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PHYTODIVERSITY AND ENDEMIC RICHNESS OF KARAMBAR LAKE VEGETATION FROM CHITRAL, HINDUKUSH-HIMALAYAS

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Abstract

The Hindukush Himalayas (HKH) is one of the world's richest biodiversity region hosting 4 global biodiversity hotspots, 60 ecoregions and 488 protected areas. More than 2500 out of total 10700 Himalayan plants are reported in HKH including the important endemic taxa like *Androsace*, *Viola, Rhododendron, Saxifraga, Gentiana, Primula, Lentopodium and Saussurea.* HKH region in North Pakistan has received limited attention due to its remoteness and inaccessibility. Current study was undertaken to get information about alpine vegetation structure and community distribution in Karambar lake surroundings, North Pakistan at 4200 m.a.s.l. A total of 108 plant species belonging to 27 families were recorded from the area in four identified plant communities. Communities showed an average species diversity of 2.18; evenness, 0.68; and species richness of 29. Asteraceae (19%), Leguminosae (13%), Capprifoliaceae (11%), Rosaceae (7%), Primulaceae (7%) and Poaceae (5%) constituted bulk of the flora of Karambar Lake. TWINSPAN and Deterrended Correspondence Analyses (DCA) revealed aspect based moisture gradient as the major limiting factor governing the distribution of plants in the area.

Introduction

The Hindukush Himalaya (HKH) is planet's glorious mountain range spreading 3500 km across the South Asia. HKH lies in the middle of worlds five most important floristic regions: Sino-Japanese in the east; Irano-Turanian in the west; Central-Asiatic in north; Indian in south; and East Asian-Malaysian in south east (Myers, 2001; Pei, 1995, Shinwari, 2010). Four global biodiversity hotspots including Himalayan hotspot, Mountains of south China, Central Asia and Indo-Burma hotspot are found in the HKH (Mittermeier *et al.,* 2004; Schickhof, 2005). About 60 ecoregions are located in HKH, 30 of which are classified as critical (Olson & Dinerstein, 2002). Twelve HKH ecoregions including Tibetan Plateau steppe; Himalayan alpines; Eastern Himalayan coniferous and broadleaved forest; Terai-Duar grassland and savannas; Middle Asian steppe; Western Himalayan moist temperate forests are included in Global top 200 ecoregions (Chettri *et al.,* 2008).

HKH range encompasses an extensive floral diversity, harboring 2500 of the 10,700 Himalayan plant species (Jansky *et al.,* 2002; Shinwari & Gilani, 2003). 90% endemic plans of western Himalayas are found here, more than 20% having high medicinal value (Hamilton & Radford, 2007). HKH alpines are probably center of origin of important endemic taxa like *Androsace, Viola, Rhododendron, Saxifraga, Gentiana, Primula, Lentopodium and Saussurea* (Uninal *et al.,* 2006; Panthi *et al.,* 2007).

The distribution and community structure of HKH alpine vegetation is governed by adverse edaphic and climatic factors like scanty rainfall, high ultraviolet (UV) radiation, high wind velocity, blizzards, low temperature and snowstorms, low productivity, high intensity of solar radiation, and high degree of resource seasonality (Bhattari & Vetaas, 2003; Korner, 2007). The plants of this zone show an adaptation to these conditions and are generally dwarfed, stunted, wooly or spiny; developing different mosaic patches in sparse populations; and possess an early growth initiation with a short vegetative span ranging from several days to a few months. Extensive research (Bhattari & Vetaas, 2003; Kala, 2004; Kunwar & Sharma, 2004; Behra *et al.,* 2005; Kharakwal *et al.,* 2005; Uninal *et al.,* 2006; Panthi *et al.,* 2007; Rawat *et al.,* 2010) in Eastern & Western Himalayan region has worked out the vegetation dynamics and diversity patterns in the area in great detail. However, less efforts have been made to investigate the vegetation distribution pattern and community structure in Hindukush Himalayas due to remoteness and inaccessibility of the area. In this paper, we present the results of an ecological study in Karambar Lake and surrounding landscape system in high altitude HKH.

