1. INTRODUCTION

The Mountains of the Himalayan region represent the longest bioclimatic gradient, i.e. Himalayan altitudinal gradient, which contains varied vegetation types and a very wide range of ecoclimatic zones (Dobremez, 1976). These Himalayan Mountains differ in altitude, topography, status of soil and climatic conditions which favors high species richness and thus supports different forest types. Climate changes with altitudinal gradients within a mountain system that results in habitat differentiation and promote the diversification of the plant species (Brown, 2001). This makes them ideal for exploring ecological and evolutionary adaptation of biota to different environmental influences within a short geographical distance (Körner, 2007). Therefore, these mountain ecosystems are excellent systems for evaluating ecological and biogeographical patterns and theories of species richness (Körner, 2000), and have been considered by many researchers as major area to test elevation-related problems and hypotheses (Nouges-Bravo *et al.,* 2009).

Species richness is the most widely used measure of diversity (Stirling & Wilsey, 2001) which is assumed as a simple and easily interpretable indicator of biological diversity (Peet, 1974; Whittaker, 1977). In most of the biodiversity assessment studies, species diversity is quantified just in terms of species richness (total number of species per unit area or number of species recorded in a sampling unit) or sometimes species-density when the sample size is expressed in terms of area (Cox & Moore, 2007).

The gradient analysis of vegetation had been long recognized (Whittaker, 1967) and now both latitudinal and altitudinal gradient in vascular plant species richness have been analysed. The ecological variation associated with an elevation range of 800 m is equivalent to a latitudinal distance of approximately 6000 km (Korner, 2002). It has long been known that richness of vascular plant species decreases with increasing latitude (Wallace, 1878; Pianka, 1966; Brown & Lomolino, 1998) and altitude (Mac Arthur, 1969; Begon *et al.*, 1990; Rohde, 1992; Rahbek, 1997; Brown & Lomolino, 1998; Givnish, 1999). Variation in species diversity along altitudinal gradients and available soil moisture shows similar pattern as latitudinal variations (Simpson, 1964; Cook, 1969).

Thus the altitudinal gradient of species richness is often considered as the mirror of latitudinal gradient (Stevens, 1992; Rahbek, 1995).

The early researchers, such as Darwin (1839, 1859); Wallace (1876, 1878) and Merriam (1890) drew the attention of striking ecological changes that occur along altitudinal gradients (cited in McCain 2004). The studies upon species richness along altitudinal gradients became increasing popular during the last few decades and the knowledge about the diversity patterns is accumulating rapidly (Rahbek, 1995, 2005). Patterns of changes in species richness with altitude characterize the vegetation in a simple but powerful way. Generally, species richness is lower at higher altitudes because of the cooler environments as one ascends mountains as the number of species decreases in progressively cooler climates moving from Tropical to Polar Region (Ohlemuller & Wilson, 2000).

The general concept of species richness pattern with altitude revealed that as the altitude increases the species richness decreases (Woodward, 1987; Stevens, 1992; Körner, 1995; Brown & Lomolino, 1998; Fossa, 2004). On the basis of several reviewed papers, Rahbek (1995, 1997) came to the conclusion that, in general there are three main patterns of species richness as: a monotonic decline in species richness from low to high elevation; a hump-shaped pattern with a maximum richness at mid-elevation or essentially a constant from the lowlands to mid-elevations followed by a strong decline further up. Lesser number of species at lower and higher altitude and greater number of species around the middle altitude, a unimodal relationship, is the most common pattern of species richness along the altitudinal gradient and this is also proved by various researches investigated on plants and animals in different parts of the world (Rahbek 1995, 1997; Brown, 2001; Lomolino, 2001; Grytnes & Vetaas, 2002; Carpenter, 2005; Nogues-Bravo *et al.,* 2009; Rowe & Lidgard, 2009).

Several researches have been done for altitudinal gradients in different plants and animals groups in various part of the world and found a specific pattern. The trend of monotonic decrease of species with altitude was found for birds and mammals in Andes of Southeastern Peru (Patterson *et al.,* 1998); vascular plants in western Norway (Odland & Briks, 1999) and New Zealand (Ohlemuller & Wilson, 2000). But species richness when studied on mountain environment often shows a mid-elevation peak in species richness i.e. the highest number or density of species occur at a certain range of mid-elevations whereas species richness or density declines towards the mountain tops or latitudes. Various studies have been done to prove this species trend in several mountain ranges and taxa, including vascular plants in Norway (Grytnes, 2003), India / Himalayas (Oomen & Shanker, 2005) and Switzerland the Alps (Wohlgemuth *et al.,* 2008) ; ants in Colarado, Nevada and Utah (Sanders, 2002); little invertebrates in Panama (Olson, 1994); small mammals in Madagascar (Goodman & Carleton, 1996), Philippines (Heaney, 2001), Mexico (Sanchez-Cordero, 2001), Nevada & Utah (Rickart, 2001) and Costa Rica (Mc Cain 2004); birds in South America (Rahbek, 1997) and Colombia / the Andes (Kattan & Franco, 2004).

It has been long recognized about the importance of scale in ecology for resolution of geographical patterns of species richness (Whittaker, 1977; Ricklefs, 1987, 2004; Levin, 1992; Schneider, 1994). The ecological reasons for variation in vegetation or different floristic composition is determined by radiation, moisture and temperature balance on both broad and local scales (Woodward, 1987). Competition, predation and population dynamics are main causes in the species richness at local scale but it also influence the number of species at large or regional scales. Confining a particular scale in floristic study is important because scales determine patterns to explain variation in species richness.

At broad scale, species richness is generally found to increase monotonically with higher evapotranspiration or productivity (Currie, 1991; Austin *et al.*, 1996; Grytnes *et al.*, 1999), but the trend is different at a local scale where maximum species richness has frequently been found at intermediate productivity levels, and hence has a unimodal relationship (Moore & Keddy, 1989; Theodose & Bowman, 1997). Scale consist both the size of study area and the size of sampled plots, used for the study (Wiens, 1989). Small plot size may cause a unimodal relationship between species richness and biomass (Abrams, 1995; Oksanen, 1996), whereas a large plot size may be inappropriate for detecting local processes that cause a unimodal pattern (Grime, 1997). This, in fact, is important to determine the pattern in species distribution along different parameter and the patterns of species richness may vary at local and broad scale study.

The methods adopted to collect data for the study may influence the species distribution in space. Interpolation of species presence between the lower and the upper extremes of recorded altitudinal ranges used in the study may also be a factor for creating the hump-shaped pattern (Rahbek, 1997; Sanders, 2002; Vetaas & Grytnes, 2002). As altitude is a complex factor, it itself represents a complex combination of related climatic variables closely related with numerous other environmental properties i.e., texture, moisture, pH, nutrients etc. (Ramsay & Oxley, 1997).

With increasing altitude there is often a change in total land area, environmental stress including climatic factors such as temperature, duration of snow cover, disturbance, competition and historical and evolutionary factors associated with isolation (Rahbek, 1995; Lomolino, 2001; Körner, 2002; Bhattarai & Vetaas, 2003; Grytnes, 2003). Pattern in species richness measured either for altitudinal intervals or species density with altitude are attributed to a range of factors acting independently, or different factor act together that determine the pattern (Nogues-Bravo *et al.*, 2009). Thus, altitudinal gradient itself is a major factor that brings changes in a range of factors, responsible for affecting species density (Grytnes, 2003).

The mechanisms underlying the patterns of species richness in altitudinal gradients have been derived from the same examined factors proposed to bring the changes about the latitudinal gradient in species richness (Stevens, 1992). Conventional explanations for species richness patterns include the influence of area, temperature, energy and productivity, topography and history (Rosenzweig, 1995; Rahbek, 1995, 1997; Lomolino, 2001; Brown *et al.,* 2004). In addition to these, the exploration of null models (Colwell & Hurtt, 1994; Lyons & Willig, 1997) led to the prediction of the mid-domain effect (MDE) and Rapoports's elevation rules are also the major. The MDE predicts the geometric constraints imposed by hard boundaries result in greater overlap of species ranges in the middle of sample domains lead to an emergent mid-domain peak in richness (Colwell & Lees, 2000). Rapoport's elevational rule proposes that there is a positive correlation between elevation and the elevational range of species (Stevens, 1992). This is usually explained by the fact that species occurring at high elevation must be able to withstand a broad range of climatic conditions and lead to a wide elevational range. This in turn, leads to more species because of a spillover effect around the range edges called a rescue effect (Stevens, 1992).

Researches based upon the species richness and altitude in the Nepalese Himalayas also shows a unimodal relationship. These studies are mainly based on the interpolation (Grytnes & Vetaas, 2002; Vetaas & Grytnes, 2002; Baniya *et al*., 2010; Bhattarai *et al.*, 2004a) and the empirical study (Bhattarai & Vetaas, 2003; Carpenter, 2005, Panthi *et al*., 2007; Rijal, 2009). Grytnes & Vetaas (2002) concluded that interpolation species richness showed a hump - shaped structure and the peak for interpolation species richness of flowering plants in Nepal is found between 1500 m & 2500 m & a plateau between 3000 m & 4000 m. Similarly, species richness of ferns peaked at 1900 m (Bhattarai *et al*., 2004a), Bryophytes & Mosses at 2800 m or 2500 m respectively (Grau *et al.*, 2007), Lichens at 3100 m - 3400m (Baniya *et al*., 2010) and orchids at 1600 m (Acharya *et al*., 2011).

The empirical study on species density and elevation from the eastern Nepal shows a unimodal pattern for understory plants and trees (Carpenter, 2005). Bhattarai & Vetaas (2003) used empirical data for vascular plants from eastern Nepal between 100 and 1500 m and found a hump shaped pattern for all spermatophytes, shrubs and trees, while, woody climbers and ferns showed a positive monotonic trend with elevation. Climbers, herbaceous climbers, all herbaceous plants and grasses have no significant relationship with elevation (Bhattarai & Vetaas, 2003). A monotonic decrease (Bhuju & Rana, 2000; Paudel, 2010) and a unimodal pattern (Rijal, 2007, 2009) were found as patterns of species richness from eastern and central Nepal respectively.

The general pattern of plant species richness also reflects the species composition and abundance of the area and the similar factors like slopes, altitude, aspect and other environmental factors also influence species composition (Ellu & Obua, 2005). Diversity of lifeforms i.e., species composition, usually changes with increasing altitude and one or two lifeforms only remains at extreme altitudes (Pavon *et.al*, 2000). Plant species richness and composition varies according to the lifeforms or functional groups of plants (woody & herbaceous, monocots or dicots) (Peet, 1978; Bhattarai & Vetaas, 2003; Pausas, 1994; Minchin, 1989); pteridophytes (Jacobsen & Jacobsen, 1989; Bhattarai *et al.,* 2004a; Kluge *et al.,* 2006); bryophytes (Grau *et al.,* 2007) and even in lichens (Baniya *et al.,* 2010).

Majority of the studies about the species richness patterns and composition along the altitudinal gradient Nepal are based on the secondary data derived from other published literatures i.e., the method of interpolation (Grytnes &Vetaas, 2002; Bhattarai *et al.,* 2004a; Grau *et al.,* 2007; Baniya *et al.,* 2010; Acharya *et al.,* 2011). Interpolation underestimates the species richness at the extremes and produces a spurious mid-elevation peak as it assumes the presence of species between the extremes (Grytnes & Vetaas, 2002) and it also violates control over sampling area and intensity. So, the empirical studies, the direct field observation give the actual picture of the patterns about species richness.

In Nepal the empirical studies are very few and they are either confined to the specific region like subtropical (Bhattarai & Vetaas, 2003) or to the specific plant groups like trees (Carpenter, 2005). Therefore, there is still a gap for the species richness patterns studies in Nepal engaging empirical methods and including all regions. The present research was done in the less explored area, the Manaslu Conservation Area, Central Nepal based upon the field samplings in the subalpine and alpine regions including all flowering plants. Thus, the present research will add a brick to the studies of species richness patterns in the local scale and exploring the flora of the Manaslu Conservation Area. It will also be relevant to develop a documented basis of the species turnover in the forest limit areas of the subalpine and alpine areas.

Research questions

Manaslu Conservation Area presents an ideal location to carry out researches of altitudinal patterns of vascular plant richness as it integrates several distinct vertical zones and the status of the vegetation and the plant species habitats are natural. Thus following research questions were generated:

i. What is the general pattern between elevation and species richness at the local scale?

ii. How does elevation influence the distribution pattern of different plant groups?

iii. Is there any role of environmental parameter like soil moisture, pH in shaping the richness pattern at high elevations?

Hypothesis

Before field work and to answer the research question, basic hypothesis was generated as:

i. The species richness patterns decrease monotonically along the altitudinal gradient.

