EXECUTIVE SUMMARY

Biodiversity loss and climate change are two of the greatest global environment challenges we face this century (Tilken et al. 2002). There is in general, bird, mammal and herpetofauna decline around the world. Hughes et al. (1997) argued that there are about 220 genetically distinct populations for each extinct species.

Knopf (1992) asserted that the definitions of biodiversity are “as diverse as the biological resources.” Definitions of biodiversity range in scope from “number of different species occurring in some locations...” (Schwarz et al. 1976) to “... all of the diversity and variability in nature” (Spellerberg and Hardes 1992) and “.... the variety of life and its processes (Delong 1996).

Biological diversity is being viewed as the potential resource capital of a state or region that possesses it. Preserving and protecting it requires clear knowledge and understanding of what we have and where they exists (Ganeshaiah and Shankar 2003). India is one of the 12 mega-diversity centres of the world. Rajmani (1998) believes that though not ‘hot spots’, there are a number of ‘warm spots’ that need attention. Indian harbours an estimated 500,000 out of 10 to 30 million species of living organisms. However, increasing human intervention and excessive exploitation of resources have resulted in great changes and provide alarming signals of accelerated biodiversity loss (Roy and Tomar 2000). Himalayas which covers 6.4% of the area constitute a significant unit for the conservation of biodiversity. It harbours a great diversity of flora and fauna distributed in variety of topographic types and climatic conditions (Rodgers et al. 2000). The forest ecosystem in Uttarakanchal (now Uttarakhand), which is part of western Himalayanas, shares the biological richness of the Himalayas.

Rationale

People and their environment are interdependent. Any change in the surrounding environment directly affects the people therein. Any effort of development should therefore improve the environment they live in. For preserving the ecological balance between natural resource development and conservation, the concept of watershed is assumed to be very important land unit, particularly in fragile and heterogeneous hilly ecosystem (Sharma et al. 1992). To ensure sustainable development a strong database is
required that shall lead to conservation and regeneration of all the resources – natural (land, water, plant and wildlife) and human within a watershed. Fauna along with flora is considered an important aspect of the creation of such a database. Being essential component in the forest ecosystem, fauna plays crucial role in ecosystem functioning and its dynamics.

Fauna acts as an indicator of the health of the ecosystem. Understanding the spatial distribution of biodiversity is the foremost prerequisite for the meaningful conservation of natural ecosystems. The construction of biodiversity maps reflecting the spatial distribution would serve several purposes such as locating the hot spots or warm spots of diversity, assigning conservation values for different areas. Since such maps are rare there is therefore critical need to map the diversity pattern of fauna in India (Ganesiaiah and Shanker 2003). Though Uttarakhand Himalayas are well studied, yet such crucial information is lacking on the ecology of diversity.

The main objectives of the study were

Objectives:

1: To assess population and community attributes of birds and mammals in Phakot and Pathri Rao Watershed Areas.

2: To carry out intensive ecological studies on large mammalian community in Phakot and Pathri Rao Watershed Areas.

3: To carry out intensive ecological studies on avian community structure in Phakot and Pathri Rao Watershed Areas.

4: To carry out intensive ecological studies on herpetofauna, in Phakot and Pathri Rao Watershed Areas.

5: To develop Habitat Suitable Index models of key faunal species using Geographical Information System (GIS) Techniques.

The field data for this study was collected from 2005 to 2007.
The present study was carried in Pathri Rao Watershed Area (PRWA) and Phakot Watershed Areas (PWA). PRWA is located between 77° 57' 07" to 78° 23' 36" East and 29° 51' 7" to 30° 15' 50" North in the Haridwar district of Uttaranchal state. The Watershed area comprises of 25 sq km inside Rajaji National Park and 19 sq km outside the protected area, which included agriculture field, habitations and plantations. Topographically it consists mainly of Shivalik Hills. The area witnesses three season, winter, summer and monsoon. Maximum of forest is covered with mixed dry deciduous type represented by *Dalbergia sisoo*, *Accacia*, Sagoon sp etc. Hills are occupied by *Shorea robusta*, and *Pinus roxburghii*. *Mangifera indica*, *Eucalyptus* sp dominate the plantation in agricultural field. PWA lies between 78° 19' 53" to 78° 22' 16" East and 30° 14' 29" to 30° 13' 17" North in the Tehri Garhwal District. It forms part of Saklana Range in the middle Himalayas. With an area of about 40 sq km, it is, represented by Oak, Sal and large patches of agriculture and fallow land.

