EFFECT OF TRANSHUMANCE IN SPECIES RICHNESS AND COMPOSITION IN A HIGH-ALTITUDE LANDSCAPE, LANGTANG NATIONAL PARK, NEPAL.

A Dissertation Submitted to the Central Department of Botany, Tribhuvan University for the Partial Fulfillment of Master's Degree in Science (M. Sc.) in Biodiversity and Environmental Management

(A Regional Master Programme Supported by NOMA – Norad's Programme for Master Studies)

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RECOMMENDATION

Date: 31st December, 2009

This is to certify that the dissertation entitled *Effect of Transhumance in Species Richness and Composition in a High-Altitude Landscape, Langtang National Park, Nepal* by Mr. Suman Aryal for the partial fulfillment of the requirement of Master's Degree in Biodiversity and Environmental Management has been carried out under our supervision and guidance.

This dissertation bears candidate's own work and results presented are original and has not been submitted for other purpose.

Therefore, we recommend his work for approval and acceptance.

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LETTER OF APPROVAL

The M. Sc. dissertation entitled *Effect of Transhumance in Species Richness and Composition in a High-Altitude Landscape, Langtang National Park, Nepal* presented by Mr. Suman Aryal, has been accepted for the partial fulfillment of the requirement of Master's Degree in Biodiversity and Environmental Management (A Regional Master Programme Supported by NOMA – Norad's Programme for Master Studies).

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Suman Aryal
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ABSTRACT

Transhumance in the Himalayas is accompanied by vertical movement of the livestock in a cyclic manner. There is a perception that, due to this activity, highland pastures are overgrazed which is associated with increasing bush cover and it has resulted decrease in biodiversity. With the main objective of exploring effect of transhumance in biodiversity in subalpine and alpine pastures in Langtang National Park, Nepal, the study addressed the following questions (i) is grazing related to change in species richness and composition along a grazing gradient [distance from *goth* (semi-permanent hut used during seasonal vertical migration of livestock in the Himalaya) to surrounding has been considered in this study to represent a grazing gradient]?; (ii) does grazing and its effect vary with different habitat patches? (iii) how does the effect of habitat type and distance from *goth* on species richness and composition vary with altitude? Data set consist of 17 environmental variables and 101 species recorded from 180 4-m^2 plots (60 plots from each grass-, shrub- and stone-dominated patches) from 6 g*oths* in three altitudes (low, mid and high; 2 g*oths* in each altitude).

Dung, trampling and bare soil showed high grazing pressure in grass-dominated patch than in other habitat patches and it decreased with increase in distance from *goth*. But species richness was lowest in grass-dominated patch and highest in shrub-dominated patch. There was an increase in species richness with the increase in distance from *goth* in grass-dominated patch reflecting decline in species richness within 70 m distance from *goth*. Canonical Correspondence Analysis (CCA) with forward selection of environmental variables in whole dataset in CANOCO showed that 12 out of 17 studied environmental variables had significant effect in species composition, being altitude, shrub and grazing more important than others. Nitrophilous and disturbance tolerance species showed affinity toward increasing level of trampling and dung in the CCA diagram. Distance from *goth* showed strong effect in species composition in grass-dominated patch and mid altitude site than in low and high altitude sites.

The study concluded that grass-dominated patches were associated with high grazing intensities and low species richness than in shrub-dominated and stone-dominated patches at the local level. Grazing gradient was clearly evedient in such heavily grazed patches and grazing had more pronounced effect in mid altitude pastures at the landscape level.

Key words: Canonical Correspondence Analysis (CCA), General Linear Model (GLM), g*oth*, grazing, ordination, pasture

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Chapter 1

INTRODUCTION

Spatial pattern of grazing creates habitat heterogeneity in the landscape and influences species richness in different ways. Studies have shown that livestock grazing increases (Rambo and Faeth 1999; Humphrey and Patterson 2000; Pykälä 2004) as well as decreases (Mcintyre and Lavorel 1994; Landsberg *et al*. 2003) plant diversity. Highest plant diversity at intermediate level of grazing (Mwendera *et al*. 1997; Taddese *et al*. 2002; Bustamante Becerra 2006) and no effect (Metzger *et al*. 2005) has also been reported. Models that have been developed for the response of plant diversity to grazing are based on evolutionary history of grazing and moisture gradient (Milchunus *et al*. 1988), and grazing history and climatic regions (Huston 1994). Similarly, history of grazing and productivity of the system are related to optimum stock density for biodiversity (Mwendera *et al*. 1997; Proulx and Mazumder 1998; Bai *et al*. 2001). Selective consumption preferences of grazing animals change species composition (Schwartz and Ellis 1981; Mcintyre and Lavorel 1994; Brooks *et al.* 2006). Understanding of heterogeneity maintained by grazing depends on preexisting nature of vegetation and scale of measurement (Adler 2001; Fuhlendorf and David 2001; Oba *et al*. 2003; Dorrough *et al*. 2007).

Effects of grazing are not uniformly distributed throughout the landscape. This is especially true in areas with free-range grazing. Grazing activities are related to the distribution of the grazing resources (food), water and minerals (Coughenour 1991; Adler 2001). Spatial variability can occur both at landscape and local habitat patch levels (Landsberg *et al*. 2002). Within local scale, grazing animal effect varies with vegetation types, accessibility of patches, area protected by obstacles such as shrub etc. Grazing disturbance gradients may develop from areas with high livestock activities to areas with low activities. Grazing disturbance gradients and the associated floristic responses have been studied from artificial watering points (Mcclaran and Anable 1992; Fuhlendorf and David 2001; Landsberg *et. al*. 2003, Nangula and Oba 2004; Todd 2006), stock posts (Riginos and Hoffman 2003), roadside-paddocks (Fensham *et al*. 1999) and from animal assembly points at mountain summer farms (Vandvik and Birks 2002a, 2004).

Transhumance is a special form of free-range grazing that is practiced in the mountains all over the world. It is an important livelihood activity of the people living in high altitude areas, developed in response to poor land quality, seasonality in production, and shortage of labor (Moktan *et al*. 2008). The common activity of transhumance is livestock grazing but the composition of livestock, mobility pattern and relative importance of pastoral activities differ from place to place. Transhumance is common in the Himalayas (Chakravarty-Kaul 1998; Ives 2004; Kreutzmann 2004; McVeigh 2004) accompanied by vertical movement of the livestock in a cyclic manner. In majority of the cases, transhumance in the Himalayas is guided by customary rules and institutions (Chakravarty-Kaul 1998; Axelby 2007; Dong *et al*. 2009). Transhumance is being practiced in the Himalayas since the early human civilization and is considered to be one of the important livelihood activities especially for the people living in the high altitude areas. However, only in recent years this practice has been under a question of debate among conservationists and resource users i.e. herders and other agro-pastoralists (Saberwal 1996; Mishra and Rawat 1998; Roder *et al*. 2002; Kala 2004; Kala and Shrivastava 2004). Herders assess the rangeland condition on the basis of livestock productivity whereas ecologists and conservationists prioritized biodiversity maintenance in the grazing land (Inam-ur-Rahim and Maselli 2004).

Langtang, which lies in the Central Himalayas, has a long history of transhumance practices. Transhumance is regarded as one of the pasture management strategies (McVeigh 2004) in the area. Livestock raring is an integral part of social, religious and agro-economic life (DUHE 1977 ; McVeigh 2004). People have been practiced transhumance at least for 300 years (McVeigh 2004) and the main livestock units in this pastoral landscape are yak and yak-cow hybrids (NARC 1997/1998). Herders move with their livestock from low to high elevation in a definite spatio-temporal pattern guided by traditional management rules (Fox *et al.* 1996). The route and *goth* (semi-permanent hut made up of stones which are assembly point for livestock and shelter for herder) used in transhumance are fixed and the ownership of these *goth* are defined by traditional rules. Two sets of local organizations namely community committees and civil associations are active in rangeland management besides state's institutional arrangement (Dong *et al*. 2009). Subalpine and lower alpine pastures in the study area are mixture of open grass- or herb-dominated patches, bushy patches and stone- or boulder-dominated patches. These patches differ in terms of livestock accessibility and represent different level of grazing intensities. Other activities associated with transhumance and are affecting rangeland resources in the area are collection and trade of medicinal plants, harvesting of wild plants, fuel wood collection and cheese making, burning, and poaching.

The establishment of a Cheese factory in 1953 has encouraged farmers in Langtang to maintain large herd sizes (Yonzon and Hunter 1991). The restriction of free access of animals in the native grasslands in Tibet (Devendra and Thomas 2002) has altered the traditional calendar of transhumance in Nepal Himalayas. There is general perception that the rangelands are overgrazed and cover of bushes and other unpalatable species is increasing in such areas (Bauer 1990; HMG/N 1993; Karki and Mcveigh 1999; Nautiyal and Kaechele 2007). But encroachment of bushes may be related to avoidance of traditional management practices like burning (Shaoliang *et al.* 2007) after the declaration of area as National Park in 1976. Major rangeland issues of the area are changes in floristic composition, soil erosion, trampling, loss of wildlife habitat and competition with wildlife for grazing resources (Karki and Mcveigh 1999).

Some of the debates in the high-altitude areas regarding the transhumance are whether grazing has a problem or not in terms of biodiversity and whether the increasing shrub cover has a negative effect on biodiversity or not. To address these, the present study has focused on the grazing animal effects on plant species richness and composition along altitudinal gradient, and investigate how grazing animal effect vary along local gradients in grazing intensity in terms of: (i) distance from goth to surrounding, and (ii) habitat patches of different accessibility to the animals. It is hypothesized that the grazing gradient is developed from goth to surrounding. If there is overgrazing and subsequent increase of unpalatable species, there should be a change in species richness and composition with increasing distance from goth. The main questions addressed in this study are: (i) is grazing related to change in species richness and composition along a gradient from goth to surrounding?; (ii) does grazing and its effect vary with different habitat patches? (iii) how does the effect of habitat type and distance from goth on species richness and composition vary with altitude?

Chapter 2

MATERIALS AND METHODS

2.1. Study Area

2.1.1 Location

The study sites lie in the valley floor and side of U-shaped valley (known as Langtang valley) inside Langtang National Park (LNP) in Central Nepal. LNP (Fig. 2.1), with an area of 1710 km^2 is situated in the north of Kathmandu extending from 27^{o}57'36" to 28^{o}22'48" and 85^{o}12'36" to 85^{o}52'48" in the central Himalayan region. The park was established in 1976 by the-then His Majesty's Government of Nepal to preserve the diversity of habitat for plants and wildlife. It is the first mountainous park of Nepal, with the highest elevation range (DUHE 1977). The elevation of Park ranges between 792 metre above sea level (m asl) (Bhote Koshi) and 7245 m asl (Mt. Langtang Lirung). The western part of Langtang Himal rises steeply to Langtang-Lirung, the highest point in the park.

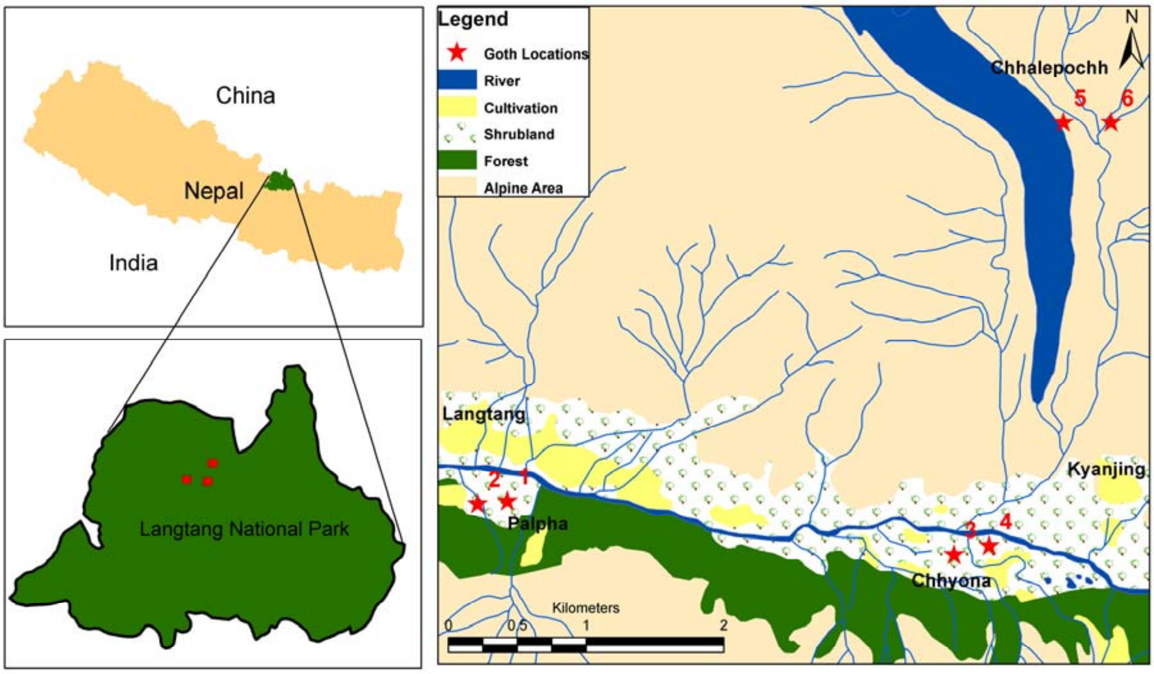

Fig. 2.1. Location of Langtang National Park and study area

2.1.2 Geomorphology

The Park consists of great Himalayan range and valleys of the inner Himalayas. The Langtang valley is one such inner Himalayan valley formed by glacier-fed Langtang river. The topography of the Park including the study site is dominantly rugged terrain. The geomorphology of the study site is related to glacial fluctuations and formations of moraine and cones (Watanabe *et al.* 1998; Barnard *et al.* 2006). Soils are formed in the moraine deposits and consist of acid gneisses (Baumler *et al.* 1997). Shallow soil scars are also formed in the valley side by continuous yak and sheep grazing (Watanabe 1994). The most common textural component in study area is sandy loam with large proportion of rocks. The mean proportion of sand decreases and proportion of gravels increases with elevation. Loamy sands become predominant in lower elevation.

2.1.3 Climate

Altitude and aspect play major role for climatic variation within the Park. The seasonal climate is dominated by the southerly monsoon which occurs from June to September. At higher altitudes (such as upper Langtang valley), the importance of orographic precipitation and rain shadow effect is considerable. Summer snow accumulates only above 5,500 m asl. In the autumn, storm from the northwest sometimes brings deep snow down to 4,000 m asl (Fox 1974).

Precipitation and temperature data (1988-2007), collected from Department of Hydrology and Meteorology, Babarhamal, Kathmandu for Langtang Station (3920m asl) located in Kyanjing (upper Langtang valley) were analyzed. Average annual precipitation for the station was found to be 674.64 mm (Fig. 2.2) with almost 75% of precipitation in the monsoon period (Fig. 2.3). Variation in amount and type of precipitation can also be found at local scale due to difference in aspect and altitude. The minimum temperature remains above 0^o C for six month (May-Oct) and for remaining six month (Nov-April), it goes below 0^o C. The maximum and minimum temperatures for the hottest month (July) are 11.7 ^{o}C and 7.3 ^{o}C and coldest month (January) are 3.2 ^{o}C and -6.6 ^{o}C respectively (Fig. 2.4).