Materials and Methods

Karambar Lake is located in HKH in Chital district of North Pakistan near Pak-Afghan border at a height of 4200 m.a.s.l. surrounded by snow capped mountains with a length and width of 3.2 km and 1.7 km respectively (Fig 1). Alpine scrub zone in the area starts from 3800 m where tree line and krummholz thicket ends, with diverse herbaceous formations and subnival vegetation up to 6000 m permanent snow line (Chettri *et al.,* 2008). Area has a cold desert climate with mean summer temperatures between 0 to 10 C^0. Diurnal temperature variations are very sharp as much as $60C^0$ Miehe, (1997). Mean annual precipitation ranges from 35-140 mm. Area remains snow capped from November to March (Breckle, 1974). The study was carried out in July - August 2010, in the blooming season of most of flora. Line transect method was used to collect the vegetation data. Transects were laid in such a way to cover maximum geographic extent at the locations being the best representatives of vegetation as well as environmental variability. A total of 24 transects, 10 m each, were laid at 6 sites along the periphery of the lake (Table 1).

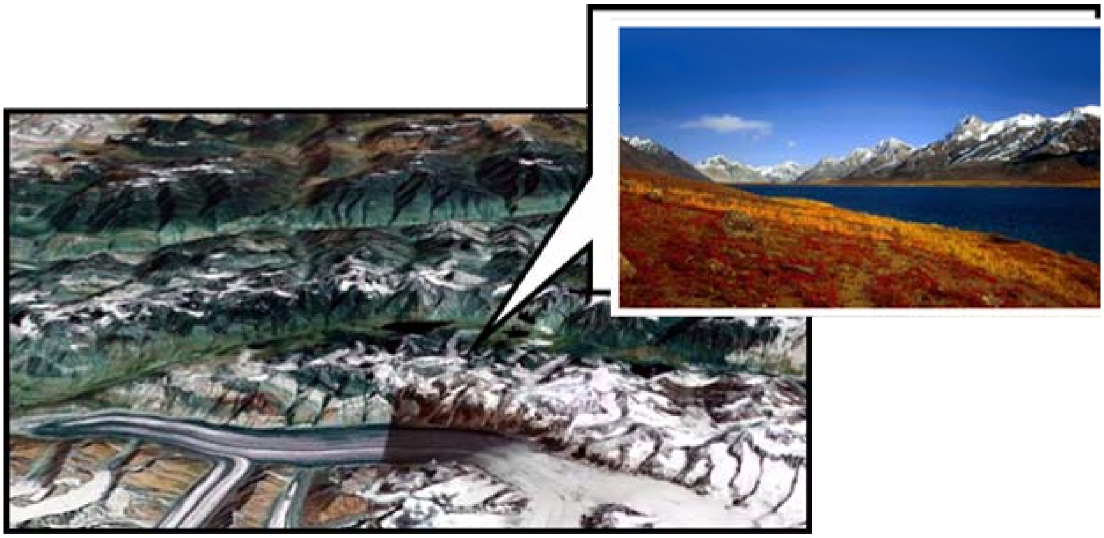

Fig: 1. Location of *Karambar* Lake in Hindukush-Himalayan range

Table 1. Locations of Sampling Sites in Study area.

Site No.	Longitude	Latitude	Altitude (Meters)
1	36.88077778	73.68875000	4217 ± 11
2	36.88463889	73.70055556	4289 ± 9
3	36.88436111	73.70975000	3976 ± 8
4	36.88508333	73.72200000	4126 ± 13
5	36.88236111	73.72138889	4296 ± 10
6	36.87766667	73.68794444	4048 ± 6

