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TECHNIQUES AND STRATEGIES

Designing of nature reserve to conserve biodiversity in mountains: A case study from Central Himalaya

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Abstract. This study emphasizes representation of habitats and diversity patterns in habitats of a protected area in the Central Himalaya. This protected area is one of the oldest Reserve Forest in the region and upgraded to the status of Wildlife Sanctuary in 1988. The wildlife sanctuary is exclusively dominated by forest landscape and few private estates. Along an altitudinal gradient six forest types were recognized. Pine (*Pinus roxburghii*) forest were preponderant in the sanctuary covering about 52% of the total area. Total tree biomass was increased with increase in elevation, and was related to the diversity. The protected area covers a number of representative types of the forest communities occuring in mid-mountain region of the Central Himalaya, and are habitats of wildlife which includes rare and endangered species. *Pinus roxburghii* and *Quercus* spp. were identified as keystone species. Altitude and area occupied by a dominant canopy community type within an altitudinal zone, and overlaping zone of vegetation along elevational gradient were identified as determining factor for designing nature reserves in mountains, particularly with sparsely distributed human population and reducing forest cover on a large landscape.
Key-words: Habitat, Sanctuary, Nature reserve, Himalaya

Introduction

Major goal of nature conservation is representation of ecosystems and species in protected areas (Nilsson & Gotmark, 1992). Due to different prominent features (topography, altitude, climate, etc.) the Central Himalayan region supports a rich habitat diversity. A prerequisite for preserving biological diversity in a given biological domain is to identify a reserve network which includes every possible species (Margules *et al.*, 1988). In recent years considerable interest has been shown to evaluate Nature reserves, National parks, and Protected areas for their conservation value (Huntley 1989; Runte 1987; Nilsson and Gotmark 1992; Margules *et al.*, 1988; Siegfried 1989). In the present study, an assessment has been made on representativeness of habitats and diversity patterns in a protected landscape of a Wildlife Sanctuary in the Central Himalaya. The objectives of this study were to identify the important factors in designing of nature reserves, and niche identification of wildlife in relation to vegetation which can help in the planning of conservation areas of the mountains. Apart, holding the conservation value, identification of key factors in designing and planning of nature reserve becomes important for a landscape with sparsely distributed human settlements and reducing forest cover, as in fragile ecosystem of Himalaya.

Case Study Area and Legal Status

The study area, Binsar Wildlife Sanctuary, lies between 29° 39'- 29° 44' N and 79° 41'- 79° 49' E in Almora district of Kumaun region of the Central Himalaya. During pre-independence era (before 1947) the study area was notified as "Protected Forest" in 1893 and was upgraded as "Reserve Forest" in 1897. This landscape holds one of the oldest Reserve Forest of the Kumaun region. Maintenance of forest resources is similar basic concept behind the Protected and Reserve categories but level of exploitation demarcates difference between these two types. In a Reserve Forest the activities of grazing, produce collection etc., are less and wildlife is not affected severely, however, in Protected Forest the local pressures are high. After independence the studied "Reserve Forest" got the status of Wildlife Sanctuary in 1988. In a wildlife sanctuary conservation values holds priority over the utilization of resources, and the exploitation activities can be made only if those are not affecting the conservation objectives. The geographical area of sanctuary is 45.59 km^2. The altitude varies between 1,300m and 2,500m with gentle slopes between 2,200m and 2,400m. Steepness of slopes increased along the streams. Mean monthly temperature ranged from 2.2 to 15.5° C during winter and from 17.2 to 26.6° C during summer. The average annual rainfall is about 1,200 mm.

Materials and Methods

Austin and Margules (1986) were followed for assessing representativeness with respect to land classification of ecological units; properties of the units; area of units; evaluation of representativeness of area. To assess the ecological units, vegetation analysis was undertaken in all accessible areas along the altitudinal gradient by using randomly distributed quadrats (Misra 1968). The field sampling and quadrat size was worked out following Saxena and Singh (1982). The data obtained were calculated for density, frequency, abundance, and basal area. Distribution of species within the sample sites was noted as abundance/ frequency ratio. Importance value index (IVI) is sum of relative density, relative frequency, and relative basal area. Diversity, Similarity index and Polar Ordination were made following Shannon and Wiever (1963), Sorenson (1948) and Bray and Curtis (1957), respectively. Landscape diversity was calculated as Beta diversity (Whittaker 1975). Biomass was estimated following Rana *et al.*, (1989). The compartmental (a small unit of forest area with defined boundaries for forest administration and records of State Forest Department) map and history were obtained from State Forest Department. On the basis of area covered by tree species the dominant species were identified in each compartment. To produce map of different forest types, compartments with similar dominant species and adjacent boundaries were pooled for a type.

