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Floristic diversity and ecological attributes of Chandra Tal and Suraj Tal – two Himalayan cold desert high-altitude wetlands (HAWs) of Lahaul-Spiti, Himachal Pradesh, India

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Abstract
The floristic assemblages in and around the high-altitude Trans Himalayan cold desert lake are excellent indicators for both terrestrial and hydrophytic communities and helps to assess the health of the wetland in a particular area. For assessment of vegetation status, the present study has been carried out in and around the catchment area of two glacial high-altitude lake i.e., Chandra Tal and Suraj Tal. The sampled area was classified based on lake distance, i.e., lower, middle and upper stretch. The result showed a total of 146 taxa were recorded from both the wetland during ecological survey period. Species like *Potentilla argyrophylla* (3.7 ind/m²), *Geranium wallichianum* (1 ind/m²), *Leontopodium himalayanum* (1 ind/m²), *Saxifraga flagelleris* (0.45 ind/m²) were the frequently occurring species in Chandra Tal whereas *Rhodiola crenulata* (0.27 ind/m²), *Pleurospermum candollei* (0.33 ind/m²), *Corydalis meifolia* (0.20 ind/m²), *Saussurea glacialis* (0.70 ind/m²) were the most common species found frequently in Suraj Tal. Overall maximum species richness was found in lower East stretch (39) and minimum in Upper North stretch (8) in Chandra Tal and maximum in middle North stretch (34) and minimum in lower South stretch (7) in Suraj Tal. Total herb density found highest in lower East stretch (29.67 ind/m²) and lowest in upper North stretch (1.8 ind/m²) in Chandra Tal and highest in lower East (5 ind/m²) and lowest in lower South stretch (2.07 ind/m²) in Suraj Tal respectively. Vegetation diversity found highest in middle North (3.39) stretch and lowest in upper North (1.75) stretch in Chandra Tal whereas in Suraj Tal highest diversity found in middle North (3.35) stretch and lowest in lower South (1.93) stretch. In recent years, due to high anthropogenic pressure, overgrazing of vegetation in and around the wetland areas, these fragile glacial lakes are under great threat which require sustainable conservation for maintaining the biodiversity that depends on these freshwater sources.

Keywords: High altitude wetlands (HAWs), Cold Desert Biosphere Reserve (CDBR), Chandra Tal, Suraj Tal

Introduction

Wetlands are the centre of evolution and houses highest number of almost all kind of biological entity. The seasonal changes of water gradient and saturated soils or frequent prolonged inundation affect on soil development and quite favourable environment to support floral diversity and density that provides food and shelters to various faunal species.

High Altitude Wetlands (HAWs) are such areas, which are located at or above an elevation of 2500 m with an area equal to or greater than five hectares. HAWs are characterized by low temperature, generally low buffering capacity, scanty rainfall, low humidity, low level of nutrients and high intensity of UV which results scanty biodiversity due to extreme harsh environmental conditions. Sometimes, such less dynamic lake condition act as reference systems for global climate change (Psenner, 2002 [5]; Catalan *et al*., 2006) [2]. In cold desert region, wetlands are mainly feed from glacial melts which generates different rivers which are the major lifeline for the people of mountains. Vegetation of these regions are very unique because of physiographical features. These wetlands have, however, received very little attention in terms of biodiversity assessment, ecosystem values and conservation. High altitude mountain lake ecosystems play an important role as water sources for communities at lower altitude and sustain a high degree of biodiversity (Boggero *et al.*, 2005) [1]. However, the plant community composition and ecosystem services provided by these High-Altitude wetlands across the World is poorly studied (Hajkova *et al*.,2006) [4].

Material & Methods

The present study was carried out in Chandra Tal (32°28.552´N; 77°37.054´E) and Suraj Tal (32°45.749´N; 77°23.957´E) in cold desert region of Lahaul-Spiti, Himachal Pradesh (Fig 1). Chandra Tal located at 4300 m above sea level and the source of Chandra River is the part of Cold Desert Biosphere Reserve (CDBR), of Indian Trans Himalaya, Himachal Pradesh and also designated as a Ramsar Site. Suraj Tal, located at 4950 m above sea level, just below the Baralacha La beside Leh-Manali highway and source of Bhaga River is the 3rd highest lake in India and 21st highest in the world. Both the glacial lakes are very renowned pilgrim destination and favourite destination for trekkers.