The Coordinates were recorded by using GPS (Garmin Carp 2005) while standing in middle of transect parallel to lake's periphery to avoid edge effect. The environmental variables including slope, aspect, terrain, grazing intensity and erosion were recorded by direct observations. The biological data including species density, frequency, cover, dominance and abundance was recorded in the transect line using the line intercept method (Canfield, 1940; Shaheen *et al*., 2011). Plants were also collected from all accessible parts along sampling sites to develop most precise baseline study on floral biodiversity. Collected plant specimens were transferred to Herbarium of Pakistan, Quaid-i-Azam University Islamabad for further confirmation of morphological features with help of floras (Stewart, 1961; Nasir & Ali, 1970-1989; Ali & Nasir, 1989-1992; Ali & Qaiser, 1993-2011). The index of diversity was calculated after Shannon-Weiner (1949). If p_i is the proportion of individuals (from the sample total) of species i, then diversity (**H'**) is: $H' = -\sum_{i=1}^{s} p_i p_i L_n p_i$. **species *evenness*** was calculated using the Shannon evenness index: J' = H'/ln (S), where H' is the Shannon–Wiener diversity index and S is species number (Pielou, 1975). The cover abundance data of sampling locations was instated to TWINSPAN (Hill, 1979a) with the aim to record the floristic variation and to detect natural groups of sampled plots, simultaneously classifying species and samples. The method used applied Oksanen & Minchin's (1997) "super strict" criteria of tolerance=0.0000001 and maximum number of iterations = 999. Species abundance data was also analyzed through DCA (Deterrended correspondence analysis), an Eigen analysis ordination technique based on reciprocal averaging (Hill, 1973). The analysis was performed with a modified version of DECORANA from the Cornell Ecology Program series (Hill, 1979b).

Results

A total of 108 herbaceous species belonging to 27 families of vascular plants were observed from the study area. Asteraceae (19%), the most predominant family in the study area, followed by Leguminosae (13%), Cappifoliaceae (11%), Rosaceae (7%), Primulaceae (7%) and Poaceae (5%) constituted bulk of the flora of Karambar Lake. Only four woody members were recorded from the area including *Juniperus excelsa, Rosa webbiana, Rhododendron anthopogon* and *Salix flabellaris*. Four different vegetation communities were identified at the 6 sites at Karambar Lake.

***Cobresia septatonodosa - Anaphalis triplinervis-Potentilla desertorum microphylla* community:** A total of 38 plant species were recorded from this community found in sites 3 and 4. The dominant species was *Cobresia septatonodosa* covering 35% of the total area followed by *Anaphalis nepalensis* (18%) *and Potentilla desertorum* (13%). The co-dominant species were *Pedicularis rhinanthoides, Cyperus eleusinoides, Berginia ciliate* and *Cyperus rotundus.* The community was dominated by low growing herbaceous species with rosette leaves. Growth was fairly dense and ground cover was continuous with creeping species. The soil seemed to hold enough moisture for dense growth, in addition to the fact that this community was located downstream of the lake. In surrounding area on scree slopes patches of *Juniperus communis, J. squamata, Salix flabellaris, Lonicera microphylla* were found. In snow bed depressions *Swertia speciosa-Sibbaldia procumbens* were dominant. Community showed a diversity value of 2.85 and evenness value of 0.58.

Carex cruenta – Geranium himalayense – Bistorta affinis* community*: A total of 31 species were recorded from this community the dominant species included *Carex cruneata* with 32 % cover followed by *Geranium himalayense* (24%); with indicator species *Bistorta affinis* (10%) and *Rosularia rosulata* (7%). This association was a characteristic feature of most North facing slopes (site 2) having maximum soil moisture and less grazing intensity. Community showed a diversity value of 2.34 and evenness value of 0.61.

***Ephedra gerardiana- Potentilla desertorum - Pedicularis pectinata* community**: A total of 29 plants were recorded from this community found in sites 1 and 6. *Ephedra gerardiana* was the dominant species with 41% cover followed by *Potentilla desertorum* (15%) *and Pedicularis pectinata* (9%). Co dominant species included *Salvia nubicola*, *Geranium nepalensis*, *Saxifraga stenophylla* and *Sibbaldia procumbens.* This plant community was located on relatively drier south facing slopes around the lake. Community showed a diversity value of 1.59 and evenness value of 0.82.

