana-Polygonum affine* mixed	14	67.80	2.11
9.	*Fragaria nubicola-Galium acutum-Viola biflora-Cardamine impatiens* mixed	21	87.70	2.62
10.	*Polygonum polystachyum*	6	26.95	1.40

Appendix I:-Diversity, nativity and endemism of vascular plants in Latakharak alpine meadows

Family/taxa	**LF**	**Nativity**	**Endemism**
Angiosperms			
Alliaceae			
Allium humile Kunth.	H	Ind Or	-
A. stracheyi Baker	H	Reg Himal	E
A. wallichii Kunth.	H	Europe Oriens	-
Apiaceae			
Angelica glauca Edgew.	H	Reg Himal	E
Bupleurum candollei Wall. ex DC.	H	Reg Himal	-
B. falcatum L.	H	Europe Oriens As Bor Reg Himal	-
B. lanceolatum Wall. ex DC.	H	Reg Himal	NE
Carum carvi L.	H	Europe Oriens As Bor	-
Cortia depressa (Don) Norman	H	Reg Himal	E
Heracleum brunonis Benth.	H	Reg Himal	NE
Pleurospermum angelicoides (DC.) Cl.	H	Reg Himal	-
P. densiflorum (Lindl.) Cl.	H	Reg Himal	E
Selinum elatum (Edgew.) Hiroe	H	Reg Himal	NE
S. vaginatum Cl.	H	Reg Himal	-
Seseli sibiricum (L.) Boiss.	H	Europe Orient	-
Trachydium roylei Lindl.	H	Reg Himal	-
Asteraceae			
Anaphalis busua (Buch.-Ham. ex D. Don) DC.	H	Reg Himal	-
A. contorta (D. Don) Hk.f.	H	Reg Himal	-
*A. nepalensis (*Spreng.) Hand.-Mazz.	H	Reg Himal	-

A. royleana DC.	H	Reg Himal	-
A. triplinervis (Sims.) Cl.	H	Reg Himal	-
Aster diplostephioides (DC.) Cl.	H	Reg Himal	-
Cirsium wallichii DC.	H	Reg Himal	NE
Cremanthodium arnecoides (Wall. ex DC.) Good	H	Reg Himal	-
Dubyaea hispida (D. Don) DC.	H	Reg Himal	-
Gerbera gossypina (Royle) Beauv.	H	Reg Himal	NE
Inula grandiflora Willd.	H	Reg Himal et Caucas	-
Jurinella macrocephala (Royle) Aswal et Goel	H	Reg Himal	NE
Lactuca dissecta D. Don	H	Reg Himal	-
L. macrorhiza (Royle) Hk. f.	H	Reg Himal	-
L. violaefolia (Decne) Cl.	H	Reg Himal	-
L. himalayanum DC.	H	Europe Reg Himal	-
Saussurea costus (Falc.) Lipsch.	H	Reg Himal	-
S. deltoidea Cl.	H	Reg Himal	-
S. obvallata Wall.	H	Reg Himal	-
Senecio alatus Wall. ex DC.	H	Reg Himal	NE
S. chrysanthemoides DC.	H	Reg Himal	-
S. graciliflorus DC.	H	Reg Himal	NE
S. kunthianus Wall. ex DC.	H	Reg Himal	NE
S. quinquelobus Hk.f. & Th.	H	Reg Himal	-
Solidago virga-aurea L.	H	Reg Bor Temp	-
Tanacetum tomentosum DC.	H	Reg Himal	NE
Taraxacum officinalis Webber	H	Reg Temp Bor et Austr	-
Balsaminaceae			
Impatiens racemosa DC.	H	Reg Himal	NE
I. thomsonii Hk. f.	H	Reg Himal	NE
Boraginaceae			
Arnebia benthamii (Wall. ex G. Don) John.	H	Reg Himal	NE
Eritrichum canum (Benth.) Kitamura	H	Ind Or (Reg Himal)	NE
Hackelia uncinata (Royle ex Benth.) Fisch.	H	Reg Himal	-
Maharanga emodi (Wall.) DC.	H	Reg Himal	NE
Brassicaceae			
Arabidopsis himalaica (Edgew.) Schultz.	H	Reg Himal	NE
A. thaliana (L.) Heynh.	H	Reg Temp	-
Cardamine impatiens L.	H	Reg Himal	-
Megacarpaea polyandra Benth.	H	Reg Himal	NE
Thlapsi andersonii (Hk.f. & Th.) Schulz.	H	Europe As Bor	-
T. arvense L.	H	Europe As Bor	-
Campanulaceae			
Campanula colorata Wall.	H	Ind Or Afghan	-
Cyananthus lobatus Wall. ex Benth.	H	Reg Himal	-
Caprifoliaceae			
Lonicera obovata Royle ex Hk. f. & Th.	Sh	Reg Himal	-
Caryophyllaceae			
Arenaria festucoides Benth.	H	Reg Himal	NE
*Cerastium cerastioides (*L.) Britton	H	Reg Himal	NE
Silene gonosperma (Rupt.) Bocqet.	H	Reg Himal	-
S. setisperma Majumdar	H	Reg Himal	NE
Stellaria decumbens Edgew.	H	Reg Himal	-
Crassulaceae			
Rhodiola bupleuroides Wall. ex Hk. f. & Th.	H	Reg Himal	-