Objectives

To meet the major goals of the hypotheses and research questions following objectives were set to:

i. analyze the species composition and distribution of the study area.

ii. find out the species richness pattern in relation to different altitudinal range.

iii. analyze the pattern of plant species richness variation from 3000 m- 4000 m altitudinal gradient and

iv. examine the response of the plant species patterns to the existing environmental variables.

2. MATERIALS AND METHODS

2.1 Site description

2.1.1 Location

The Manaslu Conservation Area (MCA) lies in the north of the Gorkha district in the Western Development Region between the latitude 28º 21’ - 28º 45’ and longitude 84º 30’ - 85º 12’, ranging from 1400 m (Jagat) - 8163 m (Mt. Manaslu). The Manaslu Conservation Area (here after MCA) is named after the Mount Manaslu, consists of seven VDCs, Samagaun, Lho, Prok, Bihi, Sirdibas, Chumchet and Chhekampar. The present study was carried out in two VDCs namely, Samagaun and Lho from an altitudinal range between 3000 m - 4400 m.

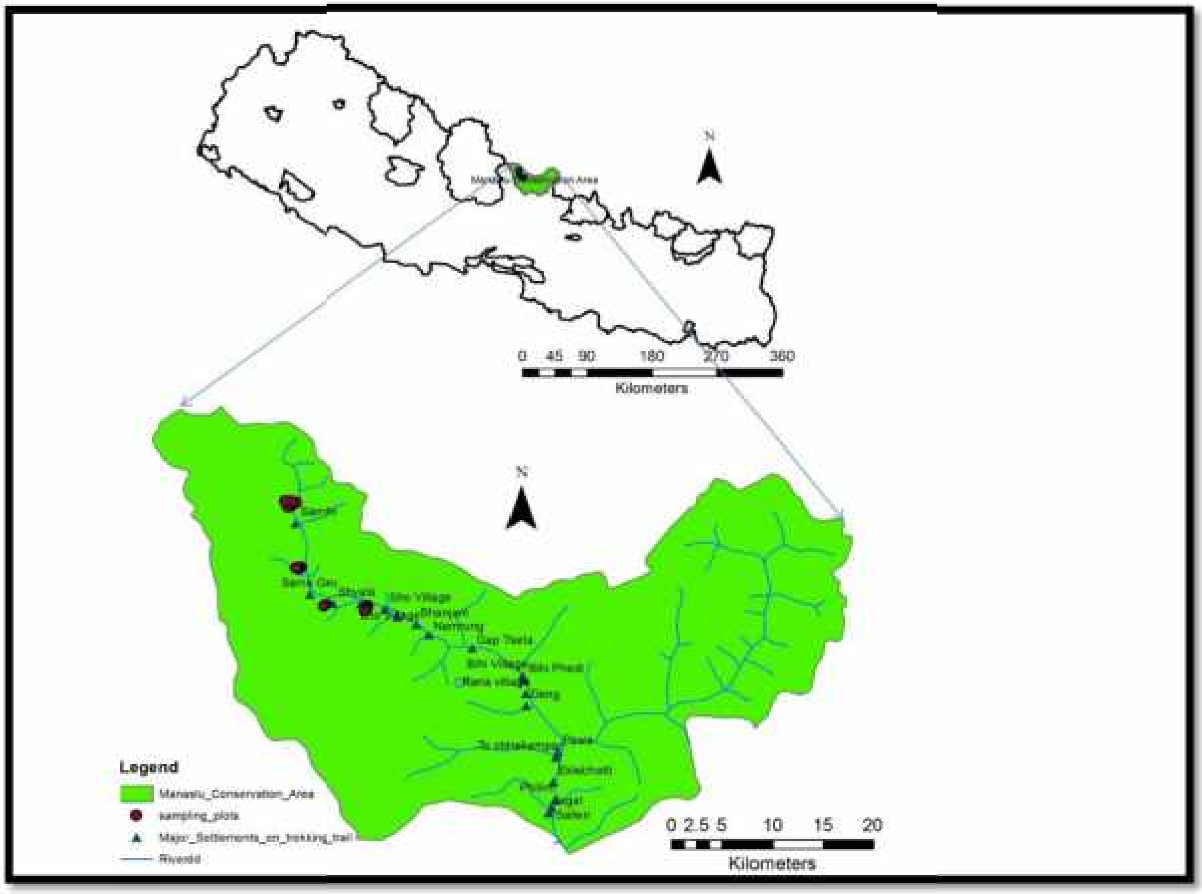


Fig. 1. Location of the study area and sampling plots (Courtesy Janardan Mainali, 2011)

2.1.2 Physiography

MCA is classified into three major physiographic regions: middle mountain region in the south, high mountain region in the middle and high Himalayan region in the north. The region is characterized by the snow Peak Mountains, cirque-headed valleys, river valleys, steep slopes, deep gorges, glacial valleys, ice fields, glaciers and glacial lands such as cirque, moraine deposit and aretes. There are a number of snow peaks in this area like The Mt. Manaslu (8163 m), 8th highest peak in the world and others as Langpo (6668 m), Himchuli (7893 m), Saula (6235 m), Sringi Himal (7187 m). The land feature is extremely rugged with deep side valley enclosed by high ridges creating a semi-arid environment at elevation ranging from 2500 m – 8000 m. MCA can be broadly categorized into three geographical areas based upon the natural setting and ethnicity. These are *Nubri valley*, the northwestern part including 3 VDCs Sama, Lho and Prok; *Kutang valley* consist of Bihi VDC and the southern area covers 2 VDCs Chumchet and Chhekampar is *Tsum valley*. The major river of the area is Buri Gandaki which is fed by a glacier originated from the Birendra Lake and other tributaries like Larke khola, Chhuli khola, Shiar khola. Lakes and glaciers are other attractions of this area. There are a number of beautiful high lakes and glaciers. The most important lakes are Kal Tal (3630 m), Birendra Tal, Prok Lake and the glaciers are Puingen glacier, Lidanda glacier, Manaslu glacier. (Source: Baskota & Shah, 1995; Mc Eachem & Shah, 1995; Gurel & Sharma, 1996 & NTNC Report, 1998).

2.1.3 Variation in geological structure and soil

Mahabharat lekh and Higher Himalayan area are the two main physio-graphical regions of this region. Geologically the Mahabharat lekh is the most complex zone composing of meta sedimentary rock of Precambrian period such as mica, schist, quartzite, garnet-mica and gneiss. This area is highly fractured area due to tremendous tectonic thrust. The higher Himalayan zone is composed of Precambrian high grades gneiss, schist and cal-silcate. It is the steeply elevated region of the Higher Himalaya. Extreme soil variation is found in the region due to variability of climate and topography. Most hills are loamy and stony loams in upper hill slopes and silt and sandy loam in the valleys and terraces. The hill soils are relatively shallow and subjected to constant erosion. (Source: Baskota & Shah, 1995; Mc Eachem & Shah, 1995; Gurel & Sharma, 1996 & NTNC Report, 1998).

2.1.4 Climate

The climatic variation in terms of temperature and precipitation of MCA is clearly noted within the short vertical distance of 100km trail between Arughat and Samdo (McEachern & Shah, 1995). There is extreme climatic contrast with tropical climate in the south to freezing climate in the north. The southern part is warmer with an average temperature of 30ºC in the summer and 10ºC in the winter; while the northern part is very cold below freezing point. Four different climatic zones are noted in this region as follows:

i. Subtropical zone (1000 m – 2000 m) with an average summer and winter temperature range between 31º to 34ºC and 8º to 13ºC respectively.
ii. Temperate climatic zone (2000 m – 3000 m) with an average summer temperature 23ºC and winter temperature 3ºC. Frost and snowfall is common in winter (January & February).
iii. Subalpine zone (3000m - 4000 m) with average temperature of 6-10ºC. Winter is very cold and there is snowfall for six months (December-May).
iv. The alpine zone (4000 m – 5000 m) and above 5000 m is the arctic climatic zone where winter is severe and snowfall is common.

In the valleys and elevated flat-land (tars), particularly in the southern and central region, the maximum temperature is 34ºC and minimum is 13ºC. June and September are the monsoon months with three-fourth of the annual rainfall. The post-monsoon period from October to November and winter months from December to February are usually dry. The rainfall ranges from 530 mm (October to November) to 1680 mm (June to September).The southern part of the region gets more rainfall than the upper sub-alpine and arctic region in the north. Beyond Jagat, the force of the monsoon is drastically reduced and diurnal valley winds are more pronounced. (Source: Baskota & Shah, 1995; Mc Eachem & Shah, 1995; Gurel & Sharma, 1996 & NTNC Report, 1998).

2.1.5 Floral diversity

Due to the altitudinal and abundance of different types of habitats and microclimatic conditions, MCA represents an ideal site for the availability of varied types of flora and vegetation within short distances. MCA lies in the border between flora of eastern and western Himalaya with the dominance of east Himalayan floral elements like *Larix himalaica, Schima wallichii* and *Castonopsis indica* whereas *Picea smithiana* is the western Himalayan element recorded from the area. The availability of very limited species of Rhododendron (*R. arboreum, R. anthopogon, R. barbatum* and *R. campanulatum*) in the MCA is undoubtedly, a west-Himalayan character while the presence of the *Rhododendron cowanianum*, a species endemic to the central Nepal, is a central Himalayan character. The flora of the region is quite interesting as large numbers of plants endemic to the country are found. The area is also rich in medicinal plants as most of the important and high value medicinal plants like *Aconitum* sp., *Nardostachys grandiflora* (Jatamansi), *Dactylorhiza hatagirea* (Panchaunle), *Valeriana jatamansi* (Sugandawal) etc are found. The flora of MCA can be categorized into 19 different forest types and about 1500-2000 species of flowering plants are estimated to record (NTNC Report, 1998; Appendix I).

Broadly the vegetation of the area can be divided into four main types. The subtropical forest lies at an altitude between 1000 m and 2000 m. *Schima wallichii, Castonopsis indica, Pinus roxburghii, Dubanga sonneratioides, Lagerstroemia parviflora, Albiza mollis, Alnus nepalensis* etc. At an altitude between 2000 m and 3000 m, the temperate vegetation with extensive forest of *Pinus wallichiana, Picea smithiana, Quercus semecarpifolia* and *Larix himalaica* are predominant. The Buri Gandaki Valley at Lho (2700 m – 3000 m) is well known as the Land of Conifer Diversity. It is a place of coniferous rich forest. In this area there are variety of coniferous trees such as *Picea smithiana, Larix himalaica, Tsuga dumosa, Abies spectabilis* and *Pinus wallichiana*. In Sub Alpine Zone between 3000m and 4000m, *Rhododendron spp., Betula utilis - Abies spectabilis, Juniper spp.* and *Picea smithiana* constitute the forests. There are also alpine meadows and grasslands in this vegetation zone. Open meadow is prevalent in Alpine Zone above 4000 m with grasses and dwarf shrubs. Nival Zone lies above 5000 m altitude and has tundra vegetation in the form of lichen and medicinal plants. (Source: Baskota & Shah, 1995; Mc Eachem & Shah, 1995; Gurel & Sharma, 1996 & NTNC Report, 1998).

2.1.6 Faunal diversity

The MCA harbors a unique environment with extremely rich biodiversity. This area encompasses suitable habitats of many protected and endangered animal species. There is a record of 33 species of mammals, 110 species of birds, 211 species of butterflies (NTNC Report, 1998). In the northern region of the MCA, the important animals are Blue sheep, Musk deer, Snow leopards, Himalayan black bears, Red pandas, Jackals, Procupines, Langur, etc. There are several bird species which are confined to small gullies sheltering broad leaf trees in the north. Choughan snow pigeons, Ruddy shelducks and Jungle crows are common bird species recorded in the area. Himalayan griffin and Lammergeyer are found in the alpine zone. In the south, there are barking deer, common leopards, jungle cats, mongooses, yellow-throated martin, porcupine, wild boar, black bears, monkeys, ghorals. (Source: Baskota & Shah, 1995; Mc Eachem & Shah, 1995; Gurel & Sharma, 1996 & NTNC Report, 1998).

2.1.7 Diversity in economic livelihood pattern

The people of MCA have different livelihood patterns. There is a contrast in the economic base of the people living in the north and south of the Manaslu Region. The people mainly depend upon the agriculture. The dominant crops are rice, wheat, barley, potato, etc. Crop farming is very limited in the north because of unfavorable climate and limited arable land. Barley, wheat, beans, soybeans and potato are major crops. Apples are also cultivated but limited to some localities.

Animal husbandry supports the farming system. In the northern region, there is enough grazing land so the animal husbandry is the major income generating source. There are more than 61 large rangelands called ‘Kharka’ in the northern region. Alpine and subalpine meadows are the major grazing lands of this area. However the productive grazing land period last for 4 to 6 months only because of severe cold climatic conditions in the winter. Lamb meat, cheese, woolen materials and butter are the animal products used by the local peoples and for tourists also. These animal products are also taken to the Tibetan market. Seasonal migration of local people is common in the MCA especially the northern area due to severe cold winter. During this time people mainly visited Pokhara, Kathmandu and also involved in trade. Tourism development is on progress in this area which has become an important economic source of the people living in the Manaslu Region. (Source: Baskota & Shah, 1995; Mc Eachem & Shah, 1995; Gurel & Sharma, 1996 & NTNC Report, 1998).