Results

Representation of Habitats on Landscape

The protected area should contain biota which represents the range of variation present within the some landclass or a region. Thus, the identification of landclass is the central problem in clarifying the idea of representativeness (Austin and Margules 1986). The protected area, Binsar Wildlife Sanctuary, is exclusively dominated by forest landscape. However, several annual and perennial streams are present, but the area occupied by streams was not sufficient to represent a water ecosystem on the landscape of sanctuary. By the legal status of sanctuary it is apparent that the protected area represents a relatively less disturbed ecosystem of the Central Himalaya where due to the destruction of forests habitat for wild life is shrinking. A number of wild life species has become rare in the Central Himalayan region and some of them are endangered (Singh *et al.*, 1984). Forest, a major habitat of wildlife, is well represented in the sanctuary area. The forests are evergreen type with few deciduous tree species (Table 1). Few Private Estates are also present within the boundary of sanctuary area.

Land classification and Properties

Forest types: The numerical representation of vegetation offers advantages to describe attributes of a community and combine with other informations. On the basis of IVI (Importance Value Index), of Large Size Trees (more than 30 cm CBH) six forest communities were recognized within sanctuary area. Representation of forest stands (based on IVI) in a two dimensional ordination showed their arrangement along an altitudinal gradient (Fig.1), running diagonally across the ordination field from lower to higher elevation (low X and Y values). These forests were 1). *Pinus roxburghii*; 2). *P. roxburghii - Quercus leucotrichophora*; 3). *Q.leucotrichophora- P. roxburghii*; 4). *Q. leucotrichophora*; 5). *Q. floribunda*; and 6). *Cedrus deodra*. Tree species composition and IVI of each species is given in Table 2. Within an altitudinal zone heterogeneity in spatial distribution was observed because of the microclimatic variations (slope aspect), and the species composition differed on different aspects of the same elevation. The community pattern in the sanctuary area, along the altitudinal gradient, was similar to as described in earlier studies of other parts of Central Himalaya (Saxena and Singh 1982; Tewari and Singh 1985; Singh and Singh, 1987; Tewari *et al.*, 1989). Except *Cedrus deodara*, which is confined to a small area, other forests are well represented in the sanctuary area (Fig. 2). The tree layer comparison of different forest types on the basis of similarity coefficient (Table 3) indicated that with an increase in elevation. The low degree of similarity of *Q. leucotrichophora* forest with the forest of lower elevations (*P. roxburghii*, and mixed types), and higher degree of similarity with *Q. floribunda* forest also indicates that species composition from lower to higher elevations of the sanctuary area is changing. Thus, the altitudinal range will be an important criteria to conserve different communities at different elevational zones for designing of nature reserve on undulated topography of mountain.

Landscape Diversity: A higher value of beta-diversity was observed for the entire sanctuary area (3.24) which indicates rapid change in the species composition from one stand to another. Along the altitudinal gradient beta-diversity was increasing (upto 1,950m, 1; < 2,100-2,200m, 2; and < above 2,200m, 5). Higher value of beta-diversity for above 2,200m is due to higher concentration of soil nutrients which is a result of because of rapid decay of leaf litter of broadleaf species, higher density of arthropods/ invertebrates, rare occurrence of fire, and high soil moisture. Contrary to these conditions beta-diversity was low in lower altitudes which largely occupied by *P. roxburghii*, a fire hardy and early successional species. A shift of dominant species in mid altitudes shows an intermediate beta-diversity between two separate elevational regimes.

Distribution of species, and diversity within the forest types: Distribution of species is a major contributor to enrichment of species in an area. The analysis of distribution pattern of various species within a forest type indicates that in *P. roxburghii* forest species were contiguously distributed while in the forests of *C. deodara* and *Q. leucotrichophora* random distribution of the species was more common. In *Q. floribunda* forest more than 75% of the species were distributed either randomly or con-

Stratum	Phenology	Species
Canopy	Evergreen	*Cedrus deodara* (Gymnosperm)
		Pinus roxburghii
		Quercus leucotrichophora (Angios.)
		Quercus floribunda
	Deciduous	*Ulmus wallichiana*
Sub Canopy	Evergreen	*Rhododendron arboreum*
	Deciduous	*Lyonia ovalifolia*
Under Canopy	Evergreen	*Euonymus pendulus*
		Eurya acuminata
		Ilex dipyrena
		Neolitsea pallens
		Machillus duthiei
		Myrica esculenta
	Deciduous	*Fraxinus micrantha*
		Lindera pulcherrima
		Pyrus pashia
		Rhus acuminata
		Viburnum cotonifolium
		Viburnum cylindricum
		Viburnum coriaceum

Table 1. A profile of tree species.

