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Floristics and Distribution of Plant Communities across Moisture and Topographic Gradients in Tso Kar Basin, Changthang Plateau, Eastern Ladakh

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Abstract

This paper deals with the floristic structure and plant-community composition in relation to environmental gradients in the Tso Kar basin, an ~300 km^2 area of the Changthang plateau. A total of 131 sites covering various landscape units—namely, sandy plains, marsh meadows, moist meadows, scrub steppe, fell-fields, and stream courses—were intensively sampled by using random quadrats of 1 m^2. In addition, these sites were searched for the presence of other vascular plants. In all, 232 species of vascular plants belonging to 38 families and 101 genera were collected and recorded from the study area. Poaceae (39 species), Asteraceae (27 species), Cyperaceae (25 species), Brassicaceae (14 species), Fabaceae (12 species), and Ranunculaceae (12 species) are the dominant families. It is interesting to note that the study area has a very high monocot:dicot ratio (1:2). Analysis of Raunkiaer's life-forms reveals that the area is dominated by two growth forms—namely, 57% hemicryptophytes (perennial grasses and sedges) and 24% chamaephytes (dwarf herbs and matted shrubs). The density of stems ranges from 28 to 744 plants per square meter. Species richness varies from 4 to 15, and diversity values are from 0.143 to 1.679. Among communities, the highest similarity (57.5%) is between *Scirpus-Carex* and *Scirpus-Kobresia-Ranunculus*. Conservation implications of the findings and the need for a participatory approach of the rangeland management are discussed.

Introduction

The Changthang plateau in eastern Ladakh represents an important biogeographic province within Indian Trans-Himalaya (Rodgers and Panwar, 1988). This tableland forms the western extension of the Tibetan plateau and is mostly higher than 4500 m above sea level (a.s.l.). The metasedimentary rocks originated by deposition on an ancient Tethyan sea-bed, and they have undergone frequent phases of glaciation and aridity during the Pleistocene and Holocene. Now this region exhibits harsh climatic conditions, low primary productivity, and unique assemblages of flora and fauna. Much of the plateau is characterized by lake basins of varying size as well as sandy plains and rolling mountains fringed by snowy peaks. The internal drainage in some of the basins has resulted in concentration of salts and minerals over the millennia, making the water bodies brackish. Less than 1% of the geographical area on the plateau is cultivated, and most of the vegetated zone is used by migratory pastoral communities—i.e., *Changpa* herders—for livestock grazing. *Changpas* rear goats, sheep, yaks, and horses. Despite a harsh climate, poor vegetation cover, and relatively low standing biomass, this area sustains a high livestock population. The area also supports diverse but low populations of typical Trans-Himalayan mammalian fauna, such as blue sheep or bharal (*Pseudois nayaur*), Tibetan argali (*Ovis ammon hodgsoni*), Tibetan antelope (*Pantholops hodgsoni*), Tibetan gazelle (*Procarpa picticaudata*), snow leopard (*Uncia uncia*), brown bear (*Ursus arctos*), Tibetan wolf (*Canis lupus chanko*), lynx (*Lynx isabellina*), red fox (*Vulpus vulpus*), and wild dog (*Cuon alpinus*). Besides, there are several species of migratory waterfowl, including the threatened black-necked crane (*Grus nigricollis*) and bar-headed goose (*Anser indicus*).

Despite immense ecological and conservation significance, no detailed ecological studies have been conducted in these rangelands until now. A few authors previously conducted floristic surveys in the region (e.g., Kachroo et al., 1977; Chaurasia and Singh, 1997; and Murti, 2001). Hartmann (1987), Rawat et al. (2001), Kala and Mathur (2002), Rawat and Adhikari (2002), and Klimes (2003) conducted vegetation surveys in other parts of the Indian Trans-Himalaya. Richard (1999) dealt with the rangelands and livestock as a niche opportunity for this region. Systematic surveys on various components of biodiversity in Changthang have started only recently (Anonymous, 2001).

This paper deals with the floristic structure and plant-community composition across various landscape units and environmental gradients in the Tso Kar basin of the Changthang plateau. The data were collected during a rapid ecological survey conducted in the summer of 2001. The role of biotic and abiotic factors in life-form structure and the distribution of plant communities are discussed herein.