R. heterodonta (Hk.f. & Th.) Boiss.	H	Reg Himal	NE
Sedum ewersii Ledeb	H	Reg Himal	-
S. multicaule Wall. ex Lindl.	H	Reg Himal China	-
Cyperaceae			
Carex nivalis Boott	H	Reg Himal	NE
C. nubigena D. Don	H	Ind Or	-
C. obscura Nees	H	Reg Himal	NE
C. setosa Boott	H	Reg Himal	-
C. stracheyi Boott ex Cl.	H	Reg Himal	NE
Kobresia duthiei Cl. ex Hk. f.	H	Reg Himal	E
K. laxa Nees	H	Reg Himal	-
Dipsacaceae			
Morina longifolia Wall. ex DC.	H	Reg Himal	NE
Ericaceae			
Cassiope fastigiata (Wall.) D. Don	Sh	Reg Himal	NE
Rhododendron anthopogon D. Don	Sh	As Bor Reg Himal	NE
R. campanulatum D. Don	Sh	Reg Himal	NE
Euphorbiaceae			
Euphorbia pilosa L.	H	Europe As Bor	-
E. stracheyi Boiss.	H	Reg Himal	-
Fabaceae			
Hedysarum kumaonense Benth. ex Baker	H	Ind Or (Reg Himal)	NE
Thermopsis barbata Royle	H	Reg Himal	-
Trigonella emodi Benth.	H	Reg Himal	-
Fumariaceae			
Corydalis cashmiriana Duthie & Prain	H	Reg Himal	NE
C. govaniana Wall.	H	Reg Himal	NE
C. thyrsiflora Prain	H	Reg Himal	NE
Gentianaceae			
Gentiana argentea (D. Don) Cl.	H	Reg Himal China	-
G. carinata Griseb.	H	Reg Himal	NE
G. kurroo Royle	H	Reg Himal	NE
Gentianella moorcroftiana (Wall. ex Griseb.) Shaw ex Rau	H	Reg Himal	NE
G. pedunculata (D. Don) Sm.	H	Reg Bor Arct	-
Halenia elliptica D. Don	H	Reg Himal	-
Lomatogonium carinthiacum (Wulf.) Br.	H	Europe As Bor	-
Swertia angustifolia Buch.-Ham.	H	Reg Himal	-
S. ciliata (D. Don) Burtt.	H	Reg Himal	NE
S. cuneata Wall. ex D. Don	H	Reg Himal	NE
S. paniculata Wall.	H	Reg Himal	NE
Geraniaceae			
Geranium wallichianum D. Don ex Sw.	H	Reg Himal	NE
G. rotundifolium L.	H	Reg Bor Temp	-
Haemodoraceae			
Aletris pauciflora (Klotz.) Hand.-Mazz.	H	Reg Himal	-
Iridaceae			
Iris kumaonensis D. Don ex Royle	H	Reg Himal	-
Juncaceae			
Juncus concinnus D. Don	H	Reg Himal	-
Lamiaceae			
Clinopodium umbrosum (Fisch. et May.) Ktze.	H	Reg BorTemp	-
Elsholtzia eriostachys Benth.	H	Reg Himal	-

E. fruticosa (D. Don) Rehder	H	Reg Himal	-
Origanum vulgare L.	H	Europe As et Afr	-
Phlomis bracteosa Royle ex Benth.	H	Reg Himal	-
Teucrium royleanum Wall. ex Benth.	H	Reg Himal	-
Thymus linearis Benth.	H	Europe As et Afr Bor	-
Liliaceae			
Fritillaria roylei D. Don ex Hk.	H	Reg Himal	NE
Lloydia serotina (L.) Reichb.	H	Europe	-
Nomocharis nana (Klotzsch) E. H. Wilson	H	Reg Himal	-
N. oxypetala (Royle) Wilson	H	Reg Himal	NE
Polygonatum cirrhifolium (Wall.) Royle	H	Reg Himal As Bor	-
P. verticillatum (L.) All.	H	Europe As Bor	-
Smilacina purpurea Wall.	H	Reg Himal	-
Onagraceae			
Circaea alpina L.	H	Europe As Bor Am Bor	-
Epilobium latifolium L.	H	Reg Bor et Arct	-
E. roseum (Schreb.) Pers.	H	Europe As Occ	-
Orchidaceae			
Dactylorhiza hatagirea (D. Don) Soo	H	Reg Himal Europe Afr Bor Oriens	-
Goodyera fusca (Lindl.) Hk.f.	H	Reg Himal	-
Gymnadenia orchidis L.	H	Reg Himal	NE
Herminium monorchis (L.) R.Br.	H	Europe As Bor	-
Malaxis muscifera (Lindl.) Ktz.	H	Europe	-
Ponerorchis chusua D. Don	H	Reg Himal	-
Papaveraceae			
Meconopsis aculeata Royle	H	Reg Himal	NE
Parnassiaceae			
Parnassia nubicola Wall.	H	Reg Himal	NE
P. pussila Wall.	H	Reg Himal	NE
Poaceae			
Agrostis pilosula Trin.	H	Ind Or	-
Bromus himalaicus Stapf.	H	Ind Or	-
B. japonicus Thunb.	H	Japan	-
Dactylis glomerata L.	H	Europe As Bor	-
Danthonia cachemyriana Faub. & Spach.	H	Ind Or (Reg Himal)	NE
Eragrostis nigra Nees ex Steud.	H	Afr Trop Ind Or Austr	-
Poa alpina L.	H	Reg Bor et Arct Tauria	-
P. pratensis L.	H	Reg Bor Temp	-
Podophyllaceae			
Podophyllum hexandrum Royle	H	Reg Himal	-
Polygonaceae			
Oxyria digyna (L.) Hill.	H	Reg Bor Alp et Arct	-
Polygonum affine D. Don	H	Reg Himal	NE
P. amplexicaule D. Don	H	Reg Himal	-
P. polystachyum Wall.	H	Reg Himal	-
P. rumicifolium Royle ex Bab.	H	Reg Himal	NE
P. vaccinifolium Wall. ex Meissn.	Sh	Reg Himal	-
Rheum australe D. Don	H	Reg Himal	NE
R. webbianum Royle	H	Reg Himal	NE
Rumex nepalensis Spreng.	H	As Occ Ind Or Malaya Afr Austr	-
R. acetosa L.	H	Europe As Bor	-
Primulaceae			

