DIVERSITY AND RARITY IN AVIFAUNAL ASSEMBLAGES IN THE WESTERN HIMALAYA: A STUDY OF PATTERNS AND MECHANISMS

THESIS
SUBMITTED TO THE
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DEEMED UNIVERSITY
DEHRADUN, UTTARANCHAL
FOR
THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN
FORESTRY
(Forest Management)

By

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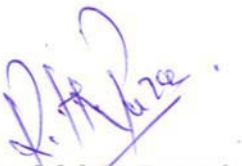
2006

DECLARATION

I hereby declare that the thesis entitled "**Diversity and rarity in avifaunal assemblages in the Western Himalaya: A study of patterns and mechanisms"** submitted to Forest Research Institute (Deemed University), Dehradun, for the award of the degree of Doctor of Philosophy in Forestry, embodies the result of my own work and observations and in that respect the investigation appears to advance knowledge in the subject.



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Appendix 2 **Bird species and Indicator values in composition groups in Kedarnath ..... k-m**

SUMMARY

1. The Indian Western Himalayas span across states of Uttaranchal, Himachal Pradesh and Jammu & Kashmir. These mountains rise from plains to snowcapped peaks, many above 7000 m. This enormous altitudinal variation causes a distinct zonation of climate and consequently the vegetation and the avifauna. The unique geographical position of the Himalayas also enable mixing of three biogeographical realms, the Oriental, Palearctic and the Ethiopian.

2. This study focuses on patterns of diversity and rarity in the avifaunal assemblages of the Western Himalaya. It attempts to find patterns at a regional scale using a secondary database and through field studies at landscape scales at two intensive study sites, Kedarnath area and Goriganga valley in Uttaranchal. The study adopts a macroecological approach in arriving at statistical generalizations emerging from the analyses of distribution and abundance patterns of birds along the altitudinal gradient. The study identifies key patterns of composition, species abundances and species diversity seen in the Western Himalayas and attempts to understand some of the mechanisms associated with these patterns.

3. Climate plays a dominant role in avifaunal composition and zonation. The major avifaunal divisions along the altitude gradient approximate bio-climatic zones. Himalayan avifauna is an immigrant one which has colonised these mountains from surrounding areas in south, south-east, Chinese and central Asian regions. Birds have colonised such

elevation zones, which are similar to the climate of their main distributions. Thus a tendency for higher elevations to have source areas from higher latitudes is visible. Disjunct distributions of birds in the Western Himalaya and Western, South Western China point to a past connection of dry forests growing in South Tibet during a post glacial warm period which facilitated colonization of avifauna of drier forests. Past glacial events seem to have led to a relatively high number of species endemic to the region due to either isolation and new species formation e.g. Western Tragopan, White throated tit or through extinction of related species from surrounding areas and formation of relict species such as Himalayan quail, Cheer pheasant and Spectacled finch.

4. At landscape scales, avifaunal composition shows a strong relationship with vegetation composition and not with structure or altitude. Remote sensing and GIS technology can identify forest types over large areas with much ease, a good correspondence of bird communities with forest types means that vegetation composition can be surrogated for bird communities and can facilitate their mapping.

Range size and abundance are positively correlated. Niche use and energetic considerations further elaborate these relationships. Larger range sizes are associated with greater resource availability (lower niche position) and higher abundances are associated with lower per capita energy demand (smaller body sizes). Thus it seems likely that smaller bodied species, which utilize widespread habitats, will inhabit large ranges, acquire high average densities in the landscape and hence will exist at large population sizes. Species rare in occurrence

may occur at high or low densities, but they occupy small geographical and altitudinal extent and have special habitat requirements, which are scarce in the landscape. A greater role of resource availability (niche position) compared to resource breadth (niche breadth) in determining geographical spread of species is supported.

5. Body size explains more than 30% of the variation in abundance, and turns out to be an important correlate of abundance. The slope value (-.49) of the log body mass log average density relationship is well supported by hypothesis related to energetic constraints due to higher costs of thermoregulation in colder environments. Metabolic rate calculated using limited interpolated temperature data scales with a slope close to –1. Hence population energy use shows no relationship with body mass, and the 'Energy equivalence rule' in this assemblage is supported.

6. Diversity shows a nonlinear trend with altitude at both regional and local scales with peak in diversity being in the mid altitude zones. Productive energy (as indexed by NDVI) explains a surprisingly large amount of variation particularly at the regional scale. Greater relative area in the mid-elevations, and ecotonal effects modify the trend at a secondary level and may explain the mid elevation peak, which is not substantial in any case.

7. In Kedarnath (landscape scale) relationship of NDVI with diversity is curvilinear and did not explain much variation. Species area regression with forest area as independent variable explains a large amount of

variation, however this also to some extent reflects a productivity mediated gradient since forest growth conditions in temperate zone are likely to be strongly temperature driven.

8. Local (site) diversity in Kedarnath was explained well by total bird-biomass (a direct measure of taxa productivity). The exceptions to the pattern were related to greater vegetation heterogeniety. This suggests that overall productivity defines the diversity gradient, but in some situations, is modified by habitat heterogeneity. However higher biomass is not achieved by increase in number of individuals (greater total density). Sites of higher biomass hold species of greater body sizes but somewhat lower densities. This does not support the 'more individuals' hypotheses, which states that sites, which can support higher density of individuals lower extinction risks of rare species and hence maintain higher species diversity.

9. Rapoport's rule does not hold in the west Himalayan assemblage. Null models of diversity gradient also fail to describe the diversity pattern along the altitude gradient. At both regional and landscape scales role of energy related variables are important in structuring diversity gradients, additionally larger area and zonal feedbacks contribute to mid-elevation peak in diversity.

10. The temperate 'biome restricted' group is the most species rich and represents more than 60% of the group present within Indian Himalaya. In contrast, the subtropical group represent less than 40% of the species present within Indian Himalaya, a large section of these species remain confined to the eastern Himalaya.

11. Peaks of diversity are generated by ecotonal effects by overlap of two distinct zones. Thus conservation planning should not put a relatively high priority on such areas alone. Instead conservation efforts should focus on conserving each of the distinct avifaunal zones. There is a need to identify and adequately protect large contiguous altitude gradients such as in Goriganga valley. These gradients represent the exceptional display of Himalayan bird diversity in a short geographical distance and small geographical area.

12. Western Himalaya has been recognised as a globally important hotspot of avian endemism and is identified as an ENDEMIC BIRD AREA by Birdlife International (Statterfield *et al* 1998). Western Himalaya has 11 RESTRICTED RANGE species, three of which are threatened. It is important that habitats and populations of these species are adequately protected, however focus should also remain on assemblage level conservation efforts. A heavy leaning of conservation policy on endemic and/or threatened species may leave much of the, at present common or widespread species without effective cover. The Important Bird Area programme of Birdlife International provides a tradeoff by introducing the concept of 'Biome restricted species' in assessing priorities, along with restricted range and threatened species.

There is an urgent need to initiate population studies of birds in the Western Himalaya. Abundance and distribution patterns of birds need to be documented with robust estimation techniques. Compared to

other vertebrates, birds intrinsically occur at lower densities, this makes bird populations potentially more vulnerable to local extinctions. Greater costs of life at high altitudes perhaps keep many species at higher risks of local extinction.

13. To conserve the bird diversity of the Western Himalaya a holistic strategy is needed. Conservation efforts will have to reassess the adequacy of protected area network in protecting distinct assemblages of birds, and will have to ensure and revitalise contiguity of natural habitats along entire gradients at landscape scales. This must be coupled with better understanding of species biology and habitat requirements. With an impending scenario of global climate change, there is an urgency to these needs.

CHAPTER 1

Introduction

Three decades back a popular textbook of Ecology, on its cover, subtitled ecology as 'The experimental analysis of distribution and abundance' (Krebs 1972). Ecology is concerned with understanding factors, which govern the distribution and abundance of species. Many of the fundamental ecological patterns are an expression of aggregate of distribution and abundance patterns of organisms. Trends in diversity patterns emerge from different degrees of overlap of distribution ranges and rarity of a species is its small distributional extent or abundance relative to a group of species. Thus studying diversity and rarity patterns connects us to the core of ecology. Such a study due to its applied aspect in conservation is also at the heart of conservation biology, well illustrated by the title of Michael Soule edited book 'Conservation Biology- The Science of Scarcity and Diversity' (Soule 1986).

Much of ecological research in the last century till eighties emphasised small scale and manipulative experimental approach to studying ecological patterns (Lawton 1999, Gaston and Blackburn 2000, Brown *et al* 2003). These studies involved studying only a few species at a time. This was also typical of research on birds (Gaston and Blackburn 2000). Though this approach added much detail to our knowledge, it was not much successful in understanding the larger picture of life and provided few generalizations to ecology (Brown 1995, Lawton 1999). Research on larger spatial or temporal scales continued as biogeography or studies on evolution, largely without a sharp focus on illuminating ecological patterns. An integrative approach to ecology was required to gain meaningful insights. In a significant initiative, Brown and

Maurer (1989) provided such an integrative program which they called 'Macroecology'. In words of Lawton (1999) "Macroecology is a blend of ecology, biogeography and evolution and seeks to get above the mind-boggling details of local community assembly to find a bigger picture, whereby a kind of statistical generalization emerges from the scrum" and in words of Brown (1999) ".... it is the enterprise of trying to infer laws of nature from the statistical manifestations of the many interacting particulate units of ecological systems". The macroecological approach is typically suited for studying ecological phenomenon at large spatial scales, though Brown *et al* (2003) emphasised that macroecology may also be seen as study of large number of 'ecological particles', without the absolute scale being large.

This thesis is embedded in the macroecological approach. I analyse patterns of composition, abundance and diversity across regional scale of the entire western Himalaya to landscape scales in two study sites in Kedarnath and Gori Ganga valley. I have attempted to arrive at statistical generalizations emerging from the analyses of distribution and abundance patterns of birds in assemblage and I have tried to explain some of the mechanisms underpinning these patterns. The analyses of the regional assemblage comprising the western Himalaya relies on a database constructed using existing sources on distribution of Himalayan birds, while the landscape level analyses is based on field sampling on two study sites in the western Himalaya.

Mountains compress environmental variations observable over thousands of kilometers or many degrees of latitude within a few kilometers. Thus they provide a very useful system to study macroecological patterns.

The Himalaya is one of the few mountain systems in the world to encompass ecoclimatic conditions ranging from tropical to tundra. The Himalaya is also at the juncture of three biogeographic realms. With this great vertical variation in ecological conditions and unique biogeographic position comes a high diversity of forest types, flora and fauna.

Approximately 8000 species of angiosperms (5000 in areas west of the river Kali, Singh 1997), 550 species of breeding birds (Martens and Eck 1995), 241 species of mammals, 149 species of reptiles, 74 species of amphibians and 218 species of fish have been recorded from the Himalayan system (Ghosh 1997). Invertebrate groups are notable for their high level of endemism (estimated at 80% for insects, Mani 1974). This high diversity is compressed in a small geographical area and arranges itself altitudinally.

Adequate representation of all altitudinal zones, and hence biomes, is essential for an effective conservation strategy in the region. However, disturbance and loss of forest cover across all zones is evident in the Himalaya, especially in the western Himalaya. Protected Area planning has helped in the conservation of representative biomes. Nonetheless, for the long-term viability of biodiversity it is imperative that a holistic understanding of biodiversity patterns and the mechanisms determining them be acquired so that ecological and evolutionary processes relating to species, populations and communities may be taken into consideration in conservation planning.

Organization of the thesis

This thesis is organised in six chapters. The first chapter provides an introduction to the general approach of this study. The second chapter describes the geographical settings of the study areas. In the third chapter I attempt a description of the composition of the bird assemblages. I discuss these patterns in the light of biogeographical and historical setting of the Himalayas. The fourth chapter looks at abundance patterns and attempts to establish statistical generalisations between abundance and distribution extent of birds. I look at the role of niche and energetic constraints across species in generating commonness and rarity continuum. The analyses for this chapter are largely based on landscape scales. In the fifth chapter, I analyse diversity patterns across regional and landscape scales. I attempt to find common mechanisms operative at both scales. I analyse the role of energy, area, and variation in range sizes and range limits across the altitude gradient in generating diversity patterns. In the sixth chapter, I attempt to synthesise the emergent themes from the preceding chapters. I focus on the role of climatic factors in generating composition, abundance and diversity patterns. I end by discussing conservation implications of this study. A bibliography of references is included in the thesis.

A chapter specific introduction is given in the beginning of each chapter. Each chapter also carries its own methods section. Though it repeats some material across the three chapters, I hope it will enhance the readability of each chapter.

CHAPTER 2
Study area

2.1 INTRODUCTION

The Himalayas are a region of superlatives. These are one of the most pronounced physical features of the earth, the youngest, loftiest and tectonically most active regions of the world. The Himalayan ranges contain about 30 mountains rising to heights greater than 24,000 feet (7,300 m) above sea level, including Mount Everest, the world's highest peak, which reaches an elevation of 29,028 feet (8,848 m). The mountains extend without interruption in a broad arc for about 1,550 miles (2,500 km) from their western end at Nanga Parbat peak in Jammu and Kashmir, eastward to Namche Barwa peak in the Tibet Autonomous Region of China, near its southern border with India. Between these western and eastern extremities lie several Indian states and the Himalayan kingdoms of Nepal and Bhutan. The Himalayas' total area covers about 5,94,400 km^2. The backbone of the mountain system is formed by the Great Himalayas, a single high range rising above the line of perpetual snow to its maximum height in Nepal and having in that section 9 of the 14 highest peaks in the world.

Several physical attributes help in making Himalayas a global biodiversity hotspot. Its large altitudinal range generates a series of habitats from tropical to alpine in a short geographical area. Its location between at the junction of palearctic and oriental realms makes its flora and fauna a diverse mixture of both these realms.

Rodgers *et al* (2002), recognize two zones in the entire Indian Himalayan range: the northern flank 'The Trans-Himalayas' and the southern flank 'The Himalayas'. The northern flank is a region of high elevations and has an arid climate as it falls in the rain shadow zone. The southern flank falls in the path of the monsoon and is consequently a much moist region. It also has a large altitudinal gradient, allowing development of tropical to alpine habitats.

The western part of the Himalayas extending from Jammu and Kashmir to eastern Uttaranchal (extending into western Nepal) is distinct from the much moist and more diverse Eastern Himalaya (**Fig.1**).

The western range of the Himalayas fall into two distinct zones:

Zone 1. The Trans-Himalayas

High altitude cold deserts of:

a) Ladakh and Kargil districts in Jammu & Kashmir, and

b) Lahul and Spiti districts in Himachal Pradesh

Zone 2. The Himalayas

Two biogeographical provinces fall within this zone:

a) The North-west Himalayas: Kashmir to the Sutlej in Himachal Pradesh

b) The West Himalayas: The Sutlej to Indo-Nepalese Border in Pithoragarh district of Uttaranchal (but in reality, extending up to the Gandak in Nepal)

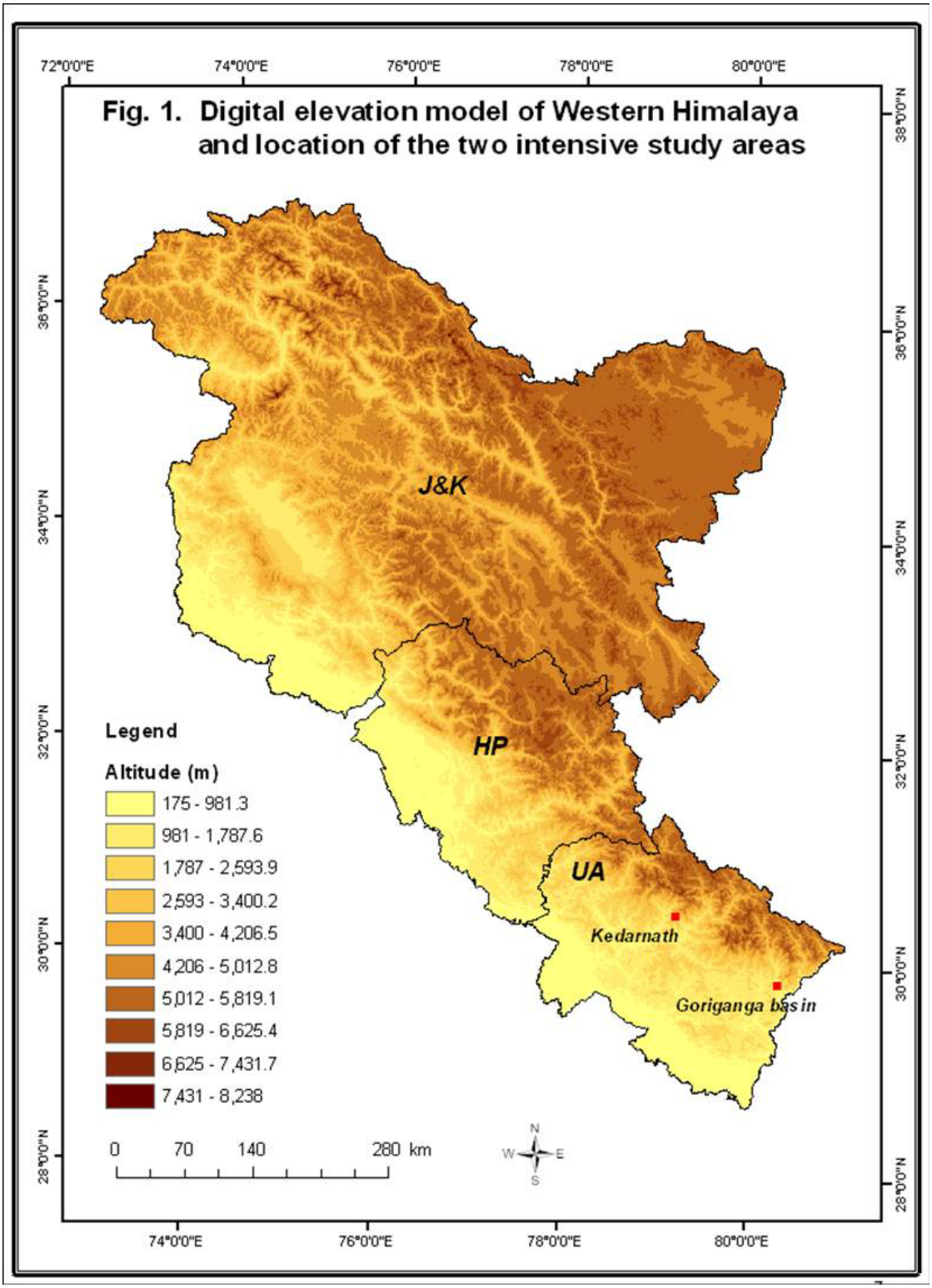


Fig. 1. Digital elevation model of Western Himalaya and location of the two intensive study areas
72°0'0"E
74°0'0"E
76°0'0"E
78°0'0"E
80°0'0"E
38°0'0"N
36°0'0"N
34°0'0"N
32°0'0"N
30°0'0"N
28°0'0"N
J&K
HP
UA
Kedarnath
Goriganga basin
Legend
Altitude (m)
175 - 981.3
981 - 1,787.6
1,787 - 2,593.9
2,593 - 3,400.2
3,400 - 4,206.5
4,206 - 5,012.8
5,012 - 5,819.1
5,819 - 6,625.4
6,625 - 7,431.7
7,431 - 8,238
0
70
140
280 km
N
W
E
S

The Trans-Himalayan zone is a region of arid high altitudes on the northern flank (the rain shadow) zone of the Himalayas. The average altitude in this region being 3000 m, where as the Himalayas comprises a large gradient of altitudes from the foothills to high peaks above 6000 m.

With the defile of river Sutlej an important change in the orientation of the mountains is visible, to the east of Sutlej (covering eastern Himachal Pradesh and Uttaranchal) the mountains are oriented in an east-west direction whereas in the west a southeast-northwest trend is found. This also leads to a latitudinal gradient in this part of the Himalaya.

While the database on the Western Himalayan birds considers all species breeding in the 'Western ranges of the Himalayas', the intensive studies are confined to the biogeographic province of the West Himalaya, as defined by Rodgers *et al* (2002).

Geologically, the arid high northern flank falls in the Trans-Himalayan zone, the high zones with peaks above 6000 m fall in the Greater Himalayan range. Below this, mountain ranges with average altitudes between 3600-4600 m fall in the Lesser Himalayas. The Duns and the Bhabhar tracts fall in the outer Himalayas. The Siwaliks ranges form the southern rim beyond the Dun valleys.

2.2 CLIMATE

The Western part of the Himalayas receives less monsoon rainfall than the eastern Himalayas but gets more winter precipitation in the form of snow.

The Trans-Himalayan zone is cold and arid throughout with rainfall less than 100 mm per year. The climate data for Leh is representative of the region. The northwestern part of the southern flank also experiences decreased monsoon rainfall. Data for Srinagar (Jammu & Kashmir) is reflective of the region (**Table 1.**). The region east of Sutlej experiences higher monsoon rainfalls Local topography and altitudinal gradient plays a dominant role in determining a temperature gradient but generally mean annual temperature falls at a lapse rate of .5° Celsius every 100 m (Singh *et al* 1994).

Table 1. Mean Annual Temperature and Precipitation in select stations in the Western Himalaya.

Station	Altitude (m)	Precipitation (mm)	Temp. Mean (°C)	Temp. Mean Max (°C)	Temp. Mean Min (°C)
Jammu	336	1069	24.2	29.4	19
Dehradun	682	2160	21.6	27.5	15.7
Srinagar (J&K)	1537	660	13.3	19.9	6.6
Chakrata	2134	1885	15.3	17.9	9.5
Shimla	2202	1573	13.3	19.9	6.6
Mukteswar	2314	1360	13.2	17.2	9.1
Leh	3514	83	5.8	12.8	-1.3

Source- Champion and Seth (1968)

2.3 VEGETATION

Due to the great climatic range present, a diverse set of vegetation types occurs ranging from moist tropical forests to alpine and tundra types. From the foothills to 1200 m the climate is warm subtropical, 1200-2400 m cool temperate, 2400-3600m subalpine and above 3600 m experiences alpine-arctic climates (Mani 1974).

As defined by Champion & Seth (1968), seven major vegetation types can be defined here:

Tropical moist deciduous (below 1300 m) Subtropical dry evergreen (foothills – 1000 m, in low rainfall areas), Subtropical pine (800-1800 m), Himalayan moist temperate (1500-3300 m), Himalayan dry temperate (2000- 2500 m), Sublapine forests (2500-3500 m) and Alpine pasture and scrub (above 3500 m). Key characteristics of these forests, mainly extracted from Champion & Seth (1968) are outlined below:

Tropical deciduous Forests (foothills –1300 m) – This forest type occurs in the low altitudes all along the foothills till the junction of temperate types. Though it is absent from Western parts of Himachal pradesh and Jammu and Kashmir where it is replaced by the Subtropical dry evergreen forests. These forests are dominated by Sal (*Shorea robusta*). Key associates are *Anogeissus latifolia, Terminalia alata, and Bauhinia retusa.* Khair-Sissoo forests (*Acacia catechu – Dalbergia sissoo*) forest occur along rivers on sandy alluvium tracts like in the floodplains. Riverine forests with much moisture have *Syzigium*

and *Toona*. *Cinnamomum tamala* and *Ougenia oojeinensis* occur in gorges. Key shrub species are *Cleredendron viscosum, Woodfordia fruticosa, Indigofera pulchella, Helicteres isora, Murraya Koengii*, and *Colebrokia oppositifolia*. *Bauhinia vahlii* is a common liana and *Dendrocalamus strictus* bamboo also occurs. This type is defined as northern dry deciduous forests by Champion and Seth (1968). On moister areas moist deciduous forests occur. It is found on lower foothills, undulating areas and on gently sloping to flat alluvial deposits as well as on steep well drained slopes with high rainfall or on low alluvium with permanent high water table (Champion & Seth 1968). Forest constitute of *Shorea robusta* mainly. *Terminalia* is the most noticeable associate. *Lagerstroemia* and *Pterocarpus* are also often prominent. Other species associated with this moist type such as *Lagerstromia parviflorea, Ehertia laevis, Mallotus philippensis, Miliusa velutina* etc may also become locally abundant in the dry type.

Subtropical dry evergreen (foothills – 1000 m) - This type occurs in the Bhabar, Siwalik hills and the foothills of Western Himalayas extending up the main valley to about 1000m. Hoshiarpur (Punjab), Himachal and Tons (U.P). These areas have typically low rainfall (usually over 500 mm) and are charcterised by long hot and very dry season with cold winters. This is a low scrubby forest of small evergreen trees and many thorny shrub species. The thorny species become prominent on hot dry exposures forming a transition to northern thorn forest. Shrubby growth is prominent. Two subtypes are distinguishable

a) *Olea cuspidata* dominated and b) *Acacia modesta* dominated. *Dodonaea viscosa* may dominate over disturbed areas. Considerable overlap with the subtropical pine forests may be seen.

Subtropical pine forests (1000-1800 m). These forests occur typically as a pure association of Chir Pine (*Pinus roxburghii*) and are found throughout the whole length of the Western Himalaya, except for Kashmir. It occurs from 1000 to 1800 m but may descend to 600 m on ridges and reach up to 2300 m on southern slopes. Top canopy is only composed of Chir pine, with practically no understorey and few shrubs. In more moist sites a broadleaved understorey is seen, composed mostly of evergreen Oaks (*Quercus leucotrichophora*), which increase in dominance with altitude. Other key species of higher altitudes are *Rhododendron arboreum* and *Lyonia ovalifolia.* Shrub species of higher parts are mainly *Rubus, Berberis* and *Rhus.* On lower slopes common tree associates are *Syzigium cumini, Malottus and Carissa.* In recent times this type has increased in extent due to anthropogenic fires in recent times (Singh & Singh 1992).

Himalayan Moist Temperate forests (1500-3300 m). These forests occur all along the temperate zone between 1800-3300 m in the Western Himalaya, lying between subtropical pine and subalpine forests. A rainfall between 1000-2500 mm is necessary for development of this type. A key characteristic of this formation is the extensive development of coniferous forests, which are much similar to coniferous forests found in North Temperate Zone in Europe and North America. A few species are dominant and pure crops of conifers are often seen. Other distinguishing character of these forests is a large contribution of evergreen Oaks (*Quercus spp)*, different dominant species replacing each other altitudinally. Though mixtures of conifers and broadleaved forests occur, generally the hot southern slopes are

occupied by broad-leaved species. Key coniferous species in order of altitude are Kail (*Pinus wallichiana*) Deodar (*Cedrus deodara*), Spruce (*Picea smithiana*), *Abies pindrow* and at the highest level *Abies spectabilis*. The dominant Oak species are Banj (*Q. leucotrichiphora*) Moru (*Q. dilatata*) and at highest levels Kharsu (*Q. semecarpifolia*). These species form forests at altitudes suited to them and are replaced by another Oak or Conifer species depending on aspect and altitude. Puri *et al* (1989) distinguish following subtypes according to altitude:

1. *Q.leucotrichiphora* extending from 2100 to 2400m with *Cedrus deodara* on the southern aspects while on the northern aspects it reaches from 2000-3000m.
2. *Q.dilitata* extending from 2100 to 2400m associated with *Abies, Picea* & *Cedrus*.
3. *Q.semecarpifolia* extending from 2400 to 3300m associated mainly with *Abies*.

R. arboreum and *L.ovalifolia* are common associates in the oak forests. Deciduous genera like *Acer, Aesculus, Corylus, Prunus, carpinus, Ulmus and Betula* also occur and often form local associations. *Alnus nepalensis* occurs along river courses and on landslip sites. Litsea, Lindera and Machilus represent Lauraceae. Other common evergreen genera are *Ilex* and *Euonymus*. Dwarf Bamboo (*Arundinaria* and related genera) often forms a dense understory. Important shrubs of these forests are *Indigofera, Desmodium, Rubus and Viburnum*. Notably Oaks are absent from the Kashmir valley, though all five species of West Himalayan Oaks were present their during the Pleistocene.

Himalayan Dry Temperate Forests (1700 m upwards): This formation occurs in the inner valleys of the Western Himalaya where impact of S.W. monsoon is weak and precipitation (below 1000 mm) is usually as winter snowfall. On the lower limit it is bounded by subtropical vegetation. Conifers predominate in this type with poor representation of broadleaved trees. Xerophytic shrubs are common. Among the conifers *C.deodara, Pinus gerardiana*, and *Juniperus* are characteristic. *Abies* and *P. wallichiana* occur at higher elevations. Among the broadleaved species, species of the moist zone such as *Acer, Fraxinus* and *Quercus* occur. The broad leaved trees are restricted to the lower elevations. Pines dominate the higher elevations with Deodar taking the place of Oaks. Important shrubs of this type are mainly xerophytic *Artemesia*, *Astragalus* and *Ephedera*. *Berberis, Rosa* and *Lonicera* also occur.

Subalpine Forests (2500-3500 m): These are the highest tree forests of western Himalaya forming the treeline. These occur above the temperate and below the alpine zone. It often occurs in strips on spurs or sheltered spots. It occurs as a dense growth of small crooked trees with patches of conifers. The characteristic broadleaved tree species are Birch (*Betula utilis*) and *Rhododendron campanulatum* and *Sorbus*. The Oak *Q.semecarpifolia* and conifers *Abies* and *P.wallichiana* may also form treelines. Other common genera are *Viburnum, Lonicera, Berberis, Ribes and Salix.*

Alpine pasture and scrub (above 3500 m): This type is found in a contiguous series all along the Western Himalaya above the treeline. Due to the high altitudes, entire zone remains snow bound for nearly

six months of the year. The lower limit varies somewhat with aspect. It is conspicuously lower in the Northwest (Kashmir) due to higher latitude. Overall it is composed of woody scrub and grassy-herbaceous meadows. Two types based on aridity may be distinguished, Moist alpine scrubs occur on the moist southern flanks above the treeline and a dry alpine scrub or alpine steppe may occur on the rainfall deficient areas of the northern flank of the Himalaya.

In the moist alpine scrub areas meadows and scrub (stunted woods) penetrate each other and change with aspect, meadows occurring on southern and the scrub on northern aspects (Puri *et al* 1989). Meadows comprise mainly of herbaceous species of *Potentilla, Geranium, Rannunculus, Carex and Kobresia.* Scrubs are dominated by species of dwarf *Rhododendron, Salix* and *Betula utilis.* The dry alpine scrub occurs above the Dry temperate forest zone. It is mainly a xerophytic formation. Dwarf shrubs are predominant. Characteristic plants are *Eurotia ceratoides*, *Juniperus communis, Caragana spp. Artemesia maritima, A. sacrorum, Lonicera spp. and Potentilla spp.*

Streams harbour a characteristic vegetation comprising *Salix, Myricaria* & *Hippophae*. These woody plants form a complete cover and are 1-3 m. high.

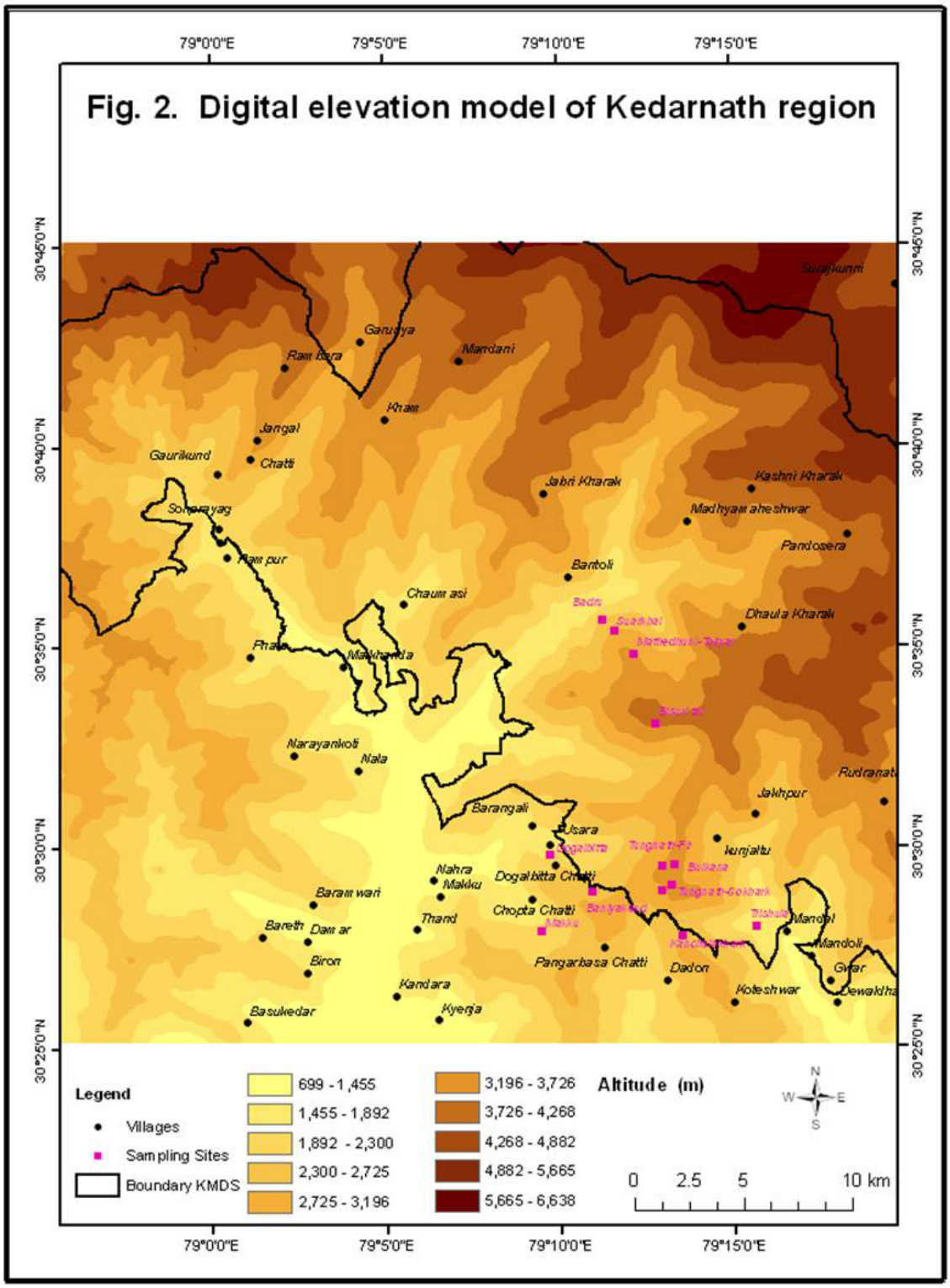


Fig. 2. Digital elevation model of Kedarnath region
79°0'0"E
79°5'0"E
79°10'0"E
79°15'0"E
30°45'0"N
30°40'0"N
30°35'0"N
30°30'0"N
30°25'0"N
Garudiya
Ramwara
Mandani
Khan
Jangal
Gaurikund
Chatti
Jabri Kharak
Kashmi Kharak
Madhyamaheshwar
Sonprayag
Rampur
Pandosera
Bantoli
Chaumasi
Badri
Dhaula Kharak
Phata
Makkumatha
Narayankoti
Nala
Barangali
Jakhpur
Rudranat
Kusara
Kunjallu
Nahra
Makku
Dogalbitta Chatti
Baramwari
Chopta Chatti
Thand
Bareth
Damar
Biron
Pangarbasa Chatti
Dadon
Mandoli
Gwar
Kotheshwar
Kandara
Basukedar
Kyerja
Legend
Villages
Sampling Sites
Boundary KMDS
699 - 1,455
1,455 - 1,892
1,892 - 2,300
2,300 - 2,725
2,725 - 3,196
3,196 - 3,726
3,726 - 4,268
4,268 - 4,882
4,882 - 5,665
5,665 - 6,638
Altitude (m)
N
W
E
S
0
2.5
5
10 km

2.4 INTENSIVE STUDY AREAS

2.4.1 Kedarnath

The Kedarnath Wildlife Sanctuary (30° 25' – 30° 41' N & 78° 55' – 79° 22' E, **Fig 1 & 2**) is one of the largest Protected Area in Uttaranchal. Established in 1972, it covers an area of 975 km^2 in Chamoli district and falls under the bio-geographic zone 2B (Rodgers *et al* 2002). The entire sanctuary lies in the upper catchments of the Alaknanda and Mandakini Rivers, which are the major tributaries of Ganges. It is bounded to the north by a range of peaks mostly over 6,000 m and in the south by the Mandal – Okhimath road. The altitude ranges from 1,160 m to 7,068 m (Chaukhamba peak). The other protected areas that lie near this sanctuary are the Nanda Devi National Park to the East, The Valley of Flowers National Park to the North east (Green 1985; Sathyakumar 1994).

The Kedarnath Wildlife Sanctuary takes its name from the famous Hindu Shrine at Kedarnath whose history dates back to the eighth century. The other shrines of the 'Panch Kedar' that lie within the sanctuary are the Tungnath, Rudranath and Madhmaheshwar temples. The fifth one, Kalpanath lies outside the sanctuary. These shrines remain open during May to October during which pilgrims visit these shrines in varying numbers. For example Tungnath is visited by a few thousands of pilgrims where as only a few hundred people may visit the temple at Rudranath. Over 175 villages are located in and along the southern boundary of the Sanctuary, whose populace depends substantially on its resources.

The main valleys of Kedarnath WS tend to be oriented in N-S direction, so that the sanctuary is fully exposed to the summer monsoon (Green 1985). The monsoon is expected to reach this part of the Himalayas in the third week of June and lasts till the end of September. The considerable influence of the Southwest monsoon on the climate in summer and the 'Western disturbance', in winter can be attributed to the central location of the Sanctuary within the Himalaya. During the monsoon (Summer, July to September), days are usually very cloudy and visibility is often reduced by thick mist with the fog clearing only briefly. In autumn (October to December) temperatures are usually below normal temperature, with morning frost covering the ground layer on most days. Vegetation becomes parched and most streams dry up. Winter (January to March) is characterized with temperatures often below 0^{o} C in the higher reaches. Snow arrives in late December. Thereafter the higher reaches are snow bound for about 3 months, not completely free of snow until 2^{nd} week of April. Snow depth increases with altitude and varies with aspect. Snow remains longer and accumulates with subsequent snowfalls on Northern slopes and melts on the warmer southern slopes. In spring or pre monsoon (April to June) the weather is usually clear but afternoon showers are a common feature this time of the year. The main growing season can be said to be from April to September that is spring and summer (Green 1985). The Sanctuary retains excellent forest connectivity with the surrounding landscape and well preserved forest patches occur along the boundary, such as Trishula reserve forest and Makku Van panchayat.

Flora and Fauna

The sanctuary has diverse vegetation types that can be divided into five major vegetation zones *viz*. subtropical, lower temperate, upper temperate, sub alpine and alpine. About 10.3 % of the area is under permanent snow cover, 7.7 % is Alpine pasture and scrub, 43.5 % under temperate forests and 31.8 % is exposed rocks (Agrawala 1973, Green 1985). Thirty two species of mammals (excluding Chiropterans), 240 species of birds and several reptile species have been reported from this sanctuary (Green 1985; Sathyakumar 1994; Islam & Rahmani 2004). Owing to its high diversity of Himalayan birds and presence of globally threatened Cheer pheasant (*Catreus wallichi*) Kedarnath area has been designated an important Bird Area (Islam & Rahmani 2004)

2.4.2 Gori Ganga valley

The Gori river basin is located in Eastern Kumaon, in the state of Uttaranchal (**Fig 1 & 3**). The Gori river is a tributary of the Kali river located between 70°45′ to 81°5′ E Longitude, and 29°5′ to 30°10′ N Latitude. Tibet lies to the north of the valley, and Nepal lies in the southeast (Kali river forming the Indo-Nepal boundary). Chamoli District lies in the west of the basin, (Higher reaches of the Nandadevi Biosphere Reserve forming the boundary).

Total area of the basin covers 2240 km^2. This is about 4% of the area of the State of Uttaranchal. The basin as such is very unusual with respect to the status of the forests. It is estimated that about 88% of the area is under protected forests (including 64.24% of village commons). About 347 km^2 of Askot WLS falls within the Gori Basin.

