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Pastoralism and wildlife conservation: assessing the coexistence of wild and domestic ungulates for multiple rangeland use in the Trans-Himalaya

Final Report

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Contents

Summary

The area north of the Himalayan range in India is described as a cold desert, but harbours a fascinating assemblage of mountain ungulates that are adapted to the high altitude and the arid conditions of the region. The species pool of the region comprises eight wild ungulates namely Tibetan gazelle Procapra Picticaudata, *Tibetan antelope* Pantholops hodgsoni, *Blue sheep* Pseudois nayaur, *Ladakh urial* Ovis vignei vignei, *Asiatic ibex* Capra ibex siberica, *Tibetan argali* Ovis ammon hodgsoni, *Kiang* Equus kiang *and wild yak* Bos grunniens. *Some of these animals were hunted indiscriminately in the past by trophy as well as pot hunters, and many of them went locally extinct from several sites. Today, they continue to face an array of threats associated modern developmental initiatives, and conservation efforts are constrained by increasing livestock population, indifferent attitude of pastoral people towards ecological integrity of the region, and lack of ecological information on the individual species as well as on forces structuring their assemblages.*

Presently, there is a spatial variation in species richness of these large herbivores in the region with some valleys supporting only one species while others supporting upto five species. Furthermore, some species are widely distributed while others are restricted to smaller areas. Why there is such an variation in large herbivore diversity across the region, and what determines the wide distribution of some species and limited distributions of others. Relying on niche related theories, I addressed these questions with a larger aim of understating the factors structuring and maintaining large herbivore communities in the Trans-Himalayan region.

Herbivore species can be packed into communities either by increasing the range of resources or by narrowing down the niche width of constituent species. I looked if this holds true for the ungulate assemblages in the Trans-Himalayan region. Secondly, I explored the hypothesis that widely distributed species have greater plasticity in their resource use. To test these hypotheses, I used blue sheep as a model species as it is a widely ranging species, occurring in a range of communities, both 'species-rich' and 'species-poor' communities. The animal's habitat and diet use was studied in three different Trans-Himalayan sites with similar environmental features but varying number of sympatric species.

I found that blue sheep's niche width, both in terms of habitat and diet, declined with the number of sympatric species in the herbivore assemblage. This difference was significant after controlling for the availability of resources in the 'species-rich' and 'species-poor' communities. Blue sheep thus showed a greater plasticity in its resource use compared to the Ladakh urial, a mountain ungulate with a very limited distribution in the region. Contrary to the results of the previous studies, I found a greater proportion of non-graminoids in the diet of blue sheep, which again suggests that the animal is flexible, using resources in according to their availability. They also included a substantial proportion of the generative parts (flowers, fruits and seeds) of the non-graminoids. Therefore, although the animals consumed fewer plant species in the areas with greater number of sympatric species, they fed even on the flowers, fruits and seeds of these plants. Therefore they use the scarce mountain resources 'frugally', which may explain how so many species coexist in such austere and low productive habitats of the Trans-Himalaya. These results are presented in Chapter 1.

Apart from these, I looked at the current scenario of wildlife conservation in eastern Ladakh called Changthang, which is the Pashmina *(fine wool of a local breed of goat, and the mainstay of the economy of the region) production centre of India. Here the livestock population has been increasing exponentially in the recent decades, which is becoming a cause of concern to the wildlife conservationists. Recognising the need to protect the unique biodiversity of Changthang, a huge area was declared as Changthang High Altitude Cold Desert Sanctuary in the late 1980s, although without settling the rights of local pastoralists residing inside the*

protected area. Recently when the conservation authorities issued a notification to settle the statutory rights of people residing inside the protective area (as part of a countrywide initiative to strictly enforce conservation laws inside the protected areas), the people of Changthang fiercely opposed the move saying that this would negatively affect their traditional livestock production system. I followed the developments associated with this movement, and the findings are presented in Chapter 2.

I in collaboration with colleagues also looked at distribution, abundance and diversity patterns of waterbirds around four high-altitude lakes in eastern Ladakh, the results of which are presented in the appendix.

Chapter 1

Dynamics of resource use by blue sheep: Influence of herbivore species richness

ABSTRACT
The species diversity of the mammalian herbivores in the Indian Trans-Himalaya varies across the landscape, providing an opportunity to assess the niche dynamics of individual species in relation to the geographical variation in species richness. I used the blue sheep *Pseudois nayaur*, a relatively widely distributed mountain ungulate in the region, as a model species to explore if niche width of a species varies in response to species richness. I selected three discrete valleys in three protected areas with almost similar environmental features but varying ungulate species richness, and studied the animal's diet and habitat utilization in them. I found that blue sheep has a narrower niche width (both diet and habitat) in the 'species-rich' valley than in the 'species-poor valleys'. Looking at the differences in habitat parameters used by the species in the three areas, I found an interaction between species composition and season with the animal using steeper and higher areas in summer in the 'species-poor' areas and using these features in winter in the 'species-rich' area. The diet of blue sheep was dominated by non-graminoids, mainly *Thermopsis* sp., *Artemisia* spp. and *Arenaria* spp. in both 'species-rich' and 'species-poor' areas. The results of the study suggest that spatial patterns of large herbivore diversity can be determined by mechanisms associated with niche space and the limiting similarity of coexisting species even in harsh and unpredictable environments like that of the Trans-Himalaya.

Keywords: Niche width, habitat, diet, *Pseudois nayaur*, species richness, mountain ungulates, Ladakh, Trans-Himalaya

INTRODUCTION
Theoretical and empirical studies in community ecology in the last four decades revolved around niche related competitive interactions and the consequent resource partitioning amongst co-occurring species, and the principle of competitive exclusion gained almost an axiomatic status (Gause, 1934; Hutchinson, 1959; Schoener, 1983). The basic tenet of the competitive exclusion is that *n* number of species cannot coexist on fewer than *n* resources (Gause, 1934; Hutchinson, 1959). This implies that resource availability constrains the number of species occurring in an area (MacArthur, 1972; Olff and Ritchie, 1998; Ritchie and Olff, 1999b). Studies across several taxa have reported a ceiling to the species richness in ecological communities (Terborgh & Faaborg, 1980; Tonn et al., 1990). The resource constraints allow the coexistence of only those species that show trade-offs in niche utilization in response to competition (Chase and Leibold, 2003). Therefore, species may avoid or reduce competition by adjusting their respective niche widths in evolutionary response to their co-inhabitants (Pianka, 1978; Chase and Leibold, 2003).

As per the rivet hypothesis every species plays an important role in the ecosystem functioning (Lawton, 1994). Loss of species from ecological communities thus affects the diversity and population dynamics of the remaining taxa (Cardinale et al., 2006). For instance, when a species goes extinct from a community, a niche becomes vacant that can either be occupied by an invading species or exploited by the extant species leading to readjustment in their niche utilization. Therefore, it is postulated that disappearance of species from ecological communities leads to increase in the niche width of the extant species, and the earlier densely packed communities become relaxed. Thus niche relations amongst sympatric species is an important factor in maintaining species diversity in ecological communities (Shmida & Wilson, 1985).

The mountainous rangelands of the Indian Trans-Himalaya support a relatively diverse assemblage of eight wild ungulates (Fox et al., 1991a) including four Caprinae species that represent 40% of this taxa found in the Himalayan region. But the populations of these animals are highly fragmented, and there is a spatial variation in the species richness with local assemblages representing biased subsets of the regional species pool. However, the plausible causes of such a variation is little known, and the factors influencing the organization of herbivore assemblages in the region is not understood. Several large herbivore species went locally extinct from many locations in the region (Mishra et al., 2002; Bhatnagar et al., 2006b). As per niche theory, the extant species in such locations should widen their niche widths to incorporate the niche vacated by the extinct species, while the species in intact communities should retain their original niche widths (see MacArthur, 1972). I explored this hypothesis by using blue sheep, a relatively widely distributed animal, as a model species, and studying its niche (habitat and diet) in areas where it occurs in absence of other Caprinae, perhaps as a result of extinction (Mishra et al., 2002) in contrast to areas where it occurs sympatrically with two other Caprinae species: Asiatic ibex *Capra ibex siberica* and Ladakh urial *Ovis vignei vignei*. These sympatric species are comparable to blue sheep in morphology (van den Tempel & de Vrij, 2006) as well as behaviour (Schaller, 1977), and thus have similar ecological requirements (i.e., the species show ecological equivalency; Shmida & Wilson, 1985). These species thus form a guild, using almost similar terrain features, i.e., relatively rugged terrain (Mallon, 1991; Namgail, 2006c).

Owing to the presence of sympatric species sharing resources, large herbivores in multi-species assemblages may use only a subset (i.e., realized niche) of all the resources available (i.e., fundamental niche) in an area (Hutchinson, 1957). Given this, species can be packed into assemblages either as a result of increasing the resource range, as alluded to earlier, or narrowing the niche width (MacArthur, 1972). Since the Trans-Himalayan rangelands are highly impoverished (Mishra, 2001), higher number of species in certain assemblages in the region may be a result of narrower niches of the constituent species, which may increase as other species go extinct. Furthermore, species that have wider distributions in homogeneous environments may have a greater plasticity in resource use, thereby persisting even in resource-limited (due to sympatric species) areas, perhaps with a lower reproductive success. Therefore, I predict (1) an inverse relationship between blue sheep's niche width and the number of co-occurring species and (2) a greater plasticity in blue sheep's resource use compared to other sympatric species.