***Sibbaldia procumbens cunneata –Saxifraga flagellaris– Eragrostis* community:** 21 species were recorded from this community (Site 5) dominated by *Sibbaldia procumbens* with 37% cover followed by *Saxifraga flagellaris* (18%) and *Eragrostis* (11%). The community was found growing exclusively in crevices and low moisture places. *Avena fatua* and *Leontopodium leontopodinum* were among the indicator species of this community. Community showed a diversity value of 1.95 and evenness value of 0.74. In areas near the lake outlet, an open 0.5-1 m high vegetation of *Juniperus excelsa, Rosa webbiana,* and *Rhododendron anthopogon* was found with *Salix flabellaris* on deep soils along creeks and streams. Severe grazing intensity was observed in the area.

The total number of sample transects that were subjected to TWINSPAN analysis was 16 and number of species recorded from these plots were 83. Minimum group size for a division was selected 5 and maximum number of indicators per division was kept 5. At first level of the divisions (Eigen value: 0.5962) two major groups of plant associations were segregated. The groups were characterized by the presence of *Cobresia septatonodosa* and *Alium carolinianum* in group 1, with transect 1-9; wheresa *Pedicularis pectinata* and *Ephedra gerardiana in* group 2 with transect 10-16.

Deterrended correspondence analysis (DCA) showed similar results as inferred by TWINSPAN analysis. Deterrended correspondence analysis (DCA) results showed very clear and understandable distribution of vegetation communities along DCA axis 1 (Fig. 2). The four positively valued North facing sites (2, 3, 4 and 5) were aggregated on the lower left separated from the south facing drier sites 1 and 6 grouped at the upper right. The 1st axis indicates soil moisture gradient as the major limiting factor controlling the structure and distribution of plant communities. The aggregation of communities in the N facing moist region can be easily interpreted to support the assumption. The distribution along the DCA axis also shows that both clusters are ecologically separated from each other.

Chorological: Results showed that the area harbors at least 17 species that are endemic to Hindukush Himalayas (HKH) having a distribution restricted to Northern Pakistan or adjoining areas (Table 2). These endemic species will need special attention while talking about the conservation or management of flora. It must be stated that complete information on the flora of Karambar Lake and its surroundings is still lacking and the area needs to be thoroughly explored in this regard.

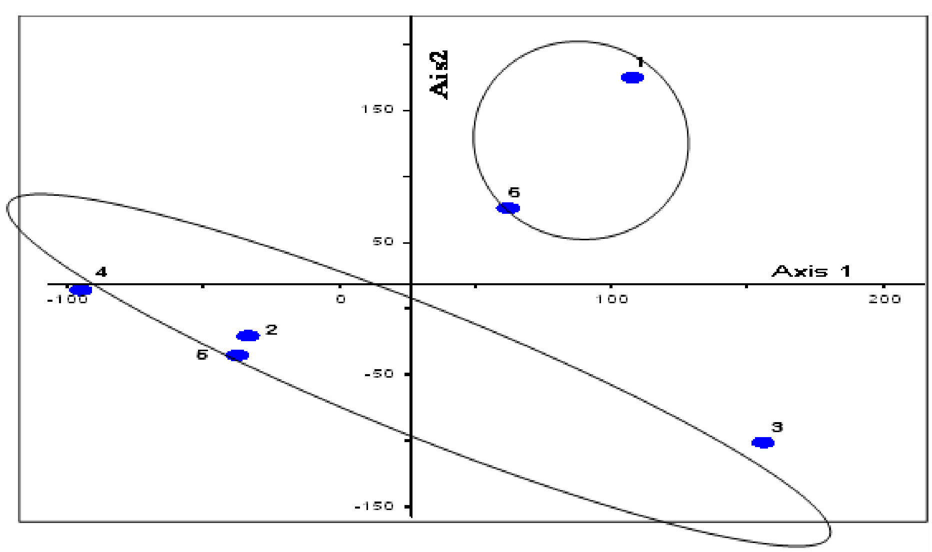

Fig. 2. DCA plot showing plant communities around *Karambar* lake.

