STUDIES ON SOME ASPECTS OF THE ECOLOGY OF THE RED PANDA (*Ailurus fulgens, Cuvier 1825*) IN THE SINGHALILA NATIONAL PARK, DARJEELING, INDIA

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SUNITA PRADHAN

POST GRADUATE DEPARTMENT OF ZOOLOGY
DARJEELING GOVERNMENT COLLEGE
DARJEELING - 734101
WEST BENGAL, INDIA

<u>CERTIFICATE</u>

This is to certify that Ms. Sunita Pradhan has worked out the thesis entitled **"Studies on some aspects of the ecology of the Red panda (*Ailurus fulgens*, Cuvier 1825) in the Singhalila National Park, Darjeeling, India"** under our joint supervision and that she fulfilled the requirements of the regulations relating to the nature and period of research and rules of the North Bengal University. It is also certified that the said thesis incorporates the results of the original investigations made by Ms. Pradhan at the Post Graduate Department of Zoology, Darjeeling Government College, Centre of Wildlife and Ornithology, Aligarh Muslim University and field (Singhalila National Park) under our joint guidance and actual supervision throughout. The thesis submitted in partial fulfilment of her Ph.D. degree in Zoology of the North Bengal University, degree in Zoology of the North Bengal University, has not been submitted previously anywhere for any degree whatsoever either by her or anyone else. We are forwarding her thesis for the award of Ph.D. degree in Zoology of North Bengal University.

Jamal A. Khan
Senior Lecturer
CENTRE OF WILDLIFE
& ORNITHOLOGY
A.M.U., ALIGARH

Goutum Kr. Saha
Assistant Professor
Department of Zoology
Darjeeling Govt. College
Darjeeling-734101

Dedicated to Ama and Baba
with love

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SUMMARY

INTRODUCTION

Red panda is an important component of the Himalayan biodiversity. It is taxonomically unique in being a monotypic genus and also the only member of family Ailuridae. It is an exemplar carnivore species which has adapted to a specialized herbivorous diet of bamboo, hence scientifically important. Its distributional range extends from Nepal in the west to a few provinces of China in the east. Growth of human population in all the places along its distributional range pose as an eminent threat to the intactness of its habitat and the very survival of this species. Moreover, red panda is also known to have a low reproductive turn over with an annual recruitment of an average of only two cubs/female. The cubs that are born are very small in size and vulnerable which suffer from high mortality rate. Current information on the distribution, population status, other ecological aspects and various problems of conservation in different areas of its distribution is scarce.

In India, too, very little is known about the status, ecology, biology, behaviour and conservation problems of this species. This dearth of information has hampered conservation efforts. The present study was initiated in an effort to generate the much needed information on the ecology of red panda. The study was conducted in the Singhalila National Park, Darjeeling (in the hills of North Bengal) and had the following objectives:

1. To document the presence/absence of the red panda in the Singhalila National Park and its adjoining area.

2. To assess the distribution, status and abundance of the red panda in the Singhalila National Park.

3. To investigate the aspects of ecology such as habitat use and feeding ecology of red panda in the Park.

4. To investigate the problems of the conservation and management of red panda in the

National Park.

The study commenced from June 1994 and ended in October 1996.

GENERAL METHODS

Vegetation description of the study area: Vegetation sampling of the study area was done along seven altitudinal gradients (2700 m, 2850 m, 3000 m, 3100 m, 3150 m, 3300 m, 3450 m, 3600 m). Sampling was done by placing 10 m^2 quadrats at 100 m distance from each other. In the 10 m^2 quadrats the following variables were recorded-

Total number of trees, gbh of the trees, height of the trees and canopy cover. Another quadrat of 3 m^2 was placed within the 10 m^2 quadrat to quantify shrub species and their cover, bamboo and bamboo cover, seedlings and saplings. Disturbance factors such as grazing pressure, cattle paths were quantified using ordinal scales. Number of cut stumps were counted in the 10m^2 quadrat. Apart from this, ten individual each of 24 species of trees, six species of shrubs and a few creepers were marked to study their phenophases in order to have a better understanding of the cover and the food available to the red panda and other wildlife in the area.

Transects/trails monitoring: Transects were not laid but the existing paths and trails in the study area were used as transects, passing through different habitat types and altitudinal zones. These **trails** are referred to as **transects** in the text. These transects were monitored on a monthly basis for indirect and direct evidences of the red panda. Dung/pellet groups of the red panda were found to be the most reliable indirect evidence which was used to assess the distribution, abundance and habitat use. The pellet groups encountered during these monitoring of the transects were collected, dried and kept for faecal analysis to investigate the food items taken by the red panda.

Distribution, abundance and status: An encounter rate of pellet groups/100 hours and red panda/100 hours was used to quantify the relative abundance of the red panda in the study area. Status of the red panda was assessed in terms of the threats, relative abundance and information on the breeding population of the species in the study area.

Habitat use: The location where any direct and indirect evidence (pellet group) of the red panda, encountered during the monitoring of the transects was quantified, using ten tree method for recording habitat variables. Around this quantified habitat unit, known as the Animal Centered Plot, four more plots were laid at random in four cardinal directions from the center of the Animal Centered Plot.

Feeding ecology: Red panda food habits were investigated for different seasons by examining the faeces or droppings. The phenophases of the food plants, density and biomass of bamboo, recruitment rate of bamboo and harvest of bamboo shoots and fruits of *Actinidia* sp. were studied to know the availability of food to the red panda. Nutritional analysis of the food items were carried out to assess the quality of the food taken by the red panda.

Conservation problems of the red panda: A socio-economic study of the villagers in the settlements in and around the National park was conducted. Apart from this, information on the various problems leading to the anthropogenic pressures on the forest resources were also recorded by talking and discussing with the local people.

ANALYSIS

Vegetation description: The data collected, was analysed for density of trees, shrubs, seedlings and saplings in different altitude. Importance Value Index was determined for all tree species encountered during the sampling. Diversity of tree species was calculated following Shannon Wierner's index and species richness was determined using Margalef's richness index. Cluster analysis was performed on the IVI of the tree species to classify the vegetation of the area. The density of the tree species in different size/girth classes was computed on per hectare basis to study the structure of the forest.

Habitat use: Multivariate techniques such as principal component factoring, ordination of the habitat plots in hypothetical species space, logistic regression were used to understand red panda-habitat relationship. The selection of habitat by the red panda was determined following Nue *et al.* (1974) and Byers *et al.* (1984). A habitat use index was computed by dividing the recent pellet groups found during a particular season by percent distance traversed in the particular habitat type, in a season.

Feeding ecology: The pellets in the pellet groups were broken and assigned to macroscopic examination. The items present were expressed in percent volume of the total volume of all food items in the pellet. Leaves and shoots of *A. maling, A. aristata*, fruits of *Actinidia strigosa, Rosa sericera* and *Sorbus microphylla* were analysed for cellulose, hemicellulose, lignin and crude protein following Goering and Van Soest (1970) and Allen (!989).

RESULTS

Vegetation of the study area: Placing current ecological data in their correct time context is an important aspect of ecological studies. The natural vegetation of the area was subjected to intense human disturbance and asresult is greatly modified. Hence it was attempted to get an overview of the status of the vegetation at present.

Four distinct clusters of vegetation communities corresponding to the vegetation communities in altitude zones were produced by the cluster analysis. The vegetation types are Oak forest (2600 m-2800 m), Broad-leafed deciduous forest (>2800 m-3100 m), Broad-leafed coniferous forest (>3100 m-3300 m and the Coniferous forest (>3300 m-3600 m). *Quercus pachyphylla* was the dominant uppercanopy tree at 2700 m with an IVI of 81.15 and the dominant undercanopy species were *Litsaea elongata* with an IVI of 55.02, *Schefflera impressa* (IVI 36.34) and *Rhododendron arboreum* (32.10).

In the Broad-leafed deciduous forest (>2800 m-3000 m), *Sorbus cuspidata* has an IVI of 48.61 and 50..55 at 2850 m and 3000 m respectively. *Symplocus* sp., *Osmanthus sauvis*, *Rhododendron arboreum* and *R. falconeri* are the major undercanopy trees. *Sorbus cuspidata* emerges as the dominant uppercanopy species (IVI 48.61) in association with *Ouercus* sp. (IVI 43.040), *Acer campbellii* (IVI 29.42) and *Vitex heterophylla* (IVI 11.32) at the lower altitudes but this association gradually gives way to a composition where the IVI of *Ouercus* sp. is zero. The uppercanopy at 3000 m is mostly deciduous with *Sorbus cuspidata* (IVI 50.55), *Acer campbellii* (IVI 20.80). *Rhododendron falconeri* commonly known as Korlinga forms both the upper and undercanopy in these altitudes and has an IVI value of 33.13. Undercanopy, dominantly has *Symplocus sp.* (IVI 58.42 and 73.11), *Osmathus sauvis* (IVI 31.97 and 14.69), *Rhododendron arboreum (IVI 41.00 and 25.55), Meliosma dilleniaefolia* (7.37 and 10.55). At an altitude range of 3150 m-3300 m, the dominant uppercanopy species are *Abies densa* (IVI 67.59), *Betula utilis* (IVI 32.34), in association with *Litsea sp.* (IVI 19.35), *Tsuga brunoniana* (IVI 14.15), *Sorbus cuspidata* (IVI 12.78), *Acer pectinatum* (IVI 5.96) at the lower altitudinal range, which is represented by 3150 m. With an increase in altitude, that is above 3150 m, *Abies densa* (IVI 69.70) is still the dominant species but with an association of *Betula utilis* (IVI 126.49). Other deciduous trees such as the *Sorbus cuspidata, Acer* and *Litsea* species are not found. *Tsuga brunoniana* was found sparsely, only in sapling and seedling stages at 3300 m and above. The undercanopy consisted of *Rhododendron arboreum, Rhododendron cinnamomeum, Anromeda villosa, Meliosma delleniaefolia, Buddleia asiatica* in the lower ranges but *A. villosa, M. dilleniaefolia, B. asiatica* were not found in the higher altitudes (i.e. 3300m and above). At altitudes 3450 m and

3600 m (Coniferous forest), *Abies densa* (IVI 185:25) at 3450 m and (IVI 124.63) at 3600 m are the dominant tree species. *Betula utilis* (IVI 56.41) and *Rhododendron arboreum* (IVI 26.92) are the undercanopy species at 3450 m. *Rhododendron arboreum* becomes absent and *Rhododendron campanulatum* (IVI 93.35) dominantes towards the higher reaches, i.e. 3600 m. The broad leaf deciduous species in addition to *Betula utilis* present in this zone are *Andromeda formosa* and *Sorbus microphylla.* The density of trees was found to be lower in the higher altitudes.

Disturbance from factors such as grazing, cattle paths, logging, construction of roads, settlements was found to be prevalent in all the altitudes or throughout the study area with a higher intensity at 3100 m, 3150 m and 3600 m. Some of the uppercanopy tree species such as *Quercus pachphylla, Abies densa, Sorbus cuspidata, Betula utilis* and *Magnolia campbellii* are important to the red panda habitat in terms of providing refuge and cover. It was found that the regeneration rate of *Sorbus cuspidata, Magnolia campellii* was found to be very poor with the species not being represented in either sapling or the seeding stages. The *Quercus pachphylla* although well represented in the seedling and sapling I stages, it was poorly represented in sapling II and size class 3 which indicated an interruption in its establishment. Although, *Abies densa* was found to be regenerating well, it is a very slow growing species. Bamboo, an important component of red panda habitat was found to be extensively grazed upon. It was also found that in the study area, at present, has an overall high density of seedlings of tree species which indicates an ecological restoration but the poor representation of the dominant tree species in immature size classes indicates an interruption in their establishment. it is thus important to give specific attention and conduct long term monitoring of the recruitment dynamics of the vegetation, especially the plant species critical to the red panda habitat. This is necessary in order to provide an intact habitat to the red panda and other wildlife species in the area.

Distribution, abundance and status: The sightings of red panda were infrequent, with a total of 32 sightings during the two years period of 1994-1996. The surveys conducted in the National Park revealed the presence of red panda in Gairibans, Kaiyakatta-Kalipokhari, Sandakphu, Molley, Sabarkum, Phalut and Upper reaches of Gorkhey. Evidences of red panda was not found in Lower Gorkhey, Rammam, Siri and Rimbick. Within the intensive area, red was more abundant in the Broad-leafed deciduous forest and the Subalpine forest as compared to the Oak forest. The encounter rate of red panda in the Broad-leafed deciduous forest was 3.81±3/100 hours, followed by Subalpine forest with 2.78± 2.2/100 hours and none in the Oak forest. Encounter of pellet groups/100 hours was 105.06±29.5, 85.00±42/100 hours and 20.31±10.05/100 hours in the Broad-leafed deciduous forest, Subalpine forest and the Oak forest respectively. The encounter rate of red panda was highest at Kaiyakatta-Kalipokahri area with an encounter rate of 3.04±2 red pandas/100 hours followed by 2.98±2/100 hours at Sandakphu and 0.44±.03/100 hours at Gairibans. From the results, it could be inferred that the abundance of the red panda was higher at altitudes above 2800 m, and sporadically present below this altitude. The lowest altitude from which red panda was reported was Upper Phedi (2400 m). A crude density of 1 red panda/1.67 km^2 was calculated for the study area. The status of red panda in terms of abundance, breeding population and availability of unfragmented habitat, was better in Sandakphu and Kaiyakatta and Kalipokhari area than at Gairibans. However, the fact that the higher altitudes, especially Sandakphu had a greater intensity of disturbance is a matter of serious concern. It was also found that the red panda used habitats of the adjoining regions of Nepal and Sikkim. However, nothing is known or done about habitats and the safety of the animals beyond the respective state boundaries. Concerted efforts of all the three regions (Nepal, Sikkim and Darjeeling) to protect the red panda in this part of the Himalayas would therefore be a better conservation strategy rather than conserving or protecting animals within each region only.

Habitat use: Red panda was found to use two habitats- Upper hill miscellaneous and Silver fir forest in higher proportion to their availability, indicating a preference for these habitat types. Habitat use index of the red panda for different seasons also indicated a greater use of the Silver fir forest and the Mixed forest (a portion of the Upper hill miscellaneous) in relation to the other habitat types. Canopy cover, bamboo height, bamboo cover were the factors significantly contributing to classify between animal used plots and random plots. Pellet-groups were found on trees, rocks or cliffs, ground, fallen logs and tree cavities. However, maximum number of evidences were found on trees. Some of the important trees species found to be used by the red panda were *Abies densa, Betula utilis, Sorbus cuspidata, Quercus pachphylla* and *Magnolia campbellii.* Red panda evidences were significantly more on the northern aspect.

Feeding ecology: Red panda in the study area was found to consume both the species of bamboo (*Arundinaria maling* and *A.aristata*) present in the Park. There was a seasonal variation in composition of diet of the red panda. Food chiefly consisted of bamboo leaves during premonsoon and winter. There was an inclusion of bamboo shoots and fruits of *Actinidia strigosa, Rosa sericera* and *Sorbus microphylla* during monsoon and postmonsoon periods. *Actinidia strigosa* was found to have a higher nutritive value with higher crude protein, higher hemicellulose and lower content of cellulose and lignin. A variation in the food availability and composition was also found in the diet of red pandas in the temperate and the subalpine zone and also between the three study sites.

Conservation problems of the red panda in the Singhalila National Park: The primary objective of the present study was to get a broad over view of the problems of the National Park vis-à-vis the people in the settlements, in and around the National Park and their impact on the conservation of the red panda. Some of the major biotic pressures on the biodiversity of the Park, prior to the notification of area as a National Park, were due to the presence of cattle stations, poaching, logging, fire and construction of roads. Despite the various conservation programs implemented by the Forest Department, the National Park is still fraught with a number of conservation problems which needs immediate attention. Some of the conservation problems are- dependence of the local people of the settlements surrounding the National Park on the forests for fuel wood and the minor forest products, and the increasing inflow of tourists to the area. However, the environmental and economic impact of tourism on the National Park was not being evaluated. The most apparent impact of tourism on the forest resource was found to be an increase in the consumption of firewood. Although the local benefits from tourism are not being fully realised it was found that tourism held promise of offering an alternative source of income to the local people of all the three regions (Nepal, Sikkim and Darjeeling). In order to conserve the biological wealth of this Himalayan region, it is also important to look into the well being of the locals, the ultimate guardian of the natural resources. However, any program of conservation and development in this region would bear better results if the responsibilities were shared by all the three regions (Nepal, Sikkim, Darjeeling).

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Rationale

An intricate and à complex web of interrelationships exist between the plants, animals, human beings and the abiotic environment forming an ecosystem. A healthy ecosystem would have a harmonious existence of all its components which are occasionally interrupted due to natural causes. However, the formidable and the irreparable interruptions are caused by human beings, which often yield unexpected results (Bowen, 1977) especially the elimination of entire habitats and complete communities of species often leading to their extinction (Myers, 1989; Oslon, 1989). From a palaeontological point of view, extinction is nearly an inescapable natural process (Myers, 1989). However, the cause of some of the historical extinction have been man, and the pressure of extinction is thus regarded as preventable (Oslon, 1989) or the rate of it slowed.

The fragile mountain ecosystem of the Himalayas remain unspared by the multifarious activities of the human beings. Along the entire Himalayan belt, high level of human and livestock population in relation to arable land and general mismanagement of land resources are among some of the important causes which have led to deforestation with serious environmental, social, economic and biological consequences (Khoshoo, 1986).

Threat of extinction lurks heavily around the future of wildlife of the Himalayas, today. There are more endangered taxa in the Himalayas than anywhere else in India

(Rodgers and Panwar, 1988). Red panda *Ailurus fulgens*, a key element of the Himalayan biodiversity, is one of them. Red panda is distributed from Nepal in the east to a few provinces of China in the west. In India, red panda is found in the Himalayan state of Sikkim, Darjeeling hills of North Bengal and North eastern state of Arunachal Pradesh.

Red panda being a bamboo eater is an unusual carnivore. Apart from this, Gittleman (1994) also revealed that the pandas had a high mortality rate, very low reproductive or protracted growth rate and very small litter size, features which are in contrast to other carnivores. Carnivores which have high mortality rate produced more litter in less interval of time (Harvey *et al.* 1989; Charnov, 1991; Gittleman, 1994). The high mortality rate of the panda was attributed to various factors such as inefficient maternal care of the vulnerable young ones, high susceptibility of the pandas to viruses of canine distemper, other bacteria and ectoparasites (Roberts and Gittleman, 1984; Gittleman, 1994). The problem of mortality due to diseases could be due to low level of dietary protein which weakened the immunity system or could be due to the deleterious effects of inbreeding (O'Brien and Knight, 1987). Therefore, in addition to the threats of habitat loss and fragmentation, poaching, death of bamboo plant after its mass flowering, low nutritive diet of bamboo, the red pandas are faced with biological sources of mortality as well (Gittleman, 1994).

The threat of extinction has been among the primary motivators of conservation movement. Conservation movement becomes a priority when we are posed with the fact of loosing a species even before knowing anything about the animal. The world knows very little about the species in its natural habitat. This is mainly because of the problems of studying a solitary and a rare animal in its remote habitat in the rugged mountainous terrain. It is listed by the International Union for Conservation of Nature and Natural Resources (IUCN) as an insufficiently known species (Anon, 1988).

The recent ecological information on the red panda in the wild comes from the work of Johnson *et al.* (1988) and Reid *et al.* (1991) who studied red panda in China and of Yonzon and Hunter (1989) in Nepal. A great deal of study in captivity and considerable amount of work for the conservation of the red panda mainly based on well coordinated captive breeding programs, has been done in zoos which is cenetred around an international studbook (Glatston, 1994).

Very little is known about the status, ecology, biology and behaviour of this species from its entire range of distribution in India. This dearth of information has hampered conservation efforts. The present study was initiated in an effort to generate the much needed information on the ecology of red panda. The study was conducted in the Singhalila National Park, Darjeeling (in the hills of North Bengal) which commenced from June 1994 and ended in October 1996.

1.2 Objective of the study

The project on the ecological study of the red panda in the Singhalila National Park, Darjeeling and its adjoining areas started with many ambitious objectives. However, to study an animal as elusive and little known as the red panda, radio telemetry is the best option which is a widely used technique but unfortunately, the plans of collaring the animals did not materialize due to various logistic and financial constraints.

Therefore, the study was mainly based on indirect and direct evidences with the following objectives:

1.2.1 To document the presence/absence of the red panda in the Singhalila National Park and its adjoining areas.

1.2.2 To assess the distribution, status and abundance of the red panda in the Singhalila National Park.

1.2.3 To investigate the aspects of ecology such as habitat use and feeding ecology of red panda in the Park.

1.2.4 To investigate the problems of conservation and management of red panda in the National Park.

1.3 Historical Account of Red panda

Red panda was first introduced to the world outside its remote habitat in 1821 by Major Thomas Hardwick but the honour of proposing a zoological name of the animal went to Federic Cuvier in 1825. Major Thomas Hardwick received a specimen of red panda and described it in his presentation to the Linnean Society of London in 1821. He however delayed the publication on further details of the animal until 1827. In the meantime, the famous French naturalist, Federic Cuvier had also received a specimen of the red panda. He published the account of the animal in his monograph Historie Naturel des Mammiferes in 1825 and also proposed the zoological name *Ailurus fulgens* to the animal. *Ailurus* (as its resemblance to cat) and *fulgens* (because of its brilliant colours). After about twenty years later, Hodgson (1847 & 1848) brought to light some accounts on the animal along with a speculation about the relationship of red panda to raccoons and other mammals. Thereafter, William Fowler (1870) gave the first account on the anatomy and skeletal structures of the animal. He also noted similarities of the red panda to the Procyonidae and also recognised the similar skull structures of the red panda and the giant panda.

1.4 Characteristic features of the red panda

Red panda or the cat bear, is a small sized carnivore with a body and tail length of 51- 63.5 cm and 28 - 48.5 cm respectively. It weighs about 3 - 4.5 kg. The average weight in the wild is 4 - 4.5 kg (Yonzon and Hunter, 1989). The head is round with a short and pointed snout. Ears are medium sized and pointed. Eyes are small and brown with black nose. The body has a dense woolly coat of fur which is chestnut brown in colour. The underside of the body and the limbs are black in colour. The face hair and hairs of the inner side of the ear is white. The rear of the ears are black. Stripes of its body colour beneath the eyes separates white snout from the white cheek. Tail is bushy and striped with light and dark shades of red brown and the tip is black. The thick body fur is used for thermoregulation (Mcnab, 1989).

The five digits on the feet are sharp and semiretractile. This aids in their climbing. The sole of the foot are covered with hair. It is the only Asian animal with the sole hair (Roberts and Gittleman, 1984). The soles have a series of small pores, which secrete a substance that are used in the depositing scent trails (Roberts, 1981). Secretions also originate from the anogenital region, and the urine may also be used for scent marking (Roberts and Gittleman, 1984). Both the sexes of adult panda have anal glands, the secretion of which is oily and has a pungent odor (Flower, 1870; Pocock, 1921; Roberts, 1981).

The possession of a thumb like wrist, also known as the pseudo thumb, is a characteristic feature in the giant and the red pandas, although this thumb is not as developed in red panda as in the giant panda. The pseudo thumb is a radial sesmoid bone of the wrist which has been enlarged. This articulates with the radial carpal bone (Davis, 1964). The red panda has a set of 36-38 teeth with a dental formula of i 3/3, c 1/1, pm 3/3-4, m 2/2. The large cheek tooth surface promotes mediolateral movement for grinding of bamboo and fibrous plant materials (Greogery,1936; Radinsky, 1981). Skull of red panda is larger as compared to other carnivore of comparable size like the Procyononids. Cervical region is short and has six lumbar vertebrae and 14 thoracics (Davis, 1964).

The red panda has adaptations for surviving on a food like bamboo which is seen in the enlarged cheek surface, development of an enlarged wrist bone but the main digestive system is ill adapted for the purpose. The intestinal tract is short and simple, stomach is simple as in all fissiped carnivores, with a spherical fundus, no caecum, and a cylindrical, thick walled pyrolus (Hodgson, 1848). The short and simple tract does not allow proper digestion of the herbivorous diet to which red panda is adapted.

Red panda females give birth mainly in June (Hodgson, 1847; Wall, 1908; Pocock, 1941). The litter consist of an average number of two youngs. The gestation period varies from 119-130 days with a mean gestation period of 132.2 days (Dittoe, 1944; Mottershead, 1958; Erken and Jacobi, 1972; Roberts and Kessler, 1979). The young ones are very small and helpless during the time of birth. Sexual maturity is reached at the age of eighteen months. Roberts (1975 & 1980) noticed a closeness in the mother- young proximity till about 120 days. The young ones in captivity does not attain independence from maternal care, until about not less than 6 months of age whereas nothing is known about the dispersal patterns in the wild (Roberts, 1981).

Mating occurs during winter, usually between early January and mid-March (Dittoe, 1944; Zucherman, 1953; Mottershead, 1958 & 1963; Erken and Jacobi, 1972; Roberts and Kessler, 1979; Keller, 1980; Roberts, 1980 & 1981). They are solitary outside their mating period in the wild (Yonzon, 1989). Johnson *et al.* (1988) also reports red panda to remain oblivious of the other red panda in the near vicinity during their study in Wolong, China. A discrete distance is also maintained when the animals are housed together in captivity (Keller, 1977). Aggression is rare (Roberts, 1984).

Different interacting modes between its conspecifics have been recognised in the red panda specially through studies in captivity. Visual displays are used for interspecific interactions through various types of body movements such as arching of the tail and back, slow raising and lowering of the head while emitting a low intensity puffing, turning of head while jaw clapping, shaking the head from side to side, raising a forearm as an extended movement before striking, and a bipedal posture with the forearms extended at a playmate or opponent (Roberts and

Gittleman, 1984). During mating season, female shows a playful bounding gait, frequently stops during movement and flickers tail frequently before copulation (Roberts and Gittleman, 1984). During social interactions, naso-naso, naso-torso, naso-flank, naso-anal contacts were noticed (Keller, 1977; Roberts, 1981). Different call types have been described by Roberts (1981) and Roberts and Gittleman (1984) like a wheet during infant distress, squeal for an adult. A high pitched twitter is recognised as a contact call in young and adults. A harsh quack snort is emitted during annoyance or aggression. Grunts and snorts are also produced by animals engaged in fighting (Roberts, 1981).

Chemical signals include deposition of urine, faeces, and scent marking. During scent marking secretions from anal and circumanal glands are deposited on various substrates of the enclosure or habitat. These chemicals are either used for marking territories and home ranges or as cues for mates during breeding season.

In captivity, Keller (1977) and Roberts (1981) reported red panda to be nocturnal and crepuscular with activity changing throughout the year in response to temperature, feeding regimes and presence of young ones. In the wild, too, red pandas are reported to be most active at dawn, dusk and at night (Hodgson, 1847; Anon., 1978; Johnson *et al.*, 1988; Yonzon and Hunter, 1989). Yonzon and Hunter (1989) reports red panda to be active 56% of its time mainly because its need to forage on a low nutrient diet of bamboo for subsistence.

1.5 Subspecies

Two subspecies of red panda has been recognised so far- *Ailurus fulgens fulgens* and *Ailurus fulgens styni.* The species described by Cuvier in 1825, is *Ailurus fulgens fulgens.* Thomas (1902) described a specimen of *A. f. styni* from Yang-ten-pa, North West Scezhwan. This specimen was bigger in size, longer coat, greater abundance of black pelage and larger skull, robust dentition, inflation of the frontal region and greater slope of the muzzle which was considered to be a subspecies by Pocock (1941). Roberts (1982c) did not find any significant difference between the two subspecies in his analysis using, cranio-morphometric comparisons of zoo specimens from either side of the River Brahmaputra. The Brahmaputra was kept as a boundary with *A. f. fulgens* to be from the western side of the river and *A. f. styni* to be from the eastern side. He however suggested, that a genetic analysis would be necessary to determine the difference. Gentz (1989) found that there was a genetic difference, indicating *A. f. fulgens* and *A. f. styni* to be valid subpecies.

1.6 Taxonomic classification

The taxonomic position of the red panda has been a subject of debate since its time of discovery with it being placed either with the procyonids or ursids. This is because of the various resemblance of red panda to raccoons, bears and the giant panda. Red panda resembles the raccoon, more specifically the North American species- *Procyon lotor* in body colour, size, stripped tail and brain size (Gittleman, 1985). Hollister *et al.* (1915), Greogory (1936), Sarich (1976) and Honacki *et al.* (1982) placed red panda with the Procyonids. However, Schimdt-Kittler (1981), Baskin

(1982) and Decker and Wozencraft (1991) argued that the inclusion of the red panda on the basis of the superficial similarities between the red panda and the *Procyon lotor* would make the Procyonids paraphylectic. The structure of skull, teeth, forepaws, various aspects of reproduction and reproductive parts, vocalization and scent marking behaviour of the red panda holds similarity with that of the giant panda (Schaller, 1993) Corbert and Hill (1986) placed the red panda in family Ailuropodidae. Pocock (1941) opined that *Ailurus* was more akin to the giant panda than to the Procyonids. Tagle *et al.* (1986) also agreed on a close relationship between the two pandas basing upon their findings of the similar protein sequence of the two pandas. Schaller (1993) suggested that the red and the giant pandas should be placed together in a separate family. The affinity of the red panda to the bears specially lies in the basicranium and the dental characters (Wozencraft, 1989). Ginsberg (1982) suggested it to be a sister group of the family Ursidae. Hunt (1974) and Wozencraft (1989) placed *Ailurus* with Ursidae arguing that characters traditionally used to indicate family level relationship among the carnivores align the red panda with the bears. It was placed in a separate subfamily of Ailurinae under Ursidae. There has also been several molecular, biochemical and genetic studies in order to give the red panda and the giant panda, a neat phylogenetic position. Studies based on DNA hybridization, isozyme isolation, immunological distance and karyotype (O'Brien *et al.*, 1985) indicated that progenitors of the modern ursids and procyonids split into two lineages about 30-40 million years ago. The study further indicated that the procyonids split into old world procyonids represented by the red panda (Ailurinae) and the new world procyonids (Procyoninae). It was only after this procyonid split, did the progenitor of the giant panda diverge from the ursid line some 18-25 million years ago. Thus, concluding the red pandas to be closer to the Procyonids and the giant panda to Ursids.

The chromosomal study (O'Brien *et al.,* 1985) showed that the acrocentric chromosomes (2N = 74) of the members of the Ursinae subfamily are homologous to the chromosome arms of the giant panda's mostly metacentric chromosomes (2N = 42). The diploid number of the chromosomes in the red panda is 36, procyonids (2N = 38), giant panda (2N = 42), bears (2N = 74) (Ewer, 1973) and the spectacled bear, *Tremarcots ornatus* (2N = 52) (O'Brien *et al.*, 1985) indicating a closer affinity of the red panda to the procyonids than to the bears or the giant pandas (Ewer, 1973). The karyological study of O'Brien *et al.* (1985) further revealed that only G-trypsin bandings of the giant panda or bear chromosomes were homologous to that of the red panda or raccoon (*Procyon lotor*) and 14 chromosomes of the red panda were homologous to that of several procyonids.

However the findings of O'Brien *et al.* (1985) is in contradiction to the study of Chinese scientists who based their work on the comparisons of mitochondrial DNA of the two pandas, Asiatic Black bear, *Selenarctos thibetanus* and sun bear, *Helarctos malayanus*. This study concluded that the giant panda and red panda are closely related than to bears (Schaller, 1993). Comparing the blood proteins from the giant pandas, bears and raccoon, Sarich (1976) stated that the red panda does not group with the Procyonids. Basing on some biochemical and genetic evidences, red panda was suggested to have a position between Ursidae and the Procyonidae (Wurster and Beniasch, 1968; Sarich, 1976). Serological studies (Pan *et al.*, 1981) found that the giant panda was more close to the Himalayan black bear, *Selenarctos thibetanus,* than to red panda.

Despite the various efforts to give a definite taxonomic place to the red panda and the giant panda, the problem remains unresolved. Even the results of the detailed molecular studies are contradictory and unable to provide a comprehensible solution to the problem (Schaller, 1993). Schaller (1993) resorted to the fossil records and pointed out the giant panda is relatively a new comer and its previous incarnations still remain uncertain in its palaeontological history. He noted that among the behavioural characters shared by the red and the giant panda, vocalization and scent marking were characters which would not be influenced by ecological pressures to be convergent adaptations. The type of vocalizations and marking behaviour which are in the red and the giant pandas are not found in the bears. Bears hibernate, giant panda and the red panda do not. The new borns of both, giant panda and the red panda are extremely small in size. The giant panda and bears, both have delayed implantation. The young of bears are born during hibernation. Considering these reproductive behaviours, Schaller (1993) accounted the small size of the new borns of the bears to be an adaptation to conserve energy of the hibernating mother whereas the causal factor of the small size of the new born of the giant panda could be some other selection pressure. He went on to argue that the red panda also has a delayed implantation of the foetus. Giant panda and the red panda shared approximately the same length of gestation period, similar weight of the new borns, foetus growth of the giant panda was faster than that of the red panda and half as slow than that of the bears. These facts showed that the reproductive characters of the giant panda is more typical of small mammal like the red panda than a bear (Schaller, 1993). He thus prefers the red panda and the giant panda to be grouped together in a separate family.

1.7 Remark

In conclusion, it can be said that there is still a huge void in the information from the wild on the red panda. A lot is yet to be known about the distribution, population status of the red panda, habitats preferred, availability and quality of such habitats catering to its food, cover and safety. Natality, mortality, dispersal , home range and movement patterns and their causal factors and various problems of conservation in different areas of its distribution needs further studies. Glatson (1994) points out the taxonomic uniqueness of red panda. *Ailurus* is not only a monotypic genus but if the classification of placing it in a separate family Ailuridae as proposed by Eisenberg (1981) is followed, it is the sole representative of the family. It can also be considered as the only representative of the old world procyonids. It is a carnivore like the giant panda, occupying a highly specialised niche as bamboo feeder which makes it important from a scientific point of view (Glatston, 1989) and which has raised questions like - "Are the pandas successful specialists or evolutionary failures ?" (Gittleman, 1994).

The present study along with a sister project on the Satyr tragopan, *Tragopan satyra* are the first scientific studies to be conducted in the Singhalila National Park and was thus carried out against many adversities. It is hoped that the findings of this study on the red panda would positively contribute to initiate conservation and better management of the red panda in this part of the Himalayas.

1.8 Organisation of the thesis

The thesis has seven chapters. Chapter 1 of the thesis is a general Introduction. Chapter 2 describes the study areas where the study was conducted. Chapter 3, on vegetation gives an overall idea of the present vegetation structure and composition of the study area. Chapter 4 is on the distribution, abundance and status of the red panda in the study area. Chapter 5 describes the habitat preference of the red panda along with an explanation on the spatial and temporal use of the habitat. Chapter 6 is on the feeding ecology of the red panda in the study area. The last chapter discusses the conservation problems of the red panda in the Singhalila National Park. Chapters 3, 4, 5 and 6 each have separate sections of introduction, methods, analyses, results and discussion.

CHAPTER 2

STUDY AREA - SINGHALILA NATIONAL PARK, DARJEELING

2.1 Location in the Himalaya

The Himalaya is part of one of the most massive and complex mountain systems in the world. The ranges of this system extend from 70° east to 97° east longitude, and from 27° north to 37° north latitude and is approximately 2500 km in length with an approximate area of 236,000 km ^{2} (Khoshoo, 1993). Associated chains stretch westwards into Afghanistian (Hindu Kush), north into Soviet Central Asia (Pamirs) and east into Western China (Min Shan) and Northern Burma (Pakti Range) and geographically, the Himalaya is divided into the eastern, central, western and northwestern Himalaya (Mani, 1974). The main Himalayan system has three parallel ranges- the outer Himalaya, great Himalaya and middle Himalaya (Wadia, 1966). Darjeeling, a hill district in the state of West Bengal (India) is situated on the eastern part of the great Himalaya, and is also known as the Darjeeling Himalaya. The Singhalila National Park, is located on the northwestern border of Darjeeling (Figure 2.1), and it lies at 87° 59'-88° 53' east longitude and 26° 31'-27° 31' north latitude. Singhalila National Park was notified a National Park in 1986 and at present is under the jurisdiction of the Wildlife Division, Department of Forest, Government of West Bengal, India.

The altitude in Darjeeling varies from 100 m in the terai to 3600 m at Phalut on the Singhalila ridges, extending from the southern face of Mt. Kunchenjonza and also has a wide variety of forest types (Sudhakar *et al.*, 1993). A portion of the montane

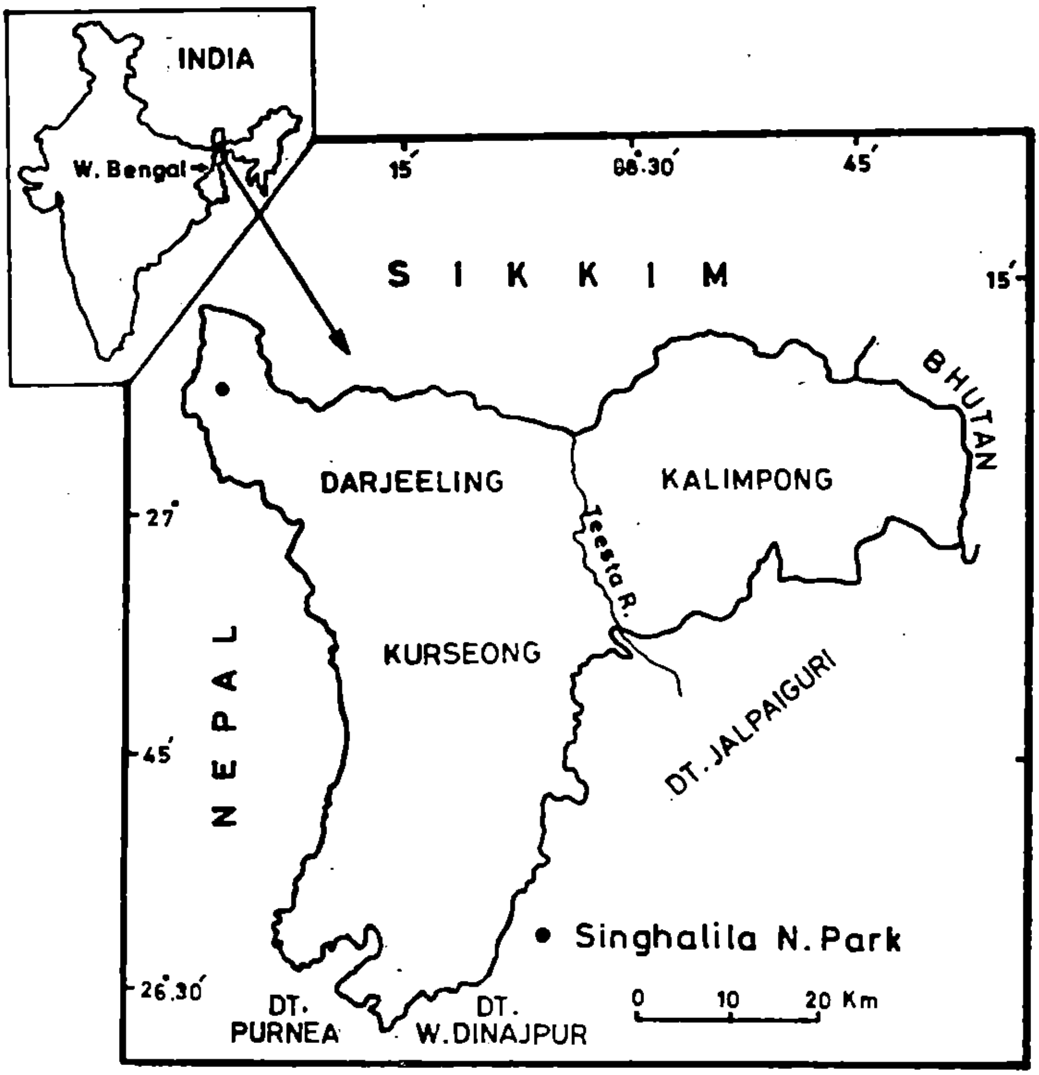


Figure 2.1 Map of Darjeeling showing the location of Singhalila National Park.

temperate and the subalpine types which fall within the Singhalila National Park forms an important refuge for the red panda.