METHODS

Study area

The western Indian Trans-Himalaya (31º36' to 34º40N and 75º0 to 79º30E) is classified as a cold desert. The moisture-laden monsoon clouds hardly reach this region due to the rain-shadow effect of the Himalayan range. The magnitude of precipitation, mostly in the form of snow during winter, is therefore minimal with the mean annual precipitation hardly crossing 100 mm. The temperature ranges from –30ºC in peak winter (Dec-Jan) to +35ºC in summer (June-August). Vegetation is characterized by dry alpine steppe (Champion & Seth, 1968), and the cover hardly crosses 30% except in marshlands around the wetlands (Rawat & Adhikari, 2005a). There are only few tree species including poplar *Populus* spp. and willow *Salix* spp., which are confined to the river-valleys. The most common vegetation includes *Caragana* spp., *Artemisia* spp. *Lonicera* sp. and *Acantholimon* sp. Some of the common herbs include *Potentilla* spp., *Oxytropis* spp., *Astragalus* spp. and *Dracocephalum* sp.

The Indian Trans-Himalaya has an impoverished environment with little primary productivity (Mishra, 2001; Rawat & Adhikari, 2005a). Nevertheless, there are eight wild ungulates including the study species, as mentioned earlier, that are preyed on by several such carnivores as the snow leopard *Uncia uncia,* Tibetan wolf *Canis lupus chanku,* wild dog *Cuon alpinus,* Eurasian lynx *Lynx l. isabellina,* red fox *Vulpes vulpes* and the Tibetan sand fox *Vulpes ferrilatus* (Mallon, 1991; Namgail et al., 2005). Besides, there are number of herbivorous (*Lepus* spp., *Marmota* spp. and *Ochotona* spp.) as well as carnivorous (*Mustela* spp. and *Martes* spp.) small mammals that enhance the biodiversity of the region. Avian predators include the golden eagle *Aquila chrysaetos,* which has a tendency to attack lambs (Pfister, 2004).

The three study sites with varying number of species are as follows: a) Rongolong (32º20'N, 78º02'E) in the Kibber Wildlife Sanctuary (hereafter Kibber) is located south of Ladakh, and is administratively a part of the Lahaul and Spiti District of the Himachal Pradesh State, b) the Puyul valley (33º43'N,77º47'E) of the proposed Gya-Miru Wildlife Sanctuary (hereafter Gya-Miru) and c) the Rumchung valley (34º08'N,77º24'E) of the Hemis High Altitude National Park (hereafter Hemis) are administratively part of the Leh (Ladakh) District of the Jammu and Kashmir State. Reconnaissance surveys were carried out in these protected areas prior to the study to find out valleys with the desired number of ungulate species. The findings of these surveys were strengthened by interviewing the local people and wildlife officials about presence or absence of species in different areas.

Thus, Kibber has only one species: blue sheep; Gya-Miru has two species: blue sheep and Ladakh urial, whereas Hemis supports three species: Ladakh urial, Asiatic ibex and blue sheep. Heretofore, I refer to these sites as species-poor (Kibber and Gya-Miru) and species-rich (Hemis) areas for the sake of simplicity. There are human habitations in all three areas, where people are agro-pastoralists, and have social, cultural and ecological affinities with Tibet. A variety of livestock, namely *dzo* (hybrid of yak and cow), yak, horse, donkey, sheep and goat, share the pastures with the blue sheep in all the three areas (Mishra et al., 2001; Namgail et al., 2004b; Namgail et al., 2006). The livestock population and density in all the three areas are however comparable.

FIELD METHODS

Habitat

Data were collected between May 2005 and Aug. 2007. Blue sheep herds were located by walking on selected trails and from vantage points (Namgail et al., 2004b; Namgail, 2006c), and also from horseback depending on the terrain type. I searched the mountain slopes with 8x40 binoculars. Scan sampling was the primary method for animal observations. Whenever a group of animal was located, its age-sex composition was recorded, and subsequently the habitat variables: slope angle, distance to cliff and elevation at the animal locations were recorded. Using a model selection procedure, Namgail (2006b) recognised these variables as important in the blue sheep habitat selection. The available habitat was determined by plotting all the locations of the animals on a 1: 50, 000 topographic map (except for Kibber for which the topographic map was not available, and thus availability determined in the field), and randomly picking a point from the same valley as that of the animal location and recording the habitat variables around it.

Diet

Microhistological analysis was carried out to determine the relationship between diet width of blue sheep and large herbivore species richness, but only for two areas: Gya-Miru (species-poor) and Hemis (species-rich). This analysis was preferred over direct observation of the feeding animals as it is difficult to determine the feeding signs correctly, and it is also difficult to get samples representing the entire grazing period (Shrestha & Wegge, 2006). For microhistological analysis, fresh faecal pellets of blue sheep were collected from the aforementioned areas. To prevent assigning pellets mistakenly to a different species than the one intended to, I collected them from bedding sites by waiting for the animals to get up and move away.

A group of *c.* 150 pellets was collected from each herd of blue sheep in the two areas. Subsequently, five pellets were randomly drawn from each group to form one sample for the respective herd. Thus there were 11 samples from Gya-Miru and 9 from Hemis. In order to test for blue sheep's plasticity in niche utilization, I contrasted the change in its resource use (in response to the number of sympatric species) with that of the Ladakh urial. Thus I also analysed 10 samples of Ladakh urial from Gya-Miru and 7 from Hemis. These samples were air-dried and stored in paper bags before boiling in water for about 1 h and soaking overnight. They were then crushed in the laboratory, and the inner tissue was separated from the epidermis and cuticle by mixing a 5g subsample with water for 1 min in a Waring blender, and was strained over a plankton sieve following de Jong et al. (2004). The residue was then washed again with tap water, transferred into a petri dish and allowed to settle. Using a Pasteur pipette, ten random grab samples of the residue were then taken, and each droplet was put on a glass slide, spread out evenly and covered with a 2.4 cm cover slip.

I prepared separate reference slides for the plant parts such as leaf, stem, flower and seeds. For this small pieces of plant parts were cleaned in household bleach overnight, washed in water, and fragments of epidermis were then stripped off and mounted in glycerol (de Jong et al., 2004). Photomicrographs of epidermal material on a set of these reference slides were used to identify the fragments of cuticles observed in samples of the animal faeces. At least 100 cuticle or epidermal fragments were identified in each sample. To quantify the composition of the faecal material the area of epidermal fragments was measured at a magnification of 100-X using a grid of small squares (each representing 0.01 mm^2) in the microscope eyepiece. This is sufficient to find ingested plant species that comprise 5% of the total volume of the faeces (Stewart, 1967). The abundance of each species was calculated as a percentage of the total area of the fragments measured (Sparks & Malechek, 1968; Putman, 1984; Cid & Brizuela, 1990; Alipayo et al., 1992; Homolka & Heroldova, 1992).

Since, the differences in plant species richness and biomass between the 'species-poor' and the 'species-rich' areas can affect the expected relationship between blue sheep niche width and ungulate species richness, I accounted for these parameters by estimating them in the two areas and assessing their differences. For this, a transect was laid at an altitudinal gradient at every 200 m alternately on either side of the valley, starting at the valley-mouth. These transects were laid in the main valleys as well as in the side valleys. Each transect was then divided into 50 m segments, and a 2 x 2 m plot was sampled at every 50 m intercept. The adequacy of the plot size was ascertained by examining the species accumulation curves, which reached an asymptote at 2 x 2 m. Plants in these plots were clipped to the ground level, stored in paper bags and were later weighed after drying in the sun till no further weight loss could be measured.

STATISTICAL ANALYSES

Blue sheep's niche width along three habitat dimensions: distance to cliff, slope angle and elevation, and two diet dimensions: graminoid and non-graminoid were determined using the Shannon's Index (H' Magurran, 1988). This index varies from 0, for minimum resource items, to about 5, for niche spectrum with maximum resource items, taking into account the number or abundance of each item. I assigned different resource units (e.g., 50 m in case of distance to cliff) into discrete categories to determine the niche (habitat) width, while for the diet width each plant species formed a discrete category. The significant differences between the niche width (both diet and habitat) of blue sheep between the 'species-poor' and 'species-rich' areas were tested with a special t-test with the Shannon indices (Poole, 1974). The difference in diet width of Ladakh urial between the two areas was also examined by the same statistical procedure. I calculated the percentage for each plant species contributing to the diet to generate a diet profile of the animal in each area. The significant difference in plant biomass between Gya-Miru and Hemis was assessed with a two sample t-test.

I pooled the habitat data of 2005 and 2006 from Kibber as there was no inter-annual variation in habitat use. The significant difference in habitat use by blue sheep in the three areas with differing herbivore species richness was checked with General Linear Models (Zar, 1984). As the availability of the estimated resource levels in the three areas could confound the results, I preferred the Analysis of Covariance (ANCOVA), using availability as covariate. It is however to be noted that this statistical test did not directly test the hypotheses. All statistical analyses were carried out using Statistica 7.

RESULTS

A total of 46 observations during summer and 86 during winter were made in Gya-Miru. The mean group size of blue sheep during summer in the area was 13.6 (range 1 to 53), while during winter it was 16.2 (range 1 to 48). A total of 74 observations during summer and 28 during winter were made in Hemis. The mean group size of the animal in Hemis during summer was 11.67 (range 1 to 34) while that during winter was 8 (range 1 to 23). In Kibber, 71 observations were made during summer and 42 were made during winter. The mean group size of blue sheep in this area during summer was 17.6 (range 1-68), while that during winter was 15 (range 3 to 48). The female : lamb ratio for blue sheep in Kibber was 1.4:1, while that in Hemis was 2:1.

