WINTER HABITAT USE BY MONAL PHEASANT
(*Lophophorus impejanus*)
IN KEDARNATH WILDLIFE SANCTUARY, WESTERN HIMALAYA

DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT,
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By
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UNDER THE SUPERVISION OF
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Wildlife Institute of India

CERTIFICATE

This is to certify that Mr. R. Suresh Kumar of the Wildlife Institute of India has carried out an original research work titled "Winter habitat use by monal pheasant (*Lophophorus impejanus*) in Kedarnath Wildlife Sanctuary, Western Himalaya" in partial fulfilment of the M.Sc. (Wildlife Science) degree of Saurashtra University. These investigations were carried out under our supervision from November 1996 to June 1997. We also certify that this research work has not been submitted for any other degree to any University.

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The Himalayan Monal Pheasant (*Lophophorus impejanus*)

This work is dedicated to

Late Shri Vikram Singh Bisht

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SUMMARY

I studied the winter habitat use by Monal pheasant (*Lophophorus impejanus*), in Kedarnath Wildlife Sanctuary, Western Himalaya, from November 1996 to April 1997. The study period included three seasons: autumn (November-December), winter (January-February-March), and spring (April). The objectives of the study were to quantify availability and utilization of the different habitats, which were named after prominent vegetation types in the three seasons, identify habitat variables influencing monal habitat use, and determine the sex ratio, group size and group composition of monal. Existing trails and transects (eight in number) were used to quantify the above mentioned parameters.

Eight different vegetation types were identified in the study area. They are : Oak-Rhododendron Forest (ORF), Oak-Rhododendron Degraded forest (ORD), Oak-Rhododendron-Lyonia (ORL), Maple-Oak-Rhododendron forest (MOR), Fir forest (FIR), Scattered Tree and Scrub (STS), Alpine Scrub (AS), Alpine Meadows and Rocks (AMR), and a separate category 'cliffs'. During the entire study period monal showed preference for ORF. Within this vegetation type, they were seen mostly close to the streams. Most of the monal sightings (66.7%) during autumn were between 2900 m and 3200 m altitudes. Monal showed movement to slightly lower altitudes (to 2800 m) during peak winter. During late March, the snow had started to melt and a gradual movement of monal to higher altitudes was noticed.

Monal showed strong preference for dense ORF with high litter cover during autumn and winter. At the onset of spring, there was a shift in the habitat use and they showed preference for cliffs. The males used such areas for displaying to the females. Other habitat variables such as bamboo cover, canopy cover, and presence of snow played an important role in the choice of habitat by monal.

The mean group size did not vary significantly across the seasons. During autumn, male and female monal were in loose groups i.e., females had tendency to form small groups, whereas males remained more or less solitary. After the first snow, distinct group formations were seen. The groups were categorised into an all-male group of seven or eight individuals, all-female groups of 10 to 12 individuals, mixed groups, and solitary males. The females remained in groups throughout the study period, while the males remained in groups only for a short span and only during peak winter. Monal started to move to the higher reaches during late March, and from then on, solitary males were quite often encountered.

1. INTRODUCTION

The Himalayan region, one of the richest biogeographic zones in India, covers an area of about 42,200 km^2, nearly 15% of India's land surface. The location, climate and topography of the Himalaya has endowed it with rich and diverse life forms (Mani 1974; Ali 1981).

The Himalayan mountains are an unique environment, with no uniformity in temperature or even the kind of weather which is governed by their location, elevation and topography (Mani,A. 1981). Seasons however are distinct and therefore define the quadrennial phases in the ecology of the system. The winter precipitation in the form of snow influences both plant and animal life to a great extent. The melting snow provides the major source of water for the growth of plants during early summer. However, the major growth phase in the ground vegetation is during the monsoon. This phase is very short and at the onset of autumn the annuals and herbaceous-perrenials die out or remain dormant as underground parts (Ram *et al.*, 1988). Concurrent with the change in phenology a marked seasonal movement in the local fauna has been observed (Pyke, 1984).

Winter is a crucial period in the life of mammals and ground dwelling birds living in the high mountains. Productivity is at its lowest and a thick layer of snow makes food hard to find. Most of the birds migrate to lower latitudes to escape the harsh winter while some continue to stay showing slight altitudinal movements and tend to choose particular habitats (Terborgh, 1989). Most species of pheasants are said to be relatively sedentary and show limited altitudinal movements (Johnsgard, 1986).

Birds living in the mountains would have to be highly adaptive to survive the severe conditions such as strong winds, low temperatures, lowered atmospheric pressure and effects of radiation (Dorst, 1974; Terborgh, 1989). The survival strategies include morphological and physiological adaptations coupled with innate and learned behavioural responses to external and internal stimuli (Block & Brennan 1993). For example, Chinese monal (*Lophophorus ihyusii*) has a larger body size and occurs at higher altitudes as compared to the Himalayan monal (*Lophophorus impejanus*). This is perhaps an ecological adaptation for survival at the higher altitudes (Johnsgard, 1986).

1.1 Review of literature :

1.1.1 Himalayan monal :

The Himalayan Monal or Impeyan pheasant (*Lophophorus impejanus* Latham 1970), is one of the three species represented in the genus *Lophophorus* of the family *Phasianidae*. The other two species are the Sclater's Monal (*Lophophorus sclateri*), and the Chinese Monal (*Lophophorus ihuysii*). Himalayan Monal exhibits a pronounced sexual dimorphism. Males are brightly coloured, metallic bronze green above with a white rump and velvety jet black underside, a marked crest and a bright orange tail. The females are brown in colour with dark and light brown streaks (Ali & Ripley, 1983).

The Himalayan Monal has a wide distributional range along the Himalaya extending from Eastern Afghanistan, North West Pakistan, India (states of Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Sikkim and Arunachal Pradesh), Nepal, Bhutan and Southern Tibet (Ali and Ripley, 1983; Johnsgard, 1986; McGowan and Garson, 1995). The Himalayan monal has also been reported from the northern part of Myanmar (Yin, 1970). It is reported to inhabit high altitude Oak-Conifer (*Quercus-Abies*) forests, Birch-Rhododendron (*Betula-Rhododendron*) forests, steep cliffs and open grassy meadows with an altitudinal range from 2600-5000 m (Ali & Ripley, 1983, Gaston *et al.*, 1981).

During winter monal pheasants are reported to occur in various habitat types including those dominated by pines and fir (Gaston *et al.*, 1981). Monal were found to exhibit the greatest altitudinal movements of all the pheasants observed in Himachal Pradesh, concentrating mainly between 2000 m and 3000 m in January - March and mostly above 3000 m during September-October (Gaston *et al.*, 1981; Gaston & Garson, 1992). Towards the Eastern Himalaya, monal are said to show less altitudinal movement because snowfall is not so severe in the east as compared to the Western Himalaya (Johnsgard, 1986).

Ecological information on monal is available only from limited studies (Gaston *et al.*, 1981; Sathyakumar *et al.*, 1992; Gaston & Garson, 1992), status surveys (Gaston, 1980; Gaston, 1981; Gaston *et al.*, 1981; Garson & Hunter, 1983; Sharma & Pandey, 1989; Kaul & Ahmed 1992; Pandey, 1992; Garson & Gaston, 1992; Kaul *et al.*, 1993; Yahya, 1992; Sathyakumar, *in press.*) and observations in captivity (Gupta, 1993).

Winter habitat use by monal is little known and such a study is vital for understanding the ecology of the species. Studies on Ring necked pheasant or Common Pheasant (*Phasianus colchicus*), showed that the choice of habitat is a key aspect in the ecology and survival of these pheasants during winter (Hill & Robertson, 1988; Robertson, 1992).

Of all 256 species of Galliformes which have been currently described, 68 species are now considered to be globally threatened and 39 (58%) of these species are found in Asia (Collar and Andrew, 1988). Pheasants are regarded as indicators of habitat quality (Ridley, 1986). Monal could serve as an indicator for assessing the quality of subalpine and alpine habitats in the Himalaya. The subalpine and alpine habitats particularly in the western Himalaya have been threatened due to increase in human and livestock pressures (Gaston & Garson, 1992; Sathyakumar, 1994; Prasad *et al.*, 1989; Rawat, 1993).

1.1.2 Habitat selection :

Literature on habitat selection in birds is voluminous. Many studies have pointed out the special significance of certain habitat features. Physical structure of the habitat (landscape features), has been shown to be important in habitat selection (Cody, 1981; Terborgh, 1985; Weins, 1969). Similarly floristic structure has been recognised as one of the important features of a habitat (Collins, 1983; Holmes & Robinson, 1981; Weins & Rotenberry, 1981). Other studies have shown that morphological aspects such as body size, leg length, bill size, moulting, sexual dimorphism, structure of the toes etc., greatly influence the habitat selection (Winkler & Leisler, 1985; Janes, 1985). Competition is also said to play an important role in habitat selection (Svärdson, 1949; Terborgh & Weske, 1975; Alatalo *et al.*, 1985; Terborgh, 1985; Cody, 1985).

Extensive studies have been done on the Common Pheasant (*Phasianus colchicus*), in Europe and America (Hudson & Rands, 1988; Gatti *et al.*, 1989). But this species has been least studied in its native habitat, primarily because of the lack of interest in it as a sporting bird (Hill & Robertson, 1988). Most other pheasants, due to their occurrence in very inhospitable and least studied terrestrial environments, have been paid less attention in terms of ecological studies (Johnsgard, 1986). Detailed studies on few species of pheasants have been conducted recently (Gaston *et al.*, 1983; Islam & Crawford, 1987; Robertson, 1992; Mc Gowan, 1992; Sathyakumar *et al.*, 1992a; Kalsi, 1992; Zheng wang *et al.*, 1992; Young *et al.*, 1991; Trivedi, 1993; Changquing *et al.*, 1992; Ping *et al.*, 1995).

1.3 Objectives :

From the foregoing it is evident that ecological information on monal is very less. Hence this study aimed to investigate winter habitat use by monal and determine whether there were preferences for particular habitat features such as specific vegetation types, altitude, aspect and vegetation cover.

The objectives of this study were to:

1. Quantify the availability and utilization of the different vegetation types by monal during winter.
2. Identify the important habitat variables which influence winter habitat use by monal.
3. Determine the sex ratio, group size and group composition of monal pheasant.

2. STUDY AREA

2.1 Location :

Kedarnath Wildlife Sanctuary (Kedarnath WS; 30° 25'- 30° 45'N & 78° 55'- 79° 22'E), is one of the largest protected areas (PAs) in the Garhwal Himalaya. It covers an area of 975 km^2. The Sanctuary was established in 1972 and derives its name from the famous Hindu shrine at Kedarnath. The Sanctuary is bounded in the north by a range of peaks, mostly over 6000 m, and in the south by the Mandal-Okhimath road (Fig 2.1) which is closed in winter due to snow. The altitudes within the sanctuary range from 1160 m (near Phata), to 7068 m (Chaukamba peak). Other PAs situated near Kedarnath WS include the Valley of Flowers National Park in the east, Nanda Devi Biosphere Reserve in the south-east, and the proposed Gangotri Wildlife Sanctuary in the north-west.

An intensive study area of 5.3 Km^2 was chosen in the southern part Kedarnath WS (30° 30' N & 79° 15'E) in the Tungnath region for this study. A small portion of the study area lies outside the Kedarnath WS and forms apart of the Trishula Reserved Forest. Two camps, Kanchulakharakh (2700 m), and Shokharakh (3050 m), were established for this study (Fig 2.2). This area was selected for intensive study due to its wide altitudinal range (2400 m to 3680 m), different habitat types, diverse aspect and slope categories. Moreover, baseline information on vegetation, large mammals and pheasants were available for this area (Green, 1985 a; Sathyakumar *et al.*, 1992 a; Sathyakumar, 1994).

2.2 Physical :

The Kedarnath WS lies in the upper catchment of Alakananda and Mandakini rivers which form major tributaries of the river Ganges. The PA is fully exposed to the south-west monsoon and there is very little rain shadow effect above 3000 m in the northern region of this PA. The general topography is rugged, with moderate to steep slopes, cliffs and ravines characterising the study area. The geology of this area is characterised by a belt of metamorphic rocks which include gneisses, granites and garnet biotite schists. This belt in Tungnath area has garnet biotite schist and some types of gneiss. The soil is light, sandy loam and micaceous, which is excellent for tree growth on favourable aspects (Agrawala, 1973). The soil is fairly acidic with a pH of 5.6 (Green, 1985 a).

Fig 2.1: Kedarnath Wildlife Sanctuary showing the location of intensive study area.