2.2 Boundaries of the National Park

Singahalila National Park is bounded by the Rabongla Khola (Khola is a small stream) from Sikkim in the north while Nepal is on the south western border. The international border between India and Nepal is identified by a road running from Phalut down to Manebhanjyang (Figure 2.2). Singhalila National Park has an area of 108.7 km^2 with a core zone of 78.6 km^2 and a buffer zone of 30.17 km^2. Administratively, the National Park is divided into ranges which are further divided into beats and compartments. The boundary between the core and the buffer zones are formed by the compartment boundaries of Phalut 4, Sabarkum 3, 4, 10, 12, Siri 3, Sandakphu 4, 5, 6, 7, 10 and the lower MR road (Figure 2.2).

2.3 Climate

Moist temperate conditions of the area show variation with altitude. The annual mean temperature for the temperate zone varies from 0.5°C to 18°C and in winter from .5°C to 10°C. In the subalpine zone, the mean annual temperature is approximately 7°C and in winter is the temperature remains below 1°C. The mean annual rainfall in the Park is varies from zero to 773.5 cm. The average relative humidity readings vary from 70.% to 96%. Moderate storms accompanied by hail are common during March-April. The Singhalila National Park receives snowfall, which starts anytime between end of November to January and continues snowing intermittently till late February

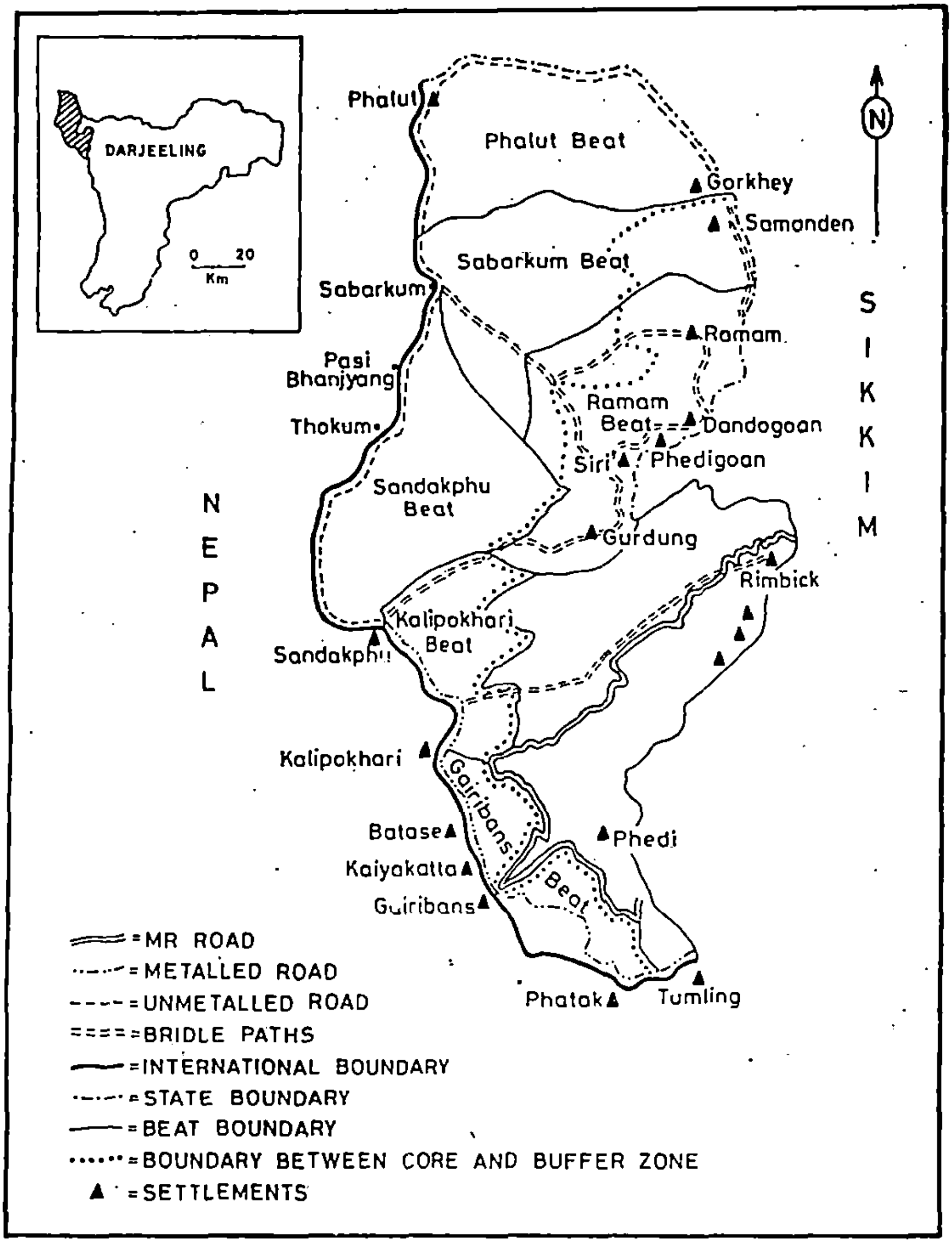


Fig.2.2 Map of Singhalila National Park, Darjeeling, showing administrative units (Beats), boundaries, settlements, roads and bridle paths.

Table 2.1 Details of temperature, humidity and rainfall recorded at Gairibans for the period of 1994-1996.

Months	Max. Temp. °centigrade	Min. Temp. °centigrade	Humidity %	Rainfall (mm)
Jan	1.00	0.50	70.80	155
Feb	3.00	2.00	91.58	164
Mar	8.00	7.00	89.85	524
Apr	12.00	11.00	87.52	1167
May	16.00	14.00	90.40	3857
Jun	18.00	16.00	91.50	5347
Jul	16.00	13.00	95.06	7735
Aug	15.00	13.00	96.70	5977
Sep	15.00	13.00	92.80	2235
Oct	11.00	10.00	95.85	512
Nov	7.00	4.00	80.11	185
Dec	4.00	2.00	85.39	0

and sometimes till mid April as observed in 1996. The snowfall is heavy and regular at the higher altitudes or the subalpine zone. In 1994, the place received its snowfall in mid- November. In 1995 and 1996 it was December and in 1997, the place received its first snowfall of the season in October.

2.3.1 Seasons: Four seasons have been distinguished mainly based on the monsoon or the rainfall in the area. The four seasons are:

2.3.1.1 Premonsoon (Spring): From March to May. This is the period just after the severe winter. During this season, the National Park experiences cool and sunny weather, clear sky, with maximum temperature ranging from 8 °C to 14 °C. Fog, frost and rainfall is minimum. The vegetation starts producing their new flush of leaves and trees like *Rhododendron* and *Magnolia* spp. flower during these months. These months approximately fall within the breeding period of the red panda.

2.3.1.2 Monsoon (Rainy Season)- From June to August. Monsoon sets in by late May and may last till early September during which the Park receives the maximum rainfall (Table 2.1). Fog and frost is very prevalent during this season. The Park also has maximum vegetative cover during this season. This season coincides with birth and lactation period of the red panda.

2.3.1.3 Postmonsoon (Autumn)- From September to November. The days remain clear, with pleasant amount of sunshine and moderate amount of rainfall (Table 2.1). The maximum temperature ranges from 5 °C to 15 °C. This is the time when a variety of ground vegetation like the *Primula* sp., *Areisma* sp., *Geranium* sp., *Saxifraga* sp., *Bistora* sp., *Senecio* sp. flower and edible fruits of *Sorbus cuspidata*, *Actinidia* *strigosa, Holboellia latifolia.* Lactation and weaning period of the red panda occurs within this season.

2.3.1.4 Winter- December to February. Harsh and cold weather is experienced during this season with the temperature going down to less 0° C, with heavy snowfall especially in the subalpine region. The forest has the least vegetative cover during this season and breeding of red panda takes place during this season.

2.4 Vegetation

The park has an altitudinal range of 2400 m-3636 m and supports a variety of vegetation types and vegetation zones. The management plan (Anon, 1986) of the Singhalila National Park describes the composition of the vegetation under four heads namely the Upper Hill Forest, Oak-Hemlock Forest, Alpine Forest and the Bamboo brakes.

2.4.1 Upper hill forests: The composition of this forest type as described, more or less corresponds to Champion and Seth's East Himalayan Wet Temperate forests within an altitudinal zone of 2150 m to 2750 m. Three altitudinal zones were distinguished by the predominance of *Lauraceae*, *Quercus lamellosa* and *Quercus pachyphylla* distributed respectively in the zones of 1800 m to 2100 m, 2121 m to 2424 m and 2424 m to 2750 m (Anon, 1967). Champion and Seth (1968) named the three zones as Lauraceous forest, Buk oak forest and High level oak forest. Only the last two zones which are described as Buk oak forest and High level oak forest fall within the Singhalila National Park.

2.4.2 Oak Hemlock Forest: This type of forest is reported to be met within the upper portions of the Singhalila Range and is known to correspond to Champions's east Himalayan mixed coniferous forest of Moist temperate Himalayan group. This type is charecterised by the composition of *Quercus pachyphylla, Betula utilis, Sorbus cuspidata, Castonopsis tribuloides* and *Rhododendron* spp. along with *Litsea elongata and Lindera neesiana*. Hemlock is described to be found on higher ridges from Rammam to Saberkum, Siri and Phalut. Silver fir is reported to grow from about 2878 m. The description of vegetation is a compilation of information obtained from sample plots in Rammam division and Sandakhpu (Champion and Seth, 1968).

2.4.3 Alpine Forests: This forest type corresponds to Champion's Himalayan dry temperate subalpine Birch-Rhododendron forest characterised by *Abies densa* along with its associates such as *Betula utilis* and *Rhododendron* species.

2.4.4 Bamboo brakes: Bamboo brakes described in the management plan correspond to Temperate bamboo brakes under Himalayan Moist Temperate Group of Champion and Seth (1968). These are vast patches of bamboo which are secondary growth after biotic disturbance in the area.

2.5 Fauna

The National Park has major mammalian fauna like the red panda, *Ailurus fulgens,* Himalayan black bear, *Selenarctos thibetanus*, Leopard cat, *Felis bengalensis*, Clouded leopard, *Neofelis nebulosa,* Barking deer, *Muntiacus muntjak*, Serow, *Capricornis sumatraensis*, Yellow throated marten, *Martes flavigula*, Great eastern horseshoe bat, *Rhinolophus luctus* , Rhesus maque, *Macaca mulatta,* Wild boar, *Sus scrofa*, Himalayan mouse hare, *Ochotona roylei*. The frequency of mammals encountered on different transects during this study is presented in Table 2.2.

Singhalila National Park is very rich in its avifauna and has many interesting galliform species like the satyr tragopan, *Tragopan satyra*, kaleej pheasant, *Lophura leucomelana*, blood pheasant, *Ithaginis cruentus*, common hill partridge, *Arborophila torquela* and the red breasted hill partridge, *Arborophila mandellii*.

2.6 Geomorphology

Being a part of the Himalaya which has been a subject to large tectonic movements in recent geological periods, the rocks of the Singhalila are much folded and faulted and consistently lie in inverted succession. The formation of the area belongs to the Darjeeling gneiss and Daling stage of archean age (O'Malley, 1907 and Mani, 1974).

2.7 Nature and distribution of water sources

The rivers like Rangit and Rammam drain water from the Singhalila range. Phalut, Sandakphu, Sabarkum and Tonglu blocks form the catchment area of number of streams such as Rithu khola, Singhpratap khola, Devithan Khola, Gurdun khola which pass through the park area. Siri khola and Lodhama drain water from various blocks of the Singhalila and Tonglu range. The Rammam river which originates from Phalut receives water from Singpratap khola and Lodhama khola before it joins the great Rangit river. These kholas (large streams) are perennial and retain water for a considerable period of the year and provide water to the people and wildlife of the area. During monsoon many rain fed streams are also seen within the area. In winter, some of these water bodies freeze.

Table 2.2 Frequency of encounter of major mammals in the study area during 24 monitorings of the transects in the study area

Species	Gairibans			Kaiyakatta-Kalipokhari				Sandakphu			
	1	2	3	4	5	6	7	8	9	10	11
Felis bengalensis	7	11	2	2	12	9	1	4	0	5	4
Capricornis sumatrensis	1	7	1*	0	0	0	0	0	0	0	0
Muntiacus muntjak	4	3	0	10	2	2	4,3*	5	2	2	4
Macaca mulata	2*	0	1*	0	2*	1*	1*	1*	0	0	0
Selenarctos thibetanus	0	1	0	0	1	0	0	1*	0	0	0
Ochotona roylei	0	0	0	0	0	0	0	0	1	1*	0
Sus scrofa	3	0	1*	2	3,1*	4	0	0	1	0	0
Martes flavigula	0	0	2*	0	3*	2*	0	0	0	1*	0

* = direct sightings

2.8 Roads

A motorable road runs from the town of Darjeeling to Manebhanjyang via Sukhiapokhari (13 km). From Manebhanjyang, a jeepable road (52 km) runs uphill to the northern most corner of the National Park- Phalut via Tonglu, Gairibans, Kalipokhari and Sandakphu. The road is mettaled till Sandakphu and unmetalled from Sandakphu onwards. A road known as MR road runs between Rimbick and Dootheria. Another road connects MR road with Kaiyakatta, which continues till Kalipokhari and is also known as MR road. This road is a good jeepable road which is not used. Apart from these, there are a number of bridle paths such as the ones running between Sandakphu-Gurdung, Phalut-Gorkhey, Molley-Siri (Figure 2.2). A good network of smaller human paths within the forest and also a good number of trekkers' paths are present in the Singhalila National Park.

2.9 Settlements

A number of human settlements are found in and around the National Park. Ten out of these fring the western border of the park and are Nepalese settlements. These are Tumling (2949 m), Phatak (2992 m), Jaubari (2900 m), Gairibans (2625 m), Kaiyakatta (2879 m), Batasay (2971 m), Kalipokhari (3100 m), Bikheybhanjyang (3200 m), Sandakphu (3626 m), Phalut (3600 m). Other settlements which are in the buffer zone of the National Park include Rammam (2300 m), Siri (2200 m), Gurdung (2300 m), Samanden (2300 m). Gorkhey (2380 m) is the only settlement within the core area of the National Park (Figure 2.2). Molley (3200 m) and Phalut (3600 m) donot not any permanent residents. These places have trekker huts for tourists and

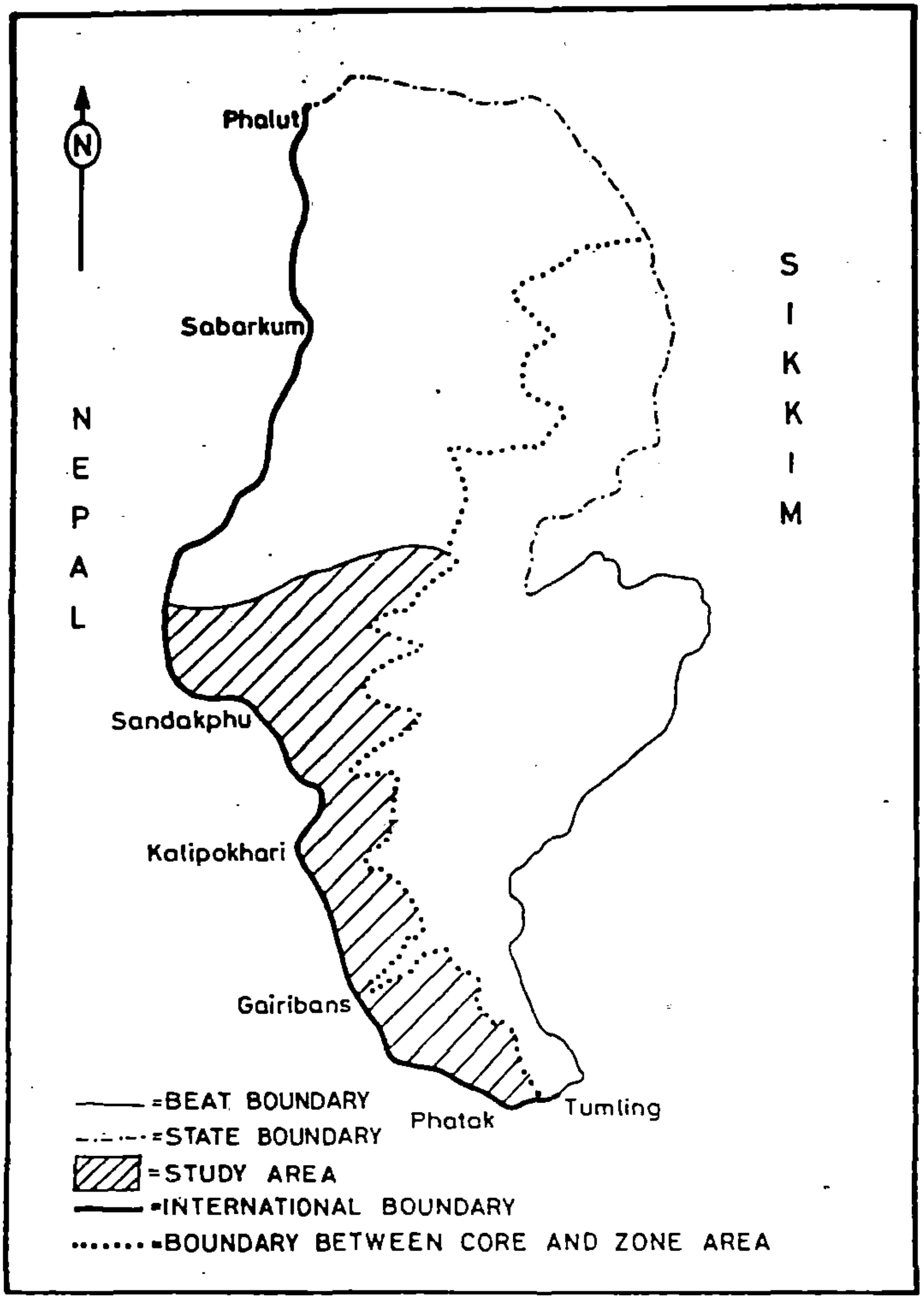


Fig. 2.3 Map of Singholila National Park, showing the intensive study area.

is a good thoroughfare for the local travellers travelling from Nepal, Sikkim to near by villages like Siri Khola, Rimbick, Bijanbari and vice versa.

2.10 Tourists

Darjeeling, being a hill station has always been a very popular tourist resort and the Singhalila area in Darjeeling is popular as a trekking area. The number of tourists visiting Singhalila National Park is found to be increasing yearly. Accommodation for the tourists or trekker huts within the National Park are found at Gairibans, Sandakphu, Phalut, Gorkhey and Molley. In the buffer zone, tourists accommodation are found at Siri, Rammam and Rimbick. These huts are run by the Tourist Department. Apart from these, there are a number of local lodges and hotels which are mushrooming along with the increase in tourist inflow to Singhalila.

2.11 Intensive Study Area

An intensive study area was selected after a year's preliminary survey. The Intensive study area comprised of Gairibans beat (site 1), Kaiyatta-Kalipokhari area (site 2) and Sandakphu area (site 3) is depicted in Figure 2.3. These sites were selected on the basis of the following criteria:

1. Relatively high encounter rate of red panda and red panda evidences.
2. The sites covered all the representative vegetation types of the Singhalila National Park.
3. Logistic and infrastructure facilities were also taken into consideration while selecting these sites. The research base at Gairibans was accessible by vehicle

which was helpful in terms of getting food supply, equipment, and better communication. The other potential study site could have been in Gorkhey and Phalut but these areas were far flung, and very remote with relatively poor communication facilities. The Intensive study area was about 25 km^2 and lied within the core area of the park (Figure 2.3).

2.11.1 Description of the study sites

2.11.1.1 Site 1 (Gairibans):

The area ranges from 2550 m-3000 m with wet temperate evergreen forest, temperate evergreen deciduous forest, pure bamboo patches, pure Rhododendron patches and plantations. Prominent water bodies are Bhote khola, Rithu khola and Pul khola. Three human settlements which are Tumling, Phatak and Gairibans fring the western border of Site 1. One trekker hut and a number forest quarters are also present at Gairibans.

2.11.1.2 Site 2 (Kaiyakatta-Kalipokhari):

It ranges within an altitudinal range of 2670 m-3100 m with the same vegetation types as Site 1. Major water sources are Kaiyakatta khola, Kalipokhari khola. There are three human settlements (Kaikatta, Batase and Kalipokhari) on the western border. There are no Government trekker huts here but a number of local hotels and lodges are found. A forest check post has recently been established by the Wildlife division.

2.11.1.3 Site 3 (Sandakphu):

The site ranges between an altitude of 3200 m-3636 m with subalpine forest, pure bamboo patches, plantations and blank areas. There are two human settlements along the border of this site and three trekker hut at Sandakphu. Apart from these, a number of other Government rest houses and staffs are also present at Sandakphu.

2.11.2 Vegetation zonation with elevation:

Four vegetation zones are present in the study area. At the lower elevations, from 2550 m (in Gairibans)-2800 m, the zone is dominated by *Quercus* spp. (Oak) in association with *Rhododendron* spp. (specifically *R.arboreum, R.griffithianum, R.cinnabarium*), *Acer, Magnolia, Litsaea* spp. with understorey of *Arundinaria maling.* Broad-leafed deciduous forest is found between an elevational range of >2800 m-3100 m. The vegetation is mainly composed of decidious trees such as *Sorbus, Acer* (Maple), *Vitex* spp. in association with *Quercus* sp. towards the lower elevation of this zone. However, in the higher reaches of this zone, *Quercus* sp. is not found. The deciduous trees are found in association with the *Rhododendron* spp. like *falconeri* and *arboreum*. The understorey is composed of both *A.maling* and *A.aristata* . Above this zone is the broad-leafed coniferous forest which is found between an elevational range of >3100 m-3300 m. *Abies densa* (Silver fir) and *Tsuga brunoniana* (Hemlock) are the conifers present in this zone and prominent deciduous trees found are *Betula utilis* (Birch), *Sorbus cuspidata, Acer* sp., *Andromeda* sp. and *Melliosma* sp. with an understorey of the *A.aristata*. Above this is the coniferous zone, with an association of *A.densa, B.utilis* and *Rhododendron* spp.

CHAPTER 3

VEGETATION DESCRIPTION OF THE STUDY AREA

3.1 Introduction

Information and description of the vegetation community allows a better insight into animal-habitat relationship and the importance of it is being increasingly realised and applied (Diernstein, 1979; Shretha, 1988; Higgins *et al.*, 1994; Sharma, 1994; Khan, 1996;). Since changes in vegetation influence the distribution and abundance of animal species, it helps in understanding the dynamics of animal population distribution, abundance and habitat use (Diernstein,1979; Gopal and Mehr Homji, 1986). Thus, such investigations form the basis for conservation and management. Examples of very detailed study of habitat and its restoration can be found in case of study of the giant panda in China (Reid *et* al.1989; Taylor and Zisheng, 1987; Taylor and Zisheng, 1988 a; Taylor and Zisheng, 1988 b; Taylor and Zisheng, 1988 c; Taylor and Zisheng, 1989).

No major quantitative analysis of vegetation has been done in the Singhalila National Park before this study. The vegetation of this area has also been subjected to intense human disturbance and as a result is greatly modified. It was thus important to have an updated knowledge of the vegetation of the area which the red panda and other fauna inhabit. This study of vegetation was taken up as a part of habitat study of the red panda in the Singhalila National Park.

An understanding of the phenological events in a forest community may reveal the structural organisation of various types of resources (Shukla and Ramakrishnan, 1982) and an appraisal of the functioning of the ecosystem (Prasad and Malati, 1986). Thus a phenological study was also undertaken in order to have a better understanding of the spatial and temporal availability of food and cover to the red panda and other fauna in the study area.

This chapter deals with the description of the structure, composition and classification, phenological or the functional aspect of vegetation and the various anthropogenic pressures on the vegetation in the study area.

3.2 Methods

3.2.1 Vegetation sampling

Sampling of vegetation of the intensive study area comprising Gairibans, Kalipokhari and Sandakphu was carried out in September-October 1995. Sampling was done at seven different altitudinal limits (2700 m, 2850 m, 3000 m, 3150 m, 3300 m, 3450 m and 3600 m) by systematically placing 10 x 10 m quadrats placed at 100 m distance from each other. In each quadrat, total number of trees (≥31.5 cm in gbh- girth at breast height) were recorded. Apart from these, other parameters recorded percent cover, height and gbh of the trees. Seedling (≤30 cm in height), Sapling I (>30 cm to <1m in height), sapling II (≤31 cm gbh and >1m height), shrub species, their number and percent shrub cover, bamboo species and bamboo cover (grazed and ungrazed bamboo), were quantified by placing 3 x 3 m quadrats within the 10 x 10 m plots.

Nomenclature for plants follow Cowan and Cowan (1929) and Stanion and Pollulin (1984).

Assessment of disturbance to the Park was done by quantifying the current grazing and lopping pressures, past disturbances of grazing and lopping, presence of cattle paths, damage done by presence of roads, paths, settlements in the park vicinity, fire, landslips and erosions. All these factors of disturbance were estimated subjectively on ordinal scales of 0= absent, 1= low, 2= medium and 3=high. The number of cut stumps were counted within the 10 x 10 m quadrat and density calculated per hectare.

3.2.2 Categorisation of size classes

Based on the gbh recorded in the sampling quadrat, trees were categorised into three size classes, that of- trees with gbh ≥31-70 cm, ≥70-150 cm and ≥150 . Size classes of trees along with the seedling and the saplings were used to explain the forest structure. Thus five size classes used in the text are-

Size class 1= Seedling

Size class 2 = Sapling (sapling I and sapling II were pooled)

Size class 3 = trees ≥31 - 70 cm

Size class 4 = trees ≥70 - 150 cm and

Size class 5 = trees ≥150.

3.2.3 Phenology: Phenophases of 24 species of trees (13 evergreen species and 11 decidious), six species of shrubs and a few creepers (Appendix III) were studied. A total of ten individuals of each tree, shrub and creeper species were marked in March 1995 for the phenological study and data were collected till October 1996. Data were collected on a monthly basis on various phenophases such as leaf buds, young leaves, mature leaves, flower buds, accession of flowers, abscission of flowers, fruit buds, immature fruits, mature fruits and abscission of fruits. A rating of 0 = absent, 1= common, 2 = very common, 3 = abundant was assigned to the phenophases following Baranga (1986). These scores were converted into 0 to 1scale by dividing the scores with the highest score. These were then averaged for each phenophase for each month by dividing with the total number of tree species studied and the result expressed in percentage.

3.3 Analyses

The important measurable quantities to describe a community are density, frequency and cover or basal area (Mueller-Dombois and Ellenberg, 1974). The data collected during the present study were analysed for abundance, density and frequency. Basal area or the area occupied by a species was determined from the gbh of the trees. The Importance Value Index (IVI) for the tree species was determined by summing the values of relative frequency, relative density and relative dominance (Curtis, 1959). The relative frequency, relative density and relative dominance were determined following Curtis and McIntosh (1950).

$$\text{Relative frequency} = \frac{\text{Frequency of one species}}{\text{Sum of all frequencies}} \times 100$$

$$\text{Relative density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Combined basal area of a single species}}{\text{Total basal area of all species}} \times 100$$

Diversity was calculated following the Shannon-Wiener's index (Greg-Smith, 1983; Shannon and Wierner,1963).

$$H' = - \sum p_i \times \log p_i$$

where,

p_i is the proportion of i^{th} species and H' is the Shannon Wiener diversity index.

Species richness was determined by the Margalef's richness index (Magurram, 1988): $D_{Mg} = (S - 1) / \ln N$

Where,

S = Number of species, N = Number of Individuals of all species and D_{mg} is species richness.

Vegetation classification of the study area was done using Cluster analysis following Causton (1988). This technique is an agglomerative classification, which groups together, individuals possessing greatest similarity in terms of the attributes used to characterise them (Ferrar and Walker, 1974; Strauss, 1982). The average linkage clustering strategy was adopted to classify the vegetation along the altitudinal gradients of the study area using SYSTAT 4.0 (1988).The cluster analysis was performed on data matrix of the Importance Value Index of the tree species with altitudes as columns and Importance Value Index values of thirty five species as rows.

In order to understand the structure of the forest, the density of each species of trees in each diameter class or size class (section 3.2.2 of this chapter) was computed following Bargali *et al.* (1989). The Non-parametric tests used were done using Stata 5.0 (1997).

3.4 Results

3.4.1 Tree layer and Classification: Details of Importance value index (IVI) of tree species are presented in Table 3.1. The cluster analysis produced four distinct clusters of vegetation communities corresponding to the vegetation in different altitudinal zones (Figure 3.1). The entire data set was divided into two major categories **A** and **B**. Category **A**, consists of two clusters **a** and **b**. Cluster **a** has altitude 2700 m and cluster **b** has altitudes 2850 and 3000 m. Category **B** consists of two clusters- **c** and **d.** Cluster **c** comprises of altitudes 3150 m and 3300 m while cluster **d** has altitudes 3450 m and 3600 m.

Cluster **a** which represents altitude of 2700 m has *Quercus pachyphylla* as the most dominant species with an IVI of 81.15. Dominant undercanopy species are *Rhododendron arboreum* (IVI 32.10), *Litsaea elongata* (IVI 55.02) and *Schefflera impressa* (IVI 36.34). This cluster represents the Oak Forest which is found within

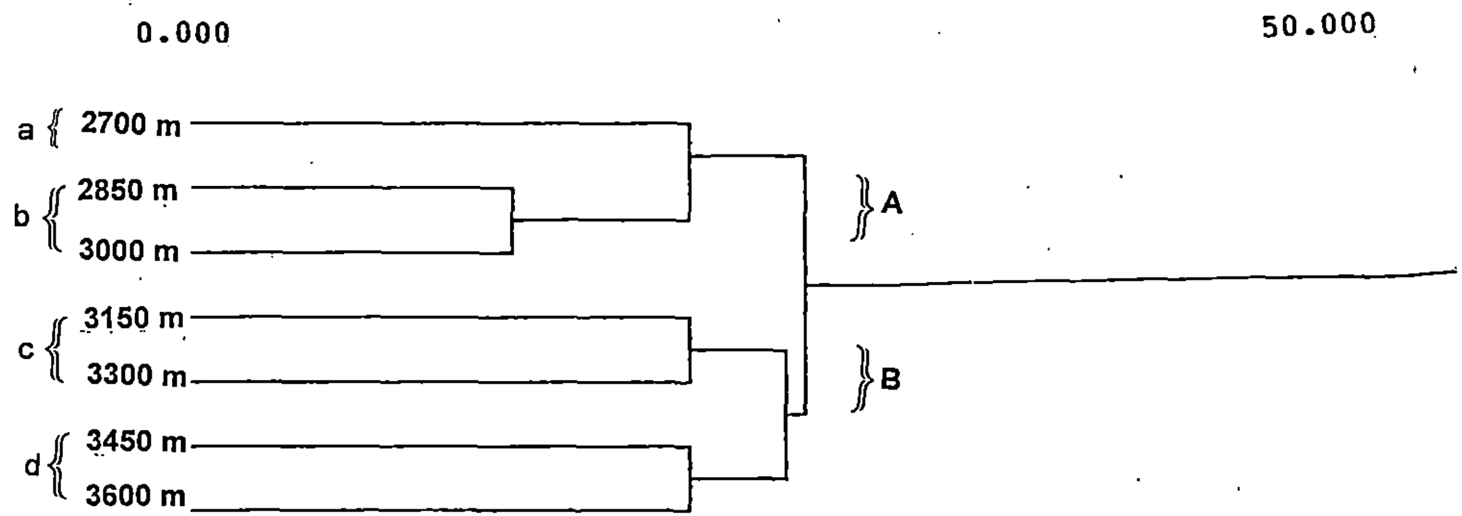
Table 3.1 Importance Value Index of tree species at different altitudes of the study area.

Tree species	2700m	2850m	3000m	3150m	3300m	3450m	3600m
Abies densa	0	0	0	67.59	69.70	185.2	24.6
Betula utilis	0	0	0	32.34	126.49	56.41	84.51
Rhodorendron arboreum	32.10	41.00	25.55	93.15	49 49	26.92	0
Rhodorendron campanulatum	0	0	0	0	0	17.02	93.35
Rhodorendron falconeri	17.58	9.70	33.13	9.37	0	0	0
Andromeda villosa	0	0	0	12.75	0.	0	0
Sorbus microphylla	0	0	0	0	0	0	23.42
Meliosma dilleniaefolia	0	7.37	10.55	9.08	0	0	0
Tsuga brunoniana	0	0	0	14.15	0	0	0
Viburnum nervosum	0	0	0	17.30	0	0	0
Sorbus cusnidata	5.99	48.61	50.55	12.78	0	0	0
Litsaea sericera	20.91	5.64	28.43	19.35	0	0	0
Buddleia asiatica	0	0	5.26	12.78	0	0	0
Andromeda formosa	0	0	0	0	11.71	0	0
Symplocus sp	2.52	58.42	73.11	0	0	0	0
Osmanthus sauvis	7.99	31.97	14.97	0	0	0	0
Ilex hookeri	4.87	27.42	0	2.37	0	0	0
Endospermum chinense	24.31	5.64	0	0	0	0	0
Acer campbellii	13.97	29.42	20.80	0	0	0	0
Acer pectinatum	0	0	0	5.96	0	0	0
Quercus pachyphylla	81.15	43.04	0	0	0	0	0
Marelo*	2..52	10.95	0	0	0	0	0
Viburmun erubescens	0	7.84	12.70	0	0	0	0
Magnolia campbellii	17.13	11.32	0	0	0	0	0
Vitex heterophylla	7.69	11.32	0	0	0	0	0
Schefflera impressa	36.34	11.32	0	0	0	0	0
Litsaea elongata	55.02	0	0	0	0	0	0
Eurya japonica	2.92	0	0	0	0	0	0
Corylus forex	2.92	0	0	0	0	0	0
Rhodorendron barbatum	0	0	0	11.77	30.28	0	0
Rhodorendron thomsoni	0	0	0	0	0	15.34	0
Rhodorendron cinnabarium	0	0	20.84	19.21	0	0	0
Rhodorendron cinnamomeum	0	0	0	0	21.49	0	0
Rhodorendron griffithianum	17.20	0	0	0	0	0	0

* = local name

2600 m-2800 m in the study area. Cluster **b** has *Sorbus cuspidata* as the dominant uppercanopy species (IVI 48.61) in association with *Quercus* sp. (IVI 43.040), *Acer campbellii* (IVI 29.42) and *Vitex heterophylla* (IVI 11.32) at the lower altitudes but this association gradually gives way to a composition where the IVI of *Quercus* sp. is zero. The uppercanopy at 3000 m is mostly deciduous with *Sorbus cuspidata* (IVI 50.55), *Acer campbellii* (IVI 20.80). *Rhododendron falconeri* commonly known as Korlinga forms both the upper and undercanopy in these altitudes and has an IVI value of 33.13. Undercanopy, dominantly has *Symplocos* sp. (IVI 58.42 and 73.11 at 2850 m and 3000 m respectively), *Osmathus sauvis* (IVI 31.97 and 14.69 at 2850 m and 3000 m respectively), *Rhododendron arboreum* (IVI 41.00 and 25.55 at 2850 m and 3000 m respectively), *Meliosma dilleniaefolia* (7.37 and 10.55 at 2850 m and 3000 m respectively). This cluster represents the Broad-leafed deciduous forest which is found within the altitudinal range of >2800 m-3100 m in the study area.

In cluster **c**, the dominant uppercanopy species are *Abies densa* (IVI 67.59) and *Betula utilis* (IVI 32.34), in association with *Litsaea* sp. (IVI 19.35), *Tsuga brunoniana* (IVI 14.15), *Sorbus cuspidata* (IVI 12.78), *Acer pectinatum* (IVI 5.96) at the lower altitudinal range, which is represented by 3150 m. With an increase in altitude, that is above 3150 m, *Abies densa* (IVI 69.70) is still the dominant species but with an association of *Betula utilis* (IVI 126.49). Other deciduous trees such as the *Sorbus cuspidata, Acer* and *Litsaea* species are not found. *Tsuga brunoniana* was found sparsely, only in sapling and seedling stages at 3300 m and above. The undercanopy consisted of *Rhododendron arboreum, Rhododendron cinnamomeum, Andromeda villosa, Meliosma delleniaefolia, Buddleia asiatica* in the lower ranges but *A. villosa,*



a = Oak forest

b = Broad-leafed deciduous forest

c = Broad-leafed coniferous forest

d = Coniferous forest

A = SUBALPINE ZONE

B = TEMPERATE ZONE

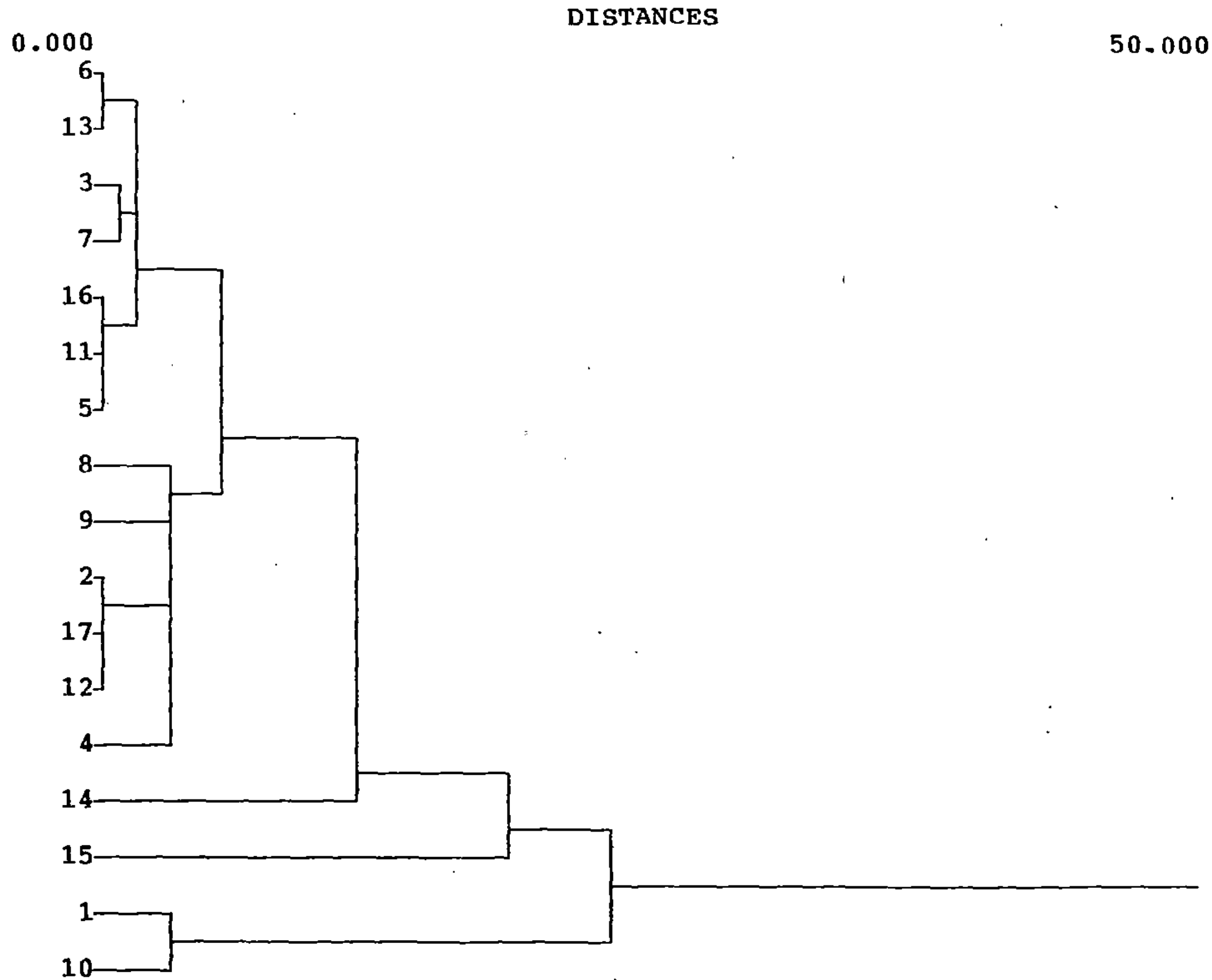
Fig. 3.1 Classification of the vegetation of the study area based on importance value index of tree species at different altitudes

M. dilleniaefolia, B. asiatica (the IVI are presented in the Table 3.1, all deciduous species were not found in the higher altitudes (i.e. 3300 m and above). This cluster represents Broad-leafed coniferous forest, which is within an altitudinal range of >3150 m-3300 m in the study area.