The blue sheep's niche width, in terms habitat, declined with increase in the number of sympatric species in the community (Fig. 1). This decline was significant during summer as well as winter, adjudged using t-tests between the 'species-poor' and 'species-rich' areas (Table 1). The summer diet width of blue sheep also declined with the number of co-occurring species (Fig. 2), which was also significant ($t = 3.471$, $p < 0.001$) with the animal consuming more diverse array of plants in Gya-Miru (H' = 2.81) than in Hemis (H' = 2.36; also see Table 2). The diet width of Ladakh urial in contrast did not differ between the two areas ($t = 0.627$, $p = 0.531$) as the animal had only a marginally wider diet (H'= 2.512) in Gya-Miru compared to that in Hemis (H' = 2.42). I did not have diet information from winter to assess the seasonal trends in the niche width of blue sheep along this dimension. The mean ($\pm$ SE) plant biomass in Gya-Miru was 6.31 ($\pm$ 0.73) g/m^2, while that in Hemis was 4.18 (($\pm$ 0.87) g/m^2, but the difference is statistically not significant ($t = 1.686$, $p = 0.101$).

(a) (b)

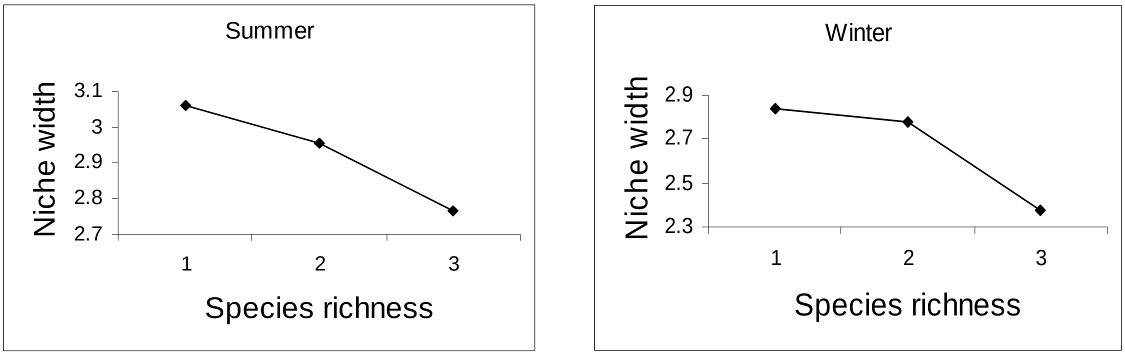

Fig. 1. The relationship between niche (habitat) width and species richness (1 = Kibber, 2 = Gya-Miru, 3 = Hemis) in the Indian Trans-Himalaya.

Table 1. Differences in niche (habitat) width of blue sheep in species-poor (Kibber and Gya-Miru) and species-rich (Hemis) areas in the Indian Trans-Himalaya.

Area pair	Summer		Winter	
	t-value	*P*	t-value	*P*
Kibber-Gya-Miru	1.546	0.123	1.077	0.282
Kibber-Hemis	3.660	<0.001	2.495	0.013
Gya-Miru-Hemis	1.621	0.106	3.664	<0.001

The blue sheep use of distance to cliff differed significantly between the three areas with different herbivore species richness (ANCOVA, F = 20.01, p < 0.001) as well as between seasons in each area (F = 23.26, p < 0.001; Table 3). For instance, the mean (± SE) distance to cliff used by blue sheep during summer in Kibber was 144.01 (± 15.39) m whereas that in Gya-Miru and Hemis were 114 (± 16.09) m and 45.58 (± 5.09) m, respectively, during this season (Table 4). The species also differed in the use of slope angle between the areas (F = 8.47, p < 0.001), but not between seasons (F = 0.38, p = 0.539). Nevertheless, there was a significant interaction between ungulate species richness and season with blue sheep using steeper areas (mean = 34.13 degrees, SE = 1.11) during summer and flatter areas (mean = 31.68 degrees, SE = 1.11) during winter in the 'species-poor' areas and vice-versa in 'species-rich' area i.e., Hemis (F = 4.56, p < 0.01; Table 4).

Table 2. Diet composition (%) of blue sheep in Gya-Miru (species-poor) and Hemis (species-rich) with varying herbivore species richness in the Indian Trans-Himalaya.

Plants	Gya-Miru	Hemis
Graminoid vegetative		
Calamagrostis sp.	1.6	4.0
Dactylis sp.	2.3	-
Elymus sp.	2.3	-
Festuca ovina	4.9	-
Koeleria sp.	-	1.3
Stipa sp.	2.1	2.8
Unidentified grass	2.3	3.0
Graminoid generative		
Glumes	0.5	-
Non-graminoid vegetative		
Aconogonum sp.	0.7	-
Allium sp.	0.5	-
Arenaria/Cerastium spp.	**17.6**	-
Artemisia spp.	5.8	**19.0**
Biebersteinia sp.	0.5	0.8
Galium sp.	-	0.5
Geranium sp.	-	1.3
Iris sp.	0.7	-
Krascheninnikovia sp.	-	0.8
Lavandula sp.	1.2	-
Lonicera sp.	1.2	-
Malva sp.	0.2	-
Nepeta sp.	0.7	-
Oxytropis sp.	0.9	2.5
Polygonum sp.	2.8	-
Thermopsis sp.	**20.0**	1.5
Caragana sp.	3.2	4.0
Dicot stems	5.3	2.3
Unidentified dicot 1	3.9	6.3
Unidentified dicot 2	1.2	-
Non-graminoid generative		
Artemisia flower heads	-	2.8
Asteraceae stems/flower heads	1.4	4.5
Rumex flower and stem	3.9	2.3
Thermopsis fruit	-	**23.3**
Unidentified flower bud	-	2.0
Unidentified fruits	2.3	8.0
Seeds	0.9	0.0
corky stem/scale/fruit	1.6	6.8
Others		
Unidentified cuticles	7.4	0.5
Total	100	100

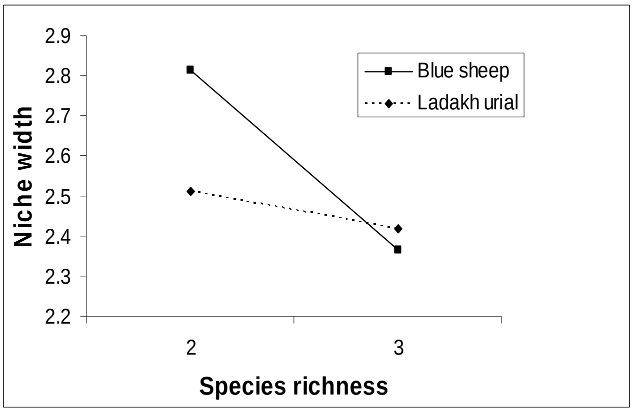

Fig. 2. The relationship between diet width and ungulate species richness (2 = Gya-Miru and 3 = Hemis) for blue sheep and Ladakh urial in two protected areas in the Indian Trans-Himalaya

The diet spectrum of blue sheep in Gya-Miru encompassed six species of graminoids, which comprised 16% of the diet, and 16 species of non-graminoids comprising 32.4% of the diet (Table 2), whereas the animal in Hemis consumed four species of graminoids, contributing 11% to its diet and 10 species of non-graminoid, contributing 39% to the diet. Thus it is apparent that the diet of the animal was dominated by non-graminoids both in Gya-Miru and Hemis. Within this functional group, *Thermopsis* sp. (20%) and *Arenaria* sp. (17.6%) were the most dominant species in the animal's diet in Gya-Miru, while *Thermopsis* (23.3%) and *Artemisia* sp. (19%) were the most dominant in Hemis (Table 2).

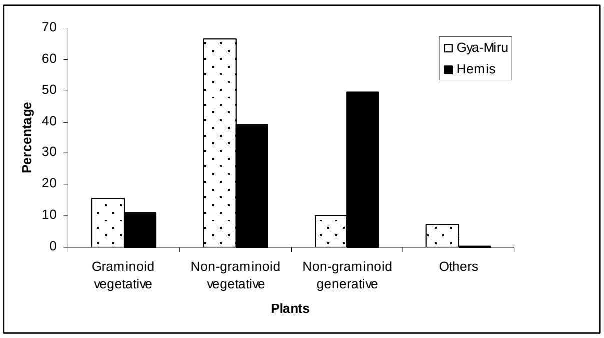

Fig. 3. Diet richness (%) of summer diet in blue sheep in two protected areas in the Indian Trans-Himalaya.

Blue sheep also differed significantly in its use of the altitudinal gradient between the areas ($F = 36.15$, $p < 0.001$) as well as seasons ($F = 18.55$, $p < 0.001$). There was also an interaction effect ($F = 6.33$, $p < 0.001$), as blue sheep used higher areas (mean = 4523.10 m asl, SE = 30.89) during summer and lower areas (mean = 4384.17 m asl, SE = 40.36) during winter in Kibber and Gya-Miru (species-poor areas), while this seasonal trend was opposite in Hemis (species-rich area; Table 4). But there is a significant effect of the available habitat on these differences ($F = 3.93$, $p = 0.048$; Table 3), and the results need to be interpreted in the light of this effect.

Table 3. Summary of ANCOVAs for the Distance to cliff, slope angle and elevation use by blue sheep in three protected areas with differing ungulate species richness in the Trans-Himalaya, using available as covariate.

Variable	Effect	F	df	P
Distance	Species	20.01	2	<0.001
	Season	23.26	1	<0.001
	Species x Season	1.75	2	0.174
	Available	0.02	1	0.885
Slope	Species	8.47	2	<0.001
	Season	0.38	1	0.539
	Species x Season	4.56	2	0.011
	Available	2.17	1	0.141
Elevation	Species	36.15	2	<0.001
	Season	18.55	1	<0.001
	Species x Season	6.33	2	<0.001
	Available	3.93	1	0.048

Table 4. Mean (± SE) of the seasonal habitat use by blue sheep in species-poor (Kibber and Gya-Miru) and species-rich (Hemis).