2.1.8 Cultural diversity

The MCA has multi-ethnic diversity in tradition and culture. Elevation has greatly influenced the general ethnic composition. The decrease in the Hindustic-Aryanpopulation with increasing elevation is clearly noted in this region. In the southern region, the ethnic communities are Brahmins, Chhetris, Thakuris, Kami, Sarki, Damai etc. The people of this region follow the Hinduism. In the northern region, there is Bhotia community where people mostly practice the Buddhism. All the villages are inhabited by the Bhotias practicing the Tibetan language and culture. The northern region of the MCA has many monasteries like Chhetenpork, Rajen, Serang, Namla, Namrung. These monastries have a great influence on decision making and developmental activities. (Source: Baskota & Shah, 1995; Mc Eachem & Shah, 1995; Gurel & Sharma, 1996 & NTNC Report, 1998).

2.2 Methodology

2.2.1 Sampling techniques and data collection

Preliminary study was carried out from 12 – 30, December, 2009. In that period study site and sampling areas were selected as well as general information of the floras was documented. Second visit was conducted in the month of October, 2010. In that period all the necessary data were collected.

A semi-systematic representative sampling method was used for data collection to cover all the possible habitat and vegetation types. All the sampling plots were located on the north eastern slope of the main Himalayan range. The sampling method was designed to include all the habitat types and vegetation zones within 3000 to 4400 m. Five plots of 10 × 10 m, each were sampled in each 100 m elevation band i.e., a total of 70 plots between 3000-4400 m. Each plot was divided into four sub-plots of 5 × 5 m size (Fig. 2) and species presences were recorded for each subplot separately. The first plot was laid by observing the tallest tree in the altitudinal range in the forest while in open shrub and grass land the plot is lead by altitude observation. The distance between two plots is not less than 20 m (walking distance) so that clustering of plots may not occur within the 100 m altitudinal range. To avoid biasness, the direction of next plot from the earlier was determined by lottery. Longitude, latitude, and elevation of each sample plot were recorded by global positioning system (GPS, eTrex Garmin) and elevation was cross-checked with a standardized altimeter. Slope and aspect of each plot were recorded by a clinometer compass. Soil moisture and pH of each sub-plot were recorded by using a gauge (Soil pH and moisture Tester; Model DM 15) with a default scale of 1 to 8 for both parameters.

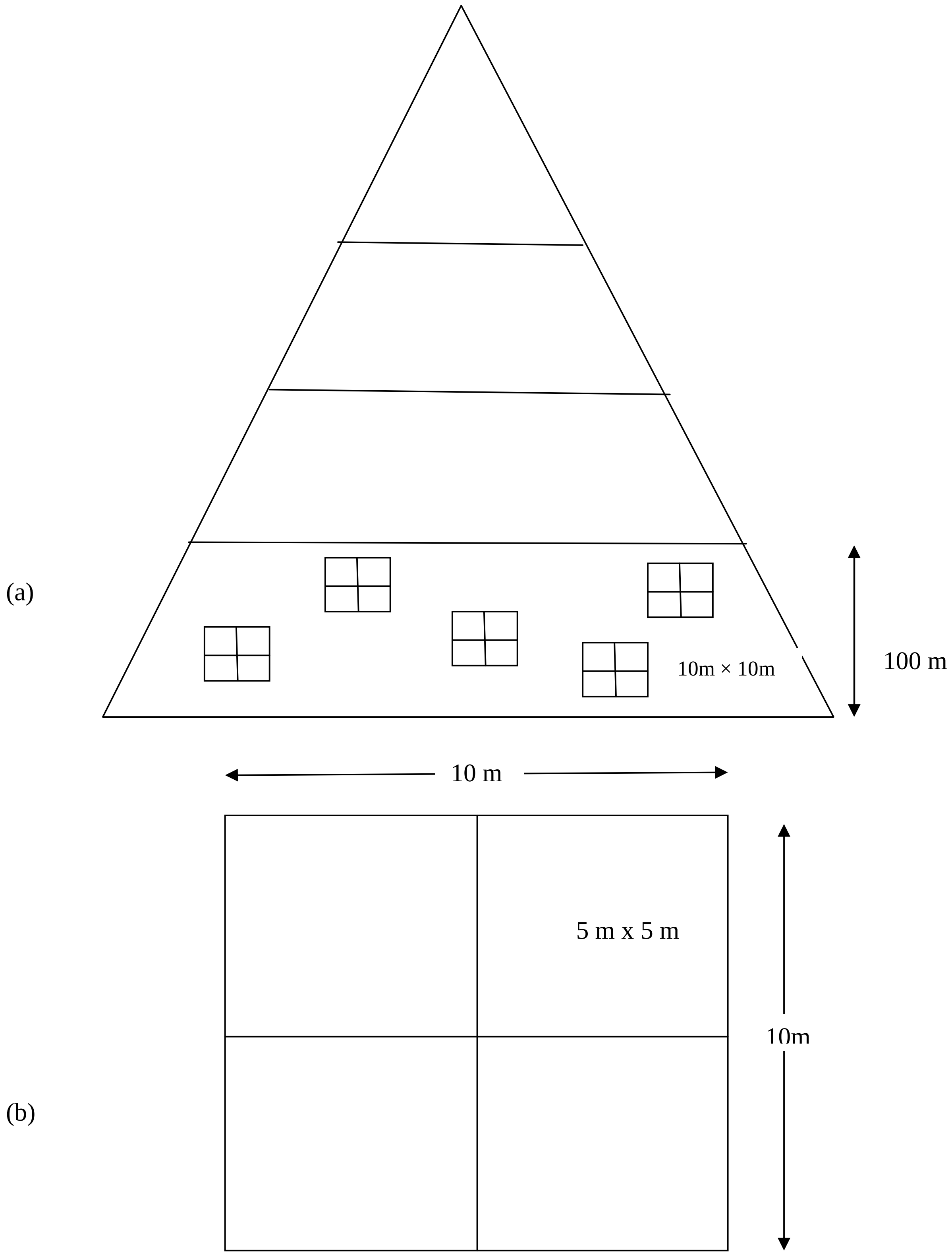


Fig. 2. Sampling design in a hypothetical mountain slope: (a) sampling strategy for each 100 m belt and (b) sampling strategy for each plot

2.2.2 Plant collection and identification

Most of the plant species were identified in the field using the floristic literatures like Polunin and Stainton (1994) and Stainton (1988). Species that could not be identified in the field were collected, tagged, dried and brought to the Central Department of Botany for further identification. Digital photographs of live plant species were taken in the field and the photo number and tag number were noted. The unidentified specimens were identified by comparing the specimens with relevant specimens deposited at Tribhuvan University Central Herbarium (TUCH) and National Herbarium and Plant Laboratories (KATH). Experts from the Central Department of Botany and KATH were consulted for further identification species along with the photographs. Tag number and photo number were used for correct naming of species. Monocotyledons were identified with the help of *Flora of Bhutan*. Press *et al.* (2000) was followed for the nomenclature. Some of the species identified to the genus level were also incorporated in the analysis. Voucher specimens are housed at TUCH.

2.2.3 Data preparation and analysis

The field data sheet were further elaborated and made reliable for the numerical analysis. The total Vascular plant species were further classified into various lifeforms or functional groups as Dicotyledons (here after dicots), Monocotyledons (here after monocots), Gymnosperms, Woody and Herbs using the *Annotated Checklist of the Flowering Plants of Nepal (*Press *et al.,* 2000). In the present study soil pH and moisture are mainly considered as environmental variables along with the altitude.

Species density is defined as the total number of species encountered within $100m^2$ or 0.01 ha plot. Species richness for each 100m band (*gamma* diversity) refers to the total number of individual species within 0.05 ha (Lomolino, 2001) thus species richness in this case is defined as the total number of unique species present in all the five plots of $100m^2$ or 0.01 ha at 100m elevation range. Interpolated empirical richness was calculated for each 100m elevation band for those species which occur between 3000-4400 m in the study. For the interpolated empirical richness, species list was taken from the field data and *An Annotated Checklist of Flowering Plants of Nepal* (Press *et al.*, 2000) was used for the elevation ranges of the species. The term species richness has been used for gamma diversity (band richness and interpolated empirical richness) for generality. Species density and species richness were treated as the response variables and regressed against altitude. Flowering plants splitted into different life-forms were also used to evaluate their richness patterns (Bhattarai & Vetaas, 2003).

Species composition of the whole study area was analyzed with the help of Detrended Correspondence analysis (DCA; Hill & Gouch, 1980). Default options like detrending by segments; non-linear rescaling and downweighting of rare species were used. DCA is one of the most popular robust indirect gradient analyses and is computionally very efficient. CANOCO version 4.5 (ter Braak, 2002) and its graphical program CANOCODRAW (Smilauer, 2002) were used to analyze the compositional pattern of the species.

Species density of total vascular plants, dicots, monocots, gymnosperms, herbs and woody plants were individually regressed against altitude while total species density was also regressed with soil moisture, pH and relative radiation index (RRI). RRI was calculated for each plot (Ôke, 1987) and its value ranges from +1 to -1. A Generalised Linear Model (GLM: McCullagh & Nelder, 1989; Dobson, 1990) was used to elucidate the pattern of species richness along the altitudinal gradient. A preliminary test showed over dispersion of the deviance thus a quasi-Poisson error distribution with an F-test stastistics was used to handle the over dispersion of the deviance (Crawley, 2007). The significance of each model was tested against the null model as well as with each other up to the second-order polynomials. Forward selection of model was done by evaluating the F-value. The model with higher F-value was selected for the model fitting and graphical representation. Presence-absence data was used for the calculation. R version 2.10.1 (R Development Core Team 2010) was used for regression analyses and graphical representation.

3. RESULTS

3.1 Species Composition and distribution

A total of 161 species were recorded from 70 different sampling plots of the study. The dicots were found dominant over the monocot representing 127 species and 24 species respectively. But in case of woody and herbaceous species the latter dominates the study including 114 species. Only 47 species of woody plants are found. The study area was highly diverse in terms of Gymnosperm. Of the total 34 species of gymnosperms (Press *et al.*, 2000) found in Nepal, the study area singly represents 10 different species within the short geographical area. By comparing the frequency of all the recorded species (Appendix II), *Potentilla cuneata* and *Viola biflora* were found dominant over the whole study area with frequency value 98.57%. Similarly, other most frequent occurring species were *Gentiana depressa, Gerbera nivea, Ligularia fischeri* etc.

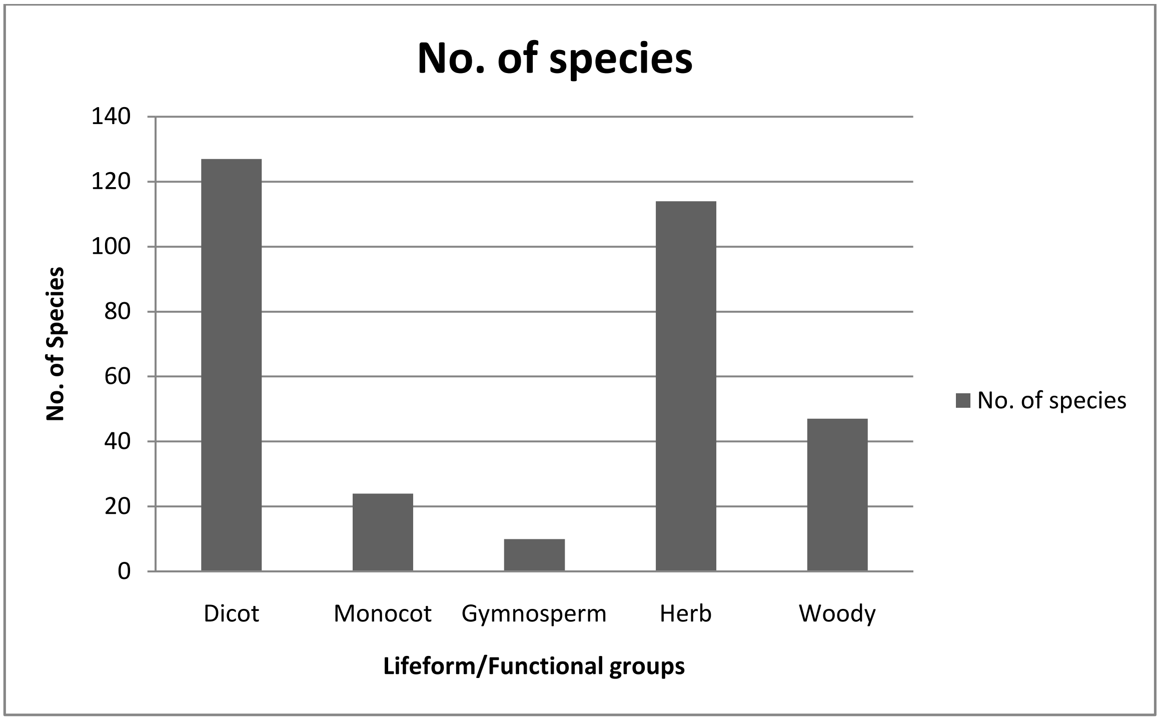


Fig.3. Diagram showing the total number of species of different lifeforms and functional groups.