Cluster **d** represented by altitudes 3450 m and 3600 m also has *Abies densa* (IVI 185.25) at 3450 m and (IVI 124.63) at 3600 m as the dominant tree species. *Betula utilis* (IVI 56.41) and *Rhododendron arboreum* (IVI 26.92) are the undercanopy species at 3450 m. *Rhododendron arboreum* becomes absent and *Rhododendron campanulatum* (IVI 93.35) dominates towards the higher reaches, i.e. 3600 m. The broad-leafed deciduous species in addition to *Betula utilis* present in this zone are *Andromeda formosa* and *Sorbus microphylla*. This cluster represents Coniferous forest found within an altitude >3500 m-3600 m in the study area.

From these groupings it is apparent that category **A** represents the temperate zone while category **B** represents the subalpine zone. Therefore, there are four distinct vegetation zones in the study area. They are Oak forest (2600 m-2800 m), Broad-leaf deciduous forest (>2800 m-3100 m), Broad-leaf coniferous forest (>3150 m-3300 m) and Coniferous forest (>3300 m-3600 m).

Dendrograms of the tree species in the four vegetation zones are presented in Figures 3.2, 3.3, 3.4, 3.5 (Distance value of zero in the figures indicate minimum dissimilarity in the IVI values and distance value of 50 or 100 indicate maximum dissimilarity in the IVI values of the tree species).



1 = *R. arboeum*
2 = *R. falconeri*
3 = *S. cuspidata*
4 = *L. sericera*
5 = *Symplocos* sp.
6 = *O. sauvis*
7 = *I.lex* sp.
8 = *E. chinensese*
9 = *A. campbellii*
10 = *Q. pachyphylla*
11 = Marelo
12 = *M. campbellii*
13 = *V. heterophylla*
14 = *S. impressa*
15 = *L. elongata*
16 = *E. japonica*
17 = *R. griffithianum*

Fig 3.2 Dendrogram of tree species in Oak forests (2600-2800 m)

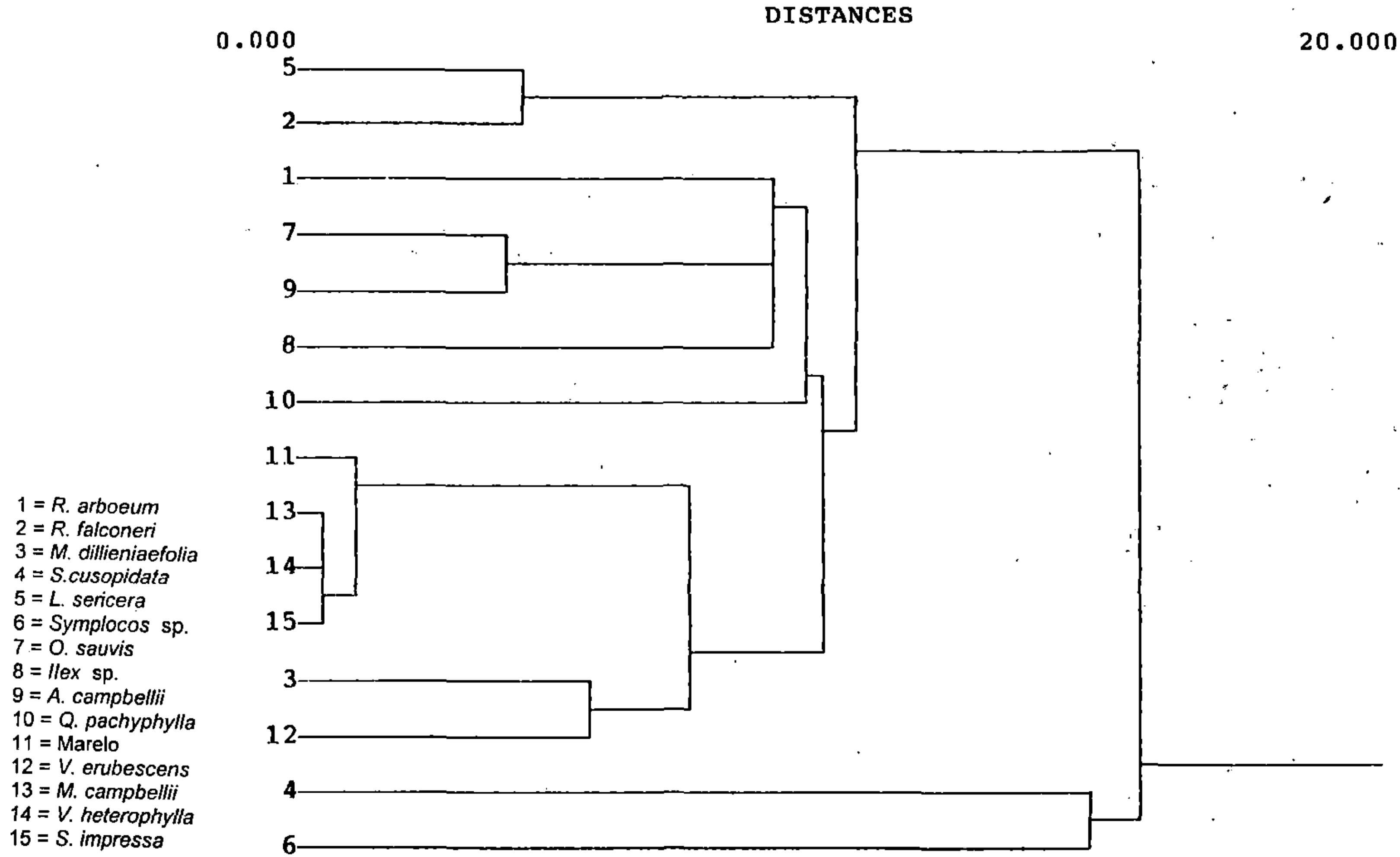
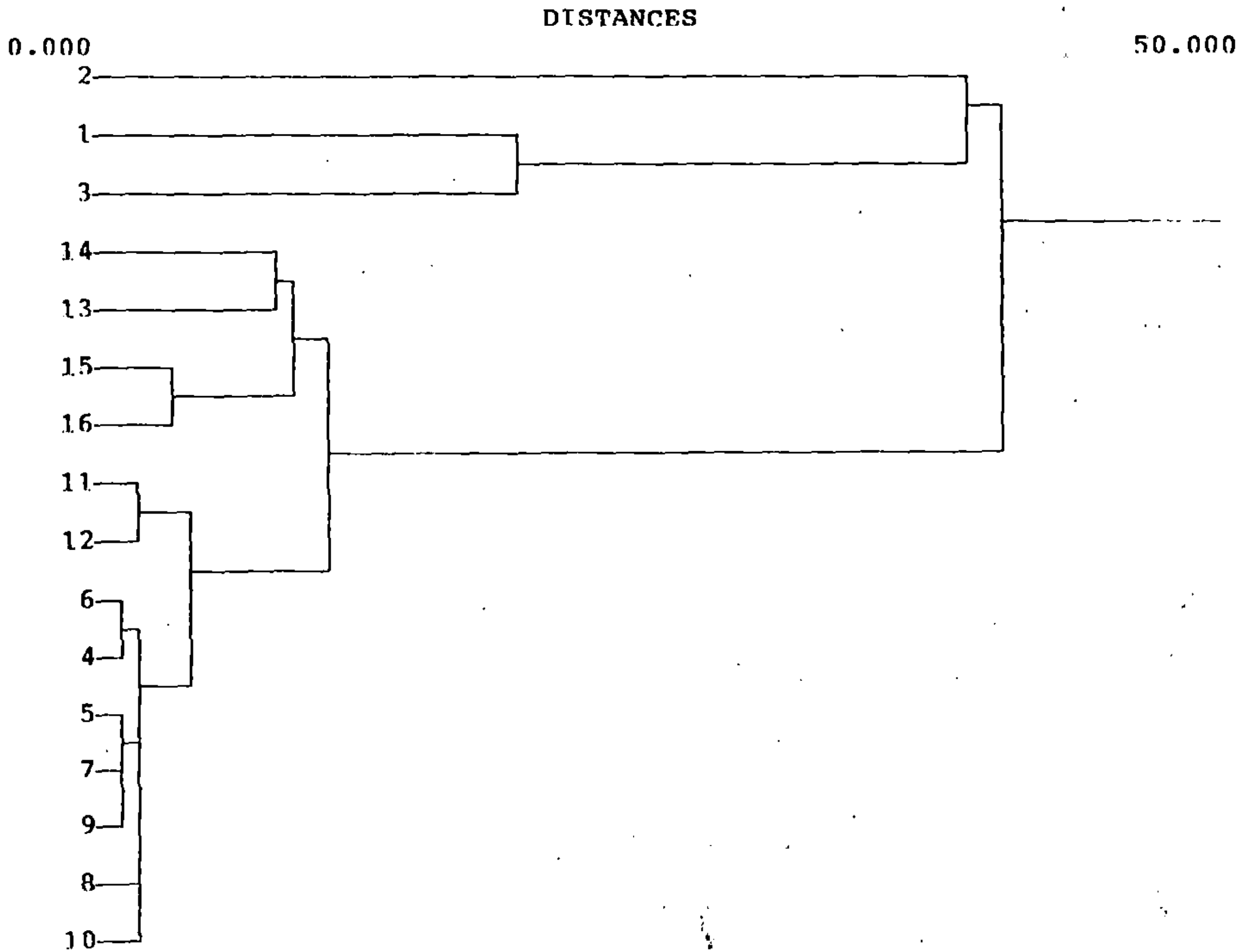
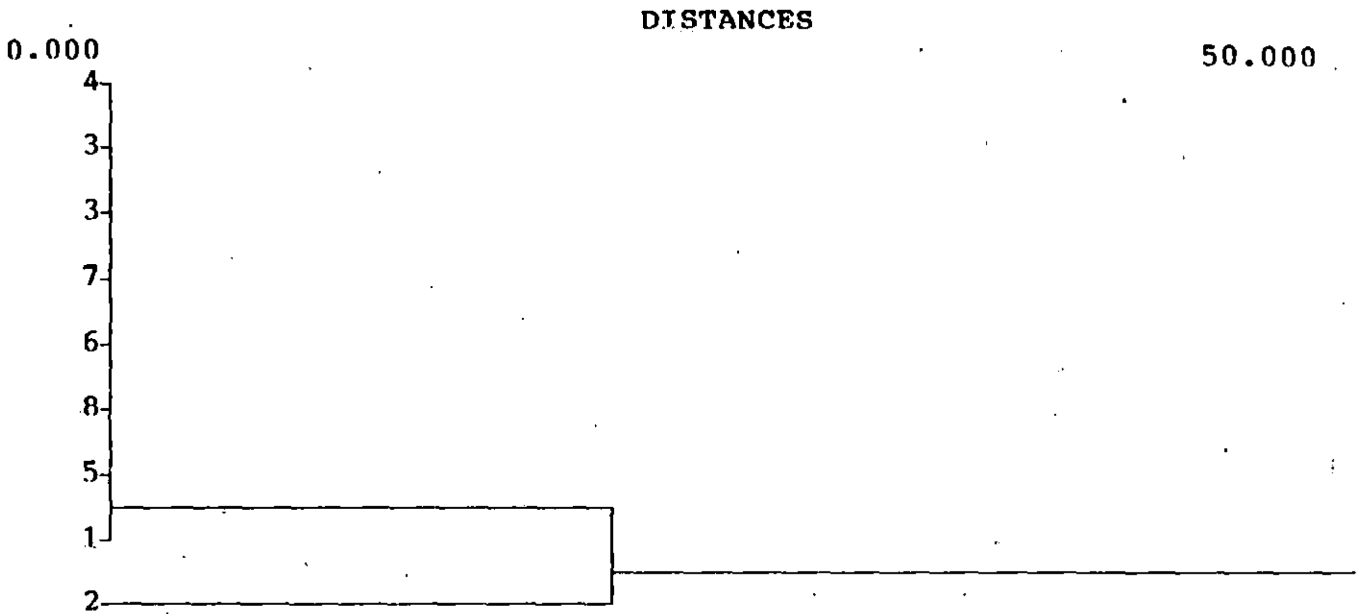


Fig 3.3 Dendrogram of tree species in Broad-leafed deciduous forest (>2800-3100 m)



1 = *A. densa*
2 = *B. utilis*
3 = *R. arboreum*
4 = *R. falconeri*
5 = *A. formosa*
6 = *M. dellinifolia*
7 = *T. brunoniana*
8 = *V. nervosum*
9 = *S. cuspidata*
10 = *L. sericera*
11 = *lex* sp.
12 = *A. campbellii*
13 = *R. barbatum*
14 = *R.cnnabarium*
15 = *R. cinnamomeum*
16 = *R.thomsoni*

Fig 3.4 Dendrogram of tree species in Broad-leafed coniferous forest (>3100-3300 m)



1 = *A. densa*
2 =*B. utilis*
3 =*R.arboreum*
4 = *R.campanulatum*
5 = *S.microphylla*
6 =*A. formosa*
7 = *R. barbatum*
8 = *R.thomsoni*

Fig 3.5 Dendrogram of the tree species in Coniferous forest (>3300-3600 m)

Relative density for certain dominant tree species were plotted against the altitudinal gradients (Figure 3.6) following Saxsena *et al.* (1982) to show their distribution. It shows that the dominant species of different forest types at their corresponding altitudes are widely distributed outside their own forest types also. *Quercus pachyphylla* is most abundant at 2700 m but its distribution is found to extend into Broad-leaf deciduous forest. Distribution of *Sorbus cuspidata* also extends from Oak forest into Broad-leaf coniferous forest, with its peak of abundance in the Broad-leaf deciduous forest. Such overlaps in the vegetation occur not only amongst the dominant tree species but can be found among the understorey species and shrubs which forms a continumm in the vegetation.

The density of trees was found to be highest at 2700 m and lowest at 3600 m. Species diversity ranged from 0.18 to 1.16. Richness was also higher in the lower altitudes which decreased towards the higher altitudes. The general trend was of a gradual decrease of all the three attributes with altitude but the values of density, diversity and richness of the tree species at 3000 m were lower as compared to 3150 m (Table 3.2).

3.4.2 Sapling and seedlings

The results of sapling and seedling densities of tree species at different altitude gradients of the study area are provided in Table 3.3 and 3.4. Regeneration of the dominant species like *Quercus* sp., *Magnolia campbellii* and *Acer campbellii* were found to be low as evidenced by the lower density of the seedling and saplings as compared to that of the undercanopy species *Litsaea elongata* at 2700 m. *Sorbus*

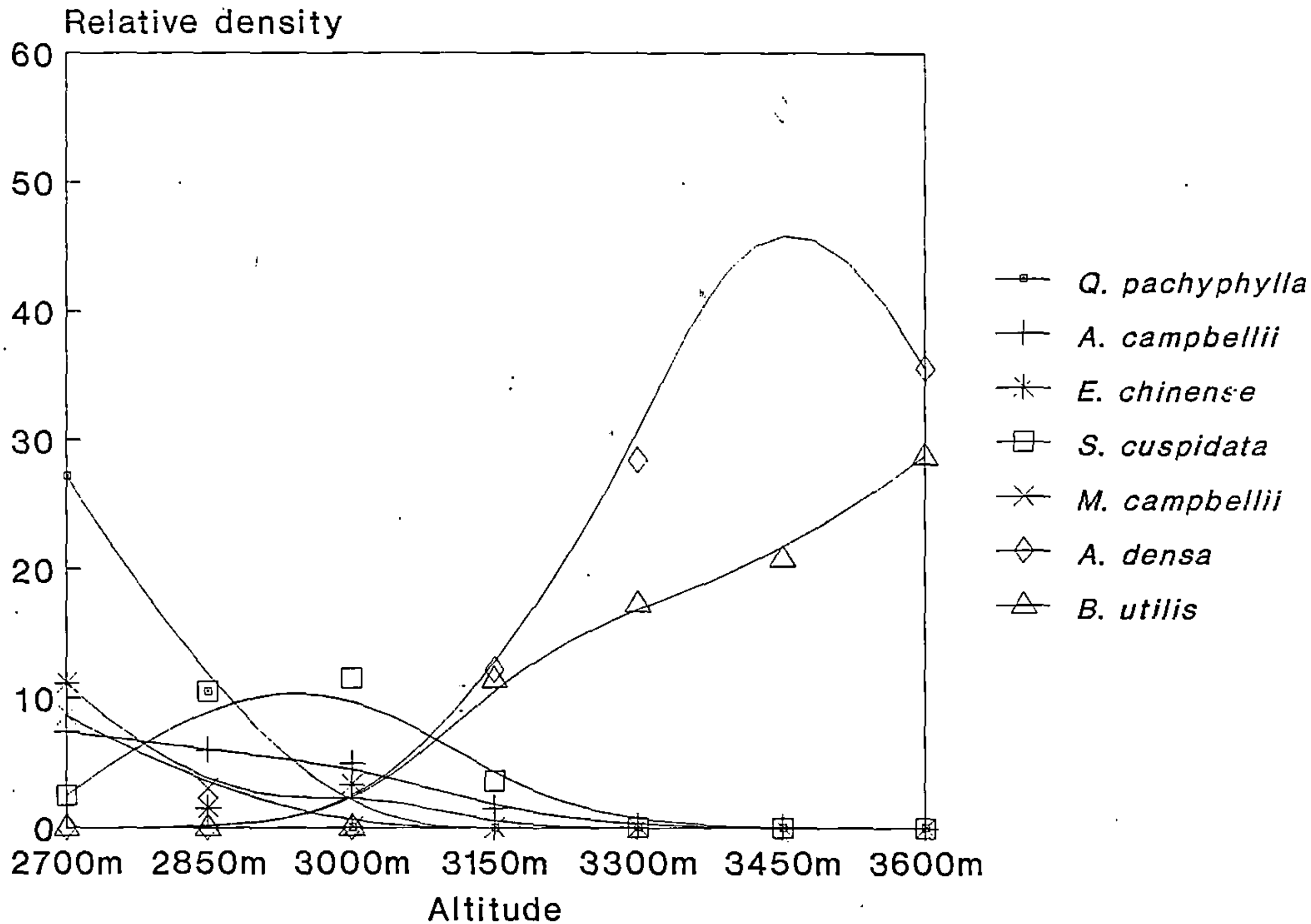


Fig.3.6 Distribution of dominant tree species in study area

Table 3.2 Density, diversity and species richness of tree species at seven altitudes of the study area.

Altitude	2700m	2850m	3000m	3150m	3300m	3450m	3600m
Density/ha	729.00	558.67	406.67	483.33	375.00	274.00	262.5
Species richness	3.73	3.61	3.00	3.94	2.18	1.08	1.24
Species diversity	1.11	1.06	0.97	1.16	0.18	0.55	0.61

Table 3.3 Seedling, Sapling and density of tree species/ha in different size classes in seven altitudes of the study area.

Altitude	Seedling	Sapling 1	Sapling 2	>31.5-70 cm	>70-150 cm	>150 cm
2700 m	2129.62	789.0	416.66	370.83	137.49	12.49
2850 m	1418.00	296.29	518.5	200.00	19.99	20.00
3000 m	1975.31	740.00	123.30	226.66	90.00	09.95
3150 m	4222.22	444.44	888.88	320.00	44.83	16.67
3300 m	6767.67	1616.1	1666.6	186.36	77.26	04.55
3450 m	5555.55	1720.4	1612.9	93.55	82.25	16.13
3600 m	14768.5	555.55	740.74	108.33	47.50	06.25

Seedling = < 30 cm height

Sapling 1 = > 30 cm height - < 1m height

Sapling 2 = < 31.5 cm girth at breast height, >1m height *cuspidata* saplings were found to be absent although represented in the seedling stage at 2850 m and 3000 m. However, *Rhododendron falconeri* which forms an important component of the vegetation in the Broad-leafed deciduous forest, was found to be represented well both in the seedling and in the sapling stages. *Betula utilis* is better represented in the sapling stage than in the seedling stage in the subalpine zone. However, sapling of *Betula utilis* was absent at 3150 m. *Abies densa* was found to have a comparatively better regeneration with it being well represented both in the seedling and sapling stages in all the altitudinal gradients of its distribution.

3.4.3 Shrubs: *Viburnum* and *Daphne* spp. are the most widely distributed shrub species which are present at six altitudes out of seven that were sampled. *Rosa sericera* and *Berberis aristata* are present above 3000 m with their highest density at 3600 m. These shrubs are known to be associated with dry disturbed sites (Shrestha, 1988). Shrubs such as *Piptanthus nepalensis, Elsholtzia fruticosa, Sambacus* sp. were found in patches in certain areas of the study area (Table 3.5).

3.4.4 Bamboo: *Arundinaria maling* and *A.aristata* are the two most dominant bamboo species present in the study area. *A.maling* is found upto an altitude of 3100m and *A.aristata* distribution ranges from 2850 m-3600 m. An increase of bamboo density with increasing altitude was indicated (Figure 3.9) by the linear regression performed on bamboo density against altitude ($r = 0.219$, $p = .001$). Evidence of bamboo grazed by yaks and cattle was found in all the altitudes that were sampled. The difference in the percent of grazed bamboo was statistically

Table 3.4 Seedling, sapling densities of few important tree species at different altitude zones in the study area.

Zone	Tree species	Seedling	Sapling 1	Sapling 2
OF	*Quercus Pachyphylla*	153.25	370.37	0
	Acer campbellii	205.33	0	24.68
	Magnolia campbellii	0	0	23.14
	Litsaea elongata	787.00	231.48	185.19
BLDF	*Sorbus cuspidata*	4.07	0	0
	Schefflera impressa	60.18	23.15	46.30
	Symplocos sp.	437.98	143.88	30.86
SAF	*Abies densa*	907.00	241.80	128.75
	Betula utilis	155.22	176.82	194.55

OF = Oak forest (2600 m-2800 m)

BLDF= Broad-leaf deciduous Forest (>2800 m-3100 m)

SAF= Subalpine forest (>3150 m-3600 m)

Table 3.5 Density/ha of shrub species at different altitude gradients of the study area

Species	2700m	2850m	3000m	3150m	3300m	3450m	3600m
Viburnum erubescense	487	1851	2098	1888	252	71	0
Daphne cannabina	185	1407	6172	2481	202	716	0
Berberis wallichii	462	2296	3333	18518	0	0	0
Rosa sericera	0	0	246	518	707	788	1851
Piptanthus nepalensis	342	0	0	74	0	0	0
Cotoneaster microphylla	0	0	0	34	101	0	0
Berberis aristata	0	0	0	74	0	0	1574
Berberis angulosa	0	0	0	148	0	0	0
Eltzostia sp.	0	0	123	148	0	0	0
Rhododendron campanulatum	0	0	0	0	0	0	2731
Rhododendron lepidotum	0	0	0	0	151	0	0

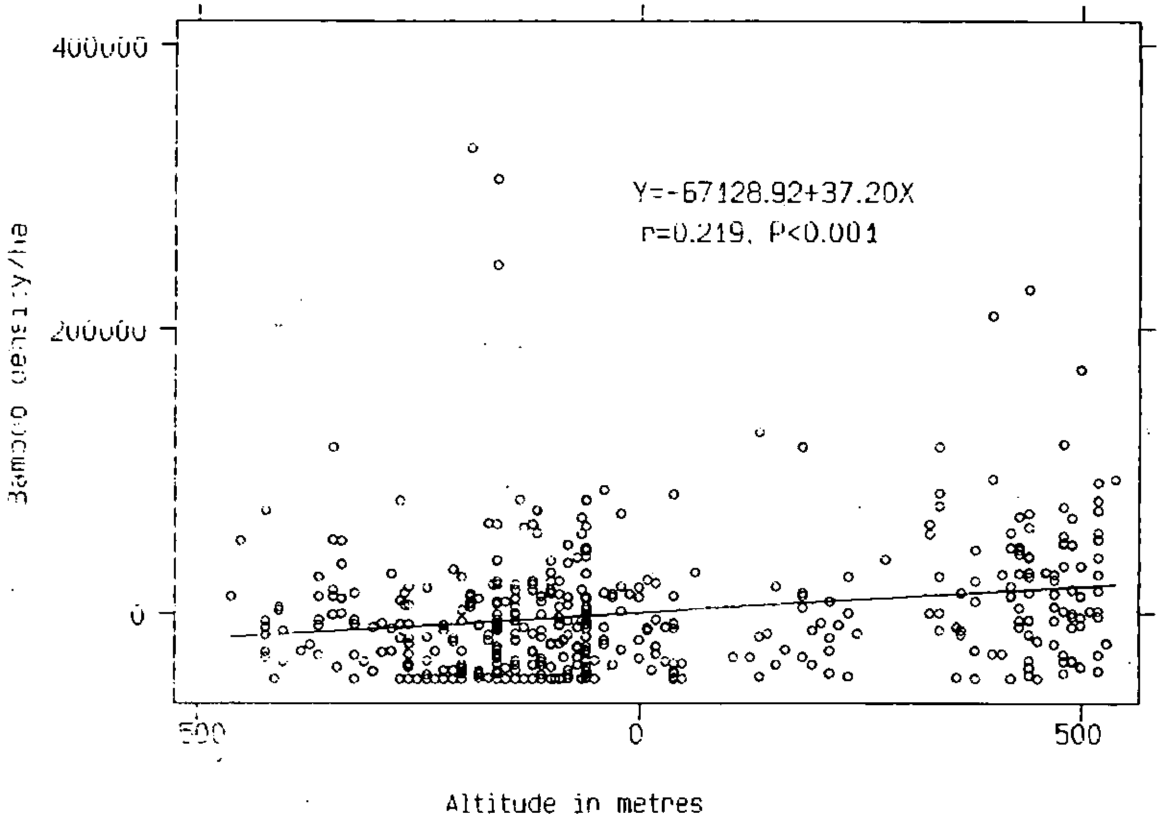


Fig.3.9 Relationship between bamboo density and altitude

significant with the percent being higher in the higher altitudes, or the subalpine zone (Kruskal Wallis, $\chi^2 = 29.32$, df=6, $p < .001$).

3.4.5 Disturbance: The vegetation of the study area and the habitat of red panda has been disturbed by several factors such as grazing, logging, lopping, construction of roads, paths, settlements, fire, landslips erosions and extraction of minor forest products. Details of disturbance factors are presented in Table 3.6. Damage from livestock as a result of grazing is not only the factor, but cowpaths or narrow trails made due to frequent use of the areas by cattle, also contribute to the damage by trampling and compacting of the soil (Shrestha, 1988). The presence of cowpath was high at 3600 m, ($\bar{x} = 1.98$), 3450 ($\bar{x} = 2.06$), and medium at 3000 m ($\bar{x} = 1.5$) and 3150 m ($\bar{x} = 1.53$). A Kruskal Wallis analysis, to test the difference in the cattle paths in different altitudes was statistically significant ($\chi^2 = 27.00$, df = 6, $p <.001$). Cattle paths are higher in the subalpine zone and were found to be positively correlated to density of percent of grazed bamboo ($r_s = 0.515$, $p <.05$). Cattle paths showed a positive correlation with the density of seedling and sapling though not statistically significant (seedling, $r_s = 0.023$, $P >.05$ and sapling, $r_s = 0.391$, $p < .05$). Density of cut stumps was highest at 3600 m with 525.00/ha followed by 3000 m (233.33/ha) and 3150 m (150.00/ha). Density of cut stumps was significantly correlated to `other disturbances' ($r_s = 0.445$, $p< .001$).The variable `other disturbances' include lopping pressure, disturbance from construction of roads, paths, settlements, fire, land slips and erosions. The highest intensity of `other disturbances' was at 3000 m ($\bar{x} = 2.2$), 3150 m ($\bar{x} = 2.3$) and 3600 m ($\bar{x} = 2.04$).

Table 3.6 Intensity of disturbance at different altitudes of the study area

Altitude	Cattle paths	Other disturbances	Cut stumps (density/ha)	Grazed bamboo(%)
2700m	0.95	1.4	112.50	10.29
2850m	1.13	1.3	54.16	7.03
3000m	1.44	2.2	233.33	17.00
3150m	1.53	2.3	150.00	48.43
3300m	1.05	1.3	20.35	2.75
3450m	2.06	0.97	36.48	43.39
3600m	1.98	2.04	525.00	90.00

0-1.00 = low, >1.00-2.00 = medium, >2.00-3.00 = high are the rating scores for the intensity of disturbance

Table 3.7 Average density/ha of different size classes of trees in the study area

Size classes	1	2	3	4	5
Average density	5089±4837	1598.96±898	215.10±102	71.33±38.27	12.16 ±5.6

The difference tested for all altitudes was statistically significant (Kruskal Wallis, χ^2 = 19.22, df=6, p <.05).

3.4.6. Forest Structure: Details of tree densities of different size classes used to describe the structure of the forest are presented in Tables 3.8, 3.9, 3.10, 3.11, 3.12, 3.13 and 3.14. Results in table 3.7 show that the size class 1 (seedling) had the highest average density followed by size class 2 (sapling I and ii), size class 3 (>31-70 cm gbh), size class 4 (> 70 - 150 cm gbh) and size class 5 (> 150 cm gbh).

The pattern of gradual decrease of density from size class 1 to size class 5, was found in all the altitudes. It is assumed that the size class or the gbh represent the age or maturity of the tree species keeping in view the maximum gbh attained by a tree species naturally. Undercanopy trees or younger trees of uppercanopy are usually represented by size class 3. At 2700 m, *Litsaea elongata* and *R. arboreum* which are important undercanopy species had a high density in size class 3. Among the intermediate class (size class 4), *Quercus pachyphylla* had the highest density (Table 3.8).

At 2800 m, the dominant uppercanopy species, *Sorbus cuspidata,* is only represented in size class 5 (i.e. mature trees). *Quercus pachyphylla*, another uppercanopy species is almost equally represented in all the size classes. But the undercanopy species, *Symplocos* sp. has the highest density. This high density of *Symplocos* sp. is contributed mainly by its density in size class 3 (Table 3.9).

Table 3.8 Density/ha of tree species in different size classes at 2700 m.

Tree species	Size class 3	Size class 4	Size class 5
Quercus sp	12.5	70.8	12.5
Endospermum chinese	33.33	25.00	0
Acer campbellii	8.3	0	0
Magnolia campbellii	25.00	4.17	0
Schefflera impresa	29.17	29.17	4.17
Litsaea elongata	54.17	37.33	4.17
Rhododendron arboreum	125.00	29.17	0

Table 3.9 Density/ha of tree species in different size classes at 2800 m

Tree species	Size class 3	Size class 4	Size class 5
Quercus pachyphylla	13.33	13.33	20.00
Sorbus cuspidata	0	6.67	26.67
Acer campbellii	13.33	20.00	6.67
Rhododendron falconeri	6.67	6.67	0
Symplocos sp.	120.00	0	0

Table 3.10 Density /ha of tree species in different size classes at 3000 m

Tree species	Size class 3	Size class 4	Size class 5
Sorbus cuspidata	0	20.00	13.33
Acer campbellii	6.67	13.33	0
Symplocus sp.	166.7	26.67	0
Rhododendron falconeri	40.00	13.33	0

Table 3.11 Density/ha of some of the tree species in different size classes at 3150 m

Tree species	Size class 3	Size class 4	Size class 5
Abies densa	26.67	33.33	13.33
Betula utilis	46.67	6.67	0
Rhododendron arboreum	63.33	6.67	0
Sorbus cuspidata	3.33	6.67	3.33

Table 3.12 Density/ha of tree species in different size classes at 3300 m

Tree species	Size class 3	Size class 4	Size class 5
Abies densa	50.00	59.09	4.55
Betula utilis	72.73	27.27	0
Rhododendron arboreum	27.27	4.55	4.55
Tsuga brunoniana	9.09	9.09	0

Table 3.13 Density/ha of tree species in different size classes at 3450 m

Tree species	Size class 3	Size class 4	Size class 5
Abies densa	38.70	103.13	62.50
Betula utilis	19.35	25.81	0
Rhododendron arboreum	3.23	9.67	0
Rhododendron campanulatum	6.45	0	0

Table 3.14 Density/ha of tree species in different size classes at 3600 m

Tree species	Size class 3	Size class 4	Size class 5
Abies densa	37.50	66.67	4.17
Betula utilis	12.5	29.17	8.33
Rhododendron campanulatum	41.67	0	0

At 3000 m, the highest density is again, in size class 3 and the species having this high density is *Symplocos* sp. *Sorbus cuspidata* is represented in size class 4 and 5, but not in size class 3 (Table 3.10).

3150 m, has a high average density of 320 trees/ha in size class 3 (Table 3.3). Tree species like *Betula utilis, Rhododendron arboreum, R. cinnabarium* and *Abies densa* contributes to this density of 320/ha in size class 3. The only tree species represented in size class 5 are *A. densa* and *Sorbus cuspidata* (Table 3.11).

Details of density of tree species in different size classes at 3300 m are presented in Table 3.12 *Abies densa* is present in all size classes. It can be seen that the maximum density of *A. densa* in size class 5 or mature trees, were at 3450 m (Table 3.13). At 3600 m, *Abies densa* and *Betula utilis* are mostly represented in size class 3 and 4. *Rhododendron campanulatum* which forms the understorey has a density of 41.67 in size class 3 (Table 3.14).

3.4.7 Phenology: Foliation of buds and flushing of leaves started by the end of March (Figure 3.7,a). Until the beginning of foliation, leaf buds remained dormant. By June, a peak of leaf flushing was reached by which 88% of the tree species had young leaves (Figure 3.8,a). Evergreen tree species like the *Quercus pachyphylla, Daphniphyllum himalayense, Schefflera impressa, Symplocos* sp., leaf buds appeared and young leaves flushed by June, replacing the old ones. By the end of July, the leaves changed colour, texture and could be called mature leaves. From

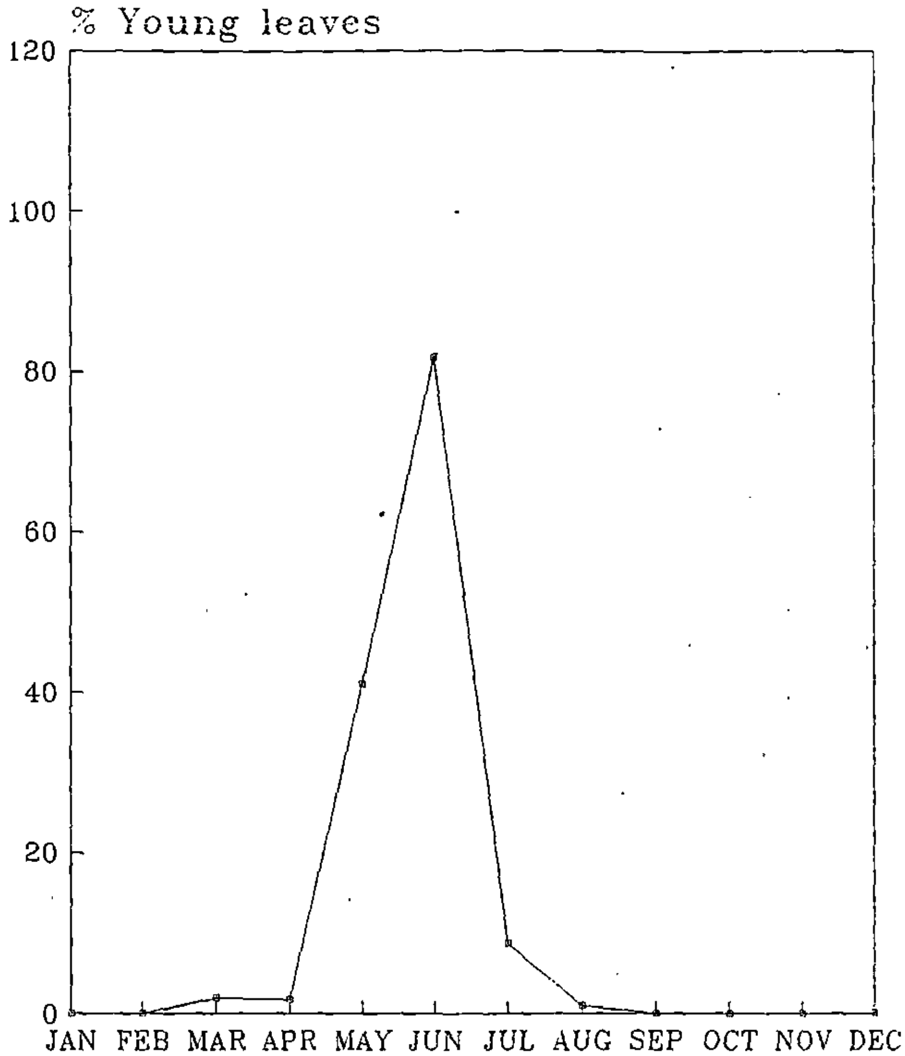


Fig.3.7a Phenological cycle showing the peak of flushing.

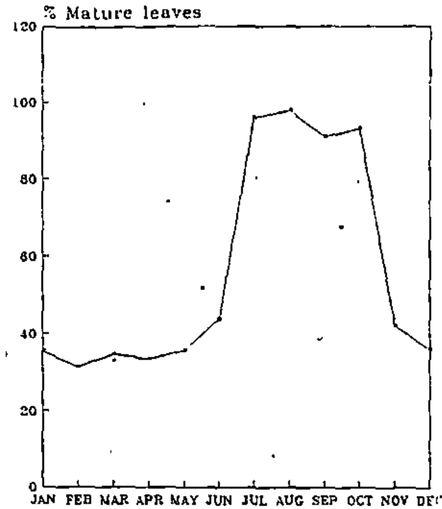


Fig.3.7b Phenological cycle showing the peak of mature leaf production

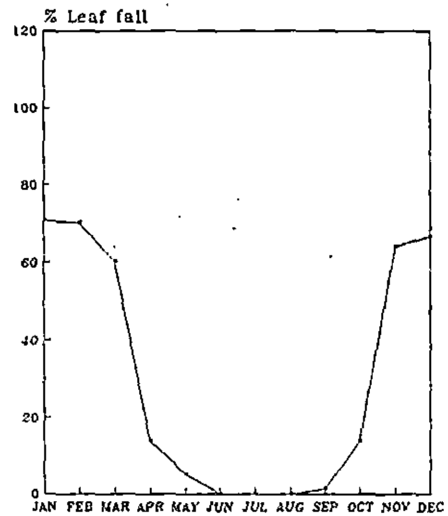


Fig.3.7c Phenological cycle showing the peak of leaf abscission

July to September, a peak in vegetative cover was reached (Figure 3.7,b) when almost all the species had mature leaves (Figure 3.8,b).