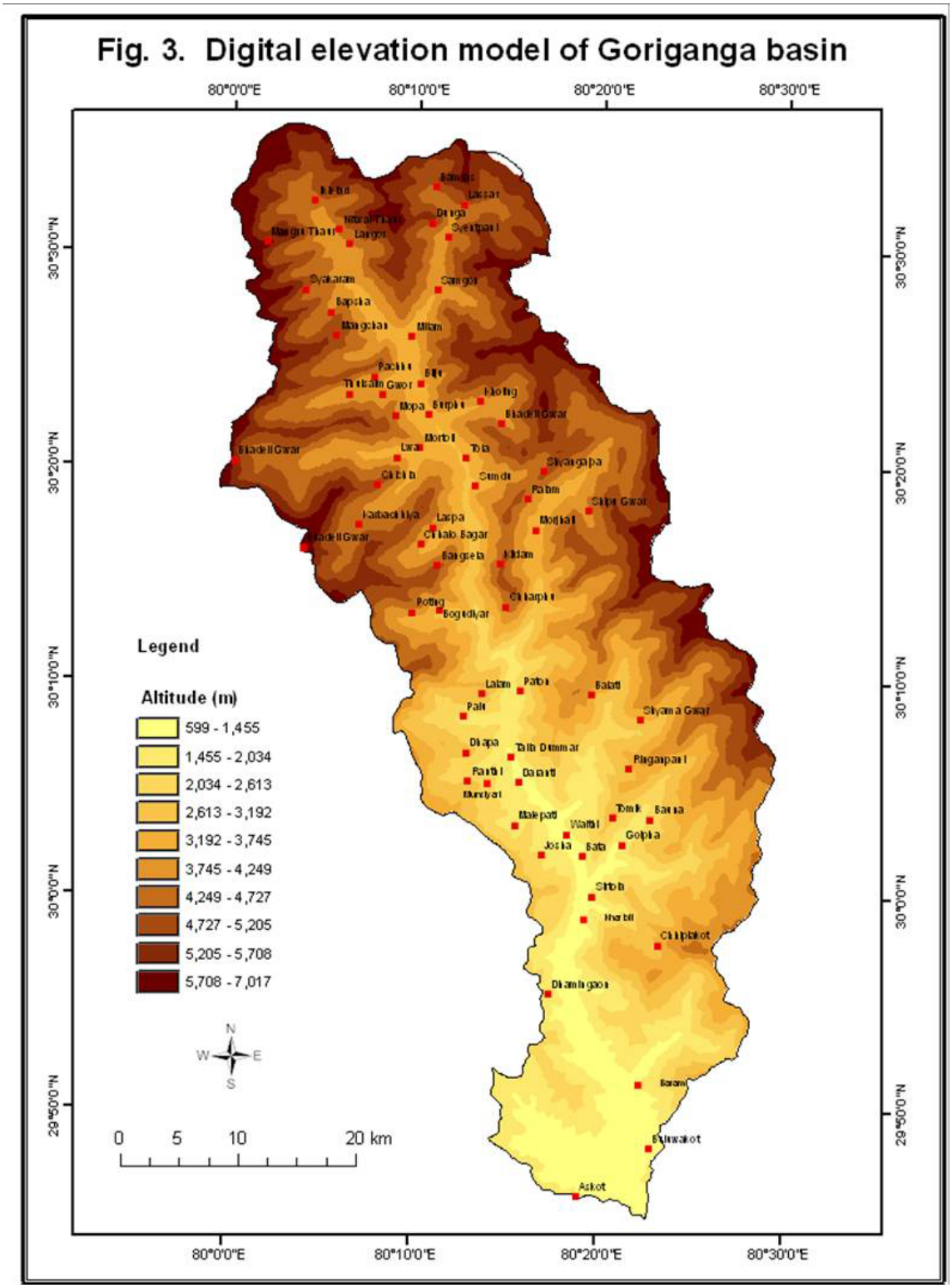


Fig. 3. Digital elevation model of Goriganga basin
80°0'0"E
80°10'0"E
80°20'0"E
80°30'0"E
30°30'0"N
30°20'0"N
30°10'0"N
30°0'0"N
29°50'0"N
Legend
Altitude (m)
599 - 1,455
1,455 - 2,034
2,034 - 2,613
2,613 - 3,192
3,192 - 3,745
3,745 - 4,249
4,249 - 4,727
4,727 - 5,205
5,205 - 5,708
5,708 - 7,017
N
W
E
S
0
5
10
20 km
Askot
Dharchula
Jauljibi
Munsyari
Pithoragarh

Chiplakot area, the gradient intensively sampled for bird diversity characterization along the altitude gradient represents a high variation in altitude and corresponding life zones and in fact is a good example of the overall picture of altitude and topography mediated variation in lifezones and floral and faunal communities.

The altitude ranges from about 800 m at Baram to above 4500m at the Chiplakot ridge giving us Subtropical to subpolar life zones. Further north more arid conditions prevail towards the Milam and Ralam glaciers and moist as well as dry alpine conditions are encountered. High peaks above 6000 m including the Panchachuli peaks form the northern boundary.

Askot WLS is probably the only PA in India to cover habitats ranging from Subtropical Sal to Alpine meadows. From an 80 km^2 area of the sanctuary (Goriganga catchment), seven forest types have been reported *viz.,* Sal *(Shorea robusta),* Chir Pine *(Pinus roxburghii*) and *(Quercus leucotrichophora),* Tilonj *(Q.floribunda),* Kharsu *(Q.semecarpifolia),* Fir *(Abies pindrow*) and Birch (*Betula utilis).* It is especially notable for its large tracts of West Himalaya Broadleaf forest and Subtropical Pine forests. It also harbours east Himalayas communities like *Tsuga* and *Macaranga*, which are known only from this region in the Western Himalaya. It provides adequate representation to >85% dominant forest types of Kumaon-West Himalaya. (*Hippophae community is also reported to be present in Darma valley within AWLS*). The Timberline zone of Panchchuli basin (in AWLS) and adjacent Ralam valley are considered to be of unique and very high importance taking naturalness, endemicity and use value of biodiversity elements into account.

Flora and Fauna

The inventory of vascular plants in Gori basin (Foundation For Ecological Security, 2002) lists the presence of over 2359 species (angiosperms 2258 spp, 891 genera, 170 families, Gymnosperms 7 spp, 7 genera, 4 families, and of pteridophytes 94 spp, 38 genera, 25 families). The list contains 2359 spp, 936 genera and 199 families. Bryophytes: 201 spp, 91 genera, 27 families, Hepatic flora: 60 spp, 34 genera, 21 families, Lichens: 49 species.

The sub-alpine forests of *Betula utilis* and *Abies spectabilis* are reported to be very rich in mycoflora.

The 'Foundation For Ecological Security biodiversity log' lists 209 trees, 284 shrubs, 1427 herbs and 268 ferns, 202 mosses, 49 lichens, 60 liverworts, and at first listing, 132 macro-fungi. Among taxonomic groups, species richness in the family Orchidaceae (120 species) is exceptionally high, and represents 62.5% of those found in Kumaon and 50.8 % of the entire Northwest Himalaya.

The Gori basin is home to many 'medicinal' plant and animal species, whose parts are highly valued in the market, fetching as much as Rs. 50 thousand per kg for *Cordyceps sinensis*, to the price of gold in weight for the musk of *Moschus chrysogaster.* The relatively lower-value plants, which fetch from Rs. 60 a kilo to Rs. 1000 a kilo, are collected and traded in large volumes from these valleys (Foundation For Ecological Security 2002).

Detailed inventories for mammals are not available, however, presence of 29 mammals is reported, 82.7% falling in protected categories. Endangered and threatened large mammals reported include Snow leopard, Himalayan Black Bear, Common Leopard, Common Otter, Musk Deer, Serow, Himalayan Tahr, Bharal and, Goral.

Judging by the large altitude gradient and high habitat diversity, it is not surprising that an inventory of birds finds representation of breeding populations of 40-50% of forest dependent birds of Western Himalaya in Gori ganga Basin, making it a truly exceptional area. It also has populations of three threatened pheasants *viz.* Himalayan Monal, Satyr Tragopan and Cheer pheasant. The Goriganga basin has been designated an Important Bird Area (Islam & Rahmani 2004).

CHAPTER 3

Bird Composition in Western Himalaya: Zonation, Regional Affinities and Role of Vegetation

3.1 INTRODUCTION

The Himalayas are the youngest and one of the largest mountains of the world. Since their rise in the tertiary, they have played a dominant role in biogeographic evolution of the subcontinent (Mani 1974). These mountains on one hand have prevented the northward migration of fauna and flora of the Indian peninsula and on the other hand have facilitated the migration of oriental forms in an east-west direction and also created suitable areas for palearctic forms in the upper reaches. This mixing of fauna has made the Himalayas one of the richest avifaunal regions in the world.

One of the most distinctive features of the Himalayas is its large altitude gradient. This makes the ecology of the Himalayas largely temperature mediated. The altitudinal variation represents a latitudinal displacement of 5000 km (Zobel and Singh, 1997). This enormous variation causes a distinct zonation of climate and consequently the vegetation and the avifauna (Ali 1981).

The role of floristics and physiognomy (vegetation structure) in determining avifaunal composition has been debated since a long time (MacArthur and MacArthur 1961, Rotenberry 1985). The traditional view has held that vegetation structure plays a dominant role in

determining bird community composition although there has been evidence for floristics influencing bird composition as well (Tomoff 1974, Power 1975, Flieshman *et al* 2003*,* see Weins 1989 for a review). At regional scales floristics and structure may be correlated (Mac Nally *et al* 2002). In the Himalayas, floristics are largely determined by altitude, with other topographic and edaphic factors playing a role nested within the effect of altitude. This is aptly reflected in the hierarchical floristic classifications of the Himalayan vegetation such as Champion & Seth (1968) and Puri *et al* (1983). Therefore it is of interest to examine the relative roles of altitude, vegetation composition and structure in determining avifaunal composition.

In this chapter I identify major patterns associated with the zonation of the avifauna in the western Himalayas.

Firstly I identify the major zones of avifauna across the Western Himalaya along the entire altitude gradient.

Secondly, I analyse the composition of the avifauna in a single valley, the Goriganga valley (thus controlling for any regional effect) covering a near complete altitude gradient, for affinities of the avifauna of different altitude zones for different source areas.

Thirdly, I analyse the composition of a temperate avifauna at a local scale, in Kedarnath area to assess the relative roles of vegetation composition, structure and altitude.

3.2 METHODS:

3.2.1 Breeding bird Database

A distributional database of 453 terrestrial bird species breeding in the western Himalayas was created. The database uses information mainly from Grimmet *et al* (1999) and Ali & Ripley (1983), but also supplements information from Kazmeirzcak and Van Perlo (2000) Martens & Eck (1995) and Roberts (1991-1992).

The database incorporates maximum and minimum altitudinal limits, geographic and habitat distribution, an index of abundance at the sub-continental scale and threat levels as classified by the Birdlife International. The Database also records if a species is 'Biome restricted' as per the Biome restricted criterion of the Birdlife International Important Bird Area program, and if it is a 'restricted range' species according to the classification of the 'Endemic Bird Area Program' of the Birdlife International.

A presence-absence matrix of 228 species of breeding birds recorded in Goriganga valley was created in 500 m altitude belts based on systematic searches (see below) and for a few species, supplemented by records of Sultana and Khan (2000). A database of global distributions of these species was constructed by assigning each species to categories based on their major area of distribution. Global distributions were assessed from Robson (2000) MacKinnon *et al* (2000) and Ali & Ripley (1983).

3.2.2 Field sampling at the landscape scale

3.2.2.1 Bird Composition

To assess breeding bird diversity and abundance at the landscape scale in Kedarnath, variable width point count censuses were conducted in the breeding season from May till August, moving up the gradient as the season progressed, tracking the breeding season of different altitude zones. Point count censuses were of 5-minute duration; each point was spaced about 200 m apart and was monitored once. Each detection was recorded as falling in of the following distance classes: 0-5, 5-10, 10-20,20-30,30-50,50-100,100-150,150-200 m classes.

The points incorporated all major vegetation types present in the study areas in a roughly proportionate manner. Mid-Temperate to alpine vegetation zone were sampled covering a gradient of about 2000-4000 m. All sampled slopes are northerly in orientation with low to almost no human disturbance. These censuses provide the data for calculation of diversity and density indices of sites along the altitude gradient, as well as the altitudinal distribution information of species.

In Gori valley, systematic searches were conducted in 16 sites spanning an altitude from 800 m to 4000 m. All species and individuals seen or heard were recorded. Thus a total of 16 sites in the valley were surveyed yielding data on species diversity, abundance and distribution along the altitude gradient. These data were subsequently grouped into 500 m altitude bands.

3.2.3 Vegetation sampling

Vegetation was sampled in 10 m radius plots centered on the bird census point. Trees above 20 cm gbh were measured in 10 m radial plots, saplings and shrubs were counted in 5 m nested plot. Species, GBH, height, height of first branch of trees, height and number of sapling and bamboo culms were recorded for each individual and bamboo clump. Length and girth (at 3 places) of fallen logs (above 20 cm gbh) were measured. Canopy closure was estimated in four 25% classes. Slope, aspect and altitude were recorded for each point.

Points were distributed across 13 sites across 3 catchments in Kedarnath namely, Akashkaminy catchment, 6 sites (Mandikini basin), Balsurti catchment, 3 sites (Alaknanda basin) and Bantoli Gad catchment, 4 sites (Madhyamaheshwar-Mandakini basin). The entire landscape was covered by 384 points with around 30 points in each site.

Sites in the Bantoli catchment are located along a single continuous gradient covering an altitude of 2000-4000 m. All catchments are sampled along a comparable gradient of 2000-4000 m. One alpine site is common to Akashkamini and Balsurti catchment as both slopes converge on the Tungnath ridge.

Table 1: Sites Sampled by Point Counts (1997-2000) in Kedarnath

Site, Year	Mean altitude (m)	Main Habitat
Dogalbitta, 99	2300	Temp. broadleaved
Makku, 99	2150	Temp. broadleaved
Trishula, 99	2200	Temp. broadleaved
Badru, 00	2250	Temp. broadleaved
Bulkana,99	3070	Up. temp broadleaved & krmmhlz
Baniyakund,99	2700	Up. temp fir (*A.pindrow*)
Kanchulakhark,99	2700	Up. temp fir mixed. (*A.pindrow*)
Suarkhal,00	2750	Up. temp fir mixed. (*A.pindrow*)
Mathdhuni-toliyar, 00	3275	Mixed decid. and *R.campanulatum*
Tungnath fir, 99	3100	Subalpine fir and krmmhlz (*A.spectabilis*)
Tungnath-krm,99	3300	*R. Campanulatum*
Bisurital,97	3800	Alpine meadow
Tung-alpine,98	3400	Alpine meadow

Table 2. Sampling localities in the Goriganga valley

S. No.	Locality	Mean Altitude (m)	Main Habitat
1	Babrihat	900	Sal
2	Dawani	1000	Subtropical Mix
3	Rauntia Udyar	1150	Subtropical Mix
4	Selapani-Lilam	1550	Low Temperate
5	Lilam	2000	Low Temperate
6	Pateligad	2050	Mid-Temperate-Deciduous
7	Ghana dhura	2150	Mid-Temperate -Rianj Oak
8	Munsiyari	2200	Mid-Temperate
9	Thuliagail	2400	Mid-Temperate
10	Kalamuni	2650	Mid-Temperate
11	Bhainsikhark	2800	Upper-Temperate
12	Rilkot	3000	Subalpine-open grassy
13	Pachwar-Bhanar	3300	Sublpine-Krummholtz
14	Martoli	3400	Alpine Meadow-Birch
15	Bhanar-alpine	3500	Alpine Meadow
16	Milam	3500	Alpine

3.2.4 Analytical methods

Cluster analysis and Factor analysis were used to identify communities /groupings based on birds, woody plant composition and habitat structure.

Since abundance/density estimated from raw counts may be highly biased due to differential detectability of species, it is advisable to correct for this detection bias in density calculations. Program DISTANCE (Thomas *et al* 2003) corrects for bias in detection probabilities by fitting a detection function. However, a limitation is that pooling species with different detection behaviour may bias the estimators. Moreover many species may have sample sizes too low to be fitted with a detection function and analysed individually. A way to circumvent both these problems is to pool species with similar detection behaviour and analyse each group separately. Densities of individual species can then be extracted by 'post-stratification'.

The species at each site were divided into three groups based on their detection behaviour (mainly calling behaviour) as those detected at small distances (warblers, flycatchers) within 30 m, medium (rufous sibia, Indian blue robin) – within 50 m and those detected beyond 50-100 m also (Cuckoos, pheasants). Separate detection functions were fitted for each of these groups. Density for individual species was extracted by 'post stratification' of density of each group.

Appropriate right truncation was used for each group. A detection model was selected after examining the fit of estimated detection function to the data. Pooling of distance classes was done if found to improve the fit

of detection function. Final model selection was based on minimum Akaike information criteria.

A few species were detected by calls of males exclusively (4 species of cuckoos) or nearly exclusively (Koklass pheasant). Their estimated densities were multiplied by 2, assuming an even sex ratio.

All densities were calculated as numbers/ha.

One high altitude site could not be adequately fitted by a detection function, so density was calculated with a fixed radius of 30 m within which most observations occurred.

Importance Value Index (Muller-Dumbois & Ellenberg 1974) was calculated for each woody plant species for each site.

Nine Vegetation structure variables were calculated for each site. These are: Average of Shrub height, Tree height, Basal area, Shrub density, Tree density, Snag density, Litter depth, Canopy depth (Canopy depth = Tree height – height of lower canopy) and %Canopy openness.

The vegetation composition matrix was arcsine transformed and vegetation structure and bird composition matrices were z transformed before subjecting to cluster or Factor analysis.

Euclidean distance was used to generate dissimilarities. All distance were rescaled to a 0-1 scale and the resultant matrices were clustered by using Unpaired Group Mean Algorithm (UPGMA, McCune & Grace 2002).

Cluster analysis was implemented in SPSS .Ver.8.

Since distances are not independent of each other so a Mantel's regression (Manly 1997) was used to test for significance of relationship between composition, structure and altitude distance matrices. This technique randomizes the distance matrices and tabulates the number of times the observed magnitude of coefficients, F ratio and t-values appear in the randomized runs. The test of significance is calculated by tabulating the percentage of times the observed values appear by chance (in the randomized runs). Thus a value, which appears less than 5% of times, is significant at $p < 0.05$. A geographic distance matrix of sites was also included to control for spatial effects as sites geographically closer to each other may have similar composition due to spatial autocorrelation rather than any environmental effects. A thousand randomizations were performed using the software RT (Manly 1997).

Factor analysis was also used to infer bird community composition groups. Factors were rotated by varimax rotation.

To identify the key species in the regional scale (Western Himalayan) and landscape scale (Kedarnath) compositional groups, an 'Indicator Species Analysis' approach was adopted (Dufrene and Legendre 1997, McCune and Grace 2000). The procedure was implemented in the software INDVAL-2004 (Dufrene-2004).

(http://mrw.wallonie.be/dgrne/sibw/outils/indval/home.html).

Indicator species are defined as the most characteristic species of each group, found mostly in a single group of the typology and present in the majority of the sites belonging to that group (Dufrene and

Legendre 1997). The method was essentially outlined for abundance data though a modified form was proposed for presence -absence data as well (Dufrene and Legendre 1997).

The Indicator Value for a species is maximum (100%) when all individuals of a species are confined to all the sites of one particular group. For presence-absence data, Indicator Value is maximum (100%) if a species distribution is restricted to a group and if it occupies all sites (altitude zones) of that group.

The indicator value is calculated as:

Indicator value = A*ij* X B*ij* X 100

For presence absence matrix:

A*ij* = N sites*ij* / N sites*i*, where N sites*ij* is the number of sites in group *j* where species *i* is present, while N $sites_{i.}$ is the total number of sites occupied by species *i.* 'A' will be maximum when a species occupies sites of a single group.

B*ij* = N sites*ij* / N sites*j*, where N sites*ij* is the number of sites in group *j* where species *i* is present, while N $sites_{j.}$ is the total number of sites in group *j*. 'B' will be maximum when a species occupies all the sites in a group.

For abundance matrix:

A*ij* = N individuals*ij*/N individuals*i*, which expresses the proportion of abundance of species 'i' present in group'j'.

Bij = N sites*ij*/N sites*j*, which expresses the proportion of sites occupied by species '*i*' in group '*j*'.

The significance of the Indicator Value for each species is computed by randomizing the data matrix, calculating the indicator Value and tabulating the % times the observed value or higher occurred in the randomizations. A species was considered significant indicator at p <=0.05, i.e. if the tabulated values occurred in less than 5% times in 1000 randomizations

Number of significant indicator species at each level of the hierarchy was plotted to identify the number of groups, which resulted in maximum number of significant indicator species.

A correspondence analysis was performed on the matrix of number of species in different global distribution categories and their occurrence in 500 m altitude bands. Three rows of 'Biome Restricted species' occurring in Biomes 5- Eurasian High Montane, 7- Sino-Himalayan Temperate forests and 8- Sino-Himalayan subtropical forests were kept passive i.e. they were not used in the analysis directly but were projected in the ordination space after the analysis.

3.3 RESULTS

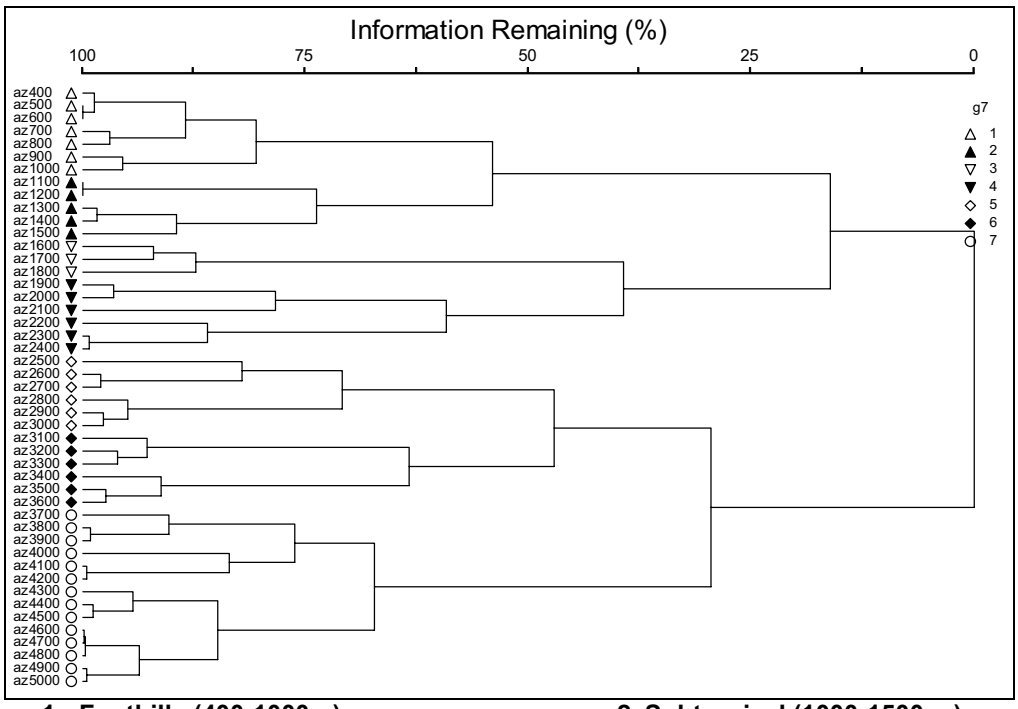
3.3.1 Composition at regional (Western Himalya) scale

The largest number of significant indicator species are identified at the level of 4-5 groups (**Fig 1b**). However, this is mainly because of the influence of some large ranged species. A seven group arrangement emphasizes stentopic (short ranged) species over eurytopic (large ranged) species. The stentopic species provide a distinct property to the foothills and the subalpine-alpine clusters, which were not identified at the 5-group level. Thus though there is some loss of significant indicator species at the 7-group hierarchy it brings out the distinctive avifaunal composition of altitudinal specialists. A complete list of bird species and their indicator values in each of the respective groups is provided in **Appendix 1**.

The seven identified zones are Foothills (400-1000m), Subtropical (1000-1500 m), Subtropical -Temperate transition (1500-1800 m), Lower temperate (1800- 2400 m), Upper Temperate (2400-3000 m), Sublapine and Alpine (3000- 3600 m), High Himalayan (3600-5000 m) **(Fig 1a**).

In the hierarchy of clusters, at the first division, warmer altitude zones (400-2400 m) are separated from the colder ones (2400-5000).

At the second division the lower zone is divided into a subtropical (400-1500 m) and a lower temperate zone (1500-2400).



1. **Foothills (400-1000m),** **2. Subtropical (1000-1500 m),**
3. **Subtropical -Temperate transition (1500-1800 m),**
4. **Lower temperate (1800- 2400 m),** **5. Upper Temperate (2400-3000 m),**
6. **Sublapine and Alpine (3000- 3600 m),** **7. High Himalayan (3600-5000 m).**

Fig 1a. Zonation of Bird communities in the Western Himalaya

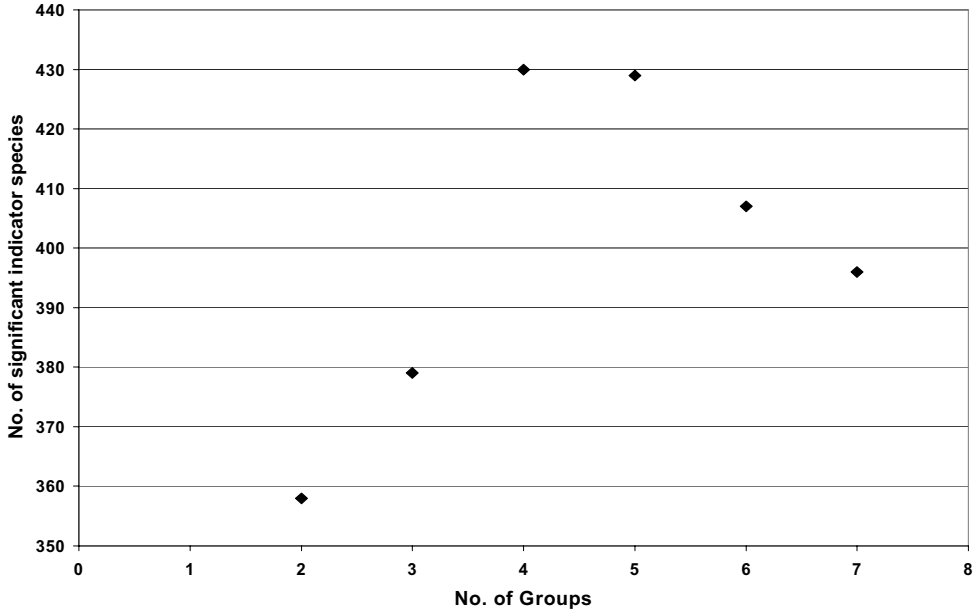


Fig 1 b Number of groups in cluster typology and indicator species significant at p <= 0.05 in altitude zones in Western Himalaya. A seven group typology was selected (see text for details)

At the third division, the upper zone is divided into Upper Temperate (2400-3600) and High Himalayan zone (3600-5000).

At the fourth division the transition between subtropical and lower temperate is identified by splitting the lower temperate group (1500-2400m) into the transition zone 1500-1800 m, and the Lower Temperate zone 1800-2400 m. Thus at this level four major zones i.e. subtropical (400-1500 m), Lower temperate (1800-2400 m), upper Temperate (2400-3600 m), High Himalayan (3600-5000 m) and the transition between subtropical and lower temperate (1500-1800 m) are identified. These are the key divisions of the West Himalayan avifauna. The last two divisions identify the subalpine - alpine and the foothills zones.

The fifth division identifies the upper temperate (2400-3000 m) and Subalpine - alpine (3000 m – 3600 m) by splitting the upper temperate zone (2400-3600 m).

The sixth and final division separates the foothills (400-1000 m) from the subtropics (1000 m – 1500 m) by splitting the subtropics (400 m-1500 m). Thus at this stage seven groups are identifiable, as outlined above.

These groups and their associated species and key habitats are described below. Common names follow Grimmett *et al* (1999).

Foothills

Altitude - 400-1000 m.

Major Habitats- Tropical moist deciduous forests, Subtropical Dry Evergreen. This zone marks the upper limit of Sal (*Shorea robusta*), which is the dominant forest forming species. No. of species – 211.

This zone primarily represents the avifauna of the surrounding plains, which inhabit the foothills, particularly the Siwaliks. It has a large number of significant indicators (170 species), which point out that this fauna is largely restricted to this zone. Some of the species which have high indicator value and are common in the zone are: Green Bee-eater, Rose-ringed Parakeet, Black Drongo, Indian Robin, Purple Sunbird, Red Junglefowl, Common Hawk Cuckoo and Grey-breasted Prinia. However, not all species present in this zone are widespread in the surrounding plains, some species extend in the northern plains just along foothills though they are more widespread in eastern India and moist parts of the peninsula, good examples are the Emerald Dove and the Velvet fronted Nuthatch present in Uttaranchal. These species extend in the north following the moist habitats present in the foothills avoiding the increasingly arid plains adjacent to the foothills as one moves west.

Two species for which this zone is of special importance is the Tawny Fish Owl which is rare throughout its range in south and south-east Asia and Grey crowned Prinia which is endemic to the subcontinent, distributed only along the foothills of the Himalaya and is listed as VULNERABLE.

Subtropical

Altitude – 1000- 1500 m

Major habitats- Himalayan Subtropical Pine (*Pinus roxburghii*) and Subtropical Dry Evergreen.

The chir pine (*Pinus roxburghii*) dominates in this zone, pure stands of chir pine as well as mixed with other broadleaved species may occur.

No. of species – 218

This zone is much alike the lower foothill zone and many species found in the foothills also reach here. Consequently, it is not easy to separate this zone from the preceding zone and it occurs late in the hierarchy of divisions. However, a small group of species is identifiable which largely occur in this zone giving it a distinct character. The prominent species are:

Grey Treepie, Bar-winged Flycatcher-shrike, Asian Brown Flycatcher, Small Niltava, Slaty-backed Forktail, Green Cochoa, Ashy Bulbul, Pale-footed Bush Warbler, White-crested Laughingthrush, Rufous-chinned Laughingthrush, Black-chinned Yuhina, Black-throated Sunbird and Long-billed Pipit. The Green Cochoa is also a NEAR THREATENED species. The pale-footed bush warbler is an uncommon species occurring only along the lower elevations of the Himalaya. Most species listed here inhabit moist forests such as the laughing thrushes, Cochoa, Niltava and the Forktail. The long billed pipit inhabits the dry rocky areas of the south facing slopes.

The subtropical-Temperate transition zone

Altitude 1500 - 1800 m

Major habitats- Subtropical Pine, Moist Temperate Forests. The chir pine continues in this zone particularly on the southern aspects, however the lowest of Temperate Oaks the Banj Oak (*Quercus leucotricophora*) is the chief forest forming species here.

No. of species – 204

A mixing of species of the subtropical and the temperate zone marks this zone. Few species are identified as significant indicators of this zone, which points out to the mixed nature of the avifauna.

The low elevation genera such as *Dicrurus*, *Pericrocatus, Streptopilia* continue in this zone and the temperate genera such as *Garrulax* (4 species) and *Tesia* (1 species) also appear.

Notable among the few species, which are significant indicators of this zone, are Blue-capped Rock Thrush, Tickell's Thrush, Black-lored Tit, Striated Prinia, and Black-chinned Babbler.

The Lower temperate

Altitude - 1800- 2400 m

Major Habitats: Moist Temperate Forests.

Banj Oak continues in the lower part of this zone, however, above it and on moister aspects Moru oak (*Quercus dilatata*) is the main forest forming species. Temperate conifers such as Deodar (*Cedrus deodara*), Spruce (*Picea smithiana*), Fir (*Abies pindrow*) appear in the upper part of this zone and form mixed as well as pure stands.

No. of species – 226.

This is a distinct zone where temperate species appear in large numbers. This is reflected in the large number of significant indicator species in this zone (83 species). Some of the common species of this zone are listed below.

Mountain Scops Owl, Eurasian Jay, Grey-winged Blackbird, Ultramarine Flycatcher, Grey-headed Canary Flycatcher, Green-backed Tit, Black-throated Tit, Grey-bellied Tesia, Black-faced Warbler, White-throated Laughingthrush, White-browed Shrike Babbler, Green Shrike Babbler, Blue-winged Minla, Rufous Sibia, Fire-breasted Flowerpecker, Green-tailed Sunbird.

These are species typical of broad-leaved, especially oak forests.
Pied Thrush and Kashmir Flycatcher are two Himalayan endemic species occurring in this zone. Kashmir flycatcher is also a RESTRICTED RANGE species and is listed as VULNERABLE.

The Upper Temperate zone

Altitude: 2400-3000 m

Major habitats- Moist Temperate Forests.
This is the upper part of the Moist Temperate Forests, Kharsu Oak (*Quercus semecarpifolia*) associated with Fir are the chief forest forming species. Pure Kharsu and Fir stands also occur.
No. of species. 206.

This zone is a continuation of the Lower Temperate zone, however a number of forest dwelling species (51 indicator species) are largely restricted to the upper temperate broadleaved and conifer forests.

These forests are chiefly of Kharsu Oak (*Quercus semecarpifolia*) and Fir (*Abies pindrow*). Some of the characteristic species of the zone are listed below.

Koklass Pheasant, Himalayan Woodpecker, Spotted Nutcracker, Long-billed Thrush, White-collared Blackbird, Mistle Thrush, Dark-sided Flycatcher, Snowy-browed Flycatcher, White-cheeked Nuthatch, Rufous-naped Tit, Rufous-vented Tit, Grey-crested Tit, Goldcrest, Aberrant Bush Warbler, Yellowish-bellied Bush Warbler, Scaly-breasted Wren Babbler, Scarlet Finch, Brown Bullfinch, Red-headed Bullfinch

The zone is particularly important for endemic and Restricted Range species, 5 species out of 11 restricted range species of the Western Himalaya are found here, they are:

Western Tragopan, Kashmir Nuthatch, White-throated Tit, Tytler's Leaf Warbler and Spectacled Finch. The Western Tragopan is also listed as VULNERABLE.

Subalpine and Alpine

Altitude - 3000- 3600 m.

Major habitats- Moist Temperate Forests, Subalpine forests, Alpine Scrub.

This zone is dominated by Temperate broad-leaved (mainly Kharsu Oak in Himachal and Uttaranchal) and Conifer (mainly Fir) forests at the lower limit. At the upper tree limit a distinct Krummholtz or stunted forest of Birch (*Betula utilis*) and *Rhododendron campanulatum* may occur. Alpine meadows form a boundary to this zone. These meadows are generally moister compared to the alpines above this zone.

Depending on the aspect the tree limit and hence the different zones may vary.

No. of species. 172

Some species of lower elevations of Transhimalya such as Bluethroat, White-browed Tit Warbler also feature in this zone. A set of 33 species is identified as indicators.

Examples of subalpine forest birds are Golden Bush Robin, White-browed Bush Robin, Rusty-flanked Treecreeper, Grey-sided Bush Warbler, Great Parrotbill, Fire-tailed Sunbird, Dark-breasted Rosefinch, Pink-browed Rosefinch, White-browed Rosefinch, Orange Bullfinch and White-winged Grosbeak.

Examples of alpine meadow species are Spotted Bush Warbler and Spot-winged Rosefinch.

The Orange Bullfinch is also a RESTRICTED RANGE species.

High Himalayan

Altitude – 3600-5000 m.

Key habitats. Moist Alpine Scrub, Dry Alpine Scrub.

The Moist Alpine pastures continue in this zone, however, westwards and at higher elevations with increasing aridity, the vegetation is of a dry type. Among woody plants, dwarf *Rhododendron*, *Juniperus,* and *Salix* may dominate.

No. of species. 112

This zone gets its distinctiveness primarily due to Transhimlayan avifauna, which occur at very high elevations. A set of 38 species is identified as indicators. Some of the examples are:

Tibetan Partridge, Tibetan Snowcock, Little Owl, Hill Pigeon, Tibetan Sandgrouse, Hume's Groundpecker, Yellow-billed Chough, Common Raven, White-throated Dipper, White-winged Redstart, Wallcreeper, Horned Lark, Tibetan Snowfinch, Alpine Accentor, Robin Accentor, Brown Accentor, Twite, Plain Mountain Finch, Brandt's Mountain Finch, Streaked Rosefinch, Great Rosefinch, Red-fronted Rosefinch.

Some species extend to the high altitudes of the southern flank of the Himalayas also, examples are:

Snow Partridge, Himalayan Snowcock, Snow Pigeon, Tickell's Leaf Warbler and Black Redstart.

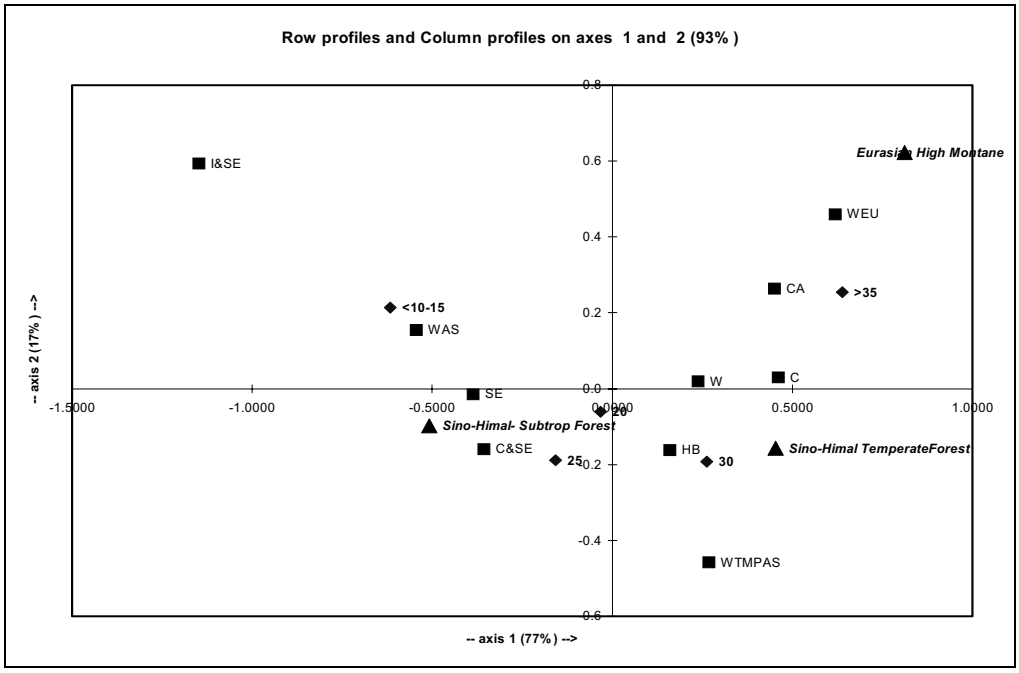
The avifauna is primarily of Tibetan plateau (Central Asian) in origin, and though poor in species is highly distinct. Some of the important genera are:

Carpodacus (Rosefinches), *Prunella* (Accentors), *Phoenicurus* (Redstarts), *Leucosticte, Montifrigilla and Pyrgilauda* (Mountainfinches).

3.3.2 Regional affinities of altitude zones

Altitude zones have distinct composition in terms of species with differing affinities to differing regions in Asia. The Correspondence Analysis of avifauna of Goriganga valley suggests that with increase in elevation species with ranges centered in higher latitudes predominate (**Fig.2**). Thus lower elevations have species with their main distributions centered in South-east Asia, and species widespread in Asia. Mid-elevations have species distributed mainly in China and South-east Asia. Species with distribution mainly in Himalayas and bordering areas are associated with 2500-3000 m zone, Central Asian, widespread Eurasian and other widespread species with large ranges in northern latitudes are associated with the highest altitudes (above 3000 m). Predictably the Biome restricted species of 'Sino-Himalayan Subtropical Forest' are associated with altitudes below 2000 m, 'Sino-Himalayan Temperate Forest' with 2500-3000 and 'Eurasian High mountains (Alpine & Tibetan)' with highest altitudes, 3000 m and above.

The distribution of Biome restricted species in the seven altitudinal groupings in the western Himlaya also points to distinct faunal composition and source (**Table.3**) (Only species whose altitudinal distribution is significantly restricted to the zone included, giving a total of 127 BIOME RESTRICTED species). Thus the lower elevations have representation of primarily Subtropical Biome (Biome 8) and as the altitude increases species of Temperate forests (Biome 7) and Alpine (Biome 5) biomes increase their presence. The lower temperate



Legends:

Diamonds: AltitudeX100, Triangle- Biomes,

Squares: Global distribution types- I&SE=India & SE Asia, C&SE= China & SE Asia, HB= Himalayas and bordering areas, C= China, CA=Central Asia, WTMPAS = Widespread in Temperate Asia, WEU = Widespread in Eurasia, W= Widespread globally

Fig.2. Regional affinity of bird communities across altitude in Goriganga Valley

zone (D) is anomalous in having a substantial representation of Subtropical Biome as well though the largest share is from the Temperate Biome.

Table 3. Distribution of Biome restricted species in bird composition zones.

BIOME	A	B	C	D	E	F	G
5- Eurasian High Montane					1	2	25
7- Sino-Himalayan Temperate forests				23	30	13	2
8- Sino-Himalayan subtropical forests	7	6	4	14			

A-Foothills (400-1000m), B-Subtropical (1000-1500 m), C-Subtropical -Temperate transition (1500-1800 m), D-Lower temperate (1800-2400 m), E-Upper Temperate (2400-3000 m), F-Sublapine and Alpine (3000- 3600 m), G-High Himalayan (3600-5000 m).