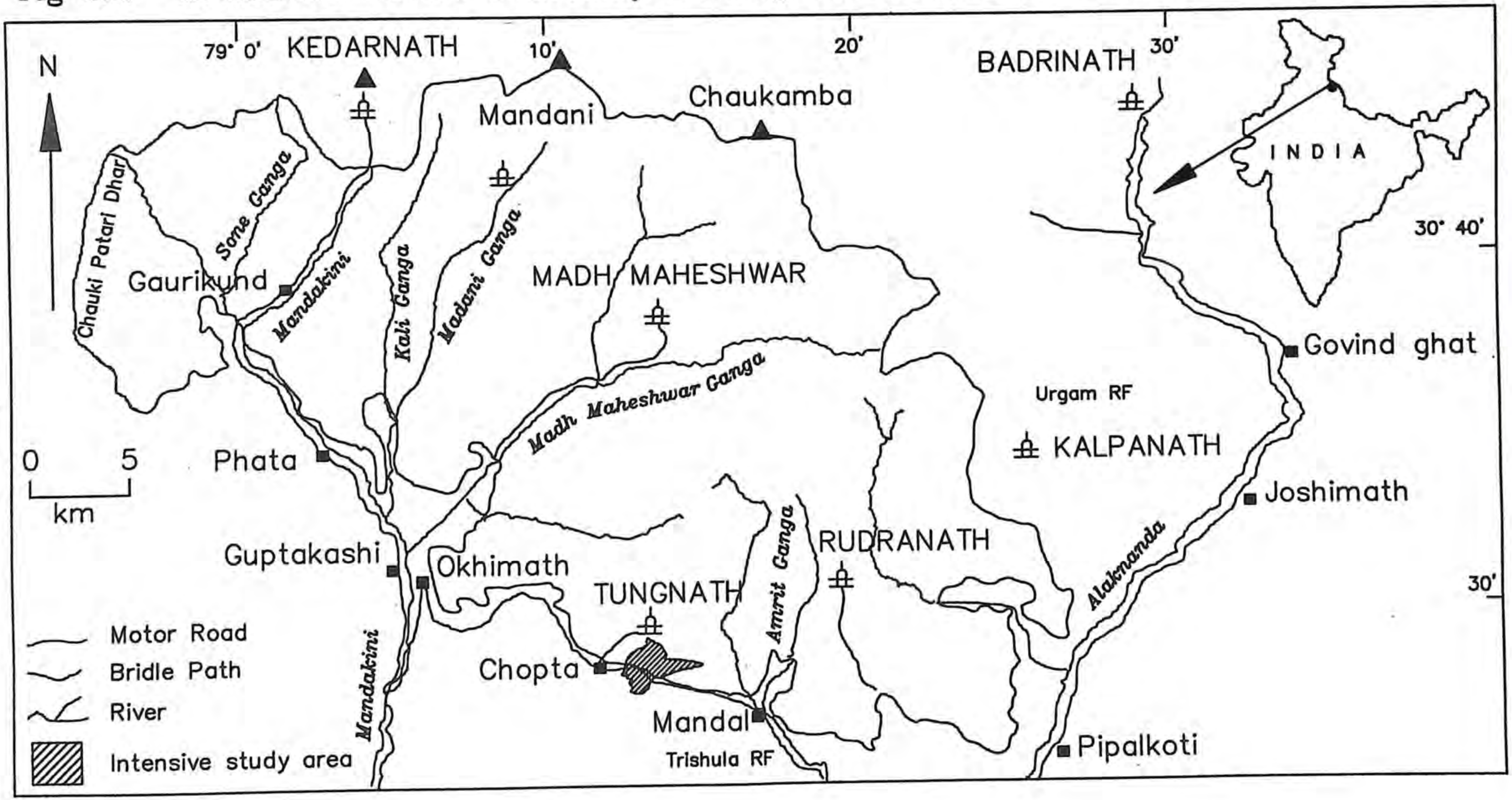
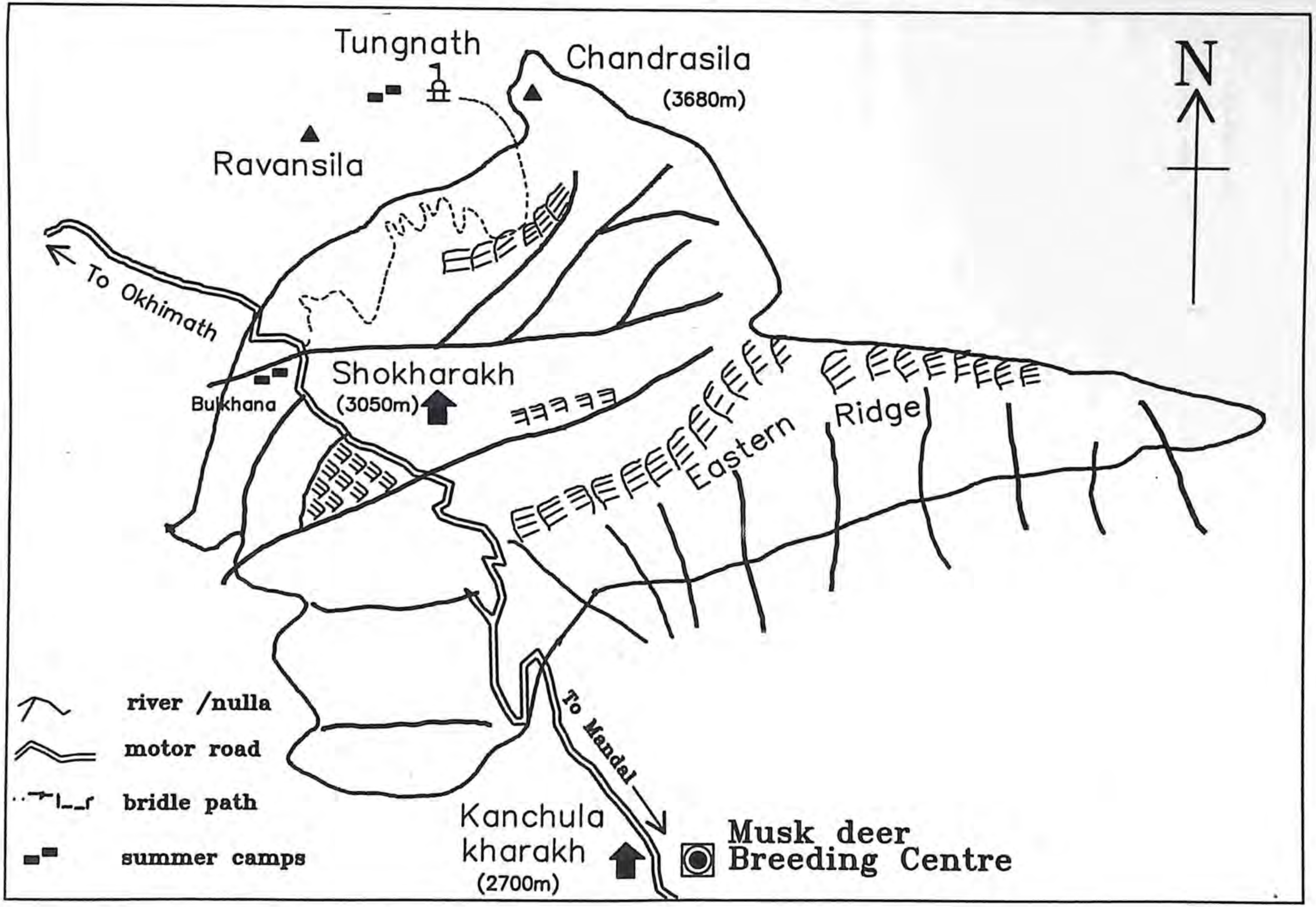


Fig. 2.2 A map of the Study Area



2.3 Climate :

The climate of the study area is influenced by the south-west monsoon in summer and by westerly disturbances in winter (Mani, A. 1981). Local relief plays an important role in the thermal effects in mountain regions, and the south-east facing slopes have warm mornings and cool afternoons, and the west facing slopes the opposite (Mani, A. 1981). Four seasons recognised for this part of the Himalaya are : winter (January-March), spring (April-June), summer-monsoon (July-September) and autumn (October-December). The monsoon reaches the Himalaya by late June and continues until the end of September (Green, 1985 a; Sathyakumar, 1994). The autumn months are usually dry. The autumn nights are usually cloudless, accompanied by frost and often the night temperatures falling below freezing point (See Fig 2.3). Heavy snow usually arrives in late December (Green, 1985 a; Sathyakumar, 1994).

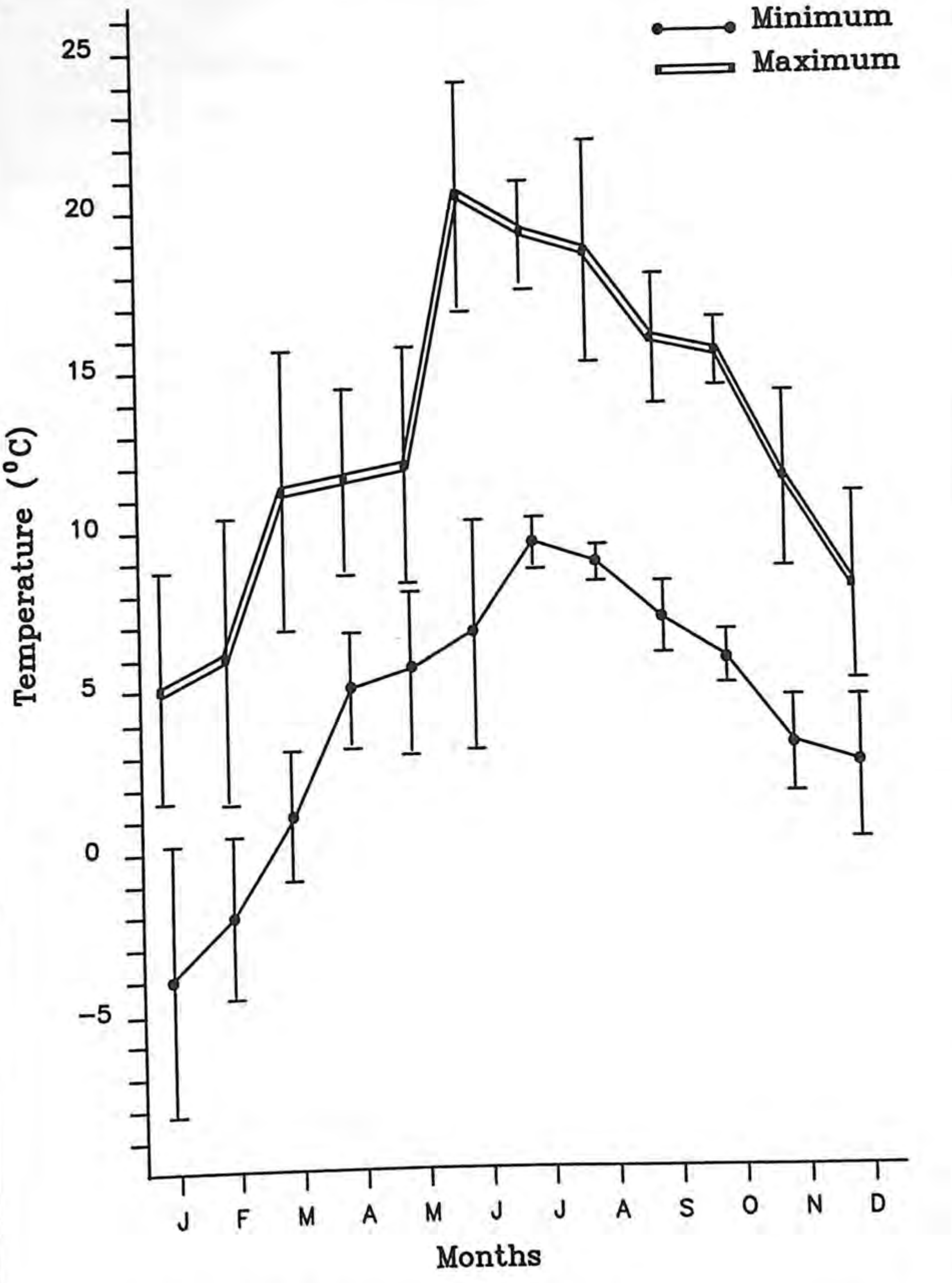
During this study frost was first observed on 17^{th} November 1996 around the Kanchulakharakh (2700 m), base camp. Short spells of snow occurred on 27^{th} November and 25^{th} December 1996. The snowfall was delayed and the first snowfall occurred only on 19th January 1997, and thereafter regular snowfall occurred until the middle of April. During peak winter, the study area had about one to one and half metre deep snow.

2.4 Vegetation :

The vegetation of the Kedarnath WS can be broadly described under the following zones: subtropical zone (below 1500 m), temperate and subalpine (1000 m - 3300 m), and alpine zone (above 3300 m). Within the Wildlife Sanctuary, the tropical zone is not represented (Green, 1985 a). Champion and Seth's (1968), categories of vegetation for this area correspond to Upper Western Himalayan temperate forest ($12/C_2$), West Himalayan dry temperate deciduous forest (13/C), West Himalayan subalpine Birch-Fir forest ($14/C_1$), Subalpine pastures ($14/DF_1$) and Birch-Rhododendron scrub forest ($15/C_1$).

The most widespread forests in the upper montane zone are the mixed oak and coniferous forests. Oak (*Quercus semecarpifolia*) - Rhododendron (*Rhododendron arboreum*), association is characterised by abundant leaf litter in the forest floor. For the purpose of this study, the vegetation of the study area were classified into eight different types.

Fig.2.3: Mean monthly temperatures at Kanchulakharakh (1989 - 1990)



Source: Musk deer Breeding Centre, Kanchulakharakh, U.P. State Forest Dept. (Sathyakumar 1994)

2.4.1 Description of vegetation types

The study area was broadly classified into eight vegetation types and into a separate category 'cliffs' based on Sathyakumar (1994), and personal observations (Fig.2.4). These vegetation types are described as follows :

(1) Oak - Rhododendron forest (ORF) :

This forest community occurs in most parts of the study area above 2850 m altitude. The Brown oak (*Quercus semecarpifolia*), is the dominant tree species forming the upper canopy. On the other hand *Rhododendron arboreum* always grows in the shade of the oak forming the lower canopy. Other tree species present within this community are silver fir (*Abies pindrow*), Himalayan yew (*Taxus baccata*), and maples (*Acer* spp.). The understorey consists of montane bamboo (*Thamnocalamus spathiflorus*), thickets which are very dense in undisturbed gullies or along the forest streams. Some of the shrub species seen in this community are *Berberis aristata, Rosa macrophylla, Viburnum nervosum* and *Cotoneaster acuminatus.* Leaf litter is present extensively and wherever the canopy is open grass growth is high.

(2) Oak-Rhododendron degraded forest (ORD) :

This vegetation type is seen around the Shokharakh base camp (3000 m). It is similar to the Oak-Rhododendron Forest type but due to earlier human activities grassy patches or meadows have been created. The ground layer vegetation is dominated by the grass *Danthonia cachemyriana.* A large number of herb species were also present. But during the study period the shoot parts of these herbs were in the dormant stage and could not be identified.