The peak of leaf abscission was attained in winter (Figure 3.7,c) when all the eleven deciduous species studied had shed their leaves and remained denuded until the time, the leaf buds started foliating again. Leaf started falling from mid-October when 16.67% of the tree species shed their leaves.

Flowering started from March. *Magnolia campbellii* flowered between April to May. *Rhododendron* spp. flowered in batches, in different months starting from March till late May. *Rhododendron* spp. and *Magnolilia campbellii* are the conspicuous flowering tree species in the Park. Peak of flowering was in May when 32% of the species were found to flower (Figure 3.8, c).

Fruits appeared by June, reaching maximum production in August-October with 48% of the species fruiting in August and September and 35% fruiting in October (Figure 3.8,d). *Osmanthus* sp. flowered in June and its fruits remained till late December. A saprophytic tree species locally known as Lahare tenga also had fruits from October to early March.

Among the shrubs and creepers, *Daphne* sp. started flowering from mid February. Others like *Berberis, Rosa, Piptanthus, Viburnum* species had flowers by May and fruits were produced from July to August. However, *Berberis* and *Rosa* species in the higher altitudes were seen to flower almost a month late- by June-July and bore fruits

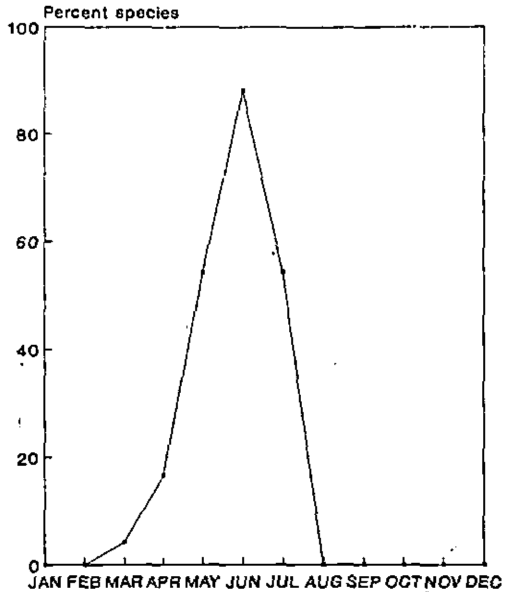


Fig.3.8a Percent species with young leaves

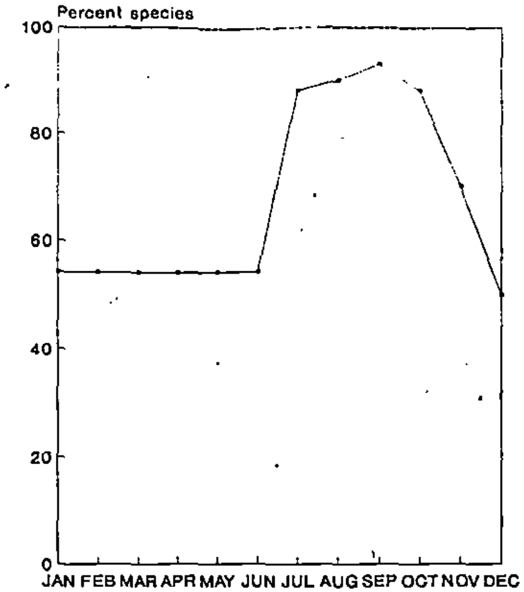


Fig.3.8b Percent species with mature leaves

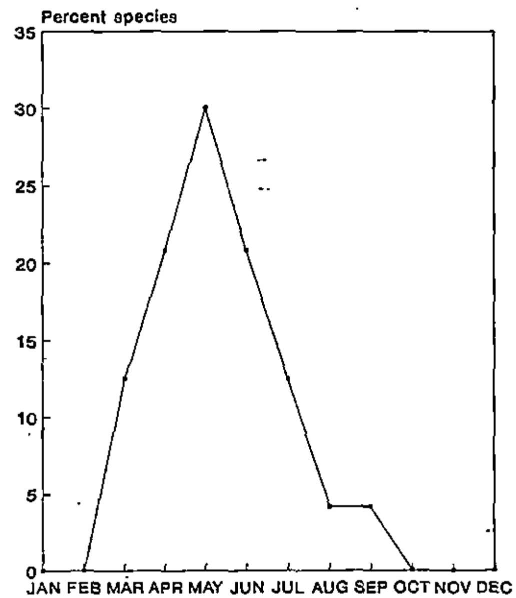


Fig.3.8c Percent species flowering

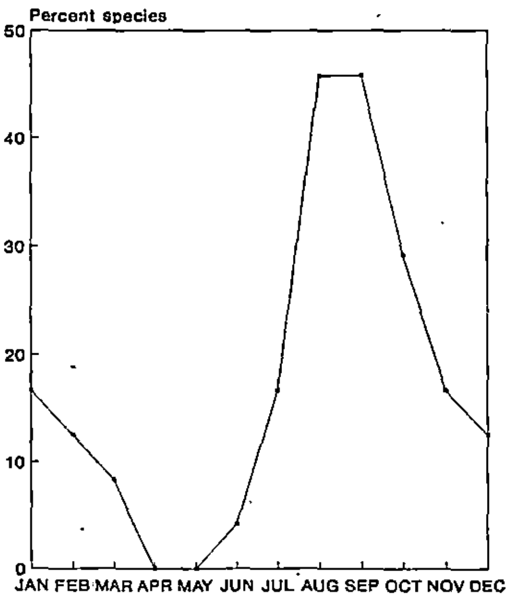


Fig.3.8d Percent species fruiting

from August. *Holboellia latifolia* and *Actinidia strigosa* were important creepers bearing edible fruits. These creepers were seen to flower from July and fruit from August to November. Leaf abscission in almost all the shrub species started from November and remained bare till April.

3.5 Discussion

The changes that are brought about in the vegetation of an area by biotic interference, management and succession would influence the habitat and thus the distribution and abundance of the animal. Placing current ecological data in their correct time context is an important aspect of ecological studies. The natural vegetation of Singhalila National Park was used and misused in the past. Hence, it was attempted to get an overview of the status of the vegetation at present.

3.5.1 Classification: The cluster analysis produced four distinct clusters of vegetation communities corresponding to the vegetation communities in altitude zones. The vegetation types are Oak forest (2700 m-2800 m), Broad-leafed deciduous forest (>2800 m-3100 m), Broad-leafed coniferous forest (>3100 m-3300 m) and the Coniferous forest (>3300 m-3450 m). This classification is followed in the thesis to explain some of the aspects of ecology of the red panda in the study area.

3.5.2 Functional spectrum of the forest: Food and cover are the two important functions that a habitat should be able to provide to the wild animals. The phenological study was incorporated here with the intention to procure some information on the availability of food and cover to the red panda in different times of the year. A general trend of phenological events in the vegetation of the study area showed that leaf flushing reached its peak during the rainy season when the area had maximum vegetative cover. Monsoon was also the season during which bamboo shoots came up along with a large varieties of mushrooms. Both, bamboo shoots as well as mushrooms serve as important food items for red panda and other animals. Mushroom was found to be taken by the red panda in the Lantang National Park, Nepal (Yonzon, 1989). Leaf fall started from October or postmonsoon season and the area had the least cover during the cold months of winter until the time leaf flushing started during premonsoon again. Bamboo forms the major understorey in the entire park and being a perennial grass, bamboo provide cover and food to the red panda and other animals throughout the year.

Peak of flowering both of the trees and the shrubs is reached during the premonsoon season and that of fruiting during the postmonsoon season during which maximum food resource in form of fruits was available in the forest. The period during which the forest has maximum cover and food coincides with red panda's birth, lactating and weaning periods.

3.5.3 Structure and Composition of the forest: Disturbance in biological balance are often recognised by changes in the physiognomy, structure and species composition of the vegetation (Dombois-Muller and Ellenberg, 1974). The present study has been able to show the distribution, abundance, dominance and regeneration status of the plant species, found to be important to the red panda habitat.

The Importance Value Index has given an overall importance of a tree species in terms of its density, total area covered and frequency of its occurrence. Data on the densities of trees in different size classes has revealed the status of individual species as well as the structure and composition of the forest. For example, the average density of tree species at 2700 m is 729/ha, but it is important to know as to which species, in which size or age group, and in what proportion is contributing to this overall density. These information are generated from the results of the densities in the five size classes studied. Some of the dominant uppercanopy trees such as the *Quercus pachyphylla, Abies densa, Sorbus cuspidata, Betula utilis, Magnolia campbellii* are important to the red panda in terms of providing refuge and cover.

S. cuspidata is also an important fruiting tree. Although the fruits of *S. cuspidata* was not found to be taken by red panda during this study, Yonzon and Hunter(1989) reported the fruit of *S. cuspidata* to be one of the important food items of the red panda. In the present study, *S. cuspidata* was found to be distributed from 2700 m to 3150 m but abundant at 2800 m-3000 m. The data on the density of trees species in different age classes revealed that *S. cuspidata* was represented only in seedling class, size class 4 (intermediate) and size class 5 (mature) whereas its representation in sapling class and size class 3 was nil. It may be recalled here that the size classes are based on the gbh of trees (refer section 3.4.6 of this chapter) and it is assumed that the increasing size classes represent the increasing age or maturity of a tree species. Absence of the species in size class 3 (immature stage) is therefore an indication of the absence of young or immature *S. cuspidata* trees. The absence of saplings of *S. cuspidata*, indicates a recruitment pattern which, according to Bargali *et al.* (1989), is of a population which reproduced in the past but at present proper establishment of saplings are not favoured, although seedlings are coming up. Absence or very low representation of the species in sapling stage indicates an interruption in regeneration (Bargali, *et al.* 1989). Such interruptions in regeneration of a species could be due to any factor of environmental disturbance to the species. *S. cuspidata* fruits are collected in large amounts by the people which could be a source of disturbance to the regeneration of the species. This fruit is used for adding flavour to the local liquor that is brewed. Recruitment of *Magnolia campbellii* was also found to be very poor with no representation in seedling class which indicates that the species is reproducing infrequently (Knight, 1975). It is thus important for the managers to give special protection and artificial regeneration priorities to *S. cuspidata* and *Magnolia campbellii.* In case of *Quercus pachyphylla,* representation was low in sapling II (<31.5 gbh, >1 m height) and size class 3. This also indicates interruption or disturbance to its proper establishment. *Betula utilis,* mostly forms the undercanopy but at places also forms the uppercanopy also. Taylor *et al.* (1991) found *Betula* spp. to colonise clear-cuts more rapidly than conifers. They reported that stands of conifers which had been clear cut, to be now solely composed of the opportunistic species of *Betula* during their study of habitat restoration of the giant panda after the flowering and death of bamboo in Wolong Nature Reserve. Loss of a dominant conifer component in these habitats of the pandas could be detrimental to the giant pandas and red pandas as they both use hollows, over-mature conifers as maternity dens (Schaller et al., 1985; Taylor and Qin, 1989). *Betula utilis,* during the present study was found to be well represented in immature and intermediate classes but has low representation in seedling class, a case similar to that of *Magnolia* *campbellii*. Contrary to the general and local belief, that *Abies densa* is in danger of being extinct in the area, it was found that the species had a better reproduction and establishment status as indicated by the density of the species in all the size classes. However, it is important to note that *A. densa* is a slow growing species which attains an average diameter of 9 inches in sixty years (Anon, 1967). Disturbance from factors such as cattle paths, grazing, felling are seen to be prevalent at all altitudes with their intensity highest at 3000 m, 3600 m and 3150 m. The higher disturbances at 3000 m, 3150 m and 3600 m is because of the presence of disturbance not only from cattle paths, grazing and lopping but from other disturbances such as construction of roads and presence of settlements. 3000 m roughly make the altitudinal limit of Gairibans and Kalipokhari and this contour is represented by ridge which is usually open and denuded. 3600 m is also the altitudinal limit of Sandakphu. A road runs along this contour which is constantly used. Apart from these, a number of trekker huts and government quarters are present at 3600 m (Sandakphu) which contributes to the biotic pressures in this altitude. Sandakphu, although has very low human population, the area receives a large number of tourists. The area being in the highest altitude is also colder than other areas. These factors increase the use of fire wood consumption and would explain the high density of cut stumps recorded in this altitude, thus effecting the intactness of the red panda habitat in the area. The disturbance in the higher altutudes have been mainly occurred due to the higher number of cattle stations in these altitudes. The sapling densities and the relatively high densities of the seedlings could imply that the tree species in the study area are now regenerating. Bamboo, one of the most important component of red panda habitat, is extensively grazed and trampled upon and more so in the subalpine region. Past records of the quantitative analysis of vegetation of the National Park for comparison is scarce. The results presented here can be used for future reference to evaluate the future changes in the vegetation. The low density of dominant trees in immature class, indicates an interruption and disturbance in their establishment. Although the overall high density of seedlings indicate recovery after the disturbance to the vegetation of the area, it is important to give specific attention and conduct long term monitorings of the recruitment dynamics of the vegetation in the National Park. The area needs complete protection and judicious management inputs. This is important in order to provide an intact habitat to the red panda and other wildlife species in the area.

The present study is a conventional method of resource survey, as compared to the latest technology of remote sensing using satellite data for forest and land use mapping. Sudhakar *et al.* (1993) opine that the conventional method suffer from various constraints such as inadequate trained manpower, lack of infrastuctural facilities, inaccessibility of remote and difficult terrain and non-availability of real time data which render the information inflow back-dated and incomplete. Sudhakar *et al.* (1993) however, also points out the disadvantages of the digital data which is not able to consider variables like texture, pattern, association and location. The technology would also be ignorant of the detailed recruitment data of critical species important to a habitat although they do have the facilities of repetitive monitoring of forest cover changes. In an area as the present one, where there has been no prior scientific investigations, this study has the importance of providing data which could be used as a reference for future monitorings of the red panda habitat, either using the conventional methods or the technology of remote sensing.

CHAPTER 4

DISTRIBUTION, ABUNDANCE AND STATUS

4.1 Introduction

The abundance and distribution of animal populations vary in space and time. Distribution and abundance are closely related ecological parameters and distribution is considered as the spatial expression of abundance (Andrewartha, 1970). Information on distribution and abundance is a basic requirement in ecological studies (Elton ,1927; Krebs, 1985) and an important necessity for formulation of effective management and conservation strategies for the wild species (Caughley and Sinclair, 1994).

However, methods for the estimation of accurate population size or abundance still continue to elude field workers. Enumeration of population size has been done at various levels- total counts, absolute density, relative density and even simple presence/absence or frequency records (Caughley, 1977; Caughley and Sinclair, 1994). Accurate estimation of animal abundance becomes a bigger challenge when applied to rare, shy, elusive, solitary animals inhabiting inaccessible terrain. Sale and Berkmuller (1987) noted that basic presence/absence data have not been worked out for many such wild animals in India. This holds true for red panda also, for which no such information exists from its distribution range in India. Very little information is available on its status in the wild (Roberts, 1982a; Glatston, 1989; Yonzon and Hunter, 1991; Glatston, 1994). The only detailed study of red panda population dynamics has been conducted in Nepal (Yonzon and Hunter, 1989) who were of the opinion that no standard method of census was applicable for estimation of red panda

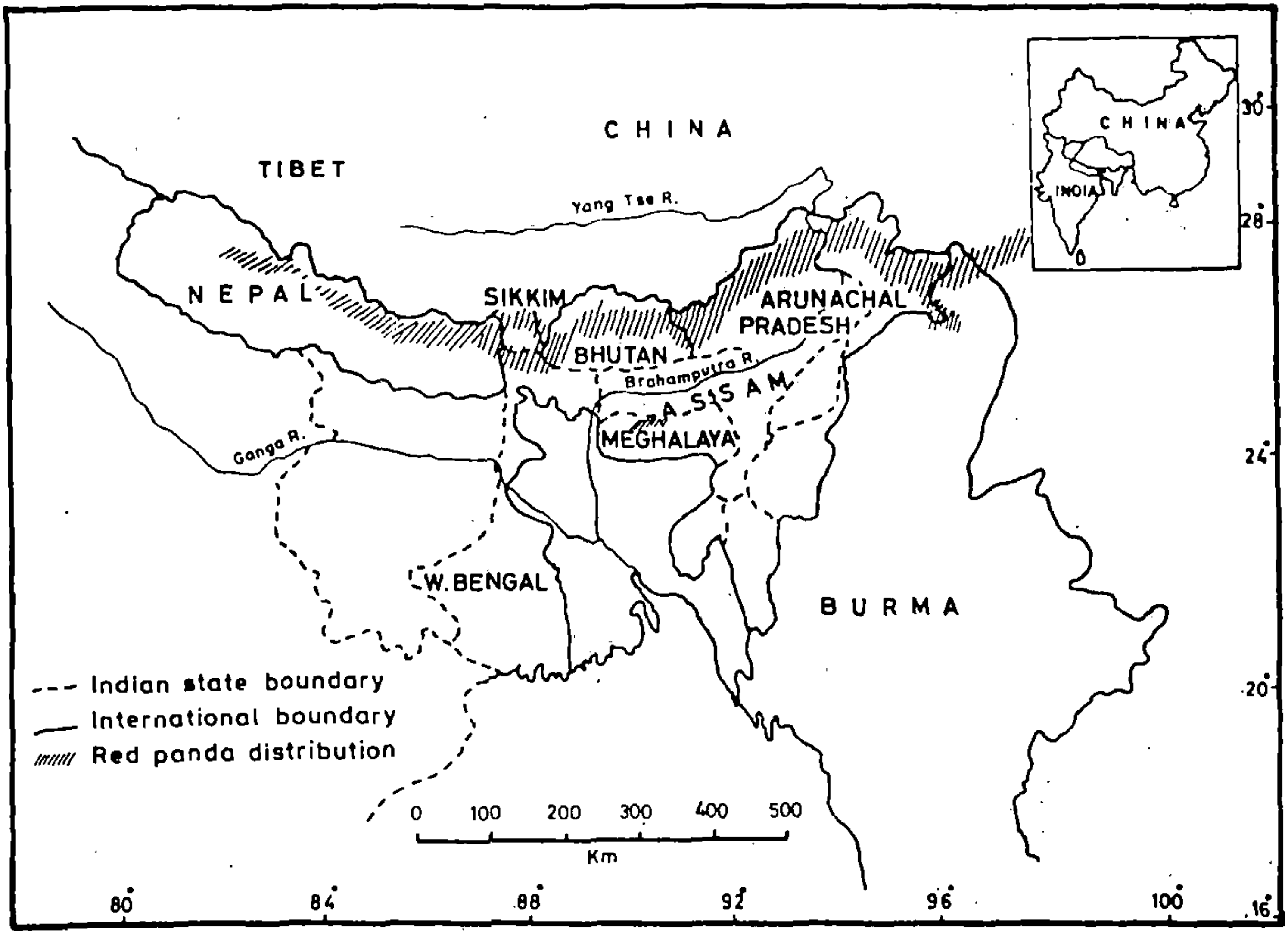


Figure 4.1 Current distribution of red panda

population. They combined radiotelemetry study, SAT imagery and GIS to work out the numbers of red panda in the Langtang National Park.

In India, red panda is known to occur in the Northeast India (Mukherjee, 1982; Rodgers and Panwar, 1988). However, so far, no detailed study or information on the population status of the red panda is available from India, apart from documenting the presence of the species in different protected areas. In the Singhalila National Park, Dareeling, some of the early records of red panda are made by Mclaren (1946), Tikadar (1983), and in the faunal list of the Management Plan of the National Park. Apart from this, nothing was known, not even whether the animal existed anymore or not.

This chapter deals with the distribution, relative abundance and status of red panda mainly based on indirect evidences of the red panda in the Singhalila National Park, along with a review of the current distribution of red panda along its distributional range.

4.2 Current distribution of the red panda

Red panda is found in the temperate forest with bamboo understorey between 1500 m-4000 m in the Himalayas, high mountains of Northern Burma, Western Sichuan and Yunnan (Sowerby, 1932; Allen 1938; Stainton, 1972; Anon, 1978; Jackson, 1978; Miewrow and Shrestha, 1978; Feng *et al.*, 1981; Roberts, 1982a; Yonzon and Hunter, 1991). This stretch of distribution includes Nepal, India, Bhutan, Northern Burma and China (Figure 4.1).

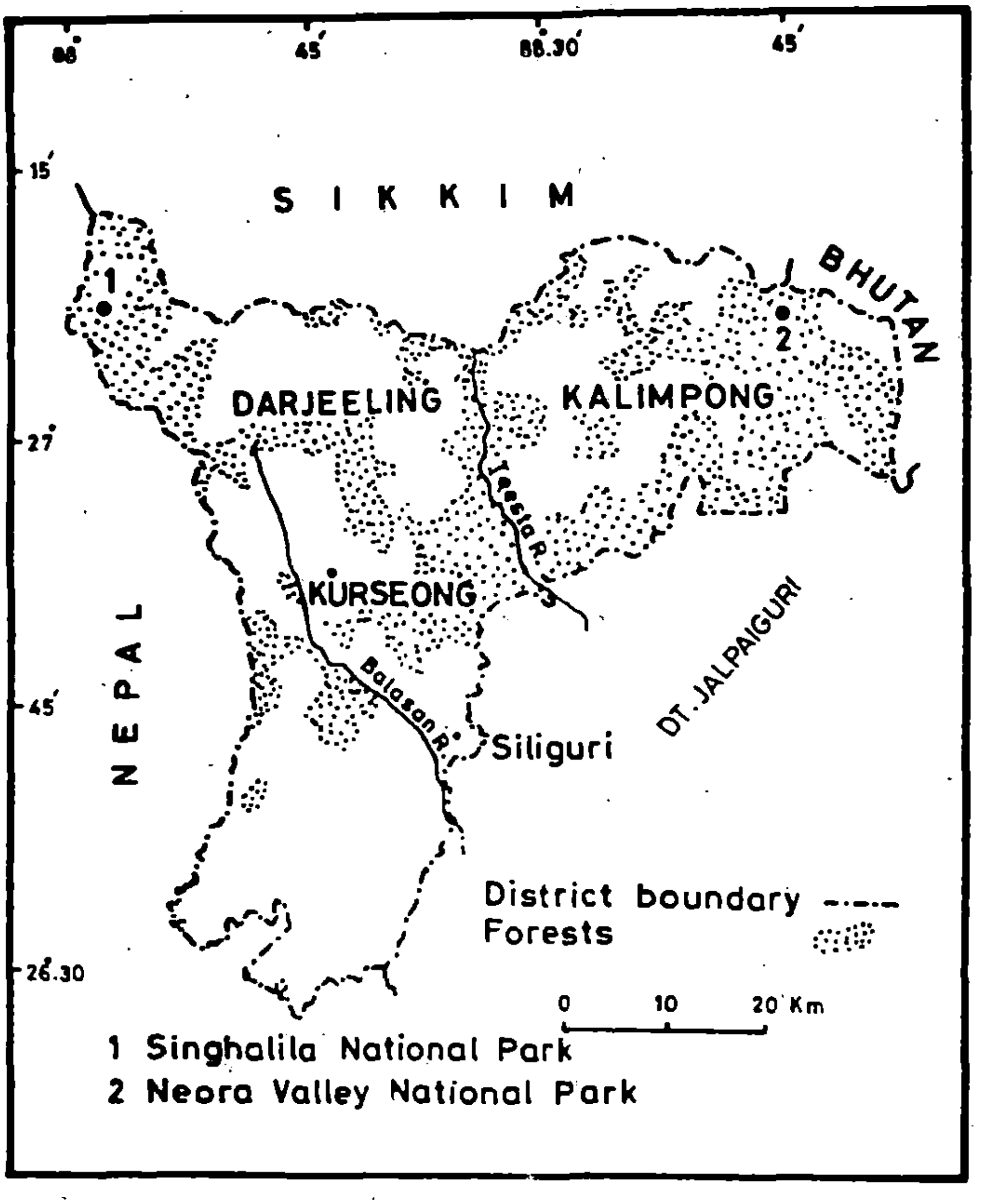


Figure. 4.2 Map showing location of two National Parks in Darjeeling holding red panda.

4.2.1 Nepal: In Nepal, red panda occurs in the Langtang, Sagarmatha, Makalu Barun and Manslu National Parks (Yonzon, 1995). The author reported red panda between 3000 m - 4000 m in the Fir bamboo forest in the Lantang National Park. He also reported red pandas from Namru, Shyla, Samagaon, Shangure Kharka areas in Manslu. Evidences were also found at an altitude of 3000 m in *Abies spectabillis, Acer campbelli* and Birch forest in the Makalu Barun region. Red panda is reported from the upper forest of lower Seng and lower Barkhe Valley (Wegge, 1979; Fox, 1985) and from the Annapurna Conservation Area (Glatston, 1994). The Namlung valley in the Mugu district and the Rara region of North western Nepal seems to be western most limit of red panda distribution (Jackson, 1978). But Yonzon (1995) opines that this needs to be authenticated. Moreover, the Shey Phokshundo Park, which lies between the Annapurna, Dhorpatan Hunting Reserve and Rara National Park has no red panda which makes it less likely for the species to occur in Rara (Glatston, 1994).

4.2.2 India: In India, range of red panda distribution, encompasses three states- West Bengal, Sikkim and Arunachal Pradesh. Recent reports of occurrence of red panda is also received from Meghalaya (Chaudhury, 1997). In the state of West Bengal, red panda is present in the Singhalila National Park and the Neora Valley in the hilly district of Darjeeling (Figure 4.2). Senchel Wildlife Sanctuary, also in the District, lies within the same latitude, with similar forest type as of the two National Parks is also expected to have red panda. However, this has to be confirmed with proper surveys of the area, prior to any scientific documentation.

Sikkim is another Himalayan State in India which has red panda distribution. Red panda in Sikkim has been reported from Kunchendzonga (Northwest Sikkim), Fambong Lho Wildlife Sanctuary and Kyangnoisia Alpine Sanctuary (East Sikkim), Shingba Rhododendron Sanctuary (North Sikkim) and Barsey Rhododendron Sanctuary (West Sikkim). In Arunachal Pradesh presence of red panda in the Eagle Nest Wildlife Sanctuary has been reported (Mukherjee, 1994; Kakkati, 1996). In Eagle Nest, red panda evidences were found in the Eagle Nest Pass, Chako and Bompa areas (Kakkati, 1996). Other National Parks, where red panda is reported from are Mouling National Park, Namdapha National Park, Mehao, Pakhui, Kamlung, Dibang , Tawang, Lado, Palin Wildlife Sanctuaries. (Rodgers and Panwar, 1988).

4.2.3. Bhutan: Little information is available about red panda in Bhutan except for the documentation of it presence in The Zigme Dorjee Wildlife Sanctuary (Yonzon, 1995). It is also present in the Thumring La National Park where it was seen in a bamboo-fir forest, 6.5 km east of Ura, at 27°28'59" N and 90°54'16" E in April (per. comm. Carol Inskipp).

4.2.4. Burma: Information from Burma on the red panda is also scarse. Its occurrence has been reported from the Chukan pass area (Milton and Estes, 1963). The National reserves holding red panda are Piduang and Hkakuborazi in Nortern Burma (per. comm. K. Htay). Zhina subregion, Yingjiang county (in China) is only approximately 17 km from the China- Myanmar border where red panda is known to be locally extirpated in recent years (Ma *et al.*, 1995). In a recent paper, Rabinowitz and Khaing (1998) considered red panda to be relatively common in the forests, north of Nam Tamai River in North Myanmar.

4.2.5. China: Red panda has been reported from the Southeastern Tibet (Feng *et al.*.1981), west Yunnan and Sichuan (Anon, 1978) in China. Recent survey in the West Yunnan (Ma, *et al.*, 1995) showed that the Gaoligongshan Region (western most region of the Yunnan Province) led to the confirmation of red panda in reasonable numbers in the northern areas of Gaoligonshan. It was also reported in the same report that its population, further south, to have declined since the 1980s. Red panda is reported to occur in the Wolong, Tangjahe, Medong and the Wanglang National Reserves (IUCN, 1993). *The eastern limit of red panda's distribution falls in the* Quingling mountains of the Shaanxi province (Wu and Hu.,1980). The Liankiang Range of western Yunnan and the upper valley of the Min Valley of Western Sichuan forms the southern and the north eastern limit of red panda distribution, respectively (Ma *et al.*, 1995).

***4.2.6. Protection Status*:** The red panda is a protected species in India, Nepal, China and Bhutan. In Myanmar, it is covered by the Forest Act, which means it is protected in the same way as all other forest products are protected (Glatston, 1994). It is listed as 'insufficiently known'- an (IUCN) category K (Anon, 1988) and in the Appendix I of (CITES) (Brautigam, 1995).

4.3 Methods

A combination of extensive surveys, interviews, intensive study based on direct and indirect evidences of the animal were used to assess the present status, abundance and distribution of red panda in the SNP.

4.3.1 Survey: *The objective of the preliminary survey (October 1993 to October* 1994) was to establish the presence/absence of the red panda in the National Park and also to locate potential study sites for a detailed study. The survey was done on foot to cover systematically all the compartments of a beat. The compartments and beats are administrative units of the National Park. The existing human, cattle and bridle paths were used to survey the compartments. Because of the presence of the cattle stations previously in the park, there is a good network of such paths. The area visited was searched for red panda signs and the animal itself. For evidence (indirect and direct) found, variables such as the altitude, general habitat, vegetation of the area compartment number, and the presence of any other animal were noted. The locations of evidences were then plotted on a map of Singhalila National Park. These surveys were done with assistance from the forest staffs and local people. Details of the survey are summarised and presented in Appendix I.

The first survey was carried out in October 1993. The next three surveys were carried out in May 1994, June - August 1994 and September 1994 and following area were covered:

Sandakphu (3636 m), Kalipokhari (3100 m), Gairibans (2625 m), Kaiyakatta (2879 m), Bikhaybhanjyang (3200 m), Molley (3250 m), Sabarkum(3540 m), Phalut (3600 m), Gorkhey (2389 m), Rammam (2300 m), Siri (2200 m), Rimbick (2250 m).

4.3.2 ***Interviews:*** Information on the status and distribution of the species was also gathered by interviewing the local people, forest officials, herders. The red panda was locally known as `pure kudo' and `hokrekpa'. The people were especially asked as to when they had last seen a red panda or red panda evidence, and where. The information given by the local people was checked by visiting the site. This was done because during the interviews with the people, I realized that some had the tendency to give exaggerated information while most of the local people feigned ignorance. However, I relied a lot on the local information as nothing was known or documented about the red pandas in the National Park.

4.3.3 ***Intensive study:*** After the preliminary surveys, and the confirmation of the presence of red panda in the Singhalila National Park, three study sites viz. Gairibans, (Site 1), Kalipokhari -Kaiyakatta (site 2), Sandakphu (site 3) were selected for initiation of more intensive investigations of red panda ecology (Figure 2.3). A total of twelve with four transects/trails in each study site were selected. Details of the transects are presented in Table 4.1. It was not possible to establish transects as defined by Burhnam, *et al.* (1980) due the rugged terrain and often dense bamboo undergrowth in the study area. Hence, the existing paths and trails in the passing through different habitat types and altitudinal zones in the study area were used as transects. These trails are referred to as transects in the text. The transects were monitored at regular intervals of one month, for collection of direct and indirect evidences of red panda. Apart from this, 91 random plots, 24 in site 1, 27 and 40 plots in site 2 and 3 respectively, were marked along the transects and monitored to check for presence of any direct or indirect evidences of the animal. Five nearest trees were marked and the distance between the fifth and the sixth nearest tree was noted. The mean of the distance from the two trees was taken as the radius and the area calculated accordingly. The vegetation (five tree species and % cover, shrub species and % cover, bamboo species and % cover, ground species and % cover), altitude, aspect, slope of these points were noted while establishing these random plots.

4.3.4 Indirect Evidences: Call, scrapes, tracks, dung, urine trails, nest sites, burrows are reliable evidence of animal presence. For the present study, I used dung and tracks to record the presence and study the pattern of distribution and abundance of red panda in the study area.

Tracts came in handy only during winter when the area was snow covered and when the foot prints stood out sharp and clear. Dung or pellet groups were found to be the best indicator of animal presence. It was comparatively long lived and more easily

Table 4.1 Salient features of the transects in the study area

Site	Transect	Altitude covered (m)	Mean altitude	Major topographies covered	Forest type
1(GB)	1	2630 -2860	2750 m	HS, RDG	OF
	2	2600 -2800	2780 m	HS,HB,RDG	OF,PLT
	3	2600 -2850	2790 m	HS, Vehicular road	OF,PR, MF
	4	2750 -3100	2990 m	HS, north facing	MF,PLT
2 (KP)	5	2645 -2870	2700 m	HS, RDG	OF, RF
	6	2690 -2870	2710 m	RDG,HS	OF, BMS,MF
	7	2870 -3000	2980 m	HS, RDG	MF, BMS
	8	3050 -2890	2910 m	HS, RDG,VA with stream	MX
3 (SD)	9	3636 -3450	3555 m	HS, north facing, RDG	SF
	10	3600 -3340	3500 m	RDG with north &south facing slopes	SF
	11	3430 -3200	3190 m	HS,VA with a stream	SF,BCF
	12	3400 -3550	3450 m	HS, north facing, six valleys.	SF

HS= hill slope, RDG= ridge, HB= hill base, VA= valley.

OF= Oak forest, PLT= plantation, BLDF= broad-leafed deciduous forest, PR= pure rhododendron, BMS= pure bamboo stand,

SAF= subalpine forest, BCF= broad-leafed coniferous forest, GB= Gairibans, KT= Kaiyakatta, SD= Sandakphu found. Red panda dung consists of pellets which are elliptical in shape. A single group comprised of an average of 8.5± 3 pellets. Red panda also have latrine sites using the same area for repeated defecation.

Whenever a pellet group was found during monitoring, data were collected on the total number of pellets in the group, number of groups at one place and the substratum such as tree trunk, tree branch, base of trees, logs, ground, rocks.
Pellet group once found, were either cleared or in case of very large piles, stamped upon to distinguish it from fresh dung when the transect was re-visited. The places where pellet group was found (dung point) was marked, and checked when the transect was re-monitored. If dung was found in a new place on the second visit, this was also marked. This became a new dung-point to be checked in subsequent visits. The random plots were also checked at regular intervals for dung deposition and cleared in case of any deposition.

4.3.5 Direct sightings: There is no apparent sexual dimorphism in red panda which makes it difficult to identify the sex of the animal when sighted. Whenever possible, I assigned sex and age to a red panda as cubs, female to the adult panda seen with the cub, subadult and adult or unsexed for others. For each sighting, note on the habitat, number of animals, sex and age, activity was noted down. Observations on the animal were done as long as it was in sight.

4.3.6 Secondary information: I maintained a record of the sightings of the red panda by others made during the course of the study, to supplement the information gathered during the present study.

4.3.7 Extensive Surveys: Parts of the national park other than the intensive study sites were revisited once again after the preliminary surveys and initiation of intensive study in order to get better information on the distribution and status of the species.

4.4 Analyses

Quantification of the red panda evidences was done based on the encounter rate of pellet groups and red panda per 100 hours in each transect, in each study site and vegetation zones. The encounter rate was used as an index for determination of relative abundance of red panda. Standard non parametric statistical tests such as Kruskal Wallis, Mann-Whitney U-test and Spearman rank correlation were used following Zar (1984). The statistical tests were done using the statistical program, Stata 5.0 (1997).

4.4.1 Estimation of red panda density in the study area: The animals were not radio collared nor were there any standard methods to identify individual animals. In the present study I have used data on the individuals/sighting, identification of individual animal by age, presence of cub pellets and my personal experience and familiarity with the study area to enumerate the number of animals in each transect. I then used this to get a crude density of red panda in the study area.

I considered only the data of individuals/sighting because number seen in one group at one time would be an independent event and thus independent animals. I also made sure that the transects were at least 3 km apart from each other so that the chances of seeing the same animal on two transects is reduced. Sighting of a cub or subadults can also ensure the sighting of independent animals. Pellet size especially of the cubs can also ensure the presence of individual animals (Table. 4.2). I have also added a male to the sighting of a female with cubs with the assumption that a male was definitely present in the area. Area of the intensive study area is approximately 25 km^2. With the total number of red panda calculated for the study area, density of the species per km^2 was calculated.

4.5 Results

4.5.1 *Survey:* During the first survey in May, no direct sightings of red panda were obtained from the areas surveyed. During this survey in May 1994, the only evidence obtained in the form of pellet-group were from the north facing slopes of Phalut at an altitude of 3555 m on a *Rhododendron sp.* tree. This evidence was based on local report (the survey team was taken to the spot where the red panda pellet groups were present), hence encounter rate was not calculated. During the second survey of June 1994-August 1994, a red panda (secondary information) was sighted in Gairibans at an altitude of 2830 m in a forest of *Acer, Rhododendron* and *Quercus* species and an understory of *Arundinaria maling*. In addition to this, 3 indirect evidences were also found from Gairibans, 5 from Kalipokhari-Kaiyakatta areas (refer Table 4.1 for encounter rates). No evidences were found from Sandakphu but reports of local sightings were gathered and the areas visited.

During the third survey in September-October 1994, a red panda was sighted (encounter rate of 1.4/100 hours) in Phalut at an altitude of 3540 m. Reports of local sighting of red panda from Saberkum was obtained. Local information of red panda with a cub was also obtained from Sandakphu from a forest staff. This was in the area which was later covered by transect 10 of Sandakphu. I was able to collect as many as 3 indirect evidences (dropping from three different areas) in Sandakphu from Fir-birch-rhododendron forest at 3450 m, an area later covered by transect 9. All these three indirect evidences of pellet groups were on Birch (*Betula utilis*) trees on the northern aspect.

Red panda evidences were not reported or found from Rammam, Gorkhey, Samanden and Rimbick. The extensive surveys carried out later to survey areas which were not covered during the preliminary survey and also to confirm the presence/absence of red panda in areas visited during the preliminary survey but no evidences were found. I was able to confirm the presence of red panda from Molley and upper Gorkhey during the extensive survey which was not done during the preliminary survey. No evidences were found from Lower Gorkhey, Rammam, Siri and Jarayotar (Rimbick), Gurdung, Pedi even during these extensive surveys (Appendix II).

4.5.2 ***Intensive study:*** An average of 32 trips per transect (total of 380 trips) were made to the transects, and a total monitoring time of 742.35 hours spent in the three study areas with 236.20 hours, 229.00 hours and 227.15 hours in Gairibans, Kalipokhari-Kaiyakatta and Sandakphu respectively.

4.5.2.1 ***Direct Sightings*:** Sightings were extremely infrequent, details of which are presented in Table 3.5. 28.12% of the sightings were made on transect 7, 18.75 % on transect 10 and 4, 9.38% on transect 8, 6.25% on transect 3 and 9, 3.15% on transect 11and 12 and none on transects 1, 5,and 6 (Table 4.4).