For assessment of vegetation status, systematic random quadrat method (Misra, 1968 [7]; Mueller-Dombois and Ellenberg, 1974) [8] was employed and ten 1m x 1m quadrat for herb was randomly laid in each 50m x 20m plot in 100m systematic interval in both study areas at different intervals. The sampled area was classified based on lake distance, i.e.,

lower, middle and upper stretch and plant specimens were categorized depending upon their habitat type like marshy, moist, dry or rocky (Dey *et al*., 2021) [3]. Individuals of all the species has been recorded in all quadrats (Fig 2). Data extraction and analysis has done in MS-Excel using standard techniques. Ecological parameters like density, frequency, richness and Shannon's diversity were calculated following Misra (1968) [7] and Magurran (1988) [6].

Result & Discussion

A total of 146 taxa were identified and recorded from both the wetland during ecological study whereas from Chandra Tal total 108 taxa and from Suraj Tal 68 taxa were recorded throughout in and around the adjacent catchment area of both wetlands respectively.

Density: Density of each species was calculated from both the wetlands (Table 1). In Chandra Tal *Leontopodium brachyactis* (3.8 ind/m²), *Potentilla argyrophylla* (3.7 ind/m²), *Halerpestis tricuspis* (3.4 ind/m²) in lower stretch, *Veronica biloba* and *Carex melanantha* (1.5 ind/m²), *Polygonum affine* (1.2 ind/m²), *Geranium wallichianum* (1 ind/m²) in middle stretch and *Leontopodium himalayanum* (1 ind/m²), *Saxifraga flagelleris* (0.45 ind/m²) in upper stretch showed maximum density respectively. Aspect specific density in Chandra Tal shows in following order in Lower stretch – East (29.67 ind/m²) > North (11.8 ind/m²) > West (8.2 ind/m²) > South (7.1 ind/m²), whereas in Middle stretch the order is East (10 ind/m²) > West(6.23 ind/m²) > South (5.38 ind/m²) > North (4.81 ind/m²) and in Upper stretch the order is East (3.95 ind/m²) > West (3.1 ind/m²) > South (2.6 ind/m²) > North (1.8 ind/m²) respectively.

In lower stretch of Suraj Tal *Cremanthodium decaisnei* (1 ind/m²) and *Gentiana leucomelaena* (0.83 ind/m²) as well as in Middle stretch *Nepetalongibracteata* (0.40 ind/m²) and *Cerastium cerastioides* (0.31 ind/m²) and in Upper stretch *Oxyria digyna* (0.93 ind/m²) and *Saussurea glacialis* (0.35 ind/m²) showed maximum density respectively. Aspect specific density in Suraj Tal shows in following order in Lower stretch – East (5 ind/m²) > North (4.33 ind/m²) > West (3.96 ind/m²) > South (2.07 ind/m²), whereas in Middle stretch the order is North (3.63 ind/m²) > West (3.13 ind/m²) > East (2.52 ind/m²) > South (2.23 ind/m²) and in Upper stretch the order is South (3.5 ind/m²) > West (3.27 ind/m²) > North (2.96 ind/m²) > East (2.47 ind/m²) respectively.

Frequency: The frequency of plant species recorded in and around the adjacent catchment area of both wetlands. The results indicate that in Chandra Tal, *Potentilla argyrophylla* is the most frequently occurring species in almost all stretch followed by *Leontopodium brachyactis*, *Halerpestis tricuspis*, *Polygonum paronychioides*, *Arnebia euchroma*, *Geranium wallichianum*, *Veronica biloba*, *Polygonum affine* and *Oxytropis lapponica*. In Suraj Tal, *Rhodiola crenulata*, *Primula minutissima* in lower stretch while *Corydalis meifolia*, *Nepeta bracteata*, *Draba glomerata* in middle stretch and *Saussurea glacialis*, *Thylacospermum caespitosum*, *Saxifraga flagellaris* in upper stretch are the frequent species.