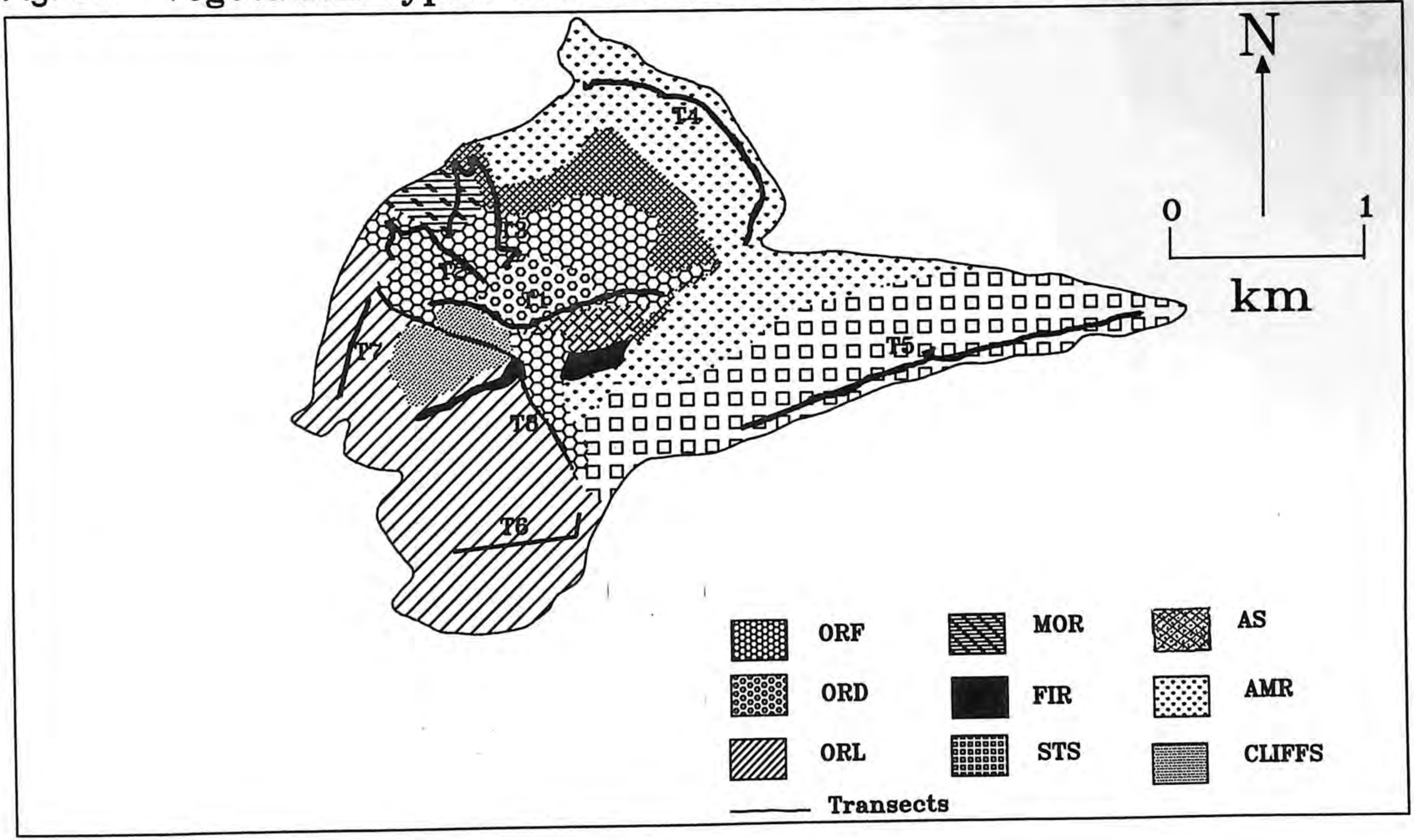
(3) Oak - Rhododendron- Lyonia forest (ORL) :

This vegetation type is similar to the ORF but occurs below 2850 m and along with oak and rhododendron another tree species *Lyonia ovalifolia* is present. Moru oak (*Quercus dilatata*), and alder (*Alnus nepalensis*), were seen growing here occasionally.

(4) Maple - Oak - Rhododendron forest (MOR) :

This association was seen between 3000 m - 3150 m altitudes. Such forest patches are more or less deciduous in nature. Maple (*Acer* spp.), was the dominant tree species in this community. Other tree species

Fig. 2.4 Vegetation types and location of transects in the study area



forming the association with MOR were horse chestnut (*Aesculus indica*), *Syringa emodi*, *Euonymus tingens*, and wild apple (*Sorbus lanata*). The shrub layer was dominated by *Viburnum nervosum*. The terrain was mostly broken and numerous bamboo thickets were also present.

(5) Fir Forest (FIR) :

This vegetation type had pure stands of fir (*Abies pindrow*). Such stands occurred mostly on steep (>40°), northern and sheltered slopes. *Rhododendron arboreum* were seen growing among the fir and bamboo was abundant in this area.

(6) Scattered Tree and Scrub (STS) :

This vegetation type is found on the steep east facing slopes below 3200 m. It is characterised by a mixture of open grassy slopes dotted with scattered (<40% cover), oak, rhododendron and *Lyonia*. The vegetation at some places appears dense due to the presence of streams. The ground vegetation had high percentage of grasses and the terrain was normally broken and usually ended in a cliff.

(7) Sub-Alpine Scrub (AS) :

This vegetation type occurs between 3150 m - 3300 m altitudes. The vegetation was shrubby characterised by stunted trees of oak and *Rhododendron arboreum*. The shrubs seen in this habitat type were: *Rhododendron companulatum*, *Viburnum nervosum*, *Berberis* spp., *Rosa* spp., *Cotoneaster microphylla*. Numerous bamboo thickets (*Thamnoclamus spathiflorus*), were present. The terrain was normally broken and grass cover occurs in high percentage. *Danthonia cachemyriana* is the dominant grass seen. This vegetation type fringes the alpine meadows.

(8) Alpine Meadows and Rocks (AMR) :

This category occurs above 3300 m which is characterized by the absence of trees. The shrub layer has *Rhododendron lepidotum*, *Rhododendron anthopogon* and *Cotoneaster microphylla*. During the study period the herbs and shrubs were in a senescent stage. The evergreen herbs seen in this vegetation type were

Gaultheria nummularioides, G. trichophylla. High cover of *Danthonia cachemyriana* were noticed in this vegetation type.

Apart from the eight vegetation types mentioned above I classified cliffs into a separate habitat type.

(9) CLIFFS :

Cliffs are considered as unique habitats and were one of the prominent habitat type found within the study area. Stunted rhododendron (*Rhododendron arboreum*) and oak (*Quercus semecarpifolia*) were seen growing at a few places. Fir (*Abies pindrow*) were seen growing on the northern aspects of cliffs. Shrubs such as *Cotoneaster microphylla, C. acuminatus* and *Viburnum neruvosum* were present. *Danthonia cachemyriana* were present in high proportion.

2.5 Fauna :

About 210 species of birds and 32 mammalian species (excluding chiropterans), have been reported from Kedarnath WS (Green 1985 a, b; Sathyakumar, 1994). Apart from Monal pheasant, three other pheasants also occur within the PA, viz., white crested kalij (*Lophura leucomelana*), koklas pheasant (*Pucrasia macrolopha*), and cheer pheasant (*Catreus wallichii*). Kalij was commonly encountered in the lower altitudes outside the study area, and showed a high degree of altitudinal migration. Koklas pheasant was usually seen near the forest streams with very dense bamboo cover and it appears to show minor altitudinal migration. Cheer pheasant is rare in this PA, and its presence has been reported in the study area (Sathyakumar *et al.*, 1992 b; Rashid Raza and Meera Anna Oommen *per.comm.*). Other galliformes within the study area were snow partridge (*Lerwa lerwa*), Himalayan snowcock (*Tetraogallus himalayensis*), and common hill partridge (*Arborophila torqueola*).

Golden eagle (*Aquila chrysaetos*), was regularly sighted in the study area, and two unsuccessful attempts by them to prey on monal were observed. A pair of Himalayan yellow-throated marten (*Martes flavigula*), was also observed making an unsuccessful attempt to prey on monal.

2.6 Human dependence :

About 182 villages are situated in and around this PA, of which about 50 are located in the best wildlife habitats inside the sanctuary (Sathyakumar, 1994). Livestock grazing and agriculture are the major occupation of the local people. Unregulated bamboo cutting, and grazing by migratory livestock during summer pose major threats to the wildlife habitats (Sathyakumar *et al.* 1992 a). Every year large number of pilgrims visit the famous Hindu shrine at Kedarnath situated inside this PA.

3. METHODS

The study was conducted between November 1996 and April 1997. The intensive study area was visited during spring & summer of 1996 for a brief reconnaissance. The following were the field and analytical methods adopted for the study.

3.1 Quantification of habitat parameters :

The broad vegetation categories were plotted on an enlarged map of the study area (scale: 5.4 cm = 1 km). The area of each vegetation category was calculated using a one mm^2 grid graph overlaid on the vegetation map. This was converted into proportions and was used in the availability - utilization analysis method of Neu *et al.* (1974). To quantify availability existing trails and paths were used as transects since it was not feasible to lay the transects in random or desired direction due to terrain features. In all eight trails/transects with varying lengths (0.5 to 2 km) were selected passing through different vegetation types except the fir forest since this habitat was not accessible (Table 4.1). Quantification of availability was repeated for the three seasons (autumn, winter and spring), since the ground cover changed during these seasons mainly due to snow.

Ten metre radius plots were laid at every 100 m interval along the transects. The plots were laid 25 m away from the trail on either side of the transect alternately following Marcum & Loftsgaarden, (1980) and Riney, (1982). In all 108 plots were laid covering all the vegetation types except the fir forest.

Within each plot the broad vegetation type was recorded and the following habitat variables were recorded : Tree species, their number, height were recorded and the canopy cover was visually estimated by looking at the projection of the canopy on the ground within the 10m radius plot. At higher altitude (>2800 m), the brown oak (*Quercus semecarpifolia*), usually forms the upper canopy and rhododendron (*Rhododendron arboreum*), forms the lower canopy. Their canopy cover were recorded separately keeping in view that structural features of the vegetation could play a role in monal habitat use.

The shrub layer was also quantified in a similar way as done for tree species within the 10 m plots. The shrub species, number, height and phenology (leafless, sprouting, flowering, fruiting), were recorded. Bamboo, if present within the plot, was recorded in terms of per cent cover. Presence of bamboo in an area could act as an escape cover for monal.

Since monal is a ground dwelling bird the ground cover could play a major role in its habitat use. Keeping this in view the ground cover variables were visually estimated within the 10 m plot. The plot was visually divided into four quarters and in each quarter the following variables were estimated: percentage cover of grass, herb, litter, bare ground, rock, and snow. The litter depth, snow depth and grass height were also recorded. Estimation of these variables was not done in a much finer scale because of the difficult working conditions during snowfall and limitations of time.

The other habitat variables such as altitude, aspect and slope were also recorded. The slope was measured using a hand made equipment as done by Bhatt (1993). A protracter was fixed to a rectangular cardboard and at the base of the protracter a hole was made. To this a thread with weight attached was tied. While measuring the slope the equipment is held in such a way that the protracter is upside down and the thread with the weight acting as a pendulum. A sunnto compass was used to record the aspect. The terrain was qualitatively recorded as smooth, broken and very broken.

For quantification of utilization the trails were walked two times each in December, January and February, and three times each in March and April. The alpine meadow area could not be walked during February due to heavy snow. But these areas were scanned regularly for monal presence using vantage points. Vantage points were also used in case of the fir forest to look for monal presence and activities. All transects were walked only in the mornings after 8:00 a.m. At every monal sighting (i.e, focal bird plots) the habitat variables were quantified as done for availability. A few sightings were very far from the trail (> 100 m), and in some cases due to inaccessible terrain, the habitat variables were recorded using a 7x35 binoculars. Sex and the number of individuals at every sighting were recorded and this was later used for group size and group composition analysis.

The visibility differed in different vegetation types and because of which serious biases can creep in if care is not taken regarding unequal visibility in habitat use studies (Trivedi, 1993). During this study monal were seen mostly in dense vegetation types which had an average visibility of 30 to 40 m. On very few occasions monal were seen in open areas for e.g., alpine meadows where the average visibility was more than 200 m. If monal were randomly distributed all over the study area, then the probability of sighting monal in the open areas would be more when compared to dense areas. Monal being a very sensitive bird often flushed at large distances. But this did not create a major problem during this study and keeping this in view the effort in sampling the different areas did not vary much.

3.2 Data analysis:

Habitat selection was evaluated by comparing the available habitats (availability), with number of observations of birds seen in each habitat (utilization). Many methods have been described for analysing availability-utilization of habitat (e.g. Friedmann, 1937; Neu *et al.*, 1974; Quade, 1979; Johnson, 1980; Marcum & Loftsgarden, 1980; Byers *et al.*, 1984). Sampling level, non independence of habitat proportions, differential habitat use by groups of animals, and arbitrary definition of habitat are major problems faced in habitat use analysis (Aebischer *et al.*, 1993). Compositional analysis have been used in recent years for analysing habitat utilization (Dowell *et al.*, 1992; Aebischer *et al.*, 1993; Baines, 1994). In this study due to certain limitations methods based on log-ratio analysis of composition could not be done. Therefore, Neu *et al.* (1974), technique was used to compare availability-utilization based on the number of sightings in each vegetation type. A computer programme PREFER 3 (Prasad & Gupta, 1992), was used to calculate bonferroni confidence intervals and significance for difference in the vegetation type use.

Analysing habitat variables using univariate statistics is perhaps far less "realistic" than analysing an array of variables simultaneously (Block and Brennan, 1993). The presence of a bird or an animal in a particular habitat may be influenced by several variables acting together than a single variable. Keeping this in view the habitat variables recorded were used in the Factor analysis, which identifies a relatively small number of factors that can be used to represent relationships among sets of many interrelated variables (Norusis 1990). Later a logistic regression analysis was done using the extracted factor scores from the factor analysis to estimate the probability of correct classification of random and monal observed plots. Non parametric Mann-Whitney U test was also done to see whether there was any difference in availability and utilization of the variables by monal. Other calculations and appropriate nonparametric statistical tests (as given by Sokal & Rohlf, 1995; Zarr, 1984) were carried out manually as well as by using Software package SPSS (Norusis, 1990), for Windows Release 6.0.

Table 3.1 : SALIENT FEATURES OF THE TRANSECTS

TRANSECT	LENGTH (km)	** VEGETATION TYPE	* ALTITUDE(m)
T1	1.0	ORF, ORD, AS, CLIFFS.	2975 - 3200
T2	1.0	ORF	2835 - 3025
T3	1.5	ORD,ORF, MOR, AS	3050 - 3150
T4	1.5	AS, AMR	3200 - 3500
T5	2.0	STS	2600 - 2750
T6	1.0	ORL	2450 - 2750
T7	0.5	ORL	2500 - 2800
T8	1.5	0RF, ORL, CLIFFS	2850 - 2835

** Changes in the vegetation type along the transect.
* The altitudes covered on each transect.

4. RESULTS

4.1 Habitat selection :

Habitat selection refers to the selection of different vegetation types in this study. In all there were 136 sightings of monal from the transects.