The nine sightings on transect 7 included the sighting of three adults (3 individuals/sighting) in December 1994, two cubs and a female (3 individuals / sighting) on two consecutive days of October 1995 and a subadult in January 1995. The

Table 4.2 Detail of sightings of red panda on transects during different months

	Transect	Sight	Individual	Age	Cub pellets
Jun	2	1	1	A	0
Jul	2	1	1	A	0
Aug	3	1	1	A	0
Dec	3	1	1	A	0
Jul	4	1	1	A	0
Aug	4	1	1	A	0
Oct	4	1	2	A	0
Jan	4	2	2	A	0
Apr	6	1	1	A	0
Jan	7	1	1	SA	0
Feb	7	2	2	A	0
Mar	7	1	1	A	0
Apr	7	2	2	A	0
May	7	1	1	A	0
Oct	7	1	3	A,C	Y
Dec	7	1	3	A	0
Jul	8	1	1	A	0
Oct	8	1	1	A	0
Nov	8	1	1	A	0
Oct	9	1	2	A,C	0
Apr	9	1	1	A	0
Mar	10	1	1	A	0
Apr	10	1	1	A	0
Jun	10	1	1	A	0
Oct	10	2	2	A	Y
Mar	11	1	1	A	0
Oct	11	0	0	0	Y
Apr	12	1	1	A	0

A= Adult, SA= subadult, C= cub

maximum number of sightings during the study period was done in October (Table 4.3).

The six sightings on transect 4 included the sighting of two adult animals together in October 1995. Two sightings of red panda on transect 9 included the sighting of a female and a cub in November 1994. Apart from these, all the other sightings were of single animal (Table 4.2).

4.5.2.1.1 Observations: The longest observation on sighting red panda in the study area was for 180 minutes (10.00 hours - 13.00 hours) when three adult red pandas were seen together on 26 th December (Winter) approximately, the period of mating for the red panda. They were seen on a huge *Rhododendron arboreum* tree resting on the different branches at Kalipokhari-Kaiyakatta transect 5 at 2900 m. Along with other tree spp. such as *Magnolia cambelli, Acer campbelli, Ilex sp.*, *Osmanthus sauvis, Sorbus cuspidata* and *Daphepyllum himalyensis*, the area where this sighting was made, is dominated by an association of Rhododendron-bamboo. Although the three red pandas interacted very little, they were together in the same tree throughout the three hours of observation. Finally one of the animal got up, climbed up to a higher branch, defecated and left the tree. While climbing up the tree, it brushed past one its mate, but no aggression or offence was shown by the animals during this short period of direct interaction.

Two adult red pandas were see together on 28 th October in Gairibans research base (2600 m) at 14.30 hours. As October is not known to fall within the breeding period of the species, it is difficult to say anything about the togetherness of these animals.

Table 4.3 Sighting records of the red panda in the study area from October 1994-October 1996.

Transects	Jan	Feb	Mar	Apr	May	Jul	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	1*	1*	0	0	0	0	0	2
3	0	0	0	0	0	0	0	1*	0	0	0	1	2
4	2	0	0	0	0	0	1*	1*	0	0	1	0	5
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	1	0	0	0	0	0	0	0	0	1
7	1	2	1	2	1	0	0	0	0	1	0	1	9
8	0	0	0	0	0	0	1	0	0	1*	1	0	3
9	0	0	0	0	1	0	0	0	0	1	0	0	2
10	0	0	1	1	0	1	0	1	0	2	0	0	6
11	0	0	1	0	0	0	0	0	0	0	0	0	1
12	0	0	1	0	0	0	0	0	0	0	0	0	1
Total	3	2	4	4	2	2	3	3	0	5	2	2	32

Table 4.4 Pellet group encounter and proportion of sighting on the transects of the study area.

Transect	Pellet group/100 hours	% Sighting
1	1.58	0
2	22.30	6.25
3	7.33	6.25
4	68.25	18.75
5	0	0
6	3.69	0
7	43.97	28.12
8	66.41	9.38
9	78.92	6.25
10	26.52	18.75
11	40.00	3.13
12	2.53	3.25

Apart from these, cubs and mother were seen during October and November. The cub seen in November 1994 in Sandakphu was suckling. The mother seemed to be resting but the cub was extremely active and playful. It climbed and descended efficiently but did not venture too far away from the mother. These two red pandas were seen on a huge Silver Fir tree at 3450 m on the northwest aspect at 14.30 hr - 15.15 hours) in Fir-birch-bamboo forest. Two cubs and a female red pandas were seen on transect 7 of Kaipokhari-Kaiyakatta at 2820 m, on the southeast aspect in Quercus-rhododendron-bamboo forest in October, 1995.

All the other animals seen were single. Out of all these animals sighted and observed, only one exhibited a kind of aggressiveness. It was sighted in August 1995, in Sandakphu, transect 10 at 3450 m in Silver fir-birch-bamboo forest in the northern aspect at 10.00 hours and was observed for thirty minutes. It was in the base of the slope when it was first seen while we were on the ridge. This animal, instead of walking or running away, walked up the hill towards us. While doing so, it scent marked by rubbing its anal portion on three occasions, twice on a fallen log and once on the base of a tree. We did not move from our place of observation, but the panda positioned itself at about 7 m from us. It stayed there for a few minutes sniffing the air around. It then descended and became out of sight. We packed up and when we were just about to move, realised that the panda had stealthily climbed the birch tree behind us and was looking at us. This was an extremely unusual behaviour for the red panda which is known to be shy. Only on one occasion was red panda observed to be feeding. This animal was sighted in a Rhododendron-bamboo forest 2890 m on a *Rhododendron* tree feeding on leaves of *A. aristata*

Table 4.5 Details of red panda sightings in the study area.

	Site 1(GB)		Site 2 (KP)		Site 3 (SD)	
	Sighting	Individual	Sighting	Individual	Sighting	Individual
JAN	2	2	1	1	0	0
FEB	0	0	2	2	0	0
MAR	0	0	1	1	3	3
APR	0	0	3	3	1	1
MAY	0	0	1	1	1	1
JUN	1*	1	0	0	1	1
JUL	2*	2	1	1	0	0
AUG	2*	2	0	0	1	1
SEP	0	0	0	0	0	0
OCT	1	2	2	4	3	4
NOV	0	0	1	1	0	0
DEC	1	0	1	3	0	0
Total	9	10	13	17	10	11

* secondary information

GB=Gairibans, KP=Kaiyakatta, SD=Sandakphu bamboo which were tall enough to reach the height of the branch where the red panda was resting.

4.5.2.1.2 Encounter rate of red panda in the three study sites: Site 1 had an encounter rate of 0.44±.03/100 hours. Site 2 and 3 had an encounter rate of 3.04±2.00/100 hours and 2.89±2.1/100 hours respectively (Kruskal wallis: $X^2 = 0.657$, df=2, $p < .05$) (Table 4.6).

4.5.2.1.3 Encounter rate of red panda in the three vegetational or elevational zones: Broad-leafed deciduous forest (>2800 m-3100 m) had the highest encounter rate of 3.81±3.00/100 hours, followed by Subalpine coniferous forest (>3150 m-3600 m) 2.78±2.2/100hours with none at Oak forest (2600 m-2800 m) (Table 3.8). The difference was significant (Kruskal wallis; X^2= 5.699, df=2, $p > .05$).

4.5.2.2 Dung/pellet groups: During this study period, I was able to locate 234 pellet groups during the monitorings of the twelve sample transects.

4.5.2.2.1 Encounter rate in the three study sites: An encounter rate of the pellet groups/100 hours in the three study sites showed site 3 with the highest encounter rate of 37.84±32.24/100 hours followed by site 2 (28.83±32.16/100 hours) and Zone 1 with 24.55±13.09/100 hours. These differences were not statistically significant (Kruskal Wallis; X^2=0.769, df=2, $p>0.05$) (Table 4.6).

The highest encounter rate within Site 1(Gairibans) was on transect 4 (68.15±32.16/100 hours) followed by transect 2 (22.30±32.30/100 hours), transect 3

Table 4.6 Encounter rate of pellet groups/100 hours and red panda/100 hours in the three study sites

Sites	Sighting	Pellet groups
Gairibans	$0.44 \pm .03$	24.55 ± 13.09
Kaiyakatta- Kalipokhari	3.04 ± 2.0	28.83 ± 32.16
Sandakphu	2.98 ± 2.1	37.84 ± 32.24

Table 4.7 Pellet group deposition in random plots in the three zones of the study area.

Zone	No. of random Points used	Frequency of occurrence in used plots	Density/ ha
1.	1(n=27)	2(0.34%)	3.26
2.	8(n=24)	25(4.44%)	43.66
3.	7(n=40)	24(1.5%)	29.19

Zone 1= Oak forest

Zone 2= Broad-leafed deciduous forest

Zone 3= Subalpine forest

(7.33±2.35/100 hours) and transect 1(58.15±5.8/100 hours) and the difference was significant (Kruskal Wallis; $X^2 = 9.265$, df=3 $p < 0.05$). (Figure 4.3)

The highest encounter rate of pellet groups in site 2 (Kaiyakatta) was on transect 7 and 8 with encounter rate of (43.97±30.57/100 hours) on transect 7, (66.41±25.70/100 hours) on transect 8. The difference in the pellet group encounter rate /100 hours was significant (Kruskal Wallis; $X^2 = 13.05$ df=3, p=<.01) (Figure 4.3).

At Site 3 (Sandakphu), the highest encounter rate of (79.82±79.5/100 hours) was in transect 9. Transect 10, 11 and 12 has an encounter rate of 40.00±37.50/100 hours, 27.52±50.12/100 hours, 2.52±7.07/100 hours respectively. The difference in the encounter rate of pellet group /100 hours among the transects was not significant (Kruskal Wallis; $X^2 = 0.332$, df=3, p >.05) (Figure 4.3).

4.5.2.2.2 ***Encounter rate of pellet groups in the three elevational or vegetation zones***: Highest encounter rate of pellet group was in the Broad-leafed deciduous forest (105.06±29.59/100 hours) followed by the Sub alpine forest (85.00±42.00/100 hours) and the Oak Forest (20.31±10.05/100 hours) the difference being statistically significant ($X^2 = 8.71$, df=2, $p<0.05$). Mann-Whitney U-test showed a significant difference between Broad-leafed deciduous forest and Oak forest (z=2.66, $p<0.01$), between Oak forest and Sub alpine coniferous forest (z=2.42, $p<0.05$). However, a significant difference was not found between Broad-leafed deciduous forest and Sub alpine coniferous forest (z=0.580, $p>0.05$).

The Kruskal Wallis test for all the difference in the encounter rates in the three vegetation zones during premonsoon monsoon, postmonsoon and winter showed

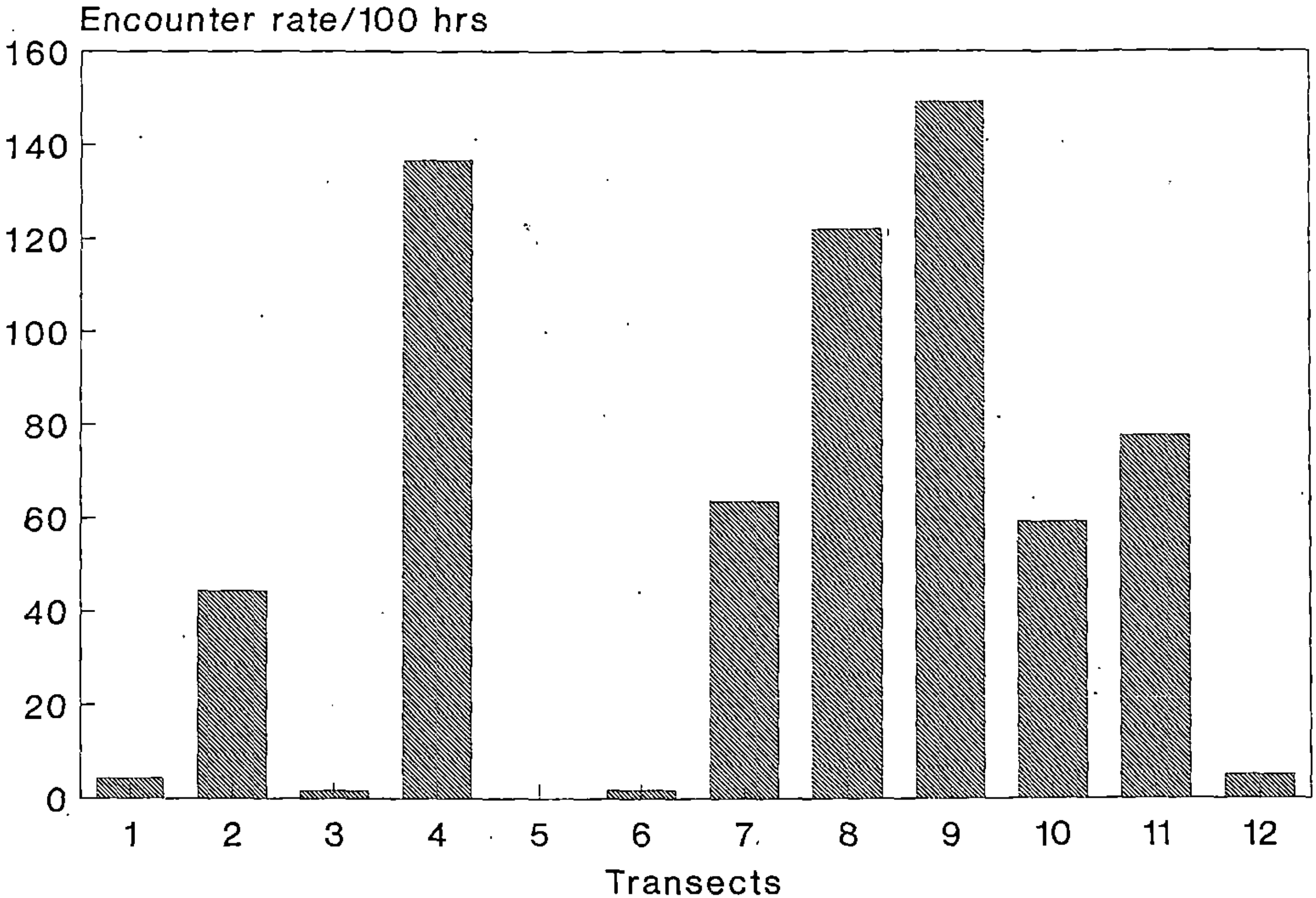


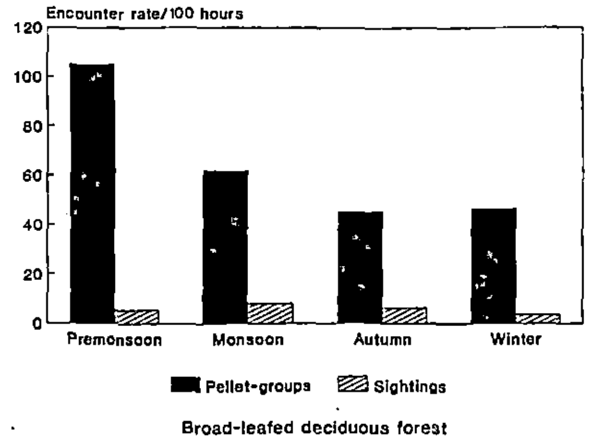
Fig.4.3 Encounter rate of pellet groups/100 hrs on transects

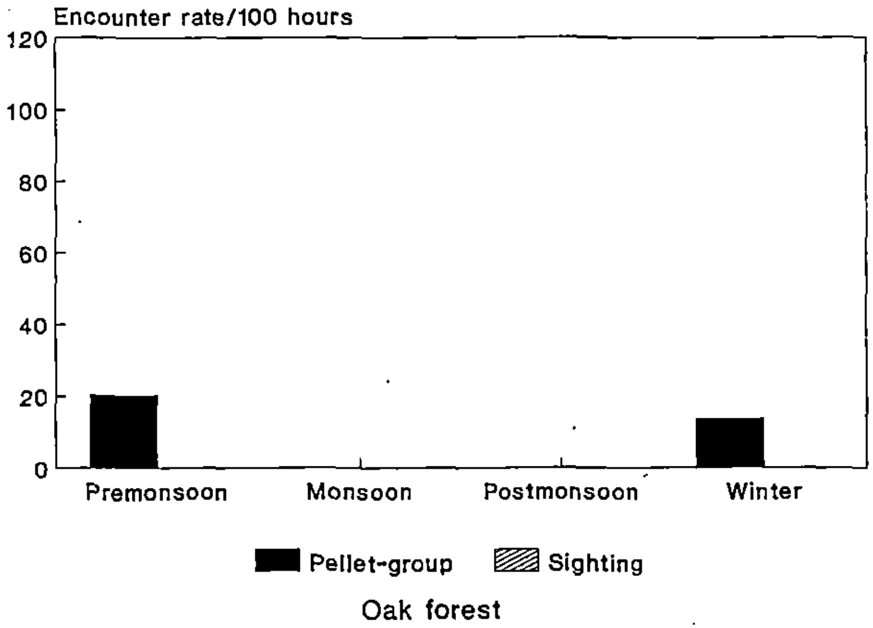
significant difference in the encounter rates between the three zones (Kruskal-Wallis $X^2 = 9.177$, $p < .01$ for premonsoon, $x^2 = 14.66$, $p < .001$ for monsoon, $x^2 = 10.59$, $p < .01$ for postmonsoooon, $x^2 = 11.2$, $p < .01$ for winter) (Figure 4. 4).

4.5.2.3 ***Indirect evidence of red panda in the random plots:*** Evidence of red panda, was found in only 16.7% of the random points (n=91). The maximum number of times an evidence was found in one random point was 10 (20.83%). The overall monthly frequency of occurrence of red panda evidence during the twenty four months of the intensive study, 0.34% of the occurrence was in Oak forest. Broad-leafed deciduous forest and Subalpine coniferous forest had a frequency of 4.3% and 2.5% respectively. The density of pellets found in the three zones are 3.26/hectare in Oak forest , 43.66 and 29.19/hectare in Broad-leafed deciduous forest and Subalpine coniferous forest respectively (Table 4.7).

4.5.2.4 ***Group size:*** The maximum number of individuals seen together or in a group during the sightings of the red panda in the study area was three, seen on three occasions. The mean group size of red panda was highest in Broad-leafed deciduous forest (1.29) followed by Subalpine coniferous forest (1.1) and Oak forest (1.0).

4.5.2.5 ***Estimation of red panda numbers in the study area:*** A summary of the estimated number of red pandas in the transects of the study area is presented in Table 4.10. With the details presented in Table 4.2 and 4.8, I estimated a maximum of fifteen animals in the intensive study area and a crude density of 1 red panda/1.67 km^2.





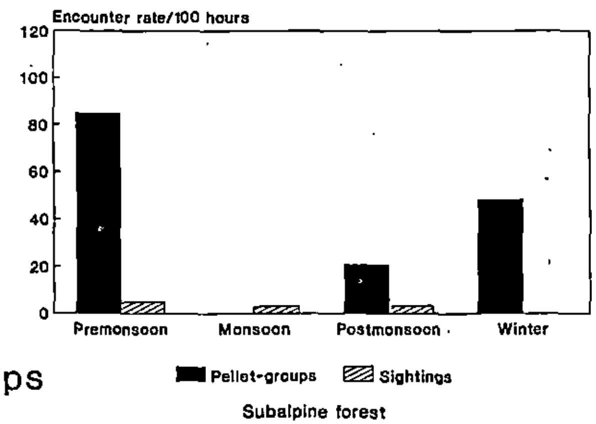


Fig.4.4 Encounter rate of red panda and its pellet groups per 100 hours in the three vegetation zones

Table 4.8 Estimated number of red pandas on the twelve transects of the study area

Transect number	Estimated number of red pandas
1	0
2	1
3	0
4	2
5	0
6	1
7	5
8	1
9	2
10	1
11	2
12	0
Total	15

4.5.2.6 Relation between encounter rate of pellet group and red panda sightings: A spearman rank correlation was used to test the correlation between encounter rate of pellet groups and red panda sightings. A positive correlation was found between the sightings and the encounter rate of the red panda ($r_s = 0.78$, $p < .05$). The correlation was also significantly positive between pellet group encounter rate and percent sightings of red panda on the transects ($r_s = 0.74$, $p < .01$) and also with the independent number of red pandas calculated for the transects ($r_s = 0.843$, $p < .001$)

4.6 Discussion

4.6.1 ***Indirect evidence:*** As seen from the results, red panda sighting was very infrequent. Therefore, it was important to resort to quantification of the pellet groups of red panda for their estimation of the relative abundance in the study area. Dung has been widely used for estimating relative abundance of several wildlife species (Neff, 1968; Putman, 1984). The standard technique involves using or knowing the time period for the accumulation of certain amount of dung per unit area, defecation rate of the species in question, which allows the estimation of population size. The present study was not able to adopt this standard technique due to the dearth of information on these aspects of red panda from the wild. Hence, encounter rate of red panda and red panda pellet groups has been used as an index for estimation of relative abundance of red panda in the study area. This index would only compare the abundance of the animal within different areas in the study area. As there is not even basic information on the red panda in wild, the results of the present study would provide base line information which could be used to assess not only the present status of the red panda in the Singhalila National Park but also the future monitorings.

An index is considered a reliable indicator of abundance if it shows a linear correlation with the population size (Caughley, 1977). However, in this case it was not possible to estimate population size to apply and test the theory. Hence, not much is known about the statistical relationship between the index and population size of the animal. However, the encounter of pellet group being a good index in the present study is testified by the fact that areas with higher pellet encounter rate had more sightings of the red panda. Moreover, a statistical significant correlation was also found between the pellet group encounter rate and the sightings.

It is however, important to take into consideration the sources of errors and biases accompanied with use of dung as index for animal abundance while interpreting the results of the present study. The most important one being the differential search ability of observer leading to unequal recovery of dung from all habitats. Biases may also come due to faecal aggregation by use of latrine sites or areas for repeated defecation by the red panda.

To address both problems, random points were established for search of red panda evidences in all the altitude zones and habitat. The establishment of the random points made the search intensive and equal in all the habitats and cover types, thereby reducing the bias arising from differential search effort.

4.6.2 Distribution and abundance: Results of the present study on the distribution, abundance and status are presented for sites as well as vegetation zones. This is because the three study sites are administrative units in the Singhalila National Park and therefore it will be easier for the managers to comprehend the results. The precision of abundance estimate is also increased when the entire area is stratified.

This is because the result now becomes a function of variability of samples within strata, not of variability across the entire area (Caughley, 1977). Moreover the results of the vegetation zones can also be extrapolated to other parts of the National Park and status of the species evaluated.

4.6.2.1 Distribution and abundance in the three study sites: It can be seen that a significant difference exists among the transects of site 1(Gairibans) and 2 (Kaiyakatta-Kalipokhari) which means the distribution of red panda and red panda evidences are restricted to a few transects or not found equally in all the transects. Whereas the difference in the transects of site 3 (Sandakphu) is not significant which shows the use of all the transects of the study site (Figure 4.3). Gairibans and Kaiyakatta-Kalipokhari areas have two vegetation zones- the Oak forest and the Broad-leafed deciduous forest. Encounter rates of both indirect and direct evidences of red panda was found to be low in the Oak forest (Figure 4.4). Therefore, the absence or low encounter rates of evidences of red panda in transects representing Oak forest accounted for the significant difference of encounter rates among the transects in Gairibans and Kaiyakatta-Kalipokhari.

4.6.2.2 Distribution and abundance in the vegetation zones: Results of the pellet groups, red panda encounter rate, density of pellet groups in the random plots, group size, in the three vegetation zones showed that the red panda in the study area was distributed in the entire study area but were more abundant within an altitudinal range *of 2800 m-3600 m which encompasses the* Subalpine *coniferous* forest and the Broad-leafed deciduous forest. (Figure 4.4)

From the results of the vegetation zones, the aggregation of red panda evidences in transects 4 of site 1 and transects 7 and 8 of sites 2 can be explained (Figure 4.3). This is because these transects represent the preferred elevational range of >2800 m-3150 m or the Broad-leafed deciduous forest.

4.6.2.3 Distribution and abundance in the entire National Park: The survey results showed that Gairibans, Kalipokhari, Sandakphu, Phalut, Molley, and upper reaches of Gorkhey had red panda but no evidences were found from Lower Gorkhey, Rammam, Siri, Samanden, Rimbick and Gurdung. These areas, where red panda evidences were not found are in the lower altitudes of the Singhalila National Park. Rammam, Siri, Samanden, Rimbick, Gurdung are in the buffer zone of the National Park and all permanent human settlements are located here. It could be that human settlements caused disturbance to red panda population and habitat which is responsible for low sighting of red panda in these areas. Recent forest fires starting from these altitudes have also destroyed vast stretches of forest at least up to an altitude of 2700 m-2800 m. Red panda being a slow breeder may not have been able to recover its already reportedly small population at these lower altitudes due to these anthropogenic pressures. The lowest altitude from where red panda was reported during the present study was Upper Phedi (2400 m), an area outside the park. From the results of the extensive surveys and of the intensive study it could be inferred that red panda is present and distributed in the entire National Park. However, red panda is abundant above 2800 m and sporadically present below this altitude. The distributional range of red panda distribution in the study area of Singhalila National Park as found during the present study is almost similar to the range (3000 m-4000 m) reported from the Central Himalayas. (Yonzon and Hunter, 1989).

A review of the current distribution of the red panda in its entire distributional range indicates the present knowledge on the distribution of red panda to be restricted to presence/absence documentation. Localities within the larger range remain unexplored for abundance and status of the species. Quick and reliable verification of the presence/absence of red panda in unsurveyed areas is required. In the present study, pellet groups were reliably used to study the distribution, abundance and status of the red panda and could be used and applied for surveys and monitorings in other areas too.

4.6.3 Status of the red panda in the study area: There are no past records on the population status of the red panda in the Singhalila National Park. The density of 1red panda per 1.67 km^2, estimated during the present study is a crude density which is higher than the density estimated for red panda in the Langtang National Park, Nepal (Yonzon and Hunter, 1989). A density of 1 red panda/2.9 km had been estimated for the red pandas in the Langtang National Park. Red panda is a protected animal in Nepal. However, anthropegenic pressures on red panda habitat as evidenced from the study in Nepal is very high with 30,000 human population in and around the Langtang National Park (Yonzon and Hunter, 1991).

In assessing the status of red panda in Singhalila National Park, I would discuss the threats due to the non contiguous habitat, movement of animal between protected and unprotected areas, relative abundance and information on the breeding population of red panda in the three study sites.

Red panda is protected by law in India under the Indian Wildlife Protection Act, 1972 (Anon, 1992). After the Singhalila area was declared a National Park In 1986, the species and its habitat was afforded better protection. However, the study area do not have a contiguous forest mainly due to the presence of settlements and altered land use pattern. The first process that results in habitat fragmentation is the reduction of habitat that inevitably follows human settlements (Scott, 1981). Habitat fragmentation is known to have various negative effects on wildlife population (Merriam, 1991; Haila and Manski, 1993). In this case, the most apparent threat to the red panda population due to this disconnected habitat is the animal getting exposed to the human settlement. It was in October 1995, that two red pandas were sighted very near to base station, Gairibans. This settlement roughly forms a barrier for the sites 1 and 2 at 2600 m. These two animals together descended from the forested area covered by transect 4 of Site 1 but returned back to the area from where they had descended. It would have been too risky for the pandas to venture across the settlement because of the people and children who were excited to see the animals. Even the domestic dogs are a great threat to the animals. I had heard of such events occurring before where the animal was chased, stoned or teased. Had there been a contiguous forest in place of the settlement, the pandas could not have been so conspicuous and such threats from human being lessened. A contiguous forest between site 1 and 2 is found only below 2600 m area which is outside the national Park and falls within the jurisdiction of yet another Division (Directorate) of the Department of Forest. Site 1 and 2 lie within an altitudinal range of 2600 m-3100 m. Therefore, the population of site 1 inhabit a very narrow preferred range of 2800 m-3100 m (Broad-leafed deciduous forest). Moreover only one face of the slope encompasses this elevational or vegetational zone in site 1. The other face of the slope is in Nepal area which is does not have a protected area status. I received a number of reports of red panda sightings crossing the International border. I also found panda tracks on the snow during winter, crisscrossing between India and Nepal.

The forest is contiguous between site 2 and 3 within the National park but the settlements at 3100 m (Kalipokhari) and 3200 m (Bikheybhanjyang) with an accompanying altered land use system could also prove to be a barrier and hinder safe movement of the red panda between the two sites. The case of sharing its preferred vegetational zone with Nepal in Site 2 and 3 is similar to that of a Site 1. Animals move freely and reciprocally between habitats, in which case the strategy of conserving one area may prove unsuccessful if the individuals go to portions where they are not protected or safe (Bernstein *et al.*, 1991). I, came across the possession of two panda cubs in a nearby Nepal area in September 1995 and possession of one subadult in September 1994. The status and well being of the red panda in Singhalila National Park also depends on the safety and protection of the species across the border.

The location and the settlements in and around of Site 1 is such that it gives very little chance for the red panda population to interact with the population of Site 2. The area had the lowest pellet group and animal encounter per 100 hours. No evidence of the breeding population was found here. Site 2 and 3 seems to be functionally connected with better chances for red panda of the two sites to interact. Moreover, the two sites also have breeding populations as evidenced by the sightings of two cubs and a female in site 2 and one cub and a female in site 3. The pellet group and animal encounter rate was also found to be significantly higher in sites 2 and 3. Hence, it can be said that the status of red panda in respect of breeding population and availability of contiguous forest, is better in Site 2 and 3 than in Site 1. However, the fact that the areas in the higher altitudes especially Sandakphu (Site 1), is under greater biotic pressure (chapter 3) is a matter of concern. Even, in Site 2, the area is sandwiched between two roads (PWD and MR road) which are in frequent use by the people and vehicles.

Other than the Intensive study area, the entire stretch of area between Sandakhpu and Phalut, which includes Sabarkum (Molley) had evidences of red panda. After Phalut, the stretch of area till upper Gorkhey also harbors red panda. This stretch shares a border with the State of Sikkim. Red panda is the state animal of Sikkim and is protected by law. But the protection of the red panda is limited to each state- Singhalila National Park, Nepal and Sikkim. Nothing is known or done about the habitats or the safety of the animals beyond the man made boundaries. Concerted efforts of all the three states, to protect the red panda in this part of the Himalayas would be therefore a better conservation strategy rather than conserving or protecting animals within each state only.

CHAPTER 5

HABITAT USE

5.1 Introduction

A suitable habitat provides an animal shelter, food, protection and also caters to its evolutionary expectations for fitness (Krebs, 1985). An understanding of the habitat use of an animal is basic to prescribing habitat management.

There has been several general and anecdotal description of red panda habitat. Pocock (1941) stated that red panda in the Lichiang range of Yunnan, was a forest dweller upto 11000 ft (3333.3 m). Sowerby (1932) described red panda habitat as being highly rugged mountainous terrain covered with typical Himalayan vegetation and further west, red panda was known to occupy the temperate forest.

In the recent times, three studies (Johnson *et al.*, 1988; Yonzon and Hunter, 1989 and Reid *et al.*, 1991) have added a great deal of information on the habitat use and preference of red panda in the wild. Yonzon and Hunter (1989) reported that the red panda preferred the fir-jhapra (a bamboo species) habitat type out of the five habitat types in the Langtang National Park. They found the red panda to have a strikingly narrow range of preferred range of habitats. Yonzon and Hunter (1989) were of the opinion that close proximity to water could be a basic requirement. Home range of the red panda in the Langtang National Park was found to vary between 1.02-9.62 km^2 with males having larger home ranges than females. They also found that females living in the marginal habitats had larger home ranges than females in the optimal habitat. Radio-locations of this study also indicated that the red panda were found at highest altitudes between late August and mid-September and at the lowest between November and mid-December. Red panda primarily rest above ground on trees and it was recorded at a height of about 10 m in fir trees, *Abies spectabilis* in summer and monsoon, *Juniper recurva, Betula utilis, Acer sterculiaceum* and *Rhododendron campanulatum* upto 7 m in winter (Yonzon and Hunter, 1989).

In describing a red panda habitat, Johnson *et al.* (1988) assumed that there was no apparent relationship between high use areas of red panda and forest canopy, degree of slope and other environmental variables. They were of the opinion that the dominant feature appeared to be a patch of live bamboo providing cover. They also found red panda to focus their activity at certain sites and quantified the number of logs, stumps, small faecal piles and latrine at such focal points of activities. They also measured such parameters at the rest sites. Water or drinking sites were found only in two of the eight sites and bamboo patches associated with the centers of red panda activities averaged 0.71 ± 0.54 ha.

Rid *et al.* (1991) reported a home range of 0.94 km^2-1.11 km^2 for the red panda in the Wolong National Park, China. They found that the use of space by the red panda markedly increased in April. They also recorded a difference between the use of space by the male and the female individuals. For the female, the range markedly decreased during May, June (late pregnancy), and showed an increase of space during lactation. The pandas (male and female) expanded their range in November. It was also seen during this study that the use of elevated substrates for defecation was significantly higher than the unelevated or the forest floors. An estimation of the habitat quality showed that the bamboo leaves in the clear cut and the mixed forest habitats had a higher nutritive value than the other three habitats in the study area. Clear cut and the mixed forest were the habitats used by the red pandas.

Despite these studies in the wild, information on habitat use and preference by red panda over larger part of its entire distribution range, still remain obscure. In order to prescribe effective management strategies for the red panda, it is important to generate sufficient information on habitat use. This chapter presents and discusses the results of the habitat study of the red panda in the Singhalila National Park.

5.2 Methods

In order to study the habitat use pattern by the red panda in the Singhalila National Park, *twelve transects, described in detail in Chapter 4, Table 4.2, were monitored on a monthly basis for quantification of presence of red panda and its signs.* Each point of red panda sighting or indirect evidence (pellet group), encountered during monitoring was marked and the area around each location was then quantified (Animal Centered Plot) using the ten tree method for recording habitat factors. Along with the Animal centered plot, four additional random plots were also established in four cardinal points from the center of the Animal centered plot. Random distances (>20 to 250 paces) were generated for establishing these random plots at four directions. Within these plots. habitat variables such as altitude, habitat type, general habitat, topography, aspect, slope angle, tree species, canopy cover were recorded. Shrub species and shrub cover, were quantified by placing 3 m^2 quadrat. Bamboo species, their number, cover and average height were also quantified in the same 3

m^2 quadrat. Ground cover was sampled in two, 1 m^2 quadrats, placed at two corners of the 3 m^2 plot. Slope was measured using an Abney's level. Canopy cover was recorded using a 60 cm long pipe, 1" in diameter. The percent of cover seen through the pipe was recorded at an interval of two paces at five points. The readings at five points were taken at four directions from the centre of the sample plot. The percent cover was categorised into 0-25, >25-50, >50-75, > 75-100. The total of 20 readings was then summed to obtain the average canopy cover. Bamboo, other shrubs and ground species cover were estimated subjectively. Registration of the number and general note of the various types of substrates used by the red panda was made.

5.3 Analyses

Principal component factoring is one of the most powerful and versatile multivariate techniques which summarises a large and a complex set of data, finds the interrelationships between the variables and also has an interpretation role (Kaghen, 1989). A data matrix of 438 plots (117 animal centred plots and 321 random plots and 9 variables each) was analysed using Principal component factor analysis, in order to understand the red panda-habitat relationship following Hamilton (1998).

The analysis was first conducted to reduce the data set and get factors which would account for the maximum variance in the data set. Only the factors with eigen values of more than one were taken into account. The animal centred and the random plots were then ordinated or positioned in the hypothetical species space in which the factors were used as coordinates. In order to get information on the spatio-temporal use of the habitat, the ordination of the plots were done on a seasonal basis. The habitat types and the general habitat types were also ordinated in the same space. The results were then compared to get a clear picture of the habitat use by the red panda in the study area. The first two factors were used as coordinates to analyse the habitat use for all the four seasons. Logistic regression was also performed on the data set (pooled for all four seasons) to classify the animal centered and the random plots (Hamilton, 1998). Raw data were transformed into their natural logarithms and percentages converted to arcsine following Zar (1984). Such transformation of the data is employed to reduce skew and linearise relations among the variables (Hamilton, 1998).

Utilization of the habitats in proportion to its availability by the red panda was determined following Nue *et al.* (1974) and Byers *et al.* (1984) and the analysis was performed using the program PREFER (Prasad and Gupta, 1992). A chi-square contingency matrix was used to detect significant differences in the use of different habitat types across the seasons following Fowler and Cohen (1986). A habitat use index was computed by dividing the percent of pellet groups observed in each habitat type by the percentage of km distance traversed in each habitat during different seasons (Hess and Swart, 1940; Piennar 1969; Petrides, 1975; Fagen, 1988).

A series of t-tests and Mann-Whitney U-tests were applied to detect differences between the animal centered and random plots for all four seasons using all habitat variables. Factors were scored and subjected to Man-Whitney U-test to compare the animal used and the random plots. Factor scores in multivariate analysis are linear composites which is treated as a variable (Hamilton, 1998). To test the significance of the use different habitat attributes, data was subjected to chi square test. Oneway ANOVA was used to determine the difference in the vegetation of different aspects. All the statistical analysis were done using the statistical program, Stata 5.0 (1997) and SPSS (Norussis, 1994).

5.4 Available habitat types

The available vegetation map of the study area delineates five major habitat types in the study area, which are Upper hill miscellaneous forest, Silver fir forest, Alpine pure rhododendron forest, Pure bamboo patch and others (plantations and blank area).

(1) Upper hill miscellaneous forest: incorporates the Oak and the Mixed forest.

(a) Oak forest: This is a habitat dominated by *Quercus pachyphylla* with undercanopy species such as *Litsaea elongata* and *Rhododendron species* especially *R. griffithianum, R. arboreum*. The understorey shrub layer has *Arundinaria maling*.

(b) Mixed Forest: As the forest types change from Oak to Broad-leafed deciduous forest, *Quercus* sp. gets associated with deciduous species such as the *Sorbus, Litsaea, Vitex, Magnolia, Acer* spp. and these associations form a number of vegetation types. Thereafter, the forest becomes Broad-leafed deciduous forest. Mixed forest includes both the Oak deciduous forest and the Broad-leafed deciduous forest. A number of vegetation types are found in the Mixed forest such as:

i. Rhododendron forest - where the *Rhododendron* species such as the *R. falconeri* locally known as the Korlinga dominates and found in association with the deciduous species such as *Sorbus, Litsaea, Vitex, Ace* and *Meliosma* spp.

ii. Symplocos forest - *Symplocos* sp. which is usually an undercanopy species dominates in this habitat type. *Symplocos* sp. usually do not grow to the height of trees like *Quercus, Acer, Sorbus, Magnolia* species. They are found in higher density (chapter 3).

ii. Daphnephyllum forest - *Daphnephyllum himalaense* is also medium sized evergreen tree which is especially dominant in the Kaiyakatta area. These trees are also found in fairly good density.

(2) Silver-fir forest: This habitat type has the dominant association of *Abies densa, Betula utilis* and *Rhododendron* spp. with understorey of *A.aristata*. Important associations observed within this forest type are:

(a) Fir-birch-rhododendron forest

(b) Fir forest- Dominated by mature *Abies densa* trees.

(c) Fir-rhododendron-forest- This habitat type is actually the Broad-leafed coniferous forest below 3300 m.

(3) Alpine pure rhododendron- This habitat type is composed of stunted trees of *R. campanulatum.*

(4) Bamboo patch- This habitat type are pure patches of bamboo which has invaded areas, as secondary growth which has been destroyed by fire.

(5) Others- include plantations and blank areas. Blank areas are found in the subalpine region and have been formed due to excessive grazing.