Androsace sarmentosa Wall.	H	Reg Himal	NE
Primula atrodentata Sm.	H	Reg Himal	NE
P. denticulata Sm.	H	Reg Himal	-
P. elliptica Royle	H	Reg Himal	NE
P. glomerata Pax.	H	Reg Himal	NE
P. macrophylla D. Don	H	As et Am Bor	-
P. reptans Hk.f. ex Wall.	H	Reg Himal	NE
Ranunculaceae			
Aconitum voilaceum Jacq.	H	Reg Himal	NE
A. balfourii Stapf.	H	Reg Himal	NE
A. heterophyllum Wall. ex Royle	H	Reg Himal	NE
Anemone obtusiloba D. Don	H	Reg Himal	-
A. polyanthes D. Don	H	Reg Himal	NE
A. rupicola Camb.	H	Reg Himal	-
Aquilegia pubiflora Wall. ex Royle	H	Ind Or	-
Caltha palustris L.	H	Reg Bor Temp et Arct	-
Clematis acuminata DC.	Sh	Reg Himal	NE
C. barbellata Edgew.	Sh	Reg Himal	NE
*Oxygraphis polypetala (*Royle) Hk.f. & Th.	H	Reg Himal	NE
Paraquilegia microphylla (Royle) Drum. & Hutch.	H	Reg Himal Sibir Altaic	-
Ranunculus hirtellus Royle	H	Reg Himal	-
Thalictrum alpinum L.	H	Reg Bor et Arct	-
T. chelidonii DC.	H	Reg Himal	-
T. elegans Wall. ex Royle	H	Reg Himal	NE
T. pauciflorum Royle	H	Europe et As Bor	-
T. reniforme Wall.	H	Reg Himal	NE
Rosaceae			
Arunchus dioicus (Walt.) Fernald	H	Reg Bor Temp	-
Cotoneaster microphyllus Wall. ex Lindl.	Sh	Reg Himal	-
Fragaria nubicola Lindl. ex Lacaita	H	Am Bor	-
Geum elatum Wall.	H	Reg Himal	NE
Potentilla argyrophylla Wall. ex Lehm.	H	Reg Himal	NE
P. atrosanguinea Lodd.	H	Reg Himal	NE
P. microphylla D. Don	H	Reg Himal	NE
P. peduncularis D. Don	H	Reg Himal	-
Rosa macrophylla Lindl.	Sh	Reg Himal China	-
Sibaldia cuneata Hornem. ex Kunge	H	Reg Bor et Austr	-
S. purpurea Royle	H	Reg Himal	NE
Rubiaceae			
Galium acutum Edgew.	H	Reg Himal	NE
G. elegans Wall. ex Roxb.	H	Europe As Temp	-
Salicaceae			
Salix lidleyana Wall. ex Ander.	Sh	Reg Himal	-
Saxifragaceae			
Bergenia stracheyi (Hk.f. & Th.) Engl.	H	Reg Himal	NE
Chrysosplenium carnosum Hk.f. & Th.	H	Reg Himal	NE
Saxifraga brachypoda D. Don var. *Frimbriata* (DC.) Engl.	H	Reg Himal	-
S. parnassifolia D. Don	H	Reg Himal	NE
S. pulvinaria Sm.	H	Reg Himal	NE
S. sibirica L.	H	As Bor et Arct	-
Scrophulariaceae			
Euphrasia himalayica Wettst.	H	Reg Himal	NE

Pedicularis bicornuta Klotz.	H	Reg Himal	NE
P. hoffmeisteri Klotz. & Garcke	H	Reg Himal	NE
P. hookeriana Wall. ex Kunth.	H	Reg Himal Persea	-
P. pectinata Wall.	H	Reg Himal	NE
Picrorhiza kurrooa Royle ex Benth.	H	Reg Himal	-
Scrophularia himalensis Royle ex Benth.	H	Reg Himal	-
Verbascum thapsus L.	H	Europe Or Reg Himal	-
Veronica capitata Benth.	H	Reg Himal	-
V. lanosa Royle ex Benth.	H	Reg Himal Afghan	NE
Valerianaceae			
Nardostachys grandiflora DC.	H	Reg Himal	-
Valeriana hardwickii Wall.	H	Reg Himal Malaya	-
V. pyrolaefolia Decne	H	Reg Himal	-
Violaceae			
Viola biflora L.	H	Reg Bor Temp	-
Gymnosperms			
Cupressaceae			
Juniperus communis L.	Sh	Reg Bor Temp et Arct	-
J. indica Bertol	Sh	Soongar Reg Himal Reg Bor	-
Pteridophytes			
Athyriaceae			
Athyrium attenuatum (Cl.) Tag. forma Attenuatum	Pt	-	-
A. duthiei (Bedd.) Bedd.	Pt	-	-
A. wallichianum Ching	Pt	-	-
Cystopteris fragilis (L.) Bernh.	Pt	-	-
C. montana (Lam.) Bernh. ex Desv.	Pt	-	-
Cryptogrammaceae			
Cryptogramma stellarii (Gmel.) Prantl.	Pt	-	-
Dryopteridaceae			
Dryopteris barbigera (Hk.) Ktze.	Pt	-	-
D. panda (Cl.) Christ.	Pt	-	-
D. wallichiana (Spr.) Hyl.	Pt	-	-
Polystichum lachenense (Hk.) Bedd.	Pt	-	-
P. prescottianum (Wall. ex Mett.) Moore	Pt	-	-
P. wilsonii Christ.	Pt	-	-
Equisetaceae			
Equisetum arvense L.	Pt	-	-
Osmundaceae			
Osmunda claytoniana L.	Pt	-	-
Polypodiaceae			
*Lepisorus morrisonensis (*Hayata) H. Ito	Pt	-	-
L. tenuipes Ching et Khullar	Pt	Reg Himal	E
Phymatopteris stracheyi (Ching) Pichi - Sermoli	Pt	-	-
Thelypteridaceae			
Pseudophegopteris levengii (Cl.) Ching	Pt	-	-
Woodsiaceae			
Woodsia lanosa Hk.	Pt	-	-

Abbreviations used: H= Herb; Sh= Shrub; Pt= Pteridophyte; LF= Life form; Afghan= Afghanistan; Afr= Africa; Alp= Alpine; Am= America; Amphig= Amphigaea; Arab= Arabia; Arct= Arctic; As= Asia; Austr= Australia; Baluchist= Baluchistan; Bor= Borealis; Caucas= Caucasus; Centr= Central; Cosmop= Cosmopolitan; et= And; Geront= Gerontia; Himal= Himalayan; Hisp= Hispan; Ind= Indian; Mediterr= Mediterranean; Mongol= Mongolia;