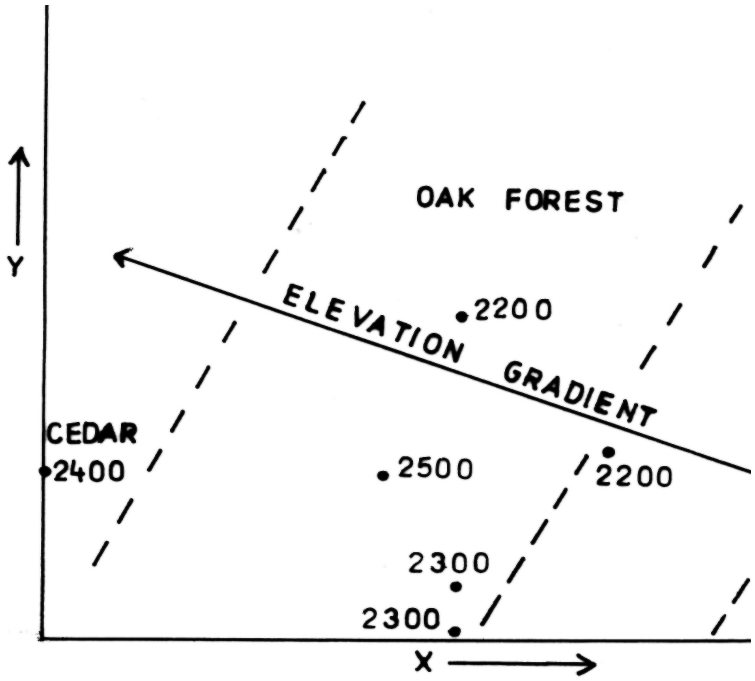

Fig. 1. Two dimensional ordination graph (x,y)based on IVI of species. Stands are arranged along an altitudinal gradient.

tiguously. Among different forests, species richness varies from 1 to 11, and diversity ranges between 0 and 2.41. The lower values are for *P. roxburghii* forest and higher for *Q. floribunda* forest. The *P. roxburghii* forest showed a single species dominance in large size tree (LST) layer.

Area: Compartmental history of the sanctuary area (obtained from State Forest Department based on the area covered by the dominant species) was analyzed to identify the area occupied by each vegetation type. As such, *Cedrus deodara* stand was merged with *Q. floribunda* forest because it confined to a very small area. The *P. roxburghii* forests are preponderant in the sanctuary covering about 52% of the total forest area. With an increase in elevation, area occupied by different forest types is decreasing *P. roxburghii* (Pine) **<** Pine mixed *Q. leucotrichophora* (Banj oak) (Pine in >60% area) **<** Banj oak mixed Pine (Banj oak >60% area) **<** Mixed Banj oak (Both equally abundant) **<** Banj oak **<** *Q. floribunda* (Tilonj oak) - *Cedrus deodara* (Cedar). Broadleaf communities occupy a smaller area than the conifers. Maximum diversity (species richness) was confined within a small area of the sanctuary (Fig. 3). Although small sites contribute to total species diversity the population of plants and dependant

Forest Types/ Altitude (m)		Species	IVI
Pine	(Upto 1,950)	*P. roxburhgii*	300
Mixed Pine - Oak		*P. roxburghii*	153.9
	(2,100)	*Lyonia ovalifolia*	51.4
		Quercus leucotrichophora	39.7
		Rhododendron arboreum	32.3
		Myrica ecsulenta	22.6
Mixed Oak - Pine		*Q. leucotrichophora*	117.4
	(2,200)	*L. ovalifolia*	75.4
		P. roxburghii	59.6
		R. arboreum	28.5
		M. esculenta	18.8
Banj oak	(2,200)	*L. ovalifolia*	112.3
		Q. leucotrichophora	65.9
		R. arboreum	50.2
		Viburnum coriaceum	42.4
		M. esculenta	29.2
	(2,300)	*Q. leucotrichophora*	147.5
		R. arboreum	89.9
		L. ovalifolia	33.1
		Viburnum cotonifolium	19.4
		Machillus duthiei	9.9
Tilonj oak	(2,300)	*Quercus floribunda*	92.7
		R. arboreum	91.8
		Ilex dipyrena	32.2
		Q. leucotrichophora	14.2
		V. cotonifolium	7.9
		Neolitsea pallens	6.9
		Viburnum cylindricum	6.9
		Lindera pulcherrima	6.3
		Eurya acuminata	6.2
		Ulmus wallichiana	6.1
	(2,500)	*Q. floribunda*	103.0
		I. dipyrena	77.8
		N. pallens	42.8
		Euonymus pendulus	21.5
		Q. leucotrichophora	19.3
		R. arboreum	13.8
		V. cotonifolium	12.3
		M.duthiei	9.6
Cedar	(2,400)	*Cedrus deodara*	184.3
		M. duthiei	92.0
		E. pendulus	23.7

Table 2. Tree species composition in the different forests of Binsar Wildlife Sanctuary.

animals within this small area are for more susceptible to extinction in the long term (Franklin 1980; Schaffer 1981). The surroundings of this species rich area is susceptible to the forest fire, as stated earlier, due to preponderance of pine. The area of a particular vegetation type, within an elevational zone, becomes second important factor to be considered for designing of reserve (especially for conservation of macro-habitats, like different forest types in the present case).