	Kibber		Gya-Miru		Hemis	
	Summer	*Winter*	*Summer*	*Winter*	*Summer*	*Winter*
Distance	144.01 ±15.39	78.42 ± 13.33	114.57 ±16.09	60.29 ±7.03	45.58 ±5.09	25.35 ±3.83
Slope	27.59 ±1.74	26.78 ±2.08	34.13 ±1.11	31.68 ±1.11	30.87 ±1.44	39.14 ±2.57
Elevation	4523.10 ±30.89	4384.17 ±40.36	4530.87 ±50.30	4158.59 ±50.21	4082.09 ±37.38	4104.48 ±39.35

DISCUSSION

Food and habitat are the most important factors determining survival and reproduction of animals, and thus broadly form the dimensions along which species separate in the use of resources (Schoener, 1974). The inverse relationship between species richness and niche width of the blue sheep in terms of these resource axes points towards interspecific competition. However, I cannot infer competition without the suppressive effect of the presence of one species on the population dynamics of other sympatric species, which is difficult to demonstrate due to complicacies associated with manipulating mountain ungulate populations. Nevertheless, I found a greater female : lamb ratio of blue sheep in the 'species-rich' area compared to the 'species-poor' area, which is indicative of a suppressive effect as density-dependent resource availability affects the fecundity in ungulates (Clutton-Brock et al., 1982; Mishra et al., 2004). Furthermore, several mountain ungulates including the study species show distributions that demarcate often abruptly (Schaller, 1998; Namgail, 2006c), thereby indicating importance of interspecific competition in structuring mountain ungulate communities. Therefore, the change in niche width of blue sheep in relation to ungulate species richness can be attributed to its response to the sympatric species.

Blue sheep is the most widely distributed mountain ungulate in the Ladakh region of the Indian Trans-Himalaya (Fox et al., 1991a). The present study indicates that blue sheep's niche width declines with number of sympatric species, whereas the niche width of the sympatric Ladakh urial doesn't differ between the 'species-rich' and 'species-poor' areas, implying that blue sheep shows a high degree of plasticity in niche utilization and thus high adaptiveness. This is in line with our hypothesis (2) that the high abundance of blue sheep on the Trans-Himalayan rangelands is explained by its versatility in the use of resources according to their availability, as also reported from other areas in the region. For instance, although the blue sheep is known to use steep cliffs as anti-predator habitat (Schaller, 1998; Namgail et al., 2004b), it uses scree slopes and boulders as escape terrain in Tibet where availability of cliffs is low (Harris & Miller, 1995). Blue sheep's wide distribution thus may be the result of flexibility in its use of diet and habitat, suggesting that compared to other Caprinae, the species may face fewer constraints to re-colonize an area after local extinction of species.

Given the environmental stress associated with the high altitude and the associated inclement weather in the Trans-Himalaya (Mishra, 2001; Mishra et al., 2004; Rawat & Adhikari, 2005a), one could speculate that the population numbers of the mountain ungulates in this region remain below the limits of their food resources. Density independent factors such as drought and snowstorms are more likely to control populations of herbivores in such potentially non-equilibrial systems, and competition is less likely to be a factor controlling population growth and structuring communities of these mountain ungulates. Nevertheless, previous studies (Namgail, 2006c) strengthened by the results of the this study where blue sheep's niche contracted in species-rich areas suggest otherwise. Therefore despite the harsh and unpredictable environment, biotic interactions still play a role in structuring and maintaining large herbivore communities in these high altitude cold desert ecosystem.

Competitive interaction have also been reported between wild and domestic ungulates that do not share a evolutionary history (Bagchi et al., 2004; Mishra et al., 2004; Namgail et al., 2007c). The blue sheep's niche dynamics in response to the number of the co-occurring native herbivores may also be confounded by possible disparity in livestock population amongst the study sites, but the three areas are comparable in the composition and population size of livestock. At any rate, since I expect blue sheep's niche width to be shaped over an evolutionary period, presence of livestock may have some influence on blue sheep's niche utilization in the short-term but not insofar as its niche relation with the other native species is substantially affected.

Conclusion

The niche width of blue sheep was narrower in Hemis (with two sympatric species) compared to that in Kibber (allopatric) and Gya-Miru (with one sympatric species), which could be related to the animal's plasticity in niche utilization, specializing in areas with higher number of species and generalizing (widening its niche width) in 'species-poor' areas. Niche width of the Ladakh urial on the other hand did not differ between the 'species-poor' and 'species-rich' areas. Although the blue sheep might be persisting in diverse communities by adjusting its niche utilization, its fecundity is perhaps compromised, as indicated by the greater female : lamb ratio in Hemis (species-rich) compared to that in Kibber (species-poor). In any case, density-dependent limitation of resources seem to have played a role in structuring communities of large herbivores on the Trans-Himalayan rangelands. The results of the study also suggest that local interactions amongst species at the same trophic level are important determinants of large herbivore distributions in the region.

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Chapter 2

Conflict of interests on roof-top of the world: wildlife protection in a pastoral environment on the Changthang plateau, Ladakh, India

ABSTRACT
The Ladakh region of northern India harbours myriad interesting plants and animals that are adapted to the austere environment of the region. These include charismatic mountain ungulates and the predators that prey on them. Most of these animals are either endangered or threatened and might soon be annihilated if conservation measures are not taken well time. Several areas have either been declared or proposed as protected areas. But such conservation efforts are often thwarted by the local communities that extract resources from the rangelands. Recognizing the need to protect the vanishing flora and fauna of Ladakh, a huge area in the Changthang region in eastern Ladakh was declared as a high altitude cold desert wildlife sanctuary under the Jammu and Kashmir Wildlife Protection Act in the year 1987. This was however done without settling the people's rights over the pasturelands, and a recent notification by government for the final settlement of the statutory rights of people is being opposed fiercely by the residents inside the protected area. Many locals believe that once the wildlife conservation laws are enforced, they will be evicted from their ancestral lands. Nevertheless, many local people also realize the potential benefits of protecting the regions wildlife especially for promoting ecotourism, and agree to earmark some smaller areas for the protection of wildlife. The current discourse on the issue of the wildlife sanctuary has important implications for the long-term coexistence of wildlife and pastoralists in Ladakh.

Keywords: Changthang Wildlife Sanctuary, livestock production, *Changpa, Pashmina*

INTRODUCTION
The drier parts of eastern Ladakh known as Changthang, literally the 'northern plains', support a diverse assemblage of mountain ungulates both native and domestic that depend on the meager resources on the less productive pastures of the region (Rawat & Adhikari, 2005a). Changthang, a western extension of the vast Tibetan plateau constitutes an important biogeographic zone in India (Chundawat & Qureshi, 1999). The nomadic pastoralists in the region, known as the *Changpas,* rear a variety of livestock for subsistence as well as for commercial use. *Pashmina,* a natural fibre produced by the high altitude goats of the region, is the mainstay of the economy of these pastoral people.

The *Changpa*s are Buddhists and have social and cultural affinities with Tibet. These people move from place to place with their livestock, following the traditional grazing routes, which helps distributing the grazing pressure equally amongst the pastures. They have been using the pastural resources frugally, adapting gradually to the high altitude environment. Nevertheless, although the traditional lifestyle of the *Changpa*s are more compatible with the local ecology of Changthang, recent developments in tourism, military establishments and a booming trade in *Pashmina* are bringing important changes (Namgail et al., 2007a), which might be detrimental to both pastoralism and wildlife.

Although Changthang represents a unique ecosystem in terms of the biotic resources, there has been little effort to understand the population status, abundance and distributional patterns of the flora and fauna in the region with new species being added to the faunal list (Namgail et al., 2005). Research work has only been started recently on few large herbivores (Namgail et al., 2007c; Namgail et al., 2008), although anecdotal information suggest that species like the wild yak *Bos grunniens*, Tibetan gazelle *Procapra picticaudata*, Tibetan argali *Ovis ammon* and the Tibetan antelope *Pantholops hodgsoni* are inching towards extinction. Any extinction event will threaten the survival of predators such as the snow leopard *Uncia uncia,* Tibetan wolf *Canis lupus* that prey on these animals (Fox et al., 1991b). The Changthang region is also an important area for avifauna, residents as well as migrants that use the marshlands of Changthang as staging sites during their strenuous journey across the Greater Himalaya (Pfister, 2004).

Given such high diversity of animals and their precarious status, Changthang was declared as a high altitude cold desert wildlife sanctuary in 1987 under the Jammu and Kashmir Wildlife Protection Act, 1978. Nevertheless, there was no effort from the government to settle the land rights of the people residing inside the protected area, as was the case elsewhere in the country at that time. But the Supreme Court of India issued a notification recently, directing all the state governments to settle the statutory rights of the communities residing inside the protected areas, which has become a legitimate cause of concern for the *Changpas,* as they believe that they would be evicted from their ancestral lands and their livelihood options would be curtailed.

This chapter looks at the grazing history of the people of Changthang, highlights the *Pashmina* production system and wildlife populations in the region, and subsequently describes the genesis of the problem and politics related to the establishment of the Changthang High Altitude Cold Desert Wildlife Sanctuary. The observations and conclusions are mainly based on extensive field trips and interviews with *Changpa*s and other stakeholders conducted during the last three years.

GRAZING HISTORY

The *Changpas* constitute a unique pastoral tribe that has inhabited Changthang for centuries. In fact, the Tibetan plateau, of which the Changthang forms a small part, has a grazing history of several millennia (Schaller, 1998). The *Changpas* are thought to have migrated from Tibet in the eight century A.D. (Jina, 1995). They have been rearing livestock ever since they arrived in the area, and have a production system that has evolved over a long period. The coexistence of pastoralists and wildlife on the rangelands of Changthang for centuries is a testimony to the fact that traditional ways of *Changpas* were effective in managing the pastural resources (Namgail et al., 2006). Nevertheless, with the increasing need and aspirations of people, and the advent of modern technology, their ways of using the natural resources are changing at an alarming rate, thereby upsetting the ecological balance of the region. There have also been land use changes and consequently the socio-economic setup. For instance, people in the past were pure nomadic pastoralists as agricultural production was not profitable, but with the advent of modern technology, early maturing seeds and climatic change, many people have begun to settle in some areas with good access to water and cultivate crops like barley (Namgail et al., 2007a).