Materials and Methods

STUDY AREA

The survey was conducted in the Tso Kar basin and the adjacent Rupshu plains of the Indian Changthang, eastern Ladakh (Fig. 1). This area (~300 km^2) lies approximately between 33°10′ and 33°30′N and between 77°55′ and 78°20′E; the altitudinal range is ~4400 m to 5800 m a.s.l. It is bordered by the Zanskar range on the south, the Sumdo Nala (a tributary of the Indus) on the east, and Tanglang La (5360 m a.s.l.; a high mountain pass and the ridge extending from it) on the north. Administratively the study area lies in the Nyoma block of the Ladakh district. According to the local herders (*Changpas*), this area is divisible in to three units: Samad, Kharnak, and Puga Valley. Meteorological data for the study area are not available, but it is regarded as colder and drier than other parts of Ladakh. A considerable proportion of the study area is flat with extensive sandy plains. Tso Kar, a broad pan-shaped basin, has two large water bodies adjacent to

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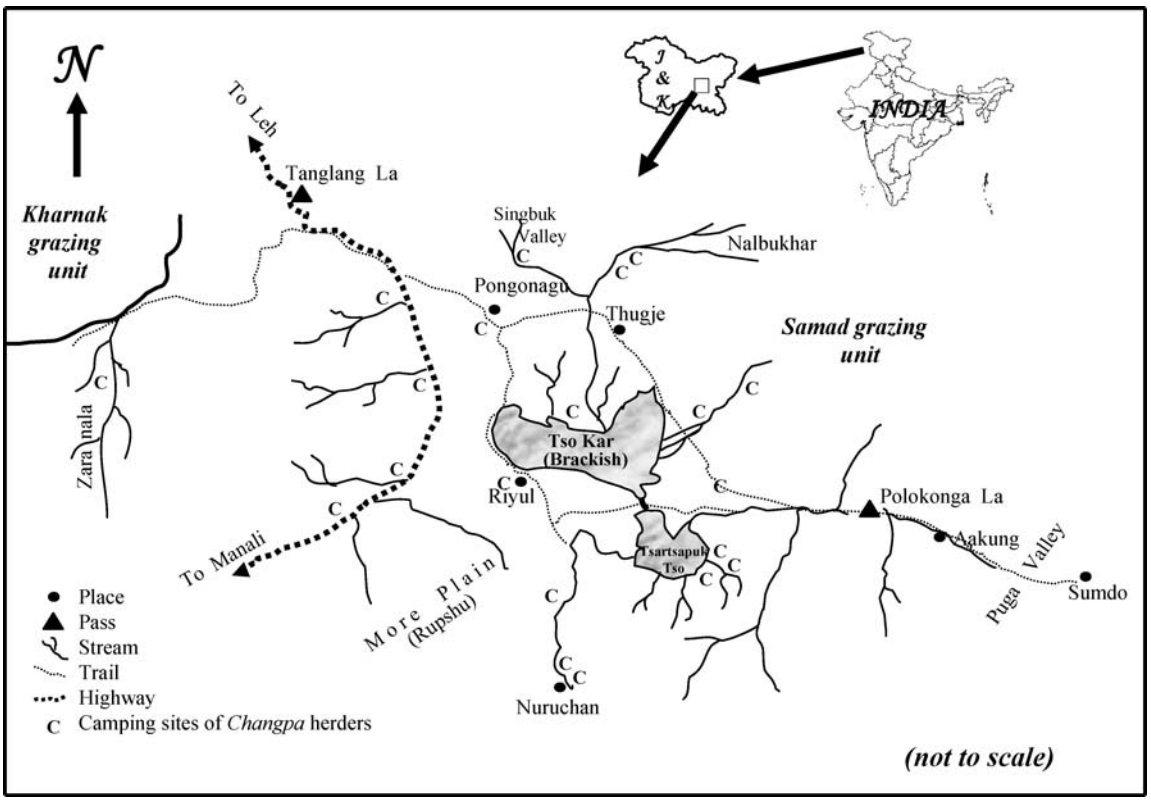

FIGURE 1. A diagrammatic sketch of Tso Kar basin.

each other—namely, Tso Kar (~19.5 km^2, 4534 m in elevation) and Tsartsapuk Tso (~2.5 km^2, 4545 m in elevation). However, Tso Kar, a dumbbell-shaped brackish-water lake receives drainage from most of the basin, whereas Tsartsapuk Tso is a freshwater lake drained mainly by two perennial streams. Tsartsapuk Tso also drains into the former lake. The northwestern and eastern banks of Tso Kar are rich in deposits of borax and common salt and hence are unfavorable for plant growth except for a few salt-tolerant species such as *Axyris amaranthoides* and *Sueda microsperma*.

