RESEARCH ARTICLE

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

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Manuscript Info

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
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; Rajada 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 km² (Core zone 712.12 km²; Buffer zone 5,148.57 km² and Transition zone 546.34 km²), 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 et 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; 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 (%) | 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 tenuepes |
| No. | Habitat Type          | SR | Altitudinal range (m) | Major Associates                                                                 |
|-----|----------------------|----|----------------------|----------------------------------------------------------------------------------|
| 14  | Shady moist          | 3850 | 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 kanthianus, 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
Picrorhiza kurrooa mixed
Danthonia cachemyriana-Polygonum affine mixed
Fragaria nubicola-Galium acutum-Viola biflora-Cardamine impatiens mixed
Polygonum polystachyum

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 (Indm²) | 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 humble 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        |
| Pleurosperrnum 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 | -         |
| Species Name                          | Range         |
|--------------------------------------|---------------|
| A. royleana DC.                       | Reg Himal     |
| A. triplinervis (Sims.) Cl.           | Reg Himal     |
| Aster diplostephioides (DC.) Cl.     | Reg Himal     |
| Cirsium wallichii DC.                | Reg Himal     |
| Cremanthodium arnecoides (Wall. ex DC.) | Reg Himal  |
| Dubyaea hispida (D. Don) DC.         | Reg Himal     |
| Gerbera gossypina (Royle) Beauv.     | Reg Himal NE  |
| Iula grandiflora Willd.              | Reg Himal et Caucas |
| Jurinella macrocephala (Royle) Aswal et Goel | Reg Himal NE |
| Lactuca dissecta D. Don              | Reg Himal     |
| L. macrorhiza (Royle) Hk. f.         | Reg Himal     |
| L. violaefolia (Decne) Cl.           | Reg Himal     |
| L. himalayanum DC.                   | Europe Reg Himal |
| Saussurea costus (Falc.) Lipsch.     | Reg Himal     |
| S. deltoidea Cl.                     | Reg Himal     |
| S. obvallata Wall.                   | Reg Himal     |
| Senecio alatus Wall. ex DC.          | Reg Himal NE  |
| S. chrysanthemoides DC.              | Reg Himal     |
| S. graciliflorus DC.                 | Reg Himal NE  |
| S. kunthianus Wall. ex DC.           | Reg Himal NE  |
| S. quinquelobus Hk.f. & Th.          | Reg Himal     |
| Solidago virga-aurea L.              | Reg Bor Temp  |
| Tanacetum tomentosum DC.             | Reg Himal NE  |
| Taraxacum officinalis Webber         | Reg Temp Bor et Austr |
| Family            | Species                                                                 | Range          | Location         |
|-------------------|-------------------------------------------------------------------------|----------------|------------------|
| 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. rubigena       | 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 duthei   | 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 anthemogon | 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 | Bentham                                                               | H              | Reg Himal        | -                |
| Taxonomic Family | Species | Distribution | Notes |
|------------------|---------|--------------|-------|
| Liliaceae        | E. fruticosa (D. Don) Rehder | H Reg Himal | - |
|                  | Origanum vulgare L. | H Europe As et Afr | - |
|                  | Phломис 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        | L. Reg Himal | - |
| Onagraceae       | Onagraceae alpina L. | H Europe As Bor Am Bor | - |
|                  | Epilobium lattifolium L. | H Reg Bor et Arct | - |
|                  | E. roseum (Schreb.) Pers. | H Europe As Occ | - |
| Orchidaceae      | Orchidaceae hatagirea (D. Don) Soo | H Reg Himal Europe Afr Bor Orients | - |
|                  | Goodvera 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 |
| Parnassiacae     | Parnassia nubicola Wall. | H Reg Himal | NE |
|                  | P.ussila 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     | Oxyloria 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 australis 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      | Primula officinalis | H Reg Himal | - |
| Species                        | Origin         | Region            | Map     |