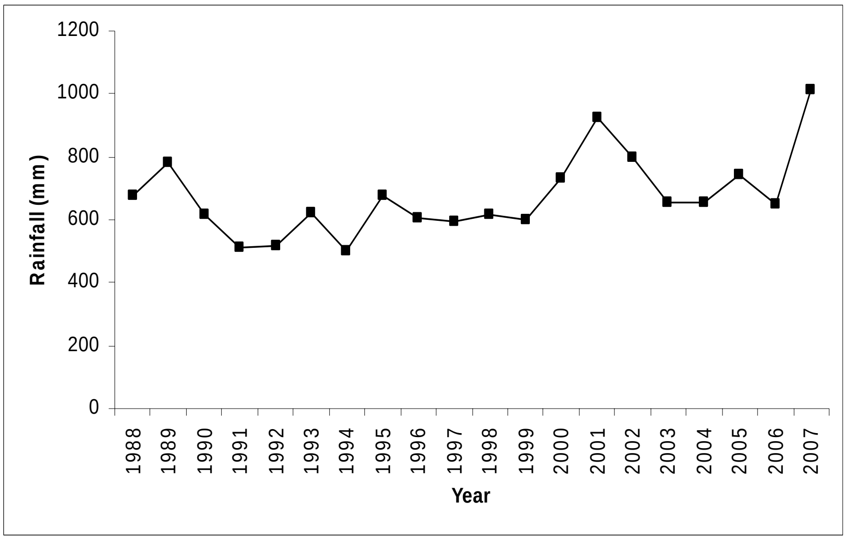

Fig. 2.2. Annual precipitation (mm) in Langtang station (Kyanjing, upper Langtang valley)

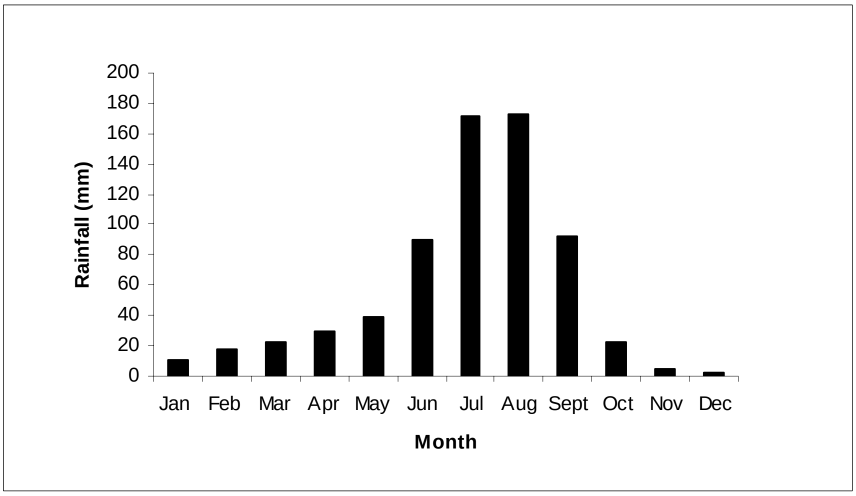

Fig. 2.3. Monthly distribution of annual precipitation for Langtang station

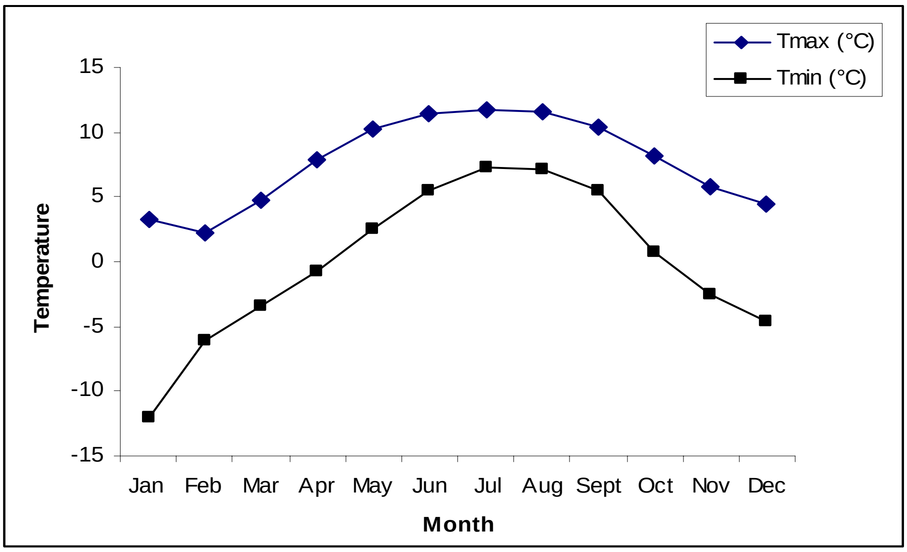

Fig.2.4. Maximum and minimum monthly temperature (°C) for Langtang station

2.1.4 Land use

The study area mainly consists of mountain pastures or grassland. The pastures in the study area are heterogeneous with mixture of open grassy, bushy and rocky patches. Although grassland only covers 4.94% of the total land area of LNP they significantly support livelihood of local people and are rich in terms of biodiversity (Ghimire *et al*. 2008). Majority of the park area (60.7%) is covered by rock, ice and glaciers, the forest, shrubland and agriculture cover 29.9%, 2.8% and 1.7% of total land area of the LNP respectively (DNPWC 2008).

2.1.5 Vegetation and flora

The great variety of vegetation types occurring within the park is one of its most striking features. The complex topography, geology and climatic patterns have enabled a wide range of plant communities to establish themselves in the Park area (Malla *et al*. 1976; DUHE 1977). So far, 17 vegetation types and 911 species of vascular plants have been described from LNP and surrounding regions (Malla *et al* 1976; DUHE 1977). Vegetation of LNP ranges from sub-tropical and temperate forests, to alpine meadows and scrubs to the nivale zone of dry, scree vegetation. The park lies in the meeting point of Indo-Malayan and Palearctic realms. Both of the realms are contributing for its rich biodiversity. The park lies in the Eastern Himalayan alpine shrub and meadow ecoregion which is one of the two prominent Global 200 ecoregions in Nepal (Basnet 2006).

The study site, i.e. the upper Langtang valley, supports forest vegetations in its lower and upper subalpine zones. The lower sub-alpine zone (3000-3600 m asl) near the study site and most part of LNP is characterized by the predominance of conifers, such as *Abies spectabilis* and *Tsuga dumosa*, which are mixed with *Acer campbellii* and *Rhododendron barbatum* in damp sites and gullies. *Abies spectabilis* forest mostly occur at relatively higher altitudes. *Rhododendron arboretum, R. campanulatum* and *Betula utilis* are also found mixed with *Abies spectabilis*. A rare conifer *Larix himalaica* is found in significant number along the Langtang River forming narrow forest belt mixed with *Rhododendron campanulatum*. The upper sub-alpine zone (3600-4000 m asl) is mainly characterized by *Betula utilis* forest in north-facing slopes. *Betula utilis* is associated with *Rhododendron campanulatum*, the later being setter and stunted above the tree line. In drier habitats (south-facing slopes), *B. utilis* is absent and *R. campanulatum* is associated with *Juniper indica* and *J. recurva*. South-facing slope also support scattered thickets of *Rosa sericea*, *Cotoneaster microphyllus*, *Berberis* spp. and *Viburnuum* spp.

Tree species such as *Abies spectabilis*, *Betula utilis*, *Sorbus microphyla* and twisted *R. campanulatum* dominate tree line vegetation in north-facing slopes. The tree line is distinct at about 4000 m asl in the north-facing slope. However, true treeline forest vegetation is rarely developed in the south-facing slope due to drier habitat and steep topography. Above treeline in lower alpine zone (4000-4500 m asl), the vegetation is dominated by shrubs, mainly comprising *Berberis* spp., *Ephedra gerardiana*, *Hippophae tibetana, Juniperus indica*, *Lonicera* spp., *Myricaria rosea*, *Potentialla fructicosa, Rhododendron anthopogon, R. setosum*, *Salix* sp., *Spiraea arcuata*, etc. Beside these, graminoid and herbaceous species, such as *Anemone rivularis*, *Bistorta amplexicaulis*, *Geranium donianum*, *Kobresia* sp., *Poa* spp., *Primula* spp., etc. dominate the open landscape in lower and upper alpine zones above tree line forming distinct communities.

2.1.6 Fauna

LNP harbor 46 species of mammals, 345 species of birds, 11 species of herpeto fauna, and 30 species of fish (DNPWC 2003). Mammal species symbolic to the Park are Snow leopard (*Uncia uncia)*, Clouded leopard (*Pardofelis nebulosa)*, Musk deer (*Moschus chrysogaster*), and Red panda *(Ailurus fulgens)*, Himalayan thar (*Hemitragnus jemalahicus*), barking Deer (*Muntiacus muntijak*). Important bird species of the Park are the Impeyan pheasant (*Lophophorous impejenus*), Ibis bill (*Ibidorhynca struthersii*), White-winged redstart, and Snow partridge (*Lerwa lerwa*) etc. Some reptiles are Rock agama, Green Pit viper, Himalayan Keel-back snake etc. and amphibians such as Himalayan toad (*Bufo himalayanus*) and Frog (*Rana poluni*) are common. Nineteen species of mammals found in LNP are protected by CITES. 12 species of mammals and two species of birds are considered endangered and protected under Appendix I of National Park and Wildlife Conservation Act 1973 (DNPWC 2003).

2.1.7 Socio-culture and economy of people

People of different ethnic groups reside within the Park. Tamang, Sherpa and Yelmu inhabit the higher elevations. At lower elevations, Gurung, Bhramin and Chhetri are found. In upper Langtang valley, the majority of people belong to Tamang ethnic group from three major settlements: Langtang gaon (about 3500 m asl), Gumba danda (about 3450 m asl), and Mundu (about 3550 m asl). These are the oldest permanent settlements known in upper Langtang valley with a history of about 300 years. However, since last few decades, after the creation of LNP, many people from these settlements have settled in Kyanjin (3920 m asl) for economic reason. Kyanjin is well known as an important tourist destination site in LNP. Buddhism is predominant religion in the area. Literacy rate is relatively low among the large majority of people living in and around the Park including upper Langtang valley.

Agriculture, pastoralism (animal husbandry), and tourism are the main sources of livelihood for the local people in upper Langtang valley (McVeigh 2004). Seasonality affects the activities of mountain life (Chaudhary *et al*. 2007). Climate restrict farmer to harvest only one crop per year in the land around settlements. Local agricultural production can not sustain more than three month to feed the people in the area (DUHE 1977). The agricultural production is limited to few high altitude crops like potato, buckwheat and barley due to climatic, topographic, soil and its fertility restriction. Therefore, the people of the upper Langtang valley have practiced livestock rearing as major livelihood activities.

Livestock owned by Langtang villagers consist of yak, cow, yak/cow hybrid, sheep, goat, and horse (Fig. 2.5). The herders from the three permanent settlements of upper Langtang valley use high-altitude summer pastures for rotational grazing. In the pastures, herders set aside some land for making *goth* (semi-permanent hut made up of stones, see Fig.2.6) which are used during seasonal vertical migration of livestock. They move with their livestock below permanent settlement area in the winter and go to high altitude pastures in summer. To support livestock rearing and milk production in high altitude areas of LNP, Dairy Development Corporation (DDC) of Government of Nepal has established cheese factories in different place and one such factory is found in Kyanjing (3840 m asl) area of upper Langtang valley.

Besides these, seasonal tourist flow in the area is providing alternative source of income for the people of upper Langtang valley (Fischer and Sulzer 1994). The LNP area as a whole represent important trekking site in Nepal, therefore there is high flow of tourists in some seasons (MoCTCA 2008). Some local people have completely changed their occupation from agro-pastoralism to tourism related activities operating hotels and lodges in the trekking routes (Fischer and Sulzer 1994).

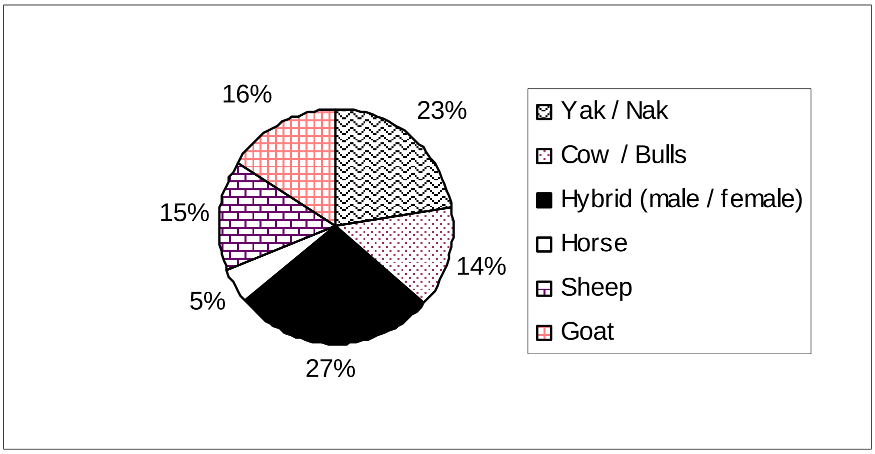

Fig. 2.5. Livestock composition in the Langtang village (NARC 1997/1998)

2.2. Study Design

Preliminary field visit was done in April, 2009 with experts and supervisor to select an appropriate study site in upper Langtang valley. Detailed field study was done in June-July 2009. First, six *goth*, which are used during seasonal vertical migration of livestock by herders were selected; two in each three different altitudeinal bands (Fig. 2.1). Though, these altitudinal bands do not cover full range of altitudes used in the seasonal transhumance, they were selected in the subalpine and alpine pastures to avoid dense forested area and other habitats below 3500 m where people graze their livestock during winter. These three altitudinal bands selected in this study are hereafter named as low (3539-3556 m asl), mid (3739-3759 m asl) and high (4140-4155 m asl) altitudes, respecitvley. *Goth* 1 and 2 were selected from Palpha Kharka (low altitude) which is just above Langtang village, opposite to Mundu, *goth* 3 and 4 in Chhyona Kharka (mid altitude) which is just below Kyanjng village and *goth* 5 and 6 in Chhalepochh Kharka (high altitude). The herders use these *goths* as shelters for themselves and young calves (Fig. 2.6). The pasture in these area consists of mixture of open grassy, bushy and rocky patches (Fig. 2.7). The dominance of each patch differ from place to place.

Fig. 2.6. A *goth* in the study area.

After milking in the morning, young calves are kept tied in *goth* and other livestock are allowed to move and graze freely. They are gathered near *goth* in the evening for milking. They are again released after milking next day morning. Hence, there are more livestock activities near *goth*. From each *goth* selected, horizontal transect of 125 m was established avoiding the core area (5 m radius of *goth*). Transect thus established was divided into different segments in every 25 m increasing distance from the *goth* (Fig. 2.8).

2.2.1 Vegetation sampling

In each segment of 25 m, two 2 m × 2 m plots were established in three habitat types/patches (grass-dominated, shrub-dominated and stone-dominated). Here, in this thesis, habitat type 'grass' or 'grassland' refers to smooth, open patches with highest coverage of herbs and grasses; 'shrub' or 'shrubland' refers to shrub dominated patches; and 'stone' or 'stoneland' refers patches with dominant cover of rock or stone. The number plots per segments were six and number of segments in each *goth* were five, making total of 30 plots in each *goth* (10 plots in each habitat patches per *goth*) (Fig. 2.8).

Fig. 2.7. Grass, shrub and stone dominated patches in the study site.

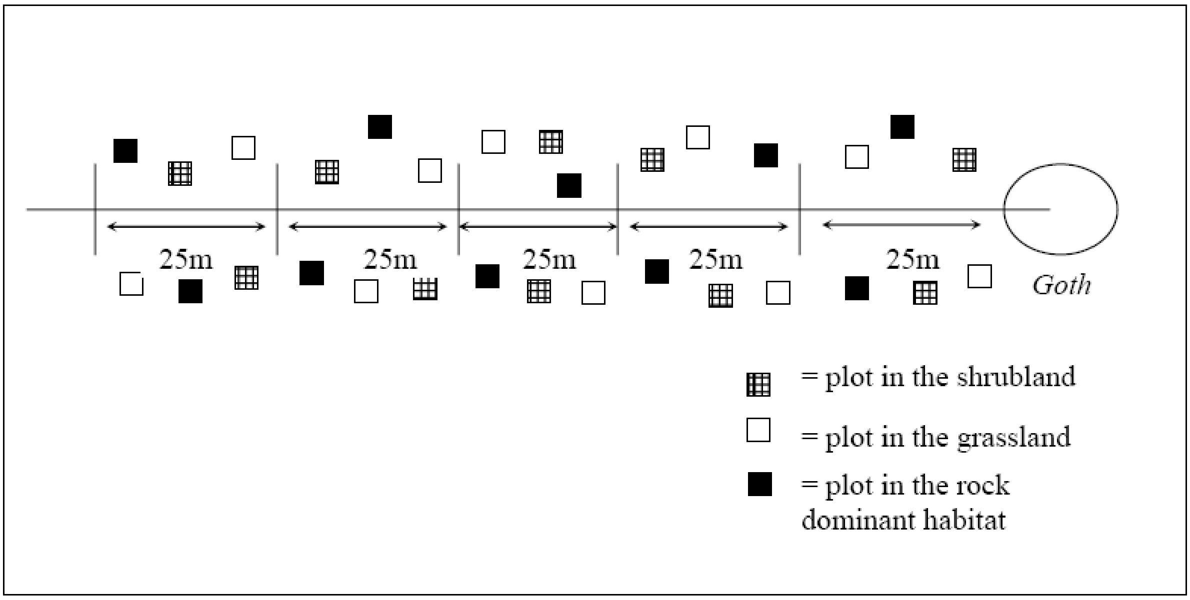

Fig. 2.8. Transect and plot design for sampling

2.2.2 Species data

Each sampling plot of 2 m × 2 m was divided into four subplots of 1 m^2. In each subplot, presence (denoted by numerical value '1') or absence (denoted by numerical value '0') of plant species was recorded, and these values were added to estimate total abundance of each species per plot. The abundance data of each species per plot was thus obtained in 0-4 scale (0 for absence in all subplots and 4 for presence in all subplots) (Shrestha 2006). Total number of plant species present in each plot were termed as species richness (α-diversity). Plant identification was done following Malla *et al*. (1977), Pollunin and Stainton (1984), and Stainton (1988). Sample herbarium was prepared for unidentified species and was identified with the help of keys and experts in Kathmandu. The scientific names are presented according to Press *et al*. (2000).

2.2.3 Environmental variables

Distance from *goth* was recorded using measuring tape, altitude using altimeter, and slope and aspect using clinometer. Radiation index of each plot was calculated as a function of latitude, aspect and slope (Oke 1987). Since the plots from the same *goth* were relatively close to each other, the same latitude and altitude of *goth* were used for all the plots from a *goth*. Different variables related to grazing and disturbances were recorded following Hendricks *et al.* (2005). Dung and trampling were recorded in five scale (0-4) starting from 0 for absence in all four subplots and 4 for highest level of occurrence of dung and trampling in all four subplots. Environmental variables measured, and their units and abbreviations used are presented in Table 2.1.