PASHMINA PRODUCTION

Pashmina is the primary source of income for *Changpa*s (Namgail et al., 2007a). The best quality *Pashmina* shawls are priced at about € 300 in the international market. *Changpa*s produce and sell the raw *Pashmina* fiber to traders from Kashmir, where it is weaved into exquisite shawls. The *Changpa*s have been involved in this lucrative business for centuries. In the past they supplied the raw *Pashmina* to middlemen, who in turn sold to traders from Kashmir. The fibers were then dehaired manually before spinning and weaving. But the local administration in Ladakh has installed a *Pashmina* dehairing plant at Leh, the capital city of Ladakh, to enhance the income of the people of Changthang, although this rendered many traditional Kashmiri *Pashmina* workers jobless.

The ban on *Shahtoosh* (the underwool of the endangered Tibetan antelope) in Kashmir also rendered thousands of Kashmiri workers jobless. The Jammu and Kashmir Government urged these workers to switch over to *Pashmina* work (Riyaz Ahmed, personal communication). Thus the demand has shot up substantially in the recent years. Whether the *Changpa*s can cater to this apparently growing market depends on the health of the rangelands, which is deteriorating fast. In any case, the government is putting pressure on the *Changpa*s to enhance the *Pashmina* production. The latter thus tend to increase the livestock population beyond the carrying capacity, and wildlife conservation is of least concern to them.

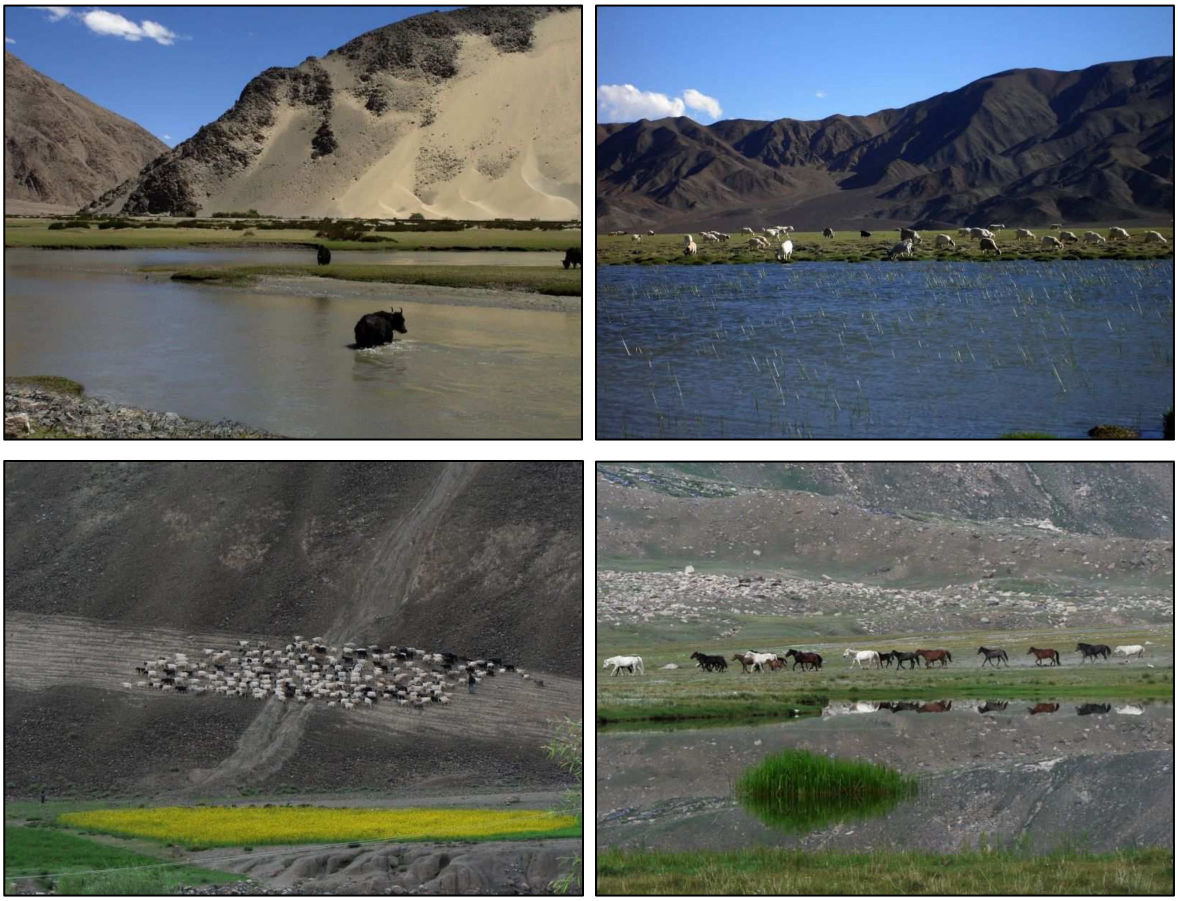

Plate 1. Changpas rear a variety of livestock such as yak, horse, sheep and goats.

WILDLIFE OF CHANGTHANG

Changthang has a unique assemblage of wild animals, as mentioned earlier, but the faunal diversity remains little known with new species being added to the list (see Namgail et al., 2005). The mountain ungulates such as the Tibetan argali*,* Tibetan gazelle*,* wild yak*,* Tibetan antelope, Tibetan wild ass *Equus kiang* and blue sheep *Pseudois nayaur* are the most prominent animals. These ungulates constitute the prey base of large predators such as the snow leopard, Tibetan wolf, Eurasian lynx *Lynx l. isabellina,* red fox *Vulpes vulpes* and the Tibetan sand fox *Vulpes ferrilata*. Most of the aforementioned ungulates underwent considerable range reduction in the last century (Bhatnagar et al., 2006a; Namgail et al., 2007b). Species such as the Tibetan gazelle and the Tibetan argali are currently on the verge of extinction in India (Namgail et al., 2004a; Bhatnagar et al., 2006a).

Plate 2. The Changthang plateau is bestowed with a fascinating assemblage of animals that include species like the blue sheep, Tibetan wild ass, Tibetan wolf and the Bar-headed Goose.

The Changthang region also has several wetlands along the shores of the high altitude lakes and along the banks of the Indus River that are critical breeding habitats for waterbirds. Ladakh is thus bestowed with a rich avifauna with over 270 species recorded (Pfister, 2004). The most celebrated migratory species are the Black-necked Crane *Grus nigricollis* and Bar-headed Goose *Anser indicus*. Prominent resident birds include the Tibetan Snowcock *Tetraogallus thibetanus*, Tibetan Partridge *Perdix hodgsoniae*, Tibetan Sandgrouse *Syrrhaptes thibetanus*, Golden Eagle *Aquila chrysaetos* and the Lammergeier *Gypaetus barbatus* (Mallon, 1987; Namgail, 2005)). There are also myriad small mammals such as marmot, hare, pika and voles (Pfister 2004; Bagchi et al. 2006).

LIVESTOCK VS. WILDLIFE

The livestock population of Changthang increased almost two-fold in the last two decades (Namgail et al., 2007a). The estimated livestock population in 1999 was *c.* 200,000, almost twice that in the late 1970s (Richard 1999). Therefore, areas that were less grazed by livestock, and thus less important wildlife habitats, are currently increasingly being used by the pastoralists. The influx of the Tibetan refugees with their livestock contributed largely to this increase in livestock population (Namgail, 2006a). Recent ecological studies in remote areas of Changthang (Namgail et al., 2007c; Namgail et al., 2008) have shown that livestock impose resource limitation on wild ungulates and also displace them from productive habitats, although the pastoralists believe the other way round.

*Changpa*s have a negative attitude especially towards the Tibetan wild ass or *Kiang,* the most visible animal close to human settlements. The *Kiang* is a bulk forager, and remove considerable amount of biomass from the rangelands, but due to their low population density consume far less than that consumed by the abundant domestic livestock (Bhatnagar et al., 2006c). A questionnaire survey revealed that the *Changpas* in the Hanle River Basin are indignant due to pasture degradation by *Kiang*, although they realized that the animal has the potential to enhance ecotourism in the region provided valleys like Hanle and Kuyul are opened to tourists.

WILDLIFE SACNTUARY: GENESIS OF THE PROBLEM

The Changthang High Altitude Cold Desert Wildlife Sanctuary was established in 1987 under the Jammu and Kashmir Wildlife Protection Act, 1978. However, there was no consultation with the local pastoral communities residing inside the protected area (Urgain Rangdol, personal communication), as protected areas across the country during those days were established without settling the statutory rights inside the protected areas. However, since the conservation laws were not strictly enforced following its establishment, the pastoralists in Changthang remained less affected and thus less aware of the legal implications of the sanctuary until the WWF (India) filed a petition in Supreme Court of India to ensure strict compliance of conservation rules in protected areas. Subsequently, the Supreme Court of India in 1999 directed all the state governments to issue proclamation under Section 21 of the Wildlife Protection Act of 1972.

Consequently, all the concerned states and union territories (UT's) filed affidavits apprising the apex court about the status of the acquisition proceedings and determination of rights. The legal submissions by the Jammu and Kashmir Government were presented to a group of stakeholders at a workshop in Leh on 26 June 2007. Some of the statements in the affidavits submitted by the state government in 1999 were rather vague. One of the affidavits mentioned that the land rights settlements could not be carried out due to intense terrorist activities in the state, and currently since the situation has improved, the matter is being taken up again and the process of land settlement rights will be completed shortly. Nevertheless, the status remains unclear to this date.