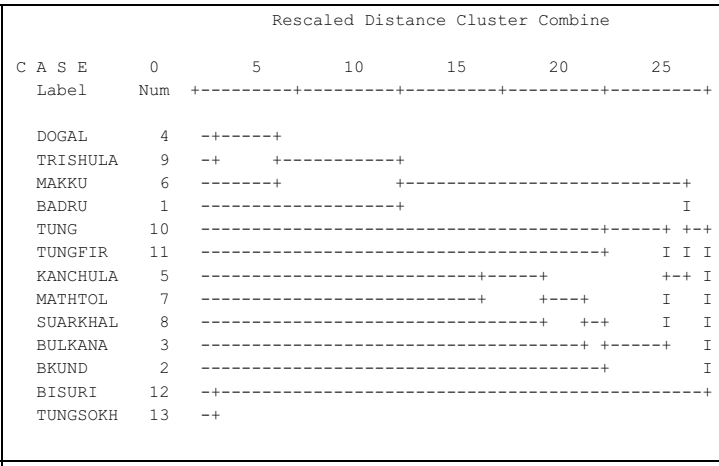
3.3.3 Composition at local scales: Bird composition in temperate assemblage in Kedarnath

Four key groups are identified with cluster analysis among the thirteen sites in kedarnath (**Fig 3a**). This arrangement also provides the largest number of significant indicator species (**Fig 4**).

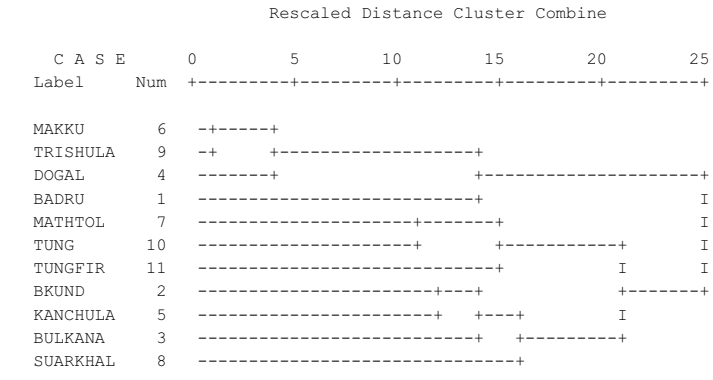
These groupings correspond to Temperate Deciduous forests, Upper Temperate forests, Sublapine forests and Alpine meadows (**Table 4**).

Factor analysis also provides four similar groupings and explains 70% of the variation (**Table 5a & 5b**).

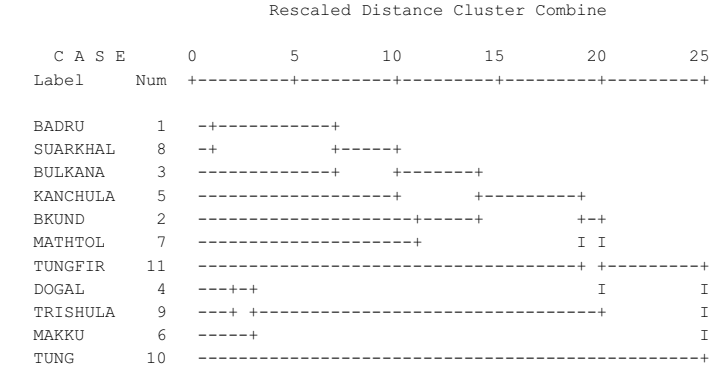
Fig. 3 Similarity of Sites based on Bird, Woody Vegetation composition, Vegetation structure, Altitude and geographical distance in Kedarnath



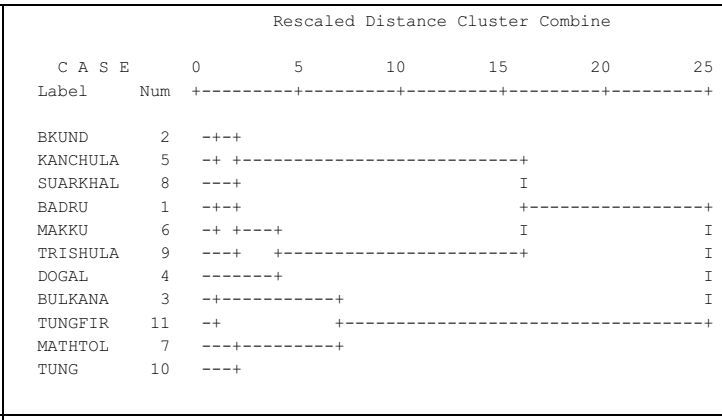
a) Grouping of sites based on Bird Composition



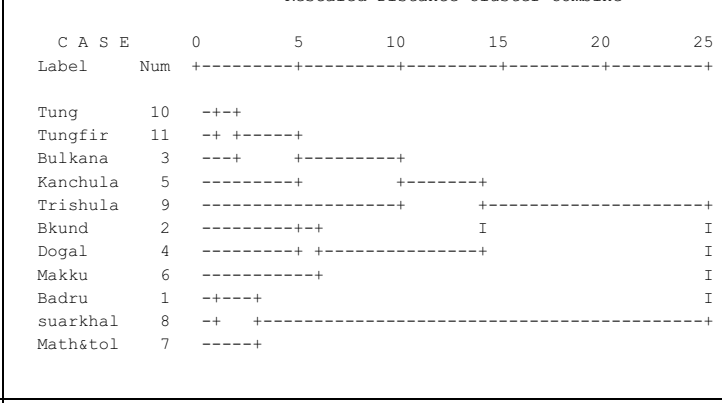
b) Grouping of sites based on Woody Vegetation Composition



c) Grouping of sites based on Woody vegetation Structure



d) Grouping of sites based on Altitude



e) Grouping of sites based on geographical proximity

Fig. 3 *(contd.)* Similarity of Sites based on Bird, Woody Vegetation composition, Vegetation structure, Altitude and Geographical distance in Kedarnath

Table 4. Cluster Membership of Sites based on Bird composition Fig.3.a.

BADRU	1	Temperate Deciduous
DOGAL	1	Temperate Deciduous
MAKKU	1	Temperate Deciduous
TRISHULA	1	Temperate Deciduous
BISURI	2	Alpine
TUNGSOKH	2	Alpine
BKUND	3	Upper Temperate
TUNGFIR	4	Subalpine
BULKANA	3	Upper Temperate
KANCHULA	3	Upper Temperate
MATHTOL	3	Upper Temperate
SUARKHAL	3	Upper Temperate
TUNG	4	Subalpine

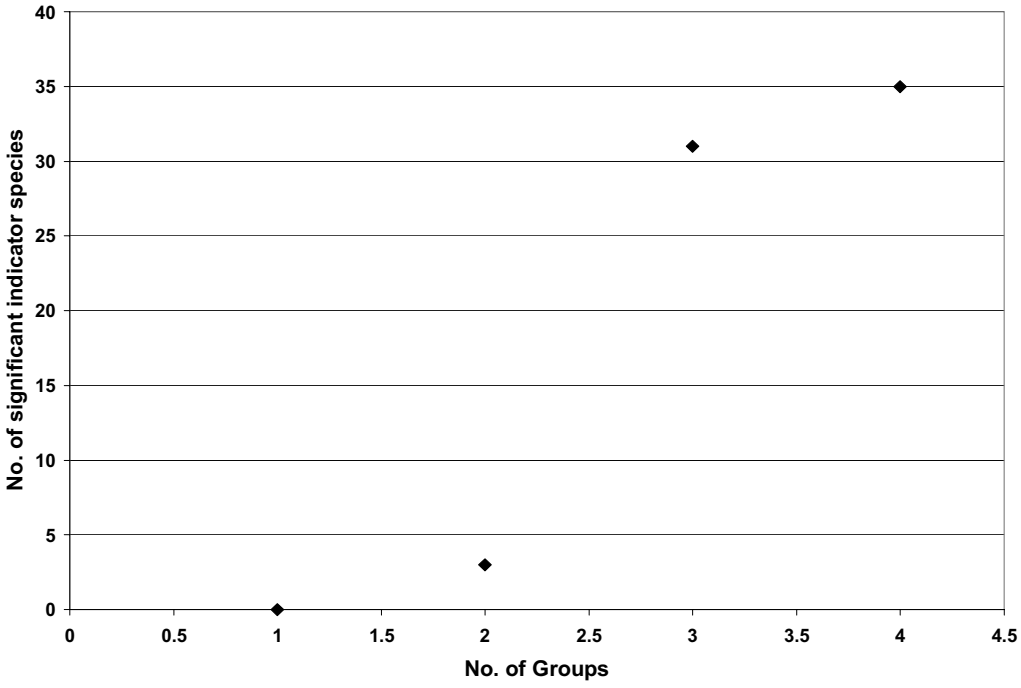


Fig.4 Number of groups in bird composition cluster typology and indicator species significant at p <= 0.05 in Kedarnath (see Fig 3a)

Temperate Deciduous Forests:

Altitude – 2000- 2500 m. Key habitats: Temperate deciduous forests dominated by Moru Oak *Q.dilatata*.

Number of species 62.

A large number (17) significant indicator species are identified for the Temperate deciduous community, these are :

Black-faced Warbler *Abroscopus schisticeps,* Black-throated Tit *Aegithalos concinnus,*, Grey-headed Woodpecker *Picus canus,* Whiskered Yuhina *Yuhina flavicollis,*, Indian Cuckoo *Cuculus micropterus,* Great Barbet *Megalaima virens,* Rufous-bellied Niltava *Niltava sundara,* White-throated Laughingthrush *Garrulax albogularis,* Snowy-browed Flycatcher *Ficedula hyperythra,* Grey-headed Canary Flycatcher *Culicicapa ceylonensis,* Striated Laughingthrush *Garrulax striatus,* Maroon Oriole *Oriolus traillii,* Ultramarine Flycatcher *Ficedula superciliaris,* Green-backed Tit *Parus monticolus,* Grey-hooded Warbler *Seicercus xanthoschistos,* Rufous Sibia *Heterophasia capistrata,* and Hill Partridge *Arborophila torqueola.*

Upper temperate Forests:

Altitude: 2700- 3300 m. Key habitats- Upper temperate deciduous forests, Kharsu Oak *Quercus semecarpifolia* and Fir *Abies pindrow* forests. Number of species- 72

The upper temperate community has comparatively fewer significant indicator species (7 species), these are :

Chestnut-headed Tesia *Tesia castaneocoronata*, Spot-winged Tit *Parus melanolophus*, Golden-spectacled Warbler *Seicercus burkii/whistlerii*, Himalayan Woodpecker *Dendrocopos himalayensis*, White-collared Blackbird *Turdus albocinctus*, Chestnut-crowned Laughingthrush *Garrulax erythrocephalus*, Ashy-throated Warbler *Phylloscopus maculipennis*

Subalpine:

Altitude- 3400-3500 m. Key habitats- Subalpine Fir – *Abies spectabilis* forest, Birch *Betula utilis* and *Rhododendron campanulatum* forests. Number of species 28.

The subalpine community has 8 significant indicator species these are: Golden Bush Robin *Tarsiger chrysaeus*, Goldcrest *Regulus regulus*, Buff-barred Warbler *Phylloscopus pulcher*, Hume's Warbler *Phylloscopus humei*, Bar-tailed Treecreeper *Certhia himalayana*, Rufous-vented tit *Parus rubidiventris*, Variegated Laughingthrush *Garrulax variegatus*, Dark-breasted Rosefinch *Carpodacus nipalensis*, Stripe-throated Yuhina *Yuhina gularis*

Alpine meadows

Altitude - 3600-3800 m. Key habitat- Alpine meadows, dominated by grass *Danthonia* and hebaceous flora.

Number of species 13.

The alpine meadow community is mainly dominated by Rosy pipit (*Anthus roseatus*) and Spotted bush warbler (*Bradypterus thoracicus*) and they are also the significant indicators of this group.

A complete listing of species indicator values in their respective groups is provided in **Appendix.2**.

Table 5a. Eigenvalue and Percentage variation explained by Bird composition factors in Kedarnath

Total Variance Explained						
	Initial Eigenvalues			Rotation Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.65	28.05	28.05	3.53	27.14	27.14
2	2.45	18.83	46.89	2.30	17.70	44.84
3	1.82	13.96	60.85	1.91	14.69	59.53
4	1.27	9.77	70.62	1.44	11.09	70.62

Table 5b. Factor loadings of Kedarnath sites on Bird composition factors.

	Temperate Deciduous	Upper-Temperate	Alpine	Subalpine
Site	1	2	3	4
BADRU	**0.81**	0.15		-0.13
BKUND	0.39	0.41		0.33
BULKANA		**0.54**		0.42
DOGAL	**0.95**			
KANCHULA	0.15	**0.81**		-0.14
MAKKU	**0.92**			
MATHTOL	-0.13	**0.75**		
SUARKHAL		**0.77**		
TRISHULA	**0.96**			
TUNG	-0.10			**0.74**
TUNGFIR				**0.75**
TUNGSOKH			**0.97**	
BISURI			**0.97**	

3.3.4 Correlates of composition: vegetation composition, structure and altitude

Vegetation composition emerges as the most important determinant of bird composition (slope = 0.67, F = 127.66) other variables are not significant in explaining bird composition. Coefficients and significance of the Mantel's regression is given in **Table.6**.

Table 6. Relationship of Bird composition with Vegetation composition, Structure, altitude and geographic distance.

Variable	Coef	t	Extra SS	F
Constant	0.27			
Vegetation Composition	**0.68**	**5.12 (0.01)**	**2.02**	**127.66 (0.01)**
Vegetation structure	0.06	0.58 (56.76)	0	0.19 (67.28)
Altitude	0.13	1.4 (16.79)	0.03	1.97 (16.68)
Geographic	-0.05	-0.85 (39.47)	0.01	0.73 (39.47)

Error SS = 0.7896 F = 32.64

Values in () are % of absolute randomization values greater than or equal to observed t or F values.

3.4 DISCUSSION

Climate plays a dominant role in avifaunal zonation. The major avifaunal divisions along the altitude gradient approximate bio-climatic zones.

Since little autochthonous evolution of avifauna has taken place in the Himalayas, the avifauna is an immigrant one which has colonised these mountains from surrounding areas in South, south-east, Chinese and central Asian regions (Matens and Eck 1995). Birds have colonised such elevation zones, which are similar to the climate of their main distributions. Thus, a tendency for higher elevations to have source

areas from higher latitudes is visible. Distribution and composition of BIOME RESTRICTED species also reinforces this pattern. In general lower elevations have sourced avifauna from the oriental and the higher from the Palearctic region. Judging by the distributions of birds in other parts of Asia (McKinnon *et al* 2000 for china, Robson 2000 for South-East Asia, Kazmierczak and Perlo 2000 for the Indian subcontinent) more specific regions can be inferred. The avifauna of the lowest elevation zones (upto 1500 m) are predominantly from the surrounding plains of the Indian subcontinent, the Indochinese subregion (Northern South-East Asia), has mainly contributed to the subtropical and lower temperate avifauna, the temperate forest avifauna of the higher forests (above 2400 m zones) are mainly from the Szechuan-Yunnan area (South-east Tibet, Central and South-west China). The high Himalayan avifauna is chiefly of the Tibetan plateau and the high plateaus of Central Asian region.

Himalays not only allowed the avifauna of more humid areas of Indochinese subregion to move westwards but also permitted birds of drier temperate forests of China to colonise the western Himalaya. Disjunct distributions of birds in the western Himalayas and Western, South Western China point to a past connection of dry forests growing in South Tibet during a post glacial warm period which facilitated colonization by avifauna of drier forests (Martens and Eck 1995). Examples of such disjunct distributions are: Koklass (*Pucrasia macrolopha*, in the Western Himalaya and then China and Central Asia), White cheeked nuthatch (*Sitta leucopsis,* Western Himalya till central Nepal and then in Western China), Bar tailed treecreeper

(*Certhia himalyana,* Western Himalaya and SW China and N Myanmar) closely related forms of white throated tit (*Aegithalos niveogularis* in the Western Himalaya and - *A.bonovalti* in C and SW China - regarded as conspecific by some workers {Martens and Eck 1995}).

Plants also show similar disjunct distributions. In a west to east transect, Stainton (1977) lists 40 plant species with discontinuous distributions in Himalayas and surrounding areas such as Western China. Among some of the examples are such prominent species such as *Quercus dilatata (*Western Himalaya and Western China)*, Acer caesium (*Western Himalaya- South east Tibet and Western China)*, Olea cuspidata (*Western Himalaya and Western China)*, Viburnum cotinifolium* (Western Himalaya and Bhutan) *Incarvillea arguta* (Western Himalaya South east Tibet and Western China) and *Rumex histatus* (western Himalaya and Western China).

An understanding of the past climatic conditions and routes of movement of these now disjunct species would be of considerable interest to Himalyan biogeographers.

Historical events such as glaciation event have played an important role in the composition of Himalayan avifauna. The disjunct distributions of species outlined above point to the mark of different climates in the past. The western Himalayas also functioned as an important refugia for palearctic species and several genera and species endemic here are regarded as palearctic relicts (Ripley 1959). These genera are *Ophrysia* (*Ophrysia superciliosa*, Himalayan quail) *Catreus* (*Catreus wallichi,* Cheer pheasant), *Callacanthis (Callacanthis burtoni*,

Spectacled Finch). All three genera are monotypic. Among examples of other species are, Black headed Jay *Garrulus lanceolatus,* Spot winged tit *Parus melanolophus*, Tytler's leaf warbler *Phylloscopus tytleri,* and Orange Bullfinch *Pyrrhula aurantiaca.*

The western Himalayas (including mountains of Pakistan and Nepal) also have a relatively high number of species of small geographical ranges (> 50,000 km^2, RESTRICTED RANGE species {Stattersfield *et al* 1998}) and is recognised as an ENDEMIC BIRD AREA (Sattersfield *et al* 1998). With 11 RESTRICTED RANGE species this region is only second to eastern Himalayas though it ranks as 9^{th} in terms of area among 12 chiefly mountainous ENDEMIC BIRD AREAs in continental Asia. Thus past glacial events seem to have led to a relatively high number of species endemic to the region due to either isolation and new species formation e.g. Western Tragopan, White throated tit or through extinction of related species from surrounding areas and formation of relict species Himalayan quail, Cheer pheasant and Spectacled finch.

Within these general patterns some distinct subregional variations also exist. Firstly the rainshadow area north of the main range – the high altitude region of the transhimalya, has a distinct arid climate. Consequently, a very distinct avifauna occupies these regions, though much species are shared between the high altitudes of moister southern flanks as well.

The inner valleys have low elevation areas due to the deep gorge formation of many Himalayan rivers but may experience much reduced

monsoons. Consequently, a much drier vegetation prevails. These valleys may have higher elevation species occurring at lower elevations *i.e.* a regional reduction in lower limit of species may be observed. Martens and Eck (1995) describe such a situation in Nepal. It requires further studies in the Western Himalayas as well.

There exists a significant latitudinal shift from Himachal Pradesh to Jammu & Kashmir, when Himalayas take a strong northwestern turn. This leads to a much reduced monsoon precipitation in Kashmir. As a result many species of more moist forests are absent from Kashmir and it has a reduced number of species (Price *et al* 2003). Perhaps the elevation limits of species also show a downward shift in response to decreased mean temperatures and consequent downward shift of the vegetation zones.

Avifaunal composition shows a strong relationship with vegetation composition and not with structure. This is understandable as most sites are relatively tall temperate forests, which are much similar structurally but differ in vegetation composition in a major way. Two dominant species of Oaks form forest at distinct parts of the altitude gradient (*Q.dilatata* above 2000 m till 2400 m and *Q.semecarpifolia* above 2500 to treeline). Similarly among conifers, Fir (*Abies pindrow*) forms forests above 2400 but at the treeline is replaced by *Abies spectabilis*. Avifaunal composition shows a stronger relationship with floristics than with altitude. Different vegetation communities may form within an altitude zone in response to edaphic, aspect or other topographical and historical factors. For instance Fir dominated and a

mixed broadleaf (*Acer, Aesculus, Quercus, Juglans*) dominated forest can develop at the same altitude as in localities of Baniyakund and Kanchulakhark and Suarkhal all at an altitude of 2700 m. Birds seem to recognise these differences and show a stronger relationship with vegetation composition.

The result that distinct forest types have distinct bird communities and bird composition can be predicted from floristic composition has much applied value. Remote sensing and GIS technology can identify forest types over large areas with much ease, a good correspondence of bird communities with forest types means that vegetation composition can be surrogated for bird communities and can facilitate their mapping. The composition at the entire Western Himalaya scale also corresponds to broad bioclimatic zones, which corresponds well with vegetation types as well. This will make mapping of bird communities at the regional scales also simpler.

CHAPTER 4

Correlates of Commonness & Rarity in Birds of Western Himalaya: Range size, niche & body mass

4.1 INTRODUCTION

Till recent times rarity was used as an intuitive concept, more as a qualitative descriptor than quantitative and without any explicit reference to its scale dependence (Usher, 1986; Soule 1986).

That species vary in abundances has held attention of ecologist for long, and has led to considerable effort in mathematically describing the patterns of species abundance. It is vividly demonstrated by titles of Preston's highly influential papers 'Commonness and rarity of species' (Preston 1948) and 'The canonical distribution of commonness and rarity' (Preston 1962). Subsequently, a large number of models have been developed to statistically describe and provide biological explanations for the abundance distribution of species (reviewed by Magurran 1988, Tokeshi 1990). Indeed, the recent development of 'ZSM' the 'Zero Sum Multinomial Model' by Hubbell (2001) provides a highly influential and compelling neutral model of biodiversity.

However, till recently there was little attempt to understand the mechanisms of commonness and rarity and document their correlates (see Cody 1986, Rabinowitz, 1986 and Hubbel and Foster 1986 for pioneering efforts).

Reveal (1981) recognised rarity as a continuous phenomenon and defined it as 'The current status of an extant organism, which by any combination of biological or physical factors is restricted either in numbers or area to a level that is demonstrably less than the majority of other organisms of comparable taxonomic entities'. Gaston (1994) in an important review of the subject has adopted this definition.

Thus it is defined that a species can be rare or common either due to abundance or geographical extent. Brown (1984) in a groundbreaking paper titled 'On the relationship between abundance and distribution of species' demonstrated that the variables of geographic range and abundance are positively correlated.

Considerable attention has been drawn towards documenting the patterns of the 'Distribution-abundance' relationship and understanding the mechanisms responsible for the pattern. Gaston *et al* (1997) reviewed the mechanisms of this relationship and provide an important conceptual framework for understanding of rarity.

Recently much attention has been focused on the relationship of body size and abundance. It is commonly observed that large bodied organisms are less abundant than the small bodied ones, however the exact form of this relationship is a matter of great interest. Damuth (1981) demonstrated that population density of 307 species of terrestrial primary consumers scaled with body mass with an exponent of -.75. Since metabolic rates scale with body mass as .75, this led to the 'Energy equivalence rule'. This rule suggests that the population

energy use by different species will be roughly equal. As larger individuals have higher energy consumption compared to smaller ones but have lower abundances. Thus both variables are suggested to balance each other, such that population energy use remains constant. However, a more accurate scenario is that no body size class has an apriori advantage over population energy use. These patterns form part of a much influential 'Metabolic theory of ecology' which links patterns in life history, abundance and diversity to metabolic rates of organisms (Brown *et al* 2004a).

The .75 scaling exponent of the bodymass and metabolic rate relationship has also faced considerable criticism and is subject to considerable debate. For birds, Reynolds & Lee (1996) demonstrated an exponent value closer to .67, Mckechnie & Wolf (2004) using a more refined dataset than Reynolds & Lee verified their findings of metabolic scaling of avian metabolism with an exponent ~.67. However, recently Mckechnie *et al* (2006) concluded that for wild-caught birds the exponent is ~ .75. They found that the earlier shallower slope values were a result of including data from captive-raised birds.

The metabolic theory of ecology also is not universally accepted and has been critiqued by several authors (e.g Cyr & Walker 2004, Sterner 2004) to which Brown *et al* (2004b) have responded. However, the debate is not settled as yet.

In this chapter for two local assemblages of forest breeding birds (Kedarnath and Askot-Goriganga valley), I outline the forms of relationship between species abundance and distributions, and the of role energetic constraints in determining species abundance.

I examine if the abundance of species and their local geographical and altitudinal ranges are positively related, i.e. if species rare in abundance are also narrowly distributed and vice-versa.

Using the dataset of the Kedarnath assemblage I investigate if species with larger niche breadth are more abundant than the narrow niche species or if specialist on widely distributed habitat features can also become abundant.

Lastly, I examine the form of relationship of body size and abundance. It has been widely reported that abundance scales with body size with a slope of -.75 (log Density = log C -.75Body size). This relationship is said to result from energetic constraints, since metabolic rate is related with body size with a slope of .75

Basal Metabolic Rate, Rb = 3.76 Bodymass $^{0.739}$ (Zar 1969) ----(**1)**

Thus abundance is expected to decrease at the same rate at which metabolic demand increases. This leads to the conclusion that in a community there is an 'Energetic Equivalence Rule', such that population energy use by different species are equivalent (Damuth

1987), since abundance decreases with the same rate as per capita energy demand increases.

However, the slope of mass density is likely to be ~.75 if organisms are within their thermoneutral zone, that is there is no excess energy demand for thermoregulation. Below thermoneutrality the scaling of metabolic rate differs from .75 and is ~.5.

Indications from limited temperature data from sites in Kedarnath suggest that the average temperature for the breeding period is considerably less than the average avian body temperature of 40°C. (Average Temperature for the months of May, June July and August were calculated by interpolating average temperatures between Mandal at 1650 m and Rudranath at 3600 m, the data is from Singh & Singh 1992 and Sathyakumar 1995). In case birds are below their thermoneutral zone the heat flux (in watts) is given by conductance (c), which scales with body mass with a slope of .5 & the temperature difference between body temperature (Tb) and the ambient temperature (Ta).

Conductance = .11Bodymass $^{0.49}$, Calder & King 1974 ------(**2)**

R = c (Tb – Ta), Peters, 1983. ------ (**3)**

R gives the rate of heat loss as well as the metabolic rate below the thermoneutral zone, since homoeothermic heat production exactly balances heat loss (Peters 1983).

Thus density is expected to scale with body size with a slope of -.5 if a large proportion of birds are below their thermoneutral zone i.e. if the ambient temperature is below their Lower critical temperature (Tlc).

Lower critical temperature is given by:

Tlc = Tb – Rb/c (Peters, 1983) ------ (**4)**

Thus density should scale with metabolic rate with a slope of –1. In case of birds below their lower critical temperature, metabolic rate is given by equation 3 and for birds above their lower critical temperature the metabolic rate is given by equation 1

In case the Energy Equivalence Rule holds in this community the population energy use (Density X Metabolic rate) should have a slope of 0 with body mass.

4.2 METHODS

4.2.1 Bird Distribution and Abundance

To assess breeding bird distribution and abundance at the landscape scale, variable width point count censuses were conducted in the breeding season from May till August, moving up the gradient as the season progressed, tracking the breeding season of different altitude zones. Point count censuses were of 5-minute duration; each point was spaced about 200 m apart and was monitored once. Each detection was recorded as falling in of the following distance classes: 0-5, 5-10, 10-20, 20-30, 30-50, 50-100, 100-150, 150-200 m classes.

The points incorporated all major vegetation types present in the study areas in roughly proportionate manner. Mid-Temperate to alpine vegetation zone were sampled covering a gradient of about 2000-4000 m. All sampled slopes are northerly in orientation with low to almost no human disturbance. These censuses provide the data for calculation of distribution and density indices of sites along the altitude gradient, as well as the altitudinal distribution information of species.

4.2.2 Analytical methods

4.2.2.1 Local and Altitude range

Percent frequency of occurrence in plots and number of sites occupied are used as two measures of local range size. Altitude range is calculated as the difference between the maximum and minimum altitude at which a species occurs. Average altitude of occurrence for each species was calculated by averaging the altitudes of points in which a species occurred.

4.2.2.2 Density and body mass calculation

Since abundance/density estimated from raw counts may be highly biased due to differential detectability of species, it is advisable to correct for this detection bias in density calculations. Program DISTANCE (Thomas *et al* 2003) corrects for bias in detection probabilities by fitting a detection function. However, a limitation is that pooling species with different detection behaviour may bias the estimators. Moreover many species may have sample sizes too low to be fitted with a detection function and analysed individually. A way to

circumvent both these problems is to pool species with similar detection behaviour and analyse each group separately. Densities of individual species can then be extracted by 'post-stratification'. Since it is assumed that species in a group have similar detection behaviour, there respective densities are in proportion to their number of detections.

The species at each site were divided into three groups based on their detection behaviour (mainly calling behaviour) as those detected at small distances (warblers, flycatchers) within 30 m, medium (rufous sibia, Indian blue robin) – within 50 m and those detected beyond 50-100 m also (Cuckoos, pheasants). Separate detection functions were fitted for each of these groups. Density for individual species was extracted by 'post stratification' of density of each group.

Appropriate right truncation was used for each group. A detection model was selected after examining the fit of estimated detection function to the data. Pooling of distance classes was done if found to improve the fit of detection function. Final model selection was based on minimum Akaike information criteria.

A few species were detected by calls of males exclusively (4 species of cuckoos) or nearly exclusively (Koklass pheasant). Their estimated densities were multiplied by 2, assuming an even sex ratio.
All densities are calculated as numbers/ha.

I also calculated average abundance/point (in a 100m radius) for each species as an index of abundance. First average numbers

detected/point was calculated for each species for each site where a species occurred. Secondly this figure was averaged across sites where a species occurred to arrive at the average abundance/point for each species in the landscape.

Average values (for each species) of densities calculated by program DISTANCE was derived by averaging the species values across sites where a species occurred. The average density of a species gives an index of density with which a species on average occurs in the landscape.

Average body size of species was calculated from information given in Ali and Ripley (1983). In case of sexual size differences an average of male and female mass was taken. In a few instances where body mass information was not available, body mass of a closely similar species was substituted.

One high altitude site could not be adequately fitted by a detection function, so density was calculated with a fixed radius of 30 m within which most observations occurred.

For Western Himalaya abundance rankings provided by Kazmireczak & Perlo (2000) are used as an index of abundance. These ranks are provided in five categories, 1.Rare, 2.Uncommon, 3.Fairly common, 4.Common and 5.Abundant. These rankings reflect the assessment of abundance status of a species by experienced observers and thus provide a useful though rough index of abundance. The limitation of this index is that it

summarizes the abundance of a species for the entire subcontinent (in most cases the Himalayas), nonetheless it provides a way of looking at the relative commonness and rarity of species found in the Western Himalaya.

4.2.2.3 Energetic calculations

First it was determined if a species was below its thermoneutral zone by subtracting it's Lower critical temperatures from the ambient temperature.

The ambient temperature at which a species occurs is assumed to be the average ambient temperature of its average altitude of occurrence.

In case it was below its thermoneutral zone the metabolic rate was calculated by equation.3, which takes into account the excess heat production for thermoregulation.

For species within thermoneutral zone basal metabolic rate was calculated by equation.1.

Average population energy use was arrived at by multiplying the average density of each species with its calculated metabolic rate.

Eight species were excluded from this analysis since they occurred at forest edges, alpine meadows or were not adequately censused (an owl and a raptor). Thus all bodymass and energetics related analysis is performed on 86 species.

4.2.2.4 Niche Metrics

For the Kedarnath assemblage Niche position and Niche breadth were calculated using Canonical Correspondence Analysis, (CCA) (Program CANOCO, ter Braak 1987-1992) following Gregory & Gaston (2000). Since only those species, which occurred at least in five plots, were included, niche metrics were calculated for only 62 species. A plot radius of 30 m was chosen so that the habitat measurements in the nested 10 m radius plot corresponds well to the bird observations.

Fifteen environmental variables reflecting the habitat characteristics of the sampled area were subjected to analyses. Four variables pertaining to vegetation types were submitted as nominal variables. All together 320 plots were submitted for analysis.

Niche position for each species is calculated as the euclidean distance of the species centroid from the community centroid. The community centroid is the arithmetic mean of the coordinates of all the species centroids. A higher niche position of a species indicates that the species occupies atypical habitats in the landscape. A value close to zero indicates that the species occupies typical and widespread conditions in the landscape (Gregory & Gaston 2000, Shenbrot *et al* 1991).

Niche Breadth is the spread of the species distribution along the environmental gradients; this is quantified by the standard deviation and is given by the program CANOCO as the 'Root mean square tolerance (RMSTOL)' (ter Braak, 1990)

For the Western Himalaya, the number of habitats in which a species occurs (excluding aerial species) and its altitude range are used as an index of habitat breadth and altitudinal amplitude.

I used spearman's rank correlation to test for association between range, abundance and niche metrics. Differences in number of habitats used and altitudinal range across abundance categories in western himalaya is tested by Kruskall-wallis one way anova.

I performed Ordinary Least Squares regression on average density, body size and energetic variables after log 10 transformation of all variables.

An added difficulty with multi-species analyses is that species may not be independent data points due to phylogenetic relatedness. Controlling for phylogenetic effects is recommended in macroecological analysis (Blcakburn & Gaston 1998, but see also Brown 1999). Controlling for phylogeny may impact some of the results however considerable disagreement over avian phylogeny makes such analyses difficult at the moment (Cracraft *et al* 2003). Though I acknowledge that it is desirable to control for phylogenetic effects in these analyses.

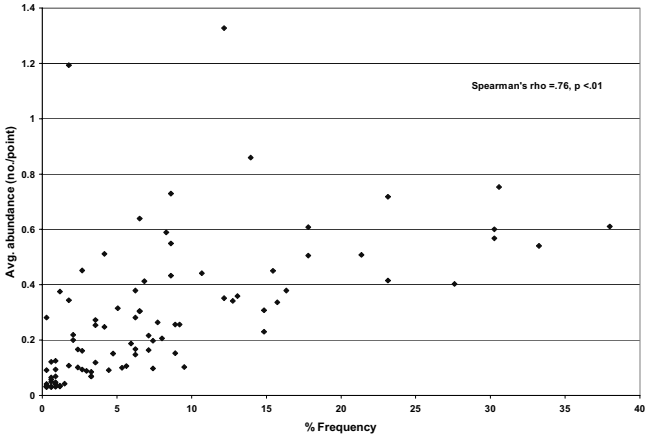
4.3 RESULTS

4.3.1 Range size and abundance

Measures of local range and abundance show significant positive correlation (spearman's rho) in Kedarnath (n= 94), **Table 1 a**, **Fig 1** as well as Askot (Rachia gradient, n = 61) **Table 1b**, **Fig 3**. though correlations are smaller with number of sites occupied .

Altitude range has significant but small positive correlation with average abundance/point as well as density (no./ha) in Kedarnath (**Table 1 a**). In Askot average abundance/point has a significant and large positive correlation with altitude range (spearman's rho, .847, p = .000, **Table 1 b**).

a)



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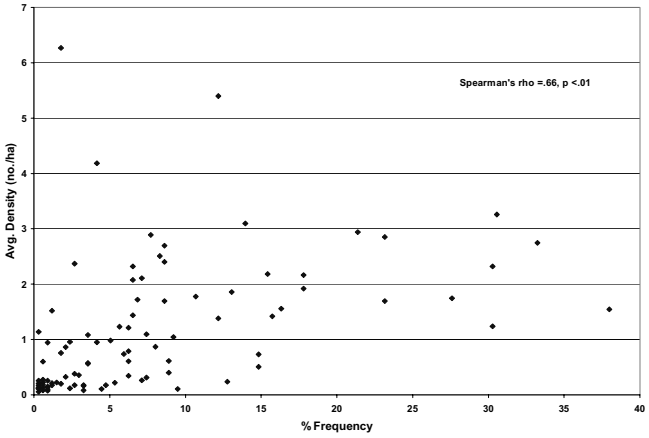

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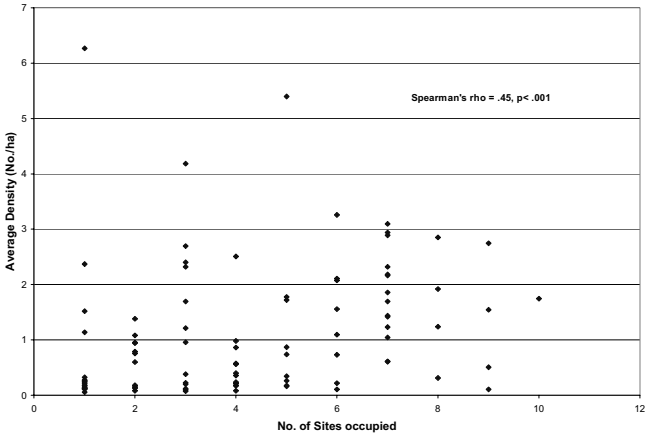


Figure 1. Relationship between Range attributes and abundance in Kedarnath assemblage

a) Average abundance/ point and percentage frequency in points

b) Average density / ha and percentage frequency in points

c) Average density / ha and number of sites occupied

Percent frequency of occurrence in points and number of sites occupied in kedarnath have a positive correlation (**Table 1 a**, **Figure 2a**). Altitude range has significant and large positive correlations with percent frequency of occurrence in plots, in Kedarnath (**Table 1 a**, **Fig 2b**) as well as Askot (**Table 1 a**, **Fig 3c**.)

The two measures of abundance; average number of birds/ point and average density calculated for Kedarnath (calculated by program DISTANCE) show a high significant positive correlation (Spearman's rho = .886, p< .000, n = 94, **Table 1 a**).

Table.1a Spearman's rank correlations between range and abundance attributes in forest bird assemblage of Kedarnath

Variable	Average density/ha	Average abundance/ point	% frequency in points	No. of sites occupied
Average abundance/point	0.8861**			
Percent frequency in points	0.6676**	0.7691**		
No. of sites occupied	0.4153**	0.4313**	0.8347**	
Altitude Range	0.3141*	0.3865**	0.7519**	0.8343**

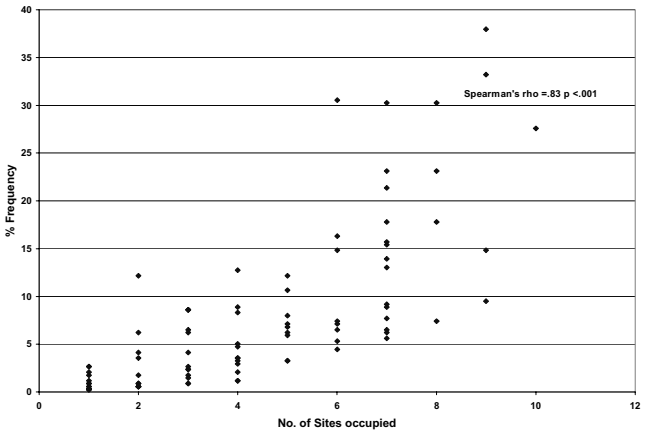
***** Correlation significant at p<.001, * p<.01, N = 94***

Table.1b Spearman's rank correlations between range and abundance attributes in forest bird assemblage of Rachia Gad gardient (Askot WLS)

Variable	Average abundance/point	% frequency in points	No. of sites occupied
Percent frequency in points	.757**		
No. of sites occupied	.367**	.773**	
Altitude Range	.847**	.847**	.843**

***** Correlation significant at p<.001 N = 61***

a)



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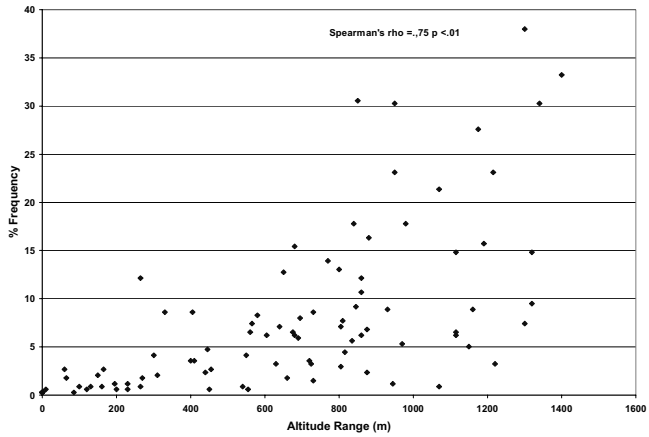
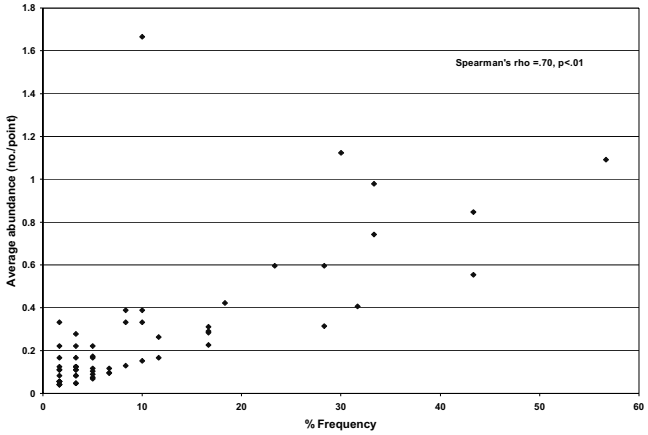


Figure 2. Relationship between Range attributes in Kedarnath assemblage

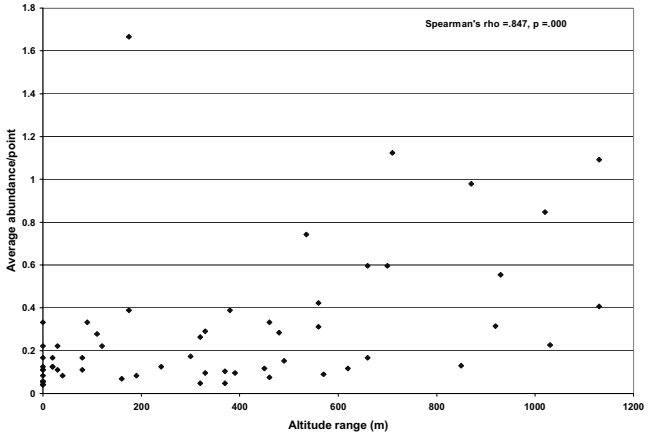
a) Percentage frequency in points and number of sites occupied

b) Percentage frequency in points and altitude range

a)



b)



c)

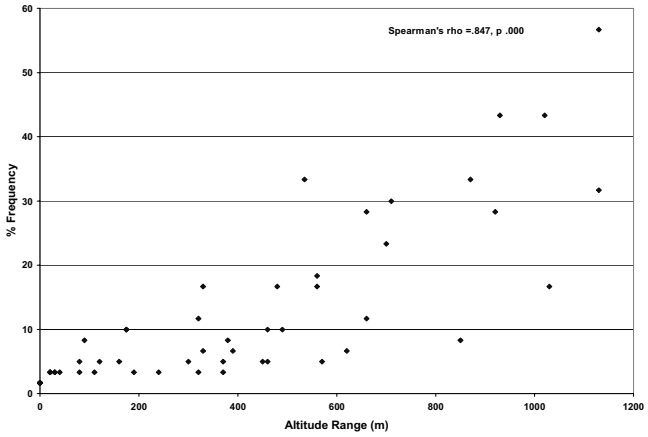


Figure 3. Relationship between Range attributes and abundance in Askot assemblage

a) Average abundance/ point and percentage frequency in points

b) Average abundance/ point and altitude range

c) Percentage frequency in points and altitude range

4.3.1.1 Niche metrics, local range and abundance

Niche use

The CANOCO ordination extracted 4 axis explaining 77.5% of the total variation. Axis 1 explains 35% of the variation, Axis 2, 21.9%, Axis 3, 12.2% and Axis 4, 8.3% of the total variation (See **supplementary Table 1a & 1b** for summary and relationship of variables to ordination axes). Altitude is the most important variable in the ordination and defines Axis 1. It has an increasing trend of altitude, trees with greater basal area, and a moderate density of stems and more open canopy. High altitude areas are highly loaded and temperate deciduous areas are negatively loaded on this axis. The second axis defines a dense habitat with high density of short stature trees and shrubs. These habitats occur in temperate deciduous as well as krummholtz areas. Third axis relates to tall shrubby areas, on moderately steep slopes, mixed conifer broadleaf habitats are negatively related and Upper temperate deciduous areas are positively related to this axis. The fourth axis is mainly related to Upper temperate deciduous habitats, which occur on gentle slopes (See supplementary figures 1a, 1b, & 1c for relationship of variables to axes and supplementary figures 2a, 2b & 2c for biplots of variables and species).