The vegetation of the study area can be broadly categorized into scrub formations, desert steppe, and marsh meadows. The major plant communities include *Caragana-Eurotia*, *Artemisia-Tanacetum*, *Stipa-Oxytropis-Alyssum*, and *Carex melanantha-Leymus secalinus*. The parts of the study area at very high altitudes (>5000 m) have sparse fell-field communities with moss or cushion-like growth forms, e.g., *Thylacospermum caespitosum*, *Arenaria bryophylla*, *Androsace sarmentosa*, and a variety of lichens. Stream banks and marsh meadows around both the lakes (except areas of borax and salt deposits) exhibit a characteristic sedge-dominated vegetation represented by species of *Carex, Kobresia*, *Scirpus*, *Triglochin*, *Pucciniella*, *Ranunculus*, and *Polygonum*. The shallow parts of Tsartsapuk support dense growths of aquatic plants such as *Hippuris vulgaris*, *Potamogeton pectinatus*, *P. perfoliatus*, *Zannichellia palustris*, and *Ranunculus nutans*.

TABLE 1

Summary of the vascular plants recorded in the Tso Kar Basin.

Group	Family	Genera	Species
Dicots	30	74	157
Monocots	7	26	74
Gymnosperms	1	1	1
Tso Kar basin (present study)	38	101	232
Ladakh (Kachroo et al. 1977)	51	190	611

The soil texture varies from sandy to sandy clay. The soil under most of the landscape units is basic in nature (pH 7.9–9.3). The soil's water-holding capacity, organic carbon, and nitrogen were observed to be highest (109%, 5.3%, and 0.623%, respectively) in boggy areas, which were mainly dominated by the *Scirpus* community (B. S. Adhikari and G. S. Rawat, unpublished data).

METHODS

The study area was traversed on foot as well as by vehicle (wherever feasible) to cover all the landscape features and landforms. The plant species were collected and recorded systematically for all landforms. These include marsh meadows, moist meadows, sandy plains, alluvial fans, lower (grassy) slopes, higher slopes, scrub steppe, fell-fields, and livestock camps. We used the standard literature (Polunin and Stainton, 1987; Aswal and Mehrotra, 1994; Murti, 2001) for plant identification in the field. Voucher specimens were collected for confirmation of species from the National Herbaria based at Dehra Dun. The species were categorized according to their growth habits (life-form) by using Raunkiaur's classification (Mueller-Dombois and Ellenberg, 1974).

A total of 131 sites were sampled for the structure and composition of vegetation. The study area was stratified into various landscape units. At each site, we used 10 random quadrats of 1 m^2 each following standard methods (Mueller-Dombois and Ellenberg, 1974; Kent and Coker, 1992). Other parameters recorded at each site were altitude, geographical coordinates (determined through the use of the Global Positioning System [GPS]), aspect, terrain, soil type, and vegetation cover. The data on the abundance (number) of individual species were recorded within each quadrat along with their approximate cover (%).

We used simple measures such as density (plants per square meter), diversity (ShannonWiener index, H'), and richness (Menhinick's Index) as given in Magurran (1988) to describe the vegetation characteristics within various landscape units. The plant communities

TABLE 2

Composition of vascular plants in Tso Kar basin.

Family	Genera	Species
Dicotyledons		
Amaranthaceae	1	2
Apiaceae	3	4
Asteraceae	9	27
Boraginaceae	2	2
Brassicaceae	9	14
Caprifoliaceae	1	1
Caryophyllaceae	4	13
Chenopodiaceae	5	7
Crassulaceae	1	3
Euphorbiaceae	1	1
Fabaceae	4	12
Fumariaceae	1	3
Gentianaceae	3	5
Geraniaceae	1	1
Hippuridaceae	1	1
Lamiaceae	5	10
Malvaceae	1	1
Parnassiaceae	1	1
Plantaginaceae	1	1
Polygonaceae	2	6
Potamogetonaceae	1	2
Primulaceae	2	3
Ranunculaceae	4	12
Rosaceae	2	9
Salicaceae	1	1
Saxifragaceae	1	2
Scrophulariaceae	3	8
Solanaceae	2	2
Tamaricaceae	1	1
Urticaceae	1	1
Violaceae	1	1
Monocotyledons		
Amaryllidaceae	1	3
Cyperaceae	4	25
Poaceae	17	39
Juncaceae	1	2
Juncaginaceae	1	2
Zannichelliaceae	1	1
Gymnospermae		
Ephedraceae	1	1
Total	101	232