N. Zel= New Zeyland; Occ= Occidentalis; Or= Oriental; Orient= Oriental; Reg= Region; Soongar= Soongarica; Subtrop= Subtropical; Temp= Temperate; Trop= Tropical; Turkist= Turkistan; E= Endemic; NE= Near Endemic

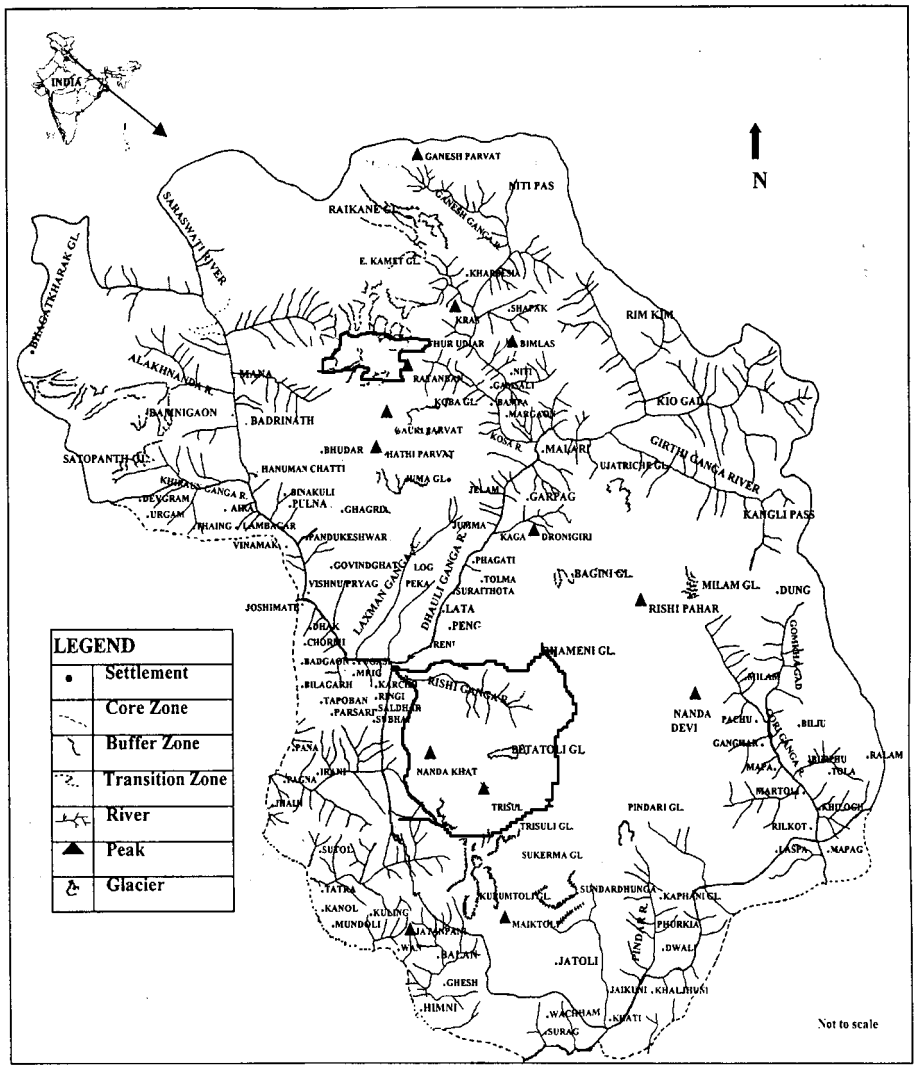

Fig 1:- Location of Nanda Devi Biosphere Reserve (Prepared by Lead Office, GBPIHED, Kosi-Katarmal, Almora)

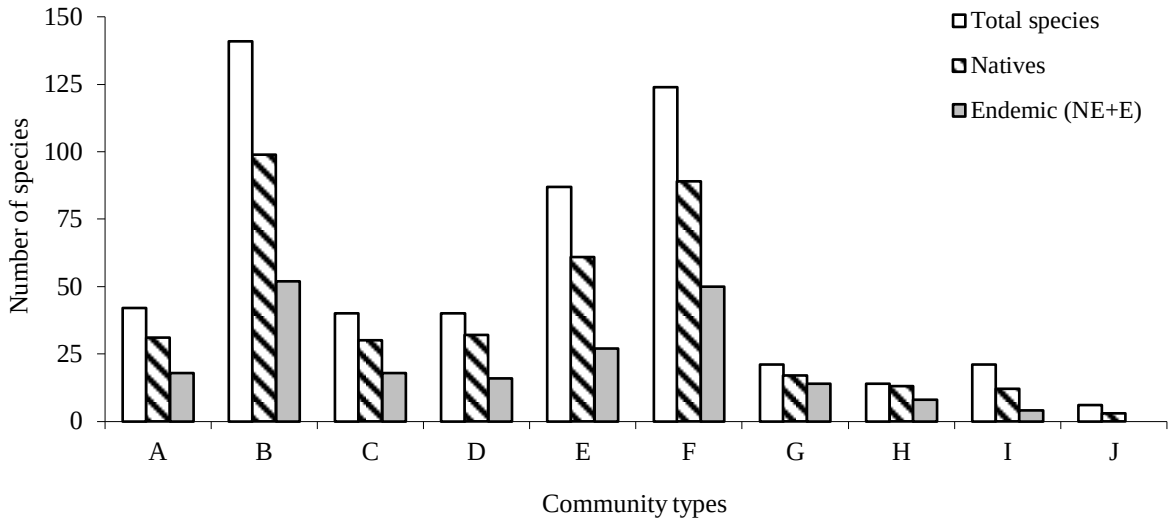

Fig. 2:- Distribution of native and endemic species in alpine communities of Latakharak area