Species are well separated along axis 1 & 2. High altitude species occurring among dense small trees (krummholtz) areas area positively related to both axis 1&2. Main species are *Cettia brunnifrons*, *Cettia flavolevacea, Phylloscopus humei Phy. pulcher*, Carpodacus nipalensis, and *Regulus regulus*. A group of low altitude restricted species occurring in medium sized tree and dense understorey habitats (Temperate deciduous forests) are negatively associated with axis 1. Main species in

this group are *Abroscopus schisticeps, Aegithalos concinnus, Aethiopygea gouldae, Garrulax striatus, Culicicapa ceylonensis, Ficedula superciliaris* and *Ficedula hyperythera*. Species occurring in mid altitude habitats with tall and large trees occur near the origin of Axis 1 and are negatively related to Axis 2. Upper temperate mixed conifer-broadleaf forest and Upper temperate deciduous forest are negatively related to axis 2. Some of the main species in this group are *Ficedula strophiata, Dendrocopus himalayensis, Pericrocotus ethologus, Luscinia brunnea, Tesia casteneocoronata* and *Mycerobos icteroides.* A group of generalist species tend to occupy a position close to the origin of these two axes, these are *Myophoneus caeruleus, Arborophila torqueala , Urocissa flavirostra* and *Sitta himalayensis.*

The third axis separates species occurring in Upper temperate deciduous and Upper temperate mixed conifer broad leaf habitats. Deciduous habitat species are *Minla strigula, Garrulax erythrocephalus, Tesia casteneocoronata*, and *Cuculus poliocephalus*, conifer broad leaf species are *Cerhia himalayana, Parus rubidivenstris* and *Lophophorus impejanus.*

The fourth axis mainly separates middle altitude habitats along a slope gradient, Upper temperate deciduous habitats on gentle slopes and Upper temperate mixed conifer broadleaf habitats occupying steep slopes. *Pucrasia macrolopha* and *Luscinia brunnea* are related to deciduous habitats on gentle slopes and *Cettia acanthizoides* and *Paradoxornis nipalensis* are associated with mixed conifer habitats on steep slopes.

Niche position

Average abundance/point and average density show non significant relationship with niche position though the direction is positive **(Table.2)**.

Percent frequency of occurrence in plots shows a significant but small negative correlation (spearman's rho -.365, p = .003, n = 62) and number of sites occupied shows a larger negative correlation (spearman's rho -.596, p = .000, n= 62) with niche position **(Table.2, Figure 4a&b)**.

Altitude range shows a significant negative correlation with niche position (spearman's rho -.617, p = .000, n= 62) **(Table.2)**.

Niche breadth

Niche breadth shows a significant relationship only with number of sites occupied (spearman's rho, .258, p = .043, **Figure 4c**). Average abundance/point has a negative sign, average density has a positive sign. Altitude range and percent frequency in plots, both have positive signs. **(Table.2)**

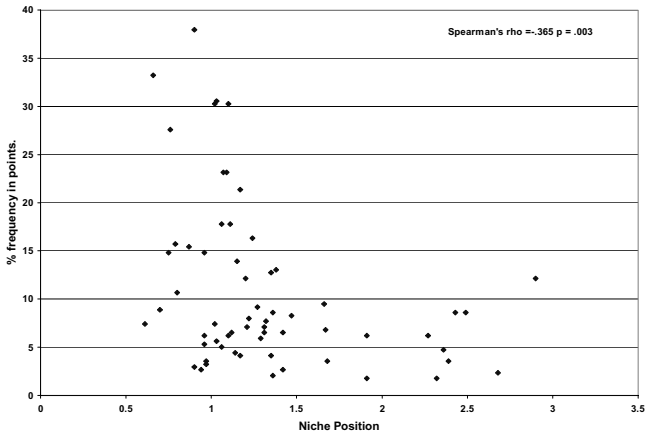
Niche position and Niche breadth show little relationship **(Table. 2)**.

Table.2 Spearman's rank correlations between Niche metrics and range and abundance attributes in forest bird assemblage of Kedarnath

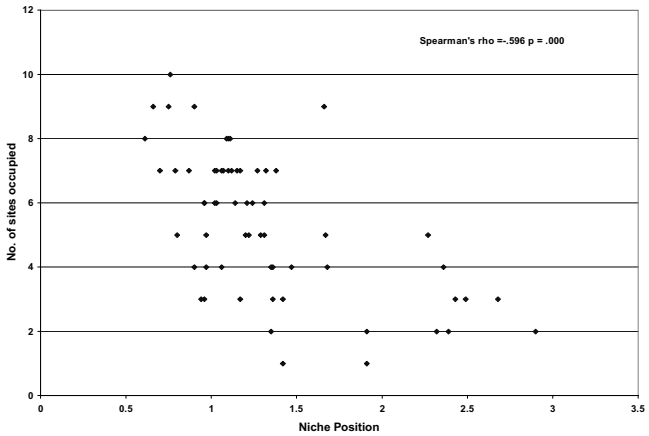
Variable	Average density/ha	Average abundance/ point	% frequency in points	No. of sites occupied	Altitude Range	Niche position
Niche Position	.075 (.563)	.127 (.327)	-.365* (.003)	-.596** (.000)	-.617** (.000)	
Niche breadth	.069 (.595)	-.150 (.244)	.086 (.506)	.258* (.048)	.186 (.148)	-0.015 (.905)

***** Correlation significant at p<.001, * p<.05 (values in parentheses are actual significance levels)***

a)



b)



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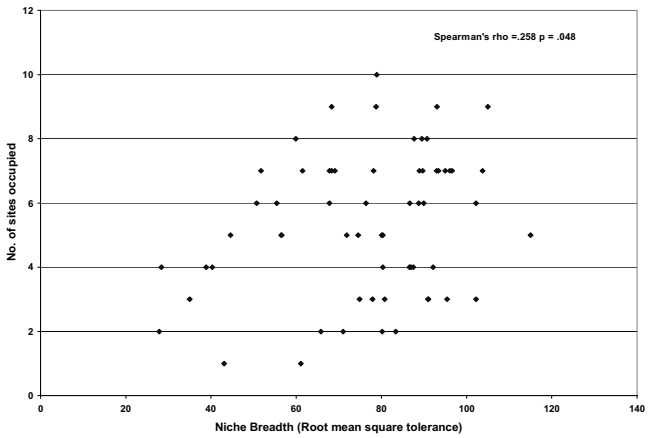


Figure 4. Relationship between Niche metrics and Range attributes in Kedarnath assemblage

a) Niche position and percentage frequency in points

b) Niche position and number of sites occupied

c) Niche breadth and number of sites occupied

Patterns across Western Himalaya

For all breeding birds of Western Himalaya, little difference is detectable in number of habitats occupied (K-W X^2 = 5.611, p = .230, d.f=4, N= 434) as well as altitude range (K-W X^2 =5.144, p = .273 d.f=4, N =453), across abundances classes (**Figure 5a & b**). This suggests that environmental amplitude or niche breadth may not be a major correlate of rarity as suggested by (Brown 1984), and may not explain the distribution-abundance relationship (Gaston *et al* 1998).

4.3.2 Body Mass and Density

The regression between Log body size and log average density has a slope of -.49 (95 % CI -.644, -.343), less steep than the expected -.75. (Log Average Density = -.898 - .493 Log body mass (in kg), Rsq = .336, F = 42.416, p = .000, n = 86, table.2), **Figure 6a**.

Table 3 a. Regression Coefficients

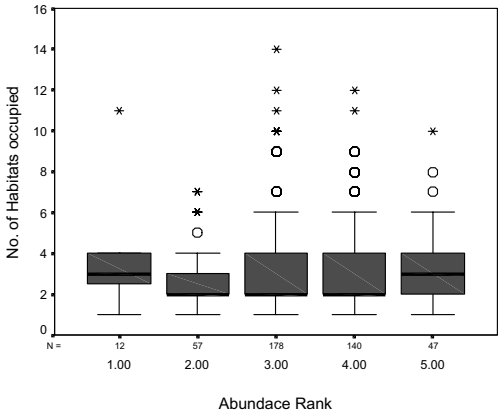
Log 10 Average Density and Log 10 Body Mass

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
	B	*Std. Error*	*Beta*			*Lower Bound*	*Upper Bound*
(Constant)	-.898	.122		-7.372	.000	-1.141	-.656
Log Mass(Kg)	-.493	.076	-.579	-6.513	.000	-.644	-.343

a Dependent Variable: Log10 avg density(ha)

The regression between Log conductance and log average density has a slope of -1 (95 % CI –1.314, -.699, Log Average Density = -1.864 – 1.007 conductance, Rsq = .336, F = 42.416, p = .000, n =86), **Figure 6b**. This is expected if most birds are under large thermoregulatory load. Calculation of Lower critical temperatures suggests that 83.7 % of birds are below their thermo-neutral zone.

a)



b)

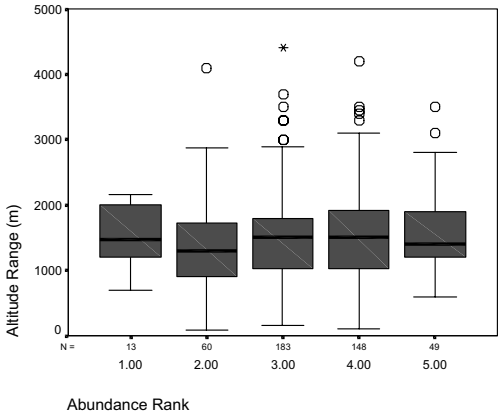


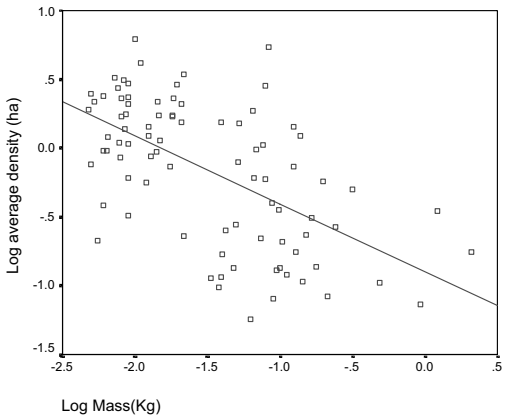
Figure 5. Differences between abundance categories of birds of Western Himalaya

a) Number of habitats used; (K-W X^2 = 5.611, p = .230, d.f=4, N= 434)

b) Altitude range (K-W X^2 =5.144, p = .273 d.f=4, N =453).

Dark line in the box is the median. Little difference is seen among different abundance categories: Values on X axis, 1-rare, 2- uncommon, 3- fairly common, 4- common, 5- abundant

a)



b)

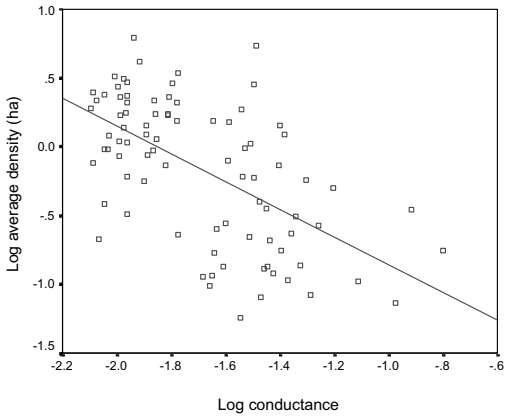


Figure 6. Relationship of Log 10 Average Density with

a) Log 10 body mass (kg);
Log 10 Avg Density = -.898 - .493 Log 10 body mass (in kg), Rsq = .336,
F = 42.416, p = .000, n = 86

b) Log 10 conductance (watts per degree);
Log Avg Density = -1.864 –1.007 Log 10 conductance, Rsq = .336,
F = 42.416, p = .000, n =86

Table 3 b. Regression Coefficients:

Log 10 Average Density and Log 10 Conductance

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
	B	*Std. Error*	*Beta*			*Lower Bound*	*Upper Bound*
(Constant)	-1.864	.265		-7.030	.000	-2.391	-1.336
LOGCOND	-1.007	.155	-.579	-6.513	.000	-1.314	-.699

a Dependent Variable: Log10 avg density(ha)

Relationship between Log metabolic rate and log average density has a slope of -.89, close to –1 (95% C.I –1.181, -.599), Log 10 Average Density = -.460 - .89 log 10 metabolic rate, Rsq = .306, F = 37.018, p =.000), **Figure 7a**.

Table 3 c. Regression Coefficients:

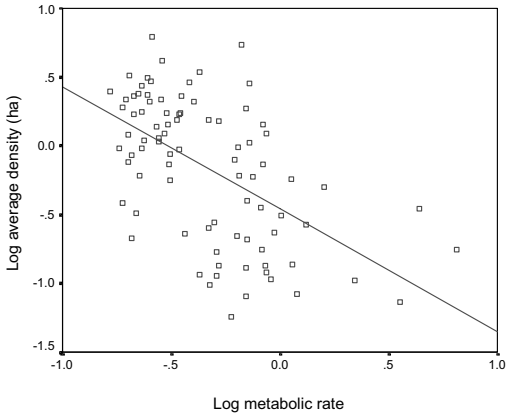
Log 10 Average Density and Log 10 R (Metabolic rate)

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
	B	*Std. Error*	*Beta*			*Lower Bound*	*Upper Bound*
(Constant)	-.460	.068		-6.793	.000	-.594	-.325
LOG_R	-.890	.146	-.553	-6.084	.000	-1.181	-.599

a Dependent Variable: Log10 avg density(ha)

Body mass and Population Energy use show no relationship and have a slope of 0, as expected (Rsq = .002, F = .186, p = .668) **Figure. 7b**.

a)



b)

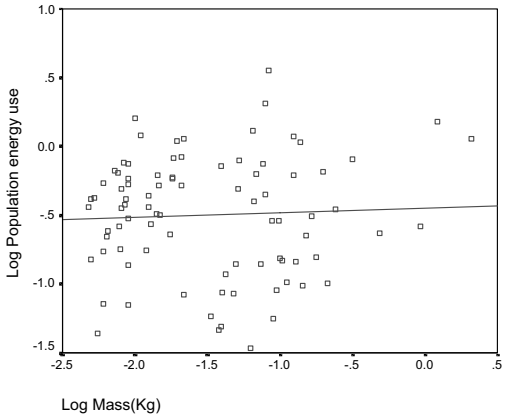


Figure 7. a) Relationship of Log 10 Average Density with Log 10 metabolic rate

Log 10 Avg Density = -.460 - .89 log 10 metabolic rate, Rsq = .306, F = 37.018, p =.000

b) Energy equivalence;
relationship of Log 10 population energy use

(Average Density X Metabolic rate) with log 10 mass (kg)

Log 10 population energy use = -.446 – 0.033log 10 Mass (kg), Rsq = .002, F = .186, p = .668.

Table 3 d. Regression Coefficients:

Log 10 Population Energy Use (Meatbolic rate X Average Density) and Log 10 Body mass (kg)

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
	B	*Std. Error*	*Beta*			*Lower Bound*	*Upper Bound*
(Constant)	-.446	.124		-3.607	.001	-.692	-.200
Log Mass(Kg)	0.03305	.077	.047	.430	.668	-.120	.186

a Dependent Variable: Log Population Energy Use.

Thus the energetic constraints on abundance are largely supported and the role of thermoregulation in relatively colder environments is highlighted. The Energy Equivalence rule in this assemblage is also supported.

4.4 DISCUSSION

The often reported positive association between range size and abundance has also bee observed in the three datasets. At the local , scale occupancy indexed as percent frequency in plots and number of sites occupied were positively correlated. Altitude range was also positively correlated with local range size as well as abundance. Thus the ubiquity of distribution-abundance relationship is reinforced by these datasets as well (Brown 1984, 1995, Gaston *et al* 1997, Gaston & Blackburn 2000).

Larger range sizes are associated with greater resource availability (lower niche position) and higher abundances are associated with lower per capita energy demand (smaller body sizes). Thus it seems likely

that smaller bodied species, which utilize widespread habitats, will inhabit large ranges, acquire high average densities in the landscape and hence will exist at large population sizes.

The niche pattern analysis reveals important features of species of rare occurrence. There is a significant negative trend with occupancy and niche position particularly with the number of sites occupied, though indices of abundance show poor relationship. This suggest that species rare in occurrence may occur at high or low densities, but they occupy small geographical and altitudinal extent and have special habitat requirements which are scarce in the landscape. Some other studies also have reported a weak positive or no relationship of niche position and abundance (Mac Nally 1989, Rogovin *et al* 1991, Shenbrot *et al* 1991).

In comparison, niche breadth has a significant positive association only with numbers of sites occupied, suggesting that species with generalist strategies may occupy greater number of sites with no necessary benefit in terms of greater area of occupancy or abundance. In contrast species with low niche position (i.e. those species which specialize on few but widespread and abundant habitat conditions) gain greater area of occupancy. However, any significant benefit at gaining higher abundance is not seen by either strategy, at this scale. A caveat that needs to be stressed is that the niche pattern analysis cannot include the rarest species in the community because of low sample sizes for them.

However, a greater role of resource availability (niche position) compared to resource breadth (niche breadth) in determining geographical spread of species is supported. This is in agreement with a similar analysis done on British birds by Gregory and Gaston (2000).

No difference was detected between abundance categories of birds and their altitude range sizes or number habitats occupied. This is also suggestive of resource breadth not being related with abundance.

Body size explains more than 30% of the variation in abundance, and turns out to be an important correlate of abundance.

The slope value (-.49) of the log body mass log average density relationship is well supported by hypothesis related to energetic constraints due to higher costs of thermoregulation in colder environments. Since below thermoneutral zone, conductance plays an important role in setting the metabolic rate, and conductance scales with body mass with -.5, density and conductance have a slope of –1. Metabolic rate calculated using limited interpolated temperature data also scales with a slope close to –1. Hence population energy use shows no relationship with body mass, and the 'Energy Equivalence Rule' in this assemblage is supported.

Incorporating the cost of thermoregulation made the relationship meaningful despite the slope value being much larger than the expected -.75 from the basal metabolic rate relationship.

Thermoregulatory needs limit winter bird distribution and abundance in cold climates (Root 1988, Meehan *et al* 2004) but this analysis suggests that significant thermoregulatory load may exist on smaller birds in high mountainous or temperate areas in the breeding season as well. This may explain some of the less steep values (mean slope values > -.75) reported for many temperate bird assemblages. However slopes much shallower than -.75 have been reported for Amazonian bird communities by Russo *et al* (2003) and Brawn *et al* (1995).

Blackburn & Gaston (1997) in a comparison of slope and coefficient of determination (Rsq) values for around 300 Body mass and abundance relationships report mean and median slope to be -.58 and -.51. Large proportion of the reported relationships had low Rsq values and One third of the values were less than .10 i.e. less than 10% of the variation was explained (Gaston and Blackburn 2000)

There is a large amount of residual variation, which remains to be explained. Various factors related to diet and foraging may influence the metabolic rate and hence energetic requirements of species (McNab 1983). Since Himalayas harbour avifauna from diverse

biogeographic regions from tropical south-east Asia to temperate China, there are likely to be some differences attributable to biogeograhic affinity of the avifauna as well.

The ambient temperature data is sparse and is based on interpolation between two lowest and highest points, hence the energetic calculations involving ambient temperature are only indicative of a likely scenario.

Nonetheless the significant relationship of abundance with variables related to metabolic rate, despite there being measurement errors in abundance and temperature, is encouraging, particularly in the light of the 'Metabolic theory of ecology' which was recently elucidated by Brown *et al* (2004a). The theory proposes that energetic constraint in particular the metabolic rate of organisms scale a wide array of ecological phenomenon, from abundances to diversity of ecosystems. This analysis is in agreement with their proposals regarding abundances.

Supplementary Table 1a. Summary of Canonical Correspondence Analysis (CCA)

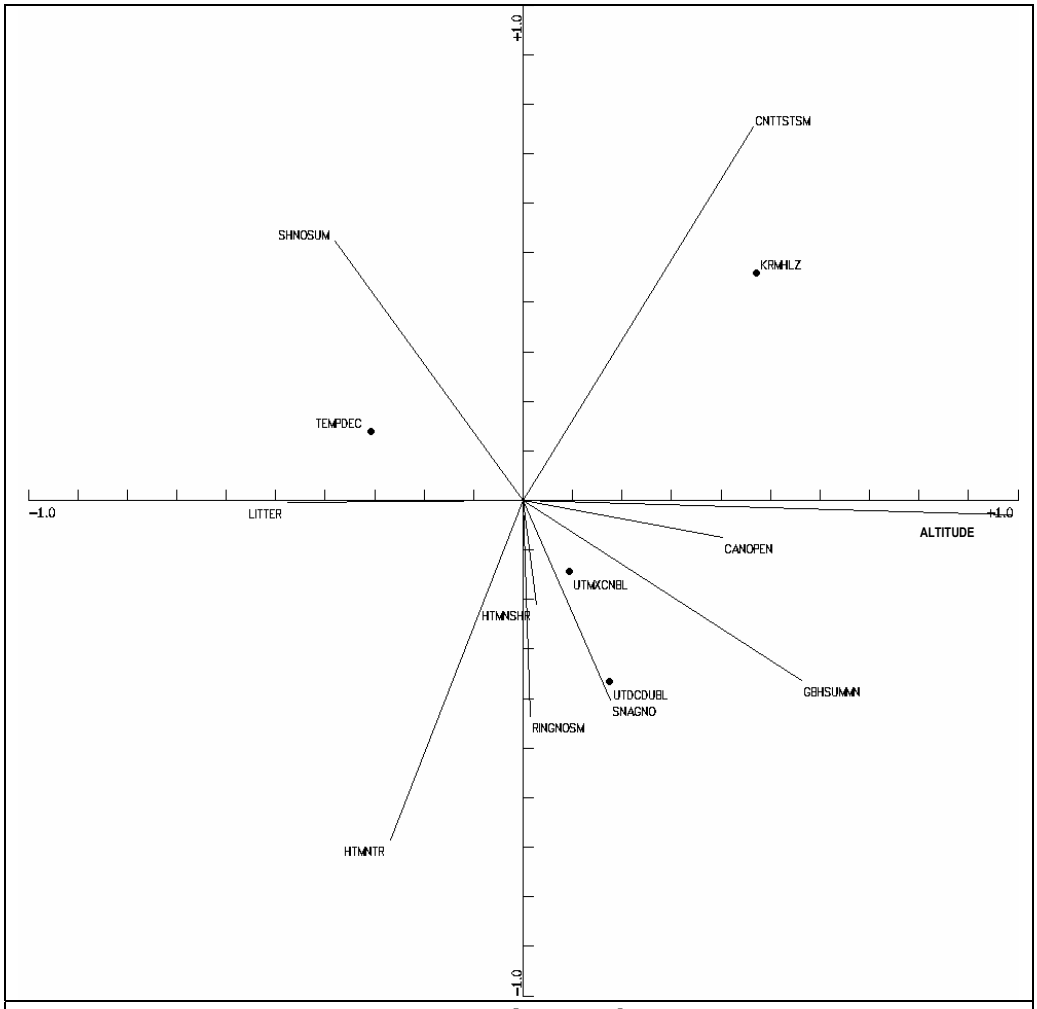
Axes	1	2	3	4	Total Inertia
Eigen Values	0.697	0.433	0.243	0.166	11.967
Species-Environment Correlations	0.955	0.856	0.742	0.671	
Cumulative Percentage Variance :					
of Species data	5.8	9.4	11.5	12.9	
of Species-Environment relation:	35.1	57	69.2	77.5	
Sum of all Unconstrained eigenvalues					11.967
Sum of all canonical eigenvalues					1.984

Supplementary Table 1b. Intraset correlations (Correlations of environmental variables with ordination axes)

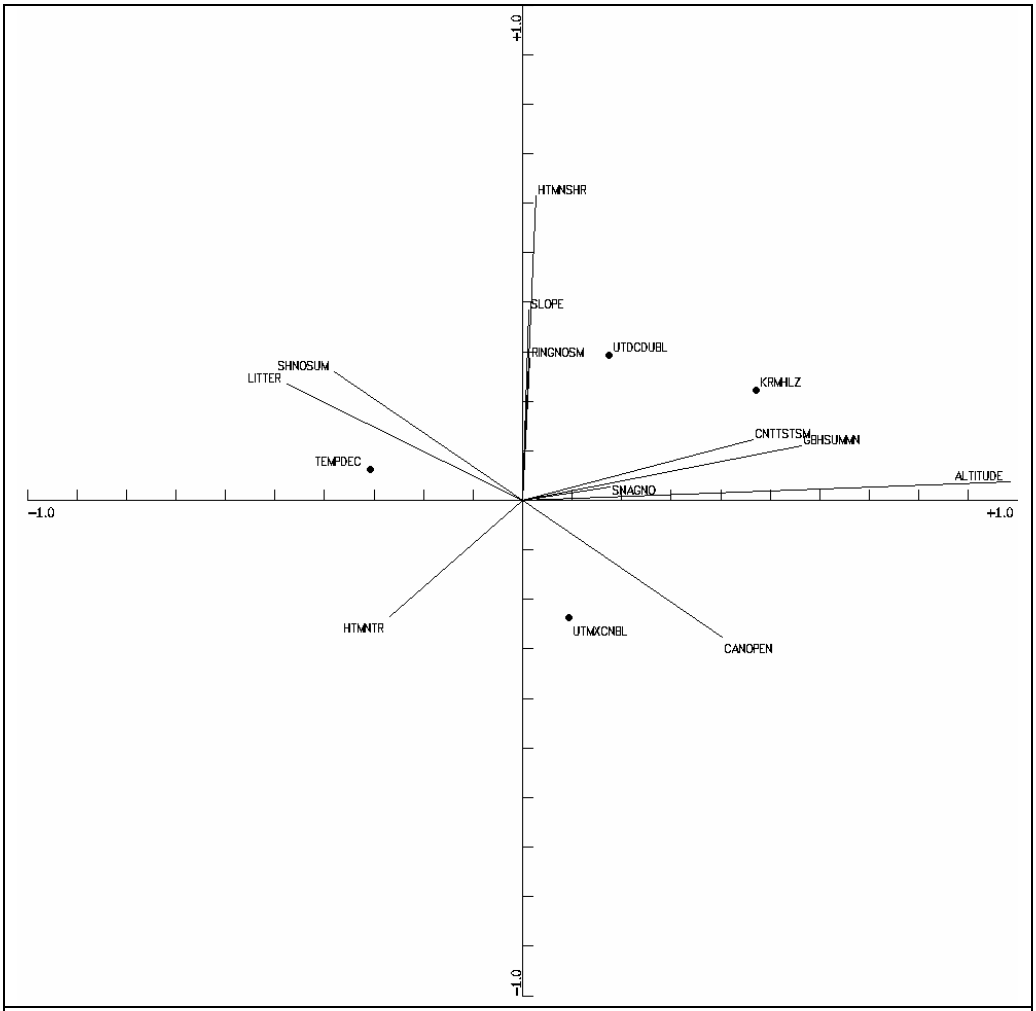
sno			Axis 1	Axis 2	Axis 3	Axis 3
1	HTMNTR	Average Tree height (m)	-0.27	**-0.69**	-0.23	-0.06
2	GBHSUMMN	Average GBH of trees	**0.56**	-0.36	0.11	-0.01
3	CNTTSTSM	No. of Tree Stems	0.47	**0.75**	0.12	0.16
4	HTMNSHR	Average Shrub height (m)	0.03	-0.21	**0.61**	-0.08
5	SHNOSUM	No. of Shrubs	-0.38	**0.52**	0.26	-0.04
6	RINGNOSM	No. of Ringal culms	0.01	**-0.44**	0.29	-0.18
7	ALTITUDE	Altitude	**0.98**	-0.03	0.04	-0.02
8	SLOPE	Average slope	0.01	-0.29	0.38	**-0.59**
9	CANOPEN	Canopy openness	0.40	-0.08	-0.28	0.30
10	LITTER	Litter depth	-0.47	0.00	0.24	0.19
11	SNAGNO	No. of Snags	0.18	**-0.40**	0.03	-0.35
12	TEMPDEC *	Temperate Decid. Forest	**-0.82**	**0.37**	0.17	0.10
13	UTMXCNBL *	Upper Temp. Mixed conifer broadleaf forest	0.26	-0.39	**-0.64**	-0.47
14	KRMHLZ *	Krummholtz forest	**0.59**	**0.58**	0.28	-0.05
15	UTDCDUBL*	Upper Temp. Decid. Forest	0.24	**-0.51**	**0.41**	**0.58**

* Nominal variables

Supplementary Figure 1. Scatter of variables on CCA ordination axes (see supplementary table 1b for correlations and mnemonics, see text for explanations)



1a. Axis 1 and 2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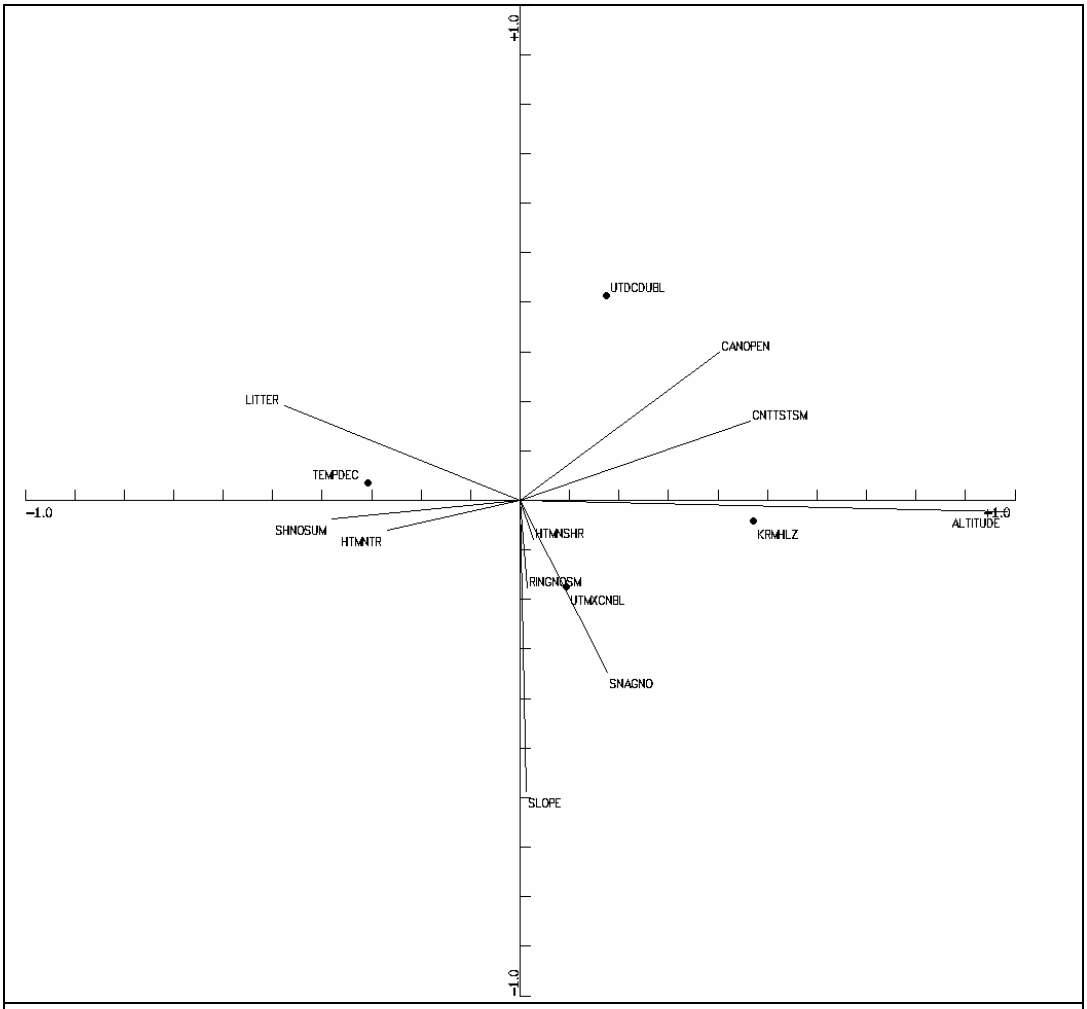
HTMNSHR
SLOPE
RINGNOSM
UTDCDUBL
SHNOSUM
LITTER
KRMHLZ
CNTTSTSM
GBHSUMMN
TEMPDEC
ALTITUDE
SNAGNO
−1.0
+1.0
HTMNTR
UTMXCNBL
CANOPEN
−1.0

1b. Axis 1 & 3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HTMNSHR
KRMHLZ
RINGNOSM
UTMXCNBL
SNAGNO
SLOPE
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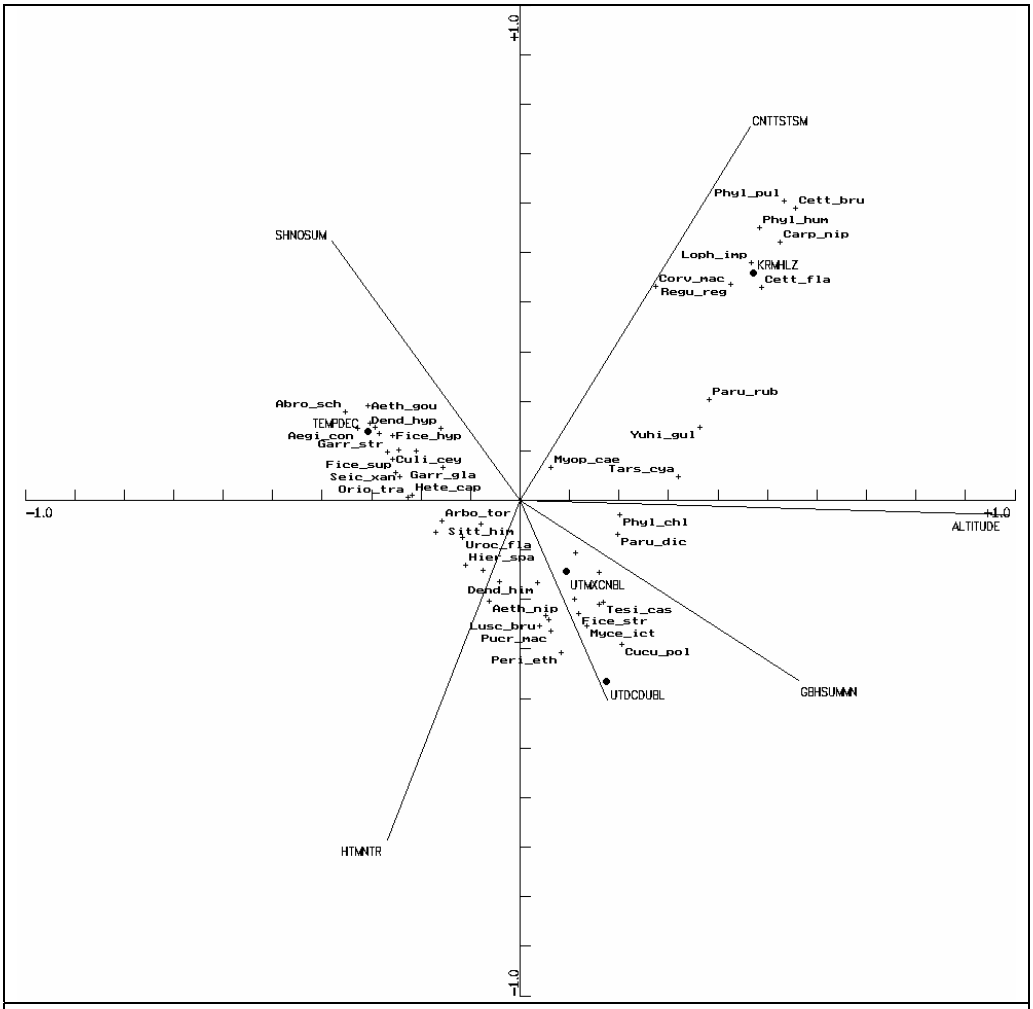
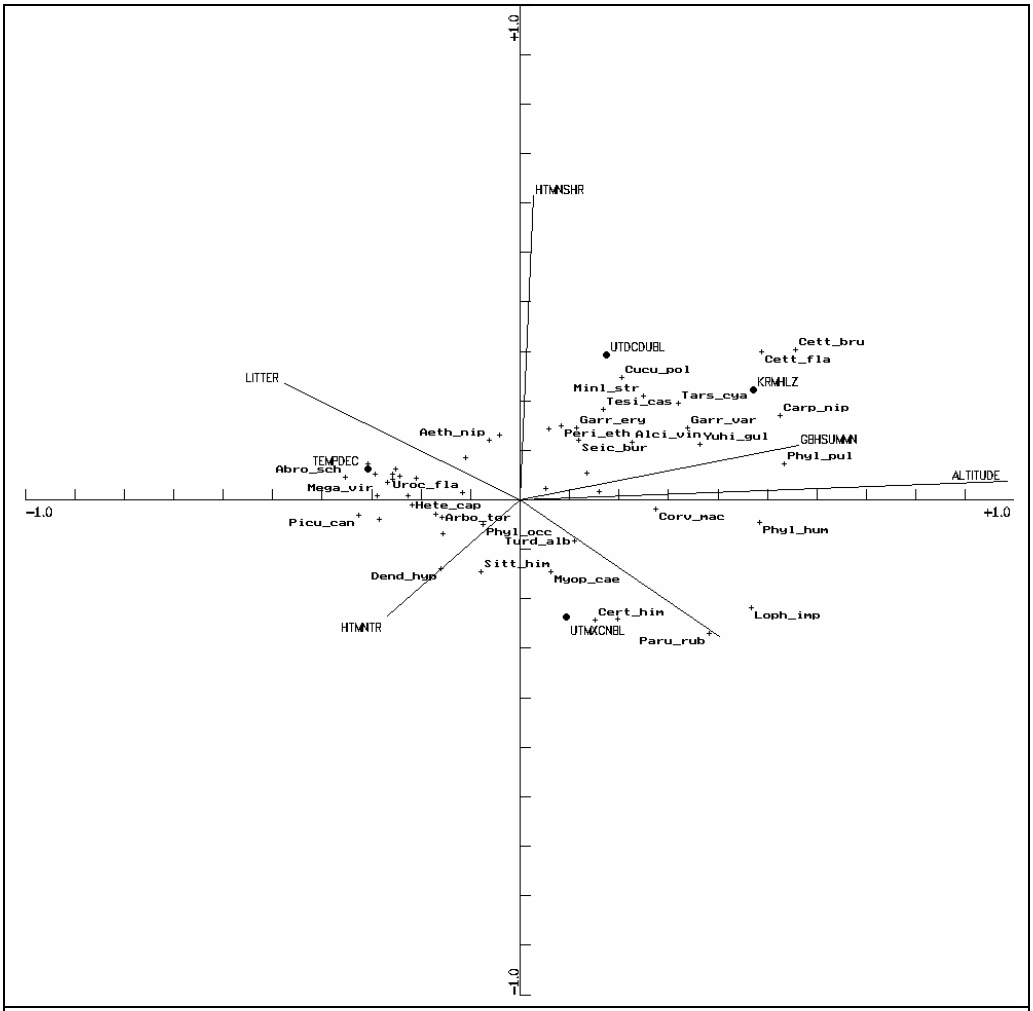
1c. Axis 1 & 4.