Representativeness: It is essential to assess the representativeness at different level. Analysis of sanctuary as a single system indicates that species richness and diversity of Trees increases with an increase in elevation (Fig. 4). A low value of biomass in lower elevation were due to high density and less basal cover of *P. roxburghii* forest. In general, biomass increases with an increase in elevation. There is a positive relation between biomass and diversity (Margalef 1968; Odum 1969; 1971), however, diversity of species may not necessarily approach a maximum in the mature stable stages of

Forest	C	QF	QL	MO-P	MP-O	P
C	100	57.1	23.5	0	0	0
QF		100	58.3	30	30	12.5
QL			100	62.5	62.5	16.6
MO-P				100	100	50
MP-O					100	50
P						100

Table 3. Similarity coefficient among different forest types. C = *Cedrus deodara*, QF = *Q. floribunda*, QL = *Q. leucotrichophora*, MO-P = Mixed Oak-Pine, MP-O = Mixed Pine-Oak, P = *P. roxburghii*

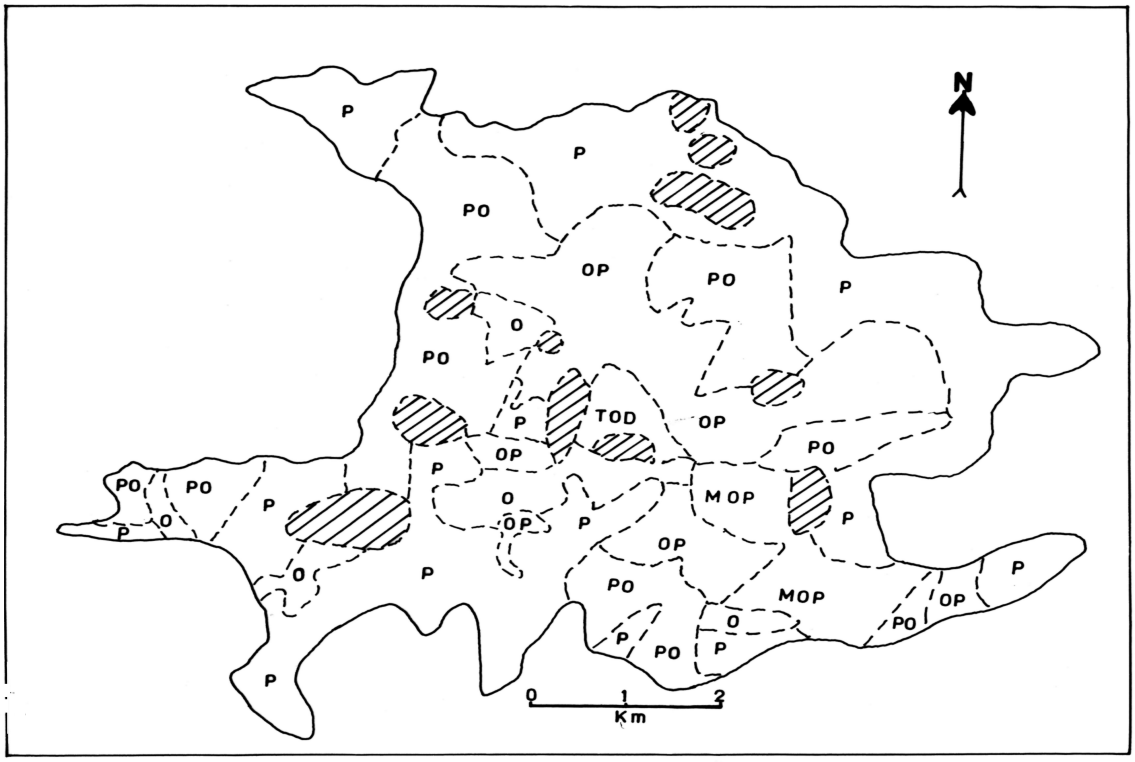

Fig. 2. Distribution of forest types in the Sanctuary area. P=Pine Forest, PO=Pine-Oak, OP=Oak-Pine, MOP=Mixed Oak Pine, O=Oak, TOD=Tilonj oak-Cedar Shaded Area=Settelments.

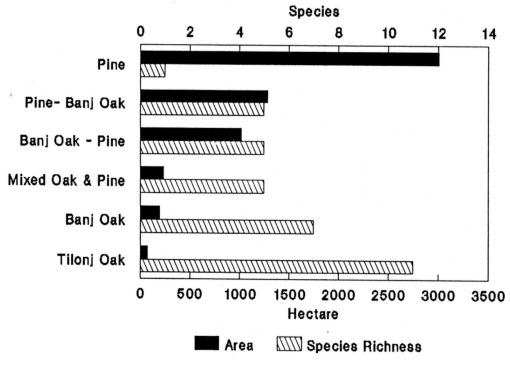

Fig. 3. Area occupied by different forest types and species richness.

the succession (Loucks 1970).