Abbreviations used (Community types A-J):- A=*Carex obscura*; B=*Carex stracheyi*; C=*Carex stracheyi-Danthonia cachemyriana* mixed; D=*Danthonia cachemyriana-Cortia depressa-Carex stracheyi* mixed; E=*Danthonia cachemyriana*; F=*Danthonia cachemyriana-Carex stracheyi* mixed; G=*Danthonia cachemyriana-Picrorhiza kurrooa* mixed; H=*Danthonia cachemyriana-Polygonum affine* mixed; I=*Fragaria nubicola-Galium acutum-Viola biflora-Cardamine impatiens* mixed; and J=*Polygonum polystachyum*

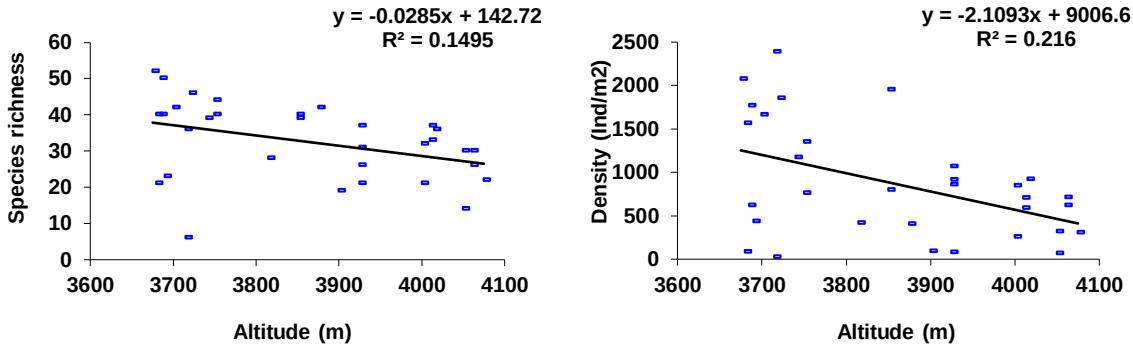

Fig. 3:-Correlations between altitude and species richness; (a) and (b) altitude and density

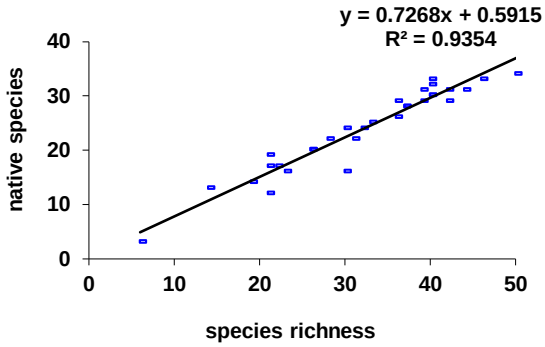

Fig. 4:-Correlations between species richness and native species

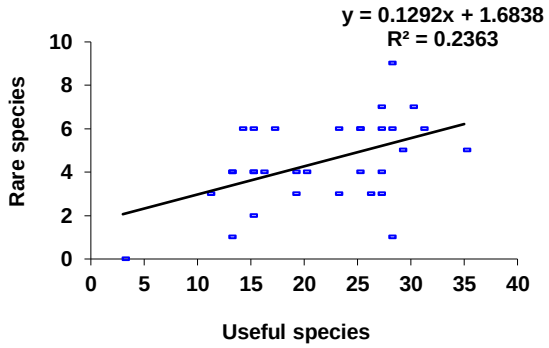

Fig 5:- Correlation between numbers of useful species with number of rare species

Discussion:-

Total 10 communities and 227 species have been recorded from Latakharak alpine meadows of Nanda Devi Biosphere Reserve. The species and communities of the meadow were analyzed for nativity, endemism, human dependence and rarity. The occurrence of high native, endemic, economically important, and rare-endangered species indicated the high conservation value of the meadows.

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. Considering all the sites together, most species showed regular distribution pattern both, among sites and communities in all the areas.

The total density range among communities (26.95-1767.20 Ind m^{-2}) was comparatively higher. 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 *Polygonum polystachyum, Danthonia cachemyriana-Polygonum affine* mixed, *Danthonia cachemyriana-Picrorhiza kurrooa* mixed, *Fragaria nubicola-Galium acutum-Viola biflora-Cardamine impatiens* 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* 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. Such species do not allow other species to grow. Among the habitats, camping sites, shrubberies and forest edges showed the lowest densities.

The species richness among communities (6-141) 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).

A significant negative correlation had been found between altitude and species richness ($r=0.387$ $p<0.01$ $n=32$) and altitude and density ($r=-0.465$, $p<0.01$ $n=32$) in Latakharak alpine meadows indicating that with the increasing altitude the species richness and density decreased. (Fig. 3 a-b).
The occurrence of maximum number of species in *Carex stracheyi* and *Danthonia cachemyriana-Carex stracheyi* mixed, community may be attributed due to their wide range of distribution and habitat preference. Similarly, the occurrence of minimum number of species in *Polygonum polystachyum and Danthonia cachemyriana-Polygonum affine mixed* communities may be due to their narrow range of distribution and restricted habitats.

The *Polygonum polystachyum* community was represented by camping site, a habitat which have been developed due to the camping by sheep grazers and also by trampling of sheep's and goats (Ram & Singh, 1994). The low species richness in *Polygonum polystachyum and Danthonia cachemyriana-Polygonum affine mixed* community was represented by shrubberries habitat. The occurrence of shrubs in the habitat might be the reason of low species diversity.

The maximum diversity in the communities, such as *Fragaria nubicola-Galium acutum-Viola biflora-Cardamine impatiens* mixed, *Danthonia cachemyriana-Picrorhiza kurrooa* mixed, *Danthonia cachemyriana-Polygonum affine* mixed may be due to heterogeneous composition of the species with almost similar trend of distribution. The minimum diversity in the communities, such as *Carex stracheyi*, *Polygonum polystachyum*, *Danthonia cachemyriana-Carex stracheyi* mixed and *Danthonia cachemyriana*, may be mainly due to narrow range of distribution, habitat restriction and dominance of some species.