were classified by using two-way indicator-species analysis (TWINSPAN; Hill, 1979), a computer-based polythetic divisive clustering package. The similarity (qualitative) was calculated following Magurran (1988).

Results

FLORISTIC STRUCTURE AND COMPOSITION

In total, 232 species of vascular plants, belonging to 38 families and 101 genera, were collected and recorded from the study area (Table 1). The dominant families include Poaceae (39 species), Asteraceae (27 species), Cyperaceae (25 species), Brassicaceae (16 species), and Fabaceae (12 species, Table 2). The ratio of monocots to dicots in the area is 1:2.1. This ratio is very high compared to the reported ratio of the Ladakh flora as a whole (1:8.30; Kachroo et al., 1977) as well as the alpine flora of the Kumaun Himalaya (1:5.2; Rawat, 1984), Deosai Plains (1:3.6; Woods et al., 1997), and the Valley of Flowers (1:4.2; Kala et al., 1998). Such a high proportion of monocots in the area may be attributed to a long history of grazing by ungulates on the plateau and the ability of grasses and sedges to withstand heavy grazing.

TABLE 3

Life-forms spectrum of the Tso Kar basin. Definitions of the various life-forms: Phanerophytes are tress >2 m high. Nannophanerophytes are small trees or shrubs <2 m high. Chamaephytes are woody or herbaceous perennials with buds close to the ground. Hemicryptophytes are rosette- or tussock-forming plants in which aboveground parts die back during unfavorable periods, e.g., graminoids. Geophytes are plants with subterranean bulbs, tubers, or thick rhizomes. Hydrophytes are aquatic plants. Therophytes are annual herbs that survive the unfavorable periods as seeds (for more details, see Kent and Coker, 1992).

	Percentage of total species by region			
Life-forms	Normal (Ramkaier, 1934)	Ladakh (Kachroo et al., 1977)	Changthang (Klimes, 2003)	Changthang (Present study)
Phanerophytes (Ph)	28	2.6	3.5	0
Nannophanerophytes (N)	15	4.8	0	0.9
Chamaephytes (Ch)	9	26.8	5.4	23.5
Hemicryptophytes (H)	26	9.6	62.1	56.5
Geophytes (G)	4	21.3	4.2	4.8
Hydrophytes (Hh)	2	0.6	1.7	2.2
Therophytes (T)	13	33.2	22.3	11.7

As the area has a cold desert environment, certain groups of plants such as orchids, ferns, and liverworts are completely absent. A low diversity of *Astragalus*, *Pedicularis*, and *Juncus* and a high ecotypic variation among *Elymus*, *Poa*, *Artemisia*, *Oxytropis*, *Carex*, and *Kobresia* are interesting features of the flora. *Hippuris vulgaris*, *Alyssum canescens*, *Zannichellia palustris*, and *Microula tibetica* are species little known in India.

The flora is dominated by hemicryptophytic (graminoids) and chamaephytic (dwarf herbs with perennial rhizome or root stock) life-forms having ~57 and 23% species, respectively. The herbaceous dicots are generally aromatic (23%), dwarf, cushion-like (17.3%) or woolly and hairy (12%). A comparative account of life-form spectrum for the study area, Ladakh, and world is given in Table 3.

VEGETATION CHARACTERISTICS

Four distinct physiognomic units of vegetation are discernible in the study area: (1) scrub steppe (*Caragana-Eurotia*, *Artemisia*, and *Tanacetum* formations), (2) desert steppe (*Stipa-Alyssum-Oxytropis*, *Leymus secalinus*, and *Carex melanantha* types), (3) wet and marsh meadows dominated by sedges, and (4) cushion-like vegetation or fell-fields at higher altitudes (>4800 m). The scrub steppe, desert steppe, sedge meadows, and fell-fields formed ~20, 40, 5, and 10% of the land surface, respectively. The remaining 25% of the area consists of steep rocky slopes and snow fields.