The landclass illustrates biotic variation within the sanctuary area and particular altitudinal range of forest communities. To assess how representative sanctuary area is, different attributes of vegetation communities along altitude (within the sanctuary) were compared with the attributes of the communities in the similar range of the Central Himalayan region. The comparison between forests recognized within the sanctuary area and earlier studies for less disturbed or undisturbed forests of the other parts of Central Himalayan region is given in Table 4. Total Basal Area (TBA) and Diversity index values of *P. roxburghii* forest were lower in the sanctuary area than the ones reported for similar type in earlier studies. A less mean basal cover of *P. roxburghii* trees was due to high density. Low value of TBA and high value of density for *P. roxburghii* forest indicates young nature of the Pine forest in sanctuary. TBA and density values were higher for Mixed forests of the sanctuary than the similar type of the region. Low diversity of Mixed forests of sanctuary indicates dominance of only few species. Among the forests of *Q. leucotrichophora* maximum diversity was observed in the sanctuary area, however, TBA and density were within the range reported for similar types of the region. For forests of *Q. floribunda*, TBA was higher in sanctuary than the other parts of the region. Diversity (2.41) and

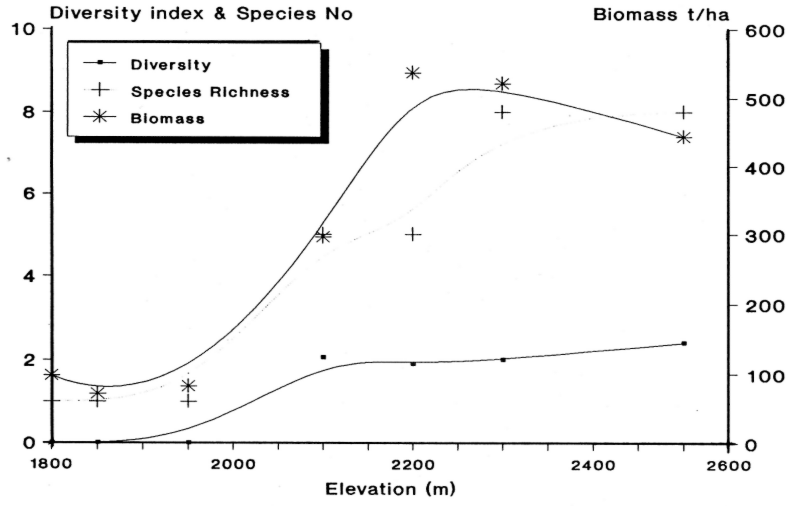

Fig. 4. Trend of diversity and species richness for LST and total tree biomass along altitudinal gradient in Binsar Wildlife Sanctuary. For an elevation, where more than one stands occur, mean value is given.

density (10.3) of *Q. floribunda* forest of sanctuary were within the range reported for similar type of the region.

It is apparent from the comparison that the forests of sanctuary are well stocked, dense and of diverse type. In the area altitude supports a climatic gradient that is reflected by landscape-diversity (beta-diversity) i.e., different assemblages of species (different in species composition and dominance) occur in different altitude of the gradient. The element of naturalness exists in the sanctuary, and the protected area covers a number of representative types of the forest communities which are common in mid mountain region (1,200m - 2,500m) of the Central Himalaya.

Wildlife in Conservation area and Habitat Linkages

Habitat for wildlife in the Himalaya, in general, is shrinking (Singh *et al.*, 1984), a number of wild animals can be observed in the sanctuary area (Table 5) few of them are rare and/or endangered

Forest type	TBA (m/ha)	Density (no/ ha)	Diversity	Source
P. roxburghii	30.2	420	0.79	Saxena and Singh (1982)
	23.0		1.56	Rikhari *et al.*,(1991)
	21.4	700	0.07	Present study
Mixed *P. roxburghii-O. leucotri -chophora*	36.0	540	2.27	Saxena and Singh (1982)
	28.0		1.56	Rikhari *et al.*,(1991)
	37.7	860	1.91	Present study
	30.5	520	0.75	Present study
Q. leucotri-chophora	53.0	940	1.88	Saxena and Singh (1982)
	42.6	1200	1.18	Rikhari *et al.*,(1991)
	44.0		1.11	Rikhari *et al.*,(1991)
	47.5	940	1.77	Present study
	36.1	970	1.58	Present study
Mixed *Quercus* spp.	29.3	360	1.22	Tripathi *et al.*,(1991)
	47.0		2.06	Rikhari *et al.*,(1991)
	56.8	1280	1.97	Present study
Q. floribunda	39.4	1300	1.10	Saxena and Singh (1982)
	39.2	410	2.17	Tripathi *et al.*(1991)
	34.5	340	0.79	Tripathi *et al.*(1991)
	43.9	1390	2.47	Rikhari *et al.*,(1991)
	44.3	1030	2.41	Present study

Table 4. Comparison of forest types of sanctuary with similar forest types of the Central Himalayan region.