The vegetation changes with topography, aspect, soil, various biotic pressures. Some of the finer divisions of the broad habitat types noticed and recorded in the sample plots as general habitat are- pure *Rhododendron* patch (Gairibans), open area of the Oak forest, *Rhododendron* dominated deciduous forest, *Symplocos* forest, *Daphnephyllum* forest, open area of the Mixed forest, open area of the Subalpine forest, were all finer divisions of the broad vegetation types and were noted down for each habitat sample plot. These are referred to as **general habitat type** in the text.

5.5 Results

5.5.1 Habitat selection: The red panda was found to be using only two of the available habitats in high frequency. The analysis for the preference of habitat by the red panda in the study area, following Nue *et al.* (1974) and Byers *et al.* (1984) was carried out on a pooled data of pellet groups for all seasons. Table 5.1 provide the details of the proportional availability and the proportional use of the habitat types by red panda in the study area, along with the Bonferroni confidence intervals to detect the significant differences. The results in Table 5.1 show that the Upper hill miscellaneous forest and the Silver fir forest are utilized more than the proportion of their availability indicating a preference for these habitat types.

5.5.2 Habitat use index: The results presented in the above section (5.5.1) obscures the seasonal use of the habitat types and also the use of other sub-habitat types such as the oak forest, mixed forest, fir-birch-rhododendron, fir-rhododendron, fir patch within the broad habitat types. However, it was not possible to work out fairly accurate areas of sub-habitat types within the broad habitat types. Including all the sub-habitat types, seven habitat types were observed in the study area. Pellet groups in seven habitat types across four seasons were subjected to a chi-square test and a habitat use index was computed for each habitat type for different seasons. The results of the chi-square tests to detect the difference in the use of

Table 5.1 Selection of habitat by red panda in the study area

Habitat type	Area km^2	Observed usage	Expected usage	Expected prop.	Bonferroni confidence interval at 0.05 level	
Silver fir forest	2.75	98	22.49	0.112	0.394	0.576 **
Alpine Rhododendron	0.75	1	7.20	0.031	0.000	0.028*
Bamboo	10.0	4	81.60	0.408	0.010	0.090*
Middle hill forest	5.50	93	44.80	0.224	0.345	0.525 **
Others	5.50	4	44.80	0.224	0.000	0.046*

Chi square, X^2 = 422.32

** = Used more than available

* = Used less than expected

Table 5.2 Habitat use index of red panda for premonsoon

Habitat type	No. of pellet-groups	% pellet-group	% distance	HUI
Oak Forest	9	7.5	34.6	0.22
Mixed Forest	40	33.3	28.21	**1.18**
Fir-birch-Rhododendron	52	43.3	15.02	**2.8**
Fir-Rhododendron	16	13.3	7.69	**1.73**
Fir patch	2	1.67	7.69	0.23
Alpine Rhododendron Pure	1	0.83	5.12	0.16
Bamboo patch	0	0	1.28	0

Table 5.3 Habitat use index of red panda for monsoon

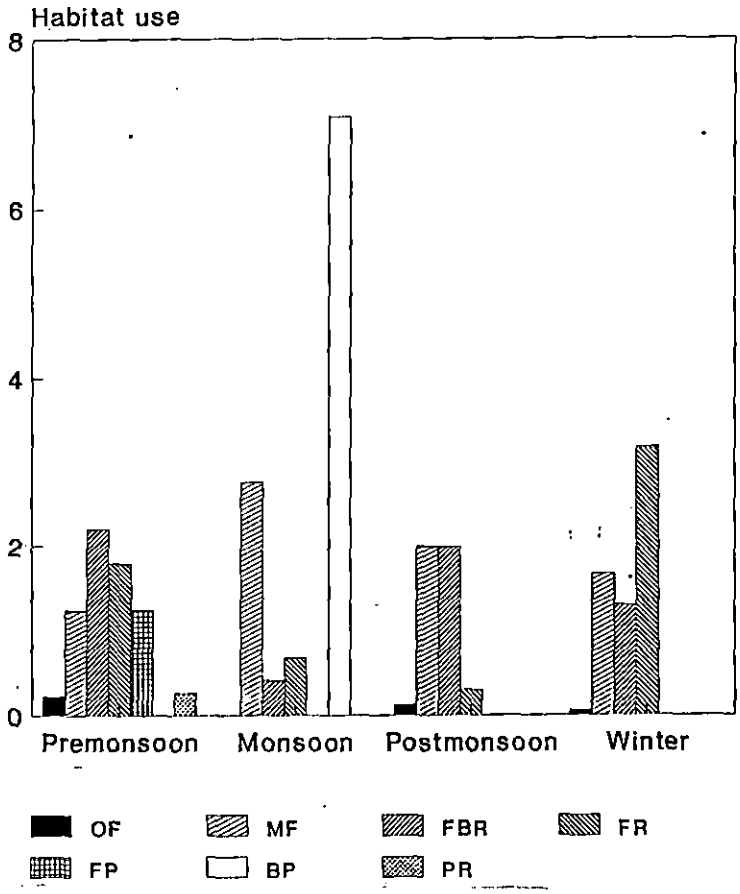
Habitat type	No. of pellet groups	%pellet group	% distance	HUI
Oak forest	0	0	34.6	0
Mixed forest	29	78.37	28.21	**2.85**
Fir-birch-rhododendron	3	8.3	15.02	0.55
Fir-rhododendron	0	0	7.69	0
Fir patch	0	0	7.69	0
Alpine Rhododendron pure	0	0	5.12	0
Bamboo patch	4	8.57	1.28	**8.67**

Table 5.4 Habitat use index of red panda for postmonsoon

Habitat type	No. of pellet groups	%pellet group	% distance	HUI
Oak forest	1	4.00	34.62	0.12
Mixed forest	14	56.00	28.21	**1.98**
Fir-birch-rhododendron	10	40	15.02	**2.66**
Fir-rhododendron	0	0	7.69	0
Fir patch	0	0	7.69	0
Alpine Rhododendron pure	0	0	5.12	0
Bamboo patch	0	0	1.28	0

Table 5.5 Habitat use index of red panda for winter

Habitat type	No. of pellet groups	%pellet group	% distance	HUI
Oak forest	1	2.04	34.62	0.05
Mixed forest	23	46.98	28.21	**1.66**
Fir-birch-rhododendron	3	26.5	15.02	**1.76**
Fir-rhododendron	12	24.49	7.69	**3.18**
Fir patch	0	0	7.69	0
Alpine Rhododendron Pure	0	0	5.12	0
Bamboo patch	0	0	1.12	0



OF = Oak Forest
MF = Mixed forest
FBR = Fir -rhododendron forest
FR = Fir -rhododendron forest
FP = Fir patch
BP = Bamboo patch
PR = Pure rhododendron patch

Fig.5.1 Habitat use index of red panda in different seasons *habitat types showed a statistically significant difference in the use of habitat types during all the four seasons (premonsoon: χ^2 = 17.49, df=6, p < .05; monsoon: χ^2 =* 20.61, df = 6, p < .01; postmonsoon: χ^2 = 14.89, df = 6, p < .05; winter: χ^2 = 27.43, df = 6, p <.01).

Fagen (1988) contended that the habitat value will be directly related to use/availability ratios whenever animals are free to choose the habitat that confers the greatest fitness. The habitat use index (HUI) was computed by dividing the percent pellet groups found in one season in a particular habitat type by the percent of distance traversed in that habitat to come across the indirect evidences. Details of the HUI has been presented in Table 5.1 and Figure 5.1. For the premonsoon season HUI was the highest for the Fir-birch-rhododendron forest (2.8) followed by the Fir-rhododendron forest (1.73), Mixed forest (1.18) and Oak forest (0.22) with no evidence of the animal in the bamboo patch. During monsoon, the bamboo patch was used and had a high habitat use index of 8.67 while 2.85 for the Mixed forest. In the postmonsoon, the Fir-birch-rhododendron forest had HUI of 2.66 followed by the mixed forest with 1.98. In winter, Fir-rhododendron forest has the highest HUI of 3.18 followed by the Mixed forest (1.66), Fir-birch-rhododendron forest (1.76) and Oak forest (0.05).

5.5.3 Seasonal pattern of habitat use

The Principal factor analysis extracted factors from the data set for all the four seasons. Although the variance in the data set differed for each season, the first and second factors for all seasons had very high loadings and positive correlation with bamboo height, bamboo cover and tree cover (canopy cover), tree density respectively. These two factors formed the axis 1 and 2 respectively of the ordination. Axis 1 represents areas with higher bamboo, lower tree density and diversity which as seen in Chapter 3 is found in the higher altitudes. Axis 2 is a gradient which represents the temperate region, with higher tree density.

Logistic regression followed by the classification table showed the model correctly classified the plots by 76 %. Canopy cover, bamboo height and bamboo cover significantly contributed to this classification (Table 5.6). A series of t-tests, between all the vegetation variables of the habitat (pooled data for all seasons) also showed that canopy cover, bamboo height and bamboo cover to be significantly different (canopy cover: $t= 3.36$, $p < 0.001$; bamboo height: $t= 2.49$, $p < .01$; bamboo cover: $t= 4.274$, $p < .001$) between animal centered plots and the random plots.

5.5.3.1 Premonsoon: Principal component analysis extracted three components for premonsoon which accounted for 68% of the variance in the data set (Table 5.7). The ordination of the animal centered and random plots in the variable space with factor 1 and factor 2 showed the animal centered plots to be widely distributed in space and evidences found in all habitat types (Figure 5.2). This indicated a wider movement and use of space by the red panda during premonsoon. This is also supported by the fact that more evidences of red panda were found during this season and in all zones and habitat types (Table 5.2).

Mann-Whitney U-test to test the differential use of the animal centered and random plots during premonsoon, using all variables showed that bamboo cover and canopy

Table 5.6 Result of the logistic regression of the animal centered plot and the random plots

Variables	Coefficient	Standard error	z	p	Confidence Interval (95 %)	
Altitude	.001	.000	1.44	0.15	-.002	.001
Bamboo cover	.038	.009	3.90	0.00	.395	.057
Bamboo height	-.193	.082	-2.4	0.01	-.355	-.032
Bamboo density	.112	.096	1.16	0.24	-.077	.030
Canopy cover	.031	.009	3.11	0.00	.011	.050
Shrub density	-.047	.073	-0.64	0.52	-.533	.468
Shrub cover	.021	.012	2.65	0.09	-.003	.045
Tree density	.017	.230	0.07	0.94	-.433	.469

cover contributed significantly to the difference (bamboo cover: $z = -3.040$ $p < .01$; canopy cover: $z = 2.93$, $p < .01$) (Table 5.11). Factor scores tested for the differential use of the two plot types showed that factor score 1 significantly contributed to the differentiation ($z = -2.96$, $p < 0.01$) (Table 5.12)

5.5.3.2 Monsoon: Results of factor analysis for monsoon data had four components with more than one eigen values. The first three factors accounted for 66.23% of the total variance in the data set (Table 5.8). The first two factors, against which the plots were plotted, accounted for 51.55% of variance. Figure 5.3 clearly shows the distribution of the red panda in the areas of high bamboo cover and low tree cover or comparatively open areas and bamboo patches.

Mann-Whitney U-test showed that the bamboo cover, shrub cover and tree density significantly differed between the animal used plots and the random plots with the animal plots having higher bamboo cover than the random plots. (bamboo cover, $z = 2.37$, $p < .01$; shrub cover, $z = 2.41$, $p < .01$; tree density, $z = 1.926$, $p < .05$) (Table 5.11). The factor score 1 significantly differentiated ($z = -2.4$, $p < 0.05$) the two plot types (Table 5.12).

5.5.3.3 Postmonsoon: For postmonsoon, the first two factors accounted for 55% of variance (Table 5.9) and the first three factors accounted for 69.16% of the variance. The positions of the plots in the variable space suggest that red panda were using areas with high canopy cover. In the temperate forest the animal was found in the *Rhododendron*, *Symplocos* and *Daphnephyllum* forests. As seen from the ordination (Figure 5.4), there is a shift of the subalpine habitats into the space of

Table 5.7 Factor loadings and the variance shown by the Principal Component analysis on the habitat variables for the premonsoon season

	Factor Loadings		
Variables	I	II	III
Altitude	0.306	-0.641	0.193
Canopy Cover	0.589	0.541	-0.063
Bamboo cover	0.694	0.053	0.322
Bamboo density	0.410	-0.023	0.585
Bamboo height	0.778	0.217	0.229
Shrub density	-0.622	0.376	0.459
Shrub cover	-0.623	0.325	0.498
Tree density	0.184	0.636	-0.362
% Variance	31.33	18.00	14.10
Eigenvalues	2.50	1.40	1.12
% Cumulative variance	63.43		

Table 5.8 Factor loadings and the variance shown by the Principal Component analysis on the habitat variables for the monsoon season

	Factor Loadings		
Variables	I	II	III
Altitude	0.478	-0.429	0.242
Canopy Cover	0.246	0.826	-0.166
Bamboo cover	0.811	-0.069	0.079
Bamboo density	0.653	0.123	0.320
Bamboo height	0.717	0.271	0.280
Shrub density	-0.193	0.196	0.773
Shrub cover	0.590	-0.029	0.549
Tree diversity	-0.204	0.872	-0.005
% Variance	29.55	22.00	14.68
Eigen values	2.36	1.76	1.17
% Cumulative variance	66.23		

Table 5.9 Factor loadings and the variance shown by the Principal Component analysis on the habitat variables for the postmonsoon season

	Factor Loadings		
Variables	I	II	III
Altitude	0.161	-0.687	-0.405
Canopy Cover	0.341	0.802	-0.130
Bamboo cover	0.866	-0.048	0.244
Bamboo density	0.647	-0.107	0.054
Bamboo height	0.715	0.008	0.511
Shrub density	- 0.456	0.146	0.694
Shrub cover	-0.743	0.097	0.199
Tree density	0.109	0.805	-0.349
% Variance	32.20	22.62	14.34
Eigen values	2.57	1.80	1.14
%Cumulative variance	69.16		

Table 5.10 Factor loadings and the variance shown by the Principal Component analysis on the habitat variables for the winter season

	Factor Loadings		
Variables	I	II	III
Altitude	0.214	-0.612	-0.320
Canopy Cover	0.408	0.732	-0.127
Bamboo cover	0.849	-0.100	-0.386
Bamboo density	0.507	0.033	0.379
Bamboo height	0.670	0.063	0.540
Shrub density	-0.433	0.171	0.620
Shrub cover	-0.709	0.175	0.396
Tree diversity	0.174	0.754	-0.386
% Variance	29.50	17.74	16.16
Eigen values	2.36	1.41	1.29
%Cumulative variance	63.40		

higher tree cover and higher bamboo cover. This shows that the animals in the subalpine zone were also using areas of higher tree and bamboo cover.

Shrub cover and bamboo density significantly differed between animal used and the random plots (Bamboo density: $z= 1.97$, $p< .05$; shrub cover, $z= 3.00$, $p< .05$; canopy cover: $z=2.13$, $p <.05$) (Table 5.11). However, none of the three factor scores significantly differentiated the animal used and random plots (Table 5.12).

5.5.3.4 Winter: Results of the factor analysis extracted three components which had a variance of 63.40 %. The first two factors accounted for 47.24% variance in the data (Table 5.10). Bamboo cover is seen to govern the distribution of the animal, both in the subalpine and the temperate zone. Most of the evidences (pellets and pellet groups) were found on the ground, paths on slopes and ridges during the winter season. These are comparatively open areas. This use of space is reflected in the ordination (Figure 5.5) with some plots in the low tree cover, low bamboo and *high tree cover and low bamboo areas. In the subalpine zone, evidences of red* panda were mostly found in the Silver fir-rhododendron forest, around 3300 m. In the temperate zone the animal was found in the deciduous, Oak, *Rhododendron*, *Symplocos* and *Quercus* deciduous forests. The distribution was wider as compared to the monsoon and the postmonsoon season.

Bamboo cover was found to be significantly higher in the animal centered plots ($z= 1.86$, $p< .05$) and shrub cover significantly lower ($z = 2.68$, $p< .01$) (Table 5.11). The third factor score which represent shrub cover or open areas significantly differentiated ($z=2.23$, $p < 0.05$) the two plot types (Table 5.12).

Table 5.11 Results of Mann-Whitney U-test comparing animal centered and random plots in different seasons

Habitat variables	Premonsoon	Monsoon	Postmonsoon	Winter
Tree density	NS	*	NS	NS
Shrub density	NS	NS	NS	NS
Bamboo density	NS	NS	*	NS
Bamboo height	NS	NS	NS	NS
Bamboo cover	**	**	NS	*
Canopy cover	NS	NS	NS	NS
Canopy height	NS	NS	NS	NS
Grass cover	NS	NS	NS	NS
Shrub cover	NS	*	*	*

* = p <.05
** = P <.01
NS = non significant

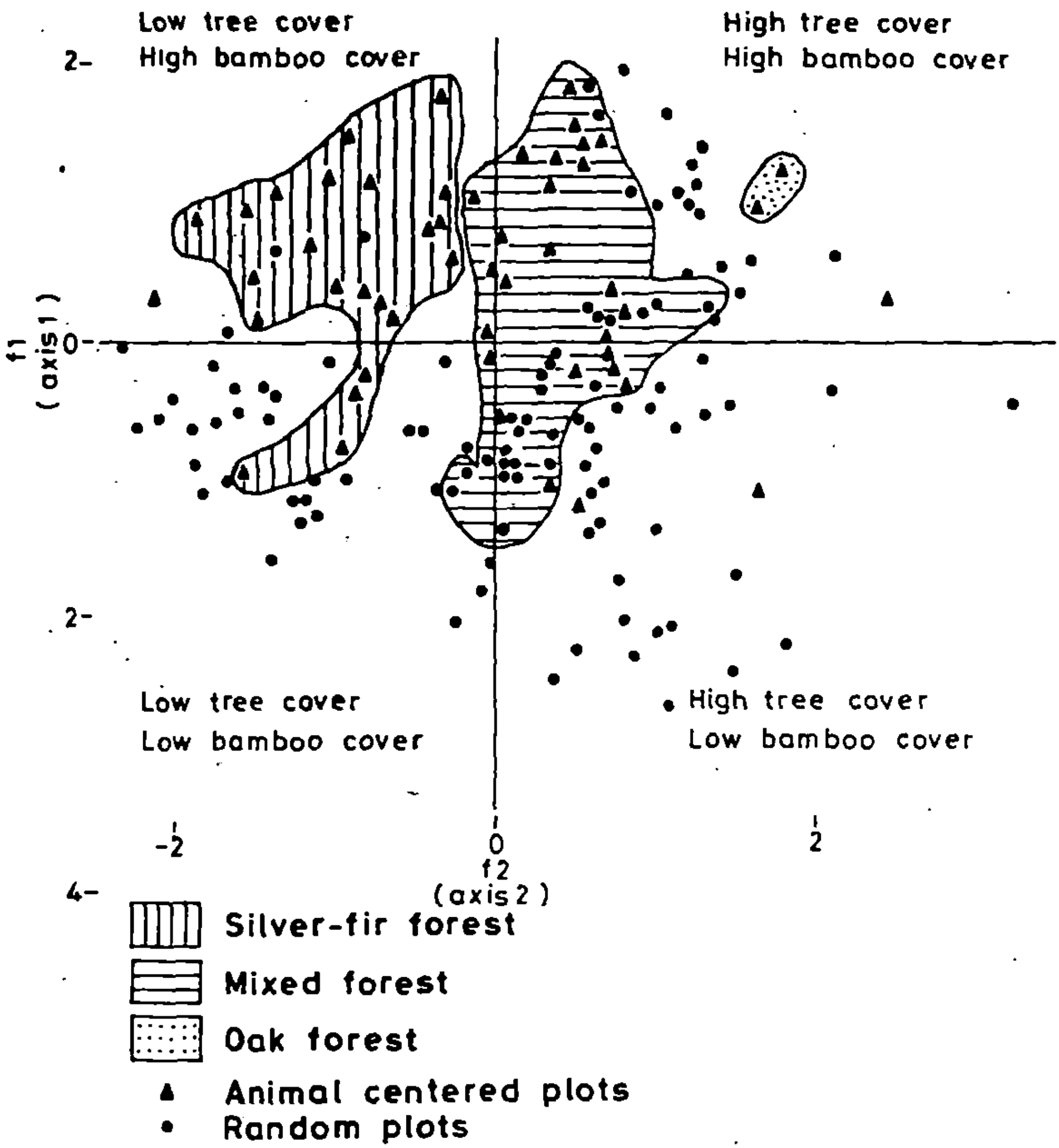


Fig.5.2 Ordination of animal centered and random plots for premonsoon season.

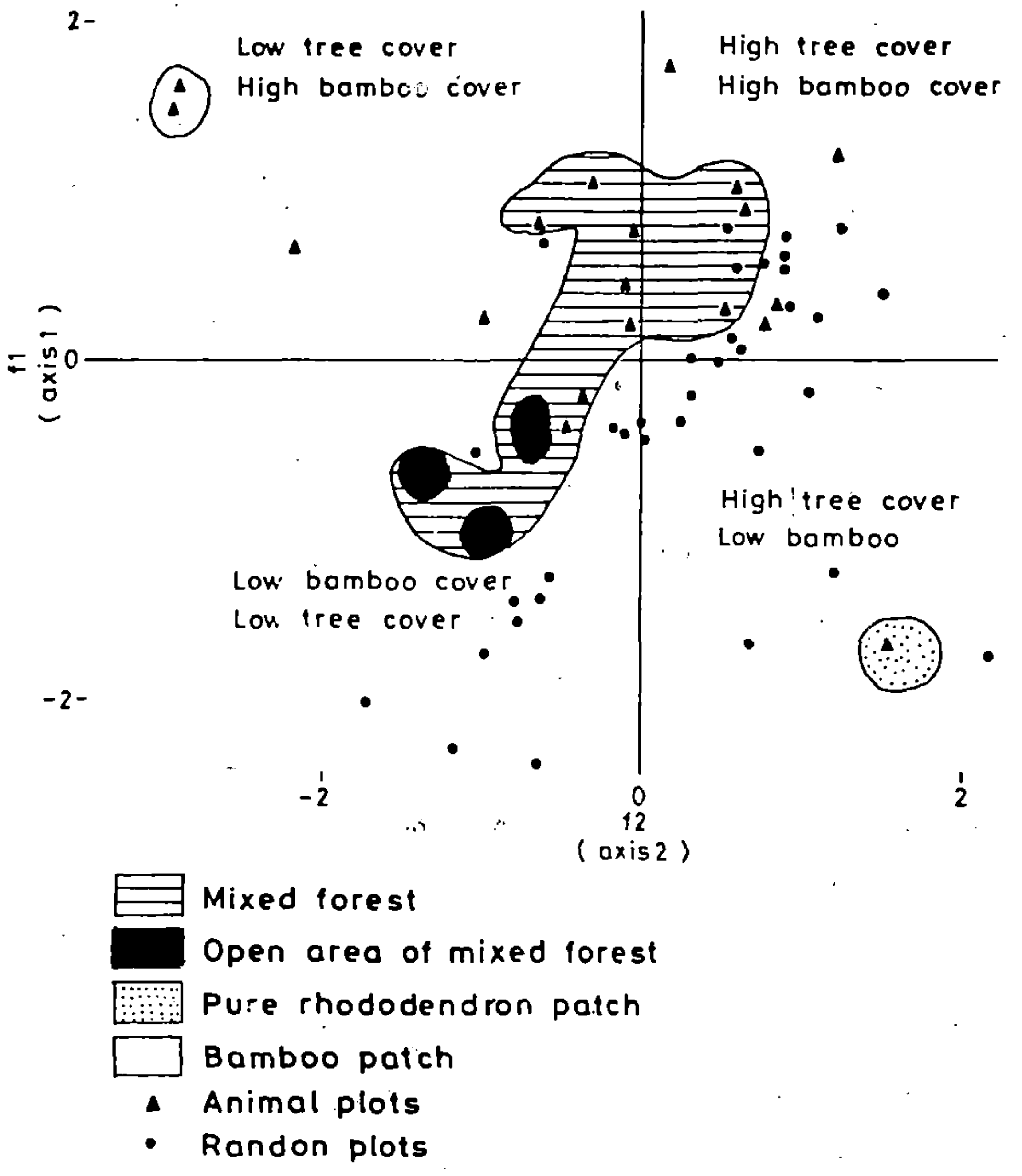


Fig.5.3 Ordination of animal centered and random plots for monson season.

5.5.4 *Use of some of the habitat attributes*

5.5.4.1 Aspect: The data indicate an overall preference of the northern aspect (52 %) ($\chi^2 = 46.01$, df=3, $p < .05$). Seasonal occurrence of the red panda and red panda evidences in different seasons are presented in Figures 5.6 a, b, c and d. In premonsoon all the eight aspects were found to be used with a higher proportional use of the northeast aspect ($\chi^2 = 45.37$, df=3, $p < .05$). During monsoon, the south and south west aspects were not used whereas the north east and northern aspects were used in equal proportion ($\chi^2 = 39.18$, df=3, $p < 0.05$). During the postmonsoon season the northern aspect was used the most ($\chi^2 = 12.3$ df = 3 , $p < 0.05$). Utility of the northern aspect was higher during winter ($\chi^2 = 29.68$, df=3, $p < 0.05$). Considering the fact that all the aspects have equal chances of being available in the study area, the preference for the northern aspect is not random. The use of northern aspect by the red panda was also reported by Yonzon *et al.,* (1995).

A oneway ANOVA analysis to see the difference between the vegetation of the different aspects showed that the bamboo height ($F = 2.26$, $p = .003$, Barlet's chi square = 11.67, $p = 0.554$) and canopy cover ($F = 1.46$, $p = 0.0029$, Barlet's chi square = 11.34, $p = 0.914$) significantly contributed to the difference in the vegetation of the different aspects.

5.5.4.2 Altitude : The mean altitude used by the red panda was found to be 3063±231 with a range of 2600 m-3600 m.

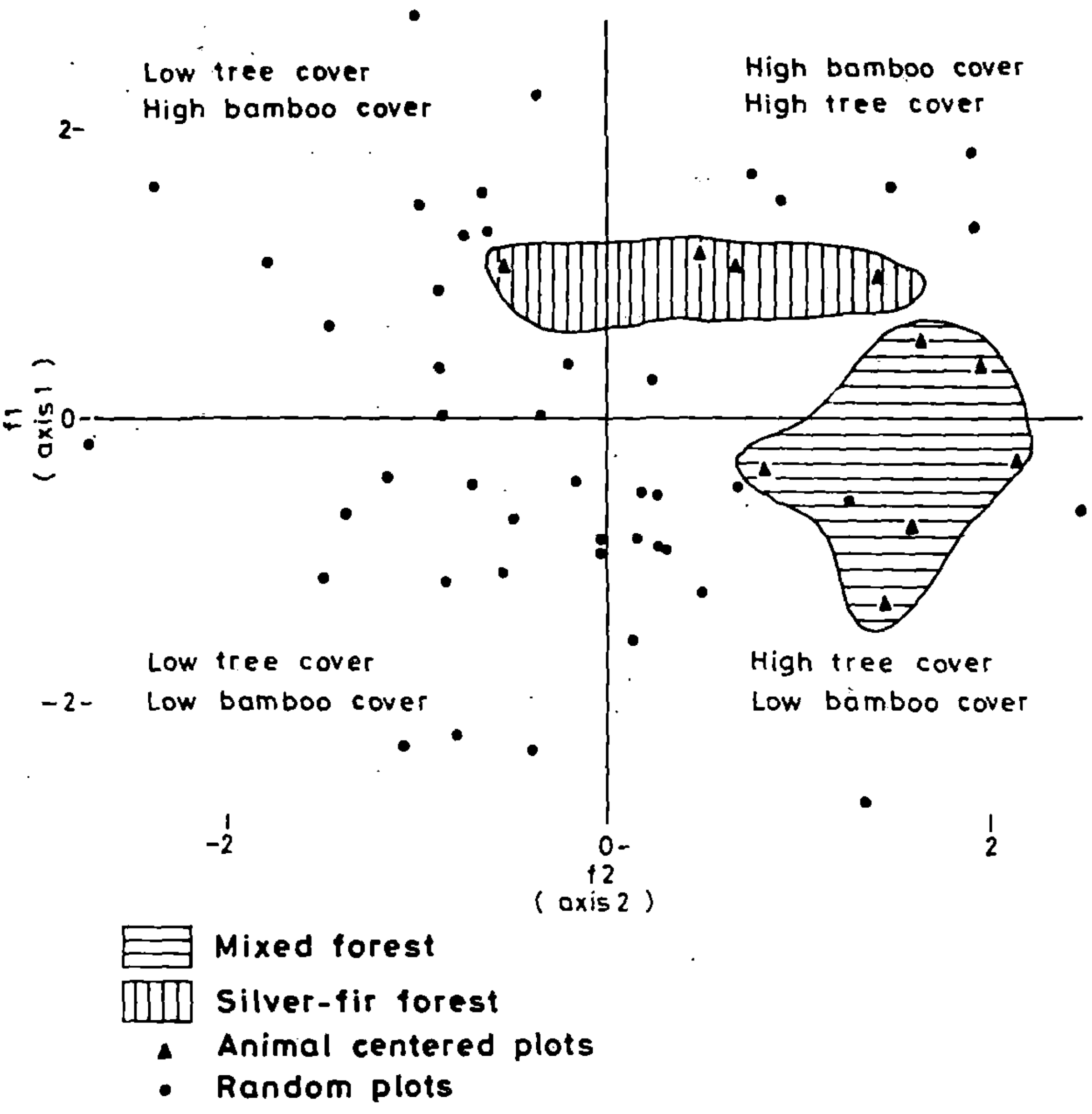


Fig.5.4 Ordination of animal centered and random plots for postmonsoon season.

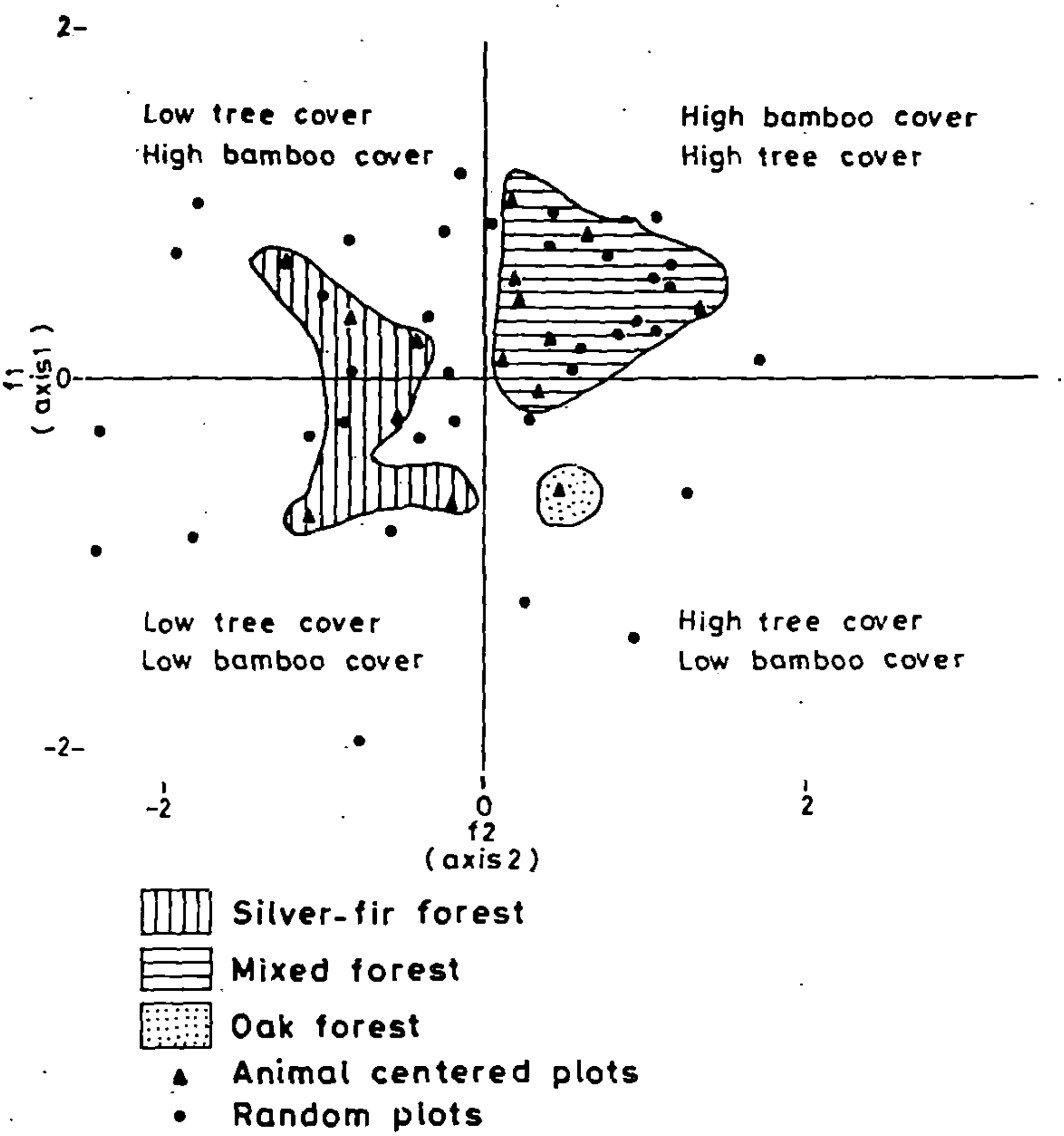


Fig. 5.5 Ordination of animal centered and random plots for winter season.

Table 5.12 Mann Whitney U-test for the factor scores of animal plot and random plots.

	Premonsoon	Monsoon	Postmonsoon	Winter
Factor Score 1	**	*	NS	NS
Factor Score 2	NS	NS	NS	NS
Factor Score 3	NS	NS	NS	*

* = P <.05
** = P <.01
NS = Non significant

Table 5.13 Use of different substrates for defecation by the red panda in the study area, during different seasons

	Substrates			
Seasons	Tree	Ground	Rock	Others
Premonsoon	70 %	16.4 %	6.7 %	6 %
Monsoon	54 %	43.5 %	0	0
Postmonsoon	80.7 %	11.52 %	7.6 %	0
Winter	29 %	45.9 %	18.9 %	5.4 %

Others - include fallen logs, stumps and tree hole.

5.5.4.3 Use of various substrates: The different substrates used for defaecation were trees, ground or the forest floor, fallen logs, stumps and tree holes (Table 5.13). Trees were the most preferred site for defecation (χ^2 = 180.00, df = 3, $p < .01$). Use of forest floor was higher during monsoon and winter. Only one evidence of the use of tree hole was found during premonsoon. 81.25 % of the sightings were made on trees and rest on the ground.

5.5.4.4 Tree species used: Details of the tree species used by the red panda is presented in Table 5.14. The maximum number of times red panda seen were on Silver fir (*Abies densa*) and *Quercus pachyphylla* tree followed by *Rhododendron* spp. The maximum number of red panda pellet groups were on *Betula utilis* followed by *Sorbus cuspidata* and *Abies densa.* Some of the other important trees used for defecation by the red panda were *Quercus pachyphylla, Rhododendron* spp., *Ilex* sp., *Osmanthus* sp. and trees supporting the saprophytic tree locally known as Lahare Tenga.

5.6 Discussion

" We must be careful to define the perpetual world of the animals in question before we begin to postulate the mechanism of habitat selection."- Krebs (1985). The distribution and abundance of red panda in different zones and areas was discussed in the three altitude zones viz. 2600m - 2800 m, >2800 m - 3100 m, and >3150 m-3600 m and areas viz. Gairibans, Kaiyakatta-Kalipokhari, Sandakphu in chapter 4. Now in this section, the ecology of space utilization by the red panda is discussed. The red panda was found to use only two broad habitat types in greater frequency.