Table 2. Species endemic to HKH region reported from study area

Species	Distribution	Levels
Arenaria ciliolata var. ciliolata Edgew.	Bhutan, North-Western India, Central Nepal, Eastern Nepal, Western Nepal, Sikkim, Southern Tibet	Lower alpine, Upper alpine
Astragalus grahamianus Royle ex Benth.	Kashmir, North-Western India, Northern Pakistan	Upper subtropical, Collinean, Montane, Lower subalpine
Astragalus strictus Grah. ex Benth.	North-Eastern India, Bhutan, Kashmir, North-Western India, Central Nepal, Eastern Nepal, Western Nepal, Sikkim, Eastern Tibet	Collinean, Montane, Lower subalpine, Upper subalpine, Lower alpine, Upper alpine
Bergenia ciliata (Haw.) Sternb.	Kashmir, North-Western India, Central Nepal, Western Nepal	Upper subalpine, Lower subalpine, Upper subtropical
Corydalis crassissima Jacquem. ex Camb.	Kashmir, North-Western India, Northern Pakistan	Upper subalpine, Lower alpine
Corydalis falconeri Hook.f. & Thoms.	Kashmir, Northern Pakistan	Montane, Lower subalpine
Delphinium vestitum Wall. ex Royle	Kashmir, North-Western India, Central Nepal, Eastern Nepal, Western Nepal, Southern Tibet	Montane, Lower subalpine, Upper subalpine, Lower alpine, Upper alpine
Ephedra gerardiana Wall. ex Stapf	North-Eastern Afghanistan, High tibetan plateau or Chantang, Kashmir, North-Western India, Western Nepal, Northern Pakistan, Southern Tibet.	Upper subalpine, Lower alpine, Upper alpine, Subnival
Epilobium latifolium L.	North-Eastern Afghanistan, High tibetan plateau or Chantang, Kashmir, North-Western India, Central Nepal, Western Nepal, Northern Pakistan, Eastern Tibet	Upper subalpine, Lower alpine
Lloydia serotina (L.) Reichenb.	North-Eastern Afghanistan, Bhutan, High tibetan plateau or Chantang, Kashmir, North-Western India, Central Nepal, Eastern Nepal, Western Nepal, Northern Pakistan, Sikkim, Southern Tibet.	Lower subalpine, Upper subalpine, Lower alpine
Lonicera spinosa (Jacquem. ex Decne.) Walp.	North-Eastern Afghanistan, Bhutan, High tibetan plateau or Chantang, Kashmir, North-Western India, Central Nepal, Eastern Nepal, Western Nepal, Northern Pakistan, Sikkim, Southern Tibet.	Upper subalpine, Lower alpine, Upper alpine
Minuartia kashmirica (Edgew.) Mattf.	North-Eastern Afghanistan, High tibetan plateau or Chantang, Kashmir, North-Western India, Western Nepal, Northern Pakistan, Southern Tibet	Upper subalpine, Lower alpine, Upper alpine
Oxytropis crassiuscula Boriss.	North-Eastern Afghanistan, Northern Pakistan	Lower subalpine, Upper subalpine, Lower alpine
Primula denticulata Sm.	North-Eastern Afghanistan, North-Eastern India, Northern Union of Myanmar, Bhutan, Kashmir, North-Western India, Central Nepal, Eastern Nepal, Western Nepal, Northern Pakistan, Sikkim, Southern Tibet.	Upper subtropical, Collinean, Montane, Lower subalpine, Upper subalpine, Lower alpine, Upper alpine
Primula macrophylla D. Don	North-Eastern Afghanistan, Bhutan, High tibetan plateau or Chantang, Kashmir, North-Western India, Central Nepal, Eastern Nepal, Western Nepal, Northern Pakistan, Sikkim, Southern Tibet	Upper subalpine, Lower alpine, Upper alpine
Rheum spiciforme Royle	North-Eastern Afghanistan, Bhutan, Kashmir, North-Western India, Central Nepal, Western Nepal, Northern Pakistan, Sikkim, Southern Tibet.	Lower alpine, Upper alpine
Saxifraga stenophylla Royle	Kashmir, North-Western India, Central Nepal, Western Nepal, Northern Pakistan	Upper subalpine, Lower alpine, Upper alpine