Species	Common Name	Schedule/Year*
Mammals		
Panthera pardus	Leopard	S I 1980
Felius chaos	Jungle cat	S II 1980
Selenarctos thibetanus	Himalayan Black Bear	S II 1977
Canis alpinus	Jackal	S II 1986
Nemorhaedus goral	Goral (a small antelope)	S III 1972
Muntiacus muntjak	Barking Deer	S III 1972
Capricornis sumatrensis	Serow	S I 1977
Sus scrofa (cristatus)	Wild Boar	S III
Martes flavigula	Chitroula (local name)	
Presbytis entellus	Common Langur	S II 1977
Macaca mulatta	Rhesus Macaque	S II 1977
Lerus nigricollis	Rabbit	
Hystrix indica	Porcupine	S IV 1986
Eunambulus penanti	Palm squirrel	S IV
Petaurista petaurista	Flying Squirrel	S II 1986
Birds		
Catreus wallichii	Chir pheasent	S I 1972
Pucrasia macrolopha	Koklas pheasant	
Lophura leucomelana	White crested kalij	
Tragopan melanocephala	Western Tragopan	S I 1972
Ictinaetus malayensis	Black eagle	
Urocissa erytirorhyricha	Karoli (local name)	
Strix aluco	Himalayan wood owl	
Gyps himaalyensis	Himalayan Griffon	
Streptopelia orientalis	Rufous Turtle Dove	
Falco severus	Oriental Hobby	
Cuculus varius	Brainfever bird	
Psittacula himalayana	Slatyheaded Parakeet	
Teron sphenura	Hariyal (local name)	
Alectoris chukar	Chukar Partridge	
Garrulus lanceolatus	Blackthroated Jay	
Corvus macrorhynchos	Jungle Crow	
Microscalis cerisdes	Nightangle	
Acridotheres fuscus	Jungle Myina	
Turdoides striatus	Jungle Babbler	
Picus squamatus	Scallybellied green woodpecker	
Arborophila torqueola	Common hill Partridge	
Spizaetus nipalensis	Hodgson's Hawk-eagle	S I 1980
Collocalia brevirostris	Himalayan Swiftlet	
Cissa flavirostris	Yellowbilled Blue Magpie	

Table 5. Some of the Wildlife of the sanctuary area.

species. Many of listed animals are in the Scheduled List of Govt. of India (1972). Hunting of any wildlife which is in Schedule I is strictly prohibited. Schedule II lists Special Game, Schedule III Big Game, and Schedule IV Small Game. Hunting of any wildlife specified in Schedules (II, III, IV) is not allowed, except the license granted with conditions. After notification of sanctuary hunting has been banned completely. To survive every species has some characteristic range of habitats and interaction with other species (plant and animal). Presence of top carnivore (*Panthera pardus*) indicates a wealthy food chain in the system. The forests provides habitat to birds and number of birds can be seen in sanctuary area. e.g., Oak and Pine forests are habitat of *Strix aluco* and *Cissa flavirostris*, while Mixed Oak-Pine are of *Picus squamatus*. But to preserve a wide range of bird habitats other areas are equally important (viz., orchards within the sanctuary, abandoned settlements), a study in Norway has shown that bird diversity is not being maximized in the same woods as the plants (Saetersdal *et al.,* 1993) as also observed in Britain for other fauna by Emberson (1985, for soil mite species richness) and Usher (1992, for arthropods).

Oak (*Quercus* spp.) dependent population of Langur (*Presbytis entellus*), a seed predator, is common in the sanctuary area. In a study carried in Himanchal Pradesh (adjacent Himalayan region of the Central part) it was observed that occurrence of Langur was most common in oak forests than in mixed forests, least in pine forest. The density of Langurs was not correlated with total tree cover but only with the amount of oak or mixed forest cover (Ross *et al.*, 1993) which indicates habitat

preference of Langur. These Oak forests are habitat of another seed predator Flying Squirrel (*Petaurista petaurista* var. *albiventer*) which is now rare in the region. Dead standing trees of *Q. leucotrichophora* and *P. roxburghii* are habitats of cavity nesting birds. Few common cavity nesting birds between 1500m and 2200m are *Sitta frontalis, S. himalyensis, Machlolophus xanthogenys, Lophophanes rufonuchalis, Psittacula himalayana, Dryobatis himalayensis, Picus squamatus*.

It was observed that oak forests provide shelter to a diverse type of wildlife but this habitat has a less representation on the forest landscape of sanctuary. Hence the reduction of these habitats due to any disturbances might result any of the following consequences. The dependent animal population will decrease or vanish. Any gap in a food chain will force to higher groups for diversification on other food sources. Loss of top carnivores have much effect on the functioning of ecosystem by the increase in the abundance of prey species (usually herbivores) and subsequent overgrazing and overbrowsing. this will lead to habitat succession and decrease in habitat diversity suitable to sustain the herbivore population. Similarily, less availability of large herbivores to carnivores will effect the management practices. Besides the disorder in sanctuary management both the situations will create managemental confentration with surrounding human societies (encroachment to orchards and crops, killing of livestock of nearby villages and man-eater).