Sixteen plant communities were segregated by using TWINSPAN. The distribution of these communities with respect to major environmental gradients—namely, soil moisture, altitude, and landscape units—is shown in the Figure 2. In terms of areal coverage, the desert steppe (*Stipa-Alyssum-Oxytropis*) and scrub steppe (*Caragana-Poa*) communities are the most extensive. Communities 1–6 (*Scirpus-Carex*, *Scirpus-Carex-Ranunculus*, *Scirpus-Kobresia-Ranunculus*, *Pucciniella-Polygonum-Carex*, *Polygonum-Glaux-Carex*, and *Carex-Polygonum-Elymus*) are confined to wet meadows along the gradients of moisture in the valley bottom and stream courses. In the higher altitudes (>4800 m), especially on the wind-blown rocky slopes, *Poa-Elymus-Artemisia* and *Tanacetum tibeticum* communities are prominent. *Eurotia ceratoides* (a

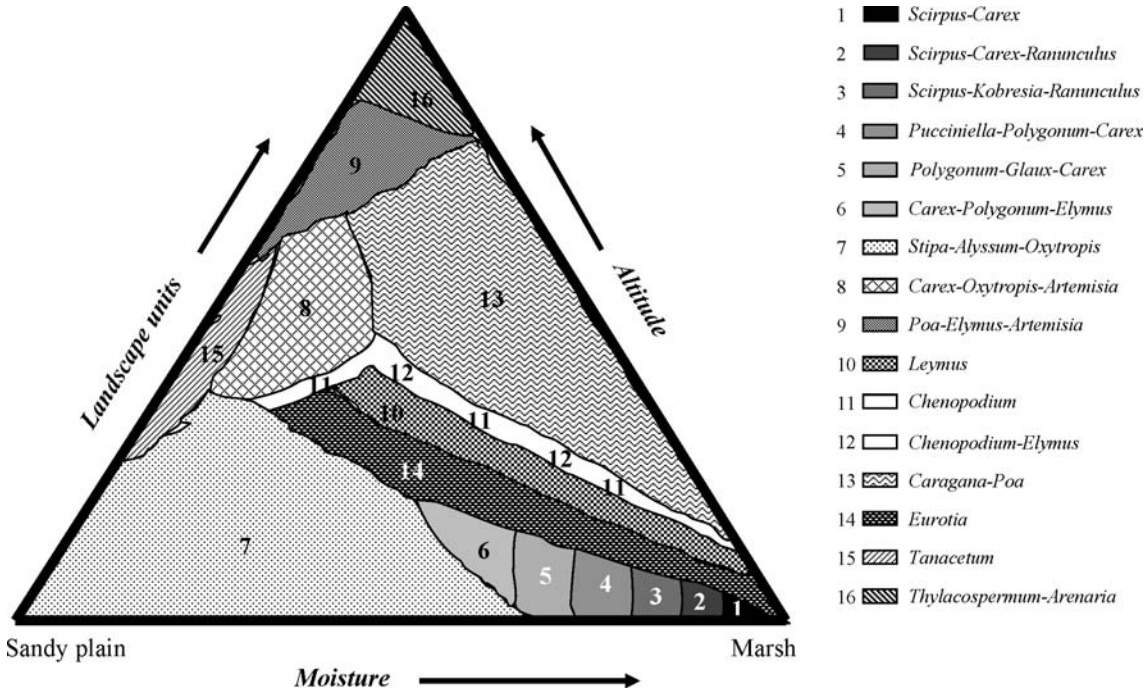

FIGURE 2. Distribution pattern of plant communities along environmental gradients.

perennial shrub) and *Leymus secalinus* (a coarse grass) form pure stands of their own near hill bases. Moist areas above 5000 m are usually dominated by the *Thylacospermum-Arenaria* community.

Percent cover, plant density, species richness, diversity, and evenness for various communities are compared in Table 4. Communities 1–6 have higher density, diversity, and species richness than all other communities. Overall cover, density, species richness, and diversity follow the gradients of soil moisture and landscape units rather than altitudinal gradient. Most of the livestock camps are characterized by the prominence of an unpalatable nitrophilic herb, *Chenopodium glaucum*, and a coarse grass, *Leymus secalinus*.