2.2.4 Soil sampling and analysis

Soil sample were collected from 5 cm below the surface removing the litter from all four corners of each 2 m × 2 m plot. These four samples were mixed to form a composite sample per plot. pH and moisture were measured immediately in the field using pH and moisture meter. Soil depth was estimated by digging iron peg in the sampling plot and using a scale. Soil samples were analyzed in the lab of Nepal Agriculture Research Council (NARC), Khumaltar, Lalitpur, Nepal for total nitrogen by Kjeldahl digestion method (Pradhan 1996), organic matter by Walkley-Black method (Pradhan 1996) and pH. The pH recorded in the field and that obtained in the lab were added and a mean value was used in the subsequent analysis.

Table 2.1. Abbreviations and units of different variables measured in each sampling plot.

Variables	Unit	Abbreviation
Altitude	m asl	alt
Distance from g*oth*	m	dist
Slope	degree	slop
Vegetation cover	%	vcover
Rock cover	%	rcov
Bare soil	%	bsoil
Dung (dropping)	0-4 (categorical)	dung
Trampling	0-4 (categorical)	tramp
pH	pH scale	pH
Moisture	0-8 (categorical)	moist
Soil depth	cm	sdepth
Total soil nitrogen	%	nitrogen
Total organic matter	%	om
Radiation Index		ri
Number of species (richness)	number	species
Habitat type		
Grassland		grass
Shrubland		shrub
Stoneland		stone

2.3. Method of Data Analysis

2.3.1 Univariate analysis

Correlation: Pearson Correlation was used to explore relationship of distance from *goth* to different grazing variables (dung, trampling and bare soil). Pearsons correlation coefficients were also calculated and compared for plot scores of unconstrained and constrained axes of undetrended and detrended ordinations. It was also used to explore the relationship between environmental variables.

Regression: Regression analysis (up to second order polynomials) was performed to explore the relationship of species richness with distance from *goth*. The response variable (species richness) is count data, so, General Linear Model (GLM) with a log link function and Poisson distribution of errors was used during regression analysis (Bhattarai *et al*. 2004; Shrestha

2006). The significance of first and second order distance in GLM was tested by Chi square test. The effect of other variables in species richness was also tested by the same method. Regression equation was used to predict the number of species at each 10 m increase in distance from *goth* for grass-dominated patch. Based on this, the distance from *goth* at which the number of species in grass-dominated patch equals to stone- and shrub-dominated patches were calculated.

Analysis of Variance (ANOVA): One-way ANOVA was used to examine whether the studied grazing variables (dung, trampling and bare soil) differ among three different habitat patches. It was also used to test the difference in mean species richness in different habitat patches; grass, shrub and stone. Tukey test was used to assess differences in variables between habitat types. The effect of interaction between habitat and distance, and habitat and altitude in species richness was tested using Analysis of Covariance (ANCOVA). However, none of the interactions were found to be significant. Before performing these parametric tests data were first evaluated for homogeneity of varience and normality.

All univariate analyses were performed using statistical computer program R version 2.7.1 (R foundation 2005).

2.3.2 Multivariate analysis

Ordination was used to explore the overall vegetation-environment relationship and to assess the relative importance of environmental variables for species composition, using CANOCO for windows 4.5.

In total, 180 plots were studied, 60 plots in each type of habitat patch. For ordination analysis, species data were prepared for each type of habitat patch (60 plots each) and combining all habitat patch types (total 180 plots). Seventeen environmental variables were studied for all 180 plots. Habitat type was used as three dummy variables (grass, shrub and stone) in ordination. Environmental data were also prepared for each type of habitat patch (60 plots each) and combining all three habitat patches (180 plots). In the same way, species and environmental data set were prepared for three altitudes (low, mid and high).

Principal Component Analysis (PCA) was carried out in the combined data set including habitat patch types as three dummy variables and variables related to grazing (dung, trampling and bare soil) to know how variables related to grazing are related with habitat patch types.

When species data and environmental data are available, there are two choices; directly calculating constrained ordination or first unconstrained ordination and then projecting environmental variables in the diagram (Lepš and Šmilauer 1999). In this study, I first used unconstrained ordination [Detrented Correspondence Analysis (DCA)] for each data set. It was done with default setting and down weighting rare species. The gradient length was found to be 2.53, 2.79 and 2.57 standard deviation units for grass-, shrub- and stone-dominated plots respectively and 2.66 standard deviation units for combining all plots. Since the length of the gradient was >2.5, unimodal relationship was assumed between the response and predictor variables. So, unimodel based methods (CA, CCA, DCA, DCCA) were used in the subsequent analyses. To examine how successfully the measured environmental variables captured the main variation in the floristic data, the results of both detrended and undetrended versions of the direct and indirect ordinations were compared (Vandvik and Birks 2002b).

To explore the overall environment vegetation relationship, Cannonical Correspondence Analysis (CCA) (terBraak 1986; Zhang 1998) was done for the combine data set of all plots. CCA describes relationship of different environmental variables with species composition and helps to find importance of measured environmental variables in the variation of species data (Cooper 2005). CCA was done in CANOCO with interspecies distances and Hills scaling option. Significance of environmental variables in explaining variation in species data was tested using Monte Carlo permutation test using forward selection (Vanderpuye 2002). In the analysis, rare species were down weighted and only significant environmental variables were included (Vetaas and Chaudhary 1998; Buscardo *et al.* 2008). Ordination diagrams were created using CANODRAW package in CANOCO version 4.5.

CCA with Global Monte Carlo test was carried out using distance from *goth* only as explanatory variables to explore its effect in the species composition for combined and for each habitat type respectively. Similarly, CCA with Global Monte Carlo test was carried out using habitat patch types only as explanatory variables to test whether the species composition is affected by habitat patch types. To quantify the effect of habitat patch types and distance from *goth* in the species composition in different altitudes, CCA with habitat patch types only as explanatory variables and CCA with distance from *goth* only as explanatory variable with Global Monte Carlo tests were used in three data sub-sets, one per altitudinal band.

Chapter 3

RESULTS

3.1. Grazing in Different Habitat Patches and its Relation with Distance from *Goth*

The grazing intensities differed in different habitat patches (Table 3.1). One-way ANOVA showed that all the surrogates of grazing (dung, trampling and bare soil) were different for different habitat patches except bare soil in shrub- and stone-dominated patches. All grazing variables had highest average value for grass-dominated patch, followed by stone-dominated patch and least for shrub-dominated patch. The relation between habitat patches and grazing variables were also analyzed using Principle Component Analysis (PCA). The PCA diagram revealed that dung and trampling were highly correlated between each other and the value of these variables were higher in grass- and stone-dominated patches (Fig. 3.1). Percentage bare soil showed affinity towards grass-dominated patch. The shrub-dominated patch was opposite to the grazing variables showing minimum grazing in such habitat patch (Fig. 3.1).

Pearson Correlation analysis revealed decreasing grazing intensities with increase in distance from *goth*. Intensity of dung ($r = -0.29$, $p < 0.05$, $n = 180$) and trampling ($r = -0.31$, $p < 0.05$, $n = 180$) particularly showed significant negative correlation with the distance from *goth*. Bare soil also showed negative relationship with distance from *goth* but the result was not much pronounced ($r = -0.08$, $p < 0.05$, $n = 180$).

Table: 3.1 Grazing variables (mean) in different habitat patches and results of one-way ANOVA comparing difference of these variables between habitat patches.

Grazing varaibles (mean)				*P*-value			
Habitat	Dung*	Trampling*	Bare soil (%)	Difference between	Dung	Trampling	Bare soil
grass	3.11	3.28	26.12	grass-shrub	<0.001	<0.001	<0.001
shrub	1.36	1.73	12.62	grass-stone	<0.001	<0.001	<0.001
stone	2.48	2.58	14.98	shrub-stone	<0.001	<0.001	0.270

*categorical variable (0-4 scale, for each plot)

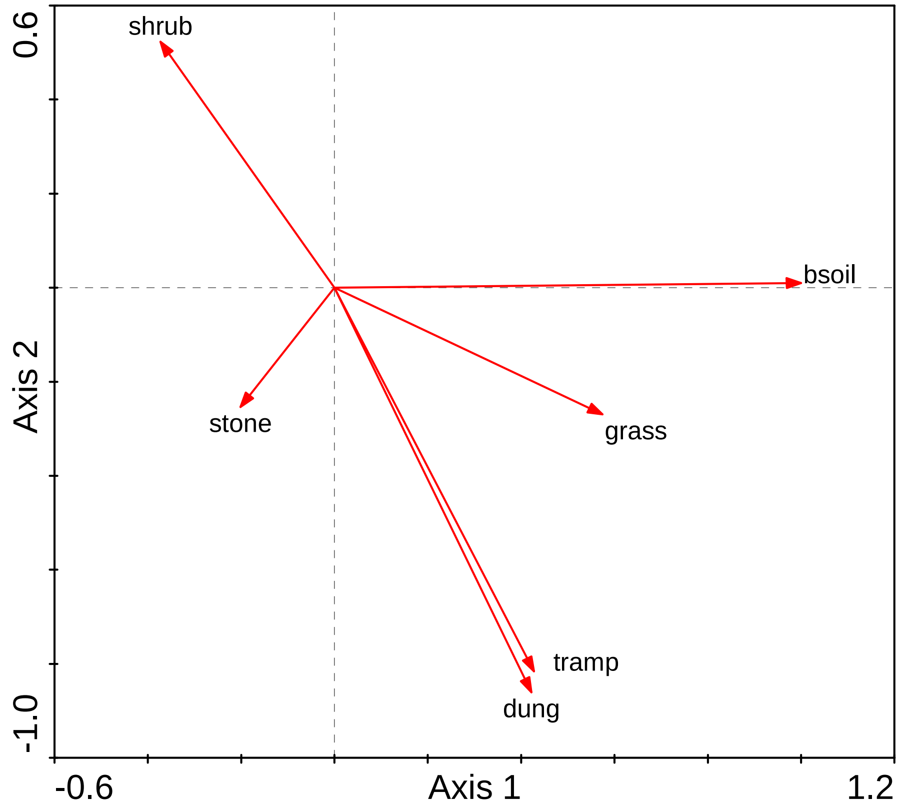

Fig. 3.1. PCA diagram showing relationship among habitat patches and variables related to grazing. For abbreviations of the variables see Table 2.1.

3.2. Species Richness: Effects of Habitats and Distance from *Goth*

The list of species recorded in this study with their abbreviations used in analysis is presented in Appendix 1. A total of 101 species were recorded from all plots, including 81 species in grass-dominated patch, 92 species in shrub-dominated patch and 82 species in stone-dominated patch. The mean number of species per plot (α-diversity) was 18.2, 20.6 and 19.7 for grass-, shrub- and stone-dominated plots respectively (Fig 3.2). One-way ANOVA showed that species richness of at least one habitat patch was significantly different from other ($F_{2,177}$ = 7.26, p = 0.0009). Tukey test showed that the species richness of shrub- and grass-dominated plots were significantly different (t = 3.78, p = 0.0005) from each other.

The relationship between species richness and distance from *goth* was examined using General Linear Model (GLM) to second order polynomial. In grass-dominated patch, species richness was linearly related to distance from *goth*, which means increasing number of species with increasing distance from *goth*. However, there was no such relationship in other types of habitat patches as well as in combined data from all habitat patches (Table 3.2; Fig. 3.3).

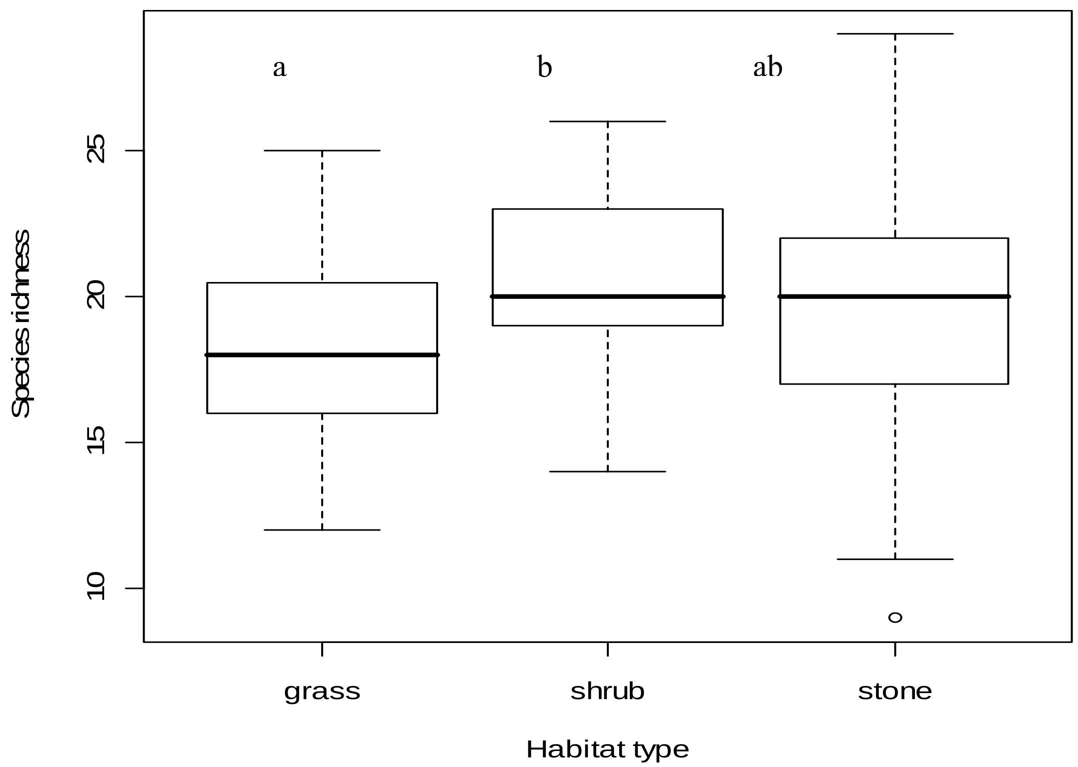

Fig. 3.2. Box plot showing difference in mean species richness among habitat patches. The different letters in the diagram (above each bar) indicate significant difference in species richness between habitat patches.

Table 3.2. Relationship between species richness and environmental variables, including distance from *goth*, in individual habitat patch and in combined data from all habitat patches as obtained from GLM. Variables with significant relations ($P < 0.05$) are bold in *P* value. For abbreviations of the environmental variables see Table 2.1.

(a) grass-dominated habitat patch (n = 60, Poisson)

Variable	Polynomial order	Res. df	Res. Dev	df.	dev.	P(>|Chi|)
dist	1	58	31.96	1	4.76	**0.03**
alt	1	58	36.01	1	0.71	0.67
slop	1	58	36.01	1	0.71	0.40
ri	1	58	36.30	1	0.42	0.51
rcov	1	58	34.70	1	2.02	0.15
vcover	1	58	36.57	1	0.15	0.69
pH	1	58	36.67	1	0.06	0.81
moist	1	58	36.03	1	0.69	0.41
sdepth	1	58	34.64	1	2.08	0.15
bsoil	1	58	36.32	1	0.40	0.53
dung	1	58	35.32	1	1.40	0.24
tramp	1	58	36.39	1	0.33	0.56
om	1	58	35.73	1	0.99	0.32
nitrogen	1	58	36.72	1	0.00	0.98

(b) shrub-dominated habitat patch (n=60, Poisson)

Variable	Polynomial order	Res. df	Res. Dev	df.	dev.	P(>|Chi|)
dist	1	58	30.78	1	0.15	0.70
alt	1	58	29.21	1	1.35	0.24
slop	1	58	30.58	1	0.34	0.56
ri	1	58	29.65	1	1.27	0.25
rcov	1	58	30.47	1	0.45	0.49
vcover	1	58	28.92	1	2.00	0.15
pH	1	58	30.79	1	0.14	0.71
moist	1	58	30.75	1	0.17	0.67
sdepth	1	58	30.92	1	0.00	0.95
bsoil	1	58	29.49	1	1.43	0.23
dung	1	58	28.41	1	2.51	0.11
tramp	1	58	29.29	1	1.63	0.20
om	1	58	27.89	1	3.03	0.08
nitrogen	1	58	29.77	1	1.15	0.28

(c) stone-dominated habitat patch (n=60, Poisson)

Variable	Polynomial order	Res. df	Res. dev	df.	dev.	P(>|Chi|)
dist	1	58	46.28	1	0.00	0.95
alt	1	58	44.23	1	1.44	0.23
slop	1	58	45.58	1	0.70	0.42
ri	1	58	46.02	1	0.02	0.60
rcov	1	58	44.26	1	2.02	0.15
vcover	1	58	46.09	1	0.19	0.65
pH	1	58	45.38	1	0.91	0.34
moist	1	58	45.32	1	0.96	0.33
sdepth	1	58	45.41	1	0.88	0.35
bsoil	1	58	43.65	1	2.64	0.10
dung	1	58	45.27	1	1.02	0.31
tramp	1	58	44.77	1	1.51	0.22
om	1	58	46.14	1	0.14	0.69
nitrogen	1	58	46.29	1	0.00	0.96
moist	2	57	39.73	2	5.59	**0.02**

(d) combined data from all habitat patches (n=180, Poisson)

Variable	Polynomial order	Res. df	Res. dev	df.	dev.	P(>|Chi|)
dist	1	178	122.01	1	1.20	0.27
alt	1	178	119.76	1	3.45	0.06
slop	1	178	123.21	1	0.00	0.98
ri	1	178	123.13	1	0.07	0.77
rcov	1	178	123.19	1	0.02	0.88
vcover	1	178	123.18	1	0.03	0.84
pH	1	178	122.85	1	0.74	0.55
moist	1	178	120.54	1	2.67	0.10
sdepth	1	178	121.3	1	1.91	0.17
bsoil	1	178	122.61	1	0.60	0.43

dung	1	178	122.28	1	0.93	0.35
tramp	1	178	122.66	1	0.54	0.45
om	1	178	118.33	1	4.88	**0.03**
nitrogen	1	178	122.66	1	0.55	0.45
rcov	2	177	119.21	2	3.98	**0.04**

Similarly, the effects of altitude and other variables in species richness were also tested combining data from all habitat patches and individually for each habitat patch (Table 3.2). None of the measured environmental variables had significant relationship with species richness in shrub-dominated habitat patch. In stone-dominated habitat patch, species richness was found to be highest at intermediate moisture level. When data from all habitat patches were combined, organic matter showed linear relationship with species richness, indicating higher number of species in the soil with higher amount of organic matter and rock cover showed unimodal relationship with species richness.