|-------------------------------|----------------|-------------------|---------|
| Androsace sarmentosa Wall.    |                | Reg Himal         | NE      |
| Primula atrodotentata Sm.     |                | Reg Himal         | NE      |
| P. denticulata Sm.            |                | Reg Himal         | -       |
| P. elliptica Royle            |                | Reg Himal         | NE      |
| P. glomerata Pax.             |                | Reg Himal         | NE      |
| P. macrophylla D. Don         |                | As et Am Bor      | -       |
| P. reptans Hk.f. ex Wall.     |                | Reg Himal         | NE      |
| **Ranunculaceae**             |                |                   |         |
| Aconitum voilaceum Jacq.      |                | Reg Himal         | NE      |
| A. balfourii Stapf.           |                | Reg Himal         | NE      |
| A. heterophyllum Wall. ex Royle|                | Reg Himal         | NE      |
| Anemone obtusiloba D. Don     |                | Reg Himal         | -       |
| A. polyanthes D. Don          |                | Reg Himal         | NE      |
| A. rupicola Camb.             |                | Reg Himal         | -       |
| Aquilegia pubiflora Wall. ex Royle |        | Reg Bor Temp et Arct | -      |
| Caltha palustris L.           |                |                   |         |
| Clematis acuminata DC.        | Sh             | Reg Himal         | NE      |
| C. barbella Edgew.            | Sh             | Reg Himal         | NE      |
| Oxygraphis polypetala (Royle) Hk.f. & Th. | Reg Himal | NE      |
| Paraquilegia microphylla (Royle) Drum. & Hutch. | Reg Himal | Sibir Altaic | -      |
| Ranunculus hirtellus Royle    |                | Reg Himal         | -       |
| Thalictrum alpinum L.         |                | Reg Bor et Arct   | -       |
| T. chelidonii DC.             |                | Reg Himal         | -       |
| T. elegans Wall. ex Royle     |                | Reg Himal         | NE      |
| T. pauciflorum Royle          |                | Europe et As Bor  | -       |
| T. reniforme Wall.            |                | Reg Himal         | NE      |
| **Rosaceae**                  |                |                   |         |
| Arunchus dioicus (Walt.) Fernald |        | Reg Bor Temp      | -       |
| Cotoneaster microphyllus Wall. ex Lindl. | Sh | Reg Himal | -      |
| Fragaria nubicola Lindl. ex Lacaita | H | Am Bor | -      |
| Geum elatum Wall.             |                | Reg Hpimal        | NE      |
| Potentilla argrophylla Wall. ex Lehmann | H | Reg Himal | NE      |
| P. atrosanguinea Lodg.        |                | Reg Himal         | NE      |
| P. microphylla D. Don         |                | Reg Himal         | NE      |
| P. peduncularis D. Don        |                | Reg Himal         | -       |
| Rosa macrophylla Lindl.       | Sh             | Reg Himal         | China   |
| Sibulda 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. Frimbiata (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      |
| Species                                      | Life Form | Herbarium | Geographic Region |
|----------------------------------------------|-----------|-----------|-------------------|
| 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                |
| Picrohiza 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. pyrolaeifolia* 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**                            |           |           |                   |
| **Athyraceae**                               |           |           |                   |
| *Athryrium attenuatum* (Cl.) Tag. forma Attenuatum | Pt | -       | -                |
| *A. dathiei* (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**                              |           |           |                   |
| *Woodsi a 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= Hispanic; Ind= Indian; Mediterr= Mediterranean; Mongol= Mongolia;
N. Zel= New Zeland; 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)
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. 2:- Distribution of native and endemic species in alpine communities of Latakharak area

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

Fig. 4:-Correlations between species richness and native 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 tussock 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 cachemiriana-Polygonum affine mixed, Danthonia cachemiriana-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 cachemiriana-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 cachemiriana-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 cachemiriana-Polygonum affine mixed community was represented by shrubberies 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.

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