Discussion

Forest is a complex habitat interms of structure and species composition. These two attributes are mainly dependent on environmental factors as well as interference of man. The geographical and climatic features of the sanctuary support patterns of diversity in the forest landscape, and the area protected represents a typical habitat of most of the common plant communities of the region. The vegetation of the sanctuary provides habitats for different wildlife which shelter in different stratum of the vegetation. It emerges from the study that in lower elevation *Pinus roxburghii* and in higher elevations *Quercus* spp. are keystone plant species (by its effective disappearance from a system, directly or indirectly results in the virtual disappearance of several other species; Soul and Kohm 1989) in the sanctuary area. The aim of conservation in the Central Himalayan region for preserving overall diversity will be adequate if the efforts will concentrate not only on the rich and diverse plant communities but as well as plant communities with low diversity (in the present case Pine forest). Focussing on richness or diversity of one species group should be avoided if protection of overall biological diversity is the goal (Nilsson 1986).

Considering the community parameters (density, total basal area, crown cover) the forest communities of sanctuary falls in "Good Forest" (generally crown cover >60%) category of Tewari *et al.*, (1985). The protected area of sanctuary represents to a small portion (0.3%) of the total forested land in the Central Himalaya. The forests of sanctuary are only 2% of the total land under "Good Forest" while Good Forests contributes 15.5% to the total forested land of Central Himalaya. The conservation value of Binsar Wildlife Sanctuary is significant on regional sacle where it contributes 19.2% to the total good forest of Almora District. The Binsar Wildlife Sanctuary becomes important for the oak forests that are declining in the region due to anthropogenic pressures (Upreti *et al.* 1985). There is need for another similar and separate 'viable' nature reserve (with more area under oak forests) to ensure against loss of species due to any disturbances, as also suggested in conservation practices.

In debat of single large *vs* several small it appears that either there is no consistent difference between single large and several small sites in species richness, or else groups of small sites tend to have more species (Simberloff 1986). The higher species richness is related with greater habitat diversity, however, other factors may contribute. In mountains where climate largely governs the vegetation patterns altitude becomes important factor to be considered for designing of nature reserves with other associated features (slope aspect, rock type), as evident by similarity coeefecient between different communities in present study. The similarity coeffecient shows changes from lower to high elevation of the sanctuary area and identifies overlap zones between two major communities (broadleaf and conifer). Keeping in view the altitudinal range for a protected area, the habitat identification (in the present case vegetation patterns of determining types, forest) should be on the elevation distribution of dominant species and an overlap zone of two dominant and distinct types. The identification of preferred elevation zone of species and overlap zone are important for vegetation manager and helpful in wildlife management because of seasonal movement of animals in search of food. The black bear (*Selenarctos thibetanus*) which is common in broadleaf forest can be seen in mixed and pine forests during the fruiting season of *Myrica esculenta*. Large herbivores move downwards, during winter, due to the shortage of ground vegetation as a consequence of snowfall.

However, the altitude is an determining factor in mountains the area of a particular habitat/vegetation type (Fig. 3) is also important for temporal variations due to successional patterns/diseases/fires/anthropogenic activities. In nature reserves area becomes second important factor when vegetation lines are demarkated by topographic restrictions as in the present case less area in higher elevations restricts the boundary of oak forests while overlap zone of pine and oak becomes more dominant (about 44% of the total forest). With due consideration of elevational range and area occupied by different habitat types/vegetation, requirement of establishing the reserve networks with similar/diverse landscape features and corridors for dispersal of species is an essential feature to preserve maximum biological diversity in mountains, especially where human population is generally scattered and have strong relationship with surrounding forests (Sharma and Singh 1994), as in Central Himalayan case.

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References

Austin, M.P. and Margules, C.R. 1986:Assessing Representativeness. In *Wildlife conservation evaluation*. (ed. M.B. Usher), pp.45-68. Chapman & Hall, London. 45-68.

Bray, J.R. and Curtis, J.T. 1957: An ordination of upland forest communities of southern Wisconsin. *Ecological Monograph,* **27**: 325-349.

Emberson, R.M. 1985: Comparisons of site conservation value using lant and soil arthropod species. *Bull.Brit.Ecol. Soci,* **16:**16-17.

Franklin, I.R. 1980: Evolutionary changes in small populations.In *Conservation Biology: An evolutionary-Ecological perspective. Sinauer Associates, Sunderland, Massachu setts* (eds.M.E. Soule and B.A. Wilcox), pp.135-149. Government of India. 1972. The Indian Wildlife (Protection) Act. Government of India.

Huntley, B.J. 1989: Biotic diversity in southern Africa: concepts and conservation. Oxford University Press, Cape Town, South Africa.

Loucks, O.L.1970: Evolution of diversity, efficiency, and community stability. *American Zoologist*, **10:** 17-25.

Margalef, R. 1968: Perspectives in Ecological theory. University of Chicago Press, Chicago.