Detrended correspondence analysis (DCA) on the species abundance data showed strong gradient in species composition. Distributions of the species were found associated with particular environmental gradients. As the first axis eigen value significantly told that elevation is the main underlying gradient. This is true as my sampling strategy is along altitudinal gradient. The DCA axis first showed the gradient length of 3.33 SD unit and eigen value of 0.559 (Appendix III) showed that the species composition along the first axis was heterogenous in comparison to the second and third axes. The eigen value (0.559) in DCA was found greater than 0.50 which indicates the complete turnover of species along the first axis. The length of gradient 3.33(greater than 1.5) indirectly supports the unimodal relationship of species with the altitude (Okansen 1996). The DCA first axis explained 27% of the total variance in species data.

The DCA diagram (Fig 4) showed dispersion of the species in first two axes. Most of the species showed high abundance towards the positive end of the both axes. Lesser number of species was found towards the lower and higher altitudes. Abundance of species was found abundant at and around the mid-altitudes. The species like *Abies spectabilis, Kobresia laxa, Aconogonum molle* were found at the lowest altitudes of the study while *Kobresia nepalensis, Rhododendron* anthopogon, *Morina polyphylla* at the high altitudes. Presence of many species towards the upper end and comparatively lesser at lower end of the figure indicates that there are some other variables affecting the distribution of species along with the altitudes.

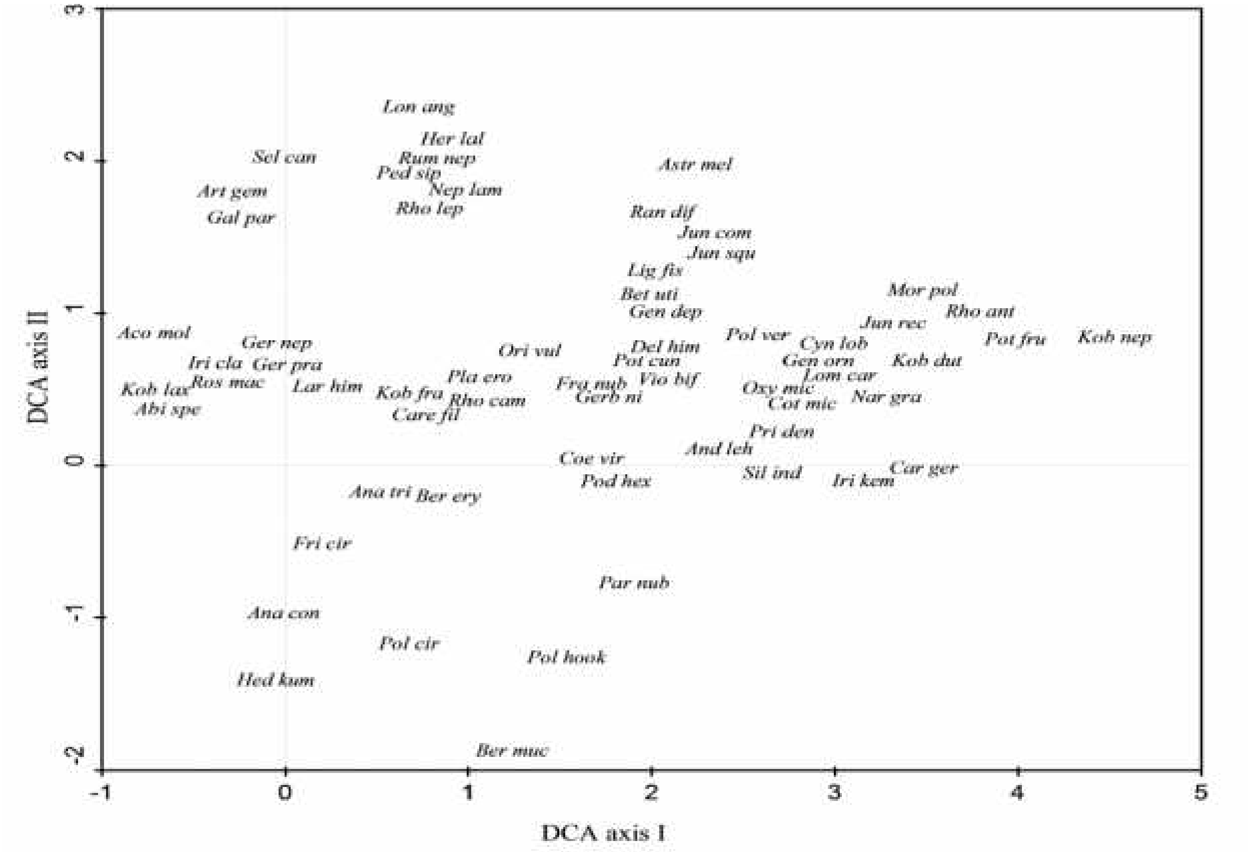


Fig. 4. DCA diagram for species distribution. Species are labeled by the first three letters of generic and species name. Complete names are given in Appendix II and for summary (see Appendix III).

3.2 Species Richness Pattern

3.2.1 Patterns of total vascular plant richness

Species density

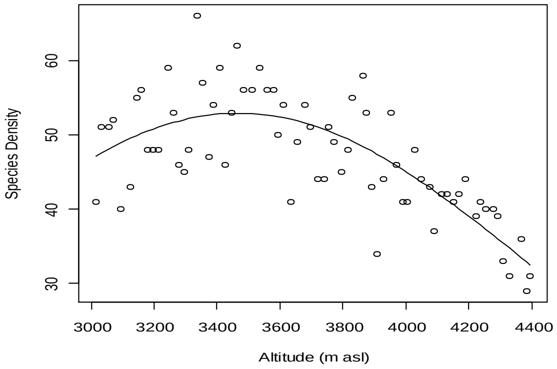
A unimodal relationship was observed between species density and altitude of whole plant group and statistically 2nd order polynomial was significant (Fig. 5 a, Appendix IV). Generally species density was lower at the upper and lower limit of the sampled altitude but in comparison to upper altitude species density lower altitude was higher. The highest species density occurred at the altitude 3462 m with the presence of 62 species. The maximum species density occurred at an altitude between 3400 m - 3600 m. From the study it was found that there was slight increase in the species density in between 3800 m – 3900 m and further up there was gentle decrease in species density.

Species richness:

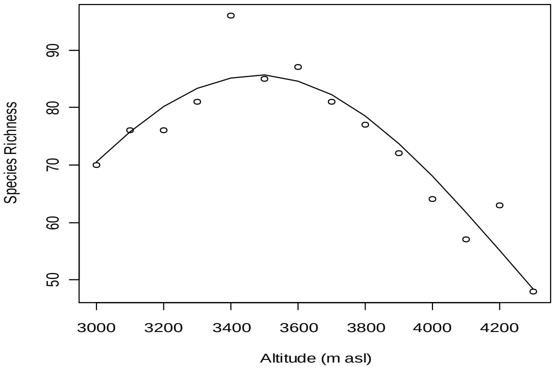
Species richness showed significant with altitude at second order polymonial. A total of 14, 100 m altitudinal band were analyzed and a unimodal or hump-shaped pattern was obtained (Fig. 5 b, Appendix IV). The species richness peaked at the range of 3400m by species 96 and gradual decrease in species afterwards.

Interpolated empirical species richness:

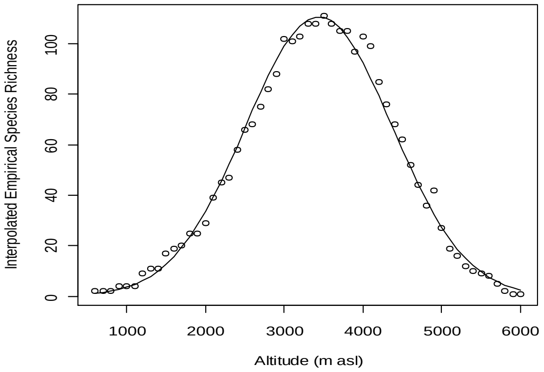
The interpolated empirical species also showed a unimodal relationship with altitude peak was found between 3400 m to 3600 m. The interpolated empirical species richness was statistically significant over the 2nd order polynomial (Fig. 5. c, Appendix IV).



(a)



(b)



(c)

Fig. 5. Relationship between plant species with altitude (lines are fitted with GLM 2nd order); see App IV for regression statistics.

3.2.2 Plant species richness of different functional groups

Species density:

Species density showed significant unimodal pattern with altitude. It was common to dicot, monocot, herbs (Fig. 6. a, b and e and Appendix V) but there was linear decrease in species density with altitude for woody species and gymnosperms (Fig. 6. c and d and Appendix V). Woody species and gymnosperms species density were higher at the lower altitudes of the gradient but the other groups peaked at the mid altitudes generally between 3400 m - 3800 m. Below and upper of this altitude there was low species density. GLM of second order was significant for dicot, monocot and herb while 1st order was more significant over 2nd order for woody species and gymnosperms.