The similarity between communities is observed to be highest (57.5%) for *Carex-Oxytropis-Artemisia* and *Stipa-Alyssum-Oxytropis*, followed by *Chenopodium-Leymus* and *Elymus* (57.4%, Table 5).

Discussion

Earlier authors have interpreted Changthang plateau as floristically impoverished compared to other areas of Ladakh (e.g., Kachroo et al., 1977; Chaurasia and Singh, 1997). An update on the flora based on the present survey reveals that the plateau harbors at least 232 species of vascular plants. This study also underlines the importance of graminoids in the flora of the region. Although forming less than 1% of the geographical area of Ladakh, the flora of the Tso Kar basin includes nearly 25% of the species reported from the region. Because the area forms a continuum with the vast Tibetan plateau, we expected very few endemic species to be found in the study area. Species sensitive to heavy trampling, grazing, and aridity (e.g., orchids and ferns) are completely absent in the present study area. The following species (which are otherwise common in other parts of the Trans-Himalaya) are either absent or extremely rare: *Ephedra gerardiana*, *Rosa webbiana*, *Lonicera spinosa*, *Salix* spp., *Juniperus* spp., *Berberis* spp., *Hippophae tibetana*, *Cicer microphylla*, and *Cotoneaster* spp. Selective removal of some of these species for fuelwood or overgrazing through the centuries and failure of regeneration cannot be ruled out. Palynological studies in the area could reveal some interesting details of phytogeography.

The plant communities in the study area follow the gradients of soil moisture and microtopography, which determine the soil type. Of

TABLE 4

Cover, density, species richness, diversity, and evenness of different plant communities in Tso Kar basin.

Community type	Cover (%, ±1 SD)	Density (m^{-2} ± 1 SD)	Species richness (±1 SD)	Diversity (H' ± 1 SD)	Evenness (±1 SD)
Scirpus-Carex	88.5 ± 8.5	468.2 ± 115.4	12.0 ± 3.2	1.301 ± 0.511	0.520 ± 0.167
Scirpus-Carex-Ranunculus	94.0 ± 6.2	743.7 ± 406.7	12.3 ± 3.3	1.472 ± 0.266	0.603 ± 0.157
Scirpus-Kobresia-Ranunculus	91.3 ± 11.1	708.2 ± 519.5	15.3 ± 3.9	1.679 ± 0.387	0.619 ± 0.113
Puccinella-Polygonum-Carex	83.3 ± 20.2	348.1 ± 300.0	4.0 ± 1.0	0.740 ± 0.743	0.496 ± 0.483
Polygonum-Glaux-Carex	85.5 ± 11.4	227.1 ± 62.3	8.3 ± 1.5	1.556 ± 0.390	0.735 ± 0.136
Carex-Polygonum-Elymus	90.0 ± 8.7	235.1 ± 32.9	9.7 ± 3.1	1.622 ± 0.605	0.712 ± 0.168
Stipa-Alyssum-Oxytropis	36.6 ± 12.5	34.7 ± 36.1	7.3 ± 2.2	1.321 ± 0.357	0.675 ± 0.124
Carex-Oxytropis-Artemisia	55.9 ± 22.6	99.4 ± 116.4	8.5 ± 3.7	1.232 ± 0.788	0.541 ± 0.308
Poa-Elymus-Artemisia	61.7 ± 23.6	27.6 ± 29.8	5.3 ± 1.5	1.006 ± 0.177	0.612 ± 0.067
Leymus	60.0 ± 0.0	55.7 ± 57.8	3.0 ± 0.0	0.143 ± 0.193	0.130 ± 0.176
Chenopodium	40.0 ± 14.1	77.8 ± 36.1	4.5 ± 0.7	0.341 ± 0.479	0.213 ± 0.298
Chenopodium-Leymus	46.0 ± 12.9	61.2 ± 45.5	3.8 ± 1.3	0.537 ± 0.217	0.496 ± 0.331

TABLE 5

Similarity (%) between different plant communities in Tso Kar basin.