The sampling was carried for mammals, birds, reptiles and amphibians. Direct and Indirect methods were employed for mammalian population. The direct method utilized Trail count. Trails were walked twice a week. Data was collected about species, their number, age and sex. Circular plots of radius 10 meters were established in order to collect indirect evidence. The plots were laid in proportion to the land use/land cover unit. Pellet groups, scats, pugmarks, hoof marks and dung piles were quantified as indirect evidence. Pellets partially or completely disintegrated were not included in the sample to avoid error.

Bird communities were sampled using the Point Count Method (Reynolds et al. 1980). Point count was carried in a stratified random fashion in each Land use/Land cover unit. A distance of 250 meters was kept between two points in order to maintain independence. Species Richness Counting Method was used in extensive survey. A list of 15 different species along with time taken to complete the lists was recorded.

Reptiles were sampled using the “Adaptive Cluster Sampling” (Ishwar et al. 2001). 5m X 5m quadrates were laid in different Land use/Land cover units. If animal was sighted in one of these quadrates (primary), additional quadrates (secondary) were searched, leaving a gap of 1 meter. Two observers searched simultaneously from opposite direction.
The amphibians were sampled using a combination of cluster sampling, visual encounter, audio surveys and opportunistic records. The adaptive sampling was done along stream on the forest floor. Quadrates of 5m X 1000 m along the stream and 5m X 5m on the forest floor were established. Loose rocks, and leaf litter was carefully turned and cavities were prodded for amphibian species.

One way ANOVA was performed to know mean group density of different species. Encounter rate was calculated for the mammalian direct data to find density of each species. Diversity of birds, mammals, reptiles and amphibians were carried using SPECDIVERS program, a modified module of STATISTICAL ECOLOGY. Shannon – Weiner Index (H) for diversity and Margalef's index (RI) was calculated for richness of species. Principal Component Analysis (PCA) was used to understand habitat use distribution of species in the study area. GIS based Habitat Suitability Index models were generated for key animal species.

Since two watersheds are located in different bio-geographic settings two methods using Point Count and Species Listing Method were used. A total of 125 points were established in PRWA and 110 in PWA. Each point was monitored at least once in a season. PRWA was sampled in summer and winter, PWA visit included monsoon in addition to summer, and winter. Overall 98 species from PWA and 106 from PRWA were reported. Chao 1 overestimated species number for PWA where as all four estimators were within 95% confidence limits for PRWA. In terms of bird diversity PRWA was more diverse as compared to PWA. Bird density was highest in PWA (30.48 ± 1.77) than in PRWA (16.82 ± 1.60). Bird density varied significantly across different seasons (F_2,6 = 14.87, P = 0.0005) but not across different habitats (F_6,12 = 1.21, P = 0.36) in PWA where as in PRWA no significant difference was found across seasons (F_1,6 = 0.57, P = 0.47) and across different habitat types (F_6,6 = 1.90, P = 0.22). Bird density, diversity and richness showed U type pattern in PWA where as in PRWA it showed steep decline along the altitudinal gradient. Based on guild structure Phakot bird community was more complex as compared to PRWA watershed area because of variation in altitude and complex vegetation structure.
Studies on population structure, habitat use and conservation problems of three sympatric ungulate species namely muntjac (*Muntiacus muntjak*), goral (*Nemorhaedus goral*) and sambar (*Cervus unicolor*) were carried in PWA. The average group size of goral and muntjac was 1.61 ± 0.15 and 1.73 ± 0.18 respectively. Mean group size was higher in winter followed by summer and monsoon. Sex ratio in all three species was female biased. Encounter rate of goral and muntjac was 0.336/km and 0.300/km respectively. The encounter rate between seasons was not significantly different. The mean pellet group density of muntjac differed significantly between seasons (F = 9.059 P<0.003), however, no such significant seasonal difference was found in mean pellet group densities of goral (F = 0.312 P=0.577) and sambar (F=0.432 P=0.432). The mean pellet densities differed significantly between different habitats for muntjac (F=2.7 P=0.001), goral (F=1.7 P=0.001) and sambar (F=1.5 P=0.001). All the three species showed positive correlation with altitude and the three species overlapped maximum in Oak forest above 1600 m. Limitations of water and habitat destruction are the key issues for the conservation of the ungulates in the study area.