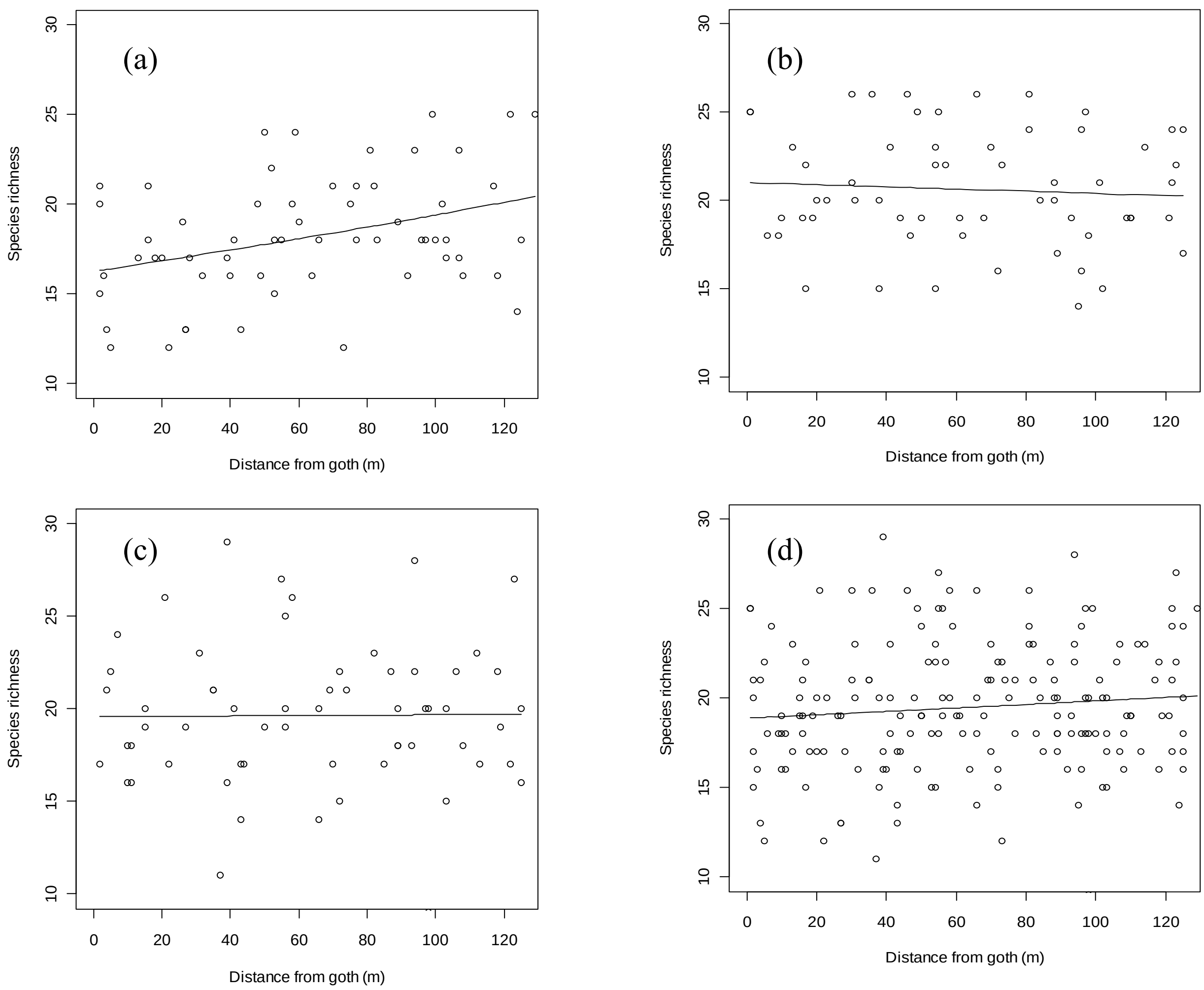

Fig. 3.3 Relationship between species richness and distance from *goth* in grass-dominated (a), shrub-dominated (b), and stone-dominated (c) habitat patches, and in all patches together (d). In the latter case data from all habitat patches were combined.

The number of species that could be expected in 2 m x 2 m plot at each 10 m increasing distance from *goth* in grass-dominated habitat patch types are calculated using regression equation (see Table 3.3). Result showed that the number of species exceeded mean species richness (18.2) of grass-dominated patch plots only when distance from *goth* is 70 m far. The number of species in grass-dominated patch plot could equal to stone-dominated patch plot and all patch types combined, at 110 m distance from *goth*. Similarly, the number species in grass-dominated patch plot could equal to shrub-dominated patch plot at 140 m distance far from *goth*.

Table 3.3. Predicted number species (in 2 m x 2 m plot) at different distance from *goth* in grass-dominated patch using regression equation.

Distance from goth (m)	Number of species
10	16.5
20	16.8
30	17.2
40	17.4
50	17.8
60	18.1
70	18.4*
80	18.7
90	19.0
100	19.4
110	19.7**
120	20.1
130	20.5
140	20.8***
150	21.2

*Number of species exceeded mean species richness (18.2) of grass-dominated patch plots

** Number of species exceeded mean species richness (19.7) of stone-dominated patch plots and mean species richness (19.5) when plots from all patch types are combined

*** Number of species exceeded mean species richness (20.6) of shrub-dominated patch plots

3.3. Ordination Result

The turnover in species composition (beta-diversity), as measured in terms of standard deviation units in DCA, showed slightly higher variation in shrub-dominated patch (gradient length 2.79) and almost equal variation in grass- and stone-dominated patches and in combined patches (in the latter three cases the gradient lengths being 2.53, 2.57, 2.66 respectively). In all the cases, eigenvalues decreased from unconstrained to the constrained ordinations which showed some of the floristic variances were un-accounted for by the measured environmental variables. However, high species-environment relationship in DCA and strong correlations between axes 1 and 2 of the CA/CCA and DCA/DCCA suggested that majority of the variation was captured by the measured environmental variables except for axis 2 in shrub-dominated and stone-dominated habitat patches (Table 3.4).

Table 3.4. Eigenvalues and species environment correlations from undetrended vs. detrended and unconstrained vs. constrained ordinations. Pearsons correlations of plot score on the unconstrained and constrained axes of undetrended and detrended ordinations are also given. (** p< 0.01 * p< 0.05).

	Habitat patches							
	grass-dominated		shrub-dominated		stone-dominated		combined	
	Axis1	Axis 2	Axis1	Axis 2	Axis1	Axis 2	Axis1	Axis 2
Eigenvalues								
CA	0.41	0.24	0.41	0.16	0.40	0.19	0.39	0.23
CCA	0.38	0.17	0.38	0.08	0.35	0.08	0.34	0.18
DCA	0.41	0.21	0.41	0.11	0.40	0.17	0.39	0.20
DCCA	0.38	0.15	0.38	0.06	0.35	0.07	0.34	0.15
Species-environment correlations								
CA	0.94	0.81	0.97	0.57	0.93	0.51	0.93	0.88
CCA	0.96	0.84	0.98	0.82	0.95	0.81	0.95	0.90
DCA	0.95	0.82	0.97	0.55	0.93	0.63	0.93	0.87
DCCA	0.96	0.87	0.97	0.83	0.95	0.76	0.95	0.89
Pearson's correlations								
CA/CCA	-0.99**	0.99**	1.00**	-0.72**	-0.99**	-0.51**	-0.99**	0.99**
DCA/DCCA	0.99**	0.94**	1.00**	0.17	0.99**	-0.27*	0.99**	0.94**

3.4. Overall Vegetation-Environment Relation

The results from CCA with all environmental variables for the combined data set (from all types of habitat patches) are given in Fig. 3.4 and Fig. 3.5. Out of 17 environmental variables, 12 variables showed significant effect on the floristic variance after forward selection in CCA for combined data set of all habitat patches. The first axis was primarily the gradient of altitude and moisture. Species that were common in high altitude and dry habitat were grouped towards right side of the first axis. Such species were *Hippophae tibetana*, *Primula denticulata*, *Rhododendron setosum*, *Viola biflora, Potentilla microphylla* etc. Species that were common in moist subalpine area were grouped toward the left side of the first axis. These species were *Iris goniocarpa*, *Centella asiatica*, *Anemone rivularis, Parnassia nubicola*, *Roscoea alpina*, *Allium wallichii*, etc. The second CCA axis represents gradients of grazing-related variables like trampling, bare soil, distance from *goth*; and edaphic variables (mainly nitrogen). Species that grow in nitrogen-rich bare soil and tolerate disturbance were grouped at the bottom of the second axis. Such species were *Ranunculus pulchellus*, *Ranunculus* sp., *Plantago* sp. and *Rumex nepalensis*. Most of these plant species are unpalatable. The species that formed bushy patches or were found in such bushes, and were protected from grazing, were primarily grouped at the top of the second axis. Such species were *Juniperus indica, Cassiope fastigiata*, *Morina nepalensis*, *Lilium nanum*, *Smilacina purpurea*, *Cyananthus microphyllus*, *Lotus corniculatus*, *Arisaema jacquemontii* etc. Species that were common and found everywhere were at the centre of the diagram. Such species were *Carex* sp., *Poa* sp., *Bistorta milletti, Cyperus cuspidatus*, *Potentilla cuneata* etc. (Fig. 3.4).

Table 3.5. Variance explained by different variables after forward selection in CCA for combining all plots. The variance explained is the variance accounted for when the variable is used as constraining variables in CCA expressed as % of total inertia. *P*-value refers to variance explained.

Variables	Variance explained (%)	*p*-value
alt	14.15	0.002
shrub*	7.16	0.002
tramp	4.68	0.002
bsoil	4.20	0.002
grass*	3.18	0.002
moist	2.87	0.002
pH	1.72	0.002
dist	1.63	0.002
slop	1.33	0.004
stone*	0.99	0.030
nitrogen	0.94	0.036
om	0.90	0.040

For abbreviations of the environmental variables see Table 2.1.

*shrub, grass and stone were used as dummy variables representing three habitat patch types.

The floristic variance explained by the significant environmental variables, when each of these was used individually as constraining variable, are presented in Table 3.5. Altitude explained the highest floristic variance among all the variables used, followed by shrub (correlated with vegetation cover). This indicates that the altitude and shrub are very important in influencing vegetation of the study area. Trampling, bare soil and grass were also important in explaining variance.

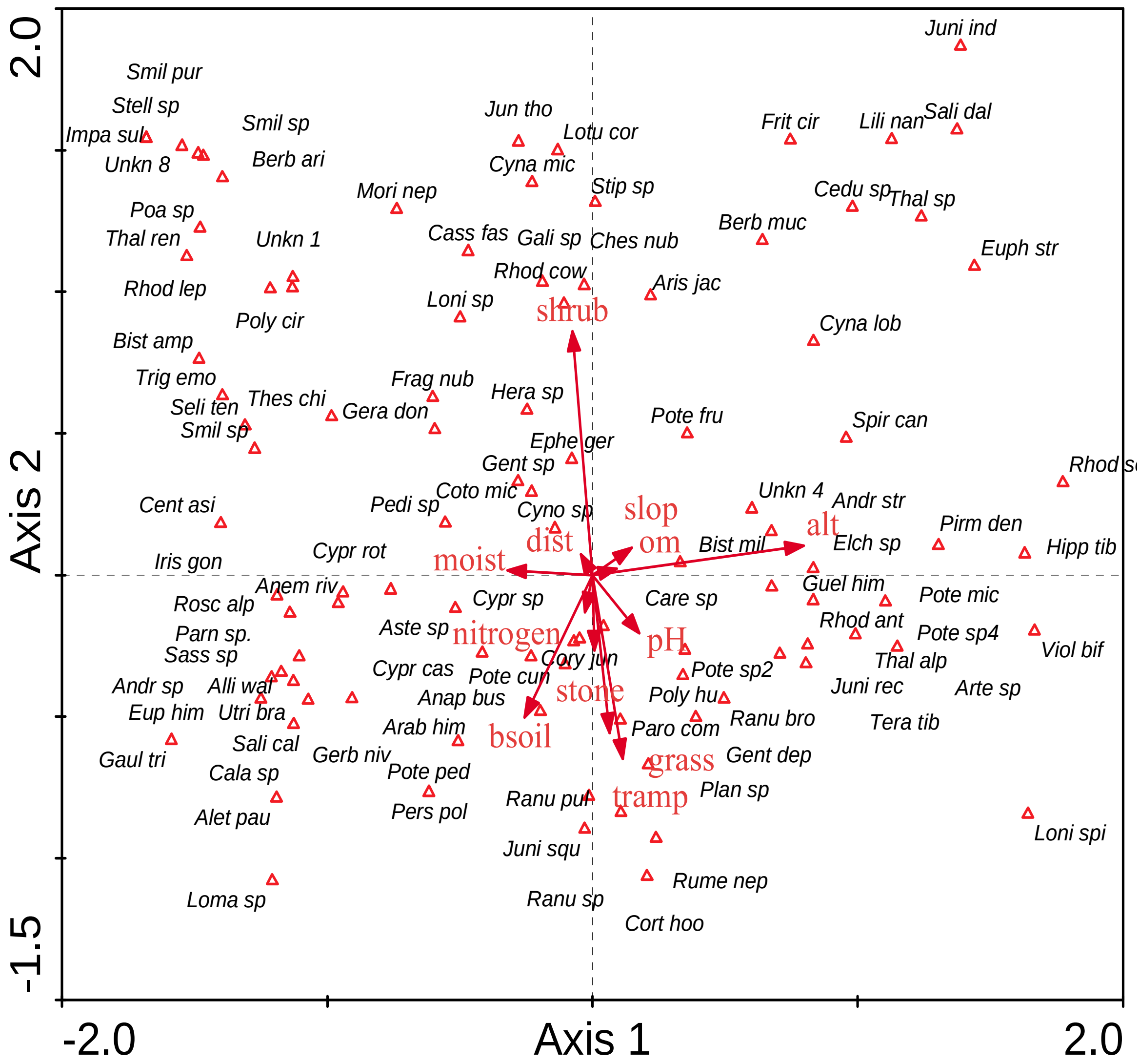

Fig. 3.4 CCA diagram (biplot of species and environmental variables) for combined plots. Abbreviations for environmental variables follow Table 2.1. Abbreviations for species follow appendix 1. Δ = species.