Recently the apex court issued fresh directives to settle all the rights of residents within the protected areas. Acting upon this, the District Magistrate of Leh issued a notification in January 25, 2007. This provoked strong reactions from the pastoral communities of Changthang. They are concerned that enforcement of the wildlife laws will restrict their movement, or even worse, will evict them from their ancestral lands.

CURRENT CRISIS

On March 13, 2007, the people of Changthang including representative councilors of the Ladakh Autonomous Hill Development Council (LAHDC) met the District Magistrate seeking withdrawal of the plan of the wildlife sanctuary. They argued that the declaration of the sanctuary would deny them access to the Changthang's rangeland resources, and curtail their traditional movement pattern. Consequently, the authorities asked them to form a committee and come up with recommendations. Nevertheless, the *Changpa*s submitted a memorandum raising strong objections against the implementation of the conservation strategies under the Wildlife Protection Act.

The people of Changthang are mostly interested in infrastructural development in the region. Some people are also interested in exploring the geological resources of the region. For example, a potential entrepreneur even expressed his willingness to set up a marble-tile manufacturing plant close to the Pangong Lake. In any case, it is safe to conclude that *Changpa*s are interpreting the Act as an intrusive threat to their freedom and traditional way of life. Some old people interviewed showed resentment, perceiving the declaration of the sanctuary as the greatest threat they ever faced.

OPPORTUNITIES AND RECOMMENDATIONS

It seems that there are unappreciated common interests between the *Changpa*s and the government. Creating awareness through special education programmes is thus needed as a first step to break the impasse. Majority of the people have economic interests associated with tourism industry, as alluded to earlier. If so, the *Changpas* need to realize that the biodiversity of Changthang, if preserved in its entirety, will attract wildlife enthusiasts from across the world, thereby providing new avenues to enhance their income. Presently, several parts of Changthang such as the Chhang Chhenmo, Hanle and Kuyul valleys are out of bound for tourists, and if these areas are opened to tourists, a unique opportunity to promote ecotourism will arise, as they harbour aesthetically important species such as the Tibetan antelope, wild yak and Tibetan gazelle, which are confined only to these valleys in Ladakh.

The people also need to realize that the current rate of increase in livestock population is unsustainable and as such is detrimental to both livestock and wildlife. Increasing the livestock number does not necessarily increase the production as the production level reaches a plateau after a certain level of stocking rate (Mishra et al., 2001). Therefore, they need to look for alternative options of livelihood such as wildlife tourism while continuing the livestock production on a limited scale.

The areas that support the most prized grazing lands are also the biodiversity hotspots and the main tourist attraction sites. If the government is unable to accommodate *Changpa*s' livelihood concerns while developing conservation strategies, people might continue to resist, and even if the protected area is established, it will not be effective. On the other hand if people continue to thwart government's effort, ignoring the environmental implications of increased livestock population, it (government) may eventually ban grazing around biological hotspots while allowing seasonal and controlled grazing in other regions as practiced elsewhere in central Asia. Thus a mutually acceptable solution needs to be worked out before the wildlife population declines irreversibly.

CONCLUSIONS

The people of Changthang constitute a unique pastoral tribe in India, but their lifestyle and socio-economic system are scantily documented. Information have started coming only in recent years. Since *Pashmina* has great economic importance, and Changthang is its production centre in India, these information are urgently needed for assessing the long-term sustainability of the *Changpa* way of life as well as the production system. Nevertheless, the pasturelands of the region are deteriorating in the wake of increasing livestock population, jeopardizing the future of livestock industry as well as the native ungulate species. Currently the *Changpa*s consider these wild ungulates as competitors of their domestic stock, not realizing the fact that these animals are important genetic reservoirs that could be exploited to improve the future breed of the livestock. Moreover they could be major tourist attractants in the coming years.

The recent directives of the Supreme Court to all the state governments to settle the pending statutory rights inside the declared protected areas is perceived as a great threat to the *Changpa*s' livelihood options. Such concerns basically sprang forth due to the lack of awareness amongst the people of Changthang regarding the ramifications of establishing a protected area (wildlife sanctuary in this case). Many *Changpa*s fear that they will be ousted from their ancestral lands, which seems unfounded as there is no such clause in the Jammu and Kashmir Wildlife Protection Act of 1978. However, if the *Changpa*s continue to ignore the laws of the country, they may be forced out of the more coveted areas for grazing lands and tourism. Thus, they need to understand the real ramifications, threats as well as the opportunities that the sanctuary brings to them and act accordingly.

Many critics of the establishment of the wildlife sanctuary argue that the present plan of the protected area encompassing almost entire Changthang region is not practical given the limited human resource with the Jammu and Kashmir Wildlife Protection Department, Leh. Guarding a sanctuary in the Trans-Himalayan desert with an area of more than 15, 000 km^2 is simply not feasible. Therefore, given the region's environmental severity and geographical peculiarities, it is more desirable to target smaller, ecologically significant areas for protection of the most endangered species, and entrusting the local people with the protection of the rest of the landscape by providing incentives to compensate their losses.

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Appendix 1

Waterbird Assemblages of High Altitude Lakes in Eastern Ladakh, India

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ABSTRACT
The Ladakh region of the Indian Trans-Himalaya contains interesting assemblages of summer-breeding and migratory waterfowl and waders in its unique high-altitude (> 3500 m) brackish and freshwater lakes. Here, we report results from a survey of the abundance and diversity of birds at four lakes in eastern Ladakh in July 2007. The diversity of birds in these lakes (Tsokar, Statsapuk Tso, Thasangkaru Tso and Tsomoriri) was low, with 11 species identified, ranging from the widespread Common Redshank *Tringa totanus* (590 individuals) to the highly endangered Black-necked Crane *Grus nigricollis* (3 individuals). Among the four lakes, bird species richness and diversity (Shannon index, H') was highest in Statsapuk Tso and Tsokar, respectively, and lowest in Thasangkaru. Similarity in bird species composition appeared to be influenced partly by proximity of lakes (Thasangkaru-Tsomoriri, Tsokar-Statsapuk Tso) and partly by similarity in salinity (Statsapuk Tso-Tsomoriri). The study discusses the relative importance of these lakes for waterbird conservation in Ladakh in the context of ongoing changes.

*Keywords:*Avifauna, Ladakh, Trans-Himalaya, Tsokar, Tsomoriri, wetland, waterfowl

INTRODUCTION

Ladakh, bounded by the Karakoram range on the north and the Greater Himalaya on the south, is a region of cold desert characterised by low primary productivity and floral and faunal assemblages adapted to the high altitudes (Kachroo et al., 1977; Pfister, 2004). Owing to its location at the Palaearctic-Oriental junction and the great altitudinal and geographical gradients, Ladakh harbours a diverse assemblage of over 270 bird species belonging to 41 families (Pfister, 2004). The wetlands of eastern Ladakh, especially the high altitude lakes, have been identified as important habitats for breeding and non-breeding migratory birds (Pfister, 2004; Chandan et al., 2006). The marshlands around these lakes are used as staging sites by birds migrating between central Asia in the Palaearctic and south Asia (Ali & Ripley, 1978 ; Williams & Delany, 1985; Williams & Delany, 1986). The region also supports an assortment of resident species that are adapted to the cold and arid conditions of Ladakh (Mallon, 1987; Namgail, 2005). Moreover there are several winter visitors from central Asia and the Tibetan plateau (Pfister, 2004).

Few studies have been carried out hitherto on the birds of Ladakh due largely to its poor accessibility, high altitude, and difficult climatic conditions (Osmaston, 1925; Mallon, 1987; Mishra & Humbert-Droz, 1998; Pfister, 2004; Namgail, 2005). Ali and Ripley's (1978) handbook was the most reliable source of information on the birds of Ladakh until Pfister's (2004) work. Most earlier works were confined to general surveys and there has hardly been any ecological study, except on the Black-necked Crane *Grus nigricollis* (Narayan et al., 1987; Gole, 1992; Pfister, 2004). Several birds such as the Bar-headed Goose *Anser indicus,* Ruddy Shelduck *Tadorna ferruginea,* and Brown-headed Gull *Larus brunnicephalus* visit the high altitude lakes of Ladakh in summer to breed, wintering in the plains of India to the south.

Although numerous comprehensive studies on waterbirds are available from elsewhere (Kumar et al., 2005), information on the status, distribution, and abundance of the waterbird assemblages of Ladakh remains rudimentary. This study was carried out to fill this gap in knowledge. India is a signatory to the Ramsar Convention, and as such needs to conduct comprehensive surveys on the population status and conservation of waterfowls (Kumar et al., 2005). We report on the abundance, flock size, and diversity patterns of migratory waterfowls in four high altitude lakes in Ladakh. Regular monitoring of the population of these birds is crucial for assessing the health of the wetlands and for evaluating the impact of climate change on the avifauna of Ladakh.

METHODS

Study area

The four surveyed lakes are located in eastern Ladakh (Fig. 1): Tsokar (33º18' N, 78º00' E), Statsapuk Tso (33º15' N, 78º02' E), Thasangkaru Tso (also known as Kiagar Tso, 33º06' N, 78º18' E), and Tsomoriri (32º54' N, 78º18' E). Statsapuk Tso and Tsokar (4,590 m asl) are close to each other; the former is a small (*c.* 6 km²), freshwater lake whereas the latter is large (*c.* 19 km²) and brackish. Tsomoriri (4,520 m) is a fresh to brackish water lake and is the largest (*c.* 143 km²), whereas Thasangkaru Tso (4,730 m) is brackish and is the smallest (*c.* 5 km²) amongst the four (Gujja et al. 2003; Philip and Mathew 2005). There are permanent human settlements on the shores of Tsokar and Tsomoriri, while there are only herders' camps on those of Statsapuk Tso and Thasangkaru. All the lakes have marshlands of varying sizes along their shores. The marshland of the Thasangkaru is the smallest, while Tsokar and Statsapuk Tso have the most extensive marshlands, and together attract a lot of birds. During summer, the marshlands are lush green and the vegetation cover exceeds 70 percent (Rawat & Adhikari, 2005a). The rangelands around the lakes are grazed by domestic livestock, mainly yak, horse, sheep and goats.