Prominence Value: The Prominence value (inclusive of relative frequency and relative density) of plant species, recorded throughout the wetland area was calculated (Table 1). The results indicate that in Chandra Tal the species with high prominence values in lower stretch are *Leontopodium brachyactis* (21.25), *Halerpestis tricuspis* (18.98), *Carex melanantha* (30.54), *Stuckenia pectinata* (20.64), *Hippuris vulgaris* (16.89) followed by *Potentilla argyrophylla* (33.05), *Veronica biloba* (24.52), *Geranium wallichianum* (19.19), *Rosularia alpestris* (11.96) in middle stretch and *Polygonum paronychioides* (45.21), *Potentilla argyrophylla* (20.16), *Saxifraga flagellaris* (16.66), *Anaphalis triplinervis* (24.44), *Waldheimia tomentosa* (27.15) in upper stretch respectively. In Suraj Tal the species with high prominence values in lower stretch are *Rhodiola crenulata* (17.51), *Halerpestis tricuspis* (26.76), *Pleurospermum candollei* (30.41) followed by *Nepeta longibracteata* (24.84), *Waldheimia tomentosa* (19.92), *Saussurea glacialis* (13.31), *Draba oreades* (18.85), *Potentilla argyrophylla* (18.37), *Nepeta eriostachya* (31.59) in middle stretch and *Saussurea glacialis* (37.56), *Waldheimia nivea* (21.49), *Eritrichium villosum* (20.9), *Saxifraga flagellaris* (23.23), *Sibbaldia tetrandra* (18.71), *Thylacospermum caespitosum* (26.75), *Epilobium latifolium* (25.28), *Epilobium latifolium* (29.96) in upper stretch respectively.

Table 1: Ecological attributes of Chandra Tal and Suraj Tal

Wetland	Stretch	Site name	Density	Prominence Value
Chandra Tal	Lower	A Lower East	29.67	*Potentilla argyrophylla* (22.66); *Leontopodium brachyactis* (21.25); *Halerpestis tricuspis* (18.98)
		B Lower North	11.8	*Polygonum affine* (17.86); *Potentilla argyrophylla* (15.24); *Oxytropis lapponica* (8.89)
		C Lower West	8.2	*Carex melanantha* (30.54); *Leontopodium himalayanum* (24.44); *Potentilla argyrophylla* (16.02)
		D Lower South	7.1	*Stuckenia pectinata* (20.64); *Halerpestis tricuspis* (18.3); *Hippuris vulgaris* (16.89)
	Middle	A Middle East	10	*Potentilla argyrophylla* (33.05); *Veronica biloba* (24.52); *Geranium wallichianum* (19.19)
		B Middle North	4.81	*Potentilla argyrophylla* (21.54); *Veronica biloba* (13.17); *Galium aparine* (10.9)
		C Middle West	6.23	*Potentilla argyrophylla* (21.41); *Veronica biloba* (15.87); *Rosularia alpestris* (11.96)
		D Middle South	5.38	*Carex melanantha* (20.51); *Halerpestis tricuspis* (20.13); *Leontopodium himalayanum* (17.95)
	Upper	A Upper East	3.95	*Polygonum paronychioides* (45.21); *Potentilla argyrophylla* (20.16); *Saxifraga flagellaris* (16.66)
		B Upper North	1.8	*Potentilla argyrophylla* (72.22); *Saxifraga flagellaris* (42.22);