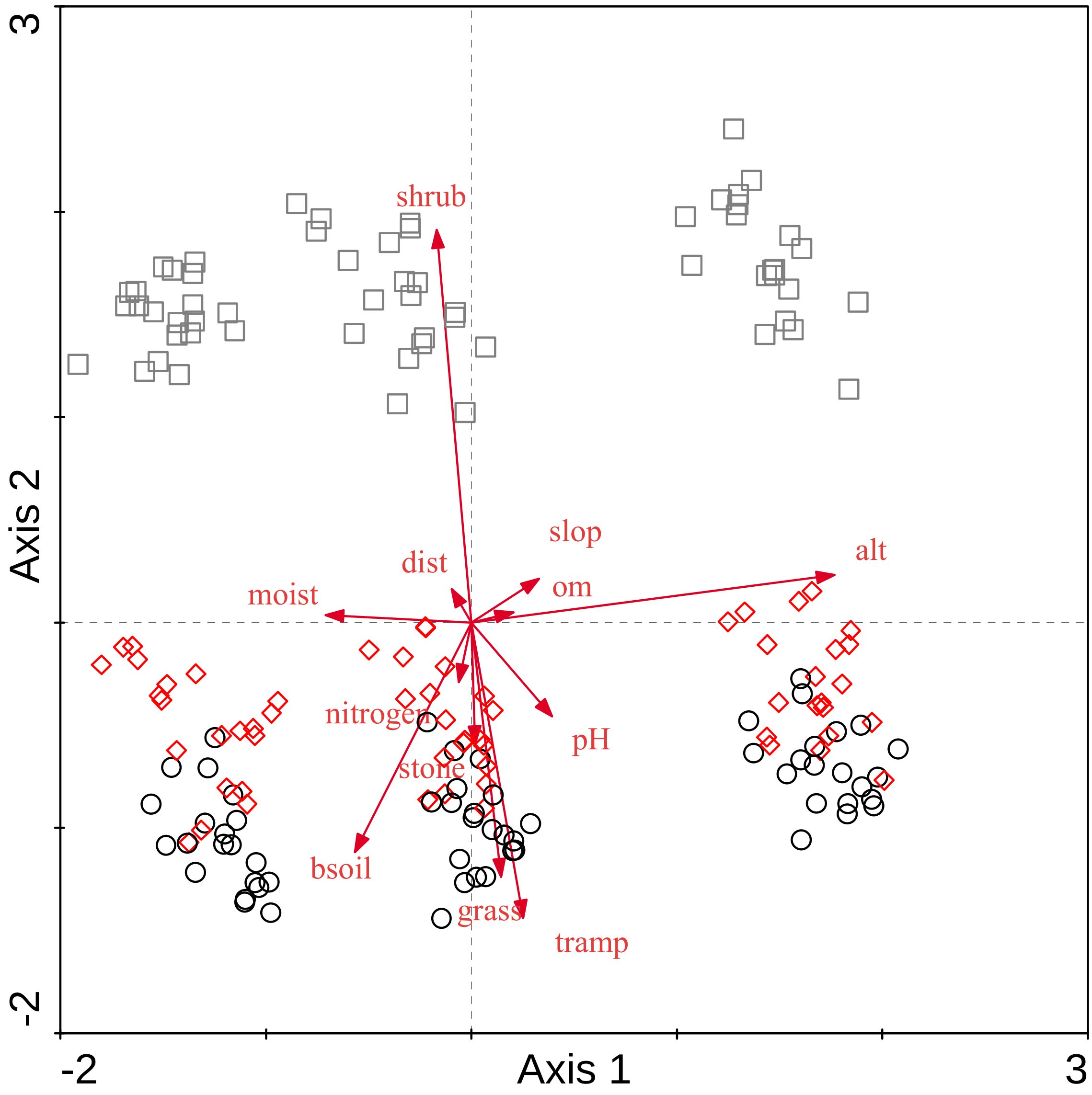

Fig. 3.5 CCA diagram (biplot of samples and environmental variables) for combined plots. Abbreviations for environmental variables follow Table 2.1. ○ = sampling plots from grass patches, □ = sampling plots shrub patches.◊ = sampling plots from stone patches.

CCA was also carried out in the data set of three habitat patch types separately. But the CCA diagrams for only grass dominated patches are presented below (Fig. 3.6, Fig. 3.7). In this patch type, the effect of distance from *goth* was strong and well reflected in the second axis of the CCA diagram. Plant species that were disturbance tolerant and nitrogen lover had shown their affinity clearly toward increasing nitrogen level near *goth*. Such species were *Rumex nepalensis, Ranunculus pulchellus*, *Ranunculus* sp., *Plantago* sp. etc.

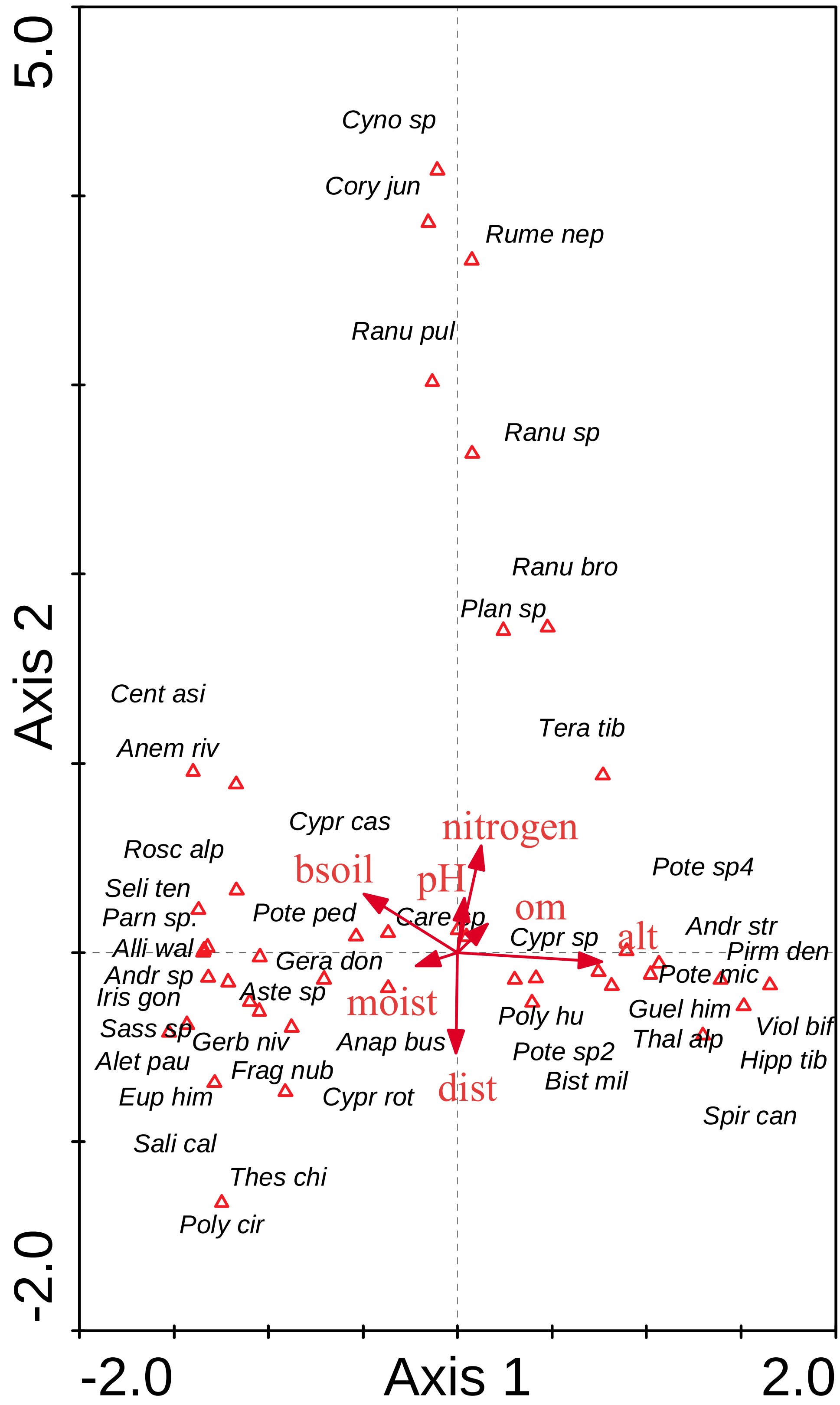

Fig. 3.6. CCA diagram (biplot of species and environmental variables) for grass dominated habitats. (species fit range 10 to 100%) Abbreviations for environmental variables follow Table 2.1. Abbreviations for species follow appendix 1. Δ = species.

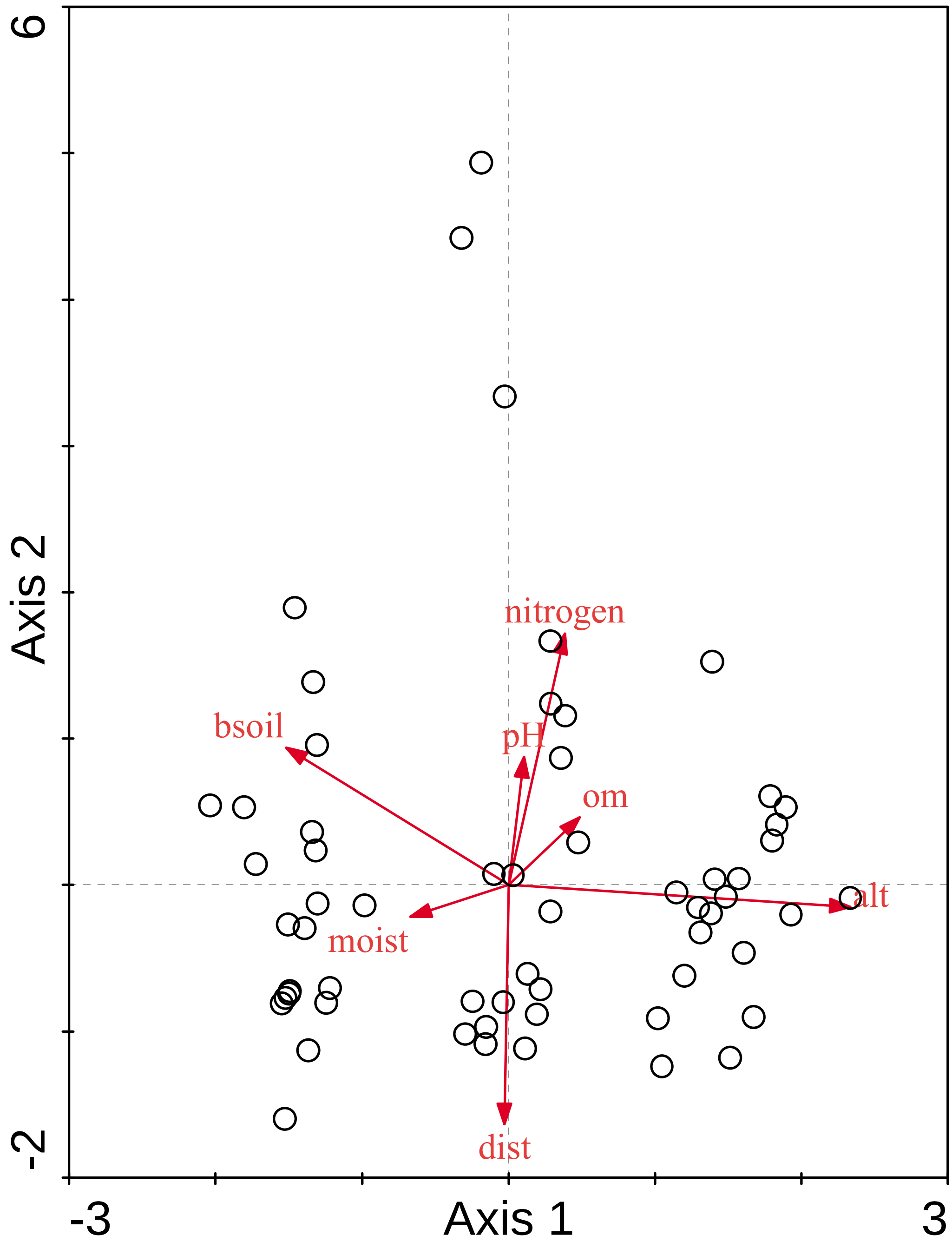

Fig.3.7. CCA diagram (biplot of samples and environmental variables) for grass habitat. Abbreviations for environmental variables follow Table 2.1.

3.5. Species Composition

3.5.1 Effect of habitat and distance from *goth*

In the whole data set (including all habitat patches from all sites), 7.4% of floristic variance was explained by the type of habitat patches. CCA analysis with Global Monte Carlo test using distance from *goth* only as explanatory variable showed that distance had significant contribution in the species composition in grass-dominated habitat patch and combined dataset from all patches. Distance had much stronger effect on species composition in grass-dominated habitat patch (4.4% of the floristic variance) than in shrub- (1.9%) and stone- (2.1%) dominated habitat patches and in total data set including all habitat patches from all sites (1.63%) (Table 3.6).

Table 3.6. Variance (%) explained by habitat patch types in combined data set from all sites and variance explained by distance in three different habitat patch types and in combined data set.

	Variance (%) explained in species data		Global Monte Carlo test *P*-value*
	Habitat	dist	
grass	-	4.4	0.026
shrub	-	1.9	0.290
stone	-	2.1	0.180
combined	7.4	1.6	0.002

* using distance only as explanatory variable

3.5.2 Effect of habitat and distance from g*oth* at different altitudes

CCA using habitat patch type only as an explanatory variable for the data set of three different altitudinal band showed that habitat patch type had strong effect at high altitude (17.1% of floristic variance) than in mid (10.3%) and low (14.1%) altitudes (Table 3.7). CCA using distance only as an explanatory variable for three different altitudinal data set showed that distance had stronger effect in species composition at mid altitude (7.1% of floristic variance explained) than at low (3.3%) and high (4.0%) altitudes (Table 3.7).

Table 3.7. Variance (%) explained by habitat patch types and distance from *goth* (both are used separately as explanatory variable in the CCA) in three different altitudes (low = 3539-3556 m, mid = 3739-3759 m and high = 4140-4155 m).

	Variance (%) explained in species data		Global Monte Carlo test *P*-value*
	Habitat	dist	
Low	14.1	3.3	0.022
Mid	10.3	7.1	0.002
High	17.1	4.0	0.010

* using distance only as explanatory variable

Chapter 4

DISCUSSIONS

4.1. Grazing Gradient in Different Habitat Patches and along Increasing Distance from *Goth*

Study of livestock grazing effect in the biodiversity is difficult for two reasons: first, grazing is difficult to measure directly; and second, biodiversity is influenced by various factors. Hence, such study should focus measuring grazing level in practical ways. Surrogates of grazing are useful indicator to differentiate grazing level (Hendricks *et al.* 2005). Grazing activities are mainly related to the distribution of the grazing resources (Coughenour 1991; Adler 2001). Livestock grazing is supposed to be distributed evenly when resources are homogenous and livestock are allowed to graze freely. But such situations seldom occur in nature. Level of dung, trampling and percentage of bare soil are useful indicators to measure grazing pressure when there is unequal grazing in the landscape. In high-altitude landscapes, resource management regimes related to transhumance practices, are based on different levels of socio-cultural controls, which are shown to have significant effect in creating habitat heterogeneity (Ghimire *et al*. 2006). Different habitat patches in the high-altitude areas with different accessibility and resources may experience different grazing pressure. A spatial gradient of grazing can also be developed along the increasing distance from the assembly point of livestock (e.g., *goth*, summer farms). The area near such assembly point may represents the area grazed heavily than distant area (Vandvik and Birks 2002a, 2004; Riginos and Hoffman 2003; Ghimire *et al*. 2006). Thus, in the present study the distance from *goth* to surrounding was tested as gradient of grazing in different habitat patches (grass-, shrub- and stone-dominated) in the high-altitude area of Langtang valley.

Surrogates of grazing (dung, trampling and bare soil) had their mean values in descending order for grass-, stone- and shrub-dominated patches. High values of these variables in grass-dominated patches indicate high grazing pressure and animal activities (Markus Stumpp *et al*. 2005; Tadey 2006) in such patches. Out of three habitat patches, livestock have easy access in open grass-dominated patches. Stone- and shrub-dominated patches in the other hand have some obstacles to livestock reducing animal activities. Distribution of such patches in the landscape may lead to uneven patchy grazing (Körner 1999). Negative correlations of dung, trampling and bare soil with the distance from *goth* indicate that there is high grazing intensities near *goth* and it gradually decreases with increasing distance. This leads to develop a grazing gradient from *goth* to the surrounding.

4.2. Species Richness and Composition in Different Habitat Patches and along Increasing Distance from *Goth*

Difference in the mean species richness in grass-, shrub- and stone-dominated patches in this study is difficult to explain based on only single factor (like grazing). Species richness and composition are related to numerous factors (Loffler 2008), including species affinity to open, shade or rocky habitats; difference in soil nutrients and other edaphic factors; and varied disturbance level. The result showed that in individual patch level, lowest species richness was found in grass-dominated patches and the relationship of species richness with distance from *goth* was significant only in grass-dominated patches, where species richness increased with the increasing distance from *goth*. As distance from *goth* represents the grazing gradient, this relation to some extent can be interpreted as response of species richness to grazing intensity (Pandey and Singh 1991; Loffler 2008). Brooks *et al.* (2006) and Dorrough *et al*. (2007) had also reported decrease in species richness and cover of native annuals in response to increasing grazing intensity.

High species richness and insignificant relationship between species richness and distance from *goth* in shrub-dominated patches may be due to protection of palatable species from grazing. In such habitat patches, shrubs create vertical heterogeneity and facilitates coexistence of herbaceous species underneath creating microhabitat (Rebollo *et al*. 2002; Callaway *et al*. 2005; Callaway 2007; Pamela *et al*. 2007; Smit 2007). Yagil *et al.* (2007) reported that grazing decreased species richness and biomass of annual plants in open patches but it increased species richness under canopy. Stone-dominated patches, also to some extent, are protected from grazing due to relative inaccessibility and showed higher species richness than in grass-dominated patches. The general perception of encroachment of bushes in the high altitude pasture due to overgrazing in Nepal should be carefully examined from the biodiversity point of view. There are several studies which show that the shrub and bush cover is significantly increased after abandonment of the pasture from grazing (Anthelme *et al*. 2003; Floyd *et al*. 2003; Manier and Hobbs 2007) and subsequent decline in species diversity when shrub cover exceeds certain level (Anthelme *et al*. 2003; Dullinger *et al*. 2003).