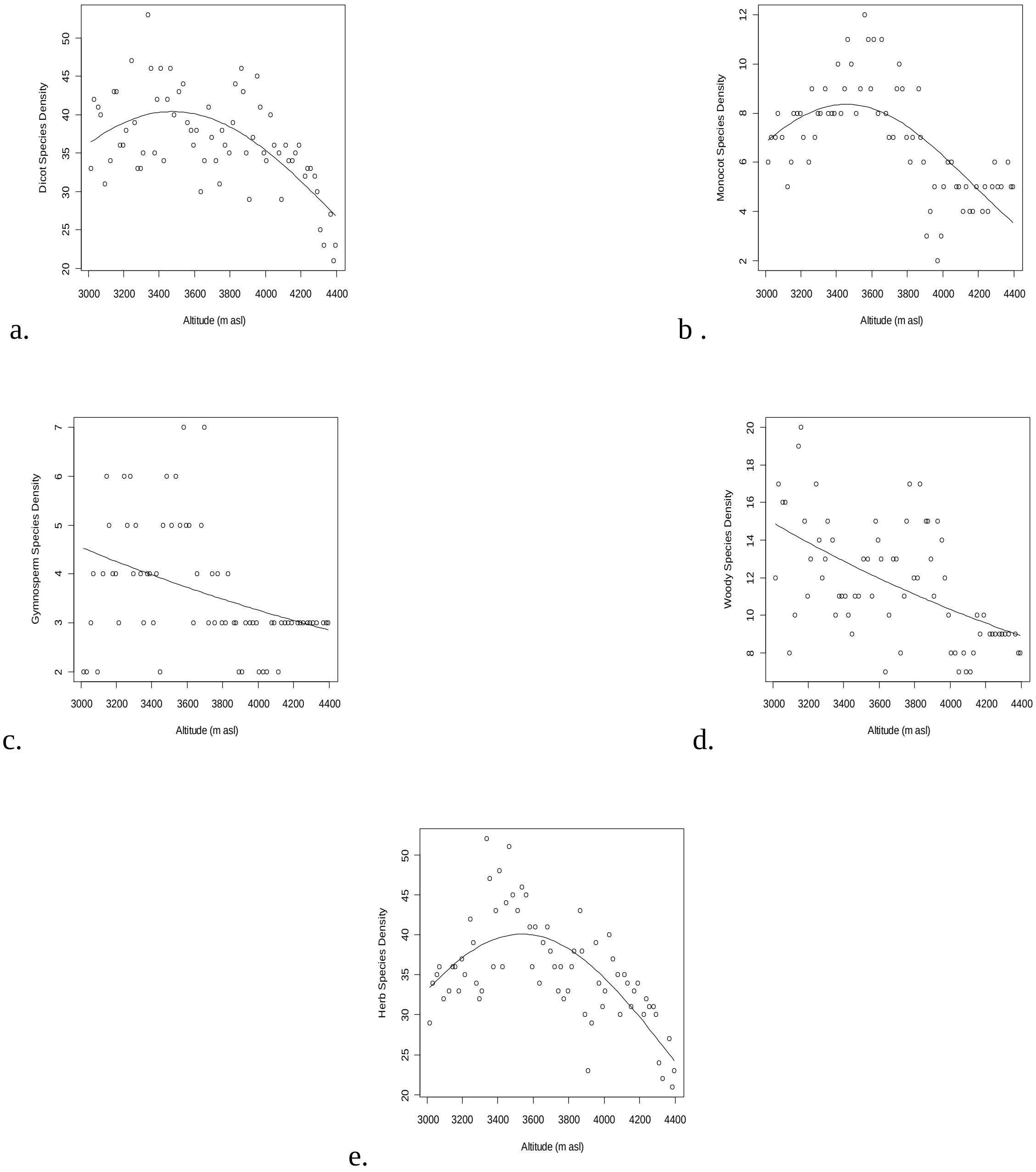
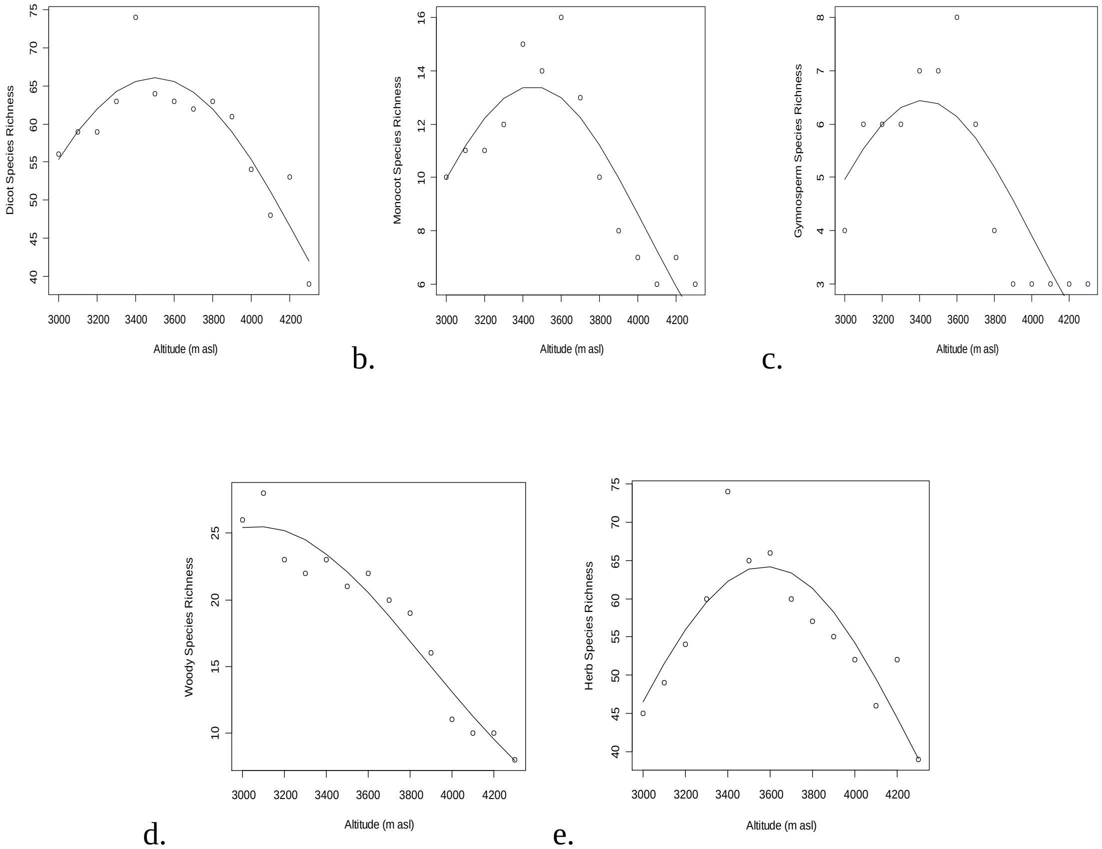


Fig. 6. Relationship between species density with altitude of different functional groups (a, b, c are fitted with 2nd order while c and d are with 1st order GLM); see Appendix V for regression statistics.

Species Richness:

Species richness of all functional group i.e., dicot, monocot, gymnosperm, woody and herb showed a humped pattern with altitude. Maximum species richness was observed at an interval of 3400 m - 3600 m for four groups excluding woody species and then linear decrease of species was found towards the high and low altitudes. But the woody species are found high at the lower elevations between 3000 m – 3200 m and approximately peaks at 3100 m. GLM of second order was significant for all groups (Fig. 7. for graphical representation and Appendix VI for regression statistics).



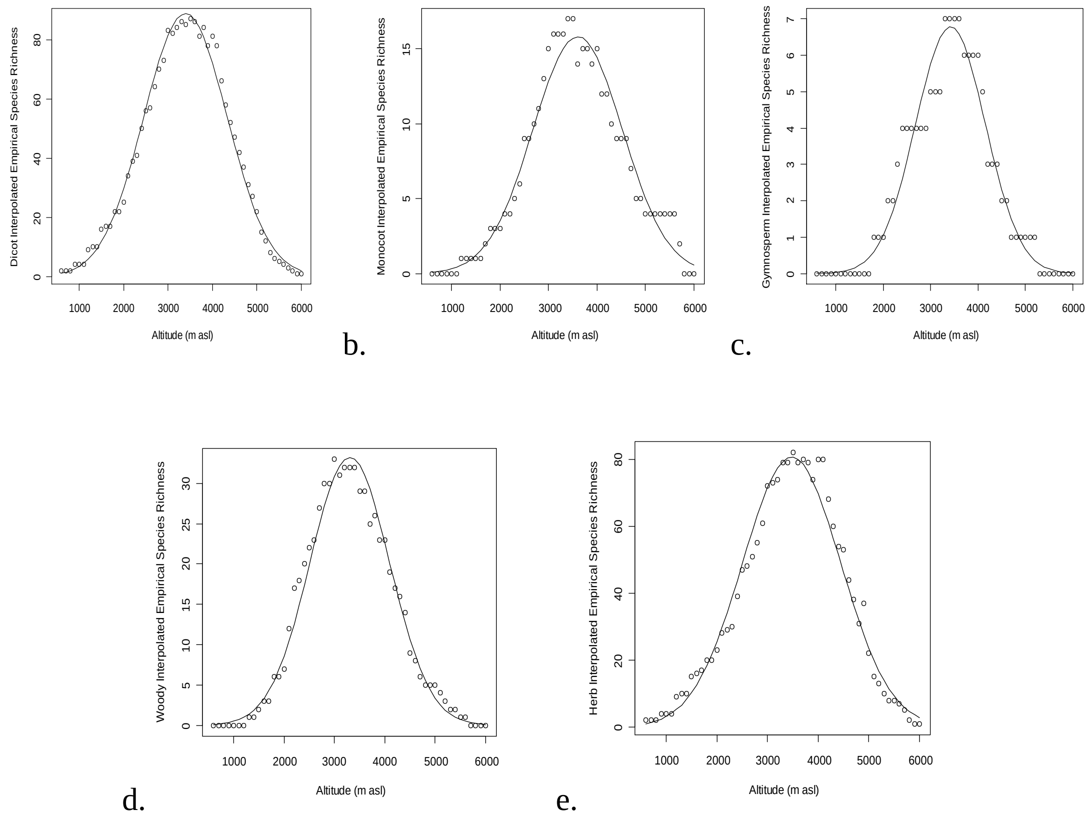
a. b. c.

d. e.

Fig. 7. Relationship between species richness with altitude of different functional groups (all are fitted with 2nd GLM); see Appendix VI for regression statistics.

Interpolated empirical species richness:

Interpolated empirical species richness along altitudinal gradient showed humped shaped pattern for all five groups. GLM of 1st order was found less significant for all so 2nd order polynomial was used to test the patterns and found strongly significant (Fig. 8. for patterns and Appendix VII for regression statistics). The result also resembled with the total interpolated empirical species richness. The maximum richness for all groups lied between the intervals of 3000 m – 3500 m. The monocot and gymnosperm interpolated richness peaked at approx. 3400 m, dicots at 3500 m while herbs peaked at 3200 m. But the highest richness for woody species was found at the lowermost gradient i.e. at an altitude of 3000 m.



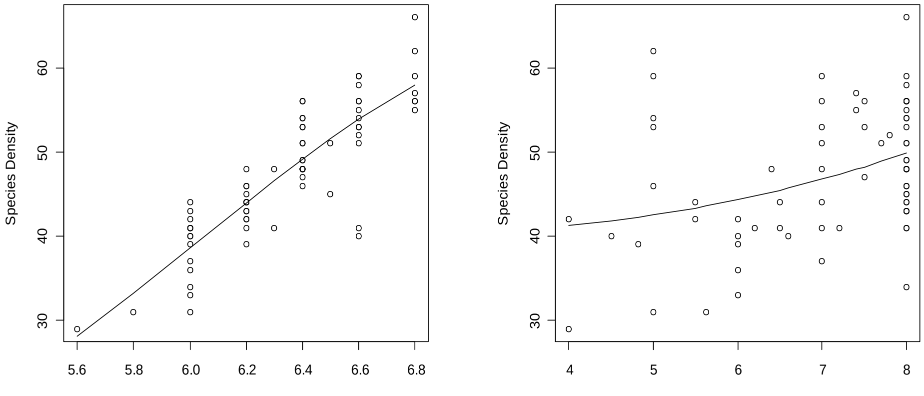
.a. b. c.

d. e.

Fig. 8. Relationship between Interpolated empirical species richness with altitude of different functional groups (all are fitted with 2nd GLM); see Appendix VII for regression statistics.

3.3 Environmental variables and species density:

The relationships between the environmental variable and species density also showed a specific pattern. The environment variables dealt in the study mainly includes soil moisture, soil pH and Relative Radiation Index (RRI). There was significant relationship found between species density pH and moisture but RRI did not reflect any trend. Both soil moisture and pH are significant over the 1st and 2nd order GLM but evaluating the F-Value they showed strong relationship at 1st order polynomial. A positive linear increase of species density was found for moisture and pH (Fig. 9. for patterns and Appendix VIII for regression statistics).



a. b.

Fig. 9. Relationship between species density and environmental variables (lines are fitted with 1st order GLM; see Appendix VIII for regression statistics).

4. DISCUSSSION

4.1 Species composition and distribution

Researches on species distribution and composition have often been used to determine the ecological drivers and the mechanism of disturbances within an ecosystem. The results of the present study indicated a regional variation in species distribution with respect to altitude. The DCA analysis explained only 27% of total variance in the species data. This low percentage of the variance explained by the axis was probably due to the larger number of zero values which might influenced the analysis. But the significance of variance explained by axes is much more important than amount of variance explained.

The result showed species composition of the study area comprised of different functional and structural groups like dicots, monocots, gymnosperms, woody and herbaceous species. Most of the species were found at the mid-altitudes, decreasing towards the lower and upper gradients thus predicting the pattern of species composition and richness as unimodal. This type of unimodal relationship of species with altitude resembled with several studies on different taxa on several mountains ranges (Grytnes, 2003; Oomen & Shanker, 2005; Grytnes & Vetaas, 2002; Vetaas & Grytnes, 2002). The woody species like *Abies spectabilis, Larix himalaica, Rhododendron campanaltum, Berberis spp.,* etc were found more abundant at the lower altitudes which suggest the decreasing trend of the woody species richness with increasing altitude. The study of Carpenter (2005) in Eastern Nepal, Aiba & Kitayama (1999) in Mount Kinabalu also showed the similarity with present study.

The DCA analysis also revealed the altitudinal distribution range of species, for example, *Kobresia laxa* (3000 m – 3500 m) and *Kobresia nepalensis* (3900 m – 4400 m) were found at the distinct part of the figure the former at the left and latter at right side, which clearly suggested that distinct species have their own distributional range in spite belonging to the same genus. Abundance of plants like *Morina, Primula, Polygonatum, Nardostachys grandiflora,* etc towards the positive end of the DCA I axis in the figure well explained the range of these species as well as distribution and composition of plants at higher altitudes. However, there are few species distributed towards the lower and upper end of the figure not showing significant relationship with the altitude. Such type of distribution may be due to other influencing factors like soil moisture or pH which may collectively interact with altitudes to determine the species distribution and composition.

4.2 Species density and richness

This quantitative study addresses the vegetation patterns, floristic distribution, life forms, and a comprehensive series of environmental factors across the full range of alpine vegetation on a representative area on the generally per humid Himalayan range. The study extended from 3000 m to 4400 m in an area that has not been significantly modified through the direct or indirect effects of human activities. The altitudinal patterns of species richness and the underlying causes have been a controversial issue for ecological research. Some studies suggest that the highest species richness appears at the mid-altitudinal zones (Sanders, 2002; McCain, 2004; Carpenter, 2005) but some indicate that species richness decreases monotonically with increasing altitude (Stevens, 1992; Ohsawa, 1995).