				Anaphalis triplinervis (24.44)
		C Upper West	3.1	*Polygonum affine* (15.62); *Potentilla argyrophylla* (15.32); *Cerastium cerastioides* (12.79)
		D Upper South	2.6	*Waldheimia tomentosa* (27.15); *Rhodiola crenulata* and *Arnebia euchroma* (23.30)
Suraj Tal	Lower	A Lower West	3.96	*Eritrichium canum* var. *spathulatum* (18.95); *Rhodiola crenulata* (17.51); *Draba oreades* and *Waldheimia tomentosa* (16.7)
		B Lower North	4.33	*Gentiana leucomalaena* (33.98); *Halerpestis tricuspis* (26.76); *Cremanthodium decaisnei* (27.63)
		C Lower East	5	*Cremanthodium decaisnei* (33.64); *Halerpestis tricuspis* (24.74); *Erigeron heterochaeta* (17.25)
		D Lower South	2.07	*Aster flaccidus* (38.4); *Cerastium cerastoides* (31.18); *Pleurospermum candollei* (30.41)
	Middle	A Middle West	3.13	*Nepeta longibracteata* (24.84); *Chorispora sabulosa*, *Eritrichium canum* var. *spathulatum* (23.77); *Waldheimia tomentosa* (19.92)
		B Middle North	3.63	*Saussurea glacialis* (13.31); *Gagea serotina* (11.47); *Pleurospermum stellatum* and *Saxifraga flagellaris* (9.98)
		C Middle East	2.52	*Cerastium cerastoides* (21.59); *Draba oreades* (18.85); *Potentilla argyrophylla* (18.37)
		D Middle South	2.23	*Draba glomerata* (47.95); *Nepeta eriostachya* (31.59); *Aster flaccidus* and *Crepis multicaulis* (23.5)
	Upper	A Upper West	3.27	*Saussurea glacialis* (37.56); *Waldheimia nivea* (21.49); *Eritrichium villosum* (20.9)
		B Upper North	2.96	*Saxifraga flagellaris* (23.23); *Sibbaldia tetrandra* (18.71); *Rhodiola imbricata* (15.48)
		C Upper East	2.47	*Thylacospermum caespitosum* (26.75); *Epilobium latifolium* (25.28); *Delphinium brunonianum* (13.74)
		D Upper South	3.5	*Oxyria digyna* (41.92); *Epilobium latifolium* (29.96); *Meconopsis aculeata* (16.84)

Species richness and diversity: The species richness and diversity values calculated for the sampled sites for both wetlands. The values of species richness for the 12 different sampled sites range from 39 in Lower East to 8 in Upper – North aspect in Chandra Tal and 34 in Middle – North to 7 in Lower – South aspect in Suraj Tal, while Shannon's diversity values range from 3.39 in Middle – North to 1.75 in Upper – North in Chandra Tal and 3.35 in Middle - North to 1.93 in Lower – South in Suraj Tal respectively, (Fig 1 and Fig 2).

Similarity index: The similarity index in the species assemblage between the three elevational gradients for both wetlands owing to the species like *Potentilla argyrophylla*, *Carex nivalis*, *Halerpestes tricuspis*, *Rhodiola crenulata* (Fig 3 and Fig 4).