Distance from *goth* had strong effect in the species composition in grass-dominated patch than in other individual habitat patches and in all habitat patches when combined. Animal activites are associated with change in soil nitrogen (Markus Stumpp *et al*. 2005). Livestock creates nutrient-rich patches mixing dung with soil in the area where their activity is high (Nash *et al*. 1999). Species that are disturbance specialist, mainly exotic, and unpalatable tend to correlate with high level of disturbance (Mcintyre and Lavorel 1994; Brooks *et al*. 2006). Hence, grazing creates ecological opportunities for additional sets of species (Vandvik *et al.* 2005). Nutrient-rich patches created by livestock activities support nitrophilous species such as *Rumex nepalensis* (Ghimire *et al.* 2006). Cover of *Plantago* sp. and *Anaphalis triplinervis* only in high intensity grazing sites in Shey Phoksundo National, Park, Nepal was reported by Carpenter and Klein (1995). In this study, species like *Cynoglossum* sp., *Corydalis juncea*, *Rumex nepalensis*, *Ranunculus pulchellus*, *Ranunculus* sp., *Plantago* sp., *Elcholzia* sp. have shown affinity towards increasing nitrogen level. Hence, presence of such species in high altitude pastures indicates high animal activities.

Insignificant relationships of species richness with distance from *goth* in combined data set (including all habitat patches from all sites) and individually in shrub-dominated and stone-dominated patches except in grass-dominated patches indicate that the distribution of grazing animal effects in the landscape is scale dependent (Oba *et al.* 2003; Markus Stumpp *et al*. 2005). Inexistence of clear grazing gradient at the landscape-level, when data from all habitat patches were combined, is due to unequal grazing pressure in mosaic of different habitat patches. The effect of grazing in species richness in grass-dominated patches is buffered to some extent by shrub- and stone-dominated patches and overall grazing gradient is not clearly evident in heterogeneous ecosystem at the landscape level (cf. Roder *et al.* 2007). The results of this study thus indicate that the effect of grazing in such heterogeneous landscape could be better explored only when the study is focused separately to each of the individual habitat patch.

Study showed that average number of species for grass-dominated patch is expected only at 70 m distance far from *goth*. The number of species in grass-dominated patch could equal and even exceed to stone-dominated patch at 110 m distance from *goth* and it could equal and exceed species number in shrub-dominated patch at 140 m distance from *goth*. Hence, it can be said that species richness is highly affected by grazing in grass-dominated patch up to 70 m distance from *goth*. Though, the study was focused in the grazing disturbance gradient, the distance to only 125 m from *goth* may not be enough to capture full range of such gradient. It is not known whether the species richness rises continuously, level off, or decrease again creating a hump-backed curve when the distance from *goth* is increased beyond 125 m. Further study is, therefore, required to find out exact response of species richness and composition beyond 125 m distance from *goth*. In the present work, it was impossible to include the longer distance because the study area was rugged, very steep and inaccessible. The attempt to cover longer distance would lead to change in other aspects including the overlapping of grazing area with another *goth*. Sometimes it would even lead across the stream, requiring the sample in area with different slope, aspect, altitude, etc.

4.3. Variation in Effect of Habitat and Distance from *Goth* in Species Composition at Different Altitudes

The effect of distance on species composition was stronger in the mid altitude site, whereas effect of habitat patch type was strongest in high altitude and low altitude sites. It showed some sort of trade off between effect of habitat and distance: the effect of habitat in species composition is stronger in the site where there is weak effect of grazing (distance) and vice versa. The lowest effect of habitat patch types in the mid altitude site may be due to homogenization of the landscape by the grazing pressure making the patch types more similar. It suggest that the grazing pressure may be the main driver of species composition at the landscape level. The stronger distance effect and high grazing pressure in mid altitude site is related to grazing system (transhumance) of the area. The mid altitude pastures are grazed three times a year: (i) when herders move from low to high altitude in the summer; (ii) when they come back to low altitude in the winter; and (iii) when they come back with their livestock in the mid summer from high altitude to celebrate their festival in the Kyanjng Gumba located in Kyanjing. High altitude pastures are grazed only once in the summer season each year. The low altitude pastures are grazed twice when they go up and down in the summer and winter seasons respectively. The result showed that the distance's and habitat patch's effect in species composition varies with grazing pressure which is reflected in the pasture of different altitude.

Large amount of unexplained variation in the combined data set may be due to existence of other important but unmeasured environmental variables. It has been shown that the interpretation of variation explained as the fraction of total inertia explained is not always good (Økland 1999). But it is highly useful to know the relative contribution of the measured environmental variables. Vegetation environment relation for combined data set showed highest variation in vegetation composition explained by elevation. This is in accordance with other studies at the landscape level (Mcintyre and Lavorel 1994; Sebastià *et al*. 2008). But, environmental heterogeneity maintained by grazing (Körner 2004) and habitat patches (Bai *et al*. 2001; Fuhlendorf and David 2001; Mcintyre *et al*. 2003) is important in finer scale to increase species number. This can be reflected in each altitude site of this study considering each altitude site as small scale observation. Habitat patches result in different levels of grazing within these patches which are important to increase species diversity (Collins 1986) as a result of increased habitat diversity.

4.4. Finding of Study from Management Perspective

The varied effect of distance from *goth* in the species richness and composition in different habitat patches and pastures of different altitude should be considered for the effective management of pastures and the maintainance of biodiversity in the landscape. This is true that livestock do not keep interest to graze in bushy patches and herders were worried with the increase of such patches. But the shrub patches are associated with high species richness compared to grass and stone dominated patches in the study area. In continuous free range grazing, the livestock are more and more concentrated in the accessible patches, and degradation of such patches may provide chance for the encroachment of bushes from neighboring patches. Obviously, the stronger effect of distance from *goth* in capturing more floristic variance in the mid altitude pastures and grass dominated patches suggest that mid-altitude pastures are affected by grazing at altitudinal (landscape) level and grass-dominated patches at patch (local) level. Another point to be considered is that patches with obstacle to livestock also protect palatable species (Callaway *et al*. 2005) to seed production and help to disperse in the heavily grazed smooth patches. It seems that shrub- and stone-dominated patches are important for maintaining biodiversity and mosaic landscape in the study area. The general perception of increasing shrub cover in the pastures should be investigated scientifically; either it is related to grazing or other factors such as avoidance of the burning. The area has complex landscape with long-term human interactions. Conservation of such areas need prioritization of traditional management practices (Vandvik *et al*. 2005) which help to promote community participation (Oba and Kaitira 2006) in rangeland management and monitoring.

Chapter 5

CONCLUSIONS

The study concludes as follows.

1. Grazing intensities differ in different habitat patches and it decrease with the increase in distance from *goth*. Grass-, stone- and shrub-dominated patches in the subalpine and lower alpine pasture in Langtang experience different level of grazing intensities in the descending order respectively.

2. Species richness is significantly different in grass- and shrub-dominated patches. Patches with shrub are richer in species than open grass-dominated patches.

3. Altitude, shrub and grazing are variables highly related to species composition at the landscape level. Species that grow in disturbed and nitrogen rich soils are common near *goth*. These species are *Rumex nepalensis, Ranunculus pulchellus*, *Corydalis juncea*, *Plantago* sp, *Cynoglossum* sp, *Ranunculus* sp, *Elcholzia* sp.

4. Distance from *goth* has different relation with species richness in different habitat patches. Distance from *goth* has strong effect on species richness and composition in grass-dominated patches. Hence, species richness in grass-dominated patches near *goth* is highly affected by transhumance related activities.

5. The study of distance from *goth* effect in species composition along the altitude showed that it has stronger effect in the mid altitude sites.

6. Ecological role of shrub and rock as refuge from cattle grazing should be taken into consideration in management practices in order to maintain the biodiversity of the alpine pastures.

7. Similar study to longer distance from *goth* is recommended to find the exact response of species richness and composition beyond 125 m distance from goth.

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APPENDIX I

Species profile

Family	**Full name**	**Abbreviation**	**Life form**	**Altitude (masl)**
Liliaceae	*Aletris pauciflora* (Klotzsch) Hand.-Mazz	Alet pau	Herb	2500-4900
Amaryllidaceae	*Allium wallichii* Kunth	Alli wal	Herb	2400-4650
Compositae	*Anaphalis busua* (Bush.-Ham.ex D.Don) DC	Anap bus	Herb	1500-2900
Primulaceae	*Androsace* sp.	Andr sp	Herb	*
Primulaceae	*Androsace strigillosa* Franch.	Andr str	Herb	2400-4700
Ranunculaceae	*Anemone rivularis* Buch.-Ham.ex DC	Anem riv	Herb	1600-4000
Cruciferae	*Arabidopsis himalaica* (Edgew.) O.E. Schulz	Arab him	Herb	3000-3800
Araceae	*Arisaema jacquemontii* Blume	Aris jac	herb	2700-4000
Compositae	*Artemisia* sp	Arte sp	Shrub	*
Compositae	*Aster* sp	Aste sp	Herb	*
Berberidaceae	*Berberis aristata* DC	Berb ari	Shrub	1800-3000
Berberidaceae	*Berberis mucrifolia* Ahrendt	Berb muc	Shrub	2100-4500
Polygonaceae	*Bistorta amplexicaulis* (D. Don) Greene	Bist amp	Herb	2100-4800
Polygonaceae	*Bistorta milletti* Lev.	Bist mil	Herb	3000-3400
Poaceae	*Calamagrotis* sp.	Cala sp	Herb	*
Cypraceae	*Carex* sp	Care sp	Herb	*
Ericaceae	*Cassiope fastigiata* (Wall.) D.Don	Cass fas	Shrub	2800-5000
Apiaceae	*Centella asiatica* (L.) Urb.	Cent asi	Herb	500-2100
Leguminosae	*Chesneya nubigena* (D.Don) Ali	Ches nub	Herb?	3600-5200
Umbelliferae	*Cortiella hookeri* (C.B.Clarke) C. Norman	Cort hoo	Herb	4800
Papaveraceae	*Corydalis juncea* Wall.	Cory jun	Herb	2500-5100
Rosaceae	*Cotoneaster microphyllus* Wall. ex Lindl	Coto mic	Shrub	2000-5400
Campanulaceae	*Cynanthus lobatus*	Cyna lob	Shrub	3300-4500
Campanulaceae	*Cynanthus microphyllus* Edgew	Cyna mic	Herb	2900-4800
Boraginaceae	*Cynoglossum* sp	Cyno sp	Herb	*
Cypraceae	*Cyperus cuspidatus* Kunth	Cypr cas	Herb	1000-1700
Cypraceae	*Cyperus rotundus* L.	Cypr rot	Herb	300-2400
Cypraceae	*Cyprus* sp	Cypr sp	Herb	*
Labiateae	*Elcholzia* sp	Elch sp	Herb	*
Ephedraceae	*Ephedra gerardiana* Wall.ex Stapf	Ephe ger	Shrub	3700-5200
Euphorbiaceae	*Euphorbia stracheyi* Boiss.	Euph str	Herb	2000-5000
Solanaceae	*Euphrasia himalayica* Wettst.	Eup him	herb	3200-4200
Rosaceae	*Fragaria nubicola* Lindl.ex Lacaita	Frag nub	Herb	1600-4000
Liliaceae	*Fritillaria cirrhosa* D.Don	Frit cir	herb	3000-4600
Rubiaceae	*Galium* sp.	Gali sp	Herb	*

APPENDIX I CONTD....

Family	Full name	Abbreviation	Life form	Altitude (masl)
Ericaceae	*Gaultheria trichophylla* Royle	Gaul tri	Shrub	2700-4500
Gentianaceae	*Gentiana depressa* D.Don	Gent dep	herb	2900-4300
Gentianaceae	*Gentianella* sp.	Gent sp	Herb	*
Geraniaceae	*Geranium donianum* Sweet	Gera doni	Herb	3200-4800
Compositae	*Gerbera nivea* (DC.) Sch.Bip	Gerb niv	Herb	2800-4500
Coriariceae	*Gueldenstaedtia himalaica* Baker	Guel him	herb	3300-4600
Apiaceae	*Heracelum* sp	Hera sp	Herb	*
Elaeagnaceae	*Hippophae tibetana* Hchltdl.	Hipp tib	Shrub or Tree	3800-4500
Balsaminaceae	*Impatiens sulcata* Wall.	Impa sul	Herb	1700-4100
Iridaceae	*Iris goniocarpa* Baker	Iris gon	Herb	3600-4400
Juncaceae	*Juncus thomsonii* Buchenau	Jun tho	Herb	2700-5200
Cupressaceae	*Juniper recurva* Buch.-Ham.ex D. Don	Juni rec	Shrub or tree	3300-4600
Cupressaceae	*Juniperus indica* Bertol.	Juni ind	Shrub or Tree?	3700-4100
Cupressaceae	*Juniperus squamata* Buch.-Ham.ex D. Don	Juni squ	shrub	3300-4400
Liliaceae	*Lilium nanum* Klotzsch	Lili nan	Herb	3700-4600
Gentianaceae	*Lomatogonium* sp	Loma sp	Herb	*
Caprifoliaceae	*Lonicera* sp	Loni sp	Shrub	*
Caprifoliaceae	*Lonicera spinosa* (Jacquem. Ex Decne.) Walp.	Loni spi	Shrub	3600-4600
Leguminosae	*Lotus corniculatus* L.	Lotu cor	Herb	3000-3700
Dipsacaceae	*Morina nepalensis* D.Don	Mori nep	Herb	3000-4500
Parneassiaceae	*Parnassia* sp.	Parn sp.	Herb	*
Leguminosae	*Parochetus communis* Buch.-Ham.ex D. Don	Paro com	Herb	900-4000
Scrophulariaceae	*Pedicularis* sp.	Pedi sp	Herb	*
Polygonaceae	*Persicaria polystachya* (Wall. Ex. Meisn) H. Gross	Pers pol	Herb	2700-4200
Plantaginaceae	*Plantago* sp	Plan sp	Herb	*
Poaceae	*Poa* sp.	Poa sp	Herb	*
Liliaceae	*Polyganatum hukari* Baker	Poly hu	Herb	2900-5000
Liliaceae	*Polygonatum cirrhifolium* (Wall.) Royle	Poly cir	Herb	1700-4600
Rosaceae	*Potentialla fruticosa* Wall.ex.Lehm	Pote fru	Shrub	2700-4300
Rosaceae	*Potentialla cuneata* Wall.ex Lehm	Pote cun	herb	2400-4900
Rosaceae	*Potentialla* sp.	Pote sp4	Herb	*
Rosaceae	*Potentilla microphylla* D.Don	Pote mic	Herb	3800-5100
Rosaceae	*Potentilla peduncularis* D.Don	Pote ped	Herb	3000-4700
Rosaceae	*Potentilla* sp	Pote sp2	Herb	*
Primulaceae	*Primula denticulata* Sm.	Pirm den	Herb	1500-4900
Ranunculaceae	*Ranunculus brotherusii* Freyn	Ranu bro	Herb	3000-5000

APPENDIX I CONTD....

Family	Full name	Abbreviation	Life form	Altitude (masl)
Ranunculaceae	*Ranunculus pulchellus* C.A. Mey	Ranu pul	Herb	3600-4900
Ranunculaceae	*Ranunculus* sp	Ranu sp	Herb	*
Ericaceae	*Rhodendron anthopogan* D. Don	Rhod ant	Shrub	3300-5100
Ericaceae	*Rhodendron lepidatum* Wall.ex G. Don	Rhod lep	Shrub	2100-4700
Ericaceae	*Rhododendron cowanianum* Davidian	Rhod cow	Shrub or Tree?	3000-3900
Ericaceae	*Rhododendron setosum* D. Don	Rhod set	Shrub	3700-5600
Zingiberaceae	*Roscoea alpina* Royle	Rosc alp	Herb	2400-3100
Polygonaceae	*Rumex nepalensis* Spreng	Rume nep	herb	1200-4200
Salicaceae	*Salix calliculata* Hook.f.ex Andersson	Sali cal	Shrub	3600- 4500
Salicaceae	*Salix daltoniana* Andersson	Sali dal	Shrub	3400-4400
Compositae	*Sassuria* sp	Sass sp	Herb	*
Crassulaceae	*Sedum* sp	Cedu sp	Herb	*
Umbelliferae	*Selinum tenuifolium* Wall. Ex.C.B Clarke	Seli ten	Herb	2700-4000
Liliaceae	*Smilacina* purpurea	Smil pur	Herb	***
Orchideceae	*Smilacina* sp	Smil sp	Herb	*
Smilacaceae	*Smilex* sp	Smil sp	Herb	*
Rosaceae	*Spiraea canescens* D.Don	Spir can	Shrub	1500-3200
Elaeagnaceae	*Stellaria* sp	Stell sp	Herb	*
Poaceae	Stipa sp	Stip sp	Herb	*
Compositae	*Teraxacum tibetianum* Hand.-Mazz	Tera tib	Herb	4000-4300
Ranunculaceae	*Thalictrum alpinum* L.	Thal alp	Herb	2800-5000
Ranunculaceae	*Thalictrum reniforme* Wall.	Thal ren	Herb	2800-3300
Ranunculaceae	*Thalictrum* sp	Thal sp	Herb	*
Santalaceae	*Thesium chinensis*	Thes chi	Herb	***
Leguminosae	*Trigonella emodi* Benth.	Trig emo	herb	1300-4900
	Unknown 1	Unkn 1	Herb	**
	Unknown 4	Unkn 4	Herb	**
	Unknown 8	Unkn 8	Shrub	**
Lentibulariaceae	*Utricularia brachiata* Oliv.	Utri bra	Herb	3000-3800
Violaceae	*Viola biflora* L.	Viol bif	Herb	2100-4500

* Identified to genus only
** Species not identified
*** Elevation range not found