Bird counts and data analysis

In each lake, birds were counted by two persons (DM and TRSR) from a good vantage point; one identifying and counting birds through a spotting scope as the other recorded observations in a notebook. The survey was carried out between 24 and 26 July 2007, during the breeding season (Pfister, 2004). Observations were made in the morning between 07h00 and 09h00 or in the afternoon between 12h30 and 17h00, when the light conditions were optimal for counting birds from the chosen vantage point. Birds were identified to the species level and care was taken not to double count birds that flew from place to place. Individuals were considered to be in a different flock when they were at least 50 m away from the flock being counted.

Although we made a total count at the smaller lakes, this was not possible at the bigger lakes due to time and logistical constraints. By examining maps of the area, we estimated that we counted birds in half the area of Tsokar lake and approximately one-sixth of the area of Tsomoriri lake, although the middle portion of this lake is deep (> 40 m) and may not be crucial habitat for birds.

The bird species diversity of each lake was assessed using the Shannon diversity index (H') that takes into account the number of individuals as well as number of species (Magurran, 1988). This index varies from 0 for assemblages with single species to high values (up to 5) for diverse assemblages of many species with abundance evenly distributed across species. We constructed 95% confidence intervals of the diversity indices using a re-sampling approach in Ecosim software (Gotelli & Entsminger, 2001) and statistically tested differences in diversity between lakes using t-tests (Magurran, 1988). The Bray-Curtis dissimilarity index was used to assess the differences amongst lakes in bird species composition. This was then used to depict similarities graphically in an ordination using non-metric multidimensional scaling (NMDS). We also examined species-abundance and species accumulation curves graphically after performing a rarefaction procedure to standardize the sample sizes (Krebs, 1989).

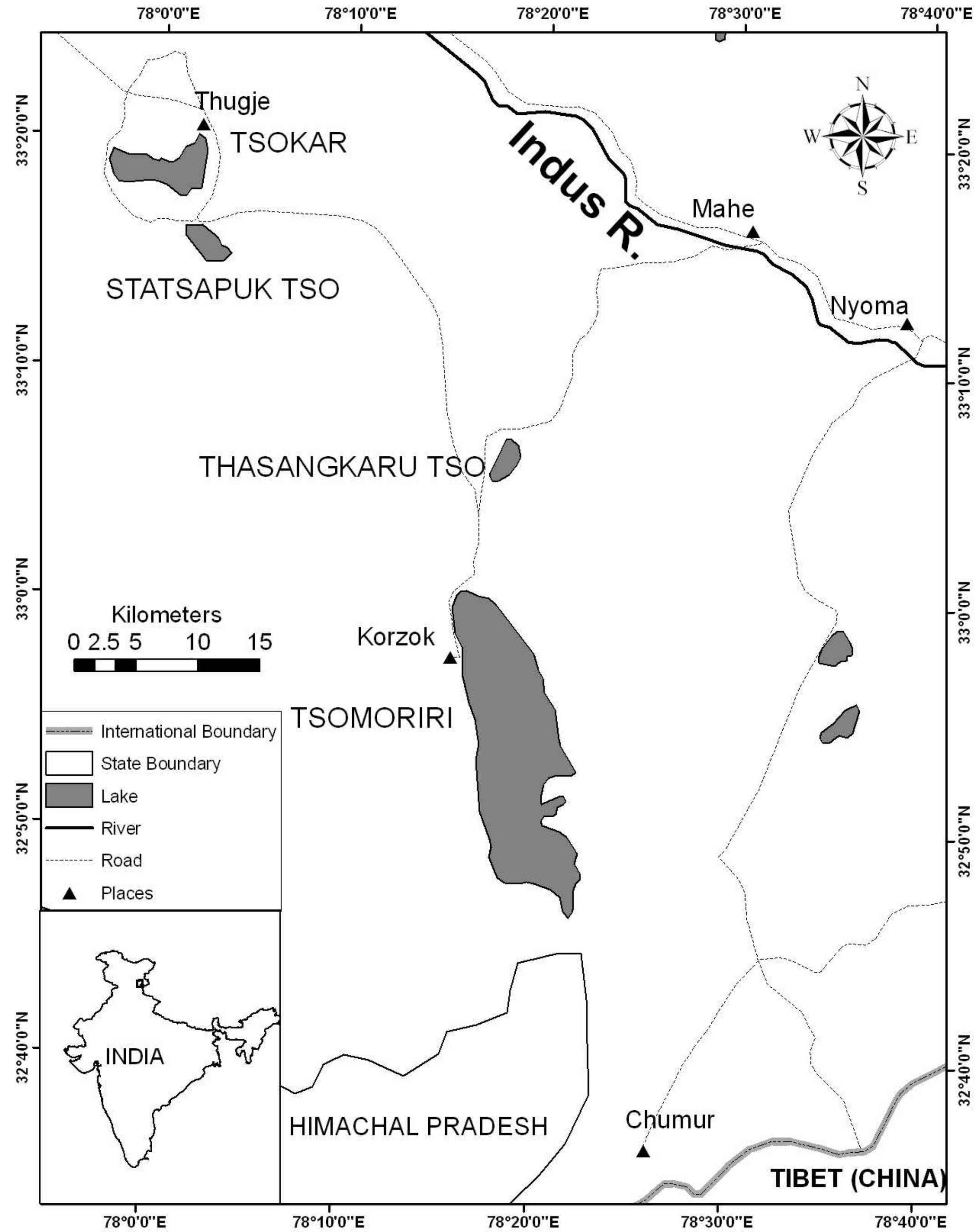


Fig.1. Map showing the locations of the four high altitude lakes in eastern Ladakh.

RESULTS

Eleven species of waterbirds were recorded in the four lakes, 9 of which breed in the area. The Black-necked Grebe *Podiceps nigricollis* is a summer visitor, whereas the Green Sandpiper *Tringa ochropus* is a passage migrant.

The highest number and species of birds were recorded in Statsapuk Tso (923 individuals, 9 species) followed by Tsokar (775, 7 species), Tsomoriri (204, 6 species), and Thasangkaru Tso (35, 3 species). Pooling data from all the lakes, Common Redshank was the most abundant species (590 individuals) followed by Ruddy Shelduck (577), and Bar-headed Goose (450; Table 1). The mean flock size of Common Redshank was 25.7 (range 1-322), Ruddy Shelduck 9.2 (range 1-98), while that of the Bar-headed Goose was 18.7 (range 1-154; Table 2). Common Redshank was however concentrated in Statsapuk Tso (408 individuals) and Tsokar (181; Table 1).

Thasangkaru is the most species-poor lake, with a sharp decrease in the rank abundance plot, while Statsapuk Tso is the richest in terms of number of species, and has higher number of abundant as well as rare species compared to the other lakes (Fig. 2). Among the four lakes, Tsokar had the highest diversity index (H' = 1.34) and Thasangkaru the lowest (H' = 0.70; Table 3). Waterbird diversity was statistically significantly different among the three more diverse lakes, Tsokar, Statsapuk Tso, and Tsomoriri ($t > 2.8$, $P < 0.004$ in all pair-wise comparisons). Thasangkaru Tso was not significantly different in diversity from the other lakes, except Tsokar ($t = 2.63$, $P = 0.012$). In terms of similarity between lakes in bird species composition, Thasangkaru was most dissimilar to the other lakes (Table 4; Fig. 3). The most similar pair was Statsapuk Tso and Tsokar followed by Statsapuk Tso and Tsomoriri.

Table 1. List of waterbirds and their abundance in four high altitude lakes in the Ladakh Trans-Himalaya.

Common name	Scientific name	Statsapuk Tso	Thasangkaru Tso	Tsokar	Tsomoriri	Total
Bar-headed Goose	*Anser indicus*	281	4	30	135	450
Brown-headed Gull	*Larus brunnicephalus*	7	1	144	31	183
Black-necked Crane	*Grus nigricollis*	3	0	0	0	3
Black-necked Grebe	*Podiceps nigricollis*	18	0	0	0	18
Common Redshank	*Tringa totanus*	408	0	181	1	590
Common Sandpiper	*Actitis hypoleucos*	0	0	1	0	1
Common Tern	*Sterna hirundo*	2	0	0	3	5
Great-Crested Grebe	*Podiceps cristatus*	17	1	0	8	26
Green Sandpiper	*Tringa ochropus*	0	0	2	0	2
Lesser Sand Plover	*Charadrius mongolus*	1	0	47	0	48
Ruddy Shelduck	*Tadorna ferruginea*	179	22	350	26	577
Unidentified duck		6	0	0	0	6
Unidentified wader		1	7	20	0	28
Total		923	35	775	204	1937

Table 2. Mean (SE) and range in flock size of waterbirds in four high altitude lakes in the Ladakh Trans-Himalaya.