In PRWA, Mean group size was highest fir chital (7.70 ±1.79), followed by nilgai (5.44 ± 0.91). Muntjac was more solitary. Except goral, mean group size of other ungulates was higher in summer than winter. There was significant difference in mean group size in two seasons in chital (F = 5.58 P< 0.02) and nilgai (F = 7.76 P<0.008).

Habitat use pattern of four sympatric ungulate species namely sambar (*Cervus unicolor*), chital (*Cervus axis*), Nilgai (*Boselaphus tragocamelus*) and goral (*Naemorhedus goral*) were studied in PRWA. Chital had the highest mean group size (7.70 ±1.793), followed by nilgai (5.44 ± 0.916), goral (3.20 ± 0.816) and sambar (1.52 ± 0.193). Chital used all the available habitat types and the difference was significant (F=3.35 P<0.04), where as goral only used three habitat types with highly significant differences (4.499 P<0.00) showing highest preference for deciduous forest (D). Similarly sambar also showed significant (F=10.17 P<0.00) differences in the use of different habitats and nilgai preferred flat areas. Discriminant Function Analysis indicated clear segregation of the four sympatric ungulate species along the three discriminant functions with total isolation between nilgai and goral along DF1. Niche overlap analysis predicted segregation of habitat use by sympatric
species along one or other niche axis which governs continued existence of the sympatric species in the study area.

During study 10 species of reptiles were recorded in PWA and 12 in PRWA. Similarly 4 species of amphibians were recorded in PWA and 9 species in PRWA. In total 16 species of reptiles were recorded and 9 species of amphibians. Forest floor density of reptiles in PWA was 46.26/ha and that of PRWA was 86.9/ha. Reptilian diversity of PRWA and PWA was 0.825 and 0.692 respectively. Richness of PRWA (2.378) was more than PWA (1.792). Density of amphibians in PWA was 15.667/ha, diversity and richness was 0.476 and 0.776 respectively. Amphibian density in PRWA was 22.6/ha. Diversity and richness values were 0.574 and 1.291 respectively. Comparison showed PRWA to be more rich and diverse than PWA because of undisturbed habitat, broad and slow stream and more forest litter.

Habitat Suitability Model was developed only for PRWA only. It was not done in PWA due to non availability of contour maps. The habitat suitability for four sympatric ungulate species namely Sambar (Cervus unicolor), Nilgai (Boselaphus tragocamelus), Chital (Axis axis) and Goral (Nemorhaedus goral) in PRWA Area using geo-statistical analysis and geo-spatial tools. All the four sympatric ungulate species showed temporal isolation to exploit the resources on ecological niche axis. A total of 25.74%, 37.94%, 18.80% and 37.07% of habitat were found highly-suitable to suitable for sambar, nilgai, chital and goral respectively. Niche overlap analysis and seasonal occupancy data was used to cross-tabulate the absolute habitat occupancy by the animals. The habitat suitability information was found to be 89.73%, 74.21%, 78.63% and 96.43% accurate for sambar, nilgai, chital and goral respectively.

Executive Summary