APPENDIX II

Environmental variables measured in each plot

Variables abbreviation follows Table 2.1. Herb cover and shrub cover are combined as vegetation cover during the data analysis.

goth no.	Plot no.	Habitat	dist	alt	slop	pH	moist	sdepth	hcov	shcov	rcov	bsoil	dung	tramp	om	nitrogen	ri	species
1	P1	grass	2	3540	0	5.70	1.25	13.00	65	0	5	35	2	2	6.72	0.55	0.88	15
1	P2	stone	11	3540	5	5.70	1.75	7.50	50	0	40	10	1	2	12.67	0.83	0.84	16
1	P3	shrub	16	3542	2	5.80	4.25	14.00	15	75	0	10	0	1	13.70	0.53	0.86	19
1	P4	grass	20	3540	0	5.70	2.10	14.50	70	0	2	28	3	3	6.72	0.55	0.88	17
1	P5	stone	22	3539	4	6.90	2.00	10.00	45	0	35	20	3	2	12.67	0.83	0.85	17
1	P6	shrub	10	3541	7	5.60	4.75	14.50	15	45	2	38	1	1	13.70	0.53	0.82	19
1	P7	grass	26	3540	2	5.60	2.25	13.50	70	0	0	30	4	4	8.27	0.36	0.86	19
1	P8	shrub	30	3539	0	5.70	3.50	13.50	5	80	0	15	2	1	14.90	0.64	0.88	21
1	P9	stone	31	3540	0	5.50	5.25	11.00	10	35	50	15	1	2	11.37	0.77	0.88	23
1	P10	grass	40	3540	10	5.50	6.50	13.50	75	0	5	20	2	3	8.27	0.36	0.79	16
1	P11	stone	44	3541	10	5.70	3.00	9.00	40	0	45	15	0	1	11.37	0.77	0.79	17
1	P12	shrub	46	3539	6	5.70	5.75	13.00	10	70	1	19	1	1	14.90	0.64	0.83	26
1	P13	grass	53	3541	10	5.50	1.75	13.00	70	0	2	28	4	3	6.20	0.43	0.79	18
1	P14	stone	56	3539	0	5.40	6.25	9.50	30	0	50	20	4	4	14.60	0.93	0.88	25
1	P15	shrub	54	3539	0	5.40	5.75	7.50	5	80	5	10	1	2	11.63	0.50	0.88	15
1	P16	grass	64	3539	3	5.30	6.05	11.50	60	0	3	37	3	3	6.20	0.43	0.86	16
1	P17	stone	66	3540	2	5.60	2.25	6.50	15	0	55	30	3	3	14.60	0.93	0.86	14
1	P18	shrub	70	3541	2	5.40	6.10	10.50	5	80	0	15	3	2	11.63	0.50	0.86	23
1	P19	grass	77	3540	3	5.60	6.00	11.50	70	0	5	25	3	3	7.49	0.36	0.86	18
1	P20	shrub	81	3539	3	5.50	7.00	12.50	25	50	0	25	2	2	13.44	0.49	0.86	26
1	P21	stone	89	3540	5	5.60	4.75	8.00	20	0	60	20	3	2	11.63	0.78	0.84	18
1	P22	grass	96	3539	0	5.70	4.50	15.00	50	0	5	45	3	2	7.49	0.36	0.88	18
1	P23	shrub	93	3539	2	5.50	5.75	9.00	20	50	10	20	2	2	13.44	0.49	0.86	19
1	P24	stone	94	3540	0	5.50	7.00	9.00	20	10	50	20	1	2	11.63	0.78	0.88	28
1	P25	shrub	101	3540	5	5.40	6.25	9.50	5	85	2	8	1	1	12.41	0.55	0.84	21
1	P26	stone	103	3539	3	5.40	7.00	9.00	25	0	60	15	2	1	11.37	0.77	0.86	20
1	P27	grass	108	3540	5	5.50	6.75	11.50	70	0	10	20	2	2	8.14	0.44	0.84	16
1	P28	stone	122	3539	5	5.50	5.25	7.50	25	0	50	25	1	1	11.37	0.77	0.84	17
1	P29	shrub	125	3540	2	5.50	8.00	14.50	30	35	10	25	0	1	12.41	0.55	0.86	24
1	P30	grass	129	3540	2	5.50	4.25	10.50	45	15	20	20	3	2	8.14	0.44	0.86	25
2	P31	grass	2	3550	0	5.50	6.75	17.00	70	0	0	30	4	4	8.01	0.45	0.88	20
2	P32	stone	5	3550	2	5.50	6.65	7.50	30	0	40	30	3	4	12.41	0.82	0.86	22
2	P33	shrub	9	3551	3	5.10	8.00	13.00	5	85	1	9	1	1	13.44	0.60	0.86	18

APPENDIX II CONTD....

goth no.	Plot no.	Habitat	dist	alt	slop	pH	moist	sdepth	hcov	shcov	rcov	bsoil	dung	tramp	om	nitrogen	ri	species
2	P34	grass	16	3551	0	5.50	6.75	14.50	65	0	0	35	4	4	9.56	0.40	0.88	18
2	P35	stone	15	3550	0	5.50	8.00	11.00	30	0	35	35	3	4	12.41	0.82	0.88	19
2	P36	shrub	19	3551	0	5.30	7.25	10.50	10	80	0	10	2	2	13.44	0.60	0.88	19
2	P37	stone	27	3550	2	5.40	7.10	11.50	20	10	60	10	2	3	13.28	0.86	0.86	19
2	P38	shrub	36	3550	0	5.40	6.25	14.50	10	60	0	30	2	2	14.48	0.46	0.88	26
2	P39	grass	39	3550	0	5.30	6.75	17.50	65	0	0	35	3	3	8.01	0.45	0.88	17
2	P40	grass	48	3551	2	5.30	7.75	19.00	75	0	1	24	2	3	9.56	0.40	0.86	20
2	P41	shrub	44	3550	0	5.40	7.00	11.00	15	65	0	20	1	1	14.48	0.46	0.88	19
2	P42	stone	43	3550	2	5.40	5.25	9.50	20	0	65	15	1	1	13.28	0.86	0.86	14
2	P43	grass	58	3552	0	5.60	6.45	13.00	60	0	0	40	4	4	9.56	0.40	0.88	20
2	P44	stone	56	3551	7	5.50	3.75	7.50	40	0	50	10	2	3	17.87	1.09	0.85	20
2	P45	shrub	55	3551	15	5.60	5.75	11.00	25	55	1	19	0	2	13.18	0.71	0.74	25
2	P46	grass	66	3552	0	5.70	4.25	6.50	50	0	0	50	3	3	13.44	0.60	0.88	18
2	P47	stone	69	3552	0	5.50	4.75	9.50	35	0	40	25	4	4	17.87	1.09	0.88	21
2	P48	shrub	73	3553	10	5.70	2.75	5.50	20	50	20	10	1	2	13.18	0.71	0.83	22
2	P49	grass	82	3553	2	5.70	8.00	9.00	45	7	10	38	4	4	13.44	0.60	0.87	21
2	P50	shrub	84	3553	7	5.70	5.25	9.00	15	75	0	10	4	2	14.48	0.45	0.82	20
2	P51	stone	89	3553	0	5.40	7.25	7.50	45	0	50	5	3	3	22.49	1.32	0.88	20
2	P52	grass	94	3553	3	5.40	6.10	11.00	65	0	2	33	4	4	13.44	0.60	0.86	23
2	P53	shrub	96	3553	5	5.50	8.00	9.00	5	90	2	3	1	1	10.34	0.49	0.84	16
2	P54	stone	97	3554	2	5.40	8.00	9.00	40	0	50	10	3	3	22.49	1.32	0.86	20
2	P55	grass	103	3554	5	5.40	7.25	19.00	70	0	2	28	4	4	11.37	0.57	0.84	18
2	P56	stone	106	3554	0	5.90	5.25	11.00	25	25	30	20	2	3	13.44	0.87	0.88	22
2	P57	shrub	109	3554	2	5.30	7.25	10.50	15	65	0	20	0	1	10.34	0.34	0.87	19
2	P58	stone	123	3555	5	5.80	4.25	6.00	30	0	40	30	4	4	13.44	0.87	0.85	27
2	P59	grass	125	3556	5	5.50	6.00	13.00	60	0	5	35	3	3	11.37	0.57	0.84	18
2	P60	shrub	122	3555	5	5.40	7.50	11.50	10	75	0	15	2	2	10.34	0.34	0.84	24
3	P61	shrub	1	3750	10	5.70	8.00	11.00	10	85	1	4	2	2	13.96	0.60	0.83	25
3	P62	grass	4	3750	5	5.80	5.50	13.00	60	7	1	32	4	4	7.49	0.99	0.84	13
3	P63	stone	10	3749	2	5.90	8.00	12.50	40	0	50	10	3	3	18.10	1.04	0.87	16
3	P64	shrub	23	3748	0	6.00	6.00	9.00	10	75	5	10	2	3	13.96	0.60	0.88	20
3	P65	grass	22	3748	0	5.80	3.00	13.00	70	0	0	30	4	4	7.49	0.99	0.88	12
3	P66	stone	15	3749	12	6.00	4.50	9.00	40	0	45	15	3	4	18.10	1.04	0.82	20
3	P67	grass	27	3748	0	5.80	6.00	11.50	50	0	0	50	4	4	21.20	1.23	0.88	13
3	P68	shrub	30	3748	0	5.50	3.50	9.50	10	80	5	5	2	3	13.70	0.63	0.88	26

APPENDIX II CONTD....

goth no.	Plot no.	Habitat	dist	alt	slop	pH	moist	sdepth	hcov	shcov	rcov	bsoil	dung	tramp	om	nitrogen	ri	species
3	P69	stone	35	3748	0	6.00	5.00	10.50	20	16	45	19	4	4	17.06	0.78	0.88	21
3	P70	shrub	41	3748	0	5.30	7.00	7.50	10	80	0	10	2	3	13.70	0.63	0.88	23
3	P71	grass	50	3748	2	5.80	4.00	8.00	70	5	3	22	2	2	21.20	1.23	0.87	24
3	P72	stone	39	3748	2	5.60	4.50	9.00	25	0	50	25	4	4	17.06	0.78	0.87	29
3	P73	grass	52	3748	0	5.60	7.00	10.50	70	2	10	18	4	4	11.89	0.62	0.88	22
3	P74	shrub	54	3748	0	5.40	7.50	9.00	15	60	2	23	2	2	13.70	0.64	0.88	23
3	P75	stone	55	3748	0	5.80	7.50	7.50	10	25	50	15	2	1	17.09	0.88	0.88	27
3	P76	grass	60	3747	0	5.70	3.50	8.50	60	10	5	25	4	4	11.89	0.62	0.88	19
3	P77	shrub	61	3747	15	5.40	7.00	9.50	25	60	0	15	1	3	13.70	0.64	0.79	19
3	P78	stone	74	3746	3	5.60	6.80	7.50	25	0	55	20	4	4	17.09	0.88	0.86	21
3	P79	grass	89	3745	0	5.70	2.00	8.50	40	20	20	20	4	4	4.91	0.28	0.88	19
3	P80	stone	82	3745	3	5.90	5.00	5.50	10	20	65	5	1	2	17.58	0.72	0.86	23
3	P81	shrub	81	3745	0	4.90	4.50	9.50	5	80	10	5	1	1	11.11	0.43	0.88	24
3	P82	grass	100	3744	0	5.80	5.50	13.00	75	10	0	15	3	3	4.91	0.28	0.88	18
3	P83	stone	98	3744	3	6.00	5.50	7.50	30	5	60	5	3	3	17.58	0.72	0.86	20
3	P84	shrub	89	3744	0	4.60	3.00	8.00	3	90	3	4	2	1	11.11	0.43	0.88	17
3	P85	grass	103	3744	4	6.00	5.00	13.00	70	2	0	28	3	3	4.13	0.22	0.85	17
3	P86	shrub	102	3744	0	5.00	3.00	11.00	10	80	0	10	1	2	8.53	0.27	0.88	15
3	P87	stone	112	3744	3	6.20	4.00	8.50	20	5	55	20	2	2	18.10	0.76	0.86	23
3	P88	grass	124	3744	2	5.80	6.00	16.50	65	0	5	30	2	3	4.13	0.22	0.86	14
3	P89	stone	119	3744	7	6.20	3.00	7.50	10	30	40	20	2	3	18.10	0.76	0.82	19
3	P90	shrub	123	3744	7	4.90	5.00	11.00	5	90	2	3	1	1	8.53	0.27	0.82	22
4	P91	shrub	1	3755	0	5.40	3.00	10.50	7	85	5	3	3	3	13.44	0.42	0.88	25
4	P92	grass	3	3755	3	5.70	3.00	9.50	63	3	5	29	4	4	16.29	0.50	0.90	16
4	P93	stone	4	3755	5	6.10	3.50	6.00	30	5	50	15	3	3	22.49	1.29	0.92	21
4	P94	grass	13	3754	0	5.60	4.00	15.50	66	0	0	34	4	4	16.29	0.50	0.88	17
4	P95	shrub	17	3754	0	5.30	7.50	9.00	3	95	0	2	1	2	13.44	0.42	0.88	15
4	P96	stone	21	3754	7	5.90	4.00	9.50	15	15	50	20	2	3	22.49	1.29	0.92	26
4	P97	shrub	31	3754	4	5.40	8.00	29.00	25	55	10	10	1	4	12.45	0.46	0.85	20
4	P98	grass	41	3755	0	6.00	4.50	19.00	60	0	0	40	4	4	11.11	0.59	0.88	18
4	P99	stone	39	3755	0	5.90	4.50	7.50	25	20	40	15	4	4	11.11	0.90	0.88	16
4	P100	grass	49	3755	0	6.00	3.00	12.00	75	0	2	23	3	4	11.11	0.59	0.88	16
4	P101	stone	50	3755	0	5.90	2.00	6.50	30	20	40	10	2	2	11.11	0.90	0.88	19
4	P102	shrub	50	3755	0	5.40	3.50	7.50	20	60	2	18	2	2	12.45	0.46	0.88	19
4	P103	grass	55	3756	0	6.00	3.00	9.50	60	5	2	33	3	4	16.00	0.87	0.88	18

APPENDIX II CONTD....

goth no.	Plot no.	Habitat	dist	alt	slop	pH	moist	sdepth	hcov	shcov	rcov	bsoil	dung	tramp	om	nitrogen	ri	species
4	P104	shrub	57	3756	5	5.40	3.00	10.50	12	65	5	18	2	3	13.44	0.48	0.84	22
4	P105	stone	58	3756	0	6.00	3.00	7.50	30	20	40	10	2	3	15.77	0.78	0.88	26
4	P106	grass	75	3757	3	6.00	3.00	10.50	65	0	2	33	4	3	16.00	0.87	0.86	20
4	P107	stone	72	3757	0	5.60	8.00	7.50	40	0	50	10	4	4	15.77	0.78	0.88	15
4	P108	shrub	66	3757	0	5.40	4.00	8.50	25	60	5	10	1	2	13.44	0.48	0.88	26
4	P109	grass	81	3757	2	5.90	3.00	7.50	50	10	10	30	3	4	16.50	0.77	0.87	23
4	P110	shrub	97	3757	0	5.70	3.50	8.00	10	70	10	10	2	1	18.22	0.88	0.88	25
4	P111	stone	98	3757	0	5.10	8.00	5.50	7	10	80	3	1	2	21.46	1.11	0.88	9
4	P112	grass	99	3757	5	5.90	0.50	8.50	40	20	10	30	0	4	16.50	0.77	0.87	25
4	P113	stone	94	3757	0	5.40	2.00	6.50	5	30	60	5	1	2	21.46	1.11	0.88	22
4	P114	shrub	96	3757	5	5.60	2.00	8.50	5	90	0	5	1	1	18.22	0.88	0.87	24
4	P115	stone	103	3758	10	5.70	3.00	4.50	25	0	60	15	3	2	19.39	0.81	0.85	15
4	P116	grass	107	3758	7	5.70	2.00	10.50	45	20	10	25	2	3	9.82	0.52	0.85	23
4	P117	shrub	110	3758	8	5.80	4.50	9.50	10	80	2	8	1	1	5.94	0.27	0.87	19
4	P118	grass	122	3739	0	5.70	4.50	11.50	45	30	5	20	2	2	9.82	0.52	0.88	25
4	P119	shrub	125	3739	5	5.90	5.00	10.50	10	75	5	10	0	2	5.94	0.27	0.84	17
4	P120	stone	118	3739	0	5.70	6.00	9.00	10	2	75	13	3	3	19.39	0.81	0.88	22
5	P121	stone	2	4140	3	5.90	2.50	7.50	20	20	50	10	3	3	13.70	0.24	0.88	17
5	P122	grass	5	4140	0	5.60	2.00	10.00	75	0	10	15	4	4	11.11	0.57	0.88	12
5	P123	shrub	6	4141	15	5.80	6.00	9.00	20	60	5	15	1	2	14.48	0.80	0.85	18
5	P124	stone	10	4141	3	5.90	3.50	9.00	35	5	50	10	3	3	13.70	0.24	0.88	18
5	P125	shrub	17	4141	5	5.80	5.00	7.00	25	65	8	2	4	3	14.48	0.80	0.88	22
5	P126	grass	18	4141	0	5.60	2.50	18.50	60	0	0	40	4	4	11.11	0.57	0.88	17
5	P127	grass	27	4141	0	5.40	2.00	13.00	65	5	10	20	4	3	13.70	0.62	0.88	13
5	P128	shrub	38	4141	3	5.70	4.00	11.00	10	65	10	15	2	2	14.22	0.74	0.88	15
5	P129	stone	37	4141	3	5.70	2.50	7.50	40	0	50	10	2	3	16.29	0.85	0.87	11
5	P130	grass	43	4141	5	5.40	2.00	12.00	75	0	5	20	4	4	13.70	0.62	0.88	13
5	P131	stone	43	4141	0	5.70	2.00	9.50	40	5	50	5	3	3	16.29	0.85	0.88	17
5	P132	shrub	49	4141	3	5.80	2.00	7.50	20	50	20	10	1	2	14.22	0.74	0.86	25
5	P133	grass	53	4141	0	5.50	3.00	6.50	75	0	10	15	2	3	10.86	0.50	0.88	15
5	P134	stone	56	4141	0	5.90	3.00	11.50	22	5	70	3	4	3	11.11	0.90	0.88	19
5	P135	shrub	62	4141	0	5.50	6.50	11.00	10	80	2	8	1	1	9.82	0.39	0.88	18
5	P136	grass	73	4141	5	5.30	4.00	17.50	80	0	1	19	3	3	10.86	0.50	0.88	12
5	P137	shrub	72	4141	5	5.60	2.00	11.00	10	80	1	9	0	1	9.82	0.39	0.85	16
5	P138	stone	70	4141	0	5.80	5.00	9.00	10	15	70	5	2	2	11.11	0.90	0.88	17