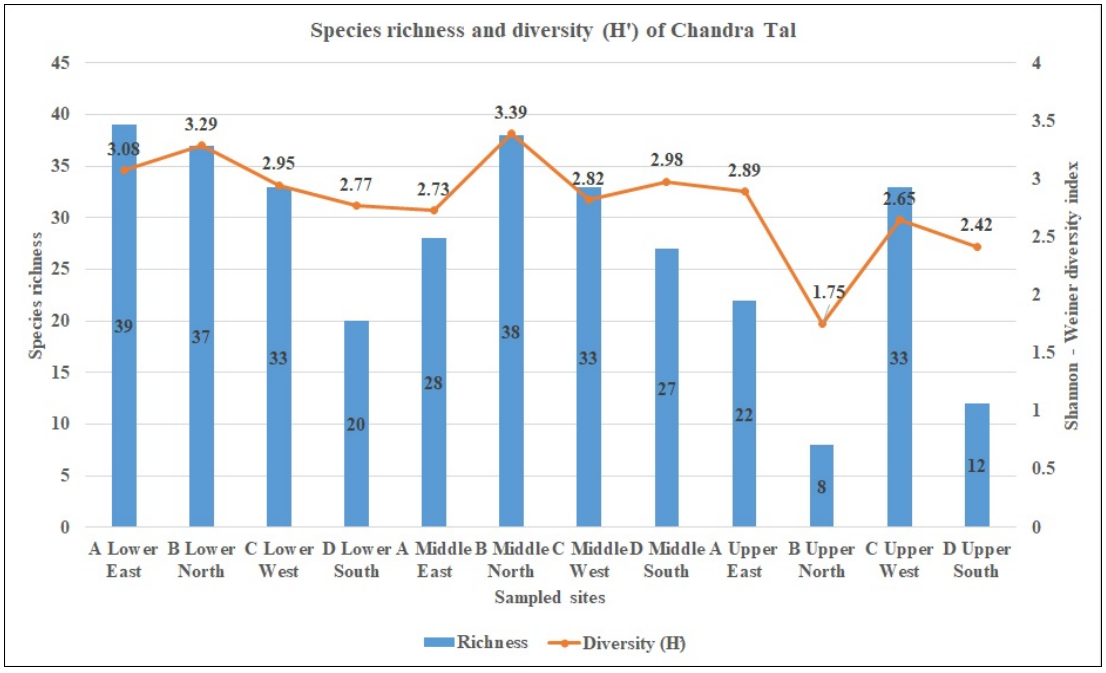

Fig 1: Species richness and Shannon-Weiner diversity (H') of Chandra Tal wetland

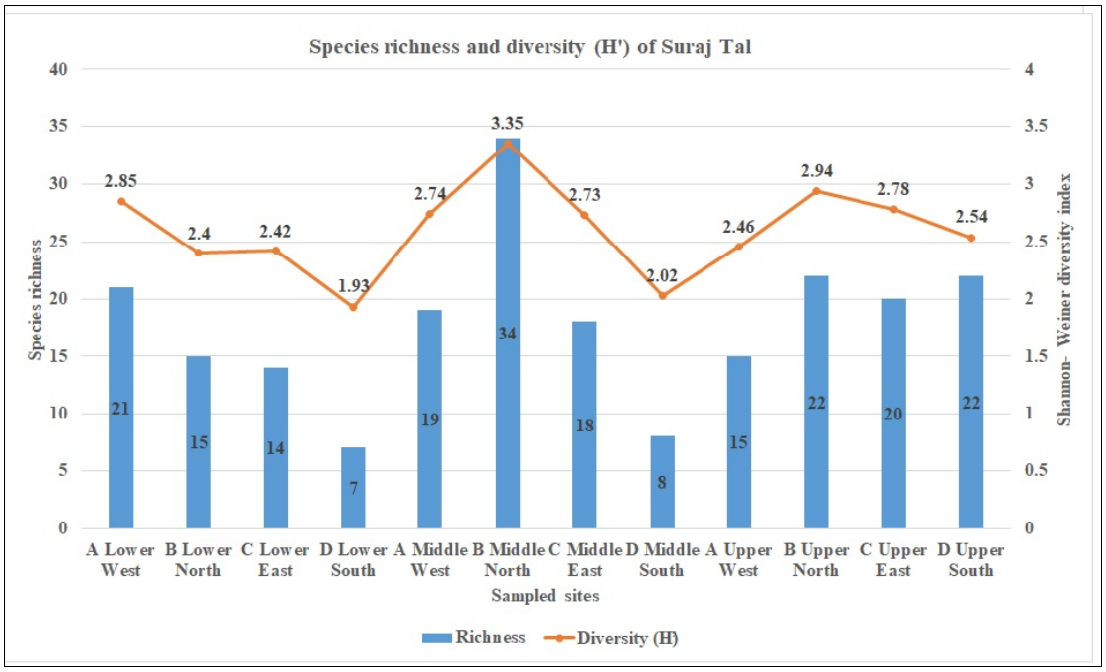

Fig 2: Species richness and Shannon-Weiner diversity (H') of Suraj Tal wetland

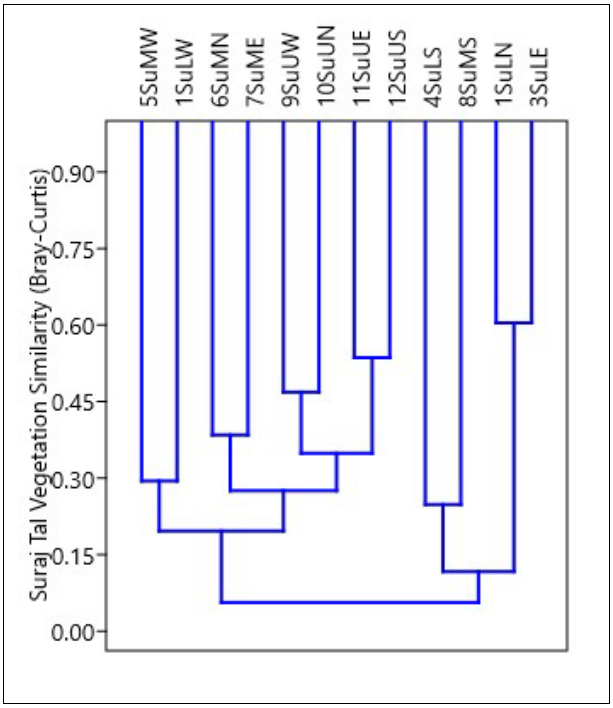

Fig 3: Vegetation Similarity index of Chandra Tal Wetland

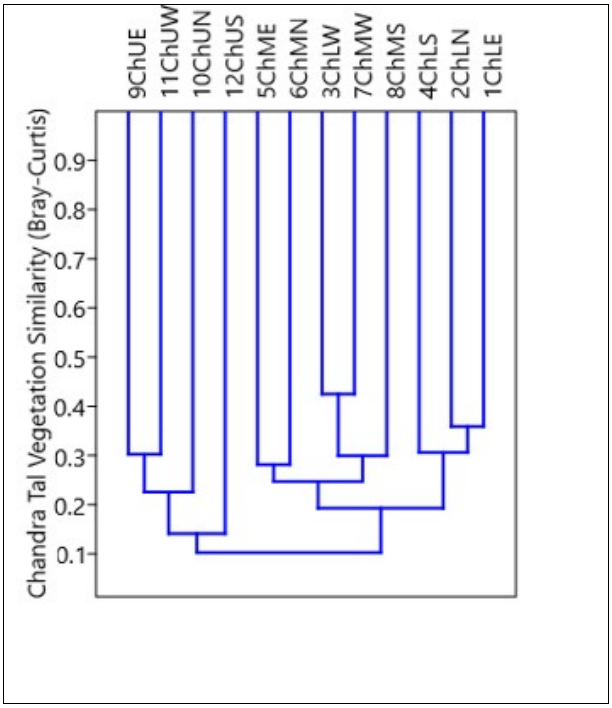

Fig 4: Vegetation Similarity index of Suraj Tal Wetland

Discussion

Majority of the species are recorded in lower stretch of Chandra Tal whereas species richness was higher in middle region of Suraj Tal. Small number of plants were recorded particularly from both wetlands may be because of the frozen condition of the cold desert glacial lakes during a long period of the year. True hydrophytes like *Hippuris vulgaris*, *Stuckenia pectinata*, *Potamogeton nodosus*, *Ranunculus tricuspis* found in very small area particularly in water logged areas. Plants of marshy and moist which are closer to adjacent lake areas are dependent on lake water but plants of upper dry region have no dependency on lake water.

Conclusion

During the survey period it is observed that, in recent years, these HAWs are under severe anthropogenic pressure, through overgrazing of vegetation in and around the wetland areas, increase soil and water pollution, hype of adventure tourism, unplanned developmental activities to accommodate the needs of increased tourist pressure and many other anthropogenic activities. All these pressures cause very adverse impacts on these very fragile ecosystems. It is, therefore, vital that these HAWs are conserved to secure hydrological regimes to maintain a steady supply of water for maintaining the biodiversity that depends on these freshwater sources. More importantly

conservation of these wetlands is also needed for safeguarding the interests of indigenous dependent communities.

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Author contributions
DD: Conceptualization, Methodology, Data curation, Formal analysis; PB: Data curation, Validation; KCS: Funding acquisition, Project administration; DA: Supervision.

Conflict of interests
The authors have no conflict of interest.

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