Due to relatively harsh climatic and topographic conditions of the alpine meadows the non-native species could not easily adapted, therefore the existence of no-native species is comparatively low in this region. Further, due to the remoteness, inaccessibility and severe climatic conditions the 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 species richness and native species among the communities (0.967, $p<0.01$ n=32) (Fig. 4).

Aconitum balfourii, *A. heterophyllum*, *Angelica glauca*, *Megacarpaea polyandra*, *Bergenia stracheyi*, *Dactylorhiza hatagirea*, *Polygonatum verticillatum*, *Arnebia benthamii*, *Picrorhiza kurrooa*, *Nardostachys grandiflora*, *Pleurospermum angelicoides*, *Podophyllum hexandrum*, *Jurinella macrocephala*, *Saussurea obvallata*, *Rheum australe*, 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 useful species and number of rare species Latakharak (0.486, $p<0.01$ n=32), (Fig. 5) indicating that the use of the species was directly proportional to the rarity of the species.

Overall, 10 communities have been identified from the Latakharak alpine meadows of NDBR, which are comparatively higher than the communities identified from Valley of Flowers (Kala et al., 1998), Baideni (Rikhari et al., 1992; Negi et al., 1992) and Panwalikantha, alpine meadows (Raizada et al., 1998). In all the alpine meadows, species richness, diversity, nativity, endemism, rarity, and use values varied from community to community.
Based on these values, in Latakharak alpine meadows, *Carex stracheyi* (Total species 141; Natives 99; Endemic 52; Rare-endangered 24; Useful species 75); and *Danthonia cachemyriana-Carex stracheyi* (Total species 124; Natives 89; Endemic 50; Rare-endangered 18; Useful species 71), communities, have been identified as high value communities and merit priority attention for conservation.

The richness of useful species in these communities indicates high anthropogenic pressure. If indiscriminate exploitation of the useful species from these communities continues, there is 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 conducted in Latakharak alpine meadows of NDBR provides data base on compositional and structural, distribution pattern of species, communities, native, endemic and rare-endangered species within different communities. The study provides a comprehensive information on human dependence on plant resources, indigenous uses, rare-endangered species, and prioritization of communities for conservation. Occurrence of 10 alpine communities, mostly representative ones and 213 species in the study area suggested its importance from the point view of conservation.

The present study indicated that species richness and density 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). Habitats play a significant role in the distribution pattern and growth of the plant species. Therefore, habitat wise assessment of the alpine vegetation has been carried out for the first time in the IHR. The conservation of habitats is most important for the conservation of 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.

Keeping in view the rich biodiversity of alpine meadows it is pertinent to make an appropriate strategy and action plan for the conservation and management of habitats, communities and ecosystems, supporting high value species.

Acknowledgements:-

The authors are thankful to the Director of the Institute for facilities and encouragement. Help received from Dr. H.C. Joshi during field surveys and preparation of the paper, Dr. K.K. Kothari, Mr. S. Pant and Mr. B.M. Joshi during the preparation of this paper is highly acknowledged. Ministry of Environment & Forests, New Delhi and Council of Scientific and Industrial Research, New Delhi, are greatly acknowledged for financial assistance.

References:-

1. Anonymous (1883-1970): *Index Kewensis Plantarum Phanerogamarum* Vol. 1-2 (1883- 1885) *and 15 Suppl. (1886-1970)*. Clarendron Press, Oxford.
2. Anonymous (1989): *The State of Forest Report 1989.* Forest Survey of India, Government of India, Dehradun.
3. Billings, W.D. (1973): Arctic and alpine vegetation: similarities, differences and susceptibility to disturbance. *Biosciences,* **23:** 697-704.
4. Dhar, U. & Samant, S.S. (1993): Endemic diversity of Indian Himalaya I. Ranunculaceae and II. Paeoniaceae. *Journal of Biogeography,* **20:** 659-668.
5. Dhar, U., Rawal, R.S. and Samant, S.S. (1997): Structural diversity and representativeness of forest vegetation in a protected area of Kumaun Himalaya, India: implications for conservation. *Biodiversity and Conservation,* **6:** 1045 -1062.
6. Greig-Smith, P. (1957): *Quantitative plant ecology*. New York: Academic Press.
7. Grime, J.P. (1979): Plant Strategies and Vegetation Processes. New York: John Wiley and Sons.
8. Hajra, P.K. and Balodi, B. (1995): *Plant wealth of Nanda Devi Biosphere Reserve.* Botanical Survey of India, Calcutta.
9. Hajra, P.K. and Jain, S.K. (1981): *A contribution to the Botany of Nanda Devi National Park in Uttar Pradesh, India*. Botanical Survey of India, Howrah.
10. Hajra, P.K. (1983): *A contribution to the Botany of Nanda Devi National Park.* Botanical Survey of India, Howrah.
11. Harper, J.L. (1977): Population Biology of Plants. London: Academic Press.
12. Johnsing, A.J.T., Rawat, G.S., Satyakumar, P.V., and Kuar, J. (1998): Prioritization of area for biodiversity conservation of alpine zone in Trans and Greater Himalaya in India. *Biodiversity Conservation Prioritization Project in India*. WWF, New Delhi. pp. 212-224.
13. Joshi, H.C., Arya, S.C. and Samant, S.S. (1999): Diversity, distribution and indigenous uses of medicinal and edible plants in a part of Nanda Devi Biosphere Reserve I. *Himalayan Biosphere Reserves,* **1(1&2):** 49-65.
14. Joshi, H.C., Arya, S.C. and Samant, S.S. (2001): Diversity, distribution and indigenous uses of plant species in Pindari area of Nanda Devi Biosphere Reserve-II. *Indian Journal of Forestry,* **24 (4):** 514-536.
15. Joshi, S.P., Raizada, A. & Srivastava, M.M. (1988): Net primary productivity of a high altitude grassland in Garhwal Himalaya. *Tropical Ecology*, **29:** 15-20.
16. Joshi, S.P. & Srivastava, M.M. (1988): Effect of grazing on species composition, diversity and productivity in a high altitude pasture in Garhwal Himalaya. *Int. Jour. Enviro. Sci.*, **14:** 221-227.
17. Joshi, S.P. & Srivastava, M.M. (1991): The status of grazing land of alpine region in Garhwal Himalayas. In: *Advances in Himalayan Ecology*. (ed.) G.S. Rajwar, Today and Tomorrow Printers and Publishers, New Delhi. pp. 1-12.
18. Joshi, H.C. & Samant, S.S. (2004): Compositional and structural diversity of woody vegetation in Nanda Devi Biosphere Reserve of west Himalaya I. International Journal of Sustainable Development and World Ecology, **11(3):** 326-336
19. Kala, C.P. and Rawat, G.S. (1999): Effects of livestock grazing on the species diversity and biomass production in the alpine meadows of Garhwal Himalaya, India. *Tropical Ecology,* **40(1):** 69-74.
20. Kala, C.P., Rawat, G.S. and Uniyal, V.K. (1998): *Ecology and conservation of the Valley of Flowers National Park, Garhwal Himalaya*. Report. Wildlife Institute of India, Dehradun.