APPENDIX II CONTD....

goth no.	Plot no.	Habitat	dist	alt	slop	pH	moist	sdepth	hcov	shcov	rcov	bsoil	dung	tramp	om	nitrogen	ri	species
5	P139	grass	77	4141	5	5.20	4.50	14.50	75	0	5	20	2	2	9.86	0.42	0.84	21
5	P140	stone	87	4141	0	5.90	2.50	9.00	35	10	50	5	2	3	11.89	0.53	0.88	22
5	P141	shrub	88	4141	0	5.50	3.00	10.50	10	75	5	10	0	1	11.89	0.50	0.88	21
5	P142	grass	92	4141	0	5.30	2.00	11.00	75	5	0	20	2	4	9.86	0.42	0.88	16
5	P143	stone	89	4141	0	5.90	1.00	7.00	30	5	60	5	1	2	11.89	0.53	0.88	18
5	P144	shrub	98	4141	0	5.60	2.50	8.00	5	90	2	3	0	0	11.89	0.50	0.88	18
5	P145	grass	107	4141	0	5.60	4.00	11.00	75	3	3	19	1	2	11.11	0.52	0.88	17
5	P146	stone	113	4141	0	5.60	2.50	10.50	25	0	50	25	3	3	19.39	0.73	0.88	17
5	P147	shrub	114	4141	3	5.70	5.50	11.00	15	60	10	15	2	2	10.34	0.45	0.90	23
5	P148	grass	118	4141	0	5.60	1.50	12.50	70	5	5	20	2	2	11.11	0.52	0.88	16
5	P149	shrub	121	4141	5	5.80	3.50	9.00	5	70	5	20	1	2	10.34	0.45	0.90	19
5	P150	stone	125	4141	0	5.70	2.50	9.00	10	10	60	20	2	2	19.39	0.73	0.88	16
6	P151	grass	2	4155	0	5.50	7.00	17.50	70	10	5	15	4	4	8.01	0.38	0.88	21
6	P152	stone	7	4155	0	6.00	3.50	15.00	15	5	70	10	4	3	23.79	0.39	0.88	24
6	P153	shrub	13	4154	5	5.60	4.00	2.00	2	65	5	28	2	1	13.20	0.89	0.90	23
6	P154	grass	16	4154	0	5.50	6.00	12.00	75	2	7	16	4	4	8.01	0.38	0.88	21
6	P155	stone	11	4154	0	5.90	4.00	10.50	5	15	65	15	3	4	23.79	0.39	0.88	18
6	P156	shrub	20	4154	0	5.70	4.50	10.50	5	70	0	25	3	3	13.20	0.89	0.88	20
6	P157	grass	32	4153	0	5.50	3.50	11.50	75	1	5	19	4	4	7.24	0.35	0.88	16
6	P158	stone	41	4153	3	5.80	5.50	4.50	8	5	80	7	2	3	14.74	0.80	0.90	20
6	P159	shrub	38	4153	5	5.60	3.00	7.50	4	70	10	16	0	2	14.60	0.93	0.92	20
6	P160	grass	28	4153	0	5.60	4.00	11.50	60	0	30	10	3	3	7.24	0.35	0.88	17
6	P161	stone	35	4153	5	5.80	3.50	9.50	10	0	60	30	3	3	14.74	0.80	0.92	21
6	P162	shrub	47	4153	0	5.50	3.00	7.00	5	75	10	10	2	2	14.60	0.93	0.88	18
6	P163	grass	59	4153	10	5.30	4.50	11.00	80	1	3	16	3	4	9.30	0.49	0.95	24
6	P164	shrub	68	4153	15	5.60	3.00	9.00	5	75	5	15	0	0	12.41	0.59	0.97	19
6	P165	stone	66	4152	10	6.10	4.00	8.00	20	7	50	23	3	3	18.36	0.71	0.95	20
6	P166	shrub	54	4152	10	5.70	5.00	7.00	15	70	0	15	3	4	12.41	0.59	0.95	22
6	P167	stone	72	4152	9	6.00	4.50	7.50	20	7	55	18	4	3	18.36	0.71	0.94	22
6	P168	grass	70	4152	9	5.30	5.00	12.50	60	5	20	15	4	3	9.30	0.49	0.94	21
6	P169	grass	83	4152	20	5.30	8.00	9.50	75	5	10	10	3	3	9.05	0.55	0.98	18
6	P170	stone	93	4152	20	5.40	2.50	9.00	5	10	80	5	1	1	18.61	1.02	0.98	18
6	P171	shrub	95	4152	20	5.60	2.50	11.00	10	85	2	3	0	0	13.70	0.57	0.98	14
6	P172	grass	97	4152	17	5.30	5.00	13.50	70	0	10	20	3	2	9.05	0.55	0.97	18
6	P173	stone	85	4152	21	5.40	3.50	7.50	10	0	75	15	3	3	18.61	1.02	0.98	17

APPENDIX II CONTD....

goth no.	Plot no.	Habitat	dist	alt	slop	pH	moist	sdepth	hcov	shcov	rcov	bsoil	dung	tramp	om	nitrogen	ri	species
6	P174	shrub	88	4152	23	5.70	4.00	10.00	2	80	10	8	2	2	13.70	0.57	0.98	20
6	P175	grass	102	4153	25	5.80	1.00	7.50	60	5	10	25	1	2	13.70	0.79	0.98	20
6	P176	shrub	110	4155	15	5.70	3.00	11.00	3	90	5	2	0	0	16.29	0.77	0.96	19
6	P177	stone	125	4155	5	5.70	6.00	6.50	10	5	70	15	0	1	16.29	0.85	0.92	20
6	P178	grass	117	4155	7	5.80	6.50	8.50	70	5	15	10	3	3	13.70	0.79	0.93	21
6	P179	stone	108	4155	11	5.70	4.00	8.50	12	15	60	13	2	3	16.29	0.85	0.95	18
6	P180	shrub	122	4155	9	5.60	5.50	7.50	5	61	20	14	1	2	16.29	0.77	0.94	21

APPENDIX III

General feature of sampling plots in different habitat patch plots and combined patches plots.

Variables abbreviations follow Table 2.1. Sd = standard deviation

	grass				shrub				stone				combined			
Variables	**Min**	**Mean**	**Max**	**Sd**	**Min**	**Mean**	**Max**	**Sd**	**Min**	**Mean**	**Max**	**Sd**	**Min**	**Mean**	**Max**	**Sd**
dist	2.00	62.38	129.00	3781.00	1.00	64.13	125.00	37.20	2.00	63.98	125.00	37.65	1.00	63.50	129.00	37.35
alt	3539.00	3815.00	4155.00	251.68	3539.00	3815.00	4155.00	251.74	3539.00	3814.00	4155.00	251.80	3539.00	3814.00	4155.00	250.33
slop	0.00	3.13	25.00	5.03	0.00	4.60	23.00	5.47	0.00	3.40	21.00	4.58	0.00	3.71	25.00	5.05
pH	5.20	5.60	6.00	0.21	4.60	5.51	6.60	0.25	5.10	5.74	6.90	0.28	4.60	5.62	6.90	0.26
moist	0.50	4.39	8.00	1.98	2.00	4.96	8.00	1.83	1.00	4.50	8.00	1.89	0.50	4.62	8.00	1.91
sdepth	6.50	12.30	19.00	3.15	2.00	10.13	29.00	3.35	4.50	8.46	15.00	1.91	2.00	10.30	29.00	3.26
ri	0.79	0.87	0.98	0.03	0.74	0.87	0.98	0.04	0.79	0.87	0.98	0.03	0.74	0.87	0.98	0.04
vcover	50	68.45	85	8.07	60	83	98	8.89	10	31.18	50	10.92	10	60.89	98	23.79
rcov	0.00	5.51	30.00	6.05	0.00	4.35	20.00	5.05	30.00	54.00	80.00	11.70	0.00	21.29	80.00	24.57
bsoil	10.00	26.12	50.00	9.45	2.00	12.62	38.00	7.17	3.00	14.98	35.00	7.81	2.00	17.91	50.00	10.19
dung	0.00	3.11	4.00	0.95	0.00	1.36	4.00	0.99	0.00	2.48	4.00	1.08	0.00	2.32	4.00	1.24
tramp	2.00	3.28	4.00	0.76	0.00	1.73	4.00	0.89	1.00	2.73	4.00	0.91	0.00	2.58	4.00	1.07
om	4.13	10.47	21.00	3.74	5.94	12.85	18.22	2.32	11.11	16.11	23.79	3.68	4.13	13.36	23.79	4.03
nitrogen	0.22	0.54	1.23	0.21	0.26	0.56	0.93	0.17	0.23	0.83	1.32	0.21	0.22	0.65	1.32	0.24
species	12.00	18.20	25.00	3.35	14.00	20.63	26.00	3.27	9.00	19.65	29.00	3.89	9.00	19.49	29.00	3.63

APPENDIX IV

Correlation between measured environmental variables

Variable with significant correlation (*p<0.05*) are bold (*n = 60* for grass, shrub, stone and *n = 180* for combined).Variables abbreviations follow Table 2.1. a) grass b) shrub c) stone d) combined.

a) grass

	dist	alt	slop	pH	moist	sdepth	ri	vcover	rcov	bsoil	dung	tramp	om	nitrogen	Species
dist	1	-0.02	**0.3**	0.03	0.07	-0.24	0.05	-0.03	0.24	-0.14	**-0.49**	**-0.48**	-0.05	-0.13	**0.36**
alt		1	0.24	-0.23	**-0.26**	-0.13	**0.53**	**0.46**	**0.31**	**-0.61**	-0.08	-0.03	0.09	0.03	-0.13
slop			1	-0.22	0.03	-0.16	**0.44**	0.14	0.21	**-0.26**	**-0.25**	**-0.29**	-0.00	0.08	0.14
pH				1	**-0.29**	**-0.27**	-0.09	**-0.30**	-0.08	**0.31**	-0.05	0.13	0.25	**0.38**	0.03
moist					1	**0.3**	-0.03	0.02	-0.08	0.02	0.22	0.05	-0.15	-0.16	0.13
sdepth						1	-0.22	0.10	**-0.40**	0.17	0.22	0.06	**-0.36**	**-0.32**	-0.23
ri							1	0.11	0.25	-0.25	-0.03	-0.06	0.14	0.13	0.10
vcover								1	-0.14	**-0.76**	-0.15	-0.07	-0.22	-0.20	-0.06
rcov									1	**-0.52**	-0.10	-0.22	-0.07	-0.11	0.23
bsoil										1	0.18	0.18	0.23	0.24	-0.10
dung											1	**0.60**	-0.02	0.01	-0.19
tramp												1	0.15	0.08	-0.09
om													1	**0.73**	0.16
nitrogen														1	-0.00
species															1

b) shrub

	dist	alt	slop	pH	moist	sdepth	ri	vcover	rcov	bsoil	dung	tramp	om	nitrogen	species
dist	1	0.03	0.15	-0.1	-0.12	-0.08	0.11	0.03	0.14	-0.12	**-0.31**	**-0.36**	**-0.39**	**-0.36**	-0.06
alt		1	**0.28**	**0.32**	**-0.48**	**-0.29**	**0.58**	-0.04	**0.34**	-0.17	-0.05	-0.01	0.04	**0.36**	-0.20
slop			1	**0.31**	-0.09	-0.02	0.16	0.06	0.10	-0.07	-0.21	-0.12	0.08	0.16	-0.10
pH				1	-0.01	-0.08	0.10	-0.24	0.21	0.13	0.01	0.09	0.22	**0.37**	0.06
moist					1	**0.34**	**-0.32**	-0.10	-0.28	0.20	0.11	0.22	-0.09	-0.22	0.07
sdepth						1	-0.19	-0.02	-0.14	0.12	-0.17	0.10	-0.07	**-0.31**	0.01
ri							1	0.01	0.20	-0.15	0.00	-0.16	0.15	0.16	-0.20
vcover								1	**-0.50**	**-0.82**	-0.01	-0.14	-0.18	**-0.29**	-0.25
rcov									1	-0.07	-0.06	0.11	0.19	**0.37**	0.12
bsoil										1	0.05	0.09	0.09	0.10	0.22
dung											1	**0.56**	0.22	0.13	**0.28**
tramp												1	0.06	0.08	0.23
om													1	**0.75**	**0.31**
nitrogen														1	0.19

APPENDIX IV CONTD....

species	1

c) stone

	dist	alt	slop	pH	moist	sdepth	ri	vcover	rcov	bsoil	dung	tramp	om	nitrogen	species
dist	1	0.00	0.09	-0.12	0.05	**-0.32**	0.05	**-0.27**	0.24	-0.00	-0.23	**-0.32**	0.07	0.12	0.01
alt		1	0.19	0.22	**-0.41**	0.03	**0.57**	**-0.30**	**0.47**	**-0.31**	0.05	0.02	0.20	**-0.41**	-0.18
slop			1	0.01	-0.23	-0.21	**0.37**	**-0.27**	0.21	0.04	-0.12	-0.16	0.14	0.16	-0.11
pH				1	**-0.4**	0.09	-0.06	**0.29**	**-0.30**	0.02	0.20	0.10	-0.01	-0.31	0.14
moist					1	0.10	-0.05	-0.12	0.05	0.09	0.10	0.13	0.05	**0.28**	0.14
sdepth						1	-0.01	0.06	-0.10	0.10	0.22	0.16	-0.01	-0.17	0.13
ri							1	**-0.36**	**0.39**	-0.07	0.07	0.03	**0.27**	0.10	0.07
vcover								1	**-0.75**	**-0.23**	-0.10	0.14	-0.21	0.04	0.06
rcov									1	**-0.44**	-0.20	**-0.32**	0.27	-0.04	-0.21
bsoil										1	**0.28**	**0.27**	-0.11	-0.01	0.24
dung											1	**0.78**	0.18	-0.03	0.14
tramp												1	0.19	0.008	0.18
om													1	**0.3**	0.05
nitrogen														1	0.01
species															1

d) combined

	dist	alt	slop	pH	moist	sdepth	ri	vcover	rcov	bsoil	dung	tramp	om	nitrogen	species
dist	1	0.00	**0.19**	-0.10	0.01	**-0.18**	**0.72**	-0.04	0.08	-0.09	**-0.29**	**-0.32**	-0.06	-0.08	0.01
alt		1	**0.24**	0.11	**-0.38**	-0.13	**0.56**	0.00	0.12	**-0.31**	-0.02	-0.00	0.10	-0.02	**-0.16**
slop			1	0.02	-0.07	-0.11	**0.30**	0.05	0.01	-0.14	**-0.23**	**-0.22**	0.06	0.08	0.00
pH				1	**-0.29**	**-0.16**	0.01	**-0.32**	**0.26**	0.12	**0.16**	**0.19**	**0.23**	**0.24**	0.05
moist					1	**0.21**	-0.15	0.05	-0.05	0.02	0.04	0.03	-0.04	-0.03	**0.14**
sdepth						1	-0.15	**0.29**	**-0.42**	**0.32**	**0.16**	**0.19**	**-0.39**	**-0.42**	-0.12
ri							1	-0.08	0.13	-0.11	0.04	-0.02	0.16	0.13	-0.02
vcover								1	-0.91	-0.13	**-0.24**	**-0.23**	**-0.46**	**-0.52**	0.02
rcov									1	**-0.27**	0.05	0.05	**0.52**	**0.52**	0.01
bsoil										1	**0.41**	**0.41**	**-0.18**	-0.04	-0.07
dung											1	**0.77**	-0.01	0.05	-0.08
tramp												1	0.00	0.07	-0.07
om													1	**0.68**	**0.20**
nitrogen														1	0.06
species															1