In this study, richness and density of seed plants at species level, showed hump-shaped patterns across a broad altitudinal range (Fig. 5. a and b) as shown by many author (Rahbek, 1995, 1997; Brown, 2000; Lomolino, 2001; Grytness & Vetaas, 2002; Carpenter, 2005; Panthi *et al.*, 2007; Nogues-Bravo *et al.*, 2009; Rijal, 2009 & Rowe & Lidgard, 2009). The species density for the three lifeforms (dicots, monocots, and herbs) followed the hump shaped pattern (Fig. 6. a, b and e) which followed the same pattern as shown by Carpenter (2005) for all understory plant in Eastern Nepal and all lifeforms in Langtang National Park, Central Nepal by Rijal (2009). But, the species density of gymnosperm and woody species showed a linear decline with altitude (Fig. 6. c and d) which didn’t follow the pattern as shown by Carpenter (2005) as he showed the hump shaped pattern of trees species with altitude. Both the richness of lifeform and total species richness in a given altitudinal belt (gamma-diversity) peaked at intermediate elevation along the altitudinal gradient. However, relative species richness within different life-form groups varied differently along the altitudinal gradient. The species richness for different life forms (dicots, monocost, gymnosperms and herbs) showed the unimodal pattern (Fig. 7. a, b, c and e) which didn't match with the trends found by Bhattarai and Vetaas (2004), where they showed that there was not any significance relationship of herbaceous plant and grasses with altitude. The richness of woody species didn't follow hump pattern (Fig. 7. d). Special combination of ecological conditions may be deterministic factor shaping this observed pattern (Lomolino, 2001; Brown 2001).

A hump-shaped pattern, where species richness increases with productivity to a maximal level and decreases at the extreme of productivity (Rosenzweig, 1971, 1995). However, productivity can be higher at intermediate altitudes due to local climatic conditions. This study supports the fact and the hump shaped pattern was found where maximum number of species was aggregated at an intermediate altitude making a unimodal pattern of species richness.

Several factors impact observed species richness–altitude patterns. The area is one among these factors. A monotonic species richness-area pattern reflects the species-area relationship, which predicts that larger areas will contain more individuals as well as greater habitat heterogeneity, and thus more species (Willing *et al.*, 2003; Rosenzweig, 1995) and has been widely observed that species richness increases as a function of area (He *et al.*, 1996; Rahbek, 1997). Area normally decreases with altitude in mountains, although high-altitude plateaus frequently occur in larger mountain chains and are often larger in area per altitudinal zone than the mid-altitude zones (Rahbek, 1995). This study did not support the fact because a hump shaped pattern was observed but to some extent the fact hold true, a linear increase or decrease in species richness was observed beyond and above mid altitudinal peak. However, the hump-shaped patterns were still identified for species, which could eliminate the effect of area (Qian, 1998). This implies that the area may not be the sole factor influencing the altitudinal diversity patterns of seed plants in study area.

Interpolation of species presence between the lower and the upper extremes of recorded altitudinal ranges used in this study may also be a factor for creating the hump-shaped pattern for interpolated empirical richness, although it has been commonly applied in previous studies (e.g. Rahbek, 1997; Sanders, 2002; Vetaas & Grytnes, 2002). Grytnes & Vetaas (2002) compared species richness patterns observed from the Nepalese Himalayan

Mountains with those derived from null models, and found that the interpolation method could underestimate species richness at the endpoints compared with the centre of an altitudinal range, thus likely generated a hump-shaped pattern. This is because the richness towards the endpoints consists only of observed species, whereas at the central regions the richness consists of the observed species and those added by interpolation. Therefore, Vetaas & Grytnes (2002) recommended not using species with narrow elevation ranges to examine the richness–altitude patterns. For this reason, this study investigated the richness patterns of species without interpolation, and found that the species richness also showed hump-shaped patterns, with the peaks at *c.* 3500 m (Fig. 5.), implying that the effect of the interpolation method on the hump-shaped patterns in our study may not be substantial. This suggests that the unimodal richness pattern of seed plants observed in this region.

The MDE due to geometric constraints (physical and biological boundaries) for species distributions is another possible cause for such hump-shaped curves (Colwell & Lees, 2000; Colwell *et al.*, 2004). Based on a null model analysis, Grytnes & Vetaas (2002) advocated that MDE was a contributor to the relationship between plant species richness and elevation in Nepalese Himalayan Mountains. Similarly, present results indicated that MDE predictions of the null models fitted the empirical patterns well. Recently, McCain (2005) analysed the published papers on the elevational biodiversity patterns of small mammals and found that the regression models between empirical species richness and MDE was small, to account the fact of hump shaped pattern.

At the regional scale, the forest limit may be regarded as a soft boundary, over which plant colonization can take place and hence create an ecotone effect. Grytnes (2003) detected an increase in plant richness well above the forest limit along altitudinal gradients. This study did not detect any richness peak near the forest limit, which didn’t support the presence of feedback effects among the two neighbouring communities (alpine grassland, forest). Contrastingly, biogeographical comparisons of Asiatic forests revealed a sharp decline in plant richness above the forest limit, which was explained by lower winter temperatures upslope (Ohsawa, 1995). Nevertheless, the study did not consider the radiation increase above the forest limit, which may enhance herb diversity at local spatial scales. Grytnes (2003) suggested that the increase in species richness above the forest limit might be enhanced by a mass effect from forest taxa. The patterns of plant richness in this study corresponded to gradients, suggesting that there was not any accumulation of the species near tree line and the study reject the hypothesis of mass effect at tree line since there is a gradual decrease in the species beyond mid altitudinal peak. Thus, this study did not support any of those above hypothesis due to different study question than discussed.

4.3 Environmental Factors

The environmental variables in particular, topography, light, temperature, snow cover, soil moisture, soil pH, have been correlated with species richness at both regional and local scales (Walker, 1985; Matveyea, 1988; Walker *et al.*, 1994; Walker, 1995; Gould & Walker, 1999). Species richness generally increased with soil pH and soil moisture. Elllenberg *et al.* (1974) explained that undergrowth species richness decreases from high moisture to lower moisture content. A positive linear pattern was also observed by Bhattarai & Vetaas (2003) for total species, shrubs, trees and climbers with moisture. This study also followed the similar pattern as shown by Bhattarai and Vetaas (2003) when species density was regressed against moisture and found the positive linear trend (Fig. 9. b).

For many years plant ecologists have documented high plant species number on high pH soil (Grime, 1979; Grubb 1987). Soil pH is directly related to species richness (Gouch *et al.*, 2000) and most of the differences in species richness among the sites are due to soil pH (van Raamsdonk, 1988; Timoney *et al.*, 1993; Walker *et al.*, 1994). Soil pH showed a specific pattern like positive monotonic, unimodal, nonsignificant or even negative relationship with species richness (Chytry *et al.*, 2003, Palmer *et al.*, 2003, Schuster & Diekmann, 2003). However, in this study a positive monotonic pattern is found where the species number increased with increase in pH (Fig. 9. a).

5. CONCLUSIONS

The relationship between altitude and species diversity followed a unimodal pattern. Here empirical species density and species richness as well as empirical interpolated species richness all showed a unimodal pattern. A unimodal pattern was also prevalent between species density and altitude for dicots, monocots and herbs but there was a linear decrease in species density of gymnosperms and woody species. Species richness for all the lifeforms showed a unimodal pattern except for woody species but the interpolated empirical species of all the life forms showede a unimodal pattern. From this it has been concluded that though the study is empirical or interpolated it is not a matter because in both cases the trend is similar that followed the unimodal trend.

The environmental factor i.e. moisture and pH when regressed against species density find that there was a positive linear trend. It means that increase in pH or moisture supports the distribution of more species. From this it can be concluded that increased pH and soil moisture favors more species present in the area.

Thus, the observations found during the study, did not support hypotheses set and were rejected. The study clearly revealed the positive and significant relationship of species richness with environmental variables and the patterns are basically unimodal. From this, it can be concluded that the trend of species richness in Manaslu Conservation Area, Central Nepal especially in North-East aspect is unimodal and suggest that species richness is dependent upon the altitude and associated factors.

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Appendix I

Vegetation types found in Manaslu Conservation Area

Vegetation/ Forest Types	**Altitude(m)**
1. Low Hill Vegetation	
i. *Pinus roxburghii* forest	1400-2000
ii. *Schima-castonopsis* forest	1400-1800
2. Middle Mountain vegetation	
i. *Alnus nepalensis* forest	1400- 2400
ii. *Quercus floribunda* forest	2000-2500
iii. Mixed *Quercus* forest	1800-2500
iv. *Pinus wallichiana* forest	2000-3000
v. *Picea smithiana- Tsuga dumosa* forest	2200-3000
vi. *Quercus semscarpifolia* forest	2200-3000
vii. Mixed hardwood forest	2500-3000
viii. *Populus ciliata* forest	1700-1900
3. High Mountain Vegetation	
i. *Larix griffithiana* forest	2800-3500
ii. *Larix himalaica* forest	2800-3800
iii. Mixed *Larix* forest	2800-3500
iv. *Abies spectabilis* forest	2800-3500
v. *Juniperus recurva* scrub	3000-3800
vi. *Betula utilis* forest	3400-3900
vii. *Rhododendron- Juniper-* Birch bushes	3500-above 4000
viii. Moist alpine scrub	3500-4800
ix. Dry alpine scrub	3900- above 5000

Appendix II

List of all plant species found on the studied plots with their family, abbreviation, habit Lifeforms and frequency.

Plant Species	Abbreviation	Family	Habit	Lifeforms	Frequency
Abies spectabilis (D.Don) Mirb.	*Abi spe*	Pinaceae	Tree	Gymnosperm	42.85
*Acer acuminatum*Wall. ex D. Don	*Ace acu*	Aceraceae	Tree	Dicot	4.28
Acer campbelli Hook. F. & Thomson ex Hiern	*Ace cam*	Aceraceae	Tree	Dicot	4.28
Aconitum bishma (Buch.-Ham.) Rapaics	*Aco bis*	Ranunculaceae	Herb	Dicot	18.57
Aconitum dhowjii Lauener	*Aco dho*	Ranunculaceae	Herb	Dicot	7.14
Aconitum ferox Wall. ex Ser.	*Aco fer*	Ranunculaceae	Herb	Dicot	21.42
Aconitum nepalense Lauener	*Aco nep*	Ranunculaceae	Herb	Dicot	15.71
Aconitum spicatum (Bruhl) Stapf	*Aco spi*	Ranunculaceae	Herb	Dicot	15.71
Aconogonum molle (D. Don) H. Hara	*Aco mol*	Polygonaceae	Herb	Dicot	31.42
Actaea spicata (Wall. ex Royle) H. Hara	*Act spi*	Ranunculaceae	Herb	Dicot	20
Allium przewalskianum Regel	*All pre*	Amaryllidaceae	Herb	Monocot	22.85
Allium wallichi Kunth	*All wal*	Amaryllidaceae	Herb	Monocot	20
Anaphalis contorta (D. Don) Hook.f.	*Ana con*	Asteraceae	Herb	Dicot	37.14
Anaphalis subumbellata C.B. Clarke	*Ana sub*	Asteraceae	Herb	Dicot	8.57
Anaphalis triplinervis (DC.) Airy Shaw	*Ana tri*	Asteraceae	Herb	Dicot	44.28
Andropogan munroi C. B. Clarke	*And mun*	Poaceae	Herb	Monocot	20
Androsace lehmannii Wall. ex Duby	*And leh*	Primulacea	Herb	Dicot	35.71
Androsace sarmentosa Wall.	*And sar*	Primulacea	Herb	Dicot	25.71
Androsace strigillosa Franch.	*And stri*	Primulacea	Herb	Dicot	27.14
Arisaema jacquemontii Blume	*Ari jac*	Araceae	Herb	Monocot	5.71
Artemisia dubia Wall. ex Besser	*Art dub*	Asteraceae	Herb	Dicot	5.71
Artemisia gmelinii Weber ex Stechm.	*Art gem*	Asteraceae	Herb	Dicot	30
Arundinella hookerii Munro ex Keng	*Aru hook*	Poaceae	Herb	Monocot	12.85
Aster albescens (DC.) Hand.-Mazz.	*Ast alb*	Asteraceae	Herb	Dicot	28.57
Aster sikkimensis Hook.	*Ast sik*	Asteraceae	Herb	Dicot	10
Aster himalaicus C.B. Clarke	*Ast him*	Asteraceae	Herb	Dicot	18.57
Astilbe rivularis Buch.-Ham. ex D. Don	*Ast riv*	Saxifragaceae	Herb	Dicot	22.85
Astragalus melanostachys Benth. ex Bunge	*Astr mel*	Fabaceae	Herb	Dicot	42.85
Astrgalus floridus Benth. ex Bunge	*Astr flo*	Fabaceae	Herb	Dicot	20
Berberis aristata DC.	*Ber ari*	Berberidaceae	Shrub	Dicot	2.85
Berberis erythroclada Ahrendt	*Ber ery*	Berberidaceae	Shrub	Dicot	31.42
Berberis mucrifolia Ahrendt	*Ber muc*	Berberidaceae	Shrub	Dicot	34.28
Betula utilis D. Don	*Bet uti*	Betulaceae	Tree	Dicot	38.57
Bistorta affinis (D. Don) Greene	*Bis aff*	Polygonaceae	Herb	Dicot	20
Bistorta amplexicaulis (D. Don) Greene	*Bis amp*	Polygonaceae	Herb	Dicot	21.42
Bistorta emodi (Meisn.) H. Hara	*Bis emo*	Polygonaceae	Herb	Dicot	14.28