21. Kaul, V. and Sarin, Y.K. (1971): The phytosociology of some alpine meadows in North West Himalaya. *Vegetatio*, **23:** 261-368.
22. Kersaw, K.A. (1973): *Quantitative and dynamic plant ecology*. Second edition. London: Edward Arnold Limited.
23. Ludwig, J.A. and Reynolds, J.F. (1988): Statistical Ecology: A primer on methods and Computing. USA: John Willey and Sons, 337 pp.
24. Mani, M.S. (1978): *Ecology and Phytogeography of the High Altitude Plants of the North West Himalaya.* New Delhi: Oxford and IBH Publishing Company, India.
25. Misra, R. (1968): *Ecological Work Book*. Calcutta: Oxford and IBH Publishing Company.
26. Mueller-Dombois, D. and Ellenberge, H. (1974): *Aims and methods of vegetation ecology*. New York: John Willey and Sons.
27. Naithani, B.D. (1984 and 1985): *Flora of Chamoli district. Vol. I and II*. Botanical Survey of India, Howrah.
28. Nautiyal, B.P., Pandey, N. and Bhatt, A.D. (1997): Analysis of vegetation pattern in alpine zone in North West Himalaya: A case study of Garhwal Himalaya with special reference to diversity and distributional patterns. *International Journal of Ecology and Environmental Science,* **23:** 49-65.
29. Nautiyal, M.C., Nautiyal, B.P. and Prakash, V. (2001): Phenology and growth form distribution in an alpine pasture at Tungnath, Garhwal, Himalaya. *Mountain Research and Development,* **21(2):** 168-174.
30. Nayar, M.P. and Sastry, A.R.K. (1987,1988, 1990): *Red Data Book of Indian Plants. Vol. I-III.* Botanical Survey of India, Calcutta.
31. Negi, C.G.S., Rikhari, H.C. and Singh, S.P. (1992): Phenological features in relation to growth forms and biomass accumulation in an alpine meadow of the central Himalaya. *Vegetatio,* **101:** 161-170.
32. Negi, G.C.S, Rikhari, H.C. and Singh, S.P. (1993): Plant re-growth following selective horse and sheep grazing and clipping in an Indian central Himalayan alpine meadow. *Arctic and Alpine Research*, **25(3):** 211-215.
33. Pangtey, Y.P.S., Rawal, R.S., Bankoti, N.S. and Samant, S.S. (1990): Phenology of high altitude plants of Kumaun in central Himalaya, India. *International Journal of Biometeorology,* **34:** 122-127.
34. Pangtey, Y.P.S., Samant, S.S. and Rawal, R.S. (1993): Enumeration of ferns of Pindari, Sarju and east Ramganga valleys of Kumaun (western Himalaya). Higher Altitude of Indian Sub continent. *Additional Series of Indian Journal of Forestry*, **4:** 119-152.
35. Polunin, O. and Stainton, A. (1984): *Flowers of the Himalaya.* Oxford: Oxford University Press.
36. Raizada, A., Joshi, S.P. and Srivastava, M.M. (1998): Composition and Vegetational diversity in an alpine grassland in the Garhwal Himalayas. *Tropical Ecology,* **39:** 133-141.
37. Ram, J. (1988): *Phytosociology and Primary Productivity of an Alpine Grassland of Garhwal Himalaya*. Ph.D. Thesis, Kumaun University, Nainital.
38. Ram, J. (1992): Effect of clipping on aboveground plant biomass and total herbage yield in a grassland above treeline in central Himalaya, India. *Arctic and Alpine Research,* **24:** 78-81.
39. Ram, J. & Singh, S.P. (1994): Ecology and Conservation of alpine meadows in Central Himalaya. India. In Y.P.S. Pangtey & R. S. Rawal (eds.) *High altitudes of the Himalaya: biogeography, ecology and conservation.* Gyanodaya Prakashan, Nainital. pp. 33-35.
40. Ram, J., Singh, S.P. and Singh, J.S. (1988): Community level phenology of grassland above treeline in Central Himalaya, India. *Arctic and Alpine Research,* **20:** 325-332.
41. Ram, J., Singh, J.S. & Singh, S.P. (1989): Plant biomass, species diversity and net primary production in a central Himalayan high altitude grassland. *Journal of Ecology*, **77:** 456-468.
42. Rau, M.A. (1975): *High altitude flowering plants of western Himalaya.* Botanical Survey of India, Calcutta.
43. Rawat, G.S. and Pangtey, Y.P.S. (1987): A contribution to the ethnobotany of alpine regions of Kumaun. *Journal of Economic and Taxonomic Botany,* **11(1):** 139-148.
44. Rawat, G.S. and Pangtey, Y.P.S. (1987): Floristic structure of snowline vegetation in central Himalaya, India. *Arctic and Alpine Research,* **19 (2):** 195-201.
45. Rawat, G.S. and Rodgers, W.A. (1988): The alpine meadows of Uttar Pradesh. An Ecological review. *In* Pathak, P.C. (ed.), *Rangelands: Resource and Management*. Jhansi. 119-137.
46. Rawat, G.S., and Uniyal, V.K. (1993): Pastoralism and plant conservation. The Valley of Flowers dilemma. *Environmental Conservation,* **20:** 164-167.
47. Rikhari, H.C., Negi, G.C.S., Rana, B.S., and Singh, S.P. (1992): Phytomass and primary productivity in several communities of a central Himalayan alpine meadow, India. *Arctic and Alpine Research,* **24:** 344-351.
48. Rodgers, W.A. and Panwar, H.S. (1988): *Planning a Wildlife Protected Area Network in India.* Vol. I. Report. Wildlife Institute of India, Dehradun.