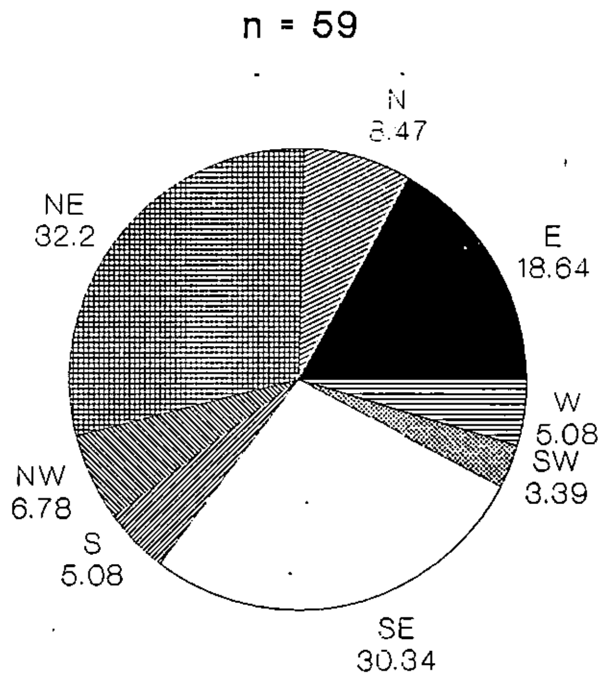


Fig.5.6 Occurrence of red panda in different aspects during premonsoon

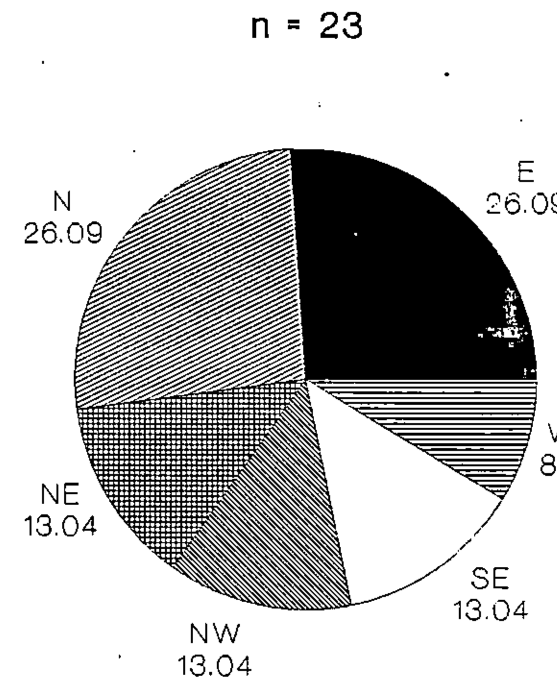


Fig.5.7 Occurrence of red panda in different aspects during monsoon

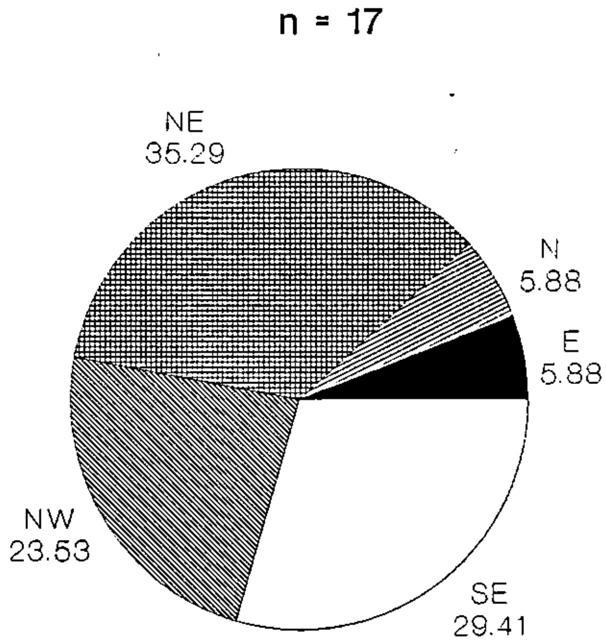


Fig.5.8 Occurrence of red panda in different aspects during postmonsoon

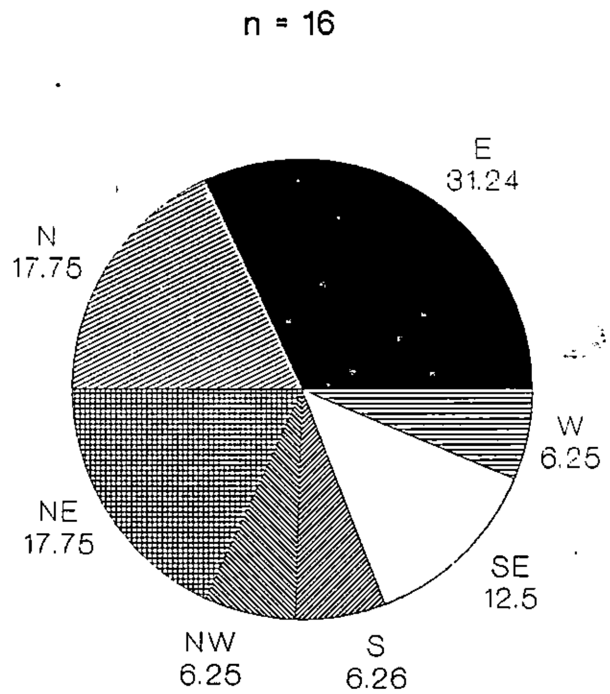


Fig. 5.9 Occurrence of red panda in different aspects during winter

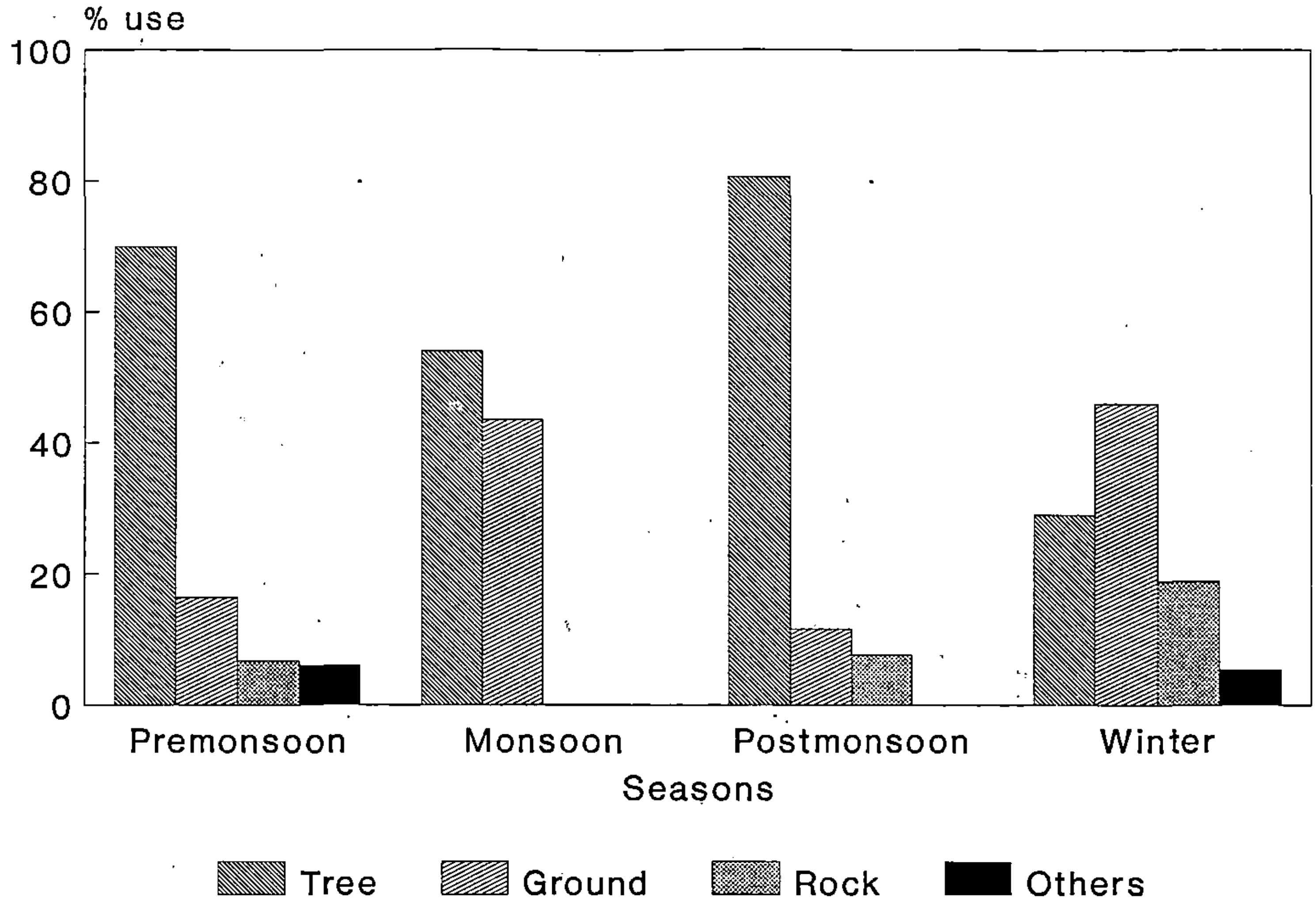


Fig.5.10 Use of different substrates by red panda

Table 5.14 Percent frequency of sightings and pellet-groups found on different tree species in the study area

Tree species	Sightings (percent)	Pellet-group (percent)
Abies desna	28	10.38
Acer sp.	0	4.09
Betula utilis	8	24.21
Ilex sp.	4	10.5
Lahare tenga*+any tree	0	5.15
Magnolia campbellii	12	3.09
Osmanthus sauvis	4	5.15
Quercus pachyphylla	24	9.09
Rhododendron spp.	16	9.5
Schefflera impressa	4	2.06
Sorbus cuspidata	0	19.58
Sorbus microphylla	0	1.03
Vitex heterophylla	0	1.03

* Local name

The technique of habitat analysis used in this study requires a sufficiently large sample size in order to assure a reasonable approximation to the chi-square distribution (Nue *et al.*, 1974 and Byers *et al.*, 1984). Byers *et al.* (1984) states that he had an expected usage of five for his study which ensures that an adequate sample size was taken. Therefore, in order to fulfill the assumptions of the technique, the data was pooled for the habitat analysis of the present study.

In factor analysis insightful meaning of the factors is one of the greatest advantage of the analysis and it is important to study the variables which define a factor and understand the essence and meaning of the factors (Kachigan, 1989). In the present case, a fairly good idea of the composition and structure of the vegetation in the study area (chapter 3), other data sets and field observations has helped to understand and interpret the factors. The ordination of the plots and the general habitat types in the variable space made it easy to visualize the distribution of red panda and the factors governing the distribution.

The ordination technique has also shown the use of finer habitat areas for example 'open area' which otherwise could have been overlooked when only broader habitat types are considered. These 'open areas' are formed due to the past disturbances of grazing, lopping, logging and presence of cattle sheds within the forests.

5.6.1 Habitat selection: From the univariate as well as the multivariate analysis used, higher bamboo height, canopy and bamboo cover emerge out to be the important habitat components governing the use of habitats by the red panda as compared to the random plots. The technique of habitat preference analysis described by Nue *et al.* (1974) is met with many criticisms, particularly because the analysis largely depend on the proportion of habitats and a slight change in this proportion could change the results (Johnson, 1980 and Porter and Church, 1987). The habitat use index which was computed is extremely simple in comparison to other statistical methods available for habitat analysis. This index however, projects the correct picture of the observations made in the field, a criteria which is very important. The rankings of- 'high', 'medium', 'low' and 'none' use of the habitat is important and adequate for most management concerns.

Thus, keeping in view the limitations discussed above, it would be appropriate to state that the Silver-fir forest and the Middle hill miscellaneous forest (Mixed forest portion of it) was used more in relation to the other available habitat types, rather than emphasize that the habitats were 'preferred' or 'avoided'.

Question arises as to why was the oak forest which offered equally good habitat not used as frequently as the other habitats ? There could be many reasons. Red panda is a difficult animal to study in the wild due to its quiet and elusive habits. Because of the infrequent sightings, the study was mainly based on indirect evidences which is a drawback of this study. Hence, I would avoid exaggerated explanations. An apparent reason which however would need further investigations in future is as follows: The transects representing the Oak forest were between two roads- MR road and the PWD road (Figure 2.2). The MR road is a wide motorable road which was constructed in the 1970s. During the construction of the road, the slopes were blasted, large proportion of the vegetation cleared and a large number of labourers resided in the area causing large scale disturbance to the flora and fauna of the area. Locals, report seeing red pandas in the area around the time of the road construction. It is possible that the red panda population was disturbed during this time and the oak forest and the species has not recolonised these areas. Some animals do not occupy all their potential range even though they are able to disperse into the unoccupied areas, an individual behaviour which limits the distribution of the species (Krebs, 1985). Alternatively, it could also be that the density of the red panda is so low that the sub adults do not disperse but get accommodated in areas where they are born. Moreover, red panda is known to have long gestation period, low fecundity and postnatal growth. This makes the species vulnerable because the recovery of the species population will be slow after the population is disturbed even if the staple food resource is present significantly (Gittleman, 1989).

The Fir-patch also has a low HUI. The transect which passes through this patch is primarily north facing. It was extremely difficult and risky to monitor this transect during heavy snowfall. Thus the less amount of search effort in this transect could account for the encounter of fewer evidences in the area. Alpine pure rhododendron was not found to be used which could be due to the sapling II (> 1m height and < 31.5 cm gbh) or size class 3 ($\geq$ 31.5 cm-70 cm gbh) types of trees present in these patches. This habitat type is also bereft of bamboo understorey.

***5.6.2 Seasonal pattern of habitat use*:**

The distribution of the plots in the entire space of the variable space during premonsoon indicated the greater movement of the animal and greater use of space.

An expanded range of the red panda in the Wolong around this season is also reported by Reid *et al.* (1991). This is also indicated by the use of six out of seven habitat types in the study area.

During monsoon, most of the evidences of the red panda were found in the temperate region. It can be seen from the ordination (Figure 5.3) that there is a shift of the temperate forest (high tree cover, high bamboo) to the subalpine space (low tree cover, high bamboo). This shift indicates that the animals, even in the temperate zone were in and using areas of low tree cover, but high bamboo cover, especially the bamboo patches. Fog, during this season reduces visibility and all the sightings were done in comparatively open areas. This also could contribute to the ordination of animal used sites in space of open areas. Animal evidences in the bamboo patches during this period obviously indicates the use of the area for bamboo shoots which forms an important supplement in red panda diet during this period. The use of the Rhododendron forest as seen in the ordination figure here needs explanation. There is a pure rhododendron patch in the Gairibans area, which has no understorey, no bamboo or any other shrubs. The Animal centered plot is seen to be ordinated in this vegetation type, because of a sighting of red panda here. The animal was seen to be traveling through the patch. This patch makes a transit between transect 2 and transect 4 in Gairibans. It was seen walking towards transect 4. The sighting might not reflect the habitat use, although it does document the presence of the animal in the area. Information on habitat use based on the direct sighting reflects the habitat usage only at the time of observation and possible source of error may be due to infrequent or chance sightings (Khan, 1993). HUI values indicated that, Mixed forest and the bamboo patch were the most highly used habitat types during this season. In the Mixed forest, red panda and red panda evidences were found in deciduous open area, deciduous forest and *Quercus* deciduous forest.

As seen from the ordination (Figure 5.4), during postmonsoon, red pandas were using areas of taller and higher bamboo cover along with a higher tree density and higher tree cover in both temperate and the subalpine zones. Postmonsoon is the period during which red panda young are born and reared up. Hence, there could be a need for a higher tree cover for security and protection of the lactating female and the young ones. HUI values were equal for mixed and fir-birch-rhododendron habitat types followed by the oak forest. From the dietary analysis of the red panda pellets, it was found that red panda during this period includes a variety of fruits in their diet, especially *Actinidia strigosa*. *A. strigosa* being a creeper are found on the canopy of trees in the temperate zone (oak and the mixed forest). A female red panda (mother) and two young ones were seen on a huge *Quercus pachyphylla* tree. *Q. pachyplylla* being an evergreen tree offered good cover and the broad branches offered larger surface area for the mother and the young ones to sit and rest. This *Q. pachyphylla* tree also had *Actinidia* creeper on it. This observation of the use of a *Quercus* tree could explain the need of the type of habitat and microhabitat needed during this period. This discussion on the use of habitat during postmonsoon is in the light of the needs of lactating female and the new borns. Not much can be said about the habitat use by the male red panda. Reid *et al.* (1991) reported that the range of both male and female increased during November.

As seen from the use of substrates approximately 50% of the pellets during winter were found on the forest floor, paths on ridges and on slopes- areas which are comparatively open and these locations are projected on the ordination figure. Mating of red panda occurs during winter. The pellets strayed on the ground could be an olfactory communication between the conspecifics. Although, evidences were also found in the Fir-Birch-Rhododendron forest, Fir-Rhododendron habitat type had higher HUI. Fir- Rhododendron forest is the type of habitat found at altitudes >3300 m in the subalpine forest. In the temperate zone the Mixed forest as well as the Oak forest was found to be used by the red panda during winter. I would restrict my explanation of the use of the Fir-Rhododendron and the Oak forest by stating that red pandas were in the lower altitudes. It is not possible to say whether this was altitudinal migration or an indication of greater movement for food and mating pairs.

It was found that trees were used significantly more than any other substrates. Some of the trees used and due to which form important components of red panda habitats were *Abies densa, Betula utilis, Quercus pachyphylla, Sorbus cuspidata* and *Magnolia campbellii.* An appraisal of the status of these tree species in Chapter 3, thus holds importance.

The habitat preference analysis (Nue *et al.*, 1974) and the HUI show the use and affinity for the Mixed forest and the Fir-Birch-Rhododendron forest. The ordinations show the use and shifts (local movement) of the animal within the broader habitat types. These differential use of the habitat seems to occur according to their need for food, cover and mate. The present study has been able to give some new insights into the temporal and spatial use of habitat by the red panda in the Singhalila National Park. However, a similar study within a known home range of collared animals could have yielded more information on these aspects.

CHAPTER 6

FEEDING ECOLOGY

6.1 Introduction

Animal species select food from which they obtain maximum energy, vital for their reproduction, growth and survival. Each species has its own feeding strategy based on its size, digestive tract anatomy and physiology (Hofmann, 1973; Robbins, 1983). Animal species also have various morphological specialization to suit their feeding strategies. Associated with such differences in feeding habits, mammals have been broadly categorised into three types namely the carnivores, herbivores and the omnivores. Carnivores basically being meat eaters have sharp ingestive aids adapted for tearing meat along with a relatively shorter alimentary canals. Herbivores, are the group of mammals which subsist on plants.

Plants have two main components from the point of herbivore digestion- the cell wall and the cell contents (Van Soest,1975 and 1977). The cell contents have soluble cell nutrients and the cell wall is composed of tough fibrous hemicellulose, cellulose and lignin. The hemicellulose and the cellulose are polysaccharides, the breakdown of which is done by degrading the cellulose and the hemicellulose by microbial fermentation in the alimentary canal of the herbivore (Figure 6.1). Herbivores, therefore have a longer digestive tract which offers more surface area and longer time for digestion of food plants.

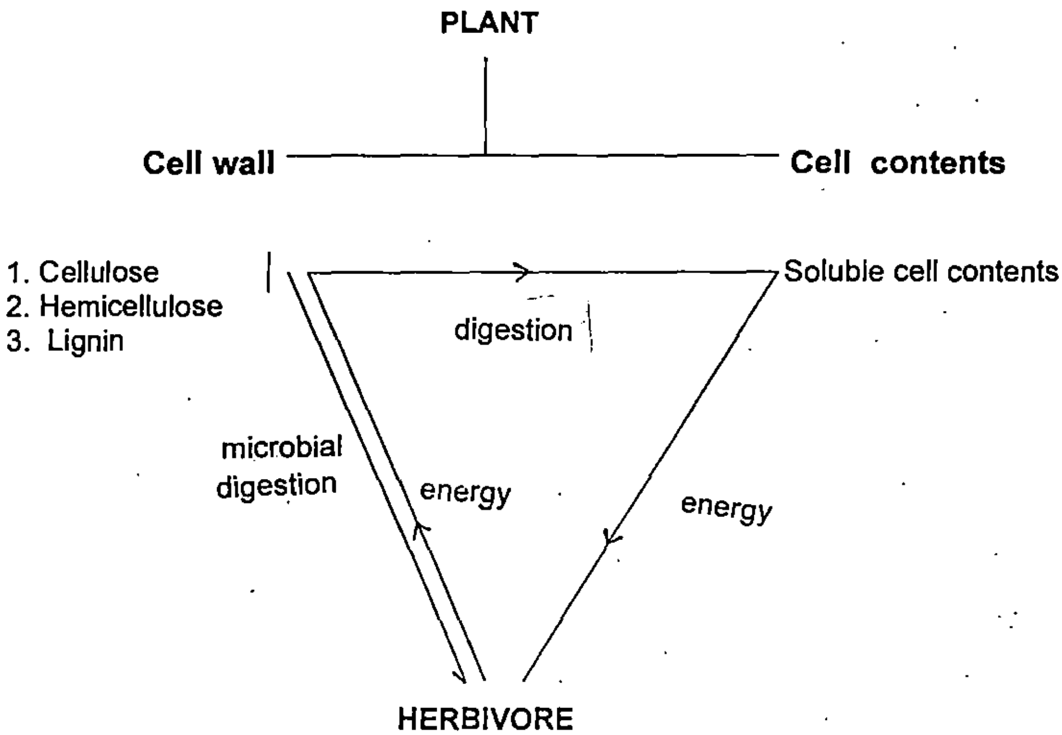


Fig.6.1 Utilisation of plant components by herbivores

Red panda and the Giant panda are carnivores with a short simple gut, devoid of microbes but have many anatomical features typical of herbivores especially the modifications in their dentition (Bleijenberg, 1984; Roberts and Gittleman, 1984) and skull structure (Roberts and Gittleman, 1984).

Dietary information available so far indicates that red panda is a herbivore. Its dietary staple in the wild is bamboo, fruits, tuberous roots, acorns, beech (Hodgson, 1847, Sowerby, 1932). Mottershead (1963) noted red pandas to be fond of pears. Later studies specify bamboo species such as *Sinarundinaria fangiana, Fargesia spathecea* to be taken in the Wolong Nature Reserve (China), with a preference for the former (Schaller *et al.*, 1985; Johnson *et al.*, 1989; Reid *et al.*, 1991;) and bamboo species locally known as jhapra in the Langtang National Park, Nepal (Yonzon and Hunter, 1989 and 1991). Fruits and berries of *Sorbus* spp., *Maddenia hypoleuca* and *Cotoneaster moupinensis. Clematoclethra tiliaceae, Rubus mesogaeus, Rubus pileatus, Ribes amupinensense* and *Ribes longiracemosum* and cherries - *Prunus vaniotti and P. brachyoda* are reported to be taken by red panda in the wild (Johnson *et al.*, 1988; Yonzon and Hunter, 1989; Reid *et al.*,1991). Bamboo is apparently the major component of red panda diet in the wild.

Bamboo has high content of fiber and low content of cell solubles (Diernfeld, 1981). But as the gut of red panda does not have the gut typical of herbivores, the cell wall of food plant does not undergo any microbial fermentation in the gut of the red panda (Roberts and Gittleman, 1984; Schaller *et al.*, 1985) which leaves the animal to obtain whatever little nutrients from the cell contents. As a result the animal has to consume a substantially high amount of bamboo (Oftedal *et al.*, 1989) in order to obtain as much digestible energy as possible. The animal was found to spend about 13 hours a day searching for and eating bamboo (Yonzon and Hunter, 1989). The red panda has also evolved a physiological adaptation of lowering the metabolic rate to cope with the low nutrient diet, reducing energy expenditure for maintainance and reproduction (McNab, 1989). McNab (1989) further explains, that as a result of the food and energy conservation strategy, red panda has a long gestation period, low fecundity and a low post natal growth.

Bamboo mass flower after a particular interval of time and after the seeds are produced, it dies (Zanzen, 1976). The panda is left without food during this phenomenal life cycle of the bamboo plant. Flowering and death of a number of species of bamboo led to giant panda mortality in China in the 1970s and 1983. (Schaller, 1987; Johnson *et al.*, 1988; Reid *et al.*, 1989; Taylor *et al.*, 1991).

Hodgson (1847) reported red panda to take eggs and small birds. Reid *et al.* (1991) found hairs of murid rodent species in the faeces that were examined. The hairs were most probably of *Apodemus* species in conifer forest above 3200 m. Apart from this, no evidences of carnivory in red panda is reported from the wild. Even in zoos, meat is not readily accepted by red panda though sometimes they have been observed to kill and eat small birds and mammals (Bleijenberg, 1984). Red panda is far too slow in movement to be a good hunter (Bleijenberg, 1984).

This chapter reports the findings of the present study on food habits of red panda in the Singhalila National Park, during which I attempted to document the food spectrum of the red panda diet, quality and quantity and spatial and temporal distribution of food. The findings open new avenues for further investigation of the feeding ecology of the red panda in the Singhalila National Park.

6.2 Methods

Observational, feeding site survey and examination of the ingested food in the gastro intestinal tracts, faeces or regurgitated substances are the most common methods for investigating food items consumed. Red panda food habits in the Singhalila National Park was investigated by examining the faeces or droppings as none of the other methods were feasible.

6.2.1 *Faecal analysis:* Pellet groups encountered during the monitoring of the transects were collected on a monthly basis. The transects monitored has been described in detail in Chapter 4 and Table 4.2. The dung points or the places where pellet groups were found during monitoring were cleared. Therefore, it is assumed that the pellets found or collected were deposited during that particular month. Pellets found in new dung points were not collected if they were thought to be old or more than a month old.

The pellets in the pellet groups were broken and assigned to macroscopic examination. Ocular estimates of percentages were used as a basis for converting to percent volume for each item, in each pellet examined (Beeman and Pelton, 1977).The fruits and berries consumed were identified from the seed remains, undigested skin of the fruits and even sheaths which survived digestion. It was not possible to separately identify the shoot of the two species of bamboo from their remains in the faeces. Therefore, the presence of bamboo shoots In the diet has been referred to as only 'bamboo shoots' irrespective of their species. The percentage of volume of food items taken by the red panda, were calculated for four seasons by pooling the data for all pellets examined from the entire study area. The diet spectrum for red panda was also investigated for the three study sites (Gairibans, Kalipokhari, Sandakphu) within the two broad vegetation zones- the temperate and subalpine zones of the study area.

6.2.2 Phenology of the food plants: In order to investigate the availability of cover and food resources present in the study area, phenological studies were undertaken (chapter 3). From the same data set, detailed phenophases of some of the trees, shrub and creeper species found to be used by the red panda as food items are investigated here. The details of methodology for the phenological methods are also presented in chapter 3.

Phenology of the two bamboo species were studied in sixty $1m^2$ plots, thirty each for the two species. The data and information on the distribution and density of bamboo in chapter 3 has been used here to assess the distribution and density of bamboo available to the red panda. A survey of the amount of bamboo shoots and *Actindia strigosa* fruit harvest by people were also done.

6.2.3 Biomass and density of bamboo: The advantage of biomass over density and cover is that biomass is closely related to forage availability and habitat carrying capacity and is based on dry weight (Daubenmire, 1959; Bonham, 1989). Bamboo biomass estimation, was done by clipping bamboos above ground level during the growing season of the plant (May-October). The culms were then cut, weighed and oven dried at 80°C. Density of bamboo was estimated in 3 m^2 quadrats during vegetation analysis (refer chapter 3).

6.2.4 Nutritional analysis: Leaves of *Arundinaria maling*, *A. aristata*, of all age class (1 year, 2 year and >2 year) were collected for one year. Fruits of *Actinidia strigosa, Sorbus* and *Rosa* spp. and shoots of both the species of bamboo, were also collected during their season of emergence. All the collected plant samples were dried to constant weight at 55°C and grinded in a Willey's mill prior to analysis. Hemicellulose, cellulose and lignin were determined following Goering and Van Soest (1970) using Fibretech System. Other constituents were determined following Allen (1989).

6.3 Results

A total of 1268 pellets, with 632 for premonsoon, 188 for monsoon, 235 for postmonsoon and 195 pellets for winter were examined. It was found that the red panda in the Singhalila National Park consumed both the species of bamboo- *Arundinaria maling* and *A.aristata*, although the intake of the two species of bamboo was not found to be statistically significant (Mann-Whitney; $z = 0.24$, $df = 12$, $p = 0.813$) along with other supplements of some fruits and bamboo shoots. The intake of the supplements however, varied with their seasonal availability.

6.3.1 Seasonal variation in diet

The diet of red panda in premonsoon, as evident from the examination of the faeces, chiefly consisted of leaves of both the species of bamboo in a combination of 51.84% *A.*

Table 6.1 Percent occurrence of food items in the diet of red panda during different seasons

Food Items	Premonsoon	Monsoon	Postmonsoon	Winter
Arundinaria aristata	51.84	34.86	45.15	53.00
Arundinaria maling	48.16	36.18	36.53	47.00
Bamboo shoots	0	28.58	7.06	0
Actinidia strigosa	0	0	13.38	0
Sorbus microphylla	0	0	Trace	0
Rosa sericera	0	0	Trace	0
Unidentified fruit	0	Trace	0	0

aristata and 48.16% of *A. maling*. In monsoon, the diet was composed of *A. aristata* leaves (34.86%), *A. maling* leaves (36.18%), bamboo shoots (28.58%), along with some trace amounts of an unidentified fruit. In postmonsoon, the diet consisted of more items of food corresponding to the increase in the availability of fruit resources in the forest (refer chapter 3, section 3.5.7). It was found to have *A. aristata* leaves (45.15%), *A. maling* leaves (36.53%), fruits such as *Actinidia strigosa* (13.38%) bamboo shoots (7.06%), *Sorbus microphylla* and seeds and sheaths of *Rosa sericera* were found in trace amounts. Winter diet of the red panda consisted of 53.00% of *A. aristata* leaves and 47.00% of *A. maling* leaves (Table 6.1).

The overall intake of *A. aristata* varied from 34.86% to 53% ($\bar{x}$ = 45.97%), while *A. maling* varied from 36.18% to 48.16% ($\bar{x}$ = 41.97%) and the rest ($\bar{x}$ = 11.82%) consisted of the fruits and bamboo shoots.

No evidence of carnivorous diet was found during the examination of the pellets, except for a few feathers with no bones or any other remains of bird. Hence, proportionwise, the presence of the feathers as an evidence of carnivory in red panda holds very little significance.

6.3.2 Feeding ecology in the three study sites

As already mentioned in the previous chapters, temperate zone is represented by Gairibans and Kaiyakatta-Kaloipokhari and the subalpine by Sandakphu. Details of the results of the food composition in the three study sites are presented in Table 6.2. Pellet examinations from Gairibans revealed the diet spectrum comprising of only *A. maling* leaves (100%) in premonsoon and winter, *A. maling* leaves (60.57%) and bamboo shoots (38.26 %) and 1.17% of an unidentified fruit in monsoon. In postmonsoon, the diet was composed of *A. maling* leaves (70.00 %), *A. strigosa* (20.00%) and bamboo shoots (10.00 %).

In Kaiyakatta-Kalipokhari area, pellet examination indicated red panda of taking both *A. aristata* leaves (55.5%) and *A. aristata* (44.5%) in premonsoon and more or less the same proportion of the two bamboo species in winter (41% of *A. maling* and 559% of *A. aristata*). During monsoon, the diet composed of 46% of *A. aristata*, 38.7% of *A. maling* and 15.30% of bamboo shoots. *A. aristata* (44.00%), *A. maling* (33.78%), *A. strigosa* (20.00%) and shoots (2.22%) during the postmonsoon season.

In Sandakphu area or the subalpine zone the diet consisted entirely of *A. aristata* leaves (100%) for premonsoon and winter. In monsoon, the pellets were found to have *A. aristata* (74.75%) and bamboo shoots (25.25%). Postmonsoon samples of Sandakphu area consisted of *A. aristata* (90.93 %), bamboo shoots (6.67%), *Sorbus microphylla* (1.73%) and *Rosa sericera* in trace amounts of 0.67%.

6.3.3 Availability and distribution of food: *Arundinaria maling,* locally known as maling is a bamboo with an average height of 4.9 m ± 0.80 and a diameter of 1.5 cm ± 0.73. The average number of nodes was 22 with average sheath lenght of 22 cm. *Arundinaria aristata,* locally known as ratnigalo is shorter with an average height of 3.9 m± 0.053. The average number of nodes is 22, and average sheath length of 12.81 cm. *A. aristata* has higher density and biomass than *A. maling* in the Singhalila National Park (Table 6.3). Both the species of bamboo forms the most prominent understorey in the entire study area.

Table 6.2 Percent occurrence of food items in red panda diet of different areas during different seasons in the Singhalila National Park.

Area	Season	Food Items						
		Ml	Rnl	Shoots	Actinidia	Sorbus	Rosa	Ufr
GB	Premonsoon	100	0	0	0	0	0	0
KT	Premonsoon	45.5	54.5	0	0	0	0	0
SD	Premonsoon	0	100	0	0	0	0	0
GB	Monsoon	60.57	0	38.26	0	0	0	1.17
KT	Monsoon	38.7	46.00	15.30	0	0	0	0
SD	Monsoon	0	74.75	25.25	0	0	0	0
GB	Postmonsoon	70.00	0	10.00	20.00	0	0	0
KT	Postmonsoon	33.73	44.00	02.22	20.00	0	0	0
SD	Postmonsoon	0	90.00	6.67	0	1.73	0.67	0
GB	Winter	100	0	0	0	0	0	0
KT	Winter	41.00	59.00	0	0	0	0	0
SD	Winter	0	100	0	0	0	0	0

GB= Gairibans, KT= Kaiyakatta-Kalipokhari, SD= Sandakphu

Ml= *Arundinaria maling* leaves, Rnl= *A.aristata* leaves, Shoots= shoots of both species of bamboo, Actinidia= fruit of *Actinidia strigosa*, Sorbus= berries of *Sorbus microphylla*, Rosa= fruits of *Rosa sericera,* Ufr= unidentified fruit.

As already mentioned in chapter 3, *A. maling* is the dominant bamboo between 2600 m to 3100 m in the study area. The mean altitude of its occurrence is 2891±130. *A. aristata* is found from 2850 m, but dominates the understorey from 3150 m to 3600 m and the mean altitude of its occurrence is 3353 m ± 226.9. Shoots of *A. maling* appear annually between early June to October whereas the shoots of *A. aristata* grow from late June to October. A total number of 60, plots of 1 m^2 for bamboo species were studied which revealed that the recruitment rate of bamboo was low with an average of 1.92/m^2 out of which only 0.98/m^2 remained intact. Out of the total bamboo shoots produced in the 60 plots studied, 48% were damaged or eaten (by insects and animals) and 9.8% were broken. The amount of bamboo shoots collected by the locals during the season of shoot production was found to be 10.96 kg/family per year.

Actinidia strigosa, a creeper with fleshy fruit was found to be an important component of red panda diet during the postmonsoon season in the temperate zone. *A. strigosa* is found within an altitudinal range of 2800 m to 3100 m in the study area. The plant which starts fruiting from September matures around October and lasts till November (Figure 6.2). The fruits of *A. strigosa* has thin skin and are sweet in taste when ripe. Fruits of *A. strigosa* is much sought after by the locals. The fruit is used to add flavour to the local liquor that is brewed. An estimated amount of approximately 3.75 kg/family per year was found to be collected by the local people during its fruiting season. *Sorbus micropylla* starts fruiting from June to July (Figure. 6.3) and are found from 3200 m to 3600 m. *Rosa sericera* is a shrub usually found as a secondary growth in disturbed areas along with *Berberis aristata* above 2850 m. *R. sericera* starts fruiting from June till November (Figure 6.4).

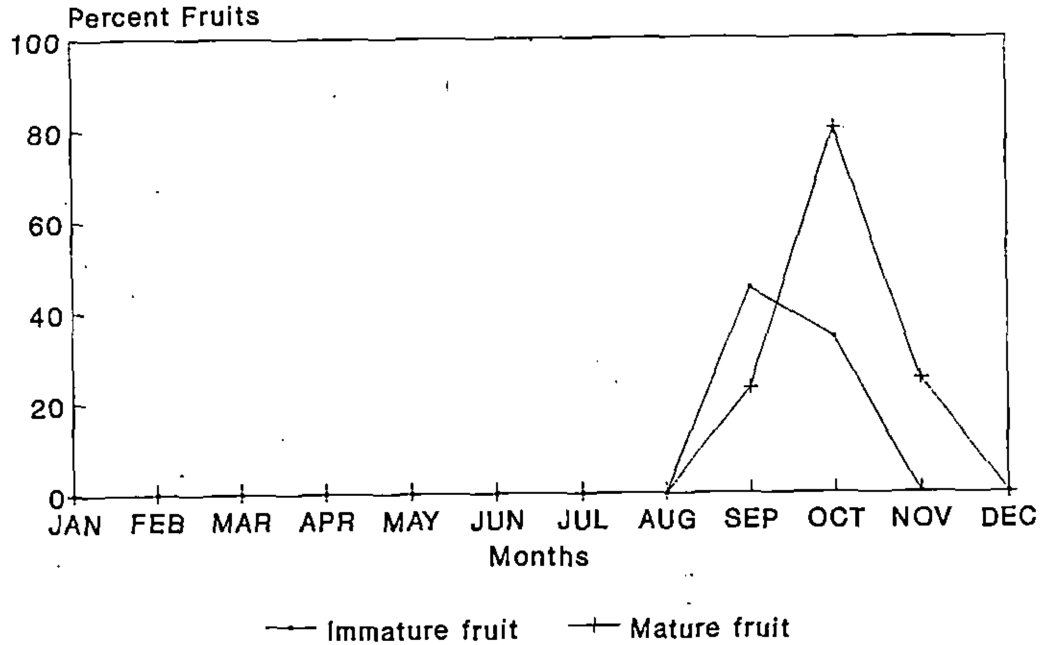


Figure 6.2 Availability of *A. strigosa* fruits

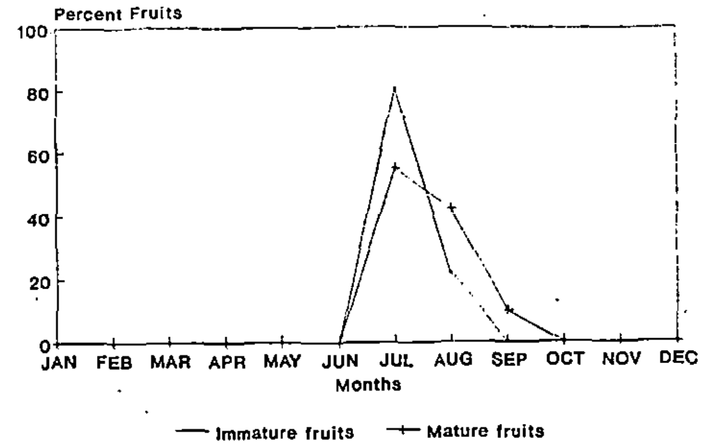


Fig. 6.3 Availability of *S. microphylla* fruits

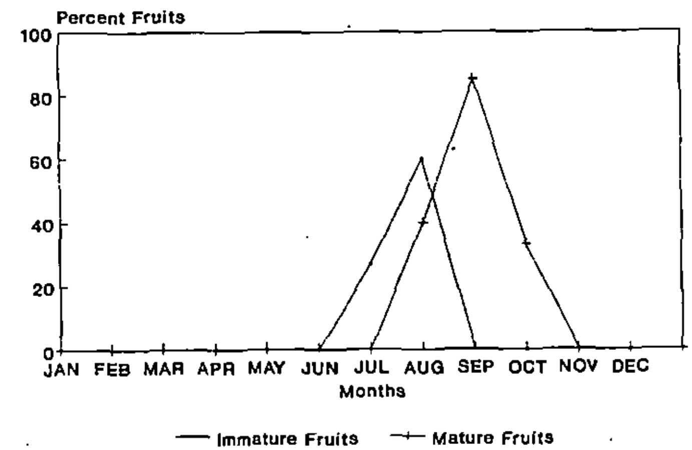


Fig.6.4 Availability of *R. sericera* fruits

6.3.4 Nutrition of the food plants: *A. maling* leaves were found to have higher cellulose and lignin content (40.12% of dry matter) than *A. aristata* (31.83%). The crude protein content of *A. aristata* was 15.1% compared to *A. maling* with 14.2% (Figure 6.5). *Actinidia strigosa* seems to be nutritionally rich with higher percent of crude protein, hemicellulose content and lower content of cellulose and lignin as compared to *S. microphylla* and *R. sericera* (Table 6.4).

6.4 Discussion

Macroscopic examination used in this study has also been successfully used by Yonzon (1989) and Reid *et al.* (1991) in describing red panda diet. The number of food items taken were more in the monsoon and the postmonsoon, than the premonsoon and the winter seasons. Monsoon and premonsoon seasons coincide with the period of birth and rearing of young ones of red panda. The nutritional requirement of animals vary with age and season (Beck and Beck, 1955). Significant increase in intake of food occurs during lactation in the red panda (Gittleman, 1989) which probably explains the consumption of fruits of *Actinidia strigosa, Sorbus, Rosa* species and bamboo shoots in addition to the bamboo leaves, during these periods.

6.4.1 Feeding ecology in the three study sites: Red panda consumes both the species of bamboo present in the study area. The amount of *A. aristata* taken is slightly higher in proportion than *A. maling* although the difference is not statistically significant. It is not possible to say how particular they are about selecting the bamboo species. As seen in chapter 4, evidences of red panda were mostly found above 2800 m, it can be

Table 6.3 Density and biomass (dry weight in Kg) / ha of *A. maling and A. aristata* in the Singhalila National Park

Bamboo species	Density/ha	Dry weight/ha (Kg)
Arundinaria aristata	56008.9± 48585	22,1390
Arundinaria maling	45278.5±45969	21,1390

Table 6.4. Protein, hemicellulose, cellulose and lignin content (% dry matter) of the three fruits identified to be taken by red panda in the Singhalila National Park.