Bistorta macrophylla (D. Don) Sojak	*Bis mac*	Polygonaceae	Herb	Dicot	12.85
Bistorta vaccinifolia (Wall. ex Meisn.) Greene	*Bis vac*	Polygonaceae	Herb	Dicot	21.42
Cassiope fastigiata (Wall.) D.Don	*Cas fas*	Ericaceae	Shrub	Dicot	14.28
Caragana brevispina Royle	*Car bre*	Fabaceae	Shrub	Dicot	5.71
Caragana gerardiana Royle	*Car ger*	Fabaceae	Shrub	Dicot	50
Caragana sukiensis C.K. Schneid.	*Car suk*	Fabaceae	Shrub	Dicot	14.28
Carex atrofusca (Boott) T. Koyama	*Care art*	Cyperaceae	Herb	Monocot	15.71
Carex cruenta Nees	*Care cru*	Cyperaceae	Herb	Monocot	10
Carex filicina Nees	*Care fil*	Cyperaceae	Herb	Monocot	67.14
Carex gracilenta Bott ex Strachey	*Care gra*	Cyperaceae	Herb	Monocot	12.85
Ceropegia pubescens Wall.	*Cer pub*	Asclepiadaceae	Herb climber	Dicot	14.28
Cirsium falconeri (Hook.f.) Petr.	*Cir fal*	Asteraceae	Herb	Dicot	25.71
Clematis barbellata Edgew.	*Cle bar*	Ranunculaceae	Woody climber	Dicot	10
Clematis montana Buch.-Ham. ex DC.	*Cle mon*	Ranunculaceae	Woody climber	Dicot	17.14
Codonopsis rotundifolia Benth.	*Cod rot*	Campanulaceae	Herb	Dicot	8.57
Coeloglossum viride (L.) hartm.	*Coe vir*	Orchidaceae	Herb	Monocot	34.28
Corydalis flaccida Hook. f. & Thomson	*Cor fla*	Papaveraceae	Herb	Dicot	7.14
Corydalis juncea Wall.	*Cor jun*	Papaveraceae	Herb	Dicot	17.14
Cotoneaster frigidus Wall. ex Lindl.	*Cot fri*	Rosaceae	Shrub	Dicot	7.14
Cotoneaster microphyllus Wall. ex Lindl.	*Cot mic*	Rosaceae	Shrub	Dicot	47.14
Cremanthodium nepalense Kitam.	*Cre nep*	Asteraceae	Herb	Dicot	4.28
Cremanthodium oblongatum C.B. Clarke	*Cre obl*	Asteraceae	Herb	Dicot	18.57
Cremanthodium purpureifolium Kitam.	*Cre pur*	Asteraceae	Herb	Dicot	21.42
Cremanthodium reniforme (DC.) Benth.	*Cre ren*	Asteraceae	Herb	Dicot	21.42
Crepis himalaica Kitam.	*Crep him*	Asteraceae	Herb	Dicot	18.57
Cyathula capitata Moq.	*Cya cap*	Amaranthaceae	Shrub	Dicot	4.28
Cynanthus lobatus Wall. ex Benth	*Cyn lob*	Campanulaceae	Herb	Dicot	30
Dactylorhiza hatagirea (D. Don) Soo	*Dac hat*	Orchidaceae	Herb	Monocot	11.42
Delphinium denudatum Wall. ex Hook.f.	*Del den*	Ranunculaceae	Herb	Dicot	5.71
Delphinium himalayai Munz	*Del him*	Ranunculaceae	Herb	Dicot	45.71
Ephedra gerardiana Wall. ex Stapf	*Eph ger*	Ephedraceae	Shrub	Gymnosperm	14.28
Epilobium latifolium P. H. Raven	*Epi lat*	Onagraceae	Herb	Dicot	15.71
Euphorbia stracheyi Boiss.	*Eup str*	Euphorbiaceae	Herb	Dicot	22.85
Fragaria nubicola Lindl. ex Lacaita	*Fra nub*	Rosaceae	Herb	Dicot	94.28
Fritillariana cirrhosa D. Don	*Fri cir*	Lilaceae	Herb	Monocot	34.28
Galium paradoxum Maxim.	*Gal par*	Rubiaceae	Herb	Dicot	32.85
Gentiana depressa D. Don	*Gen dep*	Gentianaceae	Herb	Dicot	94.28
Gentiana ornata (G. Don) Griseb.	*Gen orn*	Gentianaceae	Herb	Dicot	67.14
Geranium pratense L.	*Ger nep*	Geraniaceae	Herb	Dicot	50
Geranium pratense L.	*Ger pra*	Geraniaceae	Herb	Dicot	50
Gerbera nivea (DC.) Sch. Bip.	*Gerb ni*	Asteraceae	Herb	Dicot	91.42
*Hedysarum kumaonense*Benth. ex Baker	*Hed kum*	Fabaceae	Herb	Dicot	35.71
Heracleum lallii C. Norman	*Her lal*	Apiaceae	Herb	Dicot	32.85

Hippophae salicifolia D. Don	*Hip sal*	Elaeagnaceae	Tree or shrub	Dicot	12.85
Hippophae tibetana Schltdl.	*Hip tib*	Elaeagnaceae	Tree or shrub	Dicot	14.28
Hypericum elodioides Choisy	*Hyp elo*	Guttiferae	Shrub	Dicot	18.57
Inula hookeri C.B. Clarke	*Inu hook*	Asteraceae	Herb	Dicot	45.71
Iris clarkei Baker ex Hook. f.	*Iri cla*	Iridaceae	Herb	Monocot	41.42
Iris stantonii H. Hara	*Iri sta*	Iridaceae	Herb	Monocot	15.71
Iris kemaonensis D. Don ex Royle	*Iri kem*	Iridaceae	Herb	Monocot	48.57
Juniperus communis L.	*Jun com*	Cupressaceae	Shrub	Gymnosperm	77.14
Juniperus indica Bertol.	*Jun ind*	Cupressaceae	Shrub	Gymnosperm	11.42
Juniperus macropoda Boiss.	*Jun mac*	Cupressaceae	Tree	Gymnosperm	4.28
Juniperus recurva Buch.- Ham. ex D. Don	*Jun rec*	Cupressaceae	Shrub	Gymnosperm	54.28
Juniperus squamata Buch.- Ham. ex D. Don	*Jun squ*	Cupressaceae	Shrub	Gymnosperm	77.14
Kobressia duthiei C.B. Clarke in Hook.f.	*Kob dut*	Cyperaceae	Herb	Monocot	57.14
Kobresia fragilis C.B. Clarke	*Kob fra*	Cyperaceae	Herb	Monocot	57.14
Kobresia laxa Nees	*Kob lax*	Cyperaceae	Herb	Monocot	41.42
Kobressia nepalensis (Nees) Kuk.	*Kob nep*	Cyperaceae	Herb	Monocot	30
Larix himalaica W.C. Cheng & L.K. Fu	*Lar him*	Pinaceae	Tree	Gymnosperm	41.42
Leontopodium jacotianum Beauverd	*Len jac*	Asteraceae	Herb	Dicot	27.14
Ligularia fischeri (Ledeb.) Turcz.	*Lig fis*	Asteraceae	Herb	Dicot	95.71
Lilium nepalense D. Don	*Lil nep*	Lilaceae	Herb	Monocot	18.57
Lomatogonium carinthiacum (Wulfen) Rchb.	*Lom car*	Gentianaceae	Herb	Dicot	54.28
Lonicera angustifolia Wall. ex DC.	*Lon ang*	Caprifoilaceae	Tree	Dicot	31.42
Lonicera lanceolata Wall.	*Lon lan*	Caprifoilaceae	Shrub	Dicot	12.85
Lonicera obovata Royle ex Hook. f. & Thomson	*Lon obo*	Caprifoilaceae	Shrub	Dicot	21.42
Meconopsis regia G. Taylor	*Mec reg*	Papaveraceae	Herb	Dicot	28.57
Morina polyphylla Wall. ex DC.	*Mor pol*	Dipsacaceae	Herb	Dicot	55.71
Nardostachys grandiflora DC.	*Nar gra*	Valerianaceae	Herb	Dicot	44.28
Neopicrorhiza scrophulariiflora (Pennell) Hong	*Neo scr*	Scrophulariaceae	Herb	Dicot	28.57
Nepeta lamiopsis Benth. ex Hook. f.	*Nep lam*	Lamiaceae	Herb	Dicot	48.57
Origanum vulgare L.	*Ori vul*	Lamiaceae	Herb	Dicot	44.28
Oxytropis microphylla (Pall.) DC.	*Oxy mic*	Fabaceae	Herb	Dicot	50
Parnassia nubicola Wall. ex Royle	*Par nub*	Paranassiaceae	Herb	Dicot	54.28
Pedicularis poluninii Tsoong	*Ped pol*	Scrophulariaceae	Herb	Dicot	21.42
Pedicularis pseudoregeliana P.C. Tsoong	*Ped pse*	Scrophulariaceae	Herb	Dicot	28.57
Pedicularis siphonanta D. Don	*Ped sip*	Scrophulariaceae	Herb	Dicot	41.42
Pedicularis wallichii Bunge	*Ped wal*	Scrophulariaceae	Herb	Dicot	25.71
Pinus wallichiana A.B. Jacks.	*Pin wal*	Pinaceae	Tree	Gymnosperm	24.28
Plantago erosa Wall.	*Pla ero*	Plantaginaceae	Herb	Dicot	71.42
Podophyllum hexandraum Royle	*Pod hex*	Berberidaceae	Herb	Dicot	32.85
Polygonatum cirrhifolium (Wall.) Royle	*Pol cir*	Lilaceae	Herb	Monocot	34.28
Polygonatum hookeri Baker	*Pol hook*	Lilaceae	Herb	Monocot	34.28
Polygonatum verticillatum (L.) All.	*Pol ver*	Lilaceae	Herb	Monocot	31.42
Potentilla biflora Wild. ex Schltdl	*Pot bi*	Rosaceae	Herb	Dicot	24.28

Potentilla cuneata Wall. ex Lehm.	*Pot cun*	Rosaceae	Herb	Dicot	98.57
Potentilla fruticosa Lindl. ex Lehm.	*Pot fru*	Rosaceae	Shrub	Dicot	44.28
Primula concinna Watt	*Pri con*	Primulacea	Herb	Dicot	2.85
Primula denticulata Sm.	*Pri den*	Primulacea	Herb	Dicot	57.14
Primula rotundifolia Wall.	*Pri rot*	Primulacea	Herb	Dicot	4.28
Primula wigramiana W.W. Sm.	*Pri wig*	Primulacea	Herb	Dicot	11.42
Ranunculus diffuses DC.	*Ran dif*	Ranunculaceae	Herb	Dicot	44.28
Rheum australe D. Don	*Rhe aus*	Polygonaceae	Herb	Dicot	27.14
Rheum moorcroftianum Royle	*Rhe moo*	Polygonaceae	Herb	Dicot	28.57
Rhodendron anthopogon D. Don	*Rho ant*	Ericaceae	Shrub	Dicot	47.14
Rhododendron arboreum Sm.	*Rho arb*	Ericaceae	Tree	Dicot	17.14
Rhododendron barbatum Wall. ex G. Don	*Rho bar*	Ericaceae	Tree	Dicot	18.57
Rhododendron campanulatum D. Don	*Rho cam*	Ericaceae	Shrub	Dicot	41.42
Rhododendron lepidotum Wall. ex G. Don	*Rho lep*	Ericaceae	Shrub	Dicot	38.57
Rhododendron nivale Hook. f.	*Rho niv*	Ericaceae	Shrub	Dicot	20
Rosa macrophylla Lindl.	*Ros mac*	Rosaceae	Shrub	Dicot	40
Rosa sericea Lindl.	*Ros ser*	Rosaceae	Shrub	Dicot	27.14
Rubia manjith Roxb. ex Fleming	*Rub man*	Rubiaceae	Herb climber	Dicot	8.57
Rumex nepalensis Spreng	*Rum nep*	Polygonaceae	Herb	Dicot	40
Salix calyculata Hook. f. ex Andersson	*Sal cal*	Salicaceae	Shrub	Dicot	14.28
Salix daltoniana Andersson	*Sal dal*	Salicaceae	Shrub	Dicot	21.42
Salix sikkimensis Andersson	*Sal sik*	Salicaceae	Shrub	Dicot	20
Saxifraga poluninana H. Sm.	*Sax pol*	Saxifragaceae	Herb	Dicot	10
Selinum candollei DC.	*Sel can*	Apiaceae	Herb	Dicot	34.28
Senecio wallichi DC.	*Sen wal*	Asteraceae	Herb	Dicot	14.28
Sibbaldia cuneata Hornem. ex Kuntze	*Sib cun*	Rosaceae	Herb	Dicot	21.42
Silene indica Roxb. ex Otth	*Sil ind*	Caryophyllaceae	Herb	Dicot	31.42
Smilax menispermoidea A. DC.	*Smi men*	Lilaceae	Woody climber	Dicot	12.85
Sorbus foliolosa (Wall.) Spach	*Sor fol*	Rosaceae	Tree	Dicot	18.57
Sorbus lanata (D. Don) Schauer	*Sor lan*	Rosaceae	Tree	Dicot	18.57
Swertia angustifolia Buch.-Ham. ex D. Don	*Swe ang*	Gentianaceae	Herb	Dicot	5.71
Swertia paniculata Wall.	*Swe pan*	Gentianaceae	Herb	Dicot	28.57
Tanacetum tibeticum Hook.f. & Thom. ex C.B. Cla.	*Tan tib*	Asteraceae	Herb	Dicot	21.42
Thalictrum alpinum L.	*Tha alp*	Ranunculaceae	Herb	Dicot	25.71
Thalictrum foliosum DC.	*Tha fol*	Ranunculaceae	Herb	Dicot	18.57
Tsuga dumosa (D. Don) Eichler	*Tsu dum*	Pinaceae	Tree	Gymnosperm	15.71
Valeriana hardwickii Wall.	*Val har*	Valerianaceae	Herb	Dicot	15.71
Viburnum erubescens Wall. ex DC.	*Vib eru*	Sambucaceae	Tree	Dicot	4.28
Viola biflora L.	*Vio bif*	Violaceae	Herb	Dicot	98.57