Monal did not use certain vegetation types during the study period. Vegetation types such as MOR, FIR, AS, AMR and CLIFF in autumn; FIR and AMR in winter; and ORL, AS and AMR in spring were not used by monal in the respective seasons and hence were not used in the analysis.

The following were the main findings :

1. The results of the availability and utilization analysis using Neu *et al.* (1974), technique showed that monal used Oak-Rhododendron Forest (ORF) more than its availability across all the seasons.
2. During autumn, the ORF vegetation type was used more than available, ORL and STS were used less than available while there was no significant trend in ORD (Table 4.1).
3. During winter, ORF was used more than available, ORL, STS and AS were used less than available While use of cliffs and ORD were not significant at $P<0.05$ (Table 4.2).
4. During spring, ORF was used more than available and the use of the rest were not significant at $P<0.05$ (Table 4.3).

Table 4.1 : Availablity-utilization of different vegetation types by monal pheasant in Kedarnath WS during autumn (December 96), (N=21).

HABITAT	RELATIVE AREA (Km^2)	EXPECTED USAGE	OBSERVED USAGE	CONFIDENCE INTERVALS
ORF	0.129	2.709	14	0.409 - 0.924**
ORD	0.028	0.588	3	0.000 - 0.334
ORL	0.279	5.229	1	0.000 - 0.164 *
STS	0.227	4.767	3	0.000 - 0.334 *

$X^2 = 61.029$

** - used more than available.

* - used less than available.

Rest were not significant at P= 0.05 level.

Table 4.2 : Availablity - utilization of different vegetation types by monal pheasant in Kedarnath WS during winter (January 97 to March 97), (N=78)

HABITAT	RELATIVE AREA (Km^2)	EXPECTED USAGE	OBSERVED USAGE	CONFIDENCE INTERVALS
ORF	0.129	10.062	46	0.440 - 0.740**
ORD	0.028	2.184	5	0.000 - 0.139
ORL	0.249	19.422	5	0.000 - 0.139*
MOR	0.018	1.404	7	0.003 - 0.177
STS	0.227	17.706	9	0.018 - 0.213*
AS	0.061	4.758	1	0.000 - 0.047*
CLIFF	0.060	4.680	5	0.000 - 0.139

$X^2 = 172.273$

** - used more than available.

* - used less than available.

Rest were not significant at P= 0.05 level.

Table 4.3 : Availablity-utilization of different vegetation types by monal pheasant in Kedarnath WS during spring (April 97), (N=37).

HABITAT	RELATIVE AREA (Km^2)	EXPECTED USAGE	OBSERVED USAGE	CONFIDENCE INTERVALS
ORF	0.129	4.773	17	0.243 - 0.676**
ORD	0.028	1.036	6	0.002 -0.322
MOR	0.018	0.666	3	0.000 - 0.200
FIR	0.011	0.407	1	0.000 - 0.097
STS	0.227	8.3997	5	0.000 - 0.284
CLIFF	0.060	2.220	5	0.000 - 0.284

$X^2 = 69.007$

** - used more than available

Rest were not significant at P= 0.05 level.

4.2 Habitat Use :

The multivariate technique Factor analysis was used to reduce the dimensionality of the habitat variables and this were done separately for each of the three seasons i.e., autumn, winter and spring. The factors were extracted using Principal component analysis. The number of factors extracted for autumn were four, winter five and spring four. Only the first two factor scores were used for the three seasons since they contributed to the maximum percent variation in the data set.

<u>Autumn</u> :

The two factors accounted for 48.6% of the variation in the habitat variables data set. The first factor was highly positively correlated with tree density, tree height, upper and lower canopy, and negatively correlated with herb cover and grass height. The second factor was highly correlated with litter cover and negatively correlated with rock cover. The two factor represented wooded or forested habitat typical of temperate forests with high litter cover. The random and monal observed plots were plotted against factor 1 and factor 2 scores (Fig. 4.1). The figure showed that during autumn monal used forested areas which had higher tree density, higher tree height, higher upper and lower canopy cover with high litter cover. The logistic regression model had an efficiency of 96.09 % correct classification of random and monal observed plots based on the first and second factor scores (see Appendix - 1). The factor scores were also tested using Mann-Whitney U test to see whether there was any difference in the use of random plots (availability) and monal observed plots (utilization). They first two factors were significant suggesting that there was significant difference in the use of habitat variables in the random and monal observed plots (factor 1: U= 648, 2-tailed P=0.0046), and (factor 2: U=43, 2-tailed P=0.0000).

<u>Winter</u> :

The first two factors accounted for 45% of the variation in the data set. The first factor was again highly correlated with tree density, tree height, upper and lower canopy and was negatively correlated with altitude. The second factor was highly correlated with litter cover, litter depth. The two factors represented the wooded or forested areas with high litter cover. With an increase in ~~altitude the~~ tree density, tree height and canopy cover variables decreases. During winter with increase in altitude there is an increase in snow cover, snow depth and decrease in litter cover. The random plots and monal observed plots were plotted against factor 1 and factor 2 scores (Fig. 4.2). The figure clearly shows that monal were using areas high tree density, tree height, higher upper and lower canopy cover with moderate to higher litter cover and litter depth. The logistic regression model had an efficiency of 88.59 % correct classification of random and monal observed plots based on the following factor scores (factor 1, factor 2, factor 3 and factor 5) (see Appendix - 2). The factor scores were also tested using Mann-Whitney U test to see whether there was any difference in the use of habitat variables in the random and monal obseved plots. The use of the second, third and fifth factor showed significant difference in the use of habitat variables in the random and monal observed plots (Factor 2: U=1312.0, 2-tailed P=0.0000; Factor 3: U=2219, 2-tailed P=0.0000; Factor 5: U=3322, 2-tailed P=0.0279). The factor 3 and factor 5 represented rockiness and bare ground respectively (see Appendix - 1).

Spring :

The first two factors accounted for 52.9% of the variation in the data set. The first factor was highly correlated with higher tree density, higher tree height and higher upper and lower canopy covertree density, tree height,. The second factor was highly correlated with herb cover, rock cover, litter depth and was negatively correlated with snow, snow depth and altitude. Due to the presence of snow in the higher reaches there is very less exposed ground or rock cover. In areas with high rock cover the presence of litter and high litter depth is less. But in factor 2 litter depth, herb and grass height are highly correlated along with rock cover, this may be because in some areas with good tree cover there was also high percent rock cover and because of the presence of trees there was high litter and inturn high litter depth. The first factor represents the wooded areas. The random and monal observed plots were plotted against factor 1 and factor 2 (Fig. 4.3). During spring monal were using rocky areas such as cliffs and also forested or wooded areas with high rock cover. The males used to sit on rock outcrops along the cliffs and display. Some monal continued to use the forested areas. They also started to move to the higher reaches and there they were using rocky areas. But due to the irregular occurence of snowfall and when there was heavy snowfall monal used to move back into the wooded or forested areas. The logistic regression model had an efficiency of 87.32 % correct classification

Fig. 4.1 Ordination of available and utilized plots by monal during autumn on the principal component axes.

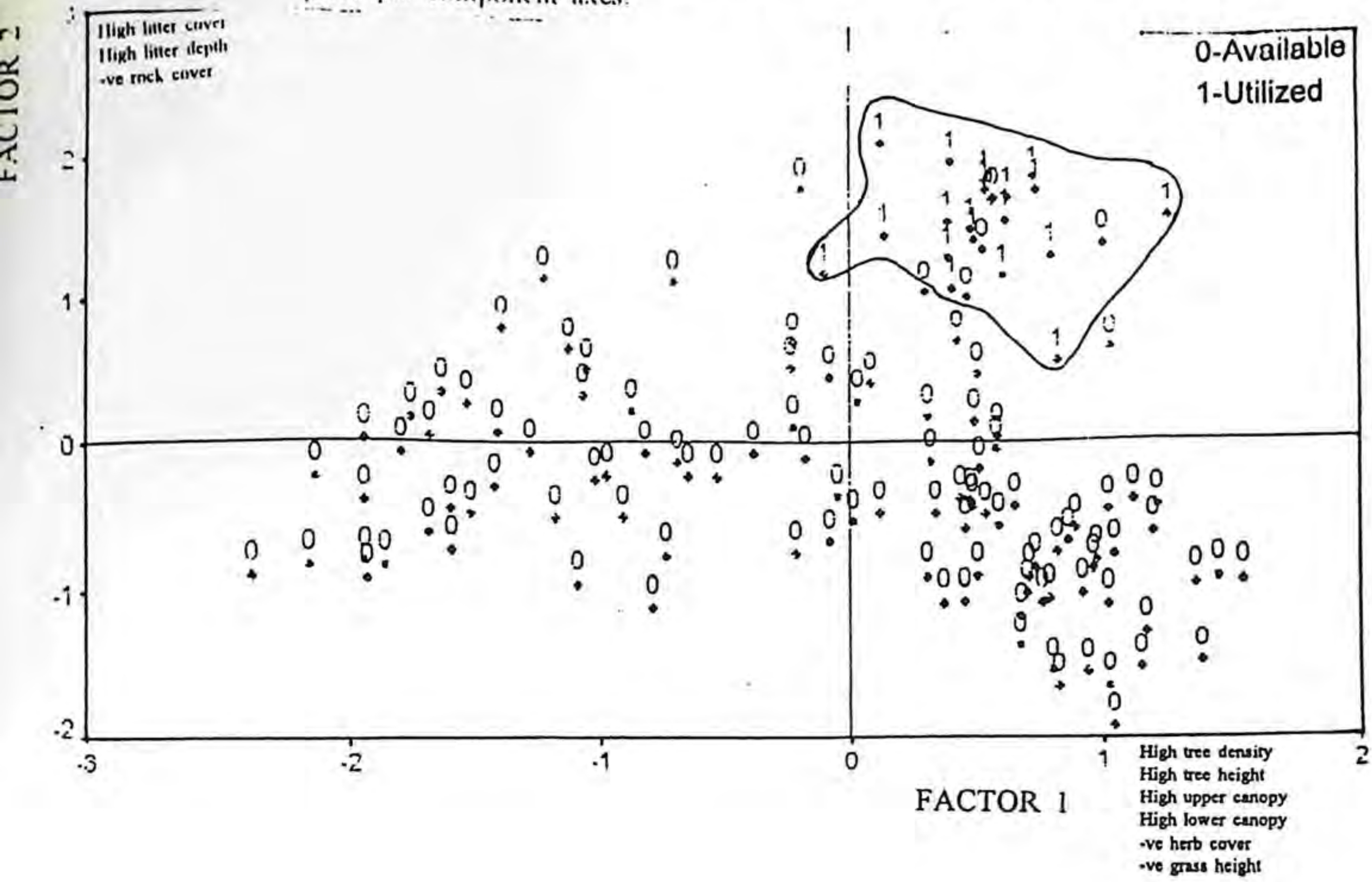


Fig. 4.2 Ordination of available and utilized plots by monal during winter on the principal component axes.