	Community											
Community	1	2	3	4	5	6	7	8	9	10	11	12
Chenopodium	100	40.0	16.7	0.0	20.3	17.2	0.0	0.0	0.0	3.8	0.0	0.0
Chenopodium-Leymus		100	54.5	10.5	17.2	15.2	12.5	8.0	8.7	3.8	0.0	0.0
Leymus			100	12.5	14.5	8.9	30.8	18.2	20.0	4.1	0.0	0.0
Poa-Elymus-Artemisia				100	28.6	16.5	0.0	13.3	0.0	14.0	5.3	4.3
Carex-Oxytropis-Artemisia					100	57.4	16.7	26.1	17.9	25.0	15.6	25.6
Stipa-Alyssum-Oxytropis						100	14.9	25.2	17.8	32.3	23.4	26.7
Puccinella-Polygonum-Carex							100	44.4	47.0	22.2	11.4	18.2
Carex-Polygonum-Elymus								100	47.1	38.1	31.8	37.8
Polygonum-Glaux-Carex									100	39.3	28.6	39.2
Scripus-Carex										100	50.7	57.5
Scripus-Carex-Ranunculus											100	42.6
Scripus-Kobresia-Ranunculus												100

the total species recorded from the study area, 132 species (57%) were found within the sample plots. General cover, density, species richness, and diversity are more clearly defined along the gradients of soil moisture and landscape units, instead of being controlled by altitude, as indicated by very low correlation coefficients. The vegetation cover, density, and species richness are higher in mesic sites than at drier sites. Diversity and evenness values are higher in valleys within *Polygonum*-mixed and *Carex*-mixed communities. Compared to the herbaceous alpine meadows of the Greater Himalaya (e.g., Kala et al., 1998; Singh and Rawat, 1999), the steppe formations in the study area have higher proportions of graminoids (Table 6). Compared to moist and smaller pockets in the alpine areas of the Greater Himalaya, the higher diversity and biomass of grazing ungulates—both wild and domestic—in the Trans-Himalaya suggest that the latter region has had a much longer history of grazing ungulates, which could have resulted in the prominence of graminoids (Bock et al., 1995). The vegetation cover during the peak of the growing season is highest within marsh meadows (92%) and lowest within the desert steppe (37%). The highest stem densities were observed in marsh meadows (544 plants per square meter), followed by the densities in moist meadows (507 plants per square meter). Such a high density is largely due to dominance of tussock- and tiller-forming sedges. The densities are low in alluvial-fan (14 plants per square meter) and scrub-steppe (23 plants per square meter) areas. Species richness is lowest around livestock camps (4.8), followed by lower slopes (6.2), sandy plains (6.6), and alluvial fans (6.8). Although moist and marsh meadows have the highest values of species richness, the higher slopes, which are dominated by a variety of grasses and forbs, have equally high species diversity (Rawat and Adhikari, 2005).

An updated inventory of Changthang (Ladakh) flora highlights the preponderance of graminoids, which is attributed to the area's history of grazing by wild and domestic ungulates and to the better adaptability of graminoids to grazing. Continued biotic pressure coupled with harsh climate conditions in the area has resulted in the dominance of hemicryptophytic and chamaephytic life-forms in most of the communities (Table 6). As many as 16 plant communities have been identified in the area during this study; they are distributed along gradients of soil moisture, altitude, and landscape units.

TABLE 6

Life-form spectrum in different communities in Tso Kar basin (for abbreviations, see Table 4).

	Percentage of total species by life-form						
Community	Ph	N	Ch	H	G	Hh	T
Chenopodium-Leymus	—	12.5	25.0	50.0	12.5	—	—
Chenopodium	—	14.3		85.7	—	—	—
Leymus	—	25.0	—	75.0	—	—	—
Poa-Elymus-Artemisia	—	—	33.3	50.0	16.7	—	—
Carex-Oxytropis-Artemisia	—	2.0	33.3	49.0	5.9	—	9.8
Stipa-Alyssum-Oxytropis	—	1.2	31.8	51.8	4.7	—	10.6
Carex-Polygonum-Elymus	—	—	—	55.6	11.1	—	33.3
Polygonum-Glaux-Carex	—	—	11.1	72.2	—	—	16.7
Puccinella-Polygonum-Carex	—	—	—	62.5	12.5	—	25.0
Scripus-Kobresia-Ranunculus	—	—	8.9	62.2	8.9	4.4	15.6
Scripus-Carex-Ranunculus	—	—	7.7	69.2	11.5	3.8	7.7
Scripus-Carex	—	—	14.3	68.6	2.9	—	14.3

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