Supplementary Figure 2. Biplot of variables and species on CCA ordination axes (see supplementary table 2 for species codes and scientific names, see text for explanations)



2a. Axis 1 & 2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HTMNSHR
UTDCDUBL
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Cett_fla
Cucu_pol
KRMHLZ
Minl_str
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Tesi_cas
Carp_nip
Garr_ery
Garr_var
Peri_eth
Alci_vin
Yuhi_gul
GBHSUMMN
Seic_bur
Phyl_pul
LITTER
Aeth_nip
TEMPDEC
Abro_sch
Mega_vir
Uroc_fla
ALTITUDE
Hete_cap
-1.0
Picu_can
Arbo_tor
Corv_mac
+1.0
Phyl_hum
Phyl_occ
Turd_alb
Sitt_him
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Myop_cae
Cert_him
Loph_imp
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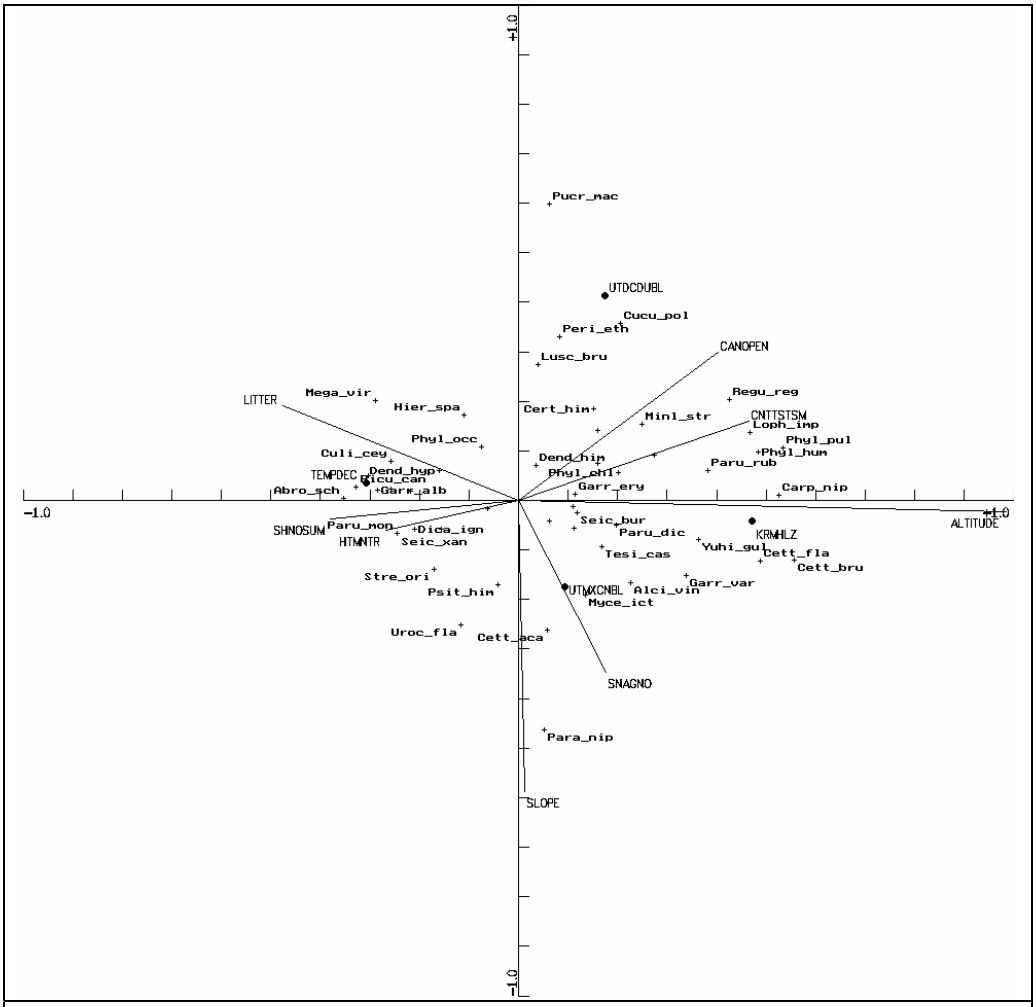
Paru_rub
-1.0

2b. Axis 1 & 3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+1.0
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UTDCDUBL
Cucu_pol
Peri_eth
Lusc_bru
CANOPEN
LITTER
Mega_vir
Hier_spa
Regu_reg
Cert_him
Minl_str
CNTTSTSM
Loph_imp
Phyl_pul
Phyl_occ
Phyl_hum
Culi_cey
Dend_him
Paru_rub
TEMPDEC
Dend_hyp
Phyl_chl
Cicu_can
Garr_ery
Carp_nip
Abro_sch
Garr_alb
Seic_bur
SHNOSUM
Paru_mon
Dica_ign
Paru_dic
KRMHLZ
HTMNTR
Seic_xan
Yuhi_gul
Tesi_cas
Cett_fla
Cett_bru
Stre_ori
Garr_var
UTMXCNBL
Alci_vin
Psit_him
Myce_ict
Uroc_fla
Cett_aca
SNAGNO
Para_nip
SLOPE

2c. Axis 1 & 4

Supplementary Table 2. Species codes in CCA biplots and scientific names.

Species code	Scientific name
Abro sch	*Abroscopus schisticeps*
Alci vin	*Alcippe vinipectus*
Arbo tor	*Arborophila torqueola*
Dicr leu	*Dicrurus leucophaeus*
Mega vir	*Megalaima virens*
Hete cap	*Heterophasia capistrata*
Lusc bru	*Luscinia brunnea*
Myop cae	*Myophonus caeruleus*
Hyps leu	*Hypsipetes leucocephalus*
Seic bur	*Seicercus burkii*
Cett bru	*Cettia brunnifrons*
Cett aca	*Cettia acanthizoides*
Cett fla	*Cettia flavolivacea*
Cucu can	*Cuculus canorus*
Garr gla	*Garrulus glandarius*
Fice hyp	*Ficedula hyperythra*
Dica ign	*Dicaeum ignipectus*
Culi cey	*Culicicapa ceylonensis*
Glau bro	*Glaucidium brodiei*
Tars chr	*Tarsiger chrysaeus*
Cono oem	*Conostoma oemodium*
Paru mon	*Parus monticolus*
Myce ict	*Mycerobas icterioides*
Aeth gou	*Aethopyga gouldiae*
Turd bou	*Turdus boulboul*
Cucu sat	*Cuculus saturatus*
Card spi	*Carduelis spinoides*
Dend him	*Dendrocopos himalayensis*
Cert him	*Certhia himalayana*
Cucu mic	*Cuculus micropterus*
Corv mac	*Corvus macrorhynchos*
Loph leu	*Lophura leucomelanos*

Species code	Scientific name
Pucr mac	*Pucrasia macrolopha*
Hier spa	*Hierococcyx sparverioides*
Peri eth	*Pericrocotus ethologus*
Uroc fla	*Urocissa flavirostris*
Orio tra	*Oriolus traillii*
Loph imp	*Lophophorus impejanus*
Fice sup	*Ficedula superciliaris*
Carp nip	*Carpodacus nipalensis*
Para nip	*Paradoxornis nipalensis*
Aeth nip	*Aethopyga nipalensis*
Nilt sun	*Niltava sundara*
Garr oce	*Garrulax ocellatus*
Tars cya	*Tarsiger cyanurus*
Fice str	*Ficedula strophiata*
Pnoe alb	*Pnoepyga albiventer*
Psit him	*Psittacula himalayana*
Paru dic	*Parus dichrous*
Phyl chl	*Phylloscopus chloronotus*
Phyl hum	*Phylloscopus humei*
Phyl mac	*Phylloscopus maculipennis*
Phyl occ	*Phylloscopus occipitalis*
Phyl pul	*Phylloscopus pulcher*
Phyl reg	*Phylloscopus reguloides*
Picu can	*Picus canus*
Paru mel	*Parus melanolophus*
Paru rub	*Parus rubidiventris*
Dicr rem	*Dicrurus remifer*
Pyrr pyr	*Pyrrhocorax pyrrhocorax*
Aegi con	*Aegithalos concinnus*

CHAPTER 5

Bird Diversity along an Altitude Gradient: Role of Energy, Area and Range Dynamics

5.1 INTRODUCTION

Understanding the determinants of spatial variation in species diversity (latitude, altitude, depth, area etc) is a major challenge in front of ecology. Increased availability of distribution datasets coupled with advancement in remote sensing and GIS technologies in measuring environmental variables has led to a growth in such studies in the past decade (Gaston 2000, Pimm and Brown 2004).

Most important among these patterns has been the latitudinal gradient in species diversity. That diversity increases as we move towards lower latitudes has fascinated biologists since Darwin and Wallace to father of modern ecology like Robert MacArthrur. Mountain gradients have been thought to mirror latitudinal gradients in terms of climatic zonations and its relationship to diversity, that of higher diversity at lower altitudes, and a negative linear decline in diversity with altitude, much like the latitude gradient (MacArthur 1972, Begon *et al* 1990). Consequently, the factors responsible for the latitudinal gradient are also thought to apply to the mountain gradients (Stevens, 1989, 1992). However, increased focus on mountain gradients has led to the realization that many altitude-diversity relationships deviate from latitudinal gradients in one important feature, diversity peaks not at the lowest altitude but somewhere above it, closer to the mid-elevation

zone, the so called 'mid-elevation peak' (Terborgh, 1977, Rahbek 1995, 1997, Rozensweig 1995). The processes responsible for these patterns (whether monotonic decline, or unimodal) may still be general and intricately linked to latitudinal patterns (Lomolino, 2001), and thus be highly instructive in understanding species diversity gradients at larger spatial scales. Some of the important variables thought to be related to latitudinal gradients such as clines in area (Rahbek 1997, Kattan and Franco 2004), productivity/energy, (Rosenzweig and Abramsky 1993 Rahbek 1997)) and variation in geographic range sizes (systematic variation - Stevens, 1992, random variation-Colwell & Hurtt 1994, Rahbek 1997) are considered to have altitudinal analogues. In addition 'Zonal feedbacks', due to overlap of distinct faunal groups may also contribute to higher diversity in middle altitudes (Shmida and Wilson 1985, Kattan and Franco 2004, Singh *et al* 1994, Lomolino 2001).

I summarize the basic premise of these theories below:

Area effect – At large spatial scales diversity is strongly related to area. Larger areas support greater number of species. This relationship can be predicted by the equation $S = CA^z$ (Macarthur 1972, Rozensweig 1995). Greater area can support larger number of individuals and hence reduce the extinction risk of species. Larger areas may contain greater habitat diversity as well, supporting more species. Thus area effects can explain either a monotonic decline or a peak at any intermediate elevation if diversity is strongly related to available area in an elevation belt.

Effects of energy availability – Diversity at large spatial scales shows a positive relationship with energy (Wright 1983, Currie 1991, Wright *et al* 1993, Mittelbach *et al* 2001, Evans *et al* 2005). Two broad categories of energy availability metrics have been used, those that measure available solar energy such as Potential evapotranspiration (PET) and temperature or as 'productive energy' metrics, which measure the energy available for biota to convert into biomass (Lennon *et al* 2000, Evans *et al* 2005). Energy available to a consumer taxa is by and large dependent on plant productivity hence Net Primary Productivity (NPP) or a surrogate such as Normalised Difference Vegetation Index (NDVI) obtainable from remote sensing satellite data has been widely used (Evans *et al* 2005, Hawkins *et al* 2003, Bonn *et al* 2004, Bailey *et al* 2004). Like NPP, NDVI is also sensitive to changes in precipitation and temperature (Kerr & Ostrovsky 2003) hence it also is a product of climatic variables. Direct measures of productivity of consumer taxa (Biomass) have also been used to index productivity of animal taxa (Ding 2000, Mittelbach *et al* 2001, but see Groner and Novoplansky 2003, who suggest unimodal patterns may result from direct productivity measures).

If productivity generates the elevational gradient in diversity then the elevation gradient in diversity may simply be a productivity gradient. Monotonic positive as well as unimodal diversity-productivity relationship (diversity peaking at an intermediate level of productivity) are reported.

In its simplest form the species energy hypothesis is supposed to work as follows - an increase in the available energy increases the amount of biomass of the consumer taxa, which in turn leads to support of greater number of individuals. This lowers the extinction rates of species and hence greater number of species can be supported. This has been termed as 'the more individuals hypothesis'. In this form it is analogous to the Species area theory (Wright 1983) Some studies have found support (Kaspari *et al* 2000) or partial support (Ding 2000) to the hypotheses. However Gaston (2000) notes that there is a paucity of documentation of relationships between biomass, animal numbers and diversity even in well-studied taxa like birds. Mechanisms related to the species energy relationship remain poorly documented. Evans *et al* (2005) have recently listed nine principle mechanisms (including the more individuals or increased population size mechanisms), which may generate a positive species energy relationship.

Variation in range sizes:

a. *Systematic variation (Rapoports rule)* – In an attempt to explain latitudinal diversity gradients, Stevens (1989) hypothesized that geographic range sizes vary systematically along the latitude gradient. Species at higher latitudes are subjected to greater severity in climatic conditions, hence are climatically more tolerant. This leads to species of higher latitudes having larger range sizes. These large ranges abut the tropics and inflate the diversity of tropical regions. This was called the Rapoport's rule, recognizing Eduardo H. Rapoport's observation of such a pattern

(Rapoport 1982). Stevens (1992) extended the latitudinal Rapoport's rule to elevational gradients as well suggesting that diversity of lower elevations are enhanced by high elevation species which have broader climatic tolerance and hence larger range sizes. The latitudinal as well as the elevational analogue of Rapoport's rule has found limited support and is not considered to be a major factor in generating diversity gradients (Gaston *et al* 1998).

b. *Random variation in range sizes* - Colwell and Hurtt (1994) proposed that a peak in the middle of a gradient is the null expectation if geographic range sizes are allocated randomly within geometrically constrained domains. They called this the mid domain effect. The mid domain effect is hypothesized to arise purely from geometric considerations of the domain, irrespective of any climatic or environmental factors. This 'null' expectation is supposed to apply at 2-D domains such as continents as well as 1-D gradients such as elevation or bathymemetric gradients. Proponents of the Mid-domain model consider such geometric constraints as a major cause of species diversity gradients (Colwell and Lees (2000) Colwell *et al* (2004). Indeed there has been some support for the 'Mid-domain model' (reviewed recently by Colwell *et al.* (2004) and Pimm and Brown (2004). However, there has been considerable critique of the model as well, chiefly on the grounds whether it truly remains a null model, since all the successful demonstrations incorporate empirical range sizes and definitions of domains are based on the environmental tolerances of the animal groups itself (Zapata *et al* 2003, Pimm and Brown

(2004)). Proponents of 'Mid-domain models' now recommend using empirical range sizes and limiting the analysis only to species endemic to a domain (which in case of environmentally defined domains are derived from environmental tolerance of the species group itself) (Colwell *et al* 2004). Fully stochastic models, which generate range sizes and allocate them randomly, fail to match the empirical patterns (Zapata *et al* 2003, Laurie and Silander 2002, Hawkins and Diniz-Filho (2002). Moreover, the mid-domain model is only applicable to species endemic to a particular domain, which makes its comparison along with other hypotheses, which typically incorporate all species present in a region or gradient, somewhat difficult.

Zonal Feedbacks- It has been suggested that the mid-elevation peak may be partly generated due to ecotonal effects (Lomolino 2001, Singh *et al* 1994). The zone of contact between two distinct faunal zones will have higher species diversity since it can receive species from both ends. Such species may be maintained by continuous immigration from the source zones or 'Mass effects' (Shmida and Wilson 1985, Lomolino 2001).

This mechanism also predicts multi-modality in the diversity gradient if more than two distinct faunal groups successively come into contact with each other. The height and locations of the peak will depend upon the richness of the zones in contact (Lomolino 2001). Such a pattern is also predicted by the Mid domain model, if two domains come into contact with each other (Colwell *et al* 2004), Oommen and Shankar (2005).

I present the variation of breeding bird species diversity along the elevation gradients at regional scale of the Indian Western Himalaya covering the entire gradient from foothills to 6000 m and temperate gradients from 2000 m to 4000 m at landscape scales in Kedarnath region and Goriganga valley in Uttaranchal. I examine the shape of the curve and ask if they are consistent across scales and localities.

I examine the relative roles of area and NDVI at regional and landscape scales in generating observed gamma diversity gradients. I expect a positive relationship with both area and NDVI and look for their relative contributions.

In a direct evaluation of productivity diversity relationship, I examine the relationship of bird biomass (as a direct measure of productivity), density and alpha diversity in one locality (Kedarnath) and relate it to the elevational gradient in diversity. If more individuals hypotheses holds true a positive relationship between biomass, density and diversity are expected. Since bird diversity is known to be influenced by vegetation structure (Macarthur 1972, Raman *et al* 1998) and vegetation structure may itself vary along the altitude gradient and across sites, I also correlate observed diversity to vegetation structure.
I examine the Rapoports effect in generating species richness gradients at the regional scales where complete ranges are documented. Larger altitude ranges are expected at higher altitudes.

I examine the role of zonal feedback mechanism in generating diversity peaks at regional as well as landscape scales. Peaks in

richness if observed should coincide with larger number of altitude range boundaries indicating faunal turnover.

In an evaluation of the Mid-domain model I compare null model simulation results with observed diversity patterns at the regional scale for three distinct groups of birds endemic to montane biomes *viz-a-viz*. subtropical, temperate and high montane biomes.

5.2 METHODS

5.2.1 Database

5.2.1.1 Breeding bird Database

A distributional database of 453 terrestrial bird species breeding in Western Himalaya was created. The database uses information mainly from Grimmet *et al* (1999) and Ali & Ripley (1983), but also supplements information from Kazmeirzcak and Van Perlo (2000) Martens & Eck (1995) and Roberts (1991-1992).

The database incorporates maximum and minimum altitudinal limits, geographic and habitat distribution, an index of abundance at the sub-continental scale and threat levels as classified by the Birdlife International. The Database also records if a species is 'Biome restricted' as per the 'Biome restricted' criterion of the Birdlife International 'Important Bird Area program', and if it is a 'Restricted range' Species according to the classification of the 'Endemic Bird Area Program' of the Birdlife International.

5.2.1.2 Spatial database

Area of elevation zones were calculated using DEM's developed from topographic maps at 1:250,000 scale.

Monsoon NDVI (peak vegetation growth season) was estimated from Wiff's sensor of IRS-ID remote sensing satellite. This sensor has a spatial resolution of 188 m. Mean positive NDVI (positive NDVI values indicate vegetation), area covered by positive values and area covered by positive NDVI values were calculated for 500 m elevation bands for entire Western Himalaya and for 200 m bands for Kedarnath. Cloud cover may affect estimation of NDVI values for the entire area, but since objective was to estimate mean NDVI value for each altitude belt, fine spatial resolution of the data provides enough pixels to calculate mean values. Though estimated area under positive NDVI is likely to have biases.

Forest area for the Kedarnath was estimated from landcover classification carried on remote sensing imagery of LISS III sensor of IRS 1D remote sensing satellite. Standard Image processing and GIS techniques were used to arrive at the landcover classification. Extent of forest area in each 200 m altitude belt was tabulated.

5.2.2 Field sampling at the landscape scale

5.2.2.1 Bird Diversity and Abundance

To assess breeding bird diversity and abundance at the landscape scale, variable width point count censuses were conducted in the breeding season from May till August, moving up the gradient as the

season progressed, tracking the breeding season of different altitude zones. Point count censuses were of 5-minute duration; each point was spaced about 200 m apart and was monitored once. Each detection was recorded as falling in of the following distance classes: 0-5, 5-10, 10-20,20-30,30-50,50-100,100-150,150-200 m classes.

The points incorporated all major vegetation types present in the study areas in roughly proportionate manner. Mid-Temperate to alpine vegetation zone were sampled covering a gradient of about 2000-4000 m. All sampled slopes are northerly in orientation with low to almost no human disturbance. (See **Table 1**). These censuses provide the data for calculation of diversity and density indices of sites along the altitude gradient, as well as the altitudinal distribution information of species.

5.2.2.2 Vegetation sampling

Vegetation was sampled in 10 m radius plots centered on the bird census point. Trees above 20 cm gbh were measured in 10 m radial plots, saplings and shrubs were counted in 5 m nested plot, and ground cover was recorded in four 1 sq m quadrates. Species, GBH, height, height of first branch of trees, height and number of sapling and bamboo culms were recorded for each individual and bamboo clump. Length and girth (at 3 places) of fallen logs (above 20 cm gbh) were measured. Canopy closure was estimated in four 25% classes. Slope, aspect and altitude were recorded for each point.

Table 1: Sites Sampled by Point Counts (1997-2002) in Kedarnath and Askot (Goriganga valley)

Site	Mean altitude (m)	Main Habitat
Dogalbitta, 99	2300	Temp. broadleaved
Makku, 99	2150	Temp. broadleaved
Trishula,99	2200	Temp. broadleaved
Badru, 00	2250	Temp. broadleaved
Thuliyagail (Gori),02	2413	Temp. broadleaved
Bulkana,99	3070	Up. temp broadleaved & krmmhlz
Baniyakund,99	2700	Up. temp fir (*A.pindrow*)
Kanchulakhark,99	2700	Up. temp fir mixed (*A.pindrow*)
Suarkhal,00	2750	Up. temp fir mixed (*A.pindrow*)
BhainsiKhark (Gori) 02	2787	Up. temp fir mixed (*A.pindrow*)
Mathdhuni-toliyar, 00	3275	Mixed decid. And *R.campanulatum*
Tungnath fir, 99	3100	Subalpine fir & krmmhlz (*A.spectabilis*)
Tungnath-krm,99	3300	*R. Campanulatum*
Pachwar-Bhanar (Gori), 02	3306	Mixed Subalp & Krmmhlz
Bisurital,97	3800	Alpine meadow
Tung-alpine,98	3400	Alpine meadow
Bhanar, 02	3585	Alpine meadow

* Sites of Goriganga valley indicated in ()

Points were distributed across 13 sites across 3 catchments in Kedarnath namely, Akashkaminy catchment, 6 sites (Mandikini basin), Balsurti catchment, 3 sites (Alaknanda basin) and Bantoli Gad catchment, 4 sites (Madhyamaheshwar-Mandakini basin). The entire landscape was covered by 384 points with around 30 points in each site.

Sites in the Bantoli catchment are located along a single continuous gradient covering an altitude of 2000-4000 m. All catchments are sampled along a comparable gradient of 2000-4000 m. One alpine site is common to Akashkamini and Balsurti catchment as both slopes converge on the Tungnath ridge

A single continuous slope in Gori valley (Rachia gad catchment) covering from 2300 m to 3700 m was sampled in the year 2001. The gradient covers temperate forests to alpine meadows. Seventy-five points were put across 4 sites with 3 sites in the forest zone and one in the alpine zone. Two forest sites had 18 points each, one 24 and the alpine had 15 points. The sampled altitude and vegetation types make it comparable to the Kedarnath gradient.

5.2.3 Analytical methods

5.2.3.1 Density and Biomass calculation

Since abundance/density estimated from raw counts may be highly biased due to differential detectability of species, it is advisable to correct for this detection bias in density calculations. Program

DISTANCE (Thomas *et al* 2003) corrects for bias in detection probabilities by fitting a detection function. However a limitation is that pooling species with different detection behaviour may bias the estimators. Moreover many species may have sample sizes too low to be fitted with a detection function and analysed individually. A way to circumvent both these problems is to pool species with similar detection behaviour and analyse each group separately. Densities of individual species can then be extracted by 'post-stratification'. since it is assumed that species in a group have similar detection behaviour, there respective densities are in proportion to their number of detections. An estimate of total bird density can be calculated by summing up the different group densities.

The species at each site were divided into three groups based on their detection behaviour (mainly calling behaviour) as those detected at small distances (warblers, flycatchers) within 30 m, medium (rufous sibia, Indian blue robin) – within 50 m and those detected beyond 50-100 m also (Cuckoos, pheasants). Separate detection functions were fitted for each of these groups and total density estimated as sum of three 'sub' densities. Density for individual species was extracted by 'post stratification' of density of each group.

Appropriate right truncation was used for each group. A detection model was selected after examining the fit of estimated detection function to the data. Pooling of distance classes was done if found to improve the fit of detection function. Final model selection was based on minimum Akaike information criteria.

A few species were detected calls of males exclusively (4 species of cuckoos) or nearly exclusively (Koklass pheasant). Their estimated densities were multiplied by 2, assuming an even sex ratio.

Average body size of species was calculated from information given in Ali and Ripley (1983). In case of sexual size differences an average of male and female mass was taken. In a few instances where body mass information was not available, body mass of a closely similar species was substituted. Mean body size of birds for each site was calculated as a weighted mean using densities as weights.

Biomass of each species was estimated by multiplying its average body mass with its density on the particular site. Sum of biomass of all species present in a site gives the total bird biomass of the site.

Density and biomass was calculated only for Kedarnath. One high altitude site could not be adequately fitted by a detection function, so density was calculated with a fixed radius of 30 m within which most observations occurred.

5.2.3.2 Species Diversity

Sample size corrected estimate of diversity

I used incidence based richness estimators based on mark recapture models to correct for sample size differences calculated by program Estimate 'S' (Colwell 1994-2004). This was used to estimate the number of species present at a site in Kedarnath or alpha diversity. First order Jack-Knife (resampled without replacement) gave stabilizing curves and stable standard deviations for most sites. Importantly all

lower altitude sites have stablized curves and only the higher elevation sites still show any increasing trend. I compare the estimated number of species at 24 points the lowest number for any site in Kedarnath. I also calculated 'Log-Series' constant, alpha, which is a robust estimator of diversity even with very small sample sizes (Rosenzweig 1995). I use 'Log-Series alpha' to compare diversity of elevation zones and in comparison between sites of Goriganga and Kedarnath.

Interpolated Species richness

A species incidence matrix was constructed for both Kedarnath and Askot slope (Goriganga valley) by interpolating species presence based on its observed upper and lower limit, in 200 m belts. Similar interpolated richness was tabulated for 500 m elevation belts for the Western Himalaya dataset. This is the gamma diversity for each elevation zone.

The interpolated richness thus obtained is used in further analysis with area and NDVI.

5.2.3.3 Range limits and Range size

Numbers of upper, lower and total range limits falling in each elevation zone were tabulated. As the number of species at their range limits is expected to rise in proportion to the richness of the zone, expected number of range limit species was calculated based on its richness. Deviations from this expected number are plotted to look for coincidence of higher positive deviations in zones of high richness (Patterson *et al* 1998).

Altitude Range size and Altitude position (Rapoport's Rule)

I calculated the mean altitude range of species occurring in each altitude belt and plot against altitude (Steven's method, Stevens 1989, 1992). I also treated each species as an individual data point and plot it's altitude range against the midpoint of its altitude range (the Midpoint method, Gaston *et al* 1998). Steven's method has been criticized as statistically non-independent, however the Mid-point method does not measure exactly the same relationship. Steven's method looks at the central tendency of range sizes of all species occurring in an elevation zone, it expects larger mean range size at higher elevations if Rapoports rule hold's true. The Mid-point method uses individual species as data points and hence looks at the tendency of species occurring at higher altitudes to have larger altitude ranges. Although both methods look at somewhat different aspects, results of both are similar if Rapoports rule is found (Gaston *et al* 1998).

5.2.3.4 Null model randomizations

Null model randomizations require that the analyses be limited to species that are endemic to a particular domain. Ideally this would mean restricting the analysis to species endemic to Western Himalaya. However, there are only 11 species restricted to Western Himalaya region, expanding the scope to species endemic to Himalaya also leaves with only 24 species, too few for meaningful randomizations.

I expanded the scope of the analysis to include all species restricted to montane biomes of Asia occurring in western Himalaya. These biomes are Eurasian High Montane (Alpine and Tibetan), Sino-Himalyan Temperate forests, and Sino-Himalyan Subtropical forests (Islam & Rahmani 2004). Species restricted to these biomes and having range sizes greater than 50,000 sq.km are classified as 'Biome Restricted' by Birdlife International (Islam & Rahmani 2004). A total of 140 such species occur in West Himalaya. I added 8 more species with 'Restricted range' distributions (range less than 50,000 sq.km) endemic to west Himalaya (Stattersfield *et al* 1998) to take the pool of montane avifauna to 148 species.

I performed 100 randomizations of the empirical range size distributions of each of these three groups and compare the simulated richness estimates with observed patterns. In the simulations for each species an altitudinal extent was allocated from the observed ranges and its placement was decided by randomly allocating an altitudinal midpoint.

5.2.3.5 Statistical methods

I used simple linear and polynomial regression to look at relationships between diversity and its correlates. Data were log transformed if it linearised the trends.

For the Kedarnath dataset, a factor analysis was performed on the vegetation structural variables to reduce the number of variables and

extract meaningful components of vegetation structure. The Principal components thus extracted were correlated with diversity, density and biomass.

While analysing correlates of diversity at landscape scales (Kedarnath and Goriganga valley), I restricted my analysis to the forest zone, excluding alpine meadow communities. This is to ensure a more comparable group, as alpine zones are markedly different in avifaunal communities and vegetation structure.

I controlled for spatial effects in the analysis of bird richness (Western Himalaya and Kedarnath data set) by Dutilleul's modified t test (Dutilleul, P. 1993) and by examining spatial autocorrelation (Moran's I coefficients) in the residuals of the OLS regression (using 6 equal distance classes). Significance of the coefficients was tested with 999 permutation tests. For west Himalaya five and for Kedarnath dataset six equal distance classes were used in Moran's I calculations.

I used geographic co-ordinates for Kedarnath and arbitrary planar coordinates for western Himalaya dataset. For the West Himalaya dataset the objective was to test for autocorrelation effects between adjacent altitude zones, as adjacent zones are also likely to be spatially closer.

Spatial analysis was implemented in the software SAM v1.0. (Rangel *et al* 2005 www.ecoevol.ufg.br/sam)

5.3 RESULTS

A total of 453 species were recorded as breeding in the entire western Himalaya (including Transhimalayas) from foothills to the high Himalayas (<500m to 6000m). The assemblage is represented in 41 families and 211 genera. The dominant families and genera are given in Table 2 & 3. The family *Sylviidae* is the most diverse family with 26 genera and 60 species. Among genera the genus *phylloscopus* is the most diverse with 12 species.

In Kedarnath 99 and in Askot slope (Goriganga valley) 74 species were detected. Inventorying surveys in Goriganga valley detected a total of 193 species additional 31 species were included in the list based on Sultana and Khan (2000) and reliable local information, to give a total of 224 species.

The local scale diversity patterns only for forest birds (excluding alpine meadow) are presented as they are comparable across various variables of forest cover structure and composition.

Table 2. Dominant Families in the Western Himalaya

FAMILY	GENERA	SPECIES
MUSCICAPIDAE	23	60
SYLVIIDAE	26	60
PASSERIDAE	19	54
CORVIDAE	20	45
ACCIPITRIDAE	18	27
PHASIANIDAE	14	18
COLUMBIDIAE	6	17
PICIDAE	8	16
CUCULIDAE	9	15
STRIGIDAE	7	15

Table 3. Dominant Genera in the western Himalaya

GENUS	SPECIES
Phylloscopus	12
Carpodacus	10
Garrulax	8
Dicrurus	7
Parus	7
Prinia	7
Zoothera	7
Anthus	6
Cettia	6
Ficedula	6
Turdus	6

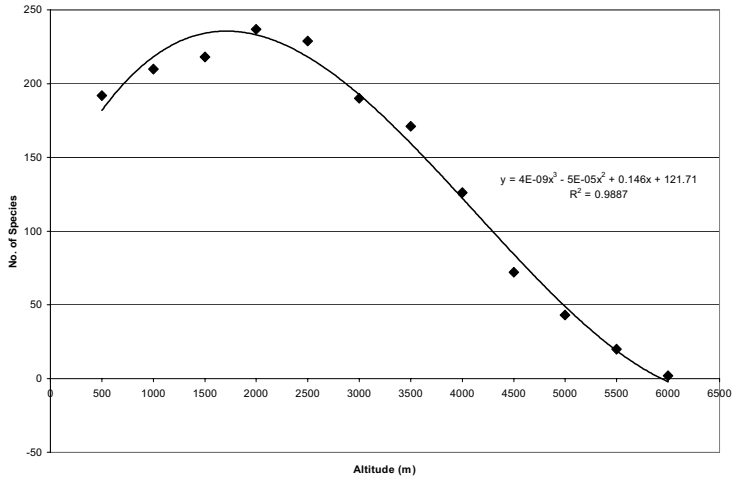
5.3.1 The relationship of Diversity and Altitude

At the regional scale, bird species diversity shows a distinct curvilinear pattern and is best described by a polynomial curve of the form $y = 0.5426x^3 - 13.453x^2 + 72.988x + 121.71$ (rsq = 0.988, F= 233.6, Sig. F = .0000 **Fig 1 a**). The peak of diversity occurs in the 1500-2000 m belt with 239 species. The highest altitude zone (5500-6000 m) has only two species and is removed from subsequent analyses.

In Kedarnath, 4235 individuals were detected in 3010 detections (forest zone) and in Gori valley (Askot slope) 682 individuals were detected in 499 detections.

In Kedarnath, a total of 104 species representing 22 families and 69 genera were detected in the point counts. Out of this 94 species were detected in the forest zone.

a)



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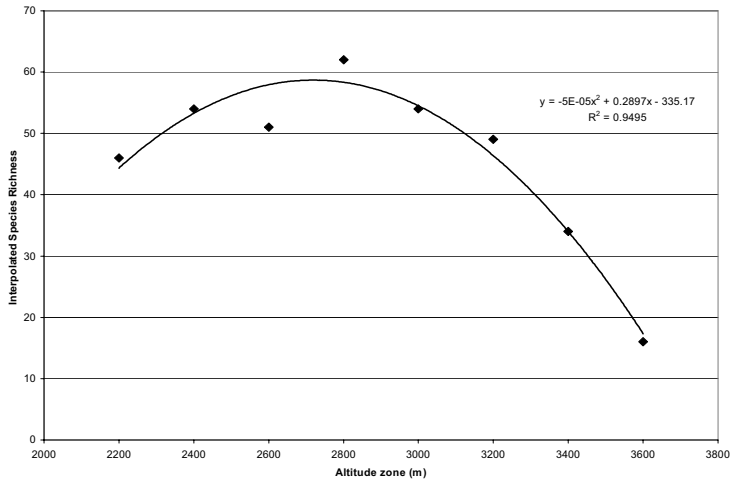

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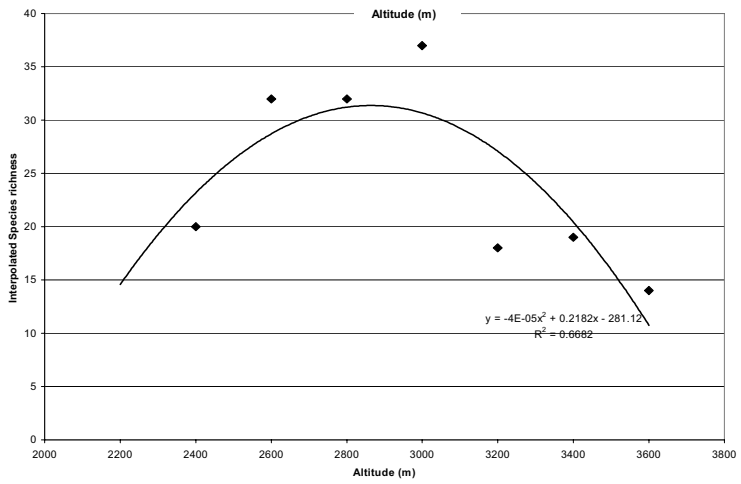


Figure 1. Relationship of bird diversity and altitude at regional and landscape scales.

a) Western Himalaya; b) Kedarnath;
c) Askot slope (Goriganga valley).
Diversity peaks above the lowest elevation in all three datasets.

In the Askot slope (Goriganga valley) a total of 74 species were detected, out of this 64 species were detected in the forest zone.

Species diversity shows a distinct hump shaped pattern peaking between 2600-2800m in KMDS with 61 species. The relationship is best described by a quadratic curve of the form y = -5E-05x^2 + 0.2897x - 335.17 (rsq = 0.9495 F= 47.03, Sig F = .006 **Fig 1b**).

Log Series alpha calculated for each altitude belt also shows a peak at 2600-2800 m belt. It shows a more symmetric pattern than the interpolated richness though a slight increase in diversity is seen at the lowest altitude belt.

The results, plotting diversity of each site against its altitude is also in agreement and shows peak at mid elevation sites, although the relationship is weaker (See Biomass and Diversity section).

In the Goriganga valley (Askot slope) diversity peaks at 2800-3000 m one 200m zone up from Kedarnath (**Fig. 1c**). Logseries Alpha values for sites at average altitude of 2400m 2800m and 3300m are 10.239, 15.187, 8.858. Diversity peaks at the mid elevation site at a similar or somewhat higher value compared to Kedarnath sites.

Across four catchments diversity peaks at mid-elevations in 3 and monotonically declines in one (Bantoli gradient, Kedarnath).

5.3.2 Range limits

All three datasets, Western Himalaya, Kedarnath and Askot slope (Gori ganga valley), show large positive deviations in the number of range limit species at mid-elevations, coincident with high richness. A distinct 'W' shaped curve is seen in total range limit deviations (**Fig 2 a**, **b & c**). Large number of species are at range limits at the either end of the gradient, it falls and then rises to peak in the middle. This is strongly suggestive of zonal feed back mechanism contributing to the peak in diversity. The large deviations at the either end of the gradient are trivial as all species are at their upper or lower limits defined by sampling scheme.

5.3.3 Relationship with Area and NDVI

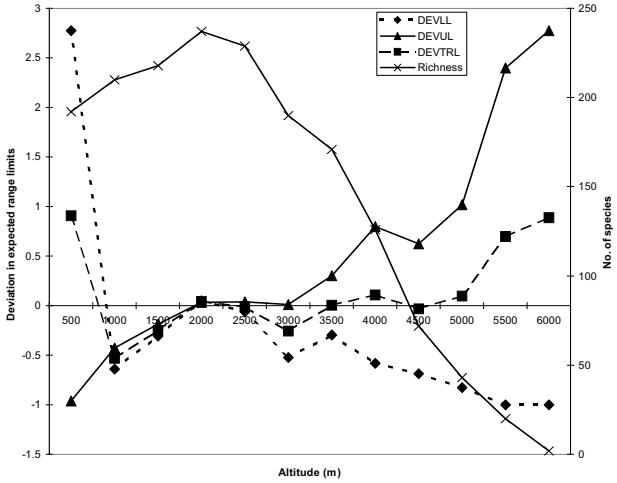
5.3.3.1 Western Himalaya

The largest land areas occur above 3000 m, below 3000 m land area peaks in 1500-2000 m belt, after which it generally declines to the lower altitudes (**Fig 3 a**).

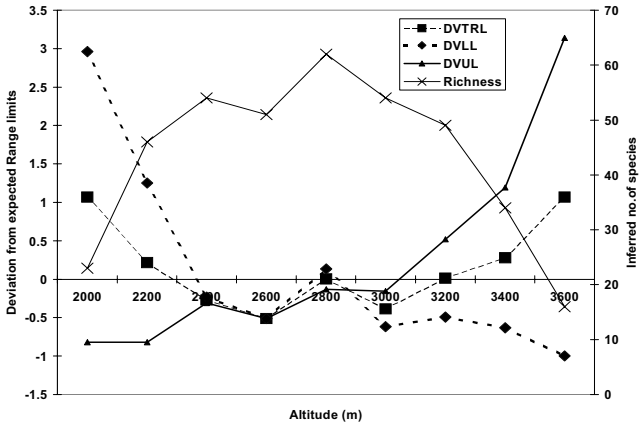
Mean Positive Monsoon NDVI rises sharply from high altitudes till 2500-3000 m after which it remains more or less constant till the low elevations. Mean values range from a low of 0.03 in the highest zone to .31 in 500-1000 m zone (**Fig.3b**).