49. Sahai, B. and Kimothi, M.M. (1996): Remote sensing for surveying, mapping and monitoring of conservation areas in Himalaya. *In* Ramakrishnan, P.S., Purohit, A.N., Saxena, K.G., Rao, K.S. and Maikhuri, R.K. (eds.), *Conservation and management of biological resources in Himalaya*. New Delhi: Oxford and IBH Publication, 233-258 pp.
50. Samant, S.S. (1993): Diversity and status of plants in Nanda Devi Biosphere Reserve. *In* Report, Army Head Quarters, *Scientific and Ecological Expedition to Nanda Devi*., New Delhi: 54-85 pp.
51. Samant, S.S. (1999): Diversity, nativity and endemism of vascular plants in a part of Nanda Devi Biosphere Reserve in west Himalaya I. *Himalayan Biosphere Reserves,* **1(1&2):** 1-28.
52. Samant, S.S. and Dhar, U. (1997): Diversity, endemism and economic potential of wild edible plants of Indian Himalaya. *International Journal of Sustainable Development and World Ecology,* **4:** 179-191.
53. Samant, S.S., Dhar, U. and Rawal, R.S. (1996a): Natural resource use by some natives within Nanda Devi Biosphere Reserve in west Himalaya. *Ethnobotany*, **8:** 40-50.
54. Samant, S.S., Dhar, U. and Rawal, R.S. (1996b): Conservation of rare endangered plants: The context of Nanda Devi Biosphere Reserve. *In* Ramakrishnan, P.S., Purohit, A.N., Saxena, K.G., Rao, K.S. and Maikhuri, R.K. (eds.), *Conservation and Management of Biological Resources in Himalaya*. New Delhi: Oxford and IBH Publishing Company Private Limited, 521-545 pp.
55. Samant, S.S., Dhar, U. and Rawal, R.S. (1998a): Biodiversity status of a protected area of west Himalaya. 1- Askot Wildlife Sanctuary. *International Journal of Sustainable Development and World Ecology,* 5: 194-203.
56. Samant, S.S., Dhar, U. and Palni, L.M.S. (1998b): *Medicinal Plants of Indian Himalaya: Diversity Distribution Potential Values.* Nainital: Gyanodaya Prakashan, pp. 163.
57. Samant, S.S., Joshi, H.C. and Arya, S.C. (2003): Planning for the conservation and management of natural resources using participatory approach. A case study from Pindari area of Nanda Devi Biosphere Reserve, west Himalaya, India. *Van Vigyan*, **38 (1-4):** 55-81.
58. Samant, S.S., Joshi, H.C. and Arya, S.C. (2000): Diversity, nativity and endemism of vascular plants in Pindari area of Nanda Devi Biosphere Reserve- II. *Himalayan Biosphere Reserves,* **2 (1&2):** 1-29.
59. Samant, S.S., Dhar, U. & Rawal, R.S. (2001): Diversity, rarity and economic importance of wild edible plants of west Himalaya. *Indian Journal of Forestry*, **24 (2):** 256-264.
60. Samant, S.S., Joshi, H.C. and Arya, S.C. (2002): Studies on the structure, composition and changes of vegetation in Nanda Devi Biosphere Reserve, west Himalaya. *In* Sharma, J.K., Easa, P.S., Mohanan, C., Saudharan, N., and Rai, R.K. (eds.), *Biosphere Reserves in India and their Management.* New Delhi: Kerala Forest Research Institute and Ministry of Environment and Forests, 133-139 pp.
61. Shannon, C.E. and Wiener, W. (1963): *The Mathematical Theory of Communication*. Urbana: University of Illinois Press.
62. Simpson, E.H. (1949): Measurement of diversity. *Nature,* 163-688.
63. Singh, S.P. (1991): *Structure and function of the low and high altitude grazing ecosystems and impact of the livestock component in the central Himalaya*. Final Technical Report. Ministry of Environment and Forests, Government of India, New Delhi.
64. Singh, S.P., Rikhari, H.C. and Negi, G.C.S. (1995): Community patterns in an alpine meadow of Indian central Himalaya. *Journal of Indian Botanical Society*, **74:** 529-538.
65. Sundriyal, R.C. (1989): Assessment of grazing ability of an alpine pasture in the Garhwal Himalaya, India. *Environment and Ecology,* **7(1):** 247-249.
66. Sundriyal, R.C. (1992): Structure, productivity and energy flow in a alpine grassland community. *Journal of Vegetation Science*, **3:** 15-20.
67. Sundriyal, R.C., Joshi, A.P., and Gupta, S.K. (1988): Effect of free grazing on population distribution of primary producers compartment in a alpine ecosystem. *Bangladesh Journal of Botany*, **17:** 13-18.
68. Sundriyal, R.C., Chauhan, B.B., Kandwal, S.K., and Joshi, A.P. (1987): Vegetation composition of certain grasslands of Garhwal Himalaya as determined by soil profile and seasonal variations. *Indian Journal of Ecology*, **14(1):** 37-46.
69. Uniyal, S.K., Awasthi, A. and Rawat, G.S. (2002): Current status and distribution of commercially exploited medicinal and aromatic plants in upper Gori Valley, Kumaun Himalaya, Uttaranchal. *Current Science,* **82(10):** 1246-1252.