Common name	Scientific name	Number of flocks	Mean flock size	SE	Minimum	Maximum	Median
Bar-headed Goose	*Anser indicus*	24	18.7	6.41	1	154	9.5
Brown-headed Gull	*Larus brunnicephalus*	16	11.1	3.53	1	58	6
Black-necked Crane	*Grus nigricollis*	1	3.0	.	.	.	.
Black-necked Grebe	*Podiceps nigricollis*	7	2.6	0.48	1	4	3
Common Redshank	*Tringa totanus*	23	25.7	13.97	1	322	4
Common Sandpiper	*Actitis hypoleucos*	1	1.0	.	.	.	.
Common Tern	*Sterna hirundo*	2	2.5	0.50	2	3	2.5
Great-Crested Grebe	*Podiceps cristatus*	15	1.7	0.25	1	4	1
Green Sandpiper	*Tringa ochropus*	1	2.0	.	.	.	.
Lesser Sand Plover	*Charadrius mongolus*	8	6.0	2.80	1	24	2
Ruddy Shelduck	*Tadorna ferruginea*	56	9.2	2.04	1	98	4
Unidentified duck		2	3.0	1.00	2	4	3
Unidentified wader		8	3.5	1.44	1	13	2
Total		164	11.4	2.35	1	322	4

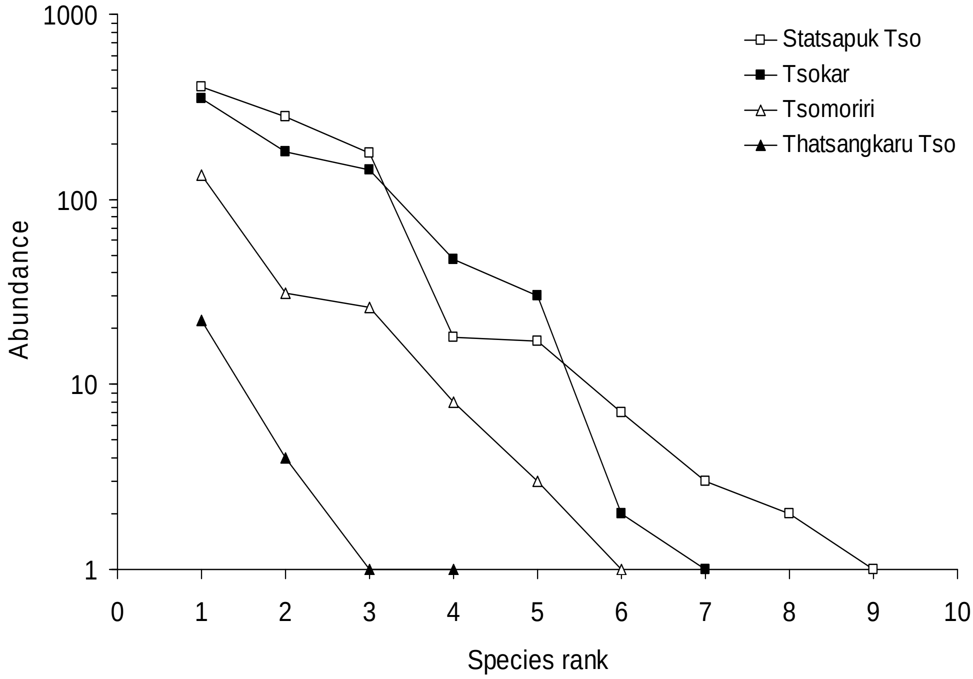
Table 3. Waterbird species diversity in four high altitude lakes in Ladakh. Shannon diversity index and confidence intervals were estimated using a re-sampling approach implemented in Ecosim computer program.

Lake	Species	N*	Shannon diversity (H')	95% confidence interval	
				Low	High
Statsapuk Tso	9	916	1.27	1.267	1.270
Thasangkaru Tso	4	28	0.70	0.572	0.723
Tsokar	7	755	1.34	1.338	1.341
Tsomoriri	6	204	1.04	1.026	1.040

*Number of individuals (excluding unidentified birds)

Table 4. Matrix of Bray-Curtis dissimilarity in waterbird species composition among the four lakes in the Ladakh Trans-Himalaya.

Lakes	Statsapuk Tso	Thasangkaru Tso	Tsokar	Tsomoriri
Statsapuk Tso				
Thasangkaru Tso	94.1			
Tsokar	52.4	93.1		
Tsomoriri	68.0	75.9	81.7	



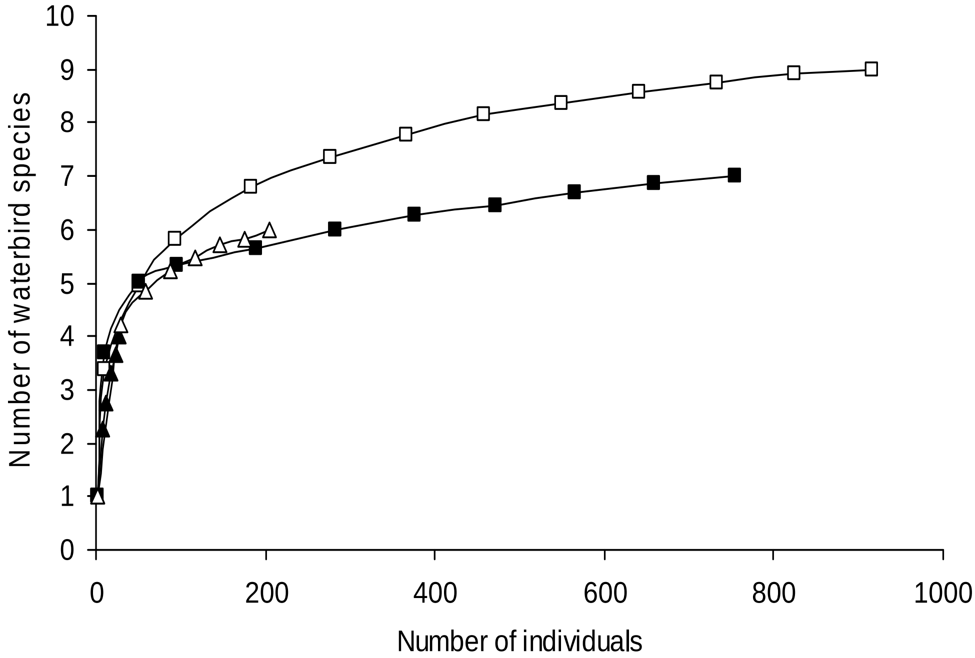


Fig. 2. Waterbird species rank-abandance plots (above) and species richness accumulation curve (below) for the four high altitude lakes in eastern Ladakh.

DISCUSSION

The 11 bird species observed during this study represents 13% of the birds visiting these lakes during summer. The high altitude lakes and the swamps along stream banks in eastern Ladakh are visited by more than 100 species of passage migrants, mostly during autumn when the birds from the Palaearctic region are on their way to wintering grounds in Peninsular India, stopping on these wetlands to replenish their fat reserves. These wetlands have thus been identified as the most important habitats for migratory waterfowls in Ladakh with Tsomoriri designated as a Ramsar Site (Kumar et al., 2005). In fact, it is the only such site in India north of the Himalayan range. The Statsapuk Tso and Tsokar lakes have been recognized as important breeding habitats for the highly endangered Black-necked Crane in Ladakh (Chandan et al., 2006). During the period of this survey, we observed two pairs of crane with one young each and two solitary individuals (including three birds recorded in Statsapuk Tso).

Figure 3. Multi-dimensional scaling ordination of waterbird bird species composition among four high-altitude lakes in the Ladakh Trans-Himalaya.

When we looked at the distribution pattern of the three most common species amongst the four lakes, Common Redshank was concentrated in Statsapuk Tso and Tsokar. This could be related to its carnivorous foraging strategy and the availability of a greater expanse of shallow water and mudflats (*c.* 1 km^2) with high abundance of molluscs, aquatic insects, and worms compared with Tsomoriri (estimated marshland of *c.* 0.3 km^2 within the surveyed area; TN personal observation). The high abundance of Bar-headed Goose in Statsapuk Tso and Tsomoriri could be related to the high availability of herbs and tender grasses along the shores of these fresh and fresh-brackish water lakes, respectively, as against that of the unpalatable, salt-tolerant plant species of the brackish lakes (Rawat & Adhikari, 2005b). Since the Ruddy Shelduck is an omnivorous species it should inhabit areas with abundant palatable plants as well as aquatic invertebrates. Its high abundance in Statsapuk Tso and Tsokar that together provide these resources could reflect such a strategy of the species.

The total number and species richness of birds was also high in the Statsapuk Tso, which could again be related to the high availability of herbs, invertebrates, and fishes in the shallow water and the mud-flats on its shores, as mentioned earlier. Tsomoriri had the highest abundance of Bar-headed Goose, and our count of the species in the northern tip of this lake amounted to 25% of the total count of the species in the entire lake in July 1996 (Mishra & Humbert-Droz, 1998), 91% of the total count in September 1998, 43% of July 2000 and 33% of August 2002 (Prins & van Wieren, 2004).

The greater similarity between Statsapuk Tso and Tsokar on the one hand and Thasangkaru and Tsomoriri on the other could be attributed to the spatial proximity of these lakes. Nevertheless, the relatively high similarity between Tsomoriri and Statsapuk Tso in bird species composition could be related to their similarity in salinity as the former is a fresh water lake, and the latter a fresh to brackish water lake and therefore may attract similar type of birds. This is apparent from the distribution of the Bar-Headed Goose that occurs predominantly in these lakes.

Conclusion

Bar-headed Goose, Ruddy Shelduck, and Common Redshank were the most common species in these lakes in July. The Bar-headed Goose was the most common species in Statsapuk Tso and Tsomoriri, while Ruddy Shelduck and Common Redshank largely occurred in Tsokar and Statsapuk Tso. Overall, Statsapuk Tso attracted more species and thus seems to be an important lake for the migratory breeding birds. Although Tsokar and Statsapuk Tso have been recognised as Important Bird Areas (Islam and Rahmani 2004), we suggest its consideration as a candidate Ramsar Site. Given our spatially and temporally limited sampling effort, however, we urge for more intensive sampling to assess the relative importance of these lakes in conserving waterbirds in Ladakh. Furthermore, in the context of long-term changes in the area of the lake and surrounding marshlands, perhaps as a result of climate change and melting glaciers (De Terra and Hutchinson 1934; Philip and Mathew 2005), studies on its impacts on the population dynamics of waterfowls are desirable.

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