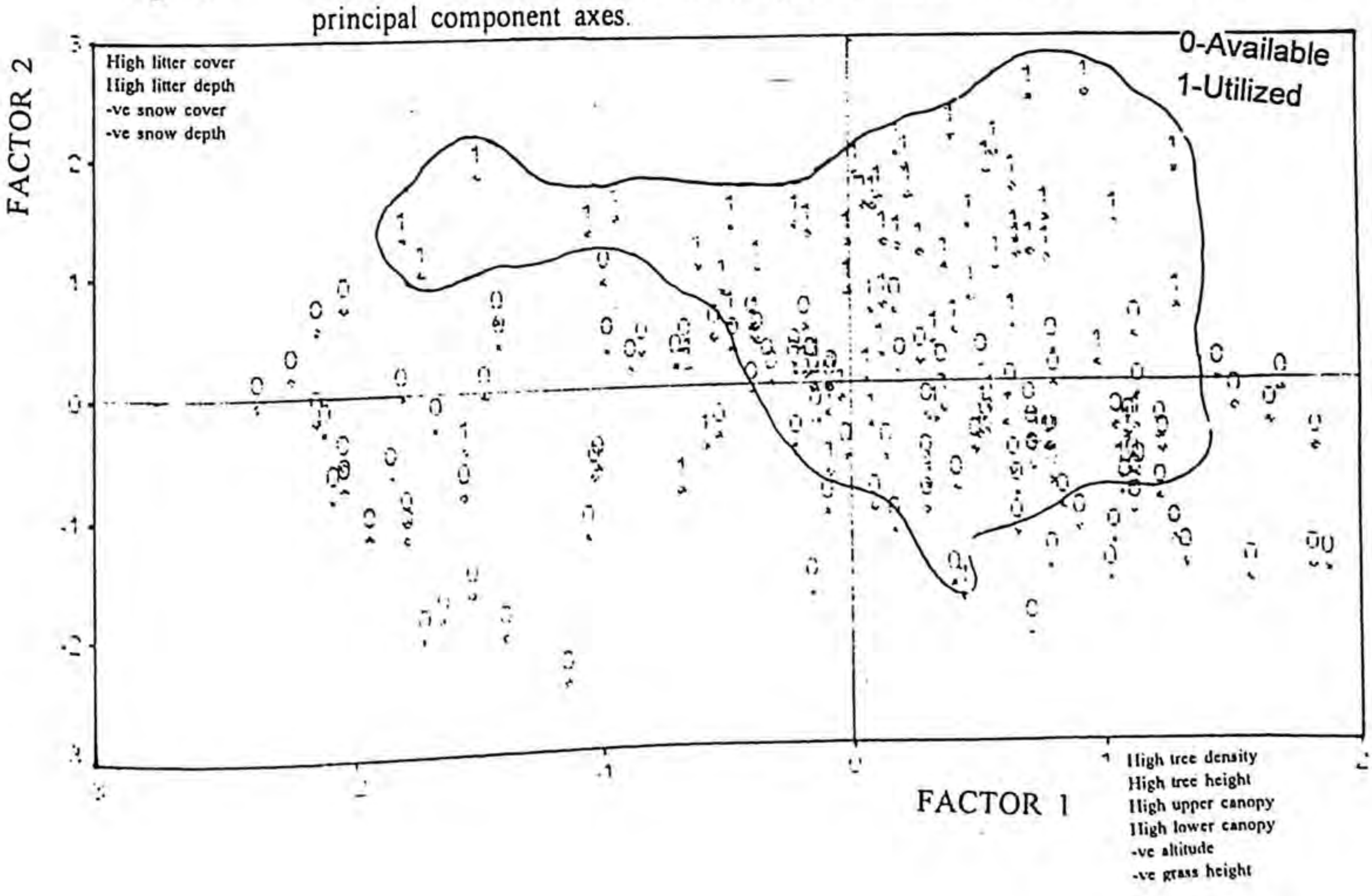
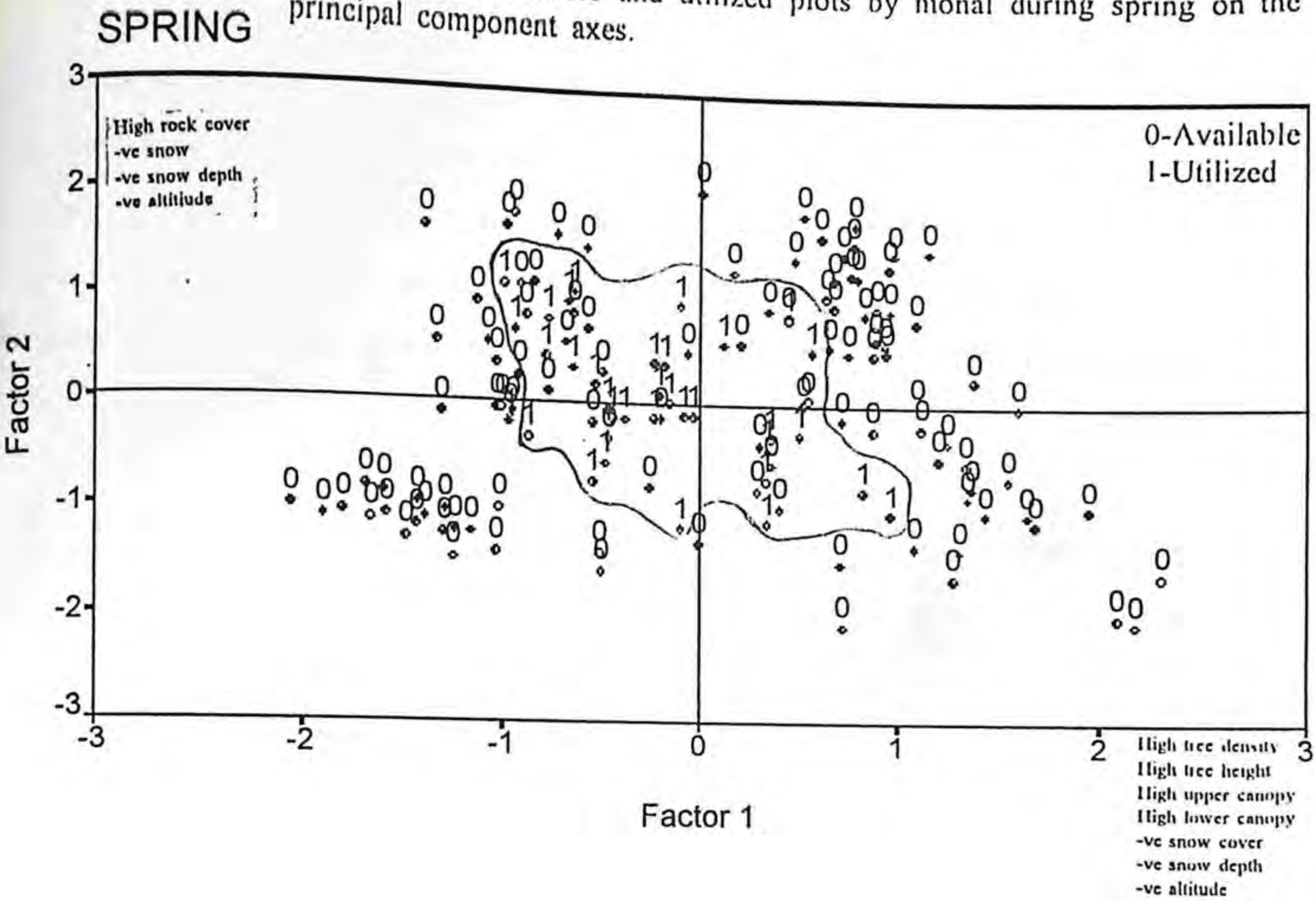


Fig. 4.3 Ordination of available and utilized plots by monal during spring on the principal component axes.



of random and monal observed plots based on the following factors (factor 3 and factor 4), (see Appendix - 2). The factor scores were also tested using Mann-Whitney U test to see whether there was any difference in the use of habitat variables in the random and monal observed plots. There was no significant difference in the use of habitat variables available and utilized (factor 3: U=374, 2-tailed P=0.000) and (factor 4: U=1281, 2-tailed P=0.0080). Factor 3 and factor 4 represented litter cover and slope respectively (see Appendix - 1).

4.3 Use of altitude, aspect and terrain :

During autumn, monal were seen mostly between 2900 m and 3100 m. About 73.8 % of the individuals (N=42) were recorded between these altitudes. During winter a slight shift in the use of altitude was noticed (see increased bar height for winter at 2800 m in fig 4.4). About 74.4% of the individuals (N=177) were seen between 2900 m and 3100 m. During spring, monal showed an upward trend in the use of altitude. They were mostly seen between 3000 m and 3100 m, and about 449.1 % of the individuals (N=57) were observed between these altitudes. The use of altitude by monal in different seasons is shown in Fig. 4.4.

The study area was mostly south facing and most of the individuals were seen using the southern aspect. The percent number of individual monal seen during autumn, winter and spring in the southern aspect were 64.3 %, 41.8 % and 52.6 % respectively (see Fig. 4.5)

The terrain was classified into smooth, broken and very broken based on the ruggedness. During autumn, most of the individuals (80.9 %) occurred in smooth terrain. In winter monal used both broken and smooth terrain. 44.6 % of the individuals occurred in smooth terrain and 42.4 % of the individuals occured in broken terrain. During spring, monal started to use very broken terrain. About 43.8 % of the individuals occurred in this category (Fig. 4.6).

Fig 4.4: Use of altitude by monal in the study area.

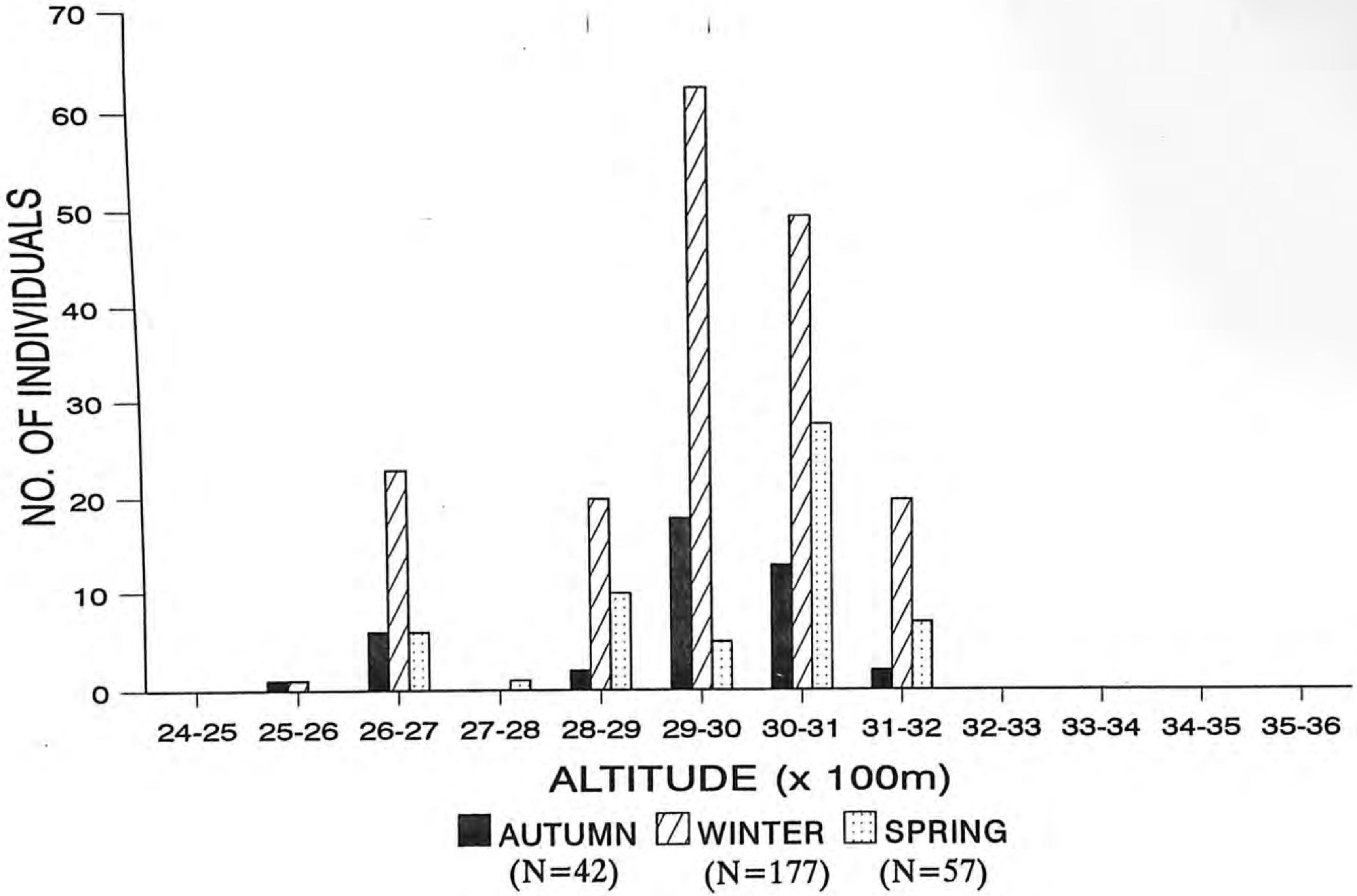


Fig.4.5: Use of aspect by monal in the study area.

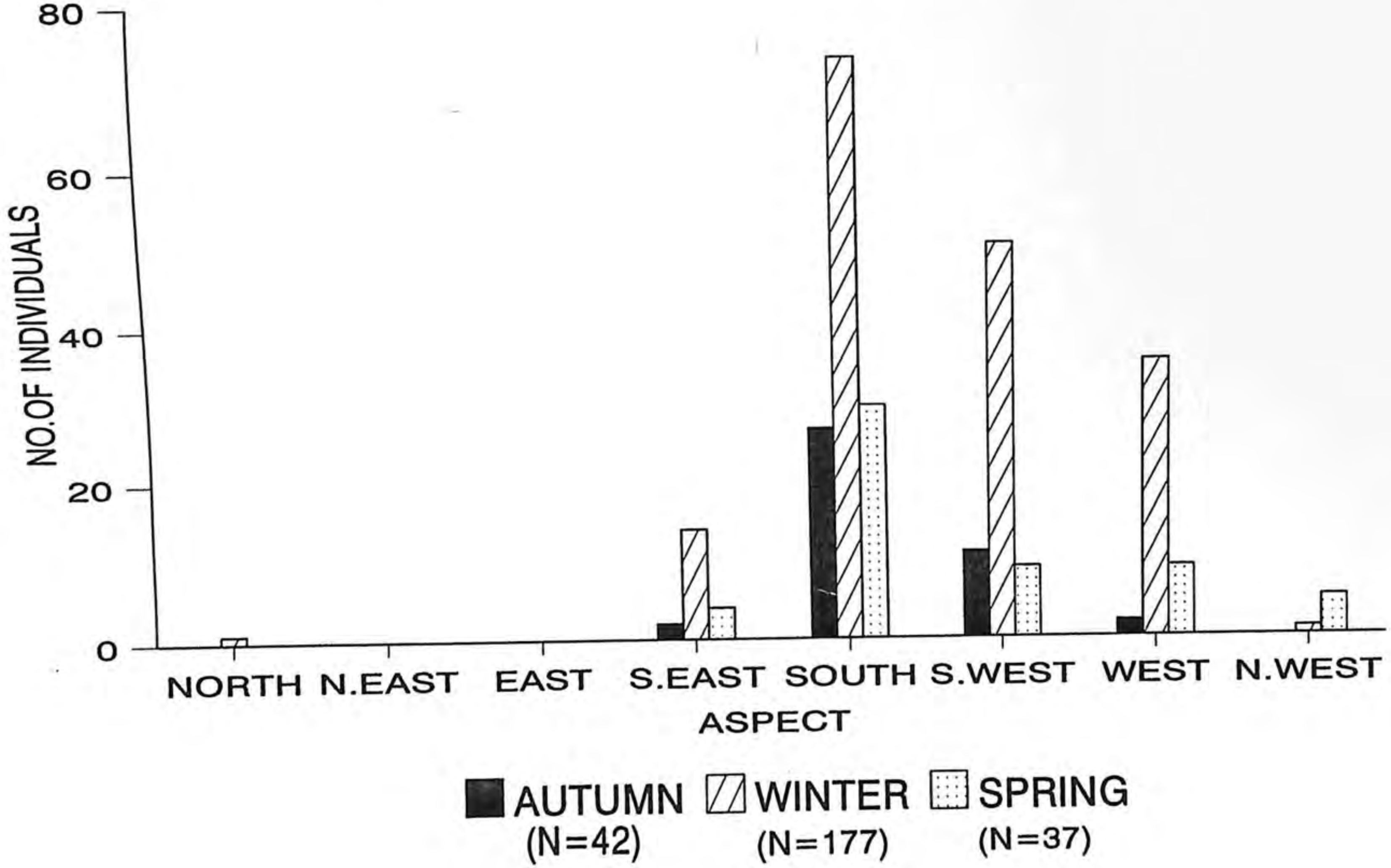
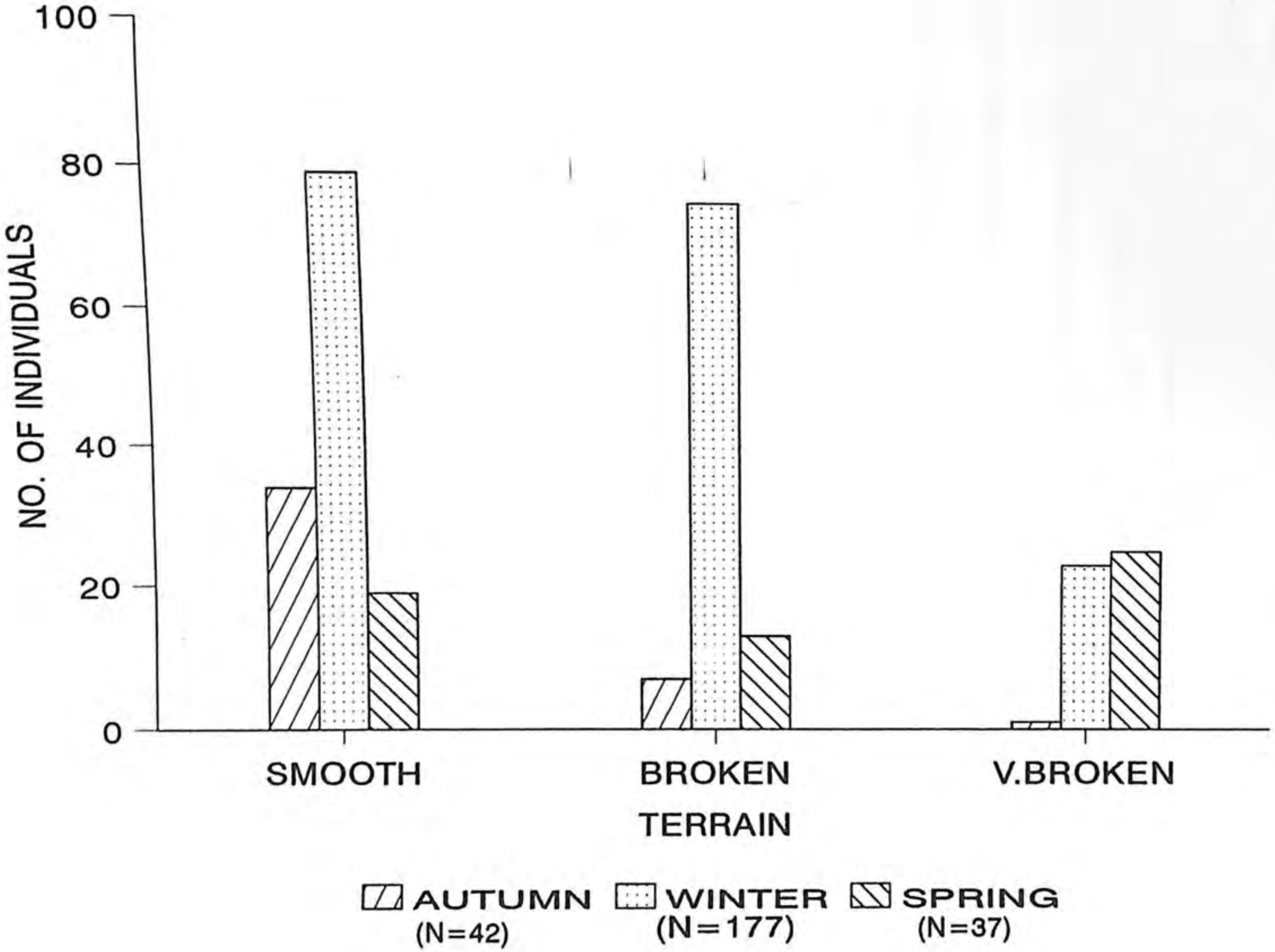