Fruit	Crude protein	Hemicellulose	Cellulose + lignin
Actinidia strigosa	10.63	8.00	20.59
Sorbus microphylla	4.38	2.54	41.00
Rosa sericera	8.88	1.95	28.01

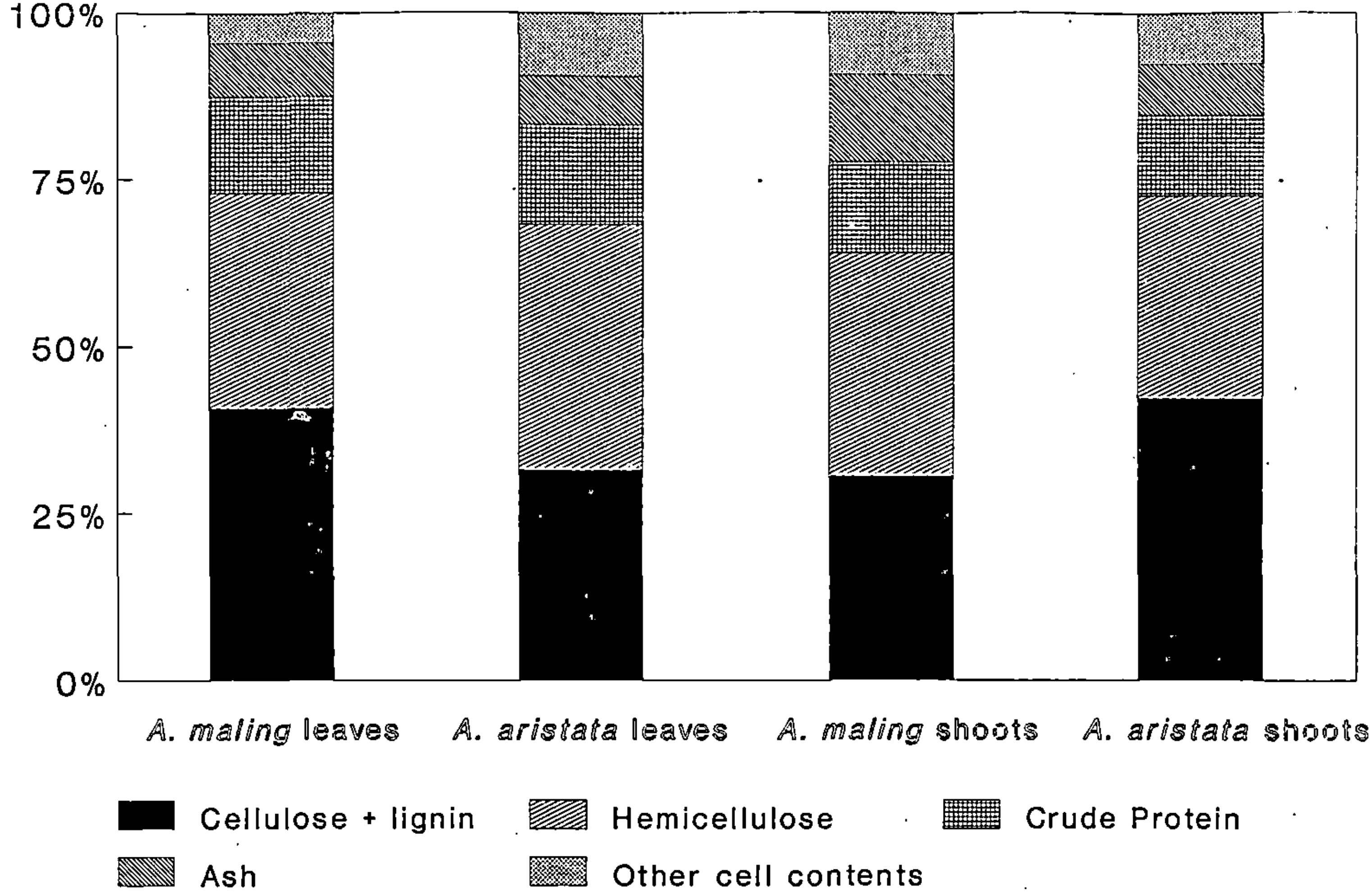


Fig.6.5 Nutrient contents of the leaves and shoots of *A. maling* and *A. aristata*

presumed that the animal occurs in the zone where both the species of bamboo are found. From the examination of pellets, red panda was found to be consuming mainly *A. maling* in Gairibans, the dominant species in the area. *A. aristata* is found only in small patches above 2850 m in the area. At Kaiyakatta-Kalipokhari area the intake of *A. aristata* was found to be more correspondingly, to the increasing availability of this bamboo species in the area. At Sandakphu, the diet is solely composed of *A. aristata* the dominant species of bamboo in the area.

The giant panda selected *Sinarundinaria* sp. over *Fargesia* sp. in the Choushuigou study area in China where both the species of bamboo were easily accessible to the animal. The preference for *Sinarundinaria* sp. over *Fargesia* sp. could be due to the higher content of protein, other nutrients and less cellulose and lignin in *Sinarundinaria* sp. However it was also found that the pandas in Jiuzhaigou (China) and elsewhere subsisted entirely on the *Fargesia* sp. and was regarded to be an adequate food (Schaller *et al.*, 1985). Schaller *et al.* (1985) attributed the cellulose content to be the discriminating factor between the favoured and unfavoured food and parts of bamboo by the giant panda, with the content of cellulose to be higher in the unfavoured food or plant part.

A. maling is the dominant bamboo species at Gairibans while at Kaiyakatta-Kalipokhari area, both *A. aristata* and *A. maling* are found. *A. aristata* is the dominant bamboo species in the Sandakphu area. The animal seems to be consuming the species of bamboo most easily available to them. However, this would need further investigations. Investigation of the quality of the food plants ascertained that the *A. aristata* leaves had higher protein, less cellulose and lignin content as compared to *A. maling* leaves. However, not much could be commented on the nutrient content of the bamboo species and infer much about the selection of the bamboo species on the basis of their nutrient content because *A. maling* and *A. aristata* leaves were found to be taken in almost equal quantity at Kaiyakatta-Kalipokhatta. Moreover, at Gairibans, *A. maling* seems to make an adequate food while *A. aristata* at Sandakphu. *Actinidia stigosa* formed a substantial quantity of red panda diet. However, more can be said about the selection of fruits only by comparing the preference and avoidance of other fruits found within a study site rather than between sites. For example, in Gairibans and Kaiyakatta area, other fruits which the red panda was suspected to consume was *Holbellia latifolia, Stephania* sp. and *Sorbus cuspidata.* But faecal examinations showed that these fruits were not taken. It was not possible to carry out the nutritional contents of the other fruits during the present study but further investigations on these aspects would reveal more about the feeding ecology of the red panda in the Singhalila National Park.

Both the species of bamboo has been affected by the intensive grazing (chapter 3). Moreover, the bamboo species were also found to have low recruitment rate. The bamboo shoots of both *A. maling* and *A. aristata* are not only eaten by other wild animals but also harvested in huge quantities by the locals. All these factors could have an effect on the growth dynamics of the bamboo, an important food plant of the red panda. *A. strigosa*, another important food plant of the red panda in the Singhalila National Park during the postmonsoon season is equally harvested by the locals. Thus it becomes important for the managers to protect these plants against rampant harvesting and destruction.

Going by the results of this study, it can be seen that red panda in the temperate zones (Gairibans and Kaiyakatta-Kalipokhari) are consuming both the species of bamboo- *A. maling* and *A. aristata*, bamboo shoots and fruits like *Actinidia strigosa* whereas in the subalpine zone, the food was found to consist of *A. aristata* leaves, shoots and fruits of *Sorbus microphylla* and *Rosa sericera*. In Kaiyakatta-Kalipokhari area, the abundance of red panda was found to be relatively higher than in other sites, along with a relatively good breeding population (chapter 4). One of the probable factors responsible for this abundance of red panda in the Kaiyakatta-Kalipokhari areas could be due to the availability of more food resources as compared to the other sites.

As it was not possible to investigate or collect information on the aspects like home range and movement of the red panda in the Singhalila National Park, it is difficult to say what portion of the subalpine and the temperate zones are used by the red panda. If a home range encompasses both the zones or the animals are freely using both the zones, then it is likely to be consuming *A. maling, A. aristata,* and other fruits. But if the distribution of the animals are, as discussed in the light of the disconnected areas (chapter 4) the red panda in the two zones or in the three sites are likely to have different food availability and hence different dietary composition.

CHAPTER 7

CONSERVATION PROBLEMS OF RED PANDA

7.1 Introduction

The red panda is currently threatened throughout its range by destruction, loss and fragmentation of its habitat and poaching. However, the severity, degree and nature of these threats would differ in different regions of its distribution. In Langtang National Park, the crux of the conservation problem lied in the presence of two cheese factories in the area. The factories required about 100,000 kg of fuel wood to process milk. The people maintained large herds of cattle, to supply milk to the factories. The presence of large number of cattle, herders, their dogs caused immense disturbance to the red panda and red panda habitat in the area (Yonzon and Hunter, 1993). In order to come in terms with the problem, Yonzon and Hunter (1991) suggested that the production of cheese and number of cattle should be reduced. As the cheese produced was mainly bought by the Western tourists, the hike in price would not effect the cheese market while at the same time increase the income of local people, without having to keep large herds of cattle. Similarly, it becomes important to identify specific problems in other areas too, for formulation of appropriate management strategies for the species. As for all other aspects of the red panda, detailed information on the conservation problems of the red panda is also scarce.

The primary objective of this chapter is to obtain a broad overview of the problems of the Singhalila National Park vis-à-vis the people in the settlements, in and around the National Park and their impact on the conservation of the red panda.

Information on the conservation problems were collected by conducting a socio-economic survey, casual discussion with all strata of people and personal observation during the course of the study.

7.2 Management history of the Singhalia National Park

The Singhalila National Park was bought by the British Government from the Sikkim Darbar in 1882 and notified as a reserve forest. Systematic exploitation and management of the Singhalila forests was for the first time proposed in Tafford's Working plan of 1908-1918 (Anon, 1967). However, due to the remoteness and inaccessibility of the area, the prescription of the working plan could not be carried out until the Singhalila forest was incorporated in Grieve's working plan in 1912 (Anon, 1967). In 1914, it is known that there was large scale exploitation of bamboo (*Arundinaria* sp.) from Phalut for the pulp factory in the plains of Jalpaiguri (Dozey,1989). A cyclic extraction of timber from the area was prescribed in these early working plans. Along with this, villages were established within the forests, residents of which did the regeneration, plantation, weeding and protection work. The villagers of the permanent forest villages were given a land holding of four acres, and allowed to keep two plough cows, two cows or buffaloes and four calves and two goats (Anon, 1967). The forest villagers in the Singhalila range were Namla, Linsebong, Gurdung, Sirikhola, Majua, Daragoan, Rammam, Samanden and

Gorkhey. These villages are now in the buffer zone. Roads were constructed to facilitate the transport of timber from the areas. The MR road constructed during the seventies was primarily an infrastructure to facilitate the transport of timber extracted from the area. It is difficult to trace the exact history of cattle grazing in the Singhalila. The earliest documented records of cattle, goats and sheep in these areas are of O'Malley (1907). It is known from the working plan of the Darjeeling Forest Division, that grazing was restricted to areas in Tonglu and the Singhalila ranges above 9000 ft (2727 m) and 9500 ft (2879 m) and in rest of the areas stall feeding was insisted upon. There were provisions for issuing grazing permits (Anon, 1967). A minimum of about 80-90 *goths* (cattle stations) were present inside the National Park area before 1993. As per the information gathered from the local people, each *goth* had a minimum average of 30-50 cattle heads. These *goths* were ultimately removed between 1991-1993. This removal of *goths* greatly reduced the anthropogenic pressures in the Singhalila.

Fire seem to have constantly posed danger to the forests of Tonglu and the Singhalila range causing damage to large tracts of forest. Some of the serious fires have been recorded in the early years of this century (Banerjee, 1964). Large patches of secondary growth of bamboo patches and skeletons of the charred trees can still be seen. A number of fire lines were created in affected areas as a protection measure. The first attempt to afforest the burnt patches in the Singhalila area was done in 1950-51. The recent fires which seriously damaged the forest and old plantations of Ramman (buffer zone) were in 1991,1992 and 1993 (Ghosh, 1997).

Poaching and trapping of the red panda and other fauna of the area was a very common phenomena in the past. Live red pandas trapped from, both Nepal and Indian areas were brought to Rimbick and sold. From here the animals were supplied to different zoos in India or shipped abroad. It was a thriving and an unabated business until the enforcement of the Indian Wildlife Protection Act (1972). This business continued in a smaller scale till the late 70s. A trader in Rimbick had received as many as sixteen red pandas in a day. Among the animals received, there would also be pregnant females which gave birth to young ones in his cage. However, with stringent protection and proper legislation after the enactment of the Indian Wildlife Protection Act (1972), poaching and trapping were brought under control and to an end.

The wilderness, climate and the natural beauty of the place have always attracted people and tourist. Some of the early rest houses and bungalows were at Phalut, Sandakphu and Tonglu (O'Malley, 1907). Some of the rest houses and forest buildings in these areas were damaged and charred down during the Gorkha agitation in Darjeeling hills during the mid 80s. A number of trekker huts were again constructed in the early 90s. Thereafter, trekking and tourism in the Singhalia National Park is being promoted.

In its history of over 100 years, the forests of Singhalila have passed through different phases of Government policies. Some of the earlier ones were concerned with managing the forests for timber extraction and revenue. Implementation of policies pertaining to conservation and ecological concerns, set in, only after post independence and that too not more than a decade earlier in the Singhalila. The area is still fraught with various conservation problems mainly arising from the surrounding settlements, dependence of the people on the forest and forest resources, the socio-economic condition of the people and the increasing popularity of the Singhalila National Park as a trekking destination.

7.3 Socio-economic profile

7.3.1 Settlements: The Singhalila National Park is surrounded by several human settlements. On its eastern side, there are ten main settlements (Figure 2.2). These are Gorkhey, Samanden, Rammam, Daragoan, Sirikhola, Gurdung, Namla forest villages and others like the Sepi, Rajabhir, Rimbick. All these settlements except Gorkhey are in the buffer zone of the National Park. Gorkhey forest village lies within the core zone. Apart from the Gorkhey forest village, the core zone also has a number of Government quarters for the staffs serving in some of the departments of the Indian Government like- Forests, Tourism, Police, Public welfare and Darjeeling Improvement Fund. The government staffs comprise the non-resident population of the area and are mostly concentrated in Gairibans and the Sandakphu area. As seen in figure 2.2, a motorable road runs along the western border of the National Park. This road is regularly used by the tourists, locals and there is a regular movement of vehicles during the tourist seasons. This road is an international border between the two countries of Nepal and India. On the other side of the road, are. several Nepalese settlements. A total of eight settlements are on the periphery of the Intensive Study Area. These settlements share the same name on the Indian and the Nepal areas and are- Phatak (population:6), Gairibans (population:30), Kaiyakatta (population:11), Batase (population:7), Kalipokhari (population:44), Chaurichowk (population:11), Bikhe (population:22) and Sandakphu (population:25). There are also a number of permanent and migratory cattle stations on the Nepal territory especially from Sandakphu to Phalut. Apart from the patrolling and vigilance of the forest staffs, there is no actual buffering on the western side of the Singhalila National Park. All these villages on the eastern side of the Park would be referred to as 'buffer villages' and all the villages on the western side as the 'border settlements'.

7.3.2. Occupation: People in settlements surrounding the National Park are involved in various occupations such as cattle herding, agriculture, tourist related activities, liquor making, Government jobs, daily labourers and business.

7.3.2.1 Cattle herding: Cattle herding was an important occupation when people had large herds of cattle and yaks in permanent cattle stations within the Singhalila Forest before it was notified as a National Park. Keeping large herds of cattle or yaks was a profitable business. The demand of milk and milk products such as 'sergem' (cottage cheese), 'churpi' (protein extract of milk), butter, is very high in the towns and fetch fairly good price in the market. Yak meat is either eaten fresh or dried for future use. Dried meat also fetches fairly high market price. The hides of the yaks are used for their own purposes or sold. Even the tail of yaks have commercial value as it holds special significance in wedding and religious ceremonies. Sheep and yak fur are also used to weave mats, rugs which are used by the locals or sold. Hence, livestock is valued for milk, milk products, meat, hide, fur and resale value. In the settlements practising agriculture, livestock is important for manure. Yaks and its breeds are important mode of transport in these remote high altitude areas.

It was noticed that some of the owners of *goths* with substantial number of livestock were wealthy and were able to start their independent business when the *goths* were removed from the area and grazing prohibited. People still keep livestock as a source to supplement their other source of income, as an important source of food and manure.

7.3.2.2 Agriculture: The people in the buffer zone settlements are mostly agriculturists. Potatoes, cabbage, peas, beans are the principal crops cultivated here which are taken to Rimbick bazaar. Bigger traders buy the crops in bulk and transport them to the towns. The villagers of the Nepalese settlements have agricultural land in their own villages lower down in the valleys. Cardamom and vegetable like potatoes, cabbage, peas, carrots are important cash crops. They also farm vegetables in the settlement areas in smaller scale.

7.3.2.3 Tourists activities: People both in the buffer and the border settlements are involved in tourist related activities, in way of providing food and boarding facilities in their own houses or in a separate lodge. Some people run small tea shops, or are guides or work as porters. People involved in this occupation would be earning seasonally only during the peak tourist seasons of March-May and September-November.

7.3.2.4 Liquor making: Liquor is brewed in almost every house, not only for their consumption but for selling and is a profitable occupation by the standards of the people.

7.3.2.5 Catering to local travellers: The people of the border as well as the buffer settlements also earn by catering the local travellers. Local travellers mostly consist of people from the Nepal villages lower down in the valleys of East Nepal who carry various vegetables like potatoes, peas, carrots, cabbages and milk products like butter, cheese to sell them at the nearest Nepal village Jaubari where traders buy the crops to be sold at higher prices at the next bigger village Manebhanjyang, from where the commodities are transported to other places in Darjeeling. These people from the villages, after selling their vegetables take back essential commodities like oil, salt, kerosene oil, flour etc. while returning. They rest and eat in the small tea shops and local lodges in the border settlements. The liquor which is brewed is mostly consumed by these local travellers. Similar trade route is in the northern side of the National Park ithrough Phalut, Sabarkum, Molley, Siri to Rimbick from Nepal area or Sikkim and vice versa.

7.3.2.6 Government jobs: The maximum number of people holding government jobs are from Rimbick bazaar. In other, buffer and border settlements very few people have Government jobs. Jobs, that these people usually hold are that of teachers of primary schools, army recruits, caretakers and forest guards.

7.3.2.7 ***Other:*** Other jobs which the people of these areas are occupied in, oft and on, are daily wage labourers in construction and maintenance of roads, houses, forest plantations and weeding.

None of these settlements, except for Rimbick bazaar has electricity. The primary source of fuel in all the settlements is still firewood. Rate of literacy is low and facilities for health and education are poor. The details of some of the civic amenities available to the people in the buffer settlements are presented in Appendix IV. The Panchayat head of the buffer settlements opined that the, population in these areas had increased along with it unemployment and people were still below poverty level. Some aspects of the socio-economic profile of the buffer settlements are presented in Table 7.1.

7.4 Dependence of the people on the forest and its impact

7.4.1 Grazing: People possessed and still possess livestock for income, food and transport. The usual system of grazing was to take the cattle to the higher altitudes, from above 3000 m to reaches above 3600 m in the Singhalila forests, Sikkim or Nepal area during the warmer seasons. The animals were brought down to the lower altitudes during winter. Temporary settlements were established in the forests where the animals grazed during this migration. In recent times, this pattern of livestock grazing is less prevalent due to National Park status of the Singhalila forest. However, migratory cattle grazers and their sheds can still to be found along the Indo-Nepal border from Bikhebhanjyang to Phalut. Cattle were found to be stall fed or

Table 7.1 Some aspects of the socio-economic profile of the buffer settlements

Name of village	Total houses	Total population	Main occupation	Livestock	No. of lodges
Gorkhey	23	140	Agriculture	50	3
Samanden	18	76	Agriculture	40	0
Rammam	40	221	Agriculture	85	3
Gurdung	27	159	Agriculture	284	1
Manedara (Rimbick)	63	491	Agriculture	644	1
Jaulegaon (Rimbick)	65	330	Agriculture	767	0
Rimbick bazaar	103	657	Business & Govt. jobs	517	2
Namla	20	159	Agriculture	162	0

fed with fodder from their agricultural land in the Rimbick area. A few *goths* within the forest are still found in the buffer zone.

Cattle grazing and presence of human beings within the forest has had a number of impacts on the forest resource of the area. Impact of cattle grazing was discussed in Chapter 3. It was seen that cattle grazing have had considerable impact on the natural population of bamboo. While grazing or browsing on bamboo, yaks and cattle pulled down the bamboo culms or trampled upon while forcing their way through the bamboo thickets. The left over portion of the pulled down bamboo dry up and die. Grazing has had a tremendous impact on the bamboo, in the entire study area. Deep furrows are also made in areas where yaks have grazed intensively. These become waterlogged during the rainy season. Such bogs are found in and around cattle stations and found to hold no vegetation.

7.4.2 Firewood use: The only source of fuel is firewood in all the settlements. In the border settlements, firewood is collected from both the National Park and the Nepal forest. People here prefer the National Park because of better forest cover and shorter travelling distance. In the buffer settlements, firewood is collected from the National Park in Gorkhey and Rammam, whereas the other settlements get firewood from the Directorate forest/buffer forest. Apart form their daily activities like cooking meals, firewood is used and burnt in order to make the various milk products and liquor which requires substantial amount of firewood. Moreover, as this region has cool climate, fire has to be kept burning to keep oneself warm. Firewood consumption was noticed to increase during the tourist season- a time when more meals are cooked, more liquor is brewed, and more firewood burnt for warming. The local lodges, tea shops also cater to the local travellers thus increasing the consumption of fuel wood.

7.4.3 Extraction of minor forest products: Some of the minor forest products like the Bamboo shoots, edible mushroom, ningro (edible fern), nakima (*Ophiopogan intermedius*), Shishnoo (*Urtica* sp.) make an important source of supplement food. Bamboo, *A. maling* is extensively used for various purposes like thatching, fencing and weaving baskets. An average of 1500 culms per family per two years are used for various repair work. Small trees of *Symplocos* sp., *Abies densa* and *Betula utilis* were used for construction of houses and cattle sheds. Fruits and berries of *Sorbus cuspidata, Actinidia strigosa, Frageria* sp. and leaves of *Rhododendron arboreum* are collected during their period of production to add flavour to the local liquor that is brewed. Leaves of *Schefflera impressa* and *Litsaea elongata* are lopped and stored as fodder for the cattle during the winter season.

7.5 Tourism and its impact

The entire biodiversity and the fragile ecosystem which the National Park is established to protect forms the resource base for tourism. Tourism is an important industry providing employment and augmenting the economy of Darjeeling. Hence, tourism is promoted and the Singhalila area is focussed as one of the important trekking destination.

7.5.1 Singhalila as a trekking destination: The Department of Tourism has constructed many trekker huts which provide good accommodation facilities at strategic places like Gairibans, Sandakphu, Phalut, Molley, Gorkhey, Rammam and Rimbick. Since the construction of the Government huts, National Park has received a recorded number of 1498, 2165, 2171 and 2700 tourists in 1993, 1994, 1995 and 1996 respectively. (The number is not substantial as compared to the mountain areas, but the annual increase in the tourists is of concern). Maximum tourists visit the park during the premonsoon (March-May) and the postmonsoon season (September-November) which is can be seen in Figure 7.1.

There are two main trekking routes which pass through both Nepal and Indian areas and also gets into Sikkim via Phalut or Gorkhey. One of the routes start from Rimbick and passes through all the buffer settlements and then come to Sandakphu. The other starts at Manebhanjyang, and passes through all the Nepalese villages on the western border of the National-Park.

Tourism can contribute to litter accumulation, trail erosion, landslides, habitat change, loss of endangered plants, resource depletion (Rai and Sundriyal, 1997) and can also have long-term negative effects on wildlife and local communities if not properly managed (Mathieson and Wall, 1982; Pleumarom, 1993; Norris, 1994; Kinnaird and O'Brien, 1996). The most apparent environmental impact of tourist inflow noticed in the Singhalila National Park was the increase in the use of firewood especially during the tourist seasons. Sandakphu is the trek summit and receives the maximum number of tourists. The place has three trekker huts and three local lodges. Moreover, the place being in the highest altitude of the National Park, is cold. The area had the highest density of cut stumps which is a clear indication of the

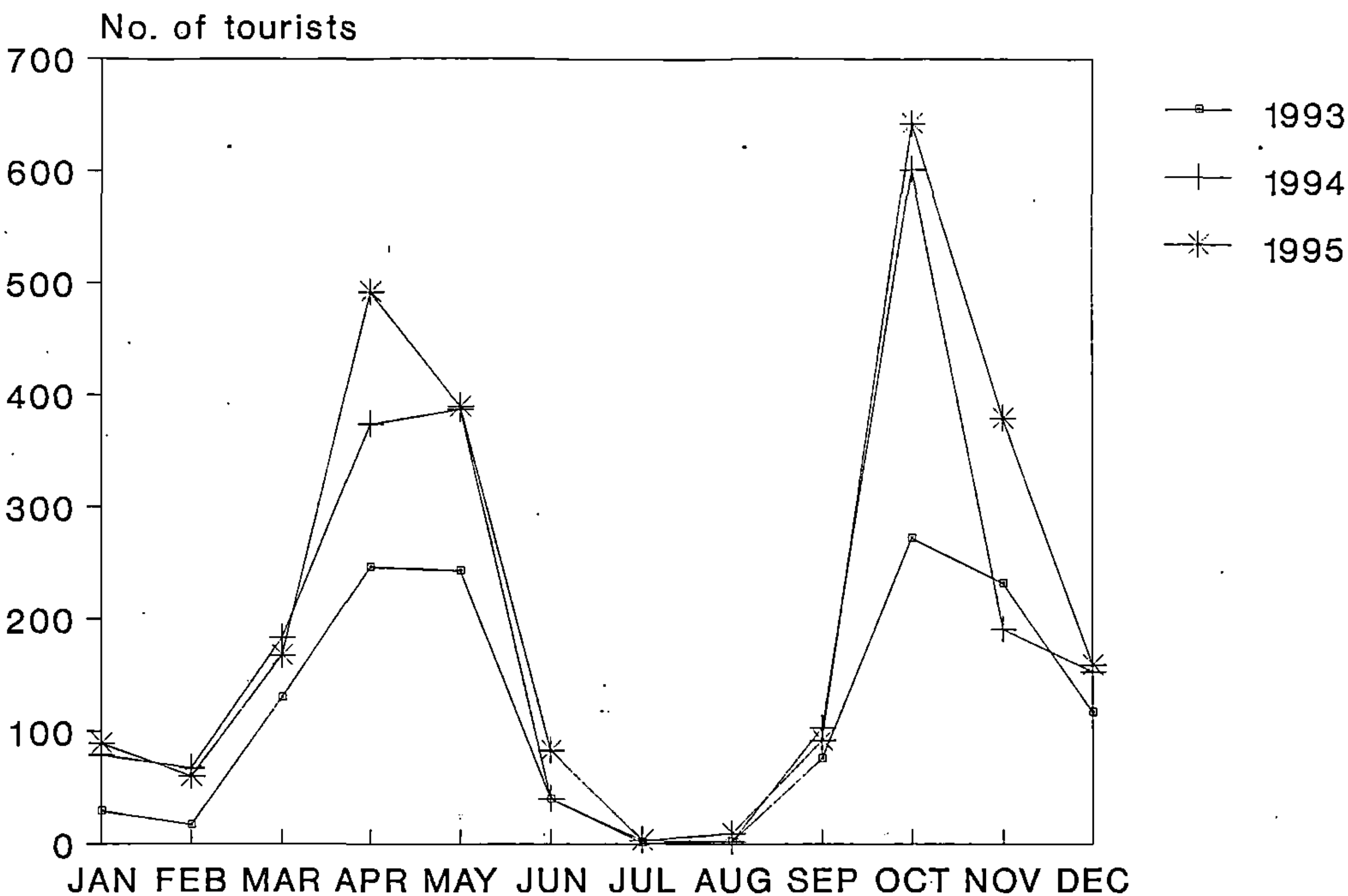


Fig.7.1 Increase in number of tourists visiting the Park

anthropogenic pressures on the forest (refer chapter 3). Similarly Phalut, Molley are also cold and comparatively more remote also.

A survey during this study in the buffer zone settlements and Rimbick revealed that agriculture system was showing signs of unsustainability. People were also of the opinion that the yield of the agricultural products as well as their markets had reduced. Human population has increased along with unemployment. Tourism held promise in being one of the best alternative source of livelihood in some of these settlements at present. There is already a number of local lodges and small shops coming up in these areas.

In the border settlements of the National Park too, there is an increase in the tourism activities. The closure of the National Park to cattle grazing has had an impact on their livelihood as grazers. Other sources of livelihood such as business of vegetables, forest products, milk products has also decreased substantially. Kalipokhari was once a very big and thriving centre for business where all agricultural products of the lower valleys in Nepal were brought and sold. These products had their market at Manebhanjyang. It is said that vehicles plied the road of the present National Park, regularly during this peak business period. The scale of this business at Kalipohkari however came down with the development of roads and other infrastructural facilities in the valleys of this part of Nepal.

Most of the residents of these settlements are also resorting to catering tourists which is evident from the increase in number of local lodges and small shops. Such lodges are seen at places like Tumling, Jaubari, Kalipokhari, Kaiyakatta, Bikhebhanjyang, and Sandakphu.

It can be seen that the local people both in the buffer zone and the border settlements dependent on tourism. However, the local people that too only a select few of them are benefiting in ways of running tea stall or providing food and boarding facilities to the tourists, by working as guides and porters or as employees of the tourist department. Tourist related activities is moreover seasonal. Thus the economic gain of tourism for the locals is not much as compared to the major bulk of the revenue earned which goes to the Department of Tourism and the bigger tourist agencies.

The economic and environmental impacts of tourism has not been so far evaluated and a detailed study on these aspects should be taken up seriously as early as possible.

7.6 Distribution and abundance of the red panda in the Singhalila National Park

It was found that the red panda are distributed and abundant in the areas above 2800 m. In the Gairibans and Kaiyakatta-Kalipokhari area the average upper altitudinal limit Is 3000 m along which, the border settlements are situated. It was also seen that the red panda moved between both sides of the border habitat. Apart from the intensive study area, the surveys also revealed that the red panda are found in areas between Sandakphu and Phalut. A number of cattle stations are found along the border of this strip. The area is comparatively remote with no check posts or permanent settlements and the area is extremely vulnerable to any type of exploitation of the red panda and other fauna of the region. The areas bordering the National Park and the Sikkim area were also found to have red panda. This makes, the protection of these border area and the habitats of both, Nepal and the Indian side (West Bengal and Sikkim), extremely important.

7.7 Present management practices

The buffer zone is under the jurisdiction of the Directorate of Forest, Government of West Bengal which enforce their protection laws and development schemes in the villages. The conservation and protection of the forest is mainly done by involving the village people under a policy of the Government of West Bengal, known as the Joint Forest Management (JFM). Under this scheme, the Forest Protection Committees (FPCs) and Ecodevelopment Committees (ECDs) are formed in which the people of the villages fringing the forest, National Parks and Wildlife Sanctuaries are eligible to become members who would be responsible for the protection of the forest (Bist, 1998). For this act of theirs, the members of the Forest Protection Committees benefits by getting cash or kind obtainable from the forest, helped in establishing alternative support systems to reduce pressure on the forest resource, and also priorities in employment during forestry work (Bist, 1997; Dhaundyal, 1997). Under this Joint Forest Management programme, a nursery with a capacity of 0.75 lakh seedlings have been established in Rammam (Dhaundyal, 1997).

Implementing Joint Forest Management in other parts of the Singhalila National Park by the Wildlife division was met with a dilemma because most of the members of the Ecodevelopment Committees would be from across the border which would not be in accordance to the Government orders. The Wildlife Division also closes down the National Park for any tourists entrance from July to September. Plantations are carried out yearly, along with maintaining nurseries. The Division has also recently started charging an entrance fee for the tourists visiting the National Park. Realising the dependence of the people of the border settlements, the Wildlife Division recently started distribution of firewood, at minimal prices to discourage the people from entering the forest. The Department of Tourism has supplied kerosene heaters to all the trekker huts but because of remoteness of these area, easy availability of kerosene becomes a problem.

7.8 Transboundary Conservation

Thus it can be seen that the forests and the fauna of this region has suffered immensely from human need and avarice. Despite the notification of the areas as a National Park, removal of the cattle sheds and some of the other efforts made by the Department of Forests and Department of Tourism, to conserve the area, there are still a number of conservation problems which has to be tackled effectively at the earliest possible.

The National Park is surrounded by human settlements. Although the buffer settlements are distant from the core zone, the increasing human population, unemployment, their socio-economic condition and dependence on the forest resources are a threat which should not be underestimated. Whereas, the border villages have a comparatively low population but poses immense threat to red panda and red panda habitat, by being on the very range of present distribution of red panda in the National Park. Moreover, tourism in the area is also expanding rapidly. This can have an adverse effect on the environment of the National Park and the adjoining areas. Therefore, the first few steps needed to correct this situation and conserve the red panda and its habitat is by- launching programs and policies to restore degraded habitats, expand the current protection within the National Park to include critical habitats either in the buffer zone or in the border area, decrease the dependence of the people on the forest resources by providing necessary facilities, by making people and tourists aware of the natural heritage the National Park is established to protect and involve the local communities in conservation and protection activities. It is also very important for all the departments in the national park- Tourism, Public welfare, Police now are working in isolation to co-operate and chalk out all their programs in conformity with the park's objectives. The revenue generated from charging entrance fees to the tourists could be used for implementing management in the National Park.

The department of tourism especially must realise the ecological importance of the region and chalk out plans and programs accordingly. If properly regulated and managed tourism has the potential of fostering sustainable management of resources (Jacobson, 1994). Planned and regulated tourism can also be used as an ideal solution for combining goals of development and conservation (Kinnaird and O'Brien, 1996). In the settlements surrounding the Singhalila National Park an increasing dependence of the locals on tourism as an alternative source of income was noticed. However, the importance of it to the local economy has not been realised yet.

The conservation measures in the Singhalila National Park, therefore, would require to take into consideration the well being of the red panda as well as the local community dependent on the habitat of the species. As already mentioned above, local community includes the border settlements as well as the buffer settlements and red panda is found to be oblivious of the state and the international borders while using the habitats of Nepal, Sikkim and the Singhalila National Park. Therefore this calls for a situation where all the three regions (Country of Nepal, Sikkim and Darjeeling) should share the onus of conserving and protecting the red panda in this part of the Himalaya. In order to do so the responsibility of developing the local community must also be taken by the three regions.

Co-operation and understanding at a regional level with the Nepal Government and the State of Sikkim or a strategy for transboundary conservation should be worked out in order to overcome such problems.Transboundary co-operation is the key to effective management and sustained conservation of areas that are along the international borders (Pradhan, 1986; Yonzon, 1994; Sharma, 1995; Yonzon, 1996; Clark, 1997). The problem such as the one faced by the forest department of the Singhalila Natinonal Park, of having to restrict their Joint Forest Management programs within the National Park and not extend beyond the border where it was needed most, could be solved by negotiation between the two countries. The fact that the people of settlements on either side of the border are depending on tourism but has not been productively used for development of the region could also need an understanding and planning at the regional level. The common goal should be protect and conserve the red panda and its historical habitat in this part of the Himalayas.

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Appendix I Summary of the Preliminary survey conducted in Singhalila National Park

Date	Location	Local report	Time spent (hours)	Encounter rate/100hr
11.10.93	Gairibans	yes	5.30 hrs	0
15.10.93	Sandakphu	no	4.15.hrs	0
16.10.93	Sandakphu	no	4.00 hrs	0
17.10.93	Kalipokhari	no	5.00 hrs	0
21.5.94	Sandakphu	yes	4.30 hrs	0
22.5.94	Molley,Sabarkum	yes	6.00 hrs	0
23.5.94	Gorkhey	no	3.30 hrs	0
23.5.94	Phalut	yes	3.00 hrs	66 pellet groups
24.5.94	Rammam	no	3.30 hrs	0
27.5.94	Jarayotar	yes	5.00 hrs	0
5.6.94 - 20.6.94	Gairibans	Yes	60.00 hrs	1.3 * 4.3 pellet groups
5.7.94 -	Gairibans	Yes	21.00 hrs	19 pellet groups
20.7.94	Sandakphu	Yes	18.00 hrs	55 pellet groups
	Kalipokhari	No	18.00 hrs	0
10.8.94	Gairibans	yes	3.00 hrs	33.3 pellet groups
31.8.94	Sandakphu	yes	4.30 hrs	54 pellet groups
	Rimbick	nc		0
2.9.94 - 5.9.94	Gairibans	yes	12 hrs	6.00
21.9.94 - 10.10.94	Phalut	yes	59.20 hrs	1.4* 5.00

* Sightings

Appendix II Summary of extensive survey

Date	Location	Local report	Time spent	Encounter rate /100 hrs
15.2.95	Bikheybhanjyang	yes	3.30 hrs	0
16.2.95	Bikheybhanjyang	yes	3.00 hrs	0
17.2.95	Sandakphu	yes	4.00 hrs	0
18.2.95	Molley	yes	2.00 hrs	0
19.2.95	Gorkhey via Samanden	no	7.00 hrs	0
20.2.95	Phalut	yes	2.00 hrs	4.5
21.5.95	Phalut	yes	3.00 hrs	3.3
22.2.95	Gorkhey	no	4.00 hrs	0
23.2.95	Rammam, Siri, Pedi	no	6.00 hrs	0
21.9.95	Sabarkum	yes	4.00 hrs	0
22.9.95	Phalut	yes	4.00 hrs	0
23.9.95	Phalut	yes	4.30 hrs	0
24.11.95	Molley	yes	5.00 hrs	0
26.11.95	Gosa (Sikkim)	yes	7.00 hrs	0
27.11.95	Phalut	yes	4.00 hrs	1.5
28.11.95	Gorkhey	yes	6.00 hrs	1.3
29.11.95 - 30.11.95	Jarayotar	yes	2.30 hrs	0
19.2.96	Molley	yes	1.45 hrs	0
20.2.96	Phalut - Gorkhey	yes	5.00 hrs	0
21.2.96	Molley	yes	4.00 hrs	55
21.2.96	Sabarkum	yes	3.00 hrs	0
22.2.96	Molley	yes	2.00 hrs	5
22.2.96	Sirikhola	yes	5.00 hrs	0
23.2.96	Gurdung	yes	3.00 hrs	0

APPENDIX III

TREES, SHRUBS AND CREPERS MARKED FOR PHENOLOGICAL STUDY:

1. Abies densa
2. Acer spp. (D)
3. Andromeda villosa (D)
4. Betula utilis (D)
5. Corylus ferox (D)
6. Daphnehyllum himalaense
7. Endospermum chinense (D)
8. Eurya japonica
9. Ilex hookerii
10. Litsaea elongata
11. Litsaea sericera (D)
12. LAHARE TENGA* (D)
13. Meliosma dellinieafolia
14. Magnolia campbellii (D)
15. Osmanthus sauvis
16. Quercus pachyphylla
17. Rhododendron arboreum
18. Rhododendron campanulatum
19. Rhododendron cinamomeum
20. Rhododendron griffithianum
21. Schefflera impressa
22. Sorbus cuspidata (D)
23. Sorbus microphylla (D)

24. Vitex heterophylla (D)

(D) = Deciduous tree species while others are evergreen species

SHRUBS

1. *Arundinaria maling*
2. *Arundianaria aristata*
3. *Rosa sericera*
4. *Berberis ariatata*
5. *Piptanthus nepalensis*
6. *Viburnum eurbescense*

CREEPERS

1. *Actinidia strigosa*
2. *Holbellia latifolia*

Appendix IV. Some of the civic amenities available to the locals of the buffer settlements

Name of village	Electricity	Primary School	High School	Pucca road	Fuel used	Firewood collected from
Gorkhey	x	x	x	x	Firewood	NP
Samanden	x	√	x	x	Firewood	NP, DF
Rammam	x	√	x	x	Firewood	DF,DF
Siri	x	√	x	x	Firewood	DF
Manedara	x	x	x	x	Firewood	DF
Jaulegoan	x	x	x	x	Firewood	DF
Gurdung	x	x	x	x	Firewood	NP
Namla	x	√	x	x	Firewood	DF
Rimbick bazaar	x	√	√	√	LPG, KR & Firewood	DF

X= not present,. √= present

LPG= Liquid petroleum gas/cooking gas, KR= Kerosene,

NP= National Park forest, DF= Directorate/buffer forest