Appendix III

DCA Summary

	Axis 1	Axis 2	Axis 3	Axis 4	Total inertia
Eigen values	0.559	0.058	0.046	0.037	2.077
Lengh of gadient	3.33	1.536	1.059	1.205	
Cummulative % variance of species data	26.9	29.7	31.9	33.7	

Appendix IV

Regression statistics for whole plant group: GLM model are significant over 2nd order (Altitude is Predictor).

Group	Responses	Model	Polynomial order	Residual degree of freedom	Residual deviance	Degree of freedom	Deviance	F-value	Pr(>F)
		Null	0	69	91.994				
	Species Density	GLM	1st	68	58.412	1	33.582	39.394	<0.001
		GLM	2nd	67	36.885	2	55.109	50.542	<0.001
		Null	0	13	29.301				
Vascular Plants	**Species Richness**	GLM	1st	12	18.04	1	11.259	7.5397	<0.005
		GLM	2nd	11	3.4662	2	25.835	40.612	<0.001
		Null	0	54	1958.5				
	Interpolated Empirical Species Richness	GLM	1st	53	1939.7	1	18.791	0.5747	<0.1
		GLM	2nd	52	23.88	2	1934.6	2145.9	<0.001

Appendix V

Regression statistics for species density of different functional groups (Altitude is the predictor)

Group	Responses	Model	Polynomial order	Residual degree of freedom	Residual deviance	Degree of freedom	Deviance	F-value	Pr(>F)
Dicot	**Species Density**	Null		69	71.446				
		GLM	1	68	53.183	1	18.264	23.507	<0.001
		GLM	2	67	40.755	2	30.691	25.258	<0.001
Monocot	**Species Density**	Null		69	49.545				
		GLM	1	68	35.438	1	14.107	27.342	<0.001
		GLM	2	67	26.437	2	23.107	31.067	<0.001
Herb	**Species Density**	Null		69	80.686				
		GLM	1	68	62.63	1	18.056	19.622	<0.001
		GLM	2	67	39.485	2	41.201	35.192	<0.001
Woody	**Species Density**	Null		69	57.08				
		GLM	1	68	39.078	1	18.002	31.687	<0.001
		GLM	2	67	38.114	2	18.965	16.66	<0.001
Gymnosperm	**Species Density**	Null		69	28.353				
		GLM	1	68	23.783	1	4.5697	12.944	<0.001
		GLM	2	67	21.479	2	6.8739	10.784	<0.001

Appendix VI

Regression statistics for species richness of different functional groups (Altitude is Predictor).

Group	Responses	Model	Polynomial order	Residual degree of freedom	Residual deviance	Degree of freedom	Deviance	F-value	Pr(>F)
		Null		13	15.9984				
Dicot	**Species Richness**	GLM	1	11	10.949	1	5.0497	5.6186	<0.05
		GLM	2	12	2.8117	2	13.187	25.202	<0.001
		Null		13	13.9456				
Monocot	**Species Richness**	GLM	1	11	8.5433	1	5.4023	7.2808	<0.05
		GLM	2	12	2.7836	2	11.162	21.864	<0.001
		Null		13	31.5359				
Woody	**Species Richness**	GLM	1	11	4.6683	1	26.867	68.829	<0.001
		GLM	2	12	1.7896	2	29.746	92.201	<0.001
		Null		13	20.3509				
Herb	**Species Richness**	GLM	1	11	18.585	1	1.7655	1.1456	<0.1
		GLM	2	12	4.6505	2	15.7	17.912	<0.001
		Null		13	8.7833				
Gymnosperm	**Species Richness**	GLM	1	11	5.2815	1	3.5018	7.775	<0.05

		GLM	2	12	2.5007	2	6.2826	13.901	<0.001

Appendix VII

Regression statistics for Interpolated empirical species richness of different functional groups (Altitude is Predictor)

Group	Responses	Model	Polynomial order	Residual degree of freedom	Residual deviance	Degree of freedom	Deviance	F-value	Pr(>F)
		Null		54	1554.5				
Dicot	**Interpolated empirical species richness**	GLM	1	53	1548.1	1	6.4207	0.2477	<0.1
		GLM	2	52	20.54	2	1534	1044.7	<0.001
		Null		54	300.74				
Monocot	**Interpolated empirical species richness**	GLM	1	53	288.44	1	12.303	2.538	<0.1
		GLM	2	52	18.478	2	282.26	430.89	<0.001
		Null		54	707.53				
Woody	**Interpolated empirical species richness**	GLM	1	53	707.53	1	0.003757	0.000002	<0.1
		GLM	2	52	78.53	2	689	1161.9	<0.001

		Null		54	1372.2				
Herb	**Interpolated empirical species richness**	GLM	1	53	1350.4	1	21.846	0.9564	<0.1
		GLM	2	52	38.02	2	1334.2	915.7	<0.001
		Null		54	158.11				
Gymnosperm	**Interpolated empirical species richness**	GLM	1	53	157.4	1	0.70519	0.2729	<0.1
		GLM	2	52	9.639	2	148.47	478.91	<0.001

Appendix VIII

Regression statistics for environmental variables against species density (models are fitted with 1st order GLM).

Predictor	Response	Model	Polynomial order	Residual degree of freedom	Residual deviance	Degree of freedom	Deviance	F-value	Pr(>F)
		Null	0	69	93.379				
Moisture	**Species Density**	GLM	1	68	80.678	1	12.7	10.605	<0.01
		GLM	2	67	80.514	2	12.864	5.3069	<0.001
		Null	0	69	93.379				
pH	**Species Density**	GLM	1	68	24.585	1	68.794	195.27	<0.001
		GLM	2	67	23.251	2	70.127	103.83	<0.001
		Null	0	69	93.379				
RRI	**Species Density**	GLM	1	68	93.328	1	0.51132	0.038	Not significant

	GLM	2	67	92.897	2	0.48179	0.1776	not significant

Appendix IX

Plot wise species density along with environmental variables

Altitude(m)	Vascular plants	Longitude(°)	Latitude(°)	Aspect(°)	Slope(°)	pH	Moisture	RRI
3016	41	84.72756	28.59199	40	30	6.6	7.2	0.577
3032	51	84.70711	28.57177	35	25	6.6	7.7	0.63
3055	41	84.70712	28.57142	40	30	6.5	7	0.577
3070	51	84.70712	28.57142	26	25	6.6	7.8	0.614
3095	51	84.70713	28.57131	35	35	6.6	6	0.494
3125	52	84.70704	28.57089	45	35	6.6	8	0.525
3145	40	84.70659	28.57074	40	28	6.2	7.4	0.603
3160	43	84.70667	28.57052	35	25	6.8	>8	0.63
3180	55	84.70648	28.57029	40	30	6.8	>8	0.577
3195	56	84.70639	28.5702	40	30	6.4	8	0.577
3215	48	84.70623	28.56989	40	25	6.3	7	0.641
3245	48	84.70669	28.56959	35	35	6.4	7	0.494

3260	48	84.70601	28.56935	30	30	6.8	7.5	0.533
3278	59	84.70617	28.5691	45	30	6.6	>8	0.591
3295	53	84.70635	28.56888	45	30	6.4	8	0.591
3310	46	84.70598	28.56874	25	20	6.5	8	0.677
3337	45	84.7058	28.56848	25	30	6.4	>8	0.543
3355	48	84.70542	28.56842	30	20	6.8	7.4	0.683
3376	66	84.70561	28.5682	45	30	6.8	7.5	0.591
3389	57	84.7056	28.568	30	35	6.4	5	0.481
3409	47	84.70651	28.5689	40	30	6.6	5	0.577
3425	54	84.70551	28.56791	40	30	6.6	5	0.577
3445	59	84.70533	28.5678	30	30	6.2	5	0.553
3462	46	84.70501	28.56767	35	35	6.6	5	0.494
3485	53	84.70496	28.56742	40	30	6.8	8	0.577
3510	62	84.66458	28.57347	30	15	6.8	8	0.741
3535	56	84.66228	28.57259	20	20	6.4	>8	0.671
3560	56	84.6639	28.57307	15	10	6.6	7	0.784
3580	59	84.661	28.57275	30	20	6.6	>8	0.683
3594	56	84.66072	28.57259	25	15	6.6	7.5	0.736
3620	56	84.63589	28.60788	50	25	6.4	>8	0.665
3635	56	84.63756	28.60805	60	30	6.4	>8	0.64
3655	54	84.63706	28.60815	60	30	6	>8	0.64
3680	41	84.63689	28.60808	50	30	6.4	>8	0.64
3695	49	84.63661	28.60762	40	25	6.4	>8	0.606
3720	54	84.63639	28.60769	30	20	6.4	>8	0.683
3740	51	84.636	28.60771	30	30	6.2	7	0.552
3756	44	84.6358	28.60722	40	20	6	>8	0.669
3770	44	84.63557	28.60792	35	20	6.4	>8	0.69
3795	51	84.63524	28.6078	40	30	6.4	8	0.576
3815	49	84.63506	28.60781	40	30	6.2	>8	0.576
3830	45	84.63463	28.60784	35	25	6.2	>8	0.629
3865	48	84.63441	28.60774	30	25	6.6	>8	0.62
3876	55	84.63419	28.60765	35	20	6.6	7	0.69
3890	58	84.63381	28.60767	40	20	6.4	>8	0.699
3910	53	84.63346	28.66772	40	20	6	>8	0.698
3930	43	84.63336	28.60759	30	20	6	>8	0.683
3954	34	84.6331	28.60768	40	15	6.2	>8	0.753
3970	44	84.63288	28.60763	35	15	6.4	>8	0.746
3990	53	84.63266	28.60753	30	10	6.2	>8	0.792
4005	46	84.62769	28.66455	60	20	6	7	0.742
4030	41	84.62678	28.66528	60	20	6.2	6.4	0.742
4050	41	84.62636	28.66553	55	25	6.4	5.5	0.678
4075	48	84.62662	28.66567	50	20	6.2	8	0.719
4090	44	84.62604	28.66583	60	25	6.2	7	0.693
4115	43	84.62615	28.66772	60	20	6	4	0.742
4132	37	84.62591	28.66835	50	30	6	5.5	0.605

4150	42	84.62562	28.66865	60	30	6.2	6.2	0.639
4170	42	84.62543	28.66857	50	30	6	6	0.605
4189	41	84.6252	28.66849	55	30	6.2	6.5	0.622
4222	42	84.6248	28.66863	60	30	6.2	6	0.639
4236	44	84.62464	28.66873	65	35	6	6.5	0.602
4256	39	84.62487	28.66891	65	35	6.3	6.6	0.602
4278	41	84.62413	28.66387	60	30	6	4.5	0.639
4292	40	84.6239	28.66873	60	20	6	4.82	0.742
4310	40	84.62369	28.66869	50	30	6.2	6	0.605
4329	39	84.6234	28.66872	55	30	6	5.63	0.622
4367	33	84.62803	28.66886	60	35	5.8	6	0.581
4383	31	84.62186	28.66907	60	40	6	4	0.577
4395	36	84.62174	28.66918	60	40	5.6	5	0.577