Fig.4.6: Use of terrain by monal in the study area



4.4 Group size and composition :

The difference in group sizes across the three seasons was tested using Kruskal-Wallis Chi-square approximation. The group sizes were not found to be different ($X^2 = 0.41$, df= 2, P=0.81).

Table 4.4 : Group size of monal in Kedarnath WS.

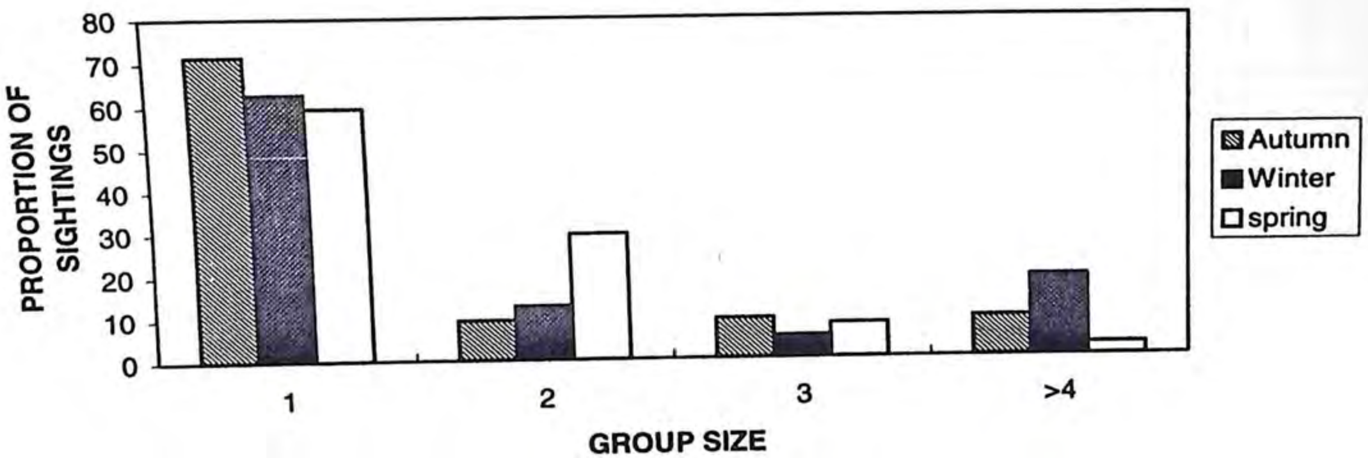
SEASON	AUTUMN	WINTER	SPRING	OVERALL
GROUPS	21	78	37	136
MEAN	2	2.3	1.5	2.0
S.E	0.50	0.27	0.13	0.18
95 % C.I	± 0.98	± 0.52	± 0.25	± 0.35

The groups seen in each season were classified into four categories : single, two, three and four or more than four based on number of individuals seen in each group. These groups were tested using Contingency table to see whether they differed across the seasons. It was found that the groups differed across the seasons ($X^2 = 11.41$, df=6, P< 0.1).

Table 4.5 : Group composition of monal in Kedarnath WS.

Season	Group types (%)				
	Solitary	Two	Three	> Four	N
Autumn	71.4	9.5	9.5	9.5	21
Winter	62.8	12.8	5.2	19.2	78
Spring	59.5	29.7	8.1	2.7	37
				Total	136

FIG. 4.4. GROUP COMPOSITION OF MONAL ACROSS SEASONS IN KEDARNATH WS.



The male to female sex ratio across the seasons is given in Table 4.6. The hypothesis that male to female ratio was equal was tested using test for proportions (Zarr, 1984). It was found that that the ratios were equal (X^2 = 0.25, df=2, P>0.80).

Table 4.6 : Sex ratio of monal in Kedarnath WS.

Sex	Autumn	Winter	Spring	Total
Male	15	77	25	117
Female	20	81	28	129
Total	35	158	53	246
Sex ratio	1:1.33	1:1.05	1:1.12	1:1.10

5. DISCUSSION

The higher reaches on the mountains are characterised by severe climatic conditions. This is partly due to the direct effect of altitude (Mani, 1981). During winter the high altitude regions become snow bound and food, an important life requisite becomes scarce or inaccessible. Most of the birds migrate to lower latitudes to escape the harsh winter while some continue to stay showing slight altitudinal movements and tend to choose particular habitats (Dorst, 1974). The choice of a habitat is a key aspect in the ecology and survival of pheasants during winter (Hill and Robertson, 1988). Many factors collectively play a role in the choice of a habitat by a bird (Cody, 1985).

5.1 Habitat use :

Disproportional use of a habitat is an indication whether a habitat is used more than available (preferred) or used less than available (avoided). Such a disproportional use or preference of a particular vegetation type was observed in monal during this study. They showed a high preference for well wooded areas especially the Oak-Rhododendron forest. They preferred this vegetation type when compared to the other types across all the three seasons. About 66.7% of the sightings occurred in ORF during autumn, 59 % during winter and 45.9 % during spring. A gradual decrease in the use of the ORF is observed along with change in season. *Phasianus colchicus* were reported to spend most of the winter in woodlands but also showed seasonal changes in habitat selection (Robertson, 1992). After reducing the habitat variables by a PCA, the logistic regression was able to successfully classify habitat plots for monal presence or absence from PCA factor scores. This suggests that the habitat parameters measured during this study were also the ones influencing monal use of an area. Also monal use of an area was not random and there was a definite preference, since the logistic regression was able to differentiate random plots from those in which monal were sighted.

During autumn, distribution of monal was clumped. They were mainly confined to the Oak-Rhododendron forest (ORF), between 2900 m and 3100 m altitude, 67% of the sightings occurred within this altitude range (n=21). This vegetation type occurred mainly on the southern aspect. Monal are reported to choose protected raised ledges on south or south-eastern slopes of steep cliffs or outjutting masses of boulders for their roosting sites (Beebe, 1918-1922). During this study monal were observed roosting on very high oak trees (15 m) in the ORF. Autumn being the dry and cold period of the year, water became scarce and most of the streams dry up. Monal were observed mostly close to water with high bamboo cover and it appears that water could be a limiting factor influencing monal habitat use. On a few occasions monal were observed digging wet soil and drinking the water seeping out. Bamboo cover could act as an escape cover for monal. Due to the dense canopy in this vegetation type the ground was covered with deep litter which is typical of the temperate broad-leaf forests (Singh & Singh 1987). Monal were often observed digging in the litter and digging signs were also common in the litter. They were mainly looking for underground fleshy roots and tubers. Some of the roots and tubers that monal were probably feeding were: *Gaultheria nummularioides, Anislaea latifolia, Satyrium nepalense, Taraxacum officinale* and *Roscoea alpina.* Identification of other species on which they fed was not possible as most of the species were in a senescent stage. Monal have been reported to feed on roots and tubers of herbaceous plants such as *Meconopsis paniculata* and *Arundinaria* spp., grass roots and mosses. They fed on the mosses *Rhacomitrium crispulum* and *Bryum* spp., and possibly insects and grubs (Yonzon & Lelliot, 1981). Feeding was the major activity observed during this season. Birds living in the higher altitudes tend to accumulate fat reserves in their body before winter so as to withstand the severe weather conditions (Dorst, 1974). Thus need for food as well as for water could be a very important factor influencing monal habitat use. Most other sightings of monal occurred between 2800 m and 2900 m altitude in similar Oak-Rhododendron forests. Monal were often seen getting flushed to the fir forest which were present on a north, north-western slopes and between an altitude of 2900 m to 3200 m adjacent to the ORF. But monal were never observed to stay in this forest for long and would soon be seen flying back to the ORF. It appeared that monal were mainly using the fir forest as an escape cover. Monal were also seen in the scattered tree and scrub vegetation type which occurred on the eastern ridge area. But due to the rugged terrain only a part of this ridge was walked. Monal in this area were always seen between 2600m and 2700m altitude. Only three birds (a male and two females) were seen in this area and they were the only birds flushed whenever the transects were walked. Monal used dense forested areas on this ridge which could be due to the presence of water. This area being rugged with cliffs proved to be a good escape terrain. Monal would often flush to the left or right along the cliff. But this vegetation type when compared with the ORF regarding the usage by monal clearly shows that monal prefer dense areas with high percentage of litter and bamboo cover. The Common pheasant is also reported to use sheltered habitats such as covert and woodlands to avoid the rigours of harsh winter weather (Hill & Robertson, 1988).

Winter is a crucial period in the life of birds living in the high altitudes and the presence of snow makes the food inaccessible and the ground dwelling birds are forced to move down to lower altitudes (Dorst, 1974). A slight shift in the altitudinal use by monal was noticed during start of February. Thereafter they were seen mostly between 2800 m and 3100 m altitude till end of March. Monal are reported to move down to 2400 m during winter in Himachal Pradesh (Gaston *et al.*, 1981). It appears that their movement is mainly influenced by the severity of the weather. Snowfall occurred very late during the present study and the snow did not remain on the ground for long. Monal continued to use the ORF during peak winter. There was no difference in use of the other areas. The maple forest was also used but only close to ORF. Gaston *et al.* (1981), found monal using various forest types including pine and fir during winter in Himachal Pradesh. Roberts (1991), found that monal dig in quite deep snow and do not descend in winter below the snow line. However, during this study, digging signs of monal were seen mainly in snow free patches at the base of trees as well as in shallow snow (10-15 cm deep). It is expected that if the winter had been very severe a significant shift in use of altitude and vegetation type may have occurred. Monal were often observed using cliffs close to the ORF and cliffs provided favourable launching sites. Snow remained on these cliffs for a short while and monal were observed using these cliffs during the snowfall.

Towards late winter and early spring, shift in the use of vegetation types by monal were observed. The snow in the upper reaches had almost melted. Monal began to use the Oak-Rhododendron degraded forest (ORD), and cliffs between 3000 m to 3200 m altitude. But some monal continued to use the ORF vegetation type. Males would often stand on rock outcrops and display to the females feeding below. Most of the sightings occurred close to the cliffs. During mid April gradual movement of monal to the higher reaches i.e., to the alpine meadows and rocks (AMR) and alpine scrub (AS) were noticed.