Overall richness and area are negatively related in the Western Himalaya dataset.

a)



b)



c)

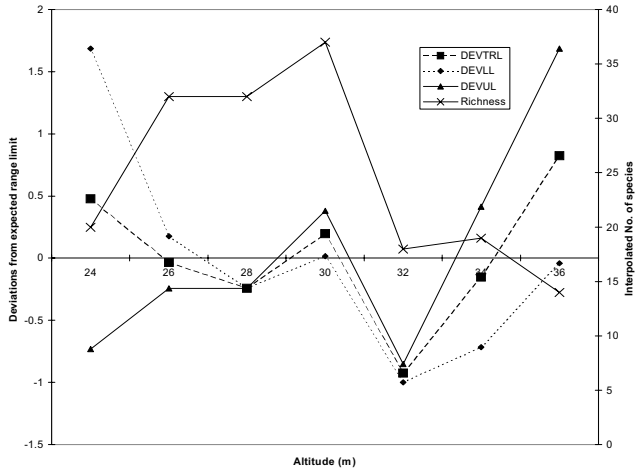
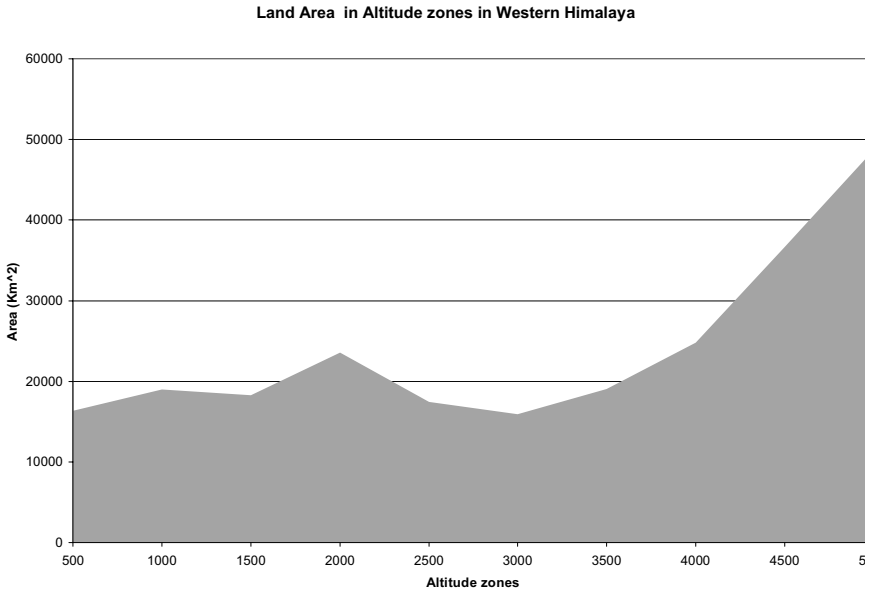


Figure 2. Role of zonal feedbacks in generating Mid-elevation peak in Diversity.

a) Western Himalaya; b) Kedarnath;
c) Askot slope (Goriganga valley)

Zone of high richness also has more species at upper and lower range limits than expected by chance. Points show deviations from expected no. of species of total range limit sp.- DEVTRL, Lower range limit – DEVLL and upper range limit- DEVUL, in each zone.

a)



b)

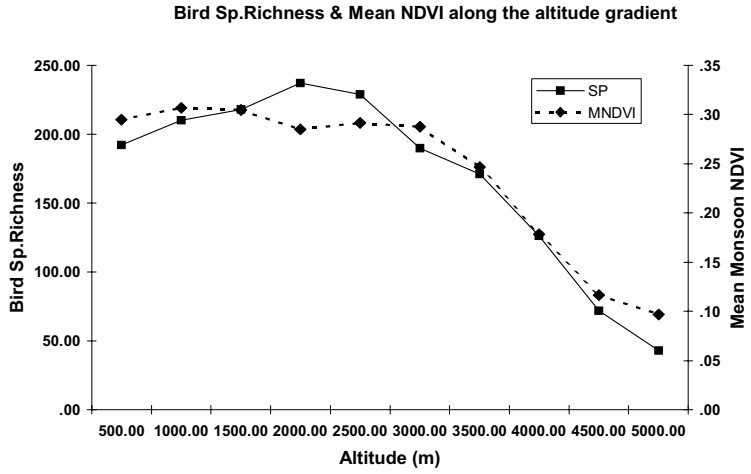


Figure 3. Distribution of land area and Mean Monsoon NDVI along the altitude gradient in Western Himalaya.

a) Land area. The 1500-2000 m zone has greater area than the lower elevations.

b) Mean monsoon NDVI, -. NDVI rises sharply till 2500- 3000 m, after that it maintains similar levels till low elevations. Bird species richness is shown for comparison.

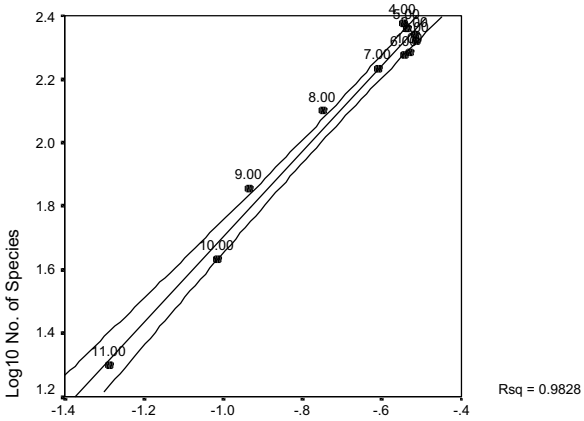
In Western Himalaya richness shows a positive increasing trend with area till 3000 m after which the slope becomes negative (below 3000 m, Log S = .506Log Area + .168 rsq = .623, F = 6.6 N.S p = .062, Above 3000 m Log S = -1.822 Log Area + 10.09 rsq = .937, F = 44.4 p=.007).

For the entire gradient, Log NDVI explains a large part of the variation (98.3%) in species richness (Log S = 1.342 Log NDVI + 3.046 rsq = .983, F= 583 p = .000). Log Area under positive NDVI (Log Area NDVI) explain 93.9% of the variation somewhat lesser than mean NDVI alone (Log S = .686 Log Area NDVI -.578., rsq = .939, F = 137.688, p = .000) (**Fig 4a &b**).

In a stepwise multiple regression with Log mean NDVI and Log Area NDVI, the latter is not selected due to high collinearity with Log mean NDVI. A full model where both variables are incorporated explains 99.3% of the variation (LogS = .955 Log Mean NDVI + .215 Log Area NDVI + 1.936, rsq = .993, F = 552.5, p = .000) (**Fig.4c**).

Correlation coefficient remains significant after applying Duitilleul's modified t test (logNDVI & logrichness- Pearson's r = 0.991, d.f =9, p = 0.000, corrected d.f = 1.758, corrected p = 0.000). None of the Moran's I coefficients (5 equal classes) of the residuals of the OLS regression of logrichness and logNDVI are significant.

a)



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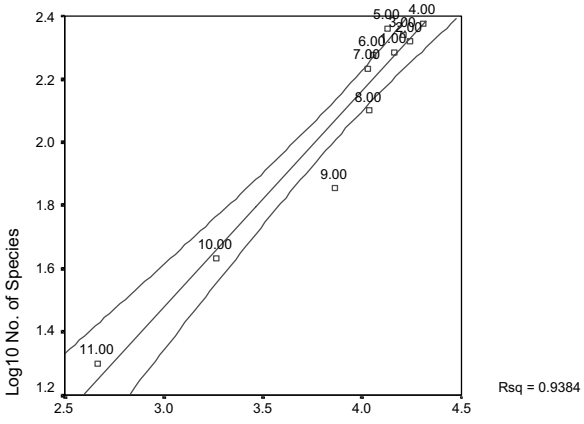

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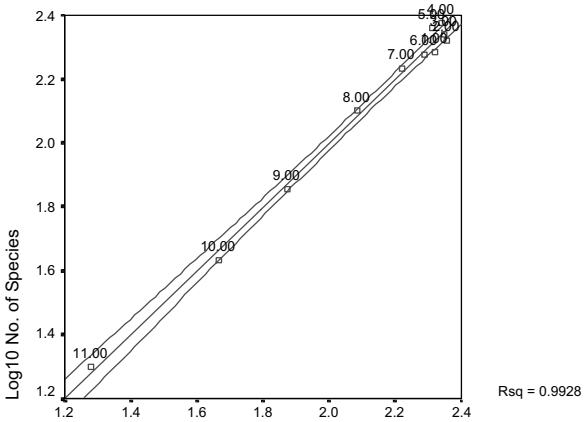


Figure 4. Relationship between NDVI and Bird species richness of altitude zones in Western Himalaya.

Log10 no. of species is linearly related to:

a) Log10 Mean monsoon NDVI;

b) Log10 Area under positive monsoon NDVI;

c) Log10 Mean monsoon NDVI & Log10 Area under positive monsoon NDVI (predicted value of multiple regression on X axis, see text)

5.3.3.2 Kedarnath

Largest land area occurs in 2400-2600 m zone, largest forest areas occur between 2400-2800 m zones (**Fig.5a**).

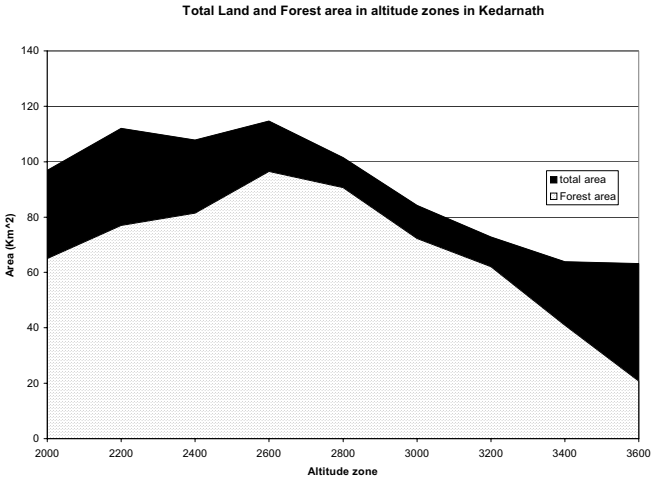
Mean NDVI of forests ranges between 0.1965 to 0.256. It declines sharply with altitude and is more or less constant after 3000 m but rises again at 3400-3600 m. zone (**Fig 5b**).

Mean NDVI of all vegetation types (including scrub and alpine) also shows a similar pattern, it declines sharply after 2400 m and continues a gentle decline till the highest elevations (**Fig 5c**).

Relationship between richness and mean NDVI of forest as well as overall NDVI shows no significant relationship, though a trend of peak at lower end is seen, suggestive of a unimodal pattern (**Fig 6a, b, c & d**).

A positive and significant SAR is obtained with forest area (interpolated richness, Log S = .815Log Area + .173 rsq = .925, F = 74.169 p = .000, Logseries Alpha, Log Alpha = .403Log Area + .344 rsq = .838, F = 30.95 p = .001, **Fig. 7 a & b**). Regression with total area though positive is not strong (interpolated richness, rsq = .478 p=.05, Alpha, rsq = .387 p=.099).

a)



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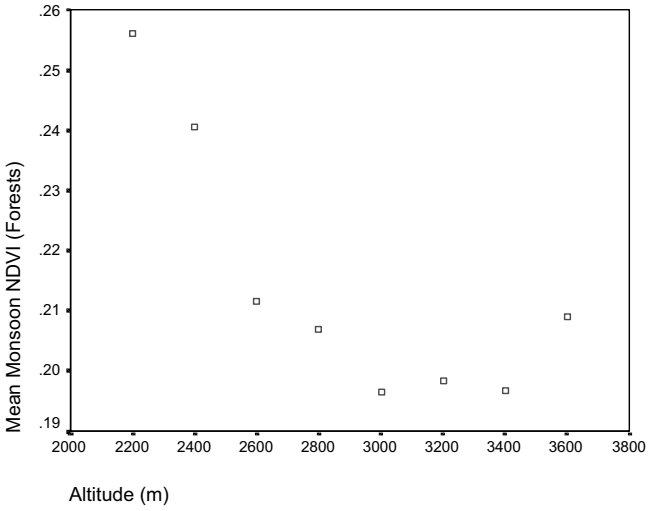

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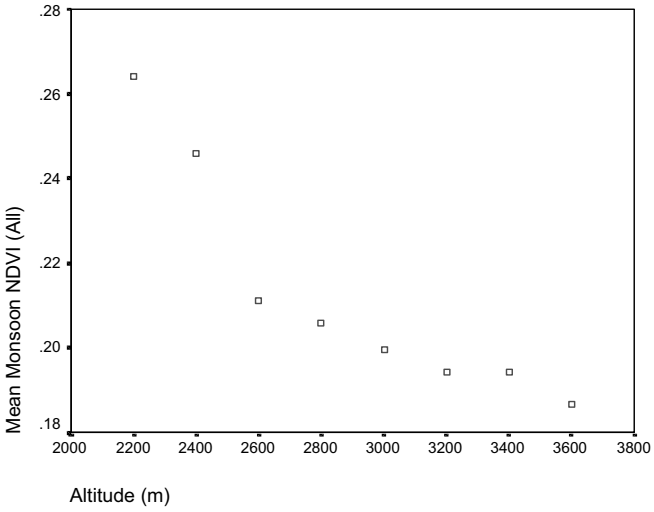


Figure 5. Distribution of area and NDVI across altitude zones in Kedarnath. Log10 no. of species is linearly related to:

a) Total land area and forest area. Mid-elevations have larger area. Mean positive monsoon NDVI:

b) Forests &; c) of all natural vegetation. – NDVI rises sharply after 2400-2600 m zone.

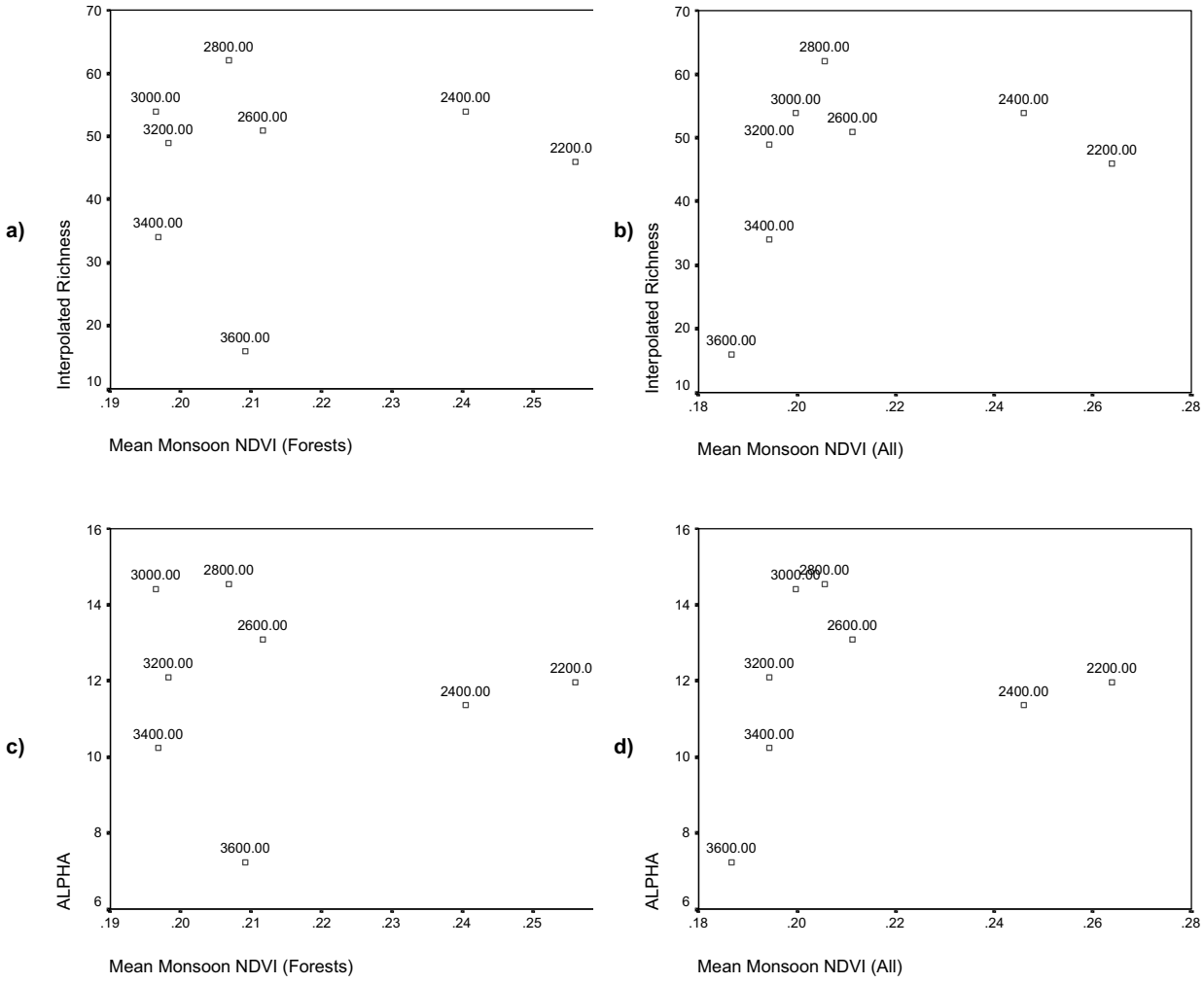


Figure 6. NDVI and bird diversity in Kedarnath.

a) Interpolated richness and NDVI of forests;

b) All natural vegetation.

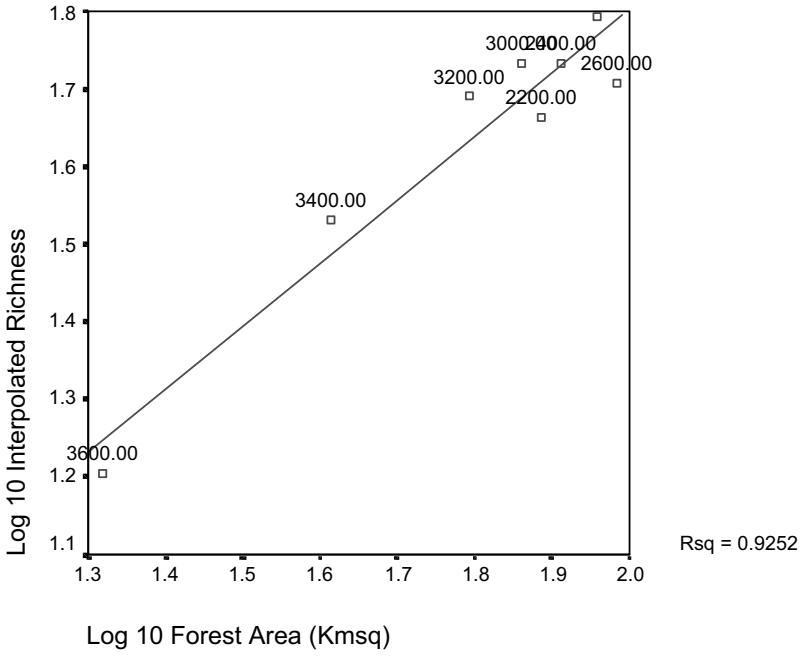
c) Logseries alpha and NDVI of forests;

d) All natural vegetation.

Points are marked by their elevation zone.

Diversity shows a somewhat unimodal pattern with NDVI though patterns are less clear with forest NDVI.

a)



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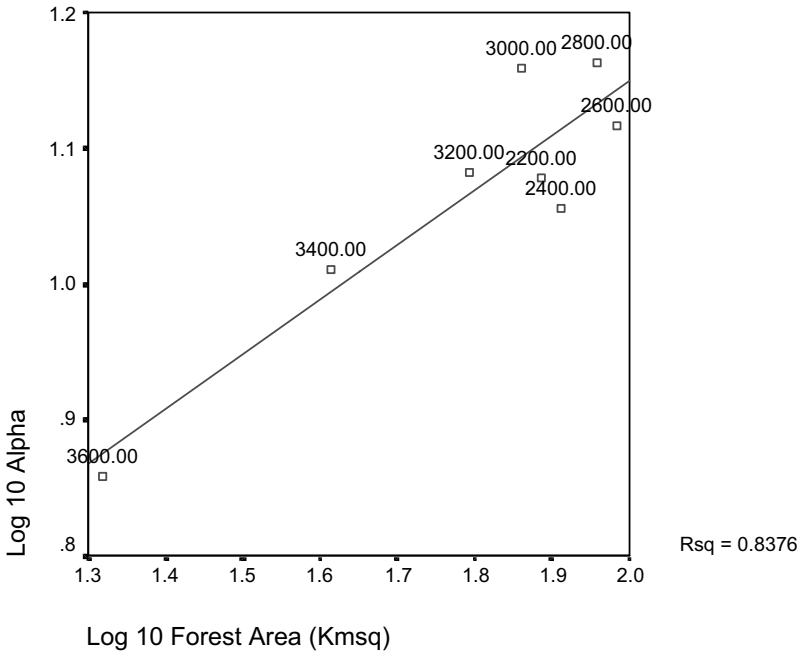


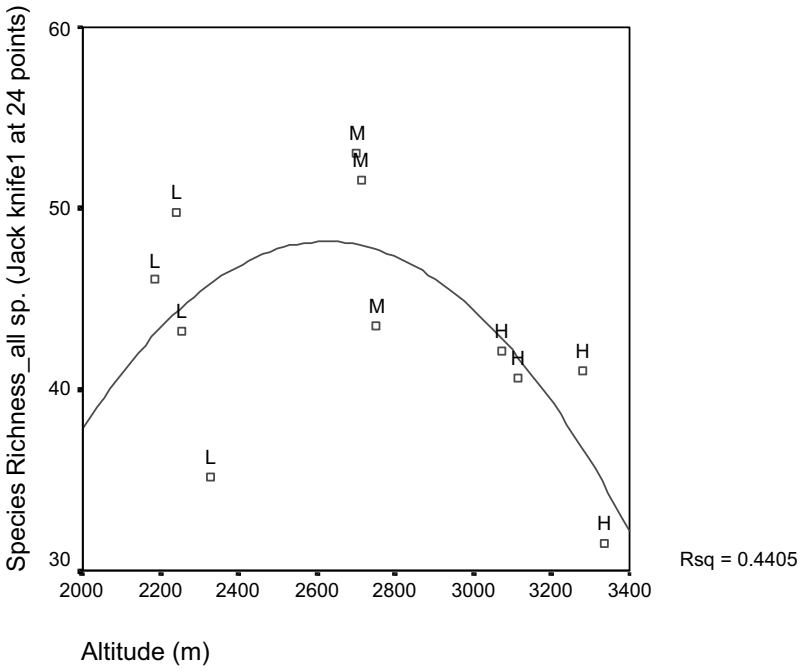
Figure 7. Area and bird diversity in Kedarnath.
Log 10 richness linearly relates to
Log 10 forest area of each altitude zone.
a) Interpolated richness;
b) Logseries alpha

5.3.4 Relationship of Species Richness with Biomass and Density (Kedarnath)

Alpha (site) diversity shows a unimodal pattern with altitude though the trend is weak (rsq = .440, **Fig 8a**). Richness shows a positive curvilinear trend with overall biomass (**Fig 8b**). At some sites, two species of galliformes (Koklass, Monal), being very large birds contribute, large proportion of biomass but small densities. Calculations were redone after removing all galliformes birds (4 species- Kaleej pheasant, Koklass pheasant, Himalyan Monal and common hill partridge), and further analysis was done excluding galliformes. (A summary of biomass, density, mean body size and richness by altitude zones is provided in box & whisker plots, **supplematary figures, a-f**). Richness increases curvilinearly with biomass with two prominent (mid-elevation) outliers (**Fig 9a**). Removing these outliers the relationship is described by a loglinear function (Log10 Species Richness = 0.415 Log10 Biomass (Kg) + 1.513, rsq = .877, F = 50.0, p = .000, **Fig 9b**).

Density shows a somewhat negative trend with biomass (with two prominent outliers), generally lower altitude sites have higher biomass but lower density and vice versa (see **Fig 10a**). Richness also shows a negative trend with density with generally lower altitude sites showing lower density and higher richness than high altitude sites (**Fig 10b**). Though Pearson's correlation coefficients are positive between log Density and log biomass and between log richness and log density. There is an altitudinal trend in body size (pearson's r -0.79, p =0.00) and density is negatively related with bodysize, though the relationship is not significant (pearson's r -0.41, p =0.21 **Supplementary table 1 and Fig 11a & b**).

a)



b)

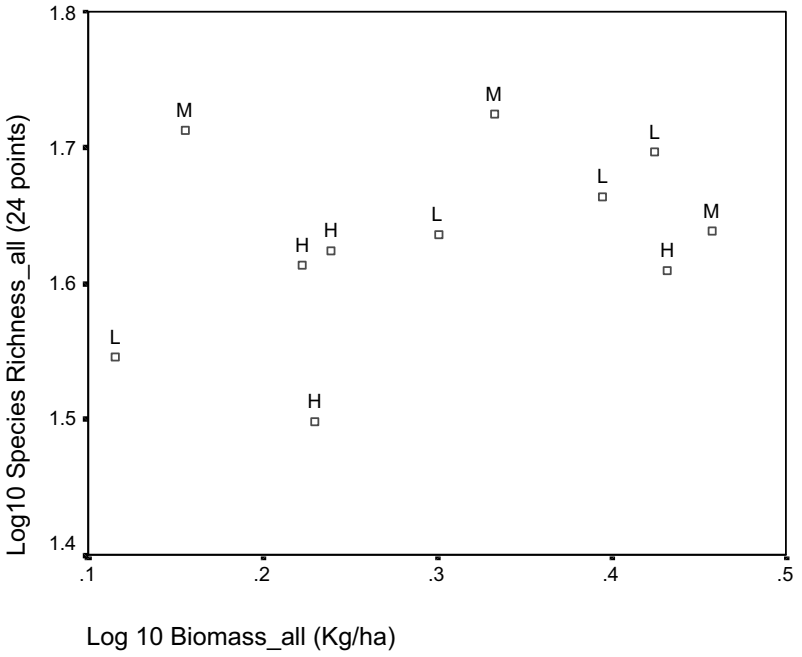


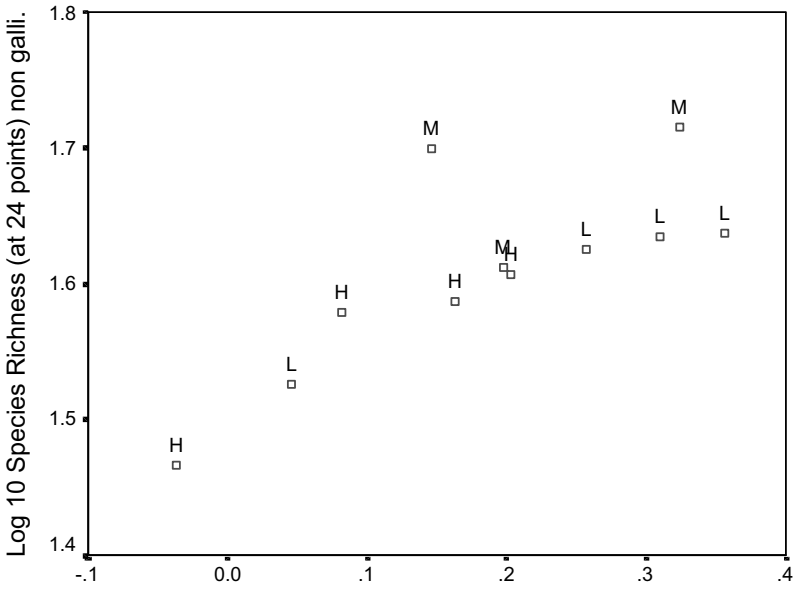
Figure 8. Alpha (site diversity) along altitude and Biomass gradient in Kedarnath.

a) Altitude;

b) Biomass.

Points are marked by elevation zone: L- Low elevation- between 2000- 2500 m, M- Mid –elevation 2500-3000, H- High elevation above 3000 m.

a)



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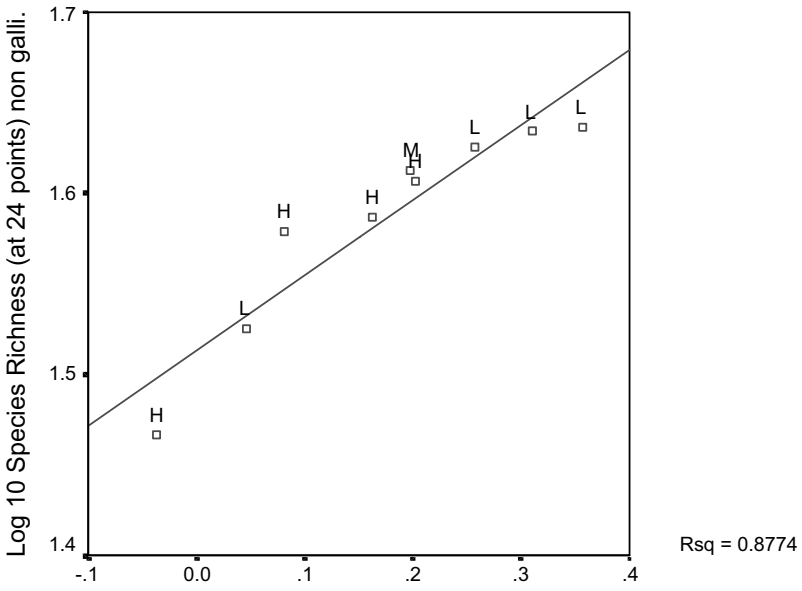
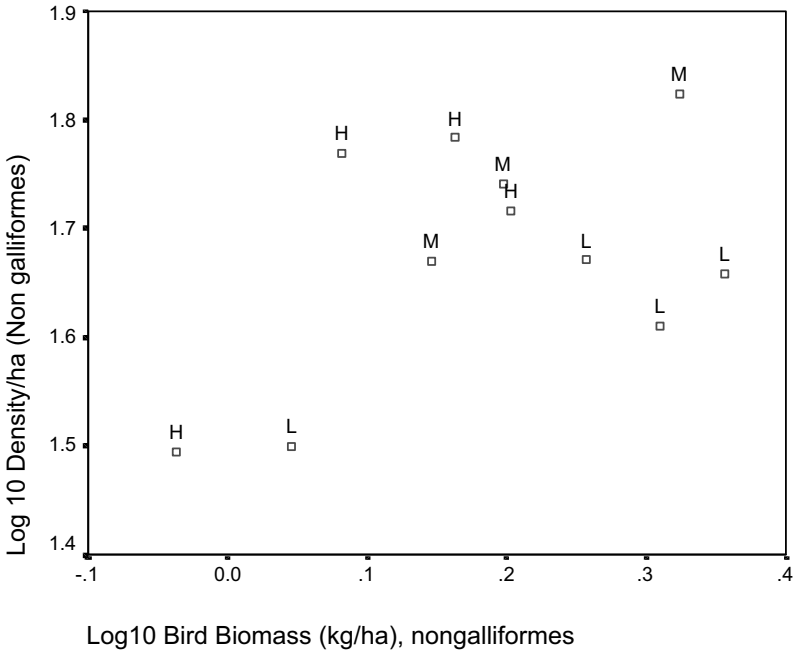


Figure 9. Site diversity and biomass (excluding galliformes).

a) Log 10 richness relates positively and linearly with log 10 biomass except for two prominent mid-elevation outliers.

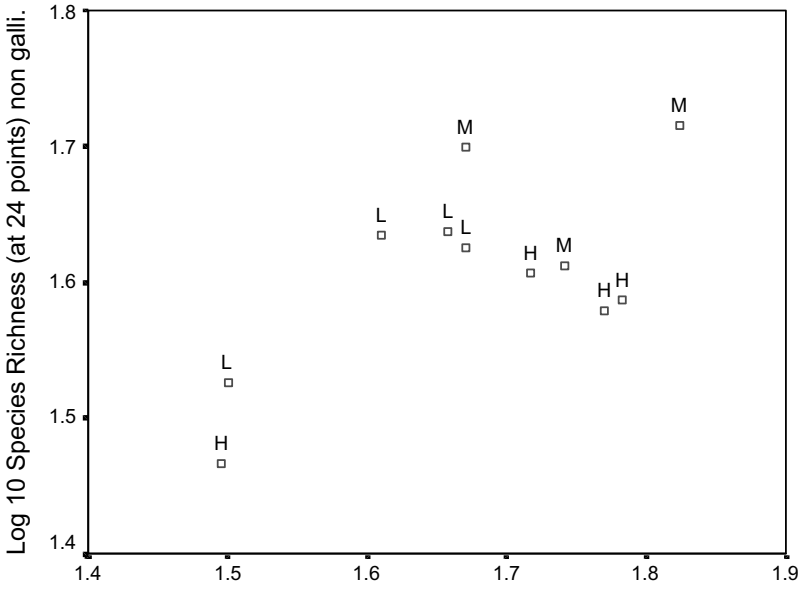
b) Log 10 Biomass and Log 10 Richness after removing outliers.

a)



Log10 Bird Biomass (kg/ha), nongalliformes

b)



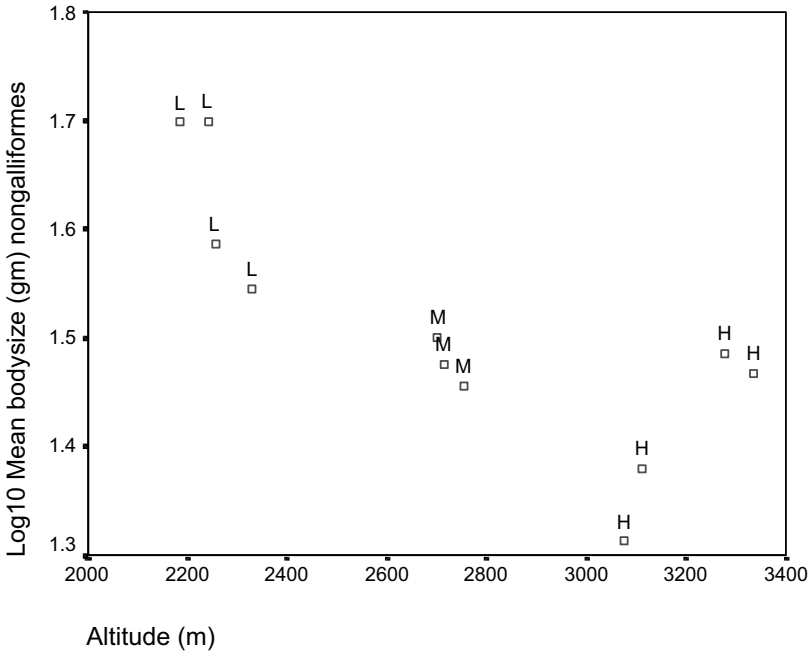
Log 10 Density/ha (Non galliformes)

Figure 10.Relationship between.

a) Log 10 biomass and log 10 density is somewhat negative;

b) Log 10 richness and Log 10 density is also somewhat negative.

a)



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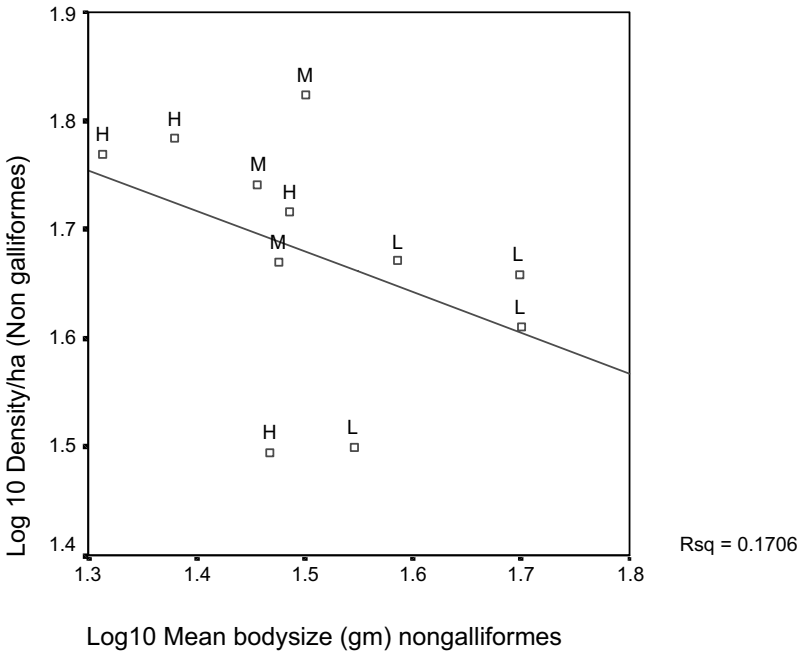


Figure 11.Trend in body size and density along the altitude gradient.

a) Log 10 Mean body size is negatively related to altitude;

b) Log 10 density and Log 10 mean body size are negatively related.

5.3.4.1 Habitat structure

Three habitat factors were extracted explaining a total of 91.8% of the variation. The third factor though has eigenvalue of less than 1, accounts for nearly 10% of the variation, so is included in the analysis (**Table 4a**). The first factor is highly positively correlated with tree height, GBH and canopy depth of trees and thus describes forests of tall stature. Second factor relates with vegetation density variables thus describing forests of greater vegetation density. The third factor describes forests with high ringal density and tall shrubs (see **Table 4b**).

Table 4 a. Factor Analysis of habitat variables

Total Variance Explained			
	Initial Eigenvalues		
Component	**Total**	**% of Variance**	**Cumulative %**
1	4.5	50.49	50.49
2	2.83	31.48	81.97
3	0.88	9.88	91.86

Table 4 b. Rotated component matrix

	Factor		
Variable	**1**	**2**	**3**
Avg. Tree ht.	**0.97**	0.11	0.16
Avg.GBH	**0.94**	-0.19	0.16
Shrub Density	-0.37	**0.85**	-0.13
Ringal clump density	0.46	**0.50**	**0.66**
Tree density	**-0.63**	**0.58**	-0.45
Avg. Canopy open	0.024	**-0.88**	-0.02
Avg.litter depth	0.10	**0.76**	0.47
Avg.canopy depth (lower canopy - tree ht)	**0.94**	-0.15	0.25
Avg shrub ht.	0.22381	-0.04131	**0.943558**

The two outlier mid-elevation sites in the biomass-diversity relationship, load highly on Factor 1 describing taller forests with deep canopies (**Fig 12a**). This is due to a mixed coniferous composition. Presence of Fir (*Abies pindrow*) added greater height and a canopy of dense and deep foliage along with a mix of broadleaved trees. The canopy of fir trees starts from a low height above the ground and continues above 20-25 mts. Thus these sites have forests, which have greater vertical stratification. This, in part explains the larger richness observed in these sites than expected from the biomass curve and hence richness positively relates to Factor 1 (pearson's r = 0.87, p = 0.00, **Fig 12b**), density and biomass do not show strong relationship with any of the habitat factors.

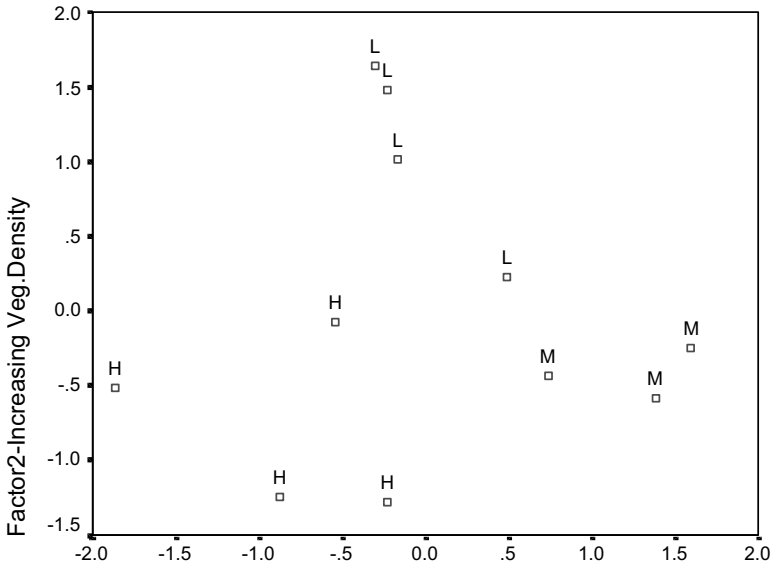
5.3.5 Rapoport's Rule

Range size plotted as means in each altitude belt (Steven's method) shows no trend of increasing range size with elevation (**Fig.13a**). Range size plotted against altitude midpoint of each species (Mid point method) shows larger range sizes in mid elevations not at higher elevations, although a large amount of scatter in the data is seen (**Fig 13b**).