Discussion

The relationship between environmental variables like elevation, climate, slope and inclination with species richness, diversity and distribution, has been a subject to extensive research (Tambe & Rawat, 2010; Schickhof, 2005; Miehe, 1989, 1997). The decrease in number of species with increasing altitude and latitude for various Himalayan ranges is a recognized pattern with certain variations in pattern (Korner, 2003). The species richness can change monotonically with an elevational gradient or form a hump shaped pattern (Grytnes and Vetaas, 2002; Bhattarai *et al.*, 2004). Average species number per site was low in 30-50 range, in accordance with the results of several related phytosociological investigations in Himalayan alpines (Kunwar & Sharma, 2004; Behra *et al.*, 2005; Kharakwal *et al.*, 2005). The north facing HKH slopes are reported to have higher species richness due to higher moisture content and evapotranspiration as compared to drier south facing slopes (Panthi *et al.*, 2007). It was evident from the lower species count at N facing sites (1 & 6). The diversity values recorded for the Karambar alpines lie within the reported range of 1.16 to 3.40 for Himalayan range (Pande, 2001; Mishra *et al.*, 2003; Kunwar & Sharma, 2004; Ahmed *et al.*, 2006; Chandra *et al.*, 2010). A slow rate of evolution and community stabilization along with severe climatic conditions can also be responsible for the low diversity values (Simpson, 1949; Conell & Oris, 1964). South facing sites 1 and 6 showed greater degree of evenness (0.86) as compared to North facing sites in 0.58-0.75 range. Maximum evenness values were represented by uniformly distributed, homogeneous communities having low species count (Fosaa, 2004). Alpine communities lack the ultra dominant tree cover which allows the herbs and grasses to flourish freely. Repeated grazing also removes the excessive cover of local dominants allowing smaller and out shaded species to persist (Eriksson, 1996) increasing the degree of evenness. The subalpine and alpine vegetation of the area on dry sites was open and poor in species, but each slope showed a different species pattern. This belt is therefore typical for a high and endemic biodiversity (Dharr, 2002). On wet sites (2, 3, 4, 5) closed species-rich meadow canopy occurred. In the alpine belt, open rocks and scree were the most common sites colonized by isolated and specially adapted species like *Corydalis*. Woody species, *Juniperus excelsa* and *Lonicera microphylla,* were found growing even above 5000 m on south-facing rocky slopes. Several steppe species are known to have very wide amplitude of elevational occurrence in dry lands (Singh & Sundriyal, 2005). Chorology of Karambar flora revealed that high altitude HKH acts as a biogeographic barrier between very contrasting floristic regions i.e. monsoonal south Asia, Mediterranean influenced Middle Asia and Central Asian expanses. Although the flora shows a very close affinity with Tibetan Plateau, being similar in geography and climate; but a significant Mediterranean influence can also be observed as well (Sherman *et al.,* 2008). Endemic taxa were found restricted to the isolated and preserved geographic locations receiving minimum grazing pressure (Uninal *et al.,* 2006). The unsustainable anthropogenic activities are posing a serious threat to these endemic texa (Byers, 2005). Himalayan pastures have been a victim of severe human exploitation from centuries (Miller, 1997). The major risk to this fragile vegetation is dearth of fodder, resulting in heavy overgrazing far beyond the carrying capacity of the area. It is recommended by vegetation scientists that grazing practices in these fragile alpine communities above 2500 meter should be very limited and controlled (Blanken, 1999). Spread of unpalatable herbs like *Sibbaldia procumbens*, *Ephedra gerardiana* and *Primula denticulata* also indicates the prevalent impacts of seasonal grazing on local flora (Vallentine, 2001; Peer *et al.*, 2007). The degraded vegetation is further not allowed to repair itself by harsh climatic conditions and very short growing period (Ge *et al*., 2005) and some taxa reported are also threatened (Yousuf *et al*. 2009).

The high percentage of species endemism in HKH suggests the conservative value of the area. Only few studies are available mentioning the importance of flora (Ali & Qaisar, 2009) and conservation of endemic taxa (Ali & Qaiser, 2010a,b – 2011). It requires immediate attention of monitoring authorities as well as to create awareness among locals about sustainable utilization and conservation of alpine pastures to maintain ecosystem balance. Modern approaches needed to determine the phylogeny of the important species (Shinwari & Shinwari, 2010).

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