5.2 Group size and composition:

Living in groups is considered advantageous since it enables the animals to find food more easily because less time is spent on scanning. The improved vigilance gained by individuals in a flock also means that more time can be spent in feeding (Caraco *et al.*, 1980; Krebs & Davies, 1993; Hill & Robertson, 1988; Reyonlds *et al.*, 1988). In case of monal, flocks are reported to form only during winter, when the birds are forced into restricted habitats (Beebe, 1918-1922). During winter food becomes a scarce resource and with very low temperatures prevailing conservation of energy becomes a nessecity. Expenditure of this energy in other activities like maintaining territories during winter would be a very expensive process. Caraco *et al.* (1980), observed that yellow eyed Junco formed flocks containing an average of seven birds at 2°C, and at 10°C the flock contained only two birds. The mean group size of monal did not vary significantly across the seasons. But my observations suggest that during autumn monal pheasants appeared to form loose groups. Females appeared gregarious forming small groups, while males remained more or less solitary. The female groups appeared very mobile, whereas males were often seen on the same or near by spot from where they were flushed earlier. This suggests that they were more parochial. After the first snow, temporary but distinct group formations were seen. An all-male group of seven or eight individuals, all-female groups of 10 to 12 individuals, mixed groups, and solitary males were seen. This sort of group formation has also been reported by Hill & Robertson (1988), from their study on the Common pheasant. The all female groups would at times be joined by one or two males. The all male groups were only seen between 3000 m to 3100 m. They were using areas with high snow cover. Groups of three or four males are reported to associate during the non-breeding season (Baker, 1930). Males tend to group only during periods of snowfall. Males due to their conspicous plumage would easiy be spotted by a predator in snow. Thus males tend to flock together probably to avoid predation. Monal is reported to be a possible prey of martens, red fox (*Vulpes vulpes*) and raptors in the study area (Sathyakumar *et al.*, 1992 a). During this study remains of monal were seen four times. It appeared that they were killed by some raptor. Two attempts by golden eagle to prey on monal were observed and on one occasion two martens were seen chasing female monal. This indicated that predators probably played a role in determining the habitat use as well as group composition in monal in the study area. Females remained in groups throughout the study period, while the males remained in groups only for a short span. Monal started to move to the higher reaches during late March, and from then on, solitary males were quite often encountered. The females were observed solitary or in small groups. The courtship display by a male was first observed during January. But the display intensity increased only during spring. Towards middle of April the males had started to show territoriality and aggressive behaviour against other males were observed. Gaston *et al.* (1982), found that males moved to the higher and open areas during spring which suggests some territoriality. The data from the transects when tested for sex-ratio showed that they were equal. But from my observations and *ad libitum* sightings it indicates that it could be just a statistical artifact. During the entire study immature birds could not be differentiated from the adults. The immature males are reported to attain their adult plumage in the second year, before which they appear similar to adult females except for some small differences. The immature males are said to be larger than the adult females, with some black spots on the throat and occasionally irredescent feathers on the underparts (Delacour, 1977; Keith Howmann *pers. comm.*). This difficulty in identifying the sexes correctly could be responsible for the obtained sex ratio. Sex ratio of monal across seasons in Kedarnath WS has been reported to be 1:1 (Sathyakumar *et al.*, 1992 a). While male : female sex ratio of Chinese monal has been reported to be 1:1.08 and 1.25:1 (Lu Tai-Chun *et al.*, 1986).

This study has shown that Oak-Rhododendron Forest with dense bamboo cover is an important vegetation type for survival of monal during winter in the study area. Exploitation of bamboo from the high altitude ORF may have negative impact on this preferred habitat by monal. On the other hand, impact of summer livestock grazing in these areas on food availability to monal during winter is not known. Sathyakumar (*in press*) has reported that disturbances in the form of large scale trekking, mountaineering and loss of wildlife habitats due to human activities WS have resulted in absence or low numbers of monal in certain areas within Govind WS. Monal has been reported to withstand a certain level of disturbance due to human activity in some areas in GHNP, Himachal Pradesh (Gaston & Garson, 1992). In the present study area and during study period there was very little human disturbance.

For the conservation of Himalayan monal and associated species such as Koklas and Himalayan musk deer (*Moschus chrysogastus*), it would be important to set aside large undisturbed areas of high altitude Oak-Rhododendron Forests.

6. CONCLUSION

Monal showed differences in habitat use across the seasons. They mainly preferred the Oak-Rhododendron forest between 2800 m and 3100 m altitude during autumn and winter. Alpine meadows and rocks, alpine scrub and other vegetation types above 3200 m were avoided. South facing slopes were used more than the others and they preferred dense forested areas with high litter and bamboo cover. Dense forested areas provided protection from predation and shelter from the cold weather conditions during winter. Presence of cliffs close to the dense ORF could prove to be an ideal habitat for monal during winter. Monal used cliffs during days of heavy snow and also as an escape terrain. A shift in the vegetation type used were observed during spring. Arrival of spring marked the beginning of the breeding season in monal. Intensive courtship display by males and aggressive behaviour towards the other males were observed during this period. They were mainly using the cliffs and also had started to disperse to the higher altitudes. Mean group sizes across the seasons were found to be the same. But personal and *ad libitum* observations suggest that monal formed loose groups during autumn and distinct group formations during winter. Towards late spring monal were mostly seen in pairs. Identification of sex in immature birds was difficult and the male to female sex ratios were equal across the seasons.

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APPENDIX - 1

AUTUMN

Final Statistics:

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
ALTITUDE	.28321	*	1	4.85717	34.7	34.7
BAMBOOT	.78216	*	2	1.94305	13.9	48.6
G._HT	.66620	*	3	1.29064	9.2	57.8
GRASST	.73331	*	4	1.08009	7.7	65.5
HERBT	.82433	*				
L.CANYT	.47828	*				
L.DEPTH	.55318	*				
LITTERT	.87098	*				
OPENT	.56479	*				
ROCKT	.85544	*				
SLOPE	.44082	*				
TR.DEN	.67866	*				
TREE.HT	.76531	*				
U.CANYT	.67429	*				

Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4
HERBT	-.89168	-.14800		
TREE.HT	.83784	.14576		-.20148
TR.DEN	.80132	-.17577		
G._HT	-.79257	.12447		.14813
U.CANYT	.75790	-.22926	-.18680	-.11145
L.DEPTH	.69099	.21031	.17044	
L.CANYT	.63505	-.26104		
LITTERT	.19011	.91324		
ROCKT	.35173	-.85482		
GRASST			-.84554	
OPENT	.43570	.16365	.54876	.21688
ALTITUDE	-.36206		.37878	
BAMBOOT		.15137	.13581	-.85827
SLOPE	-.18431	.20252	.22283	.56230

WINTER

Final Statistics:

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
		*				
ALTITUDE	.67482	*	1	3.77193	23.6	23.6
BAMBOOT	.65088	*	2	3.42750	21.4	45.0
G._HT	.56254	*	3	1.71944	10.7	55.7
GRASST	.70443	*	4	1.23315	7.7	63.5
HERBT	.63476	*	5	1.02220	6.4	69.8
L.CANYT	.51046	*				
L.DEPTH	.76475	*				
LITTERT	.76729	*				

OPENT	.78747	*
ROCKT	.75435	*
S.DEPTH	.69914	*
SLOPE	.58881	*
SNOWT	.87364	*
TR.DEN	.75001	*
TREE.HT	.72738	*
U.CANYT	.72350	*

Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
TR.DEN	.86388				
U.CANYT	.84480				
TREE.HT	.83745		-.11141		
L.CANYT	.64493	.17460		.22813	
LITTERT		.80336	-.34511		
SNOWT	-.11122	-.78998	-.45815	.14012	
L.DEPTH	.32726	.74758	.19141	.18719	-.16460
S.DEPTH		-.64901	-.49413		.15445
G._HT	-.43721	.52049		-.19334	-.23476
ROCKT	.11235	.13787	.84301	-.10980	
HERBT	-.41718		.64478	.11842	-.17328
ALTITUDE	-.49177	-.22332	-.49741	.36532	
GRASST	-.11729	.31764		-.75639	-.13014
BAMBOOT	.10775	.37206		.65730	-.24684
OPENT	.16812	-.11524	-.16054		.84786
SLOPE	-.42277		.43006		.47326

<u>**SPRING**</u>

Final Statistics:

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
		*				
ALTITUDE	.79762	*	1	5.04218	33.6	33.6
BAMBOOT	.17686	*	2	2.89248	19.3	52.9
GRASST	.31849	*	3	1.44324	9.6	62.5
G._HT	.65098	*	4	1.00149	6.7	69.2
HERBT	.66414	*				
L.CANYT	.55089	*				
LITTERT	.86782	*				
L.DEPTH	.71104	*				
OPENT	.85335	*				
ROCKT	.74406	*				
S.DEPTH	.84102	*				
SNOWT	.91638	*				
TR.DEN	.78068	*				
TREE.HT	.73103	*				
U.CANYT	.77504	*				

Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4
U.CANYT	.87634			
TR.DEN	.87529			
TREE.HT	.81148			.23677
L.CANYT	.71421	.12686	-.14731	
ALTITUDE	-.43310	-.76553	-.14343	
SNOWT	-.30933	-.76067	-.49162	
HERBT	-.32453	.73181	-.11821	
S.DEPTH	-.39553	-.70705	-.42749	
ROCKT	.36099	.68393		-.37739
L.DEPTH	.47248	.53902	.38453	-.22225
BAMBOOT		.39548		.12014
LITTERT		-.15392	.90576	.14661
G._HT	-.19652	.31848	.64886	-.29984
GRASST		.30841	.40766	-.23331
OPENT	.16849			.90322

LOGISTIC REGRESSION ANALYSIS

AUTUMN

Classification Table for MONAL

		Predicted .0 (0)	Predicted 1.0 (1)	Percent Correct
Observed .0	0	105	3	97.22%
1.0	1	2	18	90.00%
			Overall	96.09%

---------------------- Variables in the Equation ----------------------

Variable	B	S.E.	Wald	df	Sig	R	Exp(B)
FAC1_1	1.9959	1.1174	3.1907	1	.0741	.1036	7.3587
FAC2_1	3.7714	1.0335	13.3159	1	.0003	.3194	43.4415
Constant	-5.4380	1.4934	13.2592	1	.0003		

----------------- Model if Term Removed -----------------
Based on Conditional Parameter Estimates

Term Removed	Log Likelihood	-2 Log LR	df	Significance of Log LR
FAC1_1	-17.133	5.780	1	.0162
FAC2_1	-70.372	112.257	1	.0000

--------------- Variables not in the Equation ----------------
Residual Chi Square 2.745 with 2 df Sig = .2535

Variable	Score	df	Sig	R
FAC3_1	.2688	1	.6042	.0000
FAC4_1	1.1386	1	.2860	.0000

WINTER

Classification Table for MONAL

		Predicted .00 (0)	Predicted 1.00 (1)	Percent Correct
Observed .00	0	101	7	93.52%
1.00	1	14	62	81.58%
			Overall	88.59%

---------------------- Variables in the Equation ----------------------

Variable	B	S.E.	Wald	df	Sig	R	Exp(B)
FAC1_1	.6350	.2784	5.2043	1	.0225	.1133	1.8871
FAC2_1	3.1496	.5183	36.9242	1	.0000	.3741	23.3276
FAC3_1	-2.0018	.3970	25.4268	1	.0000	-.3064	.1351

FAC5_1	-1.2652	.3767	11.2800	1	.0008	-.1929	.2822
Constant	-.1237	.2844	.1891	1	.6637		

---------------- Model if Term Removed ----------------
Based on Conditional Parameter Estimates

Term Removed	Log Likelihood	-2 Log LR	df	Significance of Log LR
FAC1_1	-51.294	6.200	1	.0128
FAC2_1	-104.830	113.272	1	.0000
FAC3_1	-74.403	52.419	1	.0000
FAC5_1	-59.399	22.411	1	.0000

--------------- Variables not in the Equation ---------------
Residual Chi Square 2.037 with 1 df Sig = .1535

Variable	Score	df	Sig	R
FAC4_1	2.0367	1	.1535	.0121

SPRING

Classification Table for MONAL

		Predicted .00 (0)	Predicted 1.00 (1)	Percent Correct
Observed .00	0	103	5	95.37%
1.00	1	13	21	61.76%
			Overall	87.32%

--------------------- Variables in the Equation ---------------------

Variable	B	S.E.	Wald	df	Sig	R	Exp(B)
FAC3_1	2.5104	.4835	26.9547	1	.0000	.3995	12.3100
FAC4_1	-.7750	.2844	7.4266	1	.0064	-.1863	.4607
Constant	-1.6932	.3096	29.9103	1	.0000		

---------------- Model if Term Removed ----------------
Based on Conditional Parameter Estimates

Term Removed	Log Likelihood	-2 Log LR	df	Significance of Log LR
FAC3_1	-75.299	70.270	1	.0000
FAC4_1	-44.850	9.371	1	.0022

-------------- Variables not in the Equation ----------------
Residual Chi Square .070 with 2 df Sig = .9656