5.3.6 Null models

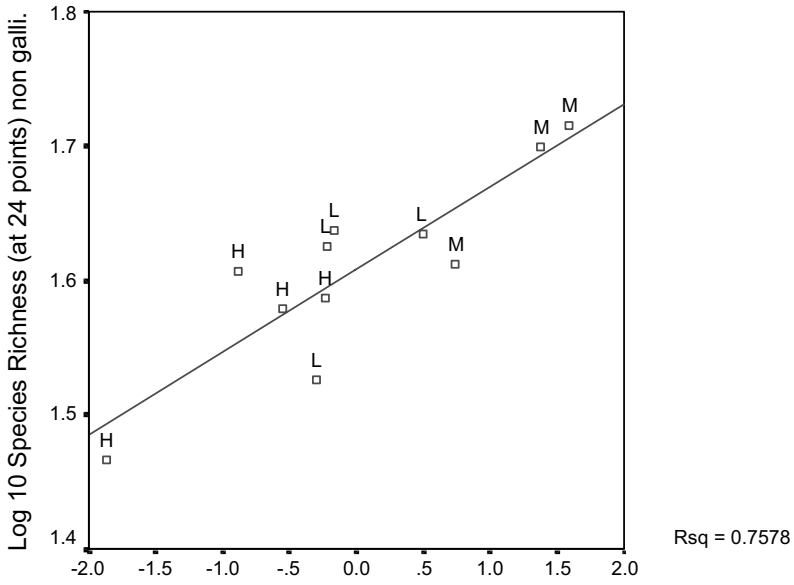
A total of 148 species are restricted to only one montane biome. The Sino-Himalayan subtropical forests (b8) has 34, Sino-Himalayan Temperate forests (b7) 82 and the Eurasian High Montane (b5) 34 species. All three groups show a unimodal peak in richness peaking in the middle of their respective bounds. Subtropical biome peaks between 1500-2000m, temperate between 2500-3000m and high

a)



Factor 1- Increasing forest Stature

b)



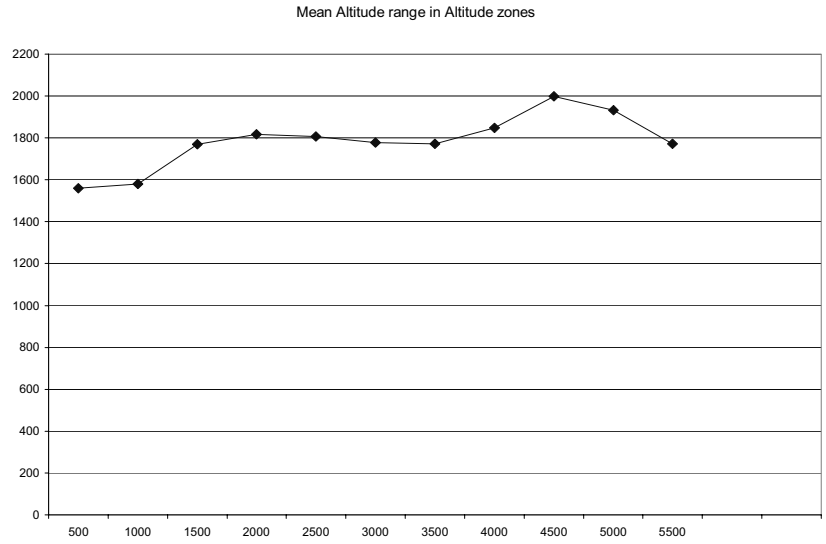
Factor 1- Increasing forest Stature

Figure 12.Habitat factors and Bird diversity.

a) Factor 1 plotted against Factor 2. Factor 1 relates to increasing tree ht, gbh and canopy depth thus to veg. stature, Factor 2 relates to greater tree ringal and shrub density, thus relates to veg. density. Mid-elevation sites load highly on Factor 1;

b) Factor 1 is positively related with richness, the two outlier mid elevation sites in biomass and richness relationship load highly on Factor 1.

a)



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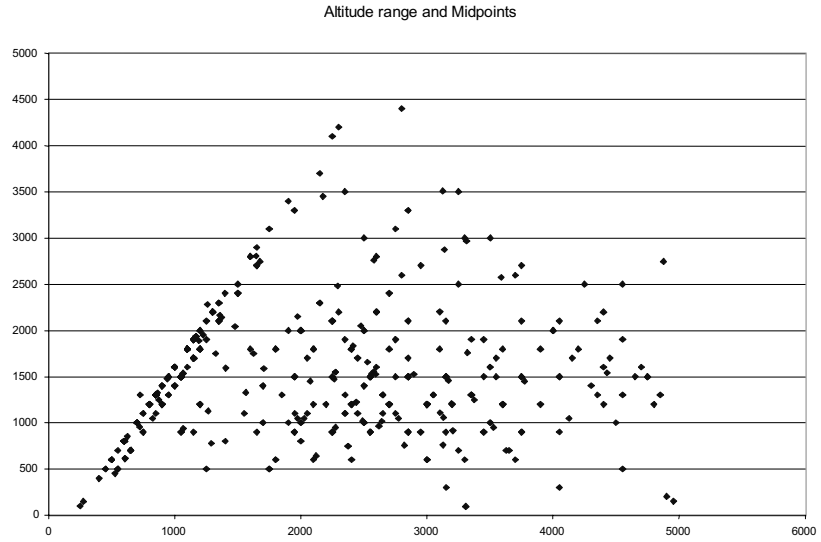


Figure 13.Rapoport's rule in Western Himalaya.

a) Mean altitude in altitude zones- Though lowest mean ranges occur in low elevations and largest ranges occur in high elevations, large part of the gradient has very similar mean ranges. The difference between mean range sizes is also small fluctuating mostly between 1600-1800 m.

b) Altitude range and Mid-points of altitude range of species – The largest ranges tend to occur in mid elevations, though there is a large amount of scatter in the data.

alpine between 4000-4500m. All biome restricted species peak between 2000-2500 m, off the peaks of subtropical and temperate biomes, where substantial overlap between two zones occurs (**Fig 14**). The null models correctly predict the zone of peak in richness for all three groups, but the height of the peak (number of species) is predicted lower in all cases. Wide variations are seen along the curve as well (**Fig 15a, b & c**).

5.4 DISCUSSION

Productive energy (as indexed by NDVI) explains a surprisingly large amount of variation particularly at the regional scale. It is the dominant variable governing diversity patterns at these scales. Greater relative area in the mid-elevations, and ecotonal effects modify the trend at a secondary level and may explain the mid elevation peak which is not substantial in any case.

Mean NDVI values are relatively similar from 2500-3000 zone till low elevations. Thus suggesting similar productive energy levels from low till at least mid-elevations. This is supported by Singh *et al* (1994) who suggest that NPP remains high and invariant till 2400 m in Kumaon Himalaya. Increase in effectiveness of precipitation till 2400 m due to lowering of temperature, inverse relationship between leaf production efficiency and leaf mass of different forests types favouring high NPP have been suggested to cause this trend.

In recent years several other authors have found positive bird diversity and plant productivity (measured by NDVI) relationship at large spatial scales (Bailey *et al* 2004, Bonn *et al* 2004, Lee *et al* 2004).

a)

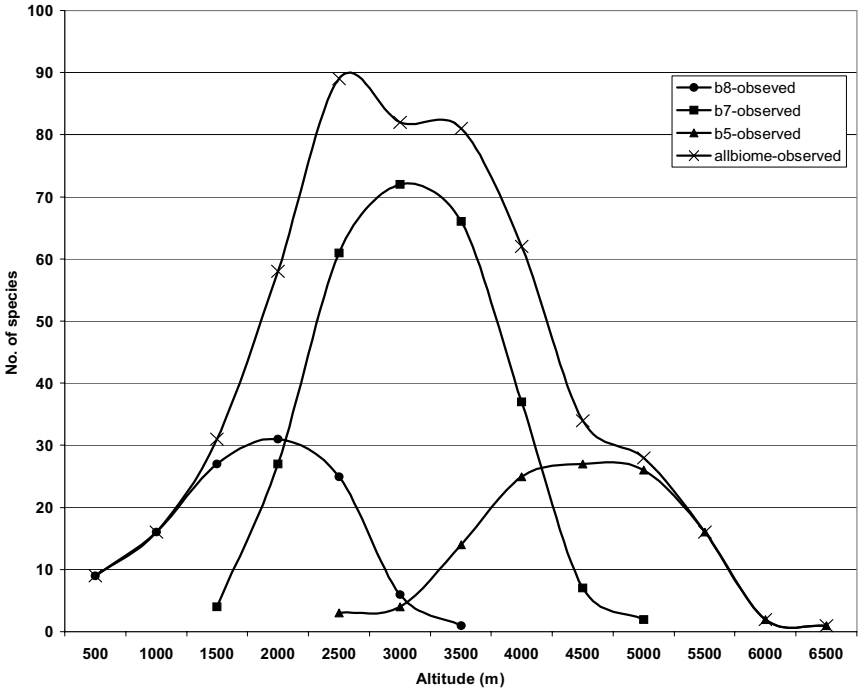


Figure 14. Distribution of diversity of 'Biome restricted' assemblages

b8- Sino-Himalayan Subtropical Forests biome;

b7- Sino- Himalayan Temperate Forest biome;

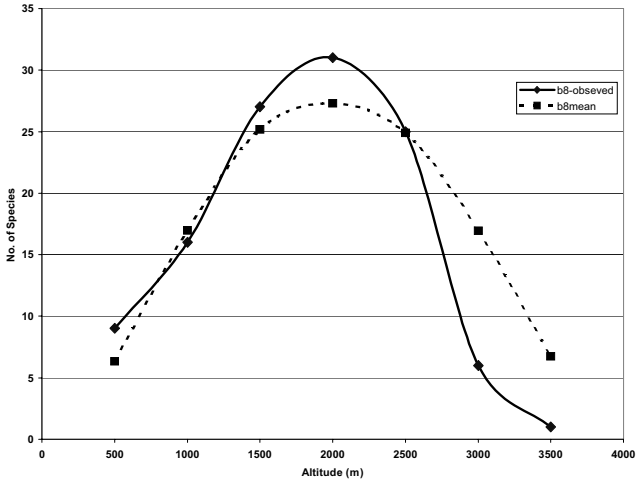
b5- Eurasian High Montane biome.

All biome – All 3 biomes pooled.

Different groups show separate peaks in richness,

peak in richness of pooled richness does not coincide with highest richness, but in zones of extensive overlap between subtropical and temperate biome species, pointing to the role of zonal overlaps in generating peaks in richness.

a)



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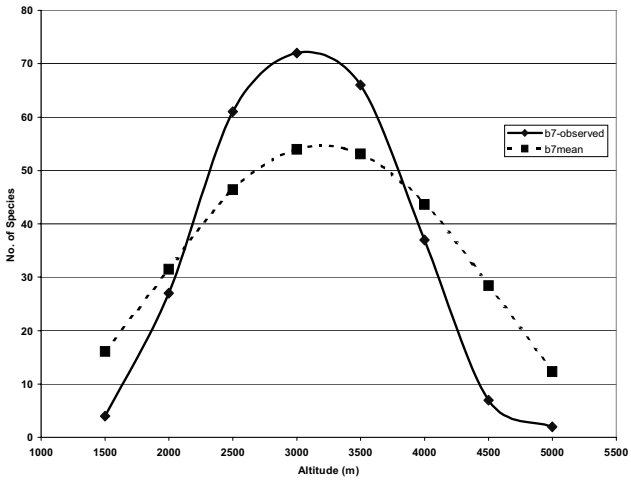

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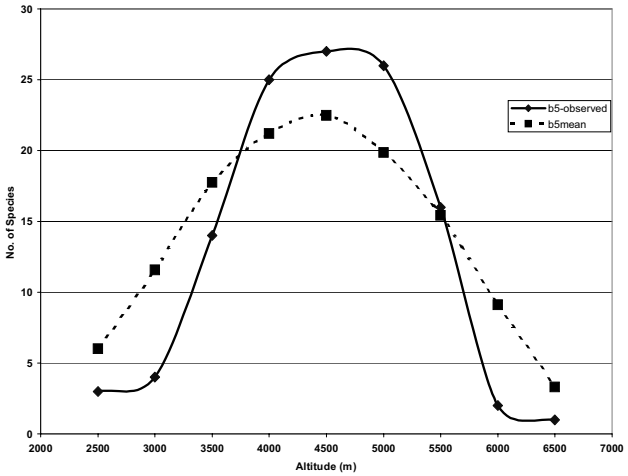

Figure 15. Null model randomizations (random placement of empirical ranges) and diversity.

a) b8- Sino-Himalayan Subtropical Forests biome;

b) b7- Sino- Himalayan Temperate Forests biome;

c) b5- Eurasian High Montane biome.

All observed peaks are above the predicted mean peak, though the zones are the same. Large variations in the observed and predicted mean curve are seen for all 3 groups.

In the scenario of similar energy levels from low to mid elevations peak in diversity will occur in zones with greater area and/or of zonal overlap (ecotones). This is the observed pattern at the west Himalaya scale. Kattan and Franco (2004) also found area to explain the mid-elevation peak in the Andes of Columbia, *i.e.* the mid-elevations had more number of species but also had larger area.

The ecotonal effects are further illustrated by the diversity pattern of Biome restricted species. The highest diversity for this group occurs where there is substantial overlap between subtropical and temperate groups. All groups (Subtropical, Temperate and High Montane) occupy distinct regions but with some overlap, along the gradients such that each group peaks at different elevations.

At the landscape level relationship of NDVI and diversity is curvilinear showing a somewhat hump shaped pattern. This may be due to scale effects. Chase and Leibold (2002) demonstrated that at local scales the relationship between productivity and diversity was hump shaped but the pattern became linear at regional scales. This happened because more species were added to the high productivity sites due to their increasing dissimilarity at regional scales. In other words high productivity sites may have fewer species at local scales but at regional scales may add many more species due to their increasing dissimilarity. On the other hand lower productivity sites may contain larger number of species but from a much similar generalized species pool, such that increasing the spatial scale to regional levels does not add many more new species.

If a larger number of species are added to the lower elevation (higher productivity) sites as we pool different altitude gradients along the west Himalaya region then a linear productivity-diversity relationship is possible.

In Kedarnath (landscape scale) species area regression with forest area as independent variable explained a large amount of variation, however, this also to some extent, reflects a productivity mediated gradient since forest growth conditions, in temperate zone are likely to be strongly temperature driven. In general forest extent declines as one approaches the tree line due to decreasing productivity of the environment. The sampled gradient in Kedarnath faces low degree of human disturbance as much of the area is under Kedarnath musk deer sanctuary and adjoining Reserve forests. The extent of forest cover here is more likely to reflect climatic and topographic favorableness of the area for forest growth. Moreover, in situations of similar productivity levels (or if the differences in productivity are not very large), diversity will be related to area.

Local (site) diversity in Kedarnath was explained well by total bird-biomass (a direct measure of taxa productivity). The exceptions to the pattern were related to greater vegetation heterogeniety. This suggests that overall productivity defines the diversity gradient, but in some situations, is modified by habitat heterogeneity. However, higher biomass is not achieved by increase in number of individuals (greater total density). Sites of higher biomass hold species of greater body

sizes but somewhat lower densities. This does not support the 'more individuals' hypotheses. Once density is corrected for body size effects, biomass is positively related to density. Larger body size of high biomass (Lower elevation) sites may result from they drawing from different species pools. This suggests that the 'more individuals' hypotheses is more likely to be found where comparison are made between assemblages of similar source pool or body-size distributions.

Bonn *et al* (2004) also found richness to increase but mean abundance to decline with productivity in South Africa. Although Ding (2000) found richness to be linearly related to total density, a hump shaped relationship between total bird biomass and total density was observed. However, Kaspari *et al* (2000) found richness and density and NPP to be positively related to each other for ant assemblages across a large latitudinal gradient. Ding (2000) also found NPP to be positively correlated with total bird biomass. It can be said that total bird biomass positively relates to bird diversity although it may not happen by greater increase in number of individuals. However, the basic premise that greater productivity lowers the risk of extinction is perhaps not questionable even if greater number of individuals are not seen, support of larger bodied taxa may also yield the same result with lower densities. Larger bodied birds may be able to survive starvation and environmental stress like low temperatures better than small bodied birds and their populations may persist at comparatively lower densities.

Total bird biomass showed considerable variation along the altitude gradient in Kedarnath and it is likely to be influenced by site specific NPP.

Rapoport's rule does not hold in the west Himalayan assemblage. Although Stevens (1992) suggested that since migrants escape the harsh climates, they may not exhibit the Rapoports rule. However, a Rapoport's effect is reported among latitudinal breeding distributions of old world *Phylloscopus* warblers (Price *et al* 1997).

There is a growing body of literature critical of use of the 'mid-domain null models' as they are formulated now. Principally the definition of domains being based on environmental tolerances of the taxa and a good match between observed and predicted patterns being dependent on using empirical range sizes (Colwell *et al* 2004, now advise use of only empirical range sizes) are considered problematic. Since the 'null' models already incorporate so much of reality, their being 'null' models is questioned, especially so when domains are being defined by environmental tolerances or have 'soft boundaries' (Koleff & Gaston 2002, Zapata *et al* 2003). Importantly null models are poor predictors of faunal turnover (Koleff & Gaston 2002) which may be important in generating mid-elevation peaks as demonstrated in this study. However the debate has not reached a conclusion as yet (Colwell *et al* 2004, Pimm & Brown 2004).

The temperate 'biome restricted' group is the most species rich and represents more than 60% of the group present within Indian

Himalaya. In contrast the subtropical group represent less than 40% of the species present within Indian Himalaya, a large section of these species remain confined to the eastern Himalaya. This may shed some light on somewhat lower richness of lower elevation belts, many species which could have colonized the subtropical belts either could not disperse from the east or were extirpated following increasing aridity of the climate in recent geological past. Species of lower latitudes have been suggested to have lower environmental tolerance. Janzen (1967) suggested that tropical species are less likely to disperse across topographic and other environmental barriers. The temperate zones were possibly also more extensive during the episodes of glaciations and enjoyed wider connectivity. Although there are few species endemic to Himalaya as most of avifauna is of an immigrant nature, the few endemic species (8 species in the Indian Western Himalaya) are all temperate species, none are in the subtropics. This also contributes to the diversity of Western Himalaya. For Taiwan, Lee *et al* (2004) suggest greater extent and time enjoyed by temperate zones during glaciation episodes to be conducive to higher speciation, similarly Kattan & Franco (2004) attribute combination of isolation and greater area in Columbian Andes to have caused higher rates of speciation.

To summarize, the gamma diversity gradient across altitude zones at the entire Western Himalaya scale is primarily governed by productive energy. Area plays a secondary role, being important between zones of similar energy levels. The observed patterns of diversity also carry the influence of biogeographic episodes of dispersal and colonizations. The

temperate regions seem to have enjoyed a greater rate of colonization as well as speciation.

At landscape scales productive energy and diversity shows a curvilinear pattern which may be due to scale effects. Forest area best explains the diversity gradient. Area may become important in comparison of zones of similar or low difference in energy input, as is probably the case in Kedarnath.

At both scales larger area and zonal feedbacks contribute to mid-elevation peak in diversity.

Alpha diversity (site diversity) patterns are primarily related to bird biomass (bird productivity), which is modified by vegetation heterogeneity.

Thus an overall role of energy variables in generating diversity gradients is supported.

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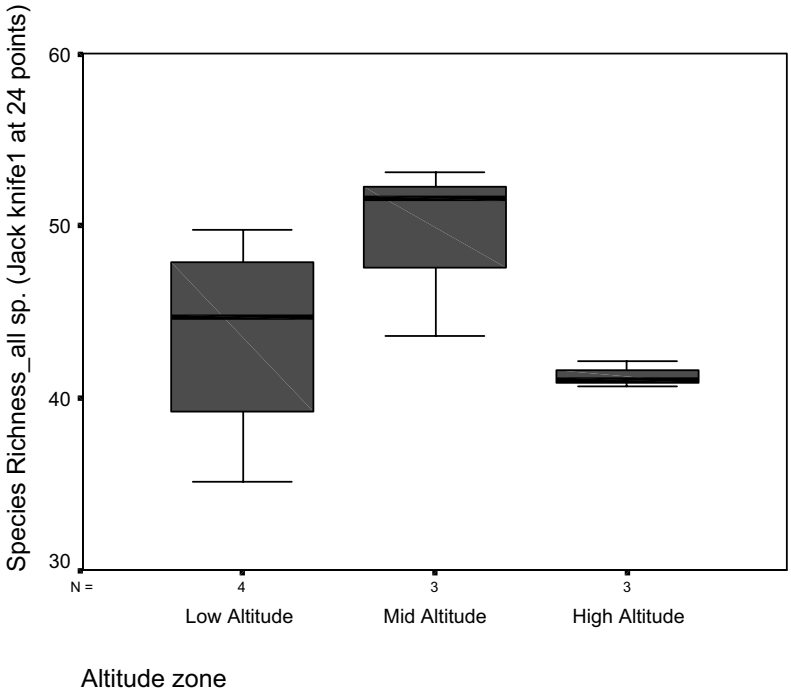

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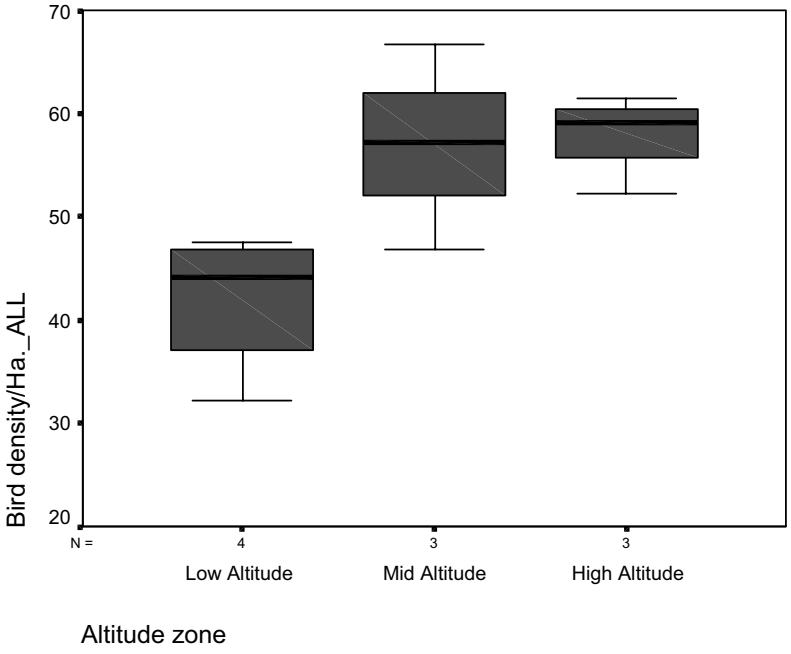
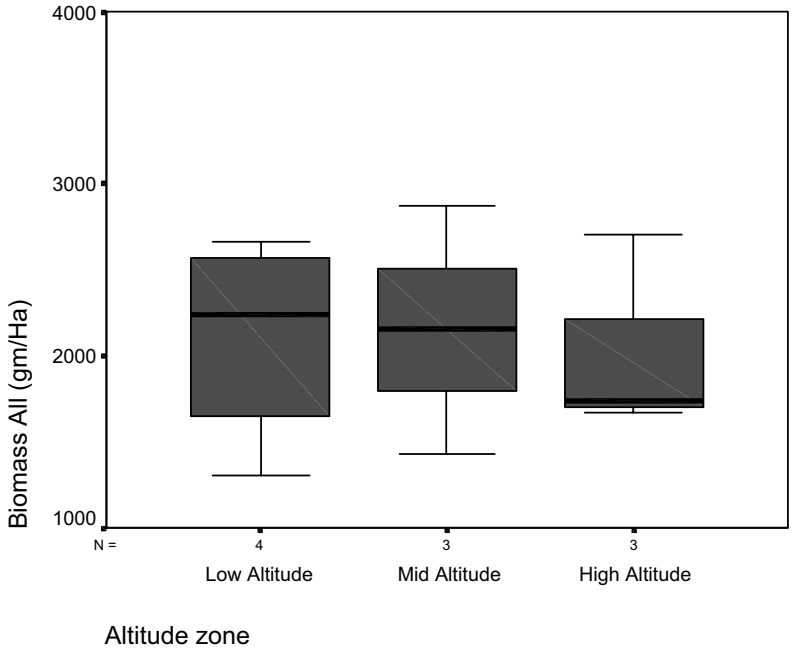


Supplementary Figures (a) and (b)

(c)



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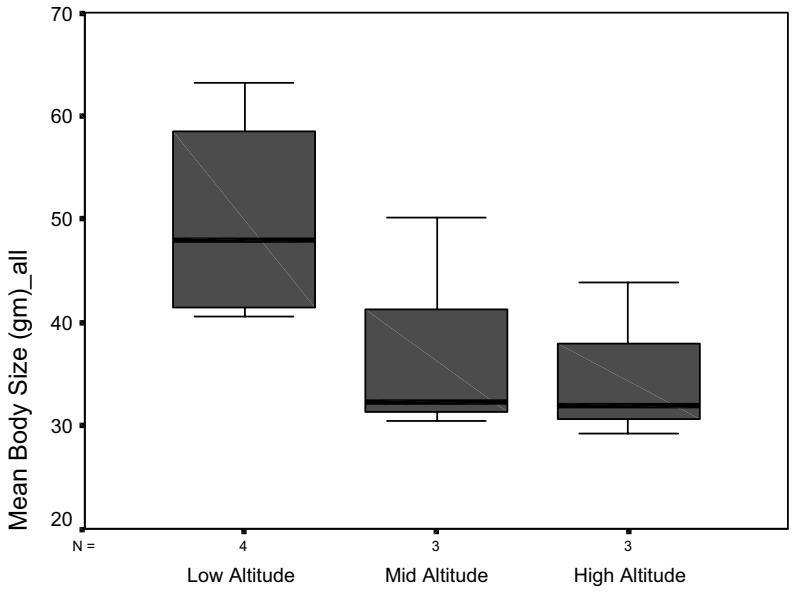
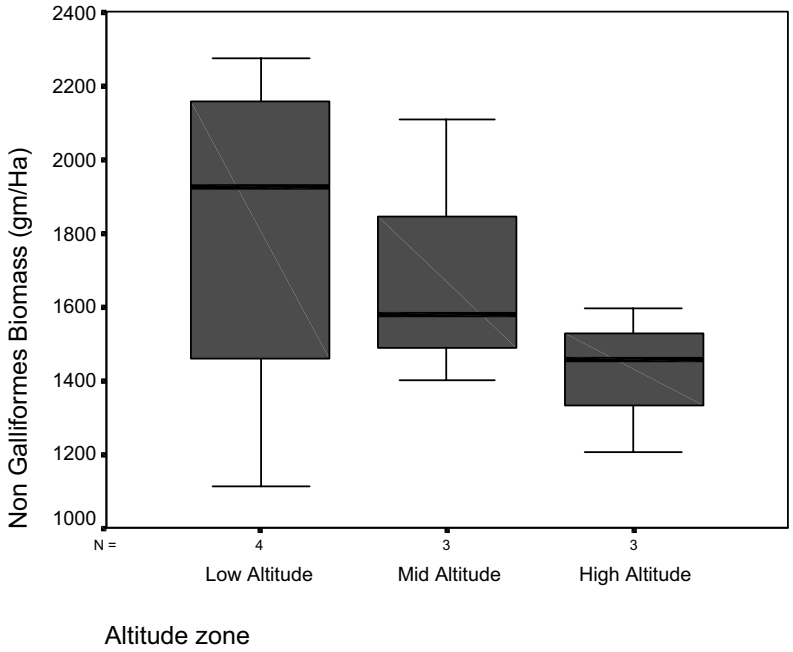


Supplementary Figures (c) and (d)

(e)



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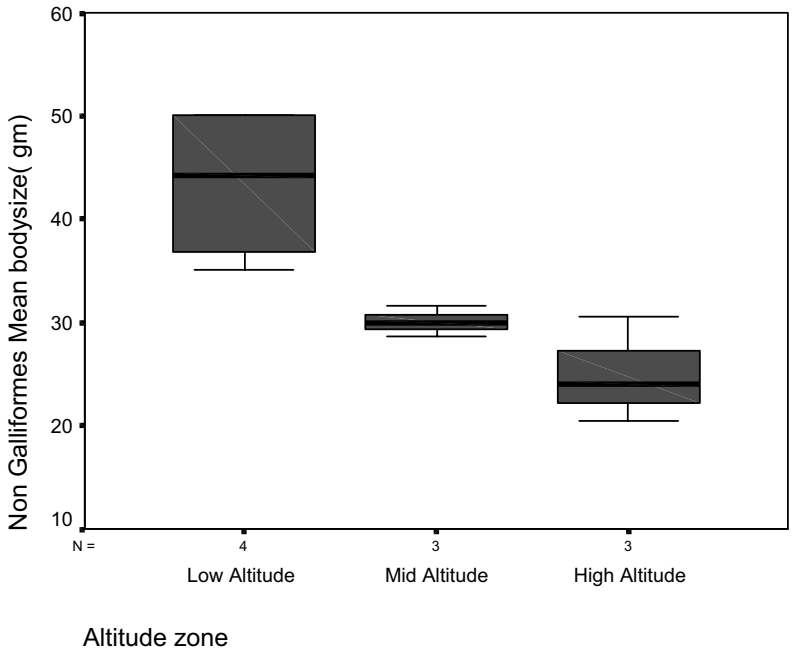

Supplementary Figures (e) and (f)

Supplementary Table. 1 Correlation between bird community attributes and habitat factors.

	Altitude (m)	Log10 Bird Biomass (kg/ha), (Non galliformes)	Log 10 Density/ha (Non galliformes)	Log10 Mean bodysize (gm) (Non galliformes)	Log 10 Species Richness (at 24 points) (Non galliformes)
Log10 Bird Biomass (kg/ha), (Non galliformes)	-0.57 (0.06,0.07)				
Log 10 Density/ha (Non galliformes)	0.21 (0.53,0.53)	0.48 (0.14,0.14)			
Log10 Mean bodysize (gm) (Non galliformes)	***-0.79*** ***(0.00,0.04)***	**0.6** **(0.05,0.12)**	-0.41 (0.21,0.21)		
Log 10 Species Richness (at 24 points) (Non galliformes)	-0.37 (0.26,0.23)	***0.77*** ***(0.01,0.02)***	***0.64*** ***(0.04,0.05)***	0.23 (0.51,0.53)	
Factor 1- Increasing forest Stature	-0.43 (0.18,0.28)	0.57 (0.07,0.12)	0.49 (0.13,0.14)	0.14 (0.67,0.73)	***0.87*** ***(0.00,0)***
Factor2- Increasing Veg. Density	***-0.82*** ***(0.00,0.05)***	0.16 (0.65,0.5)	-0.46 (0.16,0.15)	0.57 (0.06,0.11)	-0.07 (0.83,0.79)
Factor 3- High Ringal density & Shrub ht	0.04 (0.9,0.91)	0.2 (0.55,0.64)	0.23 (0.49,0.48)	0 (1,0.99)	0.02 (0.96,0.96)

Values in()- (original p value, corrected p value after Dutilleul's correction for spatial autocorrelation), Values significant in both tests are in bold and italics, significant only without Dutilleul's corrected p value are in bold.

CHAPTER 6

Synthesis and Conservation Implications

6.1 INTRODUCTION

In the preceding chapters I have presented key patterns and correlates pertaining to composition, abundance and diversity in avian assemblages in the Western Himalaya. I have looked at composition and diversity at regional and landscape scales, while I have focused on abundance patterns primarily at the landscape scales. I have endeavored to identify the key variables related to these patterns in the Western Himalaya. In discussing these patterns I have looked at the patterns and mechanisms at the latitudinal gradient as well. Altitude gradients in some respects mirror latitudinal gradients (though there are important differences) and present test situations for many ideas relevant to latitudinal gradients particularly in diversity gradients. Thus patterns and their correlates identified in this study have relevance in a latitudinal context as well.

Below I outline some of the key features, emergent themes, hypotheses and their implications for conservation of bird biodiversity in the Western Himalaya.

6.2 ROLE OF CLIMATE IN STRUCTURING AVIAN ASSEMBLAGES

At large scales climate and variables emerging from climatic factors such as ambient energy (Potential evapotrinspiration, temperature) productivity (Actual evapotrinspiration, Net priamry productivity) have been widely shown to influence patterns of diversity (Hawkins *et al* 2003, Mittelbach *et al* 2004, Currie *et al* 2005).

The role of climate in structuring assemblage patterns stands out from the analyses in this thesis. This is especially obvious in structuring composition (chapter 3) and diversity patterns (chapter 5).

The key divisions of bird composition in Western Himalaya (0-1500 m subtropical, 1500-2400 m temperate, 2400-3600 m Subalpine and 3600-5000, alpine) correspond well with bioclimatic zones. There is also evidence that composition of these zones may have different source pools in corresponding latitudes. Thus regions of distinctly different climates along the altitude seem to host avifauna of climatically similar areas along the latitude. This is likely to be a general pattern across the Himalayas and a major reason of development of such a rich assemblage, though it requires more detailed analysis of avifauna of the entire Himalayas in context of the avifauna of Asia.

At landscape scales, finer divisions of the altitude gradient on the basis of forest composition are visible. Since forest composition itself primarily tracks temperature and precipitation, the role of altitude mediated climate regimes in generating compositional patterns at both scales is obvious.

At regional scales bird diversity strongly tracks productivity, which itself is a function of climate along the altitude. High levels of productivity from low altitudes to mid altitudes despite lowering temperatures, as climate remains favourable for plant growth till 2400 m. This happens by increased effectiveness of precipitation as temperatures decline, till 2400 m (Singh and Singh 1992, Singh *et al* 1994). This high level of productivity till mid altitudes in turn fosters a high level of diversity. Bird diversity declines as productivity declines with increasing altitude. Indeed productivity is a major correlate of diversity along the latitudinal gradient as well (Mittelbach *et al* 2004, Hawkins *et al* 2003). Role of productivity in generating diversity patterns also gets support at landscape scales, though habitat heterogeneity also seems to play a role at these scales.

Declining temperatures along the altitude gradient also must influence physiological responses of birds. One important consequence may be higher energetic costs (increased metabolic rate) for thermoregulation at higher altitudes. Since metabolic rates are linked with many life history traits including abundance, birds at higher altitudes may occur at lower population densities than expected if increased energetic costs for thermoregulation were not there (i.e. if birds were within their thermoneutral zones). There is some evidence of this effect from the bird assemblage in Kedarnath. Badyaev and Ghalambor (2001) found that increase in altitude also significantly lowers fecundity and demands greater parental care from birds (participation by both parents and longer parental care). In cardueline finches (many of which also occur in the Himalayas) Badyaev (1997) also found that

with increase in altitude clutch size and broods decreased and incubation period increased. He also found that these variations were not strongly related to either food limitation or nest predation, two factors considered to be of key importance in structuring bird life history strategies. A possible hypothesis explaining lower population density and increased difficulties of reproduction is that both these patterns may be linked together by higher energetic allocation to thermoregulatory needs, at higher altitudes and hence less to reproduction by individuals. In this regard higher altitudes may differ from high latitudes in an important way; in the breeding season, given similar temperature regimes, day lengths are greater in higher latitudes. This would translate to greater foraging time and proportionately smaller duration of low night temperatures. Thus generalizations from latitudinal studies may not be entirely suitable to altitude gradients. At the same time studies across altitude gradients provide a test situation for effects of temperature by controlling for differences in day length.

Groups of bird species may show physiological adaptations such as low Lower Critical Temperature (Tlc, the temperature below which metabolic rate must rise to maintain body temperature). Though to what extent Himalayan species are in sync with their current environment merits investigation, especially in light of recent episodes of climate change. It will also be highly interesting to study physiological factors in determining altitudinal distributions of species.

6.3 PEAKS IN DIVERSITY AND ECOTONAL EFFECTS

Diversity shows a unimodal trend with altitude at regional as well as landscape scales. Though at the regional scales trends in diversity are well matched by that of productivity, the role of zonal feedbacks stand out as a factor generating a peak in diversity in the middle of the gradient. There are relatively more species at range limits in the zone of high richness. Area also was greater in the zones of peak richness. Thus at regional scales, area works synergistically with overlap of distinct zones in generating a peak in richness. At landscapes scales also overlap of temperate and subalpine zones cause a peak in richness. Singh *et al* (1994) have demonstrated such a pattern in woody vegetation of Kumaon Himalaya, recently Oomen & Shanker (2005) also reported zonal feedbacks in generating richness peaks in woody vegetation across the entire western Himalya. Kattan and Franco (2004) found zonal feedbacks coupled with enhanced area in generating richness peaks in birds of Columbian Andes.

Since in the mountains, distinct faunal or floral zones are situated in close geographical proximity, overlap of zones or ecotonal effects are likely to be a much general explanation of unimodal or non monotonic patterns of richness.

6.4 CONSERVATION IMPLICATIONS

Peaks of high diversity are generated by ecotonal effects of overlap of two distinct zones. Thus conservation planning should not put a relatively high priority on such areas alone. Instead conservation efforts should focus on conserving each of the distinct avifaunal zones. Conservation planning so far has viewed the Himalayas without considering the distinct altitudinal zonation of fauna in the mountains. Though a large proportion of total geographical area (approx. 10%) of the Western Himalaya is under the protected area network (Rodgers *et al* 2002), that this network adequately protects all distinct biological zones is doubtful. There is a need to identify and adequately protect large contiguous altitude gradients such as in Goriganga valley. These gradients represent the exceptional display of Himalayan bird diversity in a short geographical distance and in a small geographical area. There is also a need to restore connectivity and revitalise landscapes with large altitude gradients. Most species breeding in the Western Himalaya as well as elsewhere in the Himalaya are altitudinal migrants and depend on lower elevation forests during the non breeding season. Connectivity of natural vegetation from low to high elecvations may be vital for long term survival of these species.

Western Himalaya has been recognized as a globally important hotspot of avian endemism and is identified as an ENDEMIC BIRD AREA by Birdlife International (Statterfield *et al* 1998). Western

Himalaya has 11 RESTRICTED RANGE species, three of which are threatened. It is important that habitats and populations of these species are adequately protected. However focus should also remain on assemblage level conservation efforts. A heavy leaning of conservation policy on endemic and/or threatened species may leave much of the at present common or widespread species without effective cover. The Important Bird Area programme of Birdlife International (Islam & Rahmani 2004) provides a suitable trade off by introducing the concept of 'Biome restricted species' in assessing priorities, along with restricted range and threatened species. Biome restricted species are otherwise widely distributed species but occur chiefly in one particular global biome. Thus by identifying areas where a large number of these Biome restricted species occur, a larger number of species and sites can come under conservation network, irrespective of whether the site contains threatened species or not. Inclusion of Biome restricted species provides a good framework for assemblage level protection.

The strong relationship of bird composition with vegetation composition is encouraging. Floristic composition or Forest types can be predicted with reasonable accuracy by remote sensing and GIS techniques, these can be surrogated to bird assemblage types. An exercise across the Western Himalaya linking vegetation attributes to bird assemblage attributes can provide a useful basis for assemblage level conservation planning for birds.

A positive correlation between distribution and abundance identified at landscape scales might be applicable at regional scales as well. This means that many species, which occur in few sites across Western Himalayas, will also have lower population densities and consequently lower population sizes. Regional scale positive distribution and abundance correlation is well documented for birds (Brown 1995, Gaston and Blackburn 2000) as well as other taxa. There is an urgent need to initiate population studies of birds in the Western Himalaya. Abundance and distribution patterns of birds need to be documented with robust estimation techniques. Compared to other vertebrates, birds intrinsically occur at lower densities, this makes bird populations potentially more vulnerable to local extinctions. Greater costs of life at high altitudes perhaps keep many species at a high risks of local extinction.

To conserve the bird diversity of the Western Himalaya a holistic strategy is urgently needed. Conservation efforts will have to reassess the adequacy of existing protected area network in protecting distinct assemblages of birds, and will have to ensure and revitalise contiguity of natural habitats along entire gradients at landscape scales. This must be coupled with better understanding of species biology and habitat requirements. With an impending scenario of global climate change, there is an urgency to these needs.