Margules, C.R., Nicholls, A.O. and Pressey, R.L. 1988: Selecting networks of reserves to maximize biological diversity .*Biological Conservation*, **43:**63-76.

Misra, R. 1968: Ecology Workbook. Oxford and IBH Publishing Co.,Calcutta.

Nilsson, C. 1986: Methods of selecting lake shorelines as nature reserves. *Biological Conservation*, **35:** 269-291.

Nilsson, C. and Gotmark, F.1992: Protected areas in Sweden: In natural variety adequately represented. *Conservation Biology*, **6:** 232-242.

Odum, E.P. 1969: The strategy of ecosystem development. *Science,* **164:** 262-270.

Odum, E.P. 1971: Fundamentals of Ecology. W.B. Saunders Co., Philadelphia.

Rana, B.S., Singh, S.P. and Singh, R.P.1989: Biomass and net primary production in Central Himalaya Forests along an altitudinal gradient. *Forest Ecology and Management*, **27:**199-218.

Rikhari, H.C., Tewari, J.C., Rana, B.S.and Sharma, S.1991: Woody vegetation and regeneration status in a mixed oak forest of Kumaun Himalaya. *Indian Forester,* **117:** 274-283.

Rikhari, H.C., Singh, R.S. and Tripathi, S.K. 1991: Pattern of species distribution, community characters and regeneration in major forest communities along an elevational gra dient in Central Himalaya. *Inter. J. of Ecology and Environ mental Sciences,* **17:** 167-174.

Ross, C., Srivastava, A. and Pirta, R.S.1993: Human influences on the population density of Hanuman Langurs–*Presbytis entellus* and *Rhesus macaques Macaca mulatta* in Shimal, India. *Biological Conservation*, **65:** 159-163.

Runte, A. 1987: National Parks: the American experience. University of Nebraska Press, Lincoln, Nebraska.

Saetersdal, M., Line, J.M. and Birks, H.J.B. 1993: How to maximize biological diversity in nature reserve selection: Vascular plants and breeding birds in deciduous woodlands, Western Norway. *Biological Conservation*,**66:** 131-138.

Saxena, A.K. and Singh, J.S.1982: A phytosociological analysis of forest communities of a part of Kumaun Himalaya. *Vegetatio,* **50:** 3-22.

Schaffer, M.L. 1981: Minimum population sizes for species conservation. *Biosci Landscape and Urban Planning,* **29:**19-24.

Siegfried, W.R. 1989: Preservation of species in southern African nature reserves. In *Biotic diversity in southern Africa: concepts and conservation*.(ed. B.J. Huntley).Oxford University Press, Cape Town, South Africa.

Simberloff,D. 1986: Design of Nature Reserves. In *Wildlife Conservation Evaluation* (ed. M.B. Usher), pp.315-337. Chapman & Hall Ltd, London.

Singh, J.S., Pandey, U. and Tiwari, A.K.1984: Man and Forests: A Central Himalayan case study. *Ambio,* **13:** 80-87.

Singh,J.S. and Singh, S.P. 1987: Forest vegetation of the Himalaya. *Botanical Review,* **53:** 80-192.

Shannon, C.E. and Wiever, W. 1963: The mathematical theory of communication. Illinois Press, Urbana.

Sorenson, T. 1948: A method of establishing groups of equal amplitude in plant sociology based on simi larity of species content. *Det. Kong. Danske Vidensk. Salsk Biology Skr*, **5:** 1-34.

Soul, M.E. and Kohm, K.A. 1989: Research Priorities for Conservation Biology. Island Press, Wshington, D.C.

Tewari, J.C., Rikhari, H.C. and Singh, S.P.1989: Compositional and structural features of certain tree stands along an elevational gradient in Central Himalaya.*Vegetatio,* **85:** 117-120.

Tewari, J.C. and Singh, S.P.1985: Analysis of woody vegetation in a mixed oak forest of Kumaun Himalaya. *Proc. Indian National Science Academy,* **51:**332-347.

Tiwari,A.K., Saxena, A.K. and Singh, J.S. 1985: Inventory of forest biomass for Indian Central Himalaya. In *Environmental Regeneration in Himalaya: Concepts and Strategies* (ed.J.S.Singh), pp. 236-247. CHEA and Gyanodaya Prakashan, Nainital, India.

Tripathi,B.C., Rikhari, H.C. , Bargali, S.S. and Rawat, Y.S. 1991: Species composition and regeneration in disturbed forest sites in the oak zone in and around Nainital. *Proc. Indian National Science Academy,***57:** 381-390.

Upreti,N., Tewari, J.C. and Singh, S.P. 1985: The oak forests of Kumaun Himalaya (India): Composition, diversity and regeneration. *Mountain Research and Development*, **5:**163-174.

Usher, M.B. 1992: Management and diversity of arthropoda in *Calluna* heathland. *Biodiversity and Conservation,* **1:** 63-79.

Whittaker, R.H. 1975: Communities and Ecosystems. MacMillan Publishing Co.,New York.

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