Variable	Score	df	Sig	R
FAC1_1	.0466	1	.8291	.0000
FAC2_1	.0269	1	.8698	.0000

APPENDIX - 3

MANN-WHITNEY U - WILCOXON RANK SUM W TEST

AUTUMN

FAC1_1 REGR factor score 1 for analysis 1
by MONAL

Mean Rank	Cases	
86.10	20	MONAL = 1.0
60.50	108	MONAL = .0

	128	Total

U	W	Corrected for ties Z	2-Tailed P
648.0	1722.0	-2.8350	.0046

FAC2_1 REGR factor score 2 for analysis 1
by MONAL

Mean Rank	Cases	
116.35	20	MONAL = 1.0
54.90	108	MONAL = .0

	128	Total

U	W	Corrected for ties Z	2-Tailed P
43.0	2327.0	-6.8053	.0000

FAC3_1 REGR factor score 3 for analysis 1
by MONAL

Mean Rank	Cases	
59.95	20	MONAL = 1.0
65.34	108	MONAL = .0

	128	Total

U	W	Corrected for ties Z	2-Tailed P
989.0	1199.0	-.5972	.5504

FAC4_1 REGR factor score 4 for analysis 1
by MONAL

Mean Rank	Cases	
60.40	20	MONAL = 1.0
65.26	108	MONAL = .0

	128	Total

U	W	Corrected for ties Z	2-Tailed P
998.0	1208.0	-.5381	.5905

WINTER

FAC1_1 REGR factor score 1 for analysis 1
by MONAL

Mean Rank	Cases	
96.34	76	MONAL = 1.00
89.80	108	MONAL = .00

	184	Total

		Corrected for ties	
U	W	Z	2-Tailed P
3812.0	7322.0	-.8209	.4117

FAC2_1 REGR factor score 2 for analysis 1
by MONAL

Mean Rank	Cases	
129.24	76	MONAL = 1.00
66.65	108	MONAL = .00

	184	Total

		Corrected for ties	
U	W	Z	2-Tailed P
1312.0	9822.0	-7.8488	.0000

FAC3_1 REGR factor score 3 for analysis 1
by MONAL

Mean Rank	Cases	
67.70	76	MONAL = 1.00
109.95	108	MONAL = .00

	184	Total

		Corrected for ties	
U	W	Z	2-Tailed P
2219.0	5145.0	-5.2990	.0000

FAC4_1 REGR factor score 4 for analysis 1
by MONAL

Mean Rank	Cases	
91.64	76	MONAL = 1.00
93.10	108	MONAL = .00

	184	Total

		Corrected for ties	
U	W	Z	2-Tailed P
4039.0	6965.0	-.1827	.8550

FAC5_1 REGR factor score 5 for analysis 1
by MONAL

Mean Rank	Cases	
82.21	76	MONAL = 1.00
99.74	108	MONAL = .00

	184	Total

		Corrected for ties	
U	W	Z	2-Tailed P
3322.0	6248.0	-2.1983	.0279

SPRING

FAC1_1 REGR factor score 1 for analysis 1
by MONAL

Mean Rank	Cases	
69.32	34	MONAL = 1.00
72.19	108	MONAL = .00

	142	Total

		Corrected for ties	
U	W	Z	2-Tailed P
1762.0	2357.0	-.3538	.7235

FAC2_1 REGR factor score 2 for analysis 1
by MONAL

Mean Rank	Cases	
69.85	34	MONAL = 1.00
72.02	108	MONAL = .00

	142	Total

		Corrected for ties	
U	W	Z	2-Tailed P
1780.0	2375.0	-.2677	.7889

FAC3_1 REGR factor score 3 for analysis 1
by MONAL

Mean Rank	Cases	
114.50	34	MONAL = 1.00
57.96	108	MONAL = .00

	142	Total

		Corrected for ties	
U	W	Z	2-Tailed P
374.0	3893.0	-6.9891	.0000

FAC4_1 REGR factor score 4 for analysis 1
by MONAL

Mean Rank	Cases	
55.18	34	MONAL = 1.00
76.64	108	MONAL = .00

	142	Total

		Corrected for ties	
U	W	Z	2-Tailed P
1281.0	1876.0	-2.6532	.0080

APPENDIX - 4

Checklist of the birds of the Kedarnath Wildlife Sanctuary

FAMILY **ACCIPTRIDAE**

PARIAH KITE	*Milvus migrans*
KING VULTURE	*Sarcogyps calvus*
CINEREOUS VULTURE ?	*Aegypius monachus*
GRIFFON VULTURE	*Gyps fulvus*
HIMALAYAN GRIFFON VULTURE	*Gyps himalayensis*
BEARDED VULTURE or LAMERGEIER	*Gypaetus barbatus*
HEN-HARRIER	*Circus cyaneus*
CRESTED HAWK EAGLE	*Spizaetus cirrhatus*
SHIKRA	*Accipter badius*
CRESTED GOSHAWK	*Accipiter trivirgatus*
SPARROW HAWK	*Accipter nisus*
WHITE-EYED BUZZARD EAGLE ?	*Butastur teesa*
Buteo spp. ?	
GOLDEN EAGLE	*Aquila chrysaetos*
BLACK EAGLE	*Ictinaetus malayensis*

FAMILY **FALCONIDAE**

Falco spp. ?	
KESTREL	*Falco tinnunculus*

FAMILY **PHASIANIDAE**

HIMALAYAN SNOWCOCK	*Tetraogallus himalayensis*
SNOW PARTRIDGE	*Lerwa lerwa*
COMMON HILL PARTRIDGE	*Arborophila torqueola*
IMPEYAN or MONAL PHEASANT	*Lophophorus impejanus*
WHITE CRESTED KALEEJ PHEASANT	*Lophura leucomelana*
KOKLAS PHEASANT	*Pucrasia macrolopha*

FAMILY **GRUIDAE**

CRANE spp. ?	

FAMILY **CHARADRIIDAE**

WOODCOCK	*Scoplopax rusticola*

FAMILY **COLUMBIDAE**

SNOW PIGEON	*Columba leuconata*
HILL PIGEON	*Columba rupestris*
SPECKLED WOOD PIGEON	*Columba hodgsonii*
RUFOUS TURTLE DOVE	*Streptopelia orientalis*

SPOTTED DOVE	*Streptopelia chinensis*
INDIAN RING DOVE	*Streptopelia decaocto*
FAMILY **PSITTACIDAE**	
SLATY HEADED PARAKEET	*Psittacula himalayana*
FAMILY **CUCULIDAE**	
LARGE HAWK CUCKOO	*Cuculus sparverioides*
THE CUCKOO	*Cuculus canorus*
HIMALAYAN CUCKOO	*Cuculus saturatus*
FAMILY **STRIGIDAE**	
BUBO spp. ?	
HIMALAYAN WOOD OWL	*Strix aluco*
JUNGLE OWLET	*Glaucidium radiatum*
FAMILY **CAPRIMULGIDAE**	
INDIAN JUNGLE NIGHTJAR	*Caprimulgus indicus*
FAMILY **APODIDAE**	
HIMALAYAN SWIFTLET	*Collocalia brevirostris*
LARGE WHITE RUMPED SWIFT	*Apus pacificus*
FAMILY **CORACIIDAE**	
INDIAN ROLLER	*Coracias benghalensis*
FAMILY **CAPITONIDAE**	
GREAT HILL BARBET	*Megalaima virens*
LINEATED BARBET	*Megalaima lineata*
FAMILY **PICIDAE**	
SCALYBELLIED GREEN WOODPECKER	*Picus squamatus*
BLACKNAPED GREEN WOODPECKER	*Picus canus*
RUFOUSBELLIED WOODPECKER or SAPSUCKER	*Hypopicus hyperythrus*
HIMALAYAN PIED WOODPECKER	*Picoides Himalayensis*
BROWNFRONTED PIED WOODPECKER	*Picoides auriceps*
FAMILY **HIRUNDINIDAE**	
HOUSE MARTIN	*Delichon urbica*

FAMILY **LANIIDAE**

GREY SHRIKE	*Lanius excubitor*
RUFOUSBACKED SHRIKE	*Lanius schach*

FAMILY **ORIOLIDAE**

MAROON ORIOLE	*Oriolus traillii*

FAMILY **DICRURIDAE**

BLACK DRONGO	*Dicrurus adsimilis*
ASHY DRONGO	*Dicrurus leucophaeus*

FAMILY **STURNIDAE**

COMMON MYNA	*Acridotheres tristis*

FAMILY **CORVIDAE**

JAY	*Garrulus glandarius*
BLACKTHROATED JAY	*Garrulus lanceolatus*
YELLOWBILLED BLUE MAGPIE	*Cissa flavirostris*
HIMALAYAN TREE PIE	*Dendrocitta formosae*
REDBILLED CHOUGH	*Pyrrhocorax pyrrhocorax*
JUNGLE CROW	*Corvus macrorhynchos*

FAMILY **CAMPEPHAGIDAE**

LONGTAILED MINIVET	*Pericrocotus ethologus*

FAMILY **PYCNONOTIDAE**

WHITECHEEKED BULBUL	*Pycnonotus leucogenys*
REDVENTED BULBUL	*Pycnonotus cafer*
BLACK BULBUL	*Hypsipetes madagascariensis*

FAMILY **MUSCICAPIDAE**

TIMALIINAE

RUSTYCHEEKED SCIMITAR BABBLER	*Pomatorhinus erythrogenys*
SCALYBREATED WREN BABBLER	*Pnoepyga albiventer*
REDBILLED BABBLER	*Stachyris pyrrhops*
WHITETHROATED LAUGHING THRUSH	*Garrulax albogularis*
STRIATED LAUGHING THRUSH	*Garrulax striatus*
VARIEGATED LAUGHING THRUSH	*Garrulax variegatus*
STREAKED LAUGHING THRUSH	*Garrulax lineatus*
REDHEADED LAUGHING THRUSH	*Garrulax erythrocephalus*

BARTHROATED SIVA	*Minla strigula*
YELLOENAPED YUHINA	*Yuhina flavicollis*
STRIPETHROATED YUHINA	*Yuhina gularis*
WHITEBROWED TIT BABBLER	*Alcippe vinipectus*
BLACKCAPPED SIBIA	*Heterophasia capistrata*

MUSCICAPINAE

REDBREASTED FLYCATCHER	*Muscicapa parva*
ORANGEGORGETED FLYCATCHER	*Muscicapa strophiata*
WHITEBROWED BLUE FLYCATCHER	*Muscicapa superciliaris*
SMALL NILTAVA	*Muscicapa macgrigoriae*
RUFOUSBELLIED NILTAVA	*Muscicapa sundara*
VERDITER FLYCATCHER	*Muscicapa thalassina*
GREYHEADED FLYCATHCHER	*Culicicapa ceylonensis*
YELLOWBELLIED FANTAIL FLYCATCHER	*Rhipidura hypoxantha*

SYLVIINAE

CHESTNUT-HEADED GROUND WARBLER	*Tesia castaneocoronata*
ABERRANT BUSH WARBLER	*Cettia flavolivacea*
ASHY WREN-WARBLER	*Prinia socialis*
TAILOR BIRD	*Orthotomus sutorius*
PLAIN LEAF WARBLER	*Phylloscopus neglectus*
BROOKS'S LEAF WARBLER	*Phylloscopus subviridis*
PALLAS'S LEAF WARBLER	*Phylloscopus proregulus*
GREYFACED LEAF WARBLER	*Phylloscopus maculipennis*
LARGE CROWNED LEAF WARBLER	*Phylloscopus occipitalis*
BLYTH"S LEAF WARBLER	*Phylloscopus reguloides*
ALLIED FLYCATCHER-WARBLER	*Seicercus affinis*
BLACKBROWED FLYCATCHER-WARBLER	*Seicercus burkii*
GREYHEADED FLYCATCHER WARBLER	*Seicercus xanthoschistos*
BLACKFACED FLYCATCHER-WARBLER	*Abroscopus schisticeps*

TURDIINAE

ORANGEFLANKED BUSH ROBIN	*Erithacus cyanurus*
BLUEHEADED REDSTART	*Phoenicurus caeruleocephalus*
BLUEFRONTED REDSTART	*Phoenicurus frontalis*
HODGSON'S GRANDALA	*Grandala coelicolor*
SPOTTED FORKTAIL	*Enicurus maculatus*
STONE CHAT	*Saxicola torquata*
PIED BUSH CHAT	*Saxicola caprata*
DARK-GREY BUSH CHAT	*Saxicola ferrea*
WHITECAPPED REDSTART	*Chaimarrornis leucocephalus*
CHESTNUTBELLIED ROCK THRUSH	*Monticola rufiventris*
BLUE WHISTLING THRUSH	*Myiophonus caeruleus*
PLAINBACKED MOUNTAIN THRUSH	*Zoothera mollissima*
LARGE BROWN THRUSH	*Zoothera monticola*
WHITECOLLARED BLACKBIRD	*Turdus albocinctus*

GREYWINGED BLACKBIRD	*Turdus boulboul*
BLACKTHROATED THRUSH	*Turdus ruficolis atrogularis*
MISTLE THRUSH	*Turdus viscivorus*

FAMILY **TROGLODYTIDAE**

WREN	*Troglodytes troglodytes*

FAMILY **PRUNELLIDAE**

ALPINE ACCENTOR	*Prunella collaris*
ALTAI ACCENTOR	*Prunella himalayana*

FAMILY **PARIDAE**

GREY TIT	*Parus major*
GREENBACKED TIT	*Parus monticolus*
CRESTED BLACK TIT	*Parus melanolophus*
COAL TIT	*Parus ater*
BROWN CRESTED TIT	*Parus dichrous*
YELLOWCHEEKED TIT	*Parus xanthogenys*
REDHEADED TIT	*Aegithalos concinnus*
WHITETHROATED TIT	*Aegithalos niveogularis*

FAMILY **SITTIDAE**

EUROPEAN NUTHATCH	*Sitta europaea*
WHITETAILED NUTHATCH	*Sitta himalayensis*

FAMILY **CERTHIDAE**

TREE CREEPER	*Certhia familiaris*
HIMALAYAN TREE CREEPER	*Certhia himalayana*

FAMILY **MOTACILLIDAE**

INDIAN TREE PIPIT	*Anthus hodgsoni*
YELLOW WAGTAIL	*Motacilla flava*
GREY WAGTAIL	*Motacilla cinerea*

FAMILY **DICAEIDAE**

FIREBREASTED FLOWERPECKER	*Dicaeum ignipectus*

FAMILY **NEDCTARINIIDAE**

NEPAL YELLOWBACKED SUNBIRD	*Aethopyga nipalensis*
YELLOWBACKED SUNBIRD	*Aethopyga siparaja*

FAMILY **ZOSTEROPIDAE**

WHITE-EYE	*Zosterops palpebrosa*

FAMILY **PLOCEIDAE**

PASSERINAE

HOUSE SPARROW	*Passer domesticus*
CINNAMON TREE SPARROW	*Passer rutilans*

ESTRILDINAE

WHITEBACKED MUNIA	*Lonchura striata*

FAMILY **FRINGILLIADE**

CARDUELINAE

BLACK-AND-WHITE GROSBEAK	*Coccothraustes icterioides*
ALLIED GROSBEAK	*Coccothraustes affinis*
GOLDFINCH	*Carduelis carduelis*
HIMALAYAN GREENFINCH	*Carduelis spinoides*
REDBROWED FINCH	*Callacanthis burtoni*
GOLDFRONTED FINCH	*Serinus pusillus*
HODGSON'S MOUNTAIN FINCH	*Leucosticte nemoricola*
NEPAL ROSEFINCH	*Carpodacus nipalensis*
BEAUTIFUL ROSEFINCH	*Carpodacus pulcherrimus*
REDHEADED BULLFINCH	*Pyrrhula erythrocephala*

FAMILY **EMBERIZIDAE**

ROCK BUNTING	*Emberiza cia*
CRESTED BUNTING	*Melophus lathami*

? could not be clearly identified