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APPENDIX- 1

Bird species and Indicator values in composition groups in Western Himalaya

(species significant at p=0.05 are in bold)

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Black-rumped Flameback	***Dinopium benghalense***	**100**	**1**
Great Slaty Woodpecker	***Mulleripicus pulverulentus***	**100**	**1**
Lineated Barbet	***Megalaima lineata***	**100**	**1**
Indian Grey Hornbill	***Ocyceros birostris***	**100**	**1**
Indian Roller	***Coracias benghalensis***	**100**	**1**
Dollarbird	***Eurystomus orientalis***	**100**	**1**
Chestnut-headed Bee-eater	***Merops leschenaulti***	**100**	**1**
Rose-ringed Parakeet	***Psittacula krameri***	**100**	**1**
Tawny Fish Owl	***Ketupa flavipes***	**100**	**1**
Jungle Owlet	***Glaucidium radiatum***	**100**	**1**
Brown Hawk Owl	***Ninox scutulata***	**100**	**1**
Savanna Nightjar	***Caprimulgus affinis***	**100**	**1**
Yellow-footed Green Pigeon	***Treron phoenicoptera***	**100**	**1**
Black Baza	***Aviceda leuphotes***	**100**	**1**
Rufous-bellied Eagle	***Hieraaetus kienerii***	**100**	**1**
Laggar Falcon	***Falco jugger***	**100**	**1**
Black-headed Cuckooshrike	***Coracina melanoptera***	**100**	**1**
White-browed Fantail	***Rhipidura aureola***	**100**	**1**
Jungle Prinia	***Prinia sylvatica***	**100**	**1**
Pale-billed Flowerpecker	***Dicaeum erythrorynchos***	**100**	**1**
Black-naped Monarch	***Hypothymis azurea***	**87.5**	**1**
Common Woodshrike	***Tephrodornis pondicerianus***	**85.71**	**1**
Common Hawk Cuckoo	***Hierococcyx varius***	**77.78**	**1**
Emerald Dove	***Chalcophaps indica***	**77.78**	**1**
White-eyed Buzzard	***Butastur teesa***	**77.78**	**1**
Indian Pitta	***Pitta brachyura***	**77.78**	**1**
Black-hooded Oriole	***Oriolus xanthornus***	**77.78**	**1**
Bright-headed Cisticola	***Cisticola exilis***	**77.78**	**1**
Ashy Prinia	***Prinia socialis***	**77.78**	**1**
Plain Prinia	***Prinia inornata***	**77.78**	**1**
Puff-throated Babbler	***Pellorneum ruficeps***	**77.78**	**1**
Baya Weaver	***Ploceus philippinus***	**77.78**	**1**
Red Junglefowl	***Gallus gallus***	**71.43**	**1**
Brown-headed Barbet	***Megalaima zeylanica***	**71.43**	**1**
Great Hornbill	***Buceros bicornis***	**71.43**	**1**
Crow-billed Drongo	***Dicrurus annectans***	**71.43**	**1**
Asian Pied Starling	***Sturnus contra***	**71.43**	**1**
Bank Myna	***Acridotheres ginginianus***	**71.43**	**1**
Yellow-bellied Prinia	***Prinia flaviventris***	**71.43**	**1**
Chestnut-shouldered Petronia	***Petronia xanthocollis***	**71.43**	**1**
Barn Owl	***Tyto alba***	**70**	**1**
Red Collared Dove	***Streptopelia tranquebarica***	**70**	**1**

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Grey-bellied Cuckoo	*Cacomantis passerinus*	63.64	1
Spotted Owlet	*Athene brama*	63.64	1
Shikra	*Accipiter badius*	63.64	1
Red-necked Falcon	*Falco chicquera*	63.64	1
Spangled Drongo	*Dicrurus hottentottus*	63.64	1
Black-backed Forktail	*Enicurus immaculatus*	63.64	1
Grey-crowned Prinia	*Prinia cinereocapilla*	63.64	1
Greater Yellownape	*Picus flavinucha*	58.33	1
Coppersmith Barbet	*Megalaima haemacephala*	58.33	1
Green Bee-eater	*Merops orientalis*	58.33	1
Chestnut-winged Cuckoo	*Clamator coromandus*	58.33	1
Banded Bay Cuckoo	*Cacomantis sonneratii*	58.33	1
Drongo Cuckoo	*Surniculus lugubris*	58.33	1
Red-breasted Parakeet	*Psittacula alexandri*	58.33	1
Brown Fish Owl	*Ketupa zeylonensis*	58.33	1
Indian Nightjar	*Caprimulgus asiaticus*	58.33	1
Orange-breasted Green Pigeon	*Treron bicincta*	58.33	1
White-throated Fantail	*Rhipidura albicollis*	58.33	1
Black Drongo	*Dicrurus macrocercus*	58.33	1
Greater Racket-tailed Drongo	*Dicrurus paradiseus*	58.33	1
Large Woodshrike	*Tephrodornis gularis*	58.33	1
Pale-chinned Flycatcher	*Cyornis poliogenys*	58.33	1
Blue-throated Flycatcher	*Cyornis rubeculoides*	58.33	1
Indian Robin	*Saxicoloides fulicata*	58.33	1
Velvet-fronted Nuthatch	*Sitta frontalis*	58.33	1
Plain Martin	*Riparia paludicola*	58.33	1
Black-crested Bulbul	*Pycnonotus melanicterus*	58.33	1
Red-whiskered Bulbul	*Pycnonotus jocosus*	58.33	1
White-browed Scimitar Babbler	*Pomatorhinus schisticeps*	58.33	1
Thick-billed Flowerpecker	*Dicaeum agile*	58.33	1
White-browed Wagtail	*Motacilla maderaspatensis*	58.33	1
Himalayan Flameback	*Dinopium shorii*	57.14	1
Greater Flameback	*Chrysocolaptes lucidus*	57.14	1
Alexandrine Parakeet	*Psittacula eupatria*	53.85	1
Collared Scops Owl	*Otus bakkamoena*	53.85	1
Black-shouldered Kite	*Elanus caeruleus*	53.85	1
Small Minivet	*Pericrocotus cinnamomeus*	53.85	1
Orange-headed Thrush	*Zoothera citrina*	53.85	1
Grey-breasted Prinia	*Prinia hodgsonii*	53.85	1
Grey-capped Pygmy Woodpecker	*Dendrocopos canicapillus*	50	1
Streak-throated Woodpecker	*Picus xanthopygaeus*	50	1
Blue-bearded Bee-eater	*Nyctyornis athertoni*	50	1
White-rumped Needletail	*Zoonavena sylvatica*	50	1
Ashy Woodswallow	*Artamus fuscus*	50	1
Common Hill Myna	*Gracula religiosa*	50	1
Purple Sunbird	*Nectarinia asiatica*	50	1
White-rumped Munia	*Lonchura striata*	50	1
Red-headed Trogon	*Harpactes erythrocephalus*	46.67	1

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Asian Koel	*Eudynamys scolopacea*	46.67	1
Lesser Coucal	*Centropus bengalensis*	46.67	1
Green-billed Malkoha	*Phaenicophaeus tristis*	46.67	1
Oriental Scops Owl	*Otus sunia*	46.67	1
Large-tailed Nightjar	*Caprimulgus macrurus*	46.67	1
Pin-tailed Green Pigeon	*Treron apicauda*	46.67	1
Oriental Honey-buzzard	*Pernis ptilorhyncus*	46.67	1
Brahminy Kite	*Haliastur indus*	46.67	1
Golden-fronted Leafbird	*Chloropsis aurifrons*	46.67	1
Red-billed Blue Magpie	*Urocissa erythrorhyncha*	46.67	1
Eurasian Golden Oriole	*Oriolus oriolus*	46.67	1
Rosy Minivet	*Pericrocotus roseus*	46.67	1
Scarlet Minivet	*Pericrocotus flammeus*	46.67	1
Lesser Racket-tailed Drongo	*Dicrurus remifer*	46.67	1
Pale Blue Flycatcher	*Cyornis unicolor*	46.67	1
Chestnut-bellied Nuthatch	*Sitta castanea*	46.67	1
Great Tit	*Parus major*	46.67	1
Red-vented Bulbul	*Pycnonotus cafer*	46.67	1
Zitting Cisticola	*Cisticola juncidis*	46.67	1
Clamorous Reed Warbler	*Acrocephalus stentoreus*	46.67	1
Common Tailorbird	*Orthotomus sutorius*	46.67	1
Crimson Sunbird	*Aethopyga siparaja*	46.67	1
Crested Bunting	*Melophus lathami*	46.67	1
Changeable Hawk Eagle	*Spizaetus cirrhatus*	43.75	1
Common Green Magpie	*Cissa chinensis*	43.75	1
Barn Swallow	*Hirundo rustica*	43.75	1
Plum-headed Parakeet	*Psittacula cyanocephala*	42.86	1
Rain Quail	*Coturnix coromandelica*	41.18	1
Speckled Piculet	*Picumnus innominatus*	41.18	1
Fulvous-breasted Woodpecker	*Dendrocopos macei*	41.18	1
Blue-throated Barbet	*Megalaima asiatica*	41.18	1
Crested Goshawk	*Accipiter trivirgatus*	41.18	1
Collared Falconet	*Microhierax caerulescens*	41.18	1
Blue Pitta	*Pitta cyanea*	41.18	1
Long-tailed Broadbill	*Psarisomus dalhousiae*	41.18	1
Bay-backed Shrike	*Lanius vittatus*	41.18	1
Rufous Treepie	*Dendrocitta vagabunda*	41.18	1
Bronzed Drongo	*Dicrurus aeneus*	41.18	1
Common Iora	*Aegithina tiphia*	41.18	1
Oriental Magpie Robin	*Copsychus saularis*	41.18	1
Spot-winged Starling	*Saroglossa spiloptera*	41.18	1
Black Francolin	*Francolinus francolinus*	38.89	1
Sirkeer Malkoha	*Phaenicophaeus leschenaultii*	38.89	1
House Swift	*Apus affinis*	38.89	1
Spot-bellied Eagle Owl	*Bubo nipalensis*	38.89	1
Asian Barred Owlet	*Glaucidium cuculoides*	38.89	1
House Crow	*Corvus splendens*	38.89	1
Black-winged Cuckooshrike	*Coracina melaschistos*	38.89	1

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Jungle Myna	***Acridotheres fuscus***	**38.89**	**1**
Oriental White-eye	***Zosterops palpebrosus***	**38.89**	**1**
Paddyfield Pipit	***Anthus rufulus***	**38.89**	**1**
White-browed Piculet	***Sasia ochracea***	**36.84**	**1**
Lesser Yellownape	***Picus chlorolophus***	**36.84**	**1**
Grey-headed Woodpecker	***Picus canus***	**36.84**	**1**
Asian Emerald Cuckoo	***Chrysococcyx maculatus***	**36.84**	**1**
Greater Coucal	***Centropus sinensis***	**36.84**	**1**
Alpine Swift	***Tachymarptis melba***	**36.84**	**1**
Crested Serpent Eagle	***Spilornis cheela***	**36.84**	**1**
Large Cuckooshrike	***Coracina macei***	**36.84**	**1**
Silver-eared Mesia	***Leiothrix argentauris***	**36.84**	**1**
House Sparrow	***Passer domesticus***	**36.84**	**1**
Indian Cuckoo	***Cuculus micropterus***	**35**	**1**
Spotted Dove	***Streptopelia chinensis***	**33.33**	**1**
Eurasian Collared Dove	***Streptopelia decaocto***	**33.33**	**1**
Lesser Fish Eagle	***Ichthyophaga humilis***	**33.33**	**1**
Bonelli's Eagle	***Hieraaetus fasciatus***	**33.33**	**1**
Booted Eagle	***Hieraaetus pennatus***	**33.33**	**1**
Mountain Hawk Eagle	***Spizaetus nipalensis***	**33.33**	**1**
Asian Paradise-flycatcher	***Terpsiphone paradisi***	**33.33**	**1**
Himalayan Bulbul	***Pycnonotus leucogenys***	**33.33**	**1**
Crested Lark	***Galerida cristata***	**33.33**	**1**
Scaly-breasted Munia	***Lonchura punctulata***	**33.33**	**1**
Laughing Dove	***Streptopelia senegalensis***	**31.82**	**1**
Wedge-tailed Green Pigeon	***Treron sphenura***	**31.82**	**1**
Egyptian Vulture	***Neophron percnopterus***	**31.82**	**1**
White-rumped Vulture	***Gyps bengalensis***	**31.82**	**1**
Red-headed Vulture	***Sarcogyps calvus***	**31.82**	**1**
Dark-sided Thrush	***Zoothera marginata***	**31.82**	**1**
Pied Cuckoo	***Clamator jacobinus***	**30.43**	**1**
Black Eagle	*Ictinaetus malayensis*	29.17	1
Eurasian Tree Sparrow	*Passer montanus*	29.17	1
Rusty-cheeked Scimitar Babbler	***Pomatorhinus erythrogenys***	**28.57**	**1**
Orange-bellied Leafbird	*Chloropsis hardwickii*	28	1
Grey Nightjar	*Caprimulgus indicus*	25.93	1
Black Kite	*Milvus migrans*	25.93	1
Long-tailed Shrike	*Lanius schach*	25.93	1
Ashy Drongo	*Dicrurus leucophaeus*	25.93	1
Common Myna	*Acridotheres tristis*	25.93	1
Kalij Pheasant	*Lophura leucomelanos*	25	1
Eurasian Griffon	*Gyps fulvus*	25	1
Maroon Oriole	*Oriolus traillii*	25	1
Rock Pigeon	*Columba livia*	23.33	1
Himalayan Swiftlet	*Collocalia brevirostris*	21.21	1
Fork-tailed Swift	*Apus pacificus*	21.21	1
Large-billed Crow	*Corvus macrorhynchos*	21.21	1
Oriental Turtle Dove	*Streptopelia orientalis*	18.92	1

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Eurasian Eagle Owl	*Bubo bubo*	17.5	1
Common Hoopoe	*Upupa epops*	17.07	1
Oriental Pied Hornbill	*Anthracoceros albirostris*	14.29	1
Pale-footed Bush Warbler	***Cettia pallidipes***	**100**	**2**
Slaty-backed Forktail	***Enicurus schistaceus***	**62.5**	**2**
Black-throated Sunbird	***Aethopyga saturata***	**62.5**	**2**
Grey Treepie	***Dendrocitta formosae***	**55.56**	**2**
Ashy Bulbul	***Hemixos flavala***	**55.56**	**2**
Streaked Spiderhunter	***Arachnothera magna***	**55.56**	**2**
White-crested Laughingthrush	***Garrulax leucolophus***	**50**	**2**
Small Niltava	***Niltava macgrigoriae***	**45.45**	**2**
Bar-winged Flycatcher-shrike	***Hemipus picatus***	**41.67**	**2**
Green Cochoa	***Cochoa viridis***	**41.67**	**2**
Rufous-chinned Laughingthrush	***Garrulax rufogularis***	**41.67**	**2**
Long-billed Pipit	***Anthus similis***	**41.67**	**2**
Asian Brown Flycatcher	***Muscicapa dauurica***	**35.71**	**2**
Black-chinned Yuhina	***Yuhina nigrimenta***	**31.25**	**2**
Common Starling	***Sturnus vulgaris***	**60**	**3**
Black-chinned Babbler	***Stachyris pyrrhops***	**60**	**3**
Eurasian Jackdaw	***Corvus monedula***	**50**	**3**
Black-lored Tit	***Parus xanthogenys***	**50**	**3**
Striated Prinia	***Prinia crinigera***	**33.33**	**3**
Blue-capped Rock Thrush	***Monticola cinclorhynchus***	**30**	**3**
Tickell's Thrush	***Turdus unicolor***	**30**	**3**
Oriental Hobby	***Falco severus***	**100**	**4**
Eurasian Jay	***Garrulus glandarius***	**85.71**	**4**
Short-billed Minivet	***Pericrocotus brevirostris***	**75**	**4**
Pied Thrush	***Zoothera wardii***	**66.67**	**4**
Grey-winged Blackbird	***Turdus boulboul***	**66.67**	**4**
Kashmir Flycatcher	***Ficedula subrubra***	**66.67**	**4**
Grey-headed Canary Flycatcher	***Culicicapa ceylonensis***	**66.67**	**4**
Rufous Sibia	***Heterophasia capistrata***	**66.67**	**4**
Chestnut-eared Bunting	***Emberiza fucata***	**66.67**	**4**
Common Stonechat	***Saxicola torquata***	**60**	**4**
Black-throated Tit	***Aegithalos concinnus***	**60**	**4**
Chestnut-crowned Warbler	***Seicercus castaniceps***	**60**	**4**
Blue-winged Minla	***Minla cyanouroptera***	**60**	**4**
Mountain Scops Owl	***Otus spilocephalus***	**54.55**	**4**
Grey-bellied Tesia	***Tesia cyaniventer***	**54.55**	**4**
Black-faced Warbler	***Abroscopus schisticeps***	**54.55**	**4**
White-throated Laughingthrush	***Garrulax albogularis***	**54.55**	**4**
Fire-breasted Flowerpecker	***Dicaeum ignipectus***	**54.55**	**4**
Green-tailed Sunbird	***Aethopyga nipalensis***	**54.55**	**4**
Ultramarine Flycatcher	***Ficedula superciliaris***	**50**	**4**
Green-backed Tit	***Parus monticolus***	**50**	**4**
White-browed Shrike Babbler	***Pteruthius flaviscapis***	**50**	**4**
Green Shrike Babbler	***Pteruthius xanthochlorus***	**50**	**4**
Black-and-yellow Grosbeak	***Mycerobas icterioides***	**50**	**4**

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Hill Partridge	*Arborophila torqueola*	46.15	4
Slaty-headed Parakeet	*Psittacula himalayana*	46.15	4
Whiskered Yuhina	*Yuhina flavicollis*	46.15	4
Rufous-bellied Niltava	*Niltava sundara*	42.86	4
Black Bulbul	*Hypsipetes leucocephalus*	42.86	4
Western Crowned Warbler	*Phylloscopus occipitalis*	42.86	4
Red-billed Leiothrix	*Leiothrix lutea*	42.86	4
Tawny Owl	*Strix aluco*	40	4
Besra	*Accipiter virgatus*	40	4
Peregrine Falcon	*Falco peregrinus*	40	4
Yellow-bellied Fantail	*Rhipidura hypoxantha*	40	4
Little Pied Flycatcher	*Ficedula westermanni*	40	4
Slaty-blue Flycatcher	*Ficedula tricolor*	40	4
Blunt-winged Warbler	*Acrocephalus concinens*	40	4
Striated Laughingthrush	*Garrulax striatus*	40	4
Mrs Gould's Sunbird	*Aethopyga gouldiae*	40	4
Yellow-breasted Greenfinch	*Carduelis spinoides*	40	4
White-capped Bunting	*Emberiza stewarti*	40	4
Cheer Pheasant	*Catreus wallichii*	37.5	4
Speckled Wood Pigeon	*Columba hodgsonii*	37.5	4
Black-headed Jay	*Garrulus lanceolatus*	37.5	4
Yellow-billed Blue Magpie	*Urocissa flavirostris*	37.5	4
Chestnut-headed Tesia	*Tesia castaneocoronata*	37.5	4
Chestnut-crowned Laughingthrush	*Garrulax erythrocephalus*	37.5	4
Spot-winged Grosbeak	*Mycerobas melanozanthos*	37.5	4
Indian Blue Robin	*Luscinia brunnea*	35.29	4
Variegated Laughingthrush	*Garrulax variegatus*	35.29	4
Russet Sparrow	*Passer rutilans*	35.29	4
Oriental Cuckoo	*Cuculus saturatus*	33.33	4
Common Swift	*Apus apus*	33.33	4
Brown Wood Owl	*Strix leptogrammica*	33.33	4
Verditer Flycatcher	*Eumyias thalassina*	33.33	4
Bar-tailed Treecreeper	*Certhia himalayana*	33.33	4
Brown-throated Treecreeper	*Certhia discolor*	33.33	4
Mountain Bulbul	*Hypsipetes mcclellandii*	33.33	4
Large-billed Leaf Warbler	*Phylloscopus magnirostris*	33.33	4
Grey-hooded Warbler	*Seicercus xanthoschistos*	33.33	4
Cutia	*Cutia nipalensis*	33.33	4
Yellow-bellied Flowerpecker	*Dicaeum melanoxanthum*	33.33	4
Upland Pipit	*Anthus sylvanus*	33.33	4
Little Forktail	*Enicurus scouleri*	31.58	4
Grey Bushchat	*Saxicola ferrea*	31.58	4
Golden-spectacled Warbler	*Seicercus burkii*	31.58	4
Streak-breasted Scimitar Babble	*Pomatorhinus ruficollis*	31.58	4
Brown-fronted Woodpecker	*Dendrocopos auriceps*	30	4
Great Barbet	*Megalaima virens*	30	4
Large Hawk Cuckoo	*Hierococcyx sparverioides*	30	4
Common Wood Pigeon	*Columba palumbus*	30	4

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Spotted Forktail	***Enicurus maculatus***	**30**	**4**
Purple Cochoa	***Cochoa purpurea***	**30**	**4**
White-tailed Nuthatch	***Sitta himalayensis***	**30**	**4**
Rufous-throated Partridge	***Arborophila rufogularis***	**28.57**	**4**
Yellow-rumped Honeyguide	***Indicator xanthonotus***	**28.57**	**4**
Lesser Cuckoo	***Cuculus poliocephalus***	**28.57**	**4**
Long-legged Buzzard	***Buteo rufinus***	**28.57**	**4**
Eurasian Hobby	***Falco subbuteo***	**28.57**	**4**
Chestnut-bellied Rock Thrush	***Monticola rufiventris***	**28.57**	**4**
Grey Wagtail	***Motacilla cinerea***	**28.57**	**4**
Scaly-bellied Woodpecker	*Picus squamatus*	27.27	4
Collared Owlet	*Glaucidium brodiei*	27.27	4
Long-tailed Minivet	***Pericrocotus ethologus***	**27.27**	**4**
Hume's Whitethroat	*Sylvia althaea*	27.27	4
Rufous-bellied Woodpecker	*Dendrocopos hyperythrus*	26.09	4
Blue Whistling Thrush	*Myophonus caeruleus*	26.09	4
Red-rumped Swallow	*Hirundo daurica*	26.09	4
Lesser Shortwing	*Brachypteryx leucophrys*	25	4
Black-throated Parrotbill	*Paradoxornis nipalensis*	25	4
Lammergeier	*Gypaetus barbatus*	23.08	4
Tibetan Siskin	*Carduelis thibetana*	23.08	4
Oriental Skylark	*Alauda gulgula*	22.22	4
Chukar	*Alectoris chukar*	21.43	4
White-throated Needletail	*Hirundapus caudacutus*	21.43	4
Nepal House Martin	*Delichon nipalensis*	20	4
Plumbeous Water Redstart	*Rhyacornis fuliginosus*	19.35	4
Blue Rock Thrush	*Monticola solitarius*	18.18	4
Eurasian Crag Martin	*Hirundo rupestris*	18.18	4
Eurasian Cuckoo	*Cuculus canorus*	17.14	4
Brown Dipper	*Cinclus pallasii*	17.14	4
Grey-cheeked Warbler	***Seicercus poliogenys***	**75**	**5**
Kashmir Nuthatch	***Sitta cashmirensis***	**66.67**	**5**
Grey-crested Tit	***Parus dichrous***	**66.67**	**5**
Yellowish-bellied Bush Warbler	***Cettia acanthizoides***	**66.67**	**5**
Streaked Laughingthrush	***Garrulax lineatus***	**66.67**	**5**
Spectacled Finch	***Callacanthis burtoni***	**66.67**	**5**
Brown Bullfinch	***Pyrrhula nipalensis***	**66.67**	**5**
Red-headed Bullfinch	***Pyrrhula erythrocephala***	**66.67**	**5**
Osprey	***Pandion haliaetus***	**60**	**5**
Spotted Nutcracker	***Nucifraga caryocatactes***	**60**	**5**
Long-billed Thrush	***Zoothera monticola***	**60**	**5**
Scarlet Finch	***Haematospiza sipahi***	**60**	**5**
Common Quail	***Coturnix coturnix***	**54.55**	**5**
Himalayan Woodpecker	***Dendrocopos himalayensis***	**54.55**	**5**
White-collared Blackbird	***Turdus albocinctus***	**54.55**	**5**
Snowy-browed Flycatcher	***Ficedula hyperythra***	**54.55**	**5**
Rufous-vented Tit	***Parus rubidiventris***	**54.55**	**5**
Goldcrest	***Regulus regulus***	**54.55**	**5**

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Western Tragopan	***Tragopan melanocephalus***	**50**	**5**
Koklass Pheasant	***Pucrasia macrolopha***	**50**	**5**
Mistle Thrush	***Turdus viscivorus***	**50**	**5**
Dark-sided Flycatcher	***Muscicapa sibirica***	**50**	**5**
White-cheeked Nuthatch	***Sitta leucopsis***	**50**	**5**
Rufous-naped Tit	***Parus rufonuchalis***	**50**	**5**
White-throated Tit	***Aegithalos niveogularis***	**50**	**5**
Aberrant Bush Warbler	***Cettia flavolivacea***	**50**	**5**
Long-billed Bush Warbler	***Bradypterus major***	**50**	**5**
Tytler's Leaf Warbler	***Phylloscopus tytleri***	**50**	**5**
Scaly-breasted Wren Babbler	***Pnoepyga albiventer***	**50**	**5**
Ashy-throated Warbler	***Phylloscopus maculipennis***	**46.3**	**5**
White-browed Shortwing	***Brachypteryx montana***	**46.15**	**5**
Rufous-gorgeted Flycatcher	***Ficedula strophiata***	**46.15**	**5**
Spot-winged Tit	***Parus melanolophus***	**46.15**	**5**
Brownish-flanked Bush Warbler	***Cettia fortipes***	**46.15**	**5**
Stripe-throated Yuhina	***Yuhina gularis***	**46.15**	**5**
Scaly Thrush	***Zoothera dauma***	**40**	**5**
Chestnut Thrush	***Turdus rubrocanus***	**40**	**5**
Rusty-tailed Flycatcher	***Muscicapa ruficauda***	**40**	**5**
Blue-capped Redstart	***Phoenicurus coeruleocephalus***	**40**	**5**
White-bellied Redstart	***Hodgsonius phaenicuroides***	**40**	**5**
Winter Wren	***Troglodytes troglodytes***	**40**	**5**
Fire-capped Tit	***Cephalopyrus flammiceps***	**40**	**5**
Yellow-browed Tit	***Sylviparus modestus***	**40**	**5**
Chestnut-tailed Minla	***Minla strigula***	**40**	**5**
European Goldfinch	***Carduelis carduelis***	**40**	**5**
Spotted Laughingthrush	***Garrulax ocellatus***	**37.5**	**5**
Blyth's Leaf Warbler	***Phylloscopus reguloides***	**35.29**	**5**
Eurasian Sparrowhawk	***Accipiter nisus***	**33.33**	**5**
Grey-backed Shrike	***Lanius tephronotus***	**33.33**	**5**
Fire-fronted Serin	***Serinus pusillus***	**31.58**	**5**
Long-tailed Thrush	***Zoothera dixoni***	**28.57**	**5**
Rock Bunting	*Emberiza cia*	27.27	5
Eurasian Treecreeper	*Certhia familiaris*	25	5
White-browed Fulvetta	*Alcippe vinipectus*	25	5
Collared Grosbeak	*Mycerobas affinis*	25	5
Black-billed Magpie	*Pica pica*	24	5
Golden Bush Robin	***Tarsiger chrysaeus***	**100**	**6**
Grey-sided Bush Warbler	***Cettia brunnifrons***	**85.71**	**6**
Carrion Crow	***Corvus corone***	**66.67**	**6**
White-browed Tit Warbler	***Leptopoecile sophiae***	**66.67**	**6**
Mongolian Finch	***Bucanetes mongolicus***	**66.67**	**6**
Orange Bullfinch	***Pyrrhula aurantiaca***	**66.67**	**6**
Spotted Bush Warbler	***Bradypterus thoracicus***	**60**	**6**
Fire-tailed Sunbird	***Aethopyga ignicauda***	**60**	**6**
Pink-browed Rosefinch	***Carpodacus rodochrous***	**60**	**6**
Spot-winged Rosefinch	***Carpodacus rodopeplus***	**60**	**6**

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Great Parrotbill	***Conostoma oemodium***	**54.55**	**6**
Bluethroat	***Luscinia svecica***	**50**	**6**
White-browed Bush Robin	***Tarsiger indicus***	**50**	**6**
Rusty-flanked Treecreeper	***Certhia nipalensis***	**50**	**6**
Dark-breasted Rosefinch	***Carpodacus nipalensis***	**50**	**6**
White-browed Rosefinch	***Carpodacus thura***	**50**	**6**
White-winged Grosbeak	***Mycerobas carnipes***	**50**	**6**
Satyr Tragopan	***Tragopan satyra***	**46.15**	**6**
Lemon-rumped Warbler	***Phylloscopus chloronotus***	**46.15**	**6**
Olive-backed Pipit	***Anthus hodgsoni***	**46.15**	**6**
Rufous-breasted Accentor	***Prunella strophiata***	**46.15**	**6**
Red Crossbill	***Loxia curvirostra***	**46.15**	**6**
Cinereous Vulture	***Aegypius monachus***	**40**	**6**
Red-billed Chough	***Pyrrhocorax pyrrhocorax***	**40**	**6**
Northern House Martin	***Delichon urbica***	**40**	**6**
Buff-barred Warbler	***Phylloscopus pulcher***	**40**	**6**
Tree Pipit	***Anthus trivialis***	**40**	**6**
Plain-backed Thrush	***Zoothera mollissima***	**37.5**	**6**
Greenish Warbler	***Phylloscopus trochiloides***	**37.5**	**6**
Orange-flanked Bush Robin	***Tarsiger cyanurus***	**35.29**	**6**
Blue-fronted Redstart	***Phoenicurus frontalis***	**33.33**	**6**
Hume's Warbler	***Phylloscopus humei***	**33.33**	**6**
Gold-naped Finch	*Pyrrhoplectes epauletta*	33.33	6
Mountain Chiffchaff	***Phylloscopus sindianus***	**31.58**	**6**
Chestnut-crowned Bush Warbler	*Cettia major*	21.43	6
Tibetan Partridge	***Perdix hodgsoniae***	**100**	**7**
White-winged Redstart	***Phoenicurus erythrogaster***	**100**	**7**
Alpine Accentor	***Prunella collaris***	**100**	**7**
Robin Accentor	***Prunella rubeculoides***	**100**	**7**
Twite	***Carduelis flavirostris***	**100**	**7**
Yellow-billed Chough	***Pyrrhocorax graculus***	**93.33**	**7**
Streaked Rosefinch	***Carpodacus rubicilloides***	**92.86**	**7**
Tibetan Snowfinch	***Montifringilla adamsi***	**85.71**	**7**
Tibetan Snowcock	***Tetraogallus tibetanus***	**82.35**	**7**
Wallcreeper	***Tichodroma muraria***	**82.35**	**7**
Horned Lark	***Eremophila alpestris***	**82.35**	**7**
Brown Accentor	***Prunella fulvescens***	**82.35**	**7**
Plain Mountain Finch	***Leucosticte nemoricola***	**82.35**	**7**
Grandala	***Grandala coelicolor***	**78.57**	**7**
Brandt's Mountain Finch	***Leucosticte brandti***	**78.57**	**7**
Beautiful Rosefinch	***Carpodacus pulcherrimus***	**78.57**	**7**
Red-fronted Rosefinch	***Carpodacus puniceus***	**78.57**	**7**
Snow Partridge	***Lerwa lerwa***	**71.43**	**7**
Himalayan Snowcock	***Tetraogallus himalayensis***	**71.43**	**7**
Common Raven	***Corvus corax***	**71.43**	**7**
Little Owl	***Athene noctua***	**70**	**7**
Hill Pigeon	***Columba rupestris***	**70**	**7**
Snow Pigeon	***Columba leuconota***	**70**	**7**

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Citrine Wagtail	***Motacilla citreola***	**70**	**7**
Tickell's Leaf Warbler	***Phylloscopus affinis***	**68.57**	**7**
Great Rosefinch	***Carpodacus rubicilla***	**68.57**	**7**
Yellow Wagtail	***Motacilla flava***	**64.29**	**7**
Tibetan Sandgrouse	***Syrrhaptes tibetanus***	**57.14**	**7**
Hume's Groundpecker	***Pseudopodoces humilis***	**57.14**	**7**
White-throated Dipper	***Cinclus cinclus***	**57.14**	**7**
Black Redstart	***Phoenicurus ochruros***	**53.85**	**7**
Sulphur-bellied Warbler	***Phylloscopus griseolus***	**53.85**	**7**
White-tailed Rubythroat	***Luscinia pectoralis***	**48.98**	**7**
Eurasian Blackbird	***Turdus merula***	**48.21**	**7**
Hume's Short-toed Lark	***Calandrella acutirostris***	**46.67**	**7**
Himalayan Monal	***Lophophorus impejanus***	**46.43**	**7**
White Wagtail	***Motacilla alba***	**40**	**7**
Tibetan Lark	***Melanocorypha maxima***	**35.71**	**7**
White-capped Water Redstart	*Chaimarrornis leucocephalus*	34.29	7
Asian House Martin	*Delichon dasypus*	34.29	7
Northern Goshawk	*Accipiter gentilis*	33.53	7
Himalayan Griffon	*Gyps himalayensis*	31.82	7
Gould's Shortwing	*Brachypteryx stellata*	28.57	7
Rosy Pipit	*Anthus roseatus*	28.57	7
Golden Eagle	*Aquila chrysaetos*	24.63	7
Common Rosefinch	*Carpodacus erythrinus*	21.43	7
Red-mantled Rosefinch	*Carpodacus rhodochlamys*	19.05	7
White-rumped Snowfinch	*Pyrgilauda taczanowskii*	14.29	7
Plain-backed Snowfinch	*Pyrgilauda blanfordi*	14.29	7

Bird composition groups in Western Himalaya

1. Foothills (400-1000m), 2. Subtropical (1000-1500 m), 3. Subtropical - Temperate transition (1500-1800 m), 4. Lower temperate (1800- 2400 m), 5.Upper Temperate (2400-3000 m), 6. Sublapine and Alpine (3000- 3600 m), 7. High Himalayan (3600-5000 m)

APPENDIX- 2

Bird species and Indicator values in composition groups in Kedarnath

(species significant at p=0.05 are in bold)

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Black-faced Warbler	***Abroscopus schisticeps***	**100**	**1**
Black-throated Tit	***Aegithalos concinnus***	**100**	**1**
Grey-headed Woodpecker	***Picus canus***	**96.75**	**1**
Whiskered Yuhina	***Yuhina flavicollis***	**96.3**	**1**
Indian Cuckoo	***Cuculus micropterus***	**94.9**	**1**
Great Barbet	***Megalaima virens***	**94.89**	**1**
Rufous-bellied Niltava	***Niltava sundara***	**94.46**	**1**
White-throated Laughingthrush	***Garrulax albogularis***	**87.69**	**1**
Snowy-browed Flycatcher	***Ficedula hyperythra***	**83.97**	**1**
Grey-headed Canary Flycatcher	***Culicicapa ceylonensis***	**82.67**	**1**
Striated Laughingthrush	***Garrulax striatus***	**82.01**	**1**
Maroon Oriole	***Oriolus traillii***	**81.13**	**1**
Ultramarine Flycatcher	***Ficedula superciliaris***	**80.88**	**1**
Green-backed Tit	***Parus monticolus***	**80.57**	**1**
Grey-hooded Warbler	***Seicercus xanthoschistos***	**78.22**	**1**
Eurasian Cuckoo	*Cuculus canorus*	75	1
Kalij Pheasant	*Lophura leucomelanos*	75	1
Rufous Sibia	***Heterophasia capistrata***	**67.46**	**1**
Oriental Cuckoo	*Cuculus saturatus*	63.82	1
Hill Partridge	***Arborophila torqueola***	**63.66**	**1**
Large Hawk Cuckoo	*Hierococcyx sparverioides*	63.54	1
Mrs Gould's Sunbird	*Aethopyga gouldiae*	50	1
Grey-winged Blackbird	*Turdus boulboul*	50	1
Rufous-bellied Woodpecker	*Dendrocopos hyperythrus*	48.45	1
Eurasian Jay	*Garrulus glandarius*	47.77	1
Fire-breasted Flowerpecker	*Dicaeum ignipectus*	43.88	1
Yellow-billed Blue Magpie	*Urocissa flavirostris*	42.2	1
Wedge-tailed Green Pigeon	*Treron sphenura*	41.93	1
Oriental Turtle Dove	*Streptopelia orientalis*	38.3	1
Black Bulbul	*Hypsipetes leucocephalus*	25	1
Lesser Racket-tailed Drongo	*Dicrurus remifer*	25	1
White-browed Shrike Babbler	*Pteruthius flaviscapis*	25	1
Spotted Forktail	*Enicurus maculatus*	25	1
Grey-bellied Tesia	*Tesia cyaniventer*	25	1
Grey Treepie	*Dendrocitta formosae*	25	1
Tickell's Thrush	*Turdus unicolor*	25	1
Verditer Flycatcher	*Eumyias thalassina*	25	1
Black-lored Tit	*Parus xanthogenys*	25	1
Collared Owlet	*Glaucidium brodiei*	18.14	1

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Chestnut-headed Tesia	***Tesia castaneocoronata***	**94.41**	**2**
Spot-winged Tit	***Parus melanolophus***	**83.39**	**2**
Golden-spectacled Warbler	***Seicercus burkii***	**82.11**	**2**
Himalayan Woodpecker	***Dendrocopos himalayensis***	**80.28**	**2**
White-collared Blackbird	***Turdus albocinctus***	**80**	**2**
Blyth's Leaf Warbler	*Phylloscopus reguloides*	75	2
Chestnut-crowned Laughingthrush	***Garrulax erythrocephalus***	**74.72**	**2**
Ashy-throated Warbler	***Phylloscopus maculipennis***	**71.98**	**2**
Long-tailed Minivet	*Pericrocotus ethologus*	69.56	2
White-browed Fulvetta	*Alcippe vinipectus*	60	2
Black-and-yellow Grosbeak	*Mycerobas icterioides*	55.67	2
Lemon-rumped Warbler	*Phylloscopus chloronotus*	54.52	2
Grey-crested Tit	*Parus dichrous*	54.51	2
White-tailed Nuthatch	*Sitta himalayensis*	46.56	2
Lesser Cuckoo	*Cuculus poliocephalus*	40	2
Yellow-breasted Greenfinch	*Carduelis spinoides*	36.49	2
Indian Blue Robin	*Luscinia brunnea*	36.35	2
Western Crowned Warbler	*Phylloscopus occipitalis*	31.41	2
Spotted Laughingthrush	*Garrulax ocellatus*	30.19	2
Green-tailed Sunbird	*Aethopyga nipalensis*	29.48	2
Ashy Drongo	*Dicrurus leucophaeus*	28.93	2
Yellow-bellied Fantail	*Rhipidura hypoxantha*	28.6	2
Eurasian Treecreeper	*Certhia familiaris*	24.32	2
Accipiter sp	*Accipiter sp*	20	2
Yellowish-bellied Bush Warbler	*Cettia acanthizoides*	20	2
Black-throated Parrotbill	*Paradoxornis nipalensis*	20	2
Scarlet Finch	*Haematospiza sipahi*	20	2
Slaty-headed Parakeet	*Psittacula himalayana*	12.9	2
Golden Bush Robin	***Tarsiger chrysaeus***	**100**	**3**
Goldcrest	***Regulus regulus***	**100**	**3**
Buff-barred Warbler	***Phylloscopus pulcher***	**97.75**	**3**
Hume's Warbler	***Phylloscopus humei***	**94.6**	**3**
Bar-tailed Treecreeper	***Certhia himalayana***	**89.82**	**3**
Rufous-vented Tit	***Parus rubidiventris***	**82.86**	**3**
Variegated Laughingthrush	***Garrulax variegatus***	**76.99**	**3**
Chestnut-tailed Minla	*Minla strigula*	76.94	3
Dark-breasted Rosefinch	***Carpodacus nipalensis***	**74.08**	**3**
Stripe-throated Yuhina	***Yuhina gularis***	**72.81**	**3**
Koklass Pheasant	*Pucrasia macrolopha*	65.46	3
Blue Whistling Thrush	*Myophonus caeruleus*	51.44	3
Black Redstart	*Phoenicurus ochruros*	50	3
Scaly-bellied Woodpecker	*Picus squamatus*	50	3
Dark-sided Flycatcher	*Muscicapa sibirica*	50	3
Spot-winged Rosefinch	*Carpodacus rodopeplus*	50	3

COMMON NAME	SCIENTIFIC NAME	IV	GROUP
Plain-backed Thrush	*Zoothera mollissima*	50	3
Orange-flanked Bush Robin	*Tarsiger cyanurus*	48.87	3
Himalayan Monal	*Lophophorus impejanus*	47.96	3
Great Parrotbill	*Conostoma oemodium*	46.92	3
Large-billed Crow	*Corvus macrorhynchos*	39.27	3
Rufous-gorgeted Flycatcher	*Ficedula strophiata*	39.26	3
Mistle Thrush	*Turdus viscivorus*	38.34	3
Aberrant Bush Warbler	*Cettia flavolivacea*	32.3	3
Spotted Bush Warbler	***Bradypterus thoracicus***	**100**	**4**
Rosy Pipit	***Anthus roseatus***	**100**	**4**
Grey-sided Bush Warbler	*Cettia brunnifrons*	60.15	4
Blue-fronted Redstart	*Phoenicurus frontalis*	50	4
Eurasian Hobby	*Falco subbuteo*	50	4
Rufous-breasted Accentor	*Prunella strophiata*	50	4
Red-billed Chough	*Pyrrhocorax pyrrhocorax*	27.39	4
Scaly-breasted Wren Babbler	*Pnoepyga albiventer*	23.17	4

Bird composition groups in Kedarnath
1. Temperate Deciduous forests, 2. Upper Temperate forests,
3. Sublapine